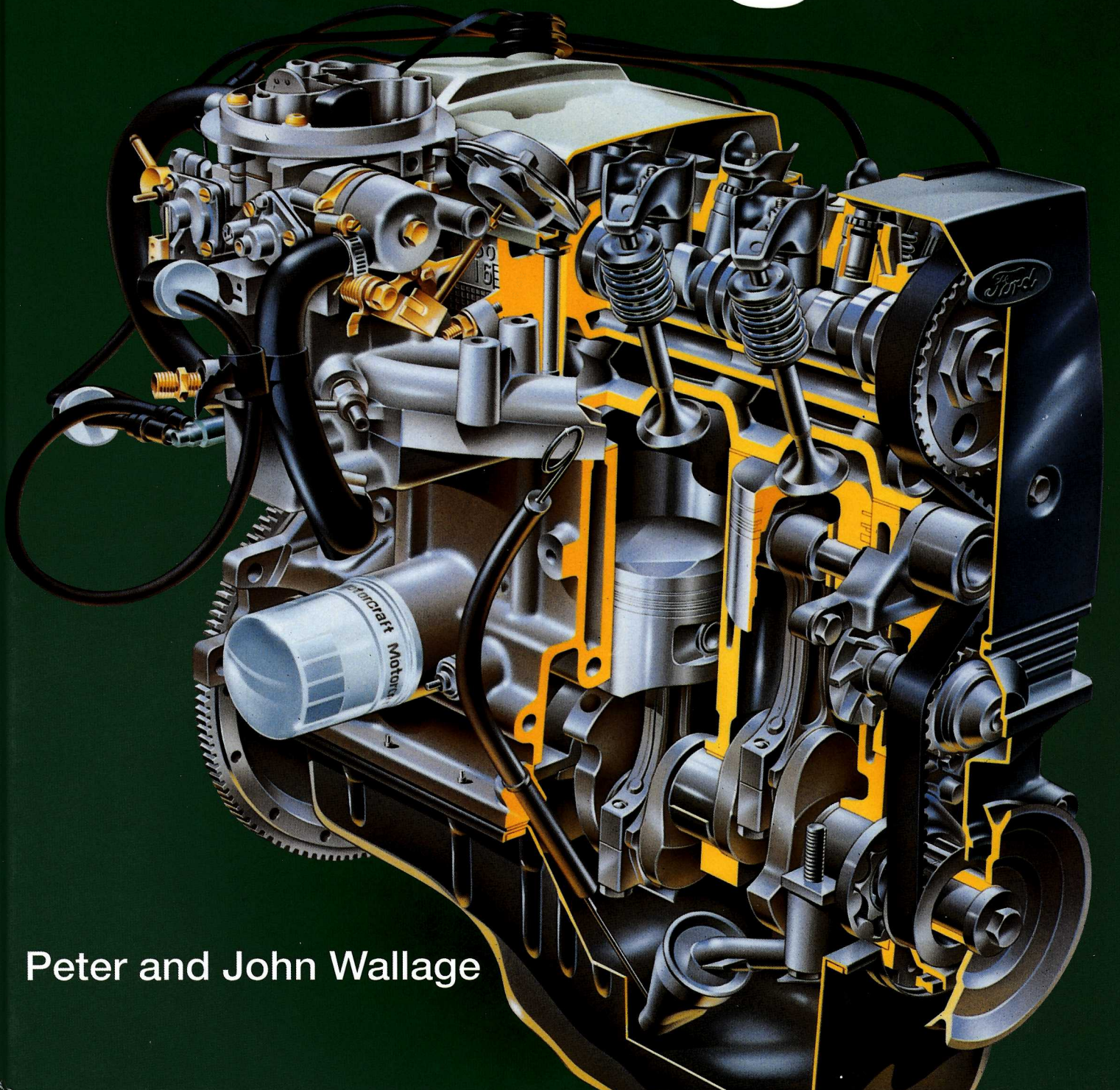
Rebuilding and Tuning

Ford's CVH Engine



Peter and John Wallage

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Introduction

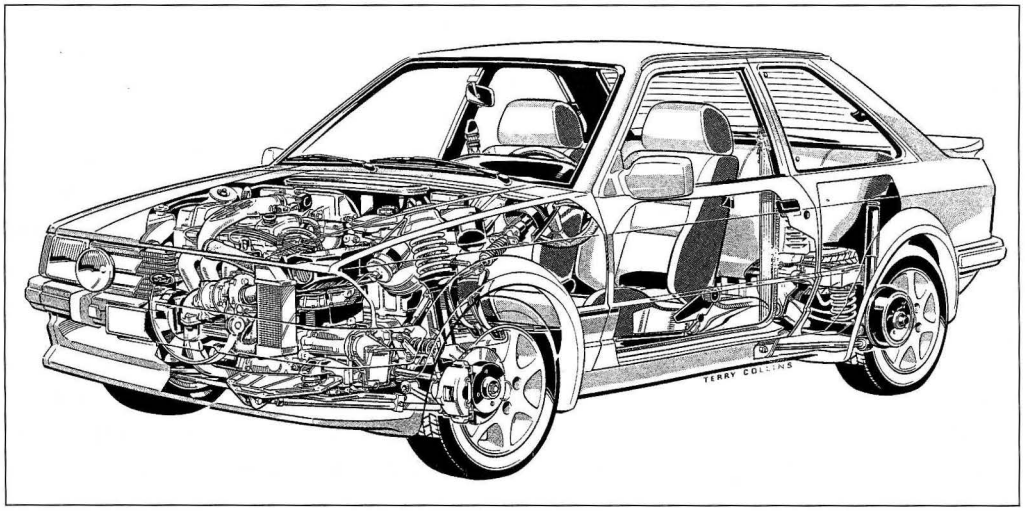
Ford introduced the CVH (compound valve angle, hemispherical combustion chamber) engine in 1981 with the new-look, front-wheel drive Escort. It was expected to be a replacement for the Kent Crossflow engine but this did not disappear and lives on in various modified forms. The CVH was produced in three capacities for the UK market, the 1.3 litre (1,296cc), 1.4 litre (1,392cc) and 1.6 litre (1,597cc). There was also a fairly short-lived 1.1 litre version sold in overseas markets but this is not dealt with in detail in this book. You are not very likely to find one in the UK and, even if you do, it does not lend itself to tuning for power. Should you come across a car with one of these engines it would be easier and cheaper to fit one of the larger engines and a straight rebuild is the same as for the larger capacity engines.

The CVH was also built in the USA as a 1.8-litre engine, the so-called tall block version, and some engine specialists have imported this block to build 'big' CVH engines instead of boring out the 1.6. There is not very much metal between the bores and the water jacket on the 1.6 and it is quite easy to break through when boring out.

Most CVH engines have been fitted to transverse-engined Escorts, Orions and Fiestas, but it was also turned round and used in-line in fairly small numbers of Sierras in 1.8 and 1.6 litre capacities. Both these engines, it is believed, were built in



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◀ *After a try-out with a turbocharger kit for private-entry rally drivers, Ford produced the Escort RS Turbo. It is relatively easy to tune by modifying the turbo control system, and specialist tuners have taken it up to well over 200bhp.*

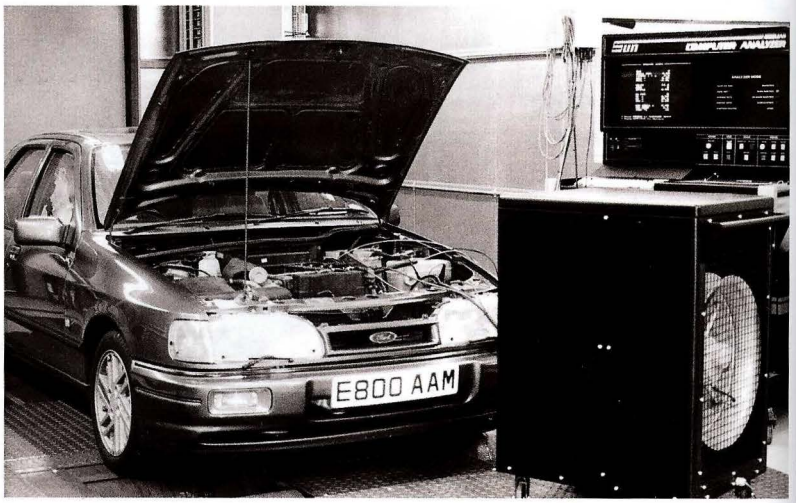
the USA but they follow the general design and principles of UK CVHs. However, few tuning firms cater specially for them so we have not dealt with them in great detail here, except to point out in the chapter on carburettors, that a change from a tired Pierburg to a Weber on the 1.8 can almost transform the engine. The 1.6 litre in the Sierra uses the Ford CFi fuel injection system, (central fuel injector) with one injector in the centre of the inlet manifold. Apart from that it follows the 1.6-litre engine as used in the Escort pretty closely.

Another, fairly short-lived, variant of the CVH was fitted to the Escort RS 1600i. This used the same basic engine but with solid adjustable lifters in the head to avoid hydraulic pump-up at high revs. Two things killed it. One was the introduction of the XR3i Escort and the other was the introduction by tuning firms of anti-pump-up hydraulic lifters which really made the solid lifters superfluous. For rebuilding, the variants in the Sierra and the 1600i follow the other versions very closely.

Whether Ford's designers had greater power in mind when the CVH was first laid out, or if they just followed their usual practice of designing a rugged engine, like the Crossflow and Pinto, only they know. Either way, over the past 20 years, it has proved to be a surprisingly tough engine despite early misgivings by some tuners. They possibly did not like it at first just because it was unfamiliar. Things like exchange gas-flowed heads had to wait a little while until tuners had built up their experience and tested their theories but, once under way, the market for tuning goodies for the CVH blossomed so that today you can buy, more or less over-the-counter, a whole range of bits and pieces to increase the power of your CVH. All of these items can be fitted in the home workshop with gratifying results, provided you don't go silly with a hit-and-miss policy of 'mixing and matching'.

Don't, for example, try to marry heads and blocks from different capacity engines, despite what some 'saloon-bar pundits' may tell you, unless you know exactly what

▼ *A session on a rolling-road is the best way to set up a modified engine, and is almost essential for a turbocharged engine.*



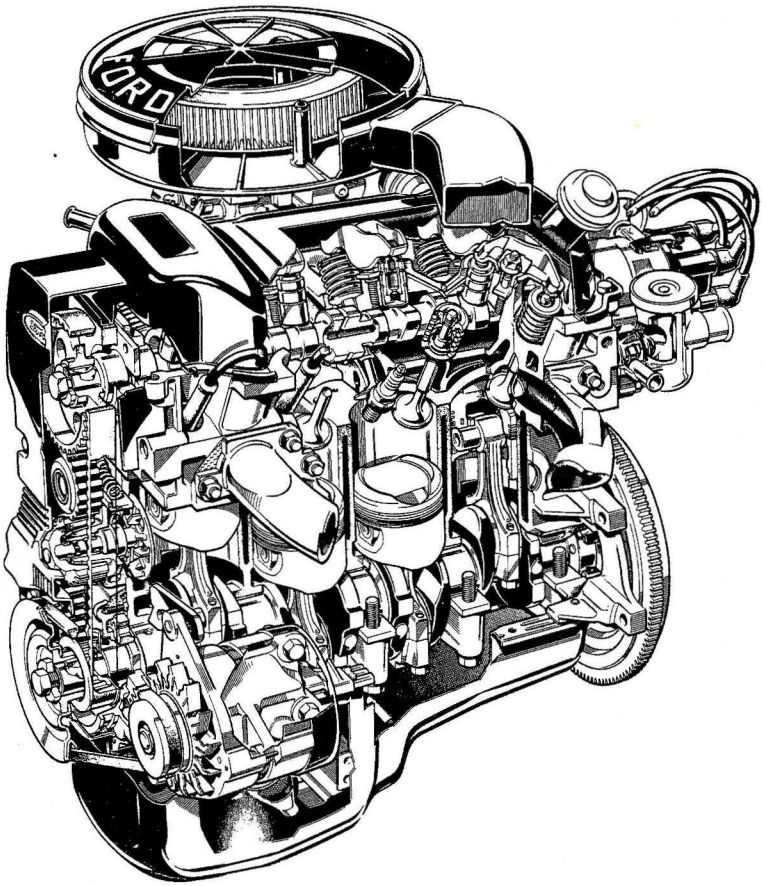
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▲ *Considerable improvements can often be made to non-injection CVH engines by changing to a performance carburettor. You will also need to change the air filter and probably the exhaust, to get the most benefit.*

you are doing and can obtain advice from a tuning firm or someone who has done the job before. The head will probably fit, although the head gaskets are different, but there are differences in combustion chamber volume and depth with differences in port sizes as well as varying sized valves and valve lifts for the various capacities. You could end up with less power than you started with or, much worse, get severe detonation or find the valves hitting the tops of the pistons with very expensive noises. Unless you don't mind disappointment and starting all over again, take advice from experienced tuning firms and follow the well-worn paths to more power. It is cheaper in the long run as well as pretty well guaranteeing a successful result.

There are a number of markings by which you can identify a CVH engine. The capacity is easy. It will have a figure like 1.3 or 1.6 cast on both the block and the head. At the front, timing belt end, just below the first fixing for the exhaust manifold, is a boss carrying the engine number. A



▶ *The basic CVH engine changed little in its various capacities except on the 1.8 litre in the Sierra where the distributor was in a different position.*

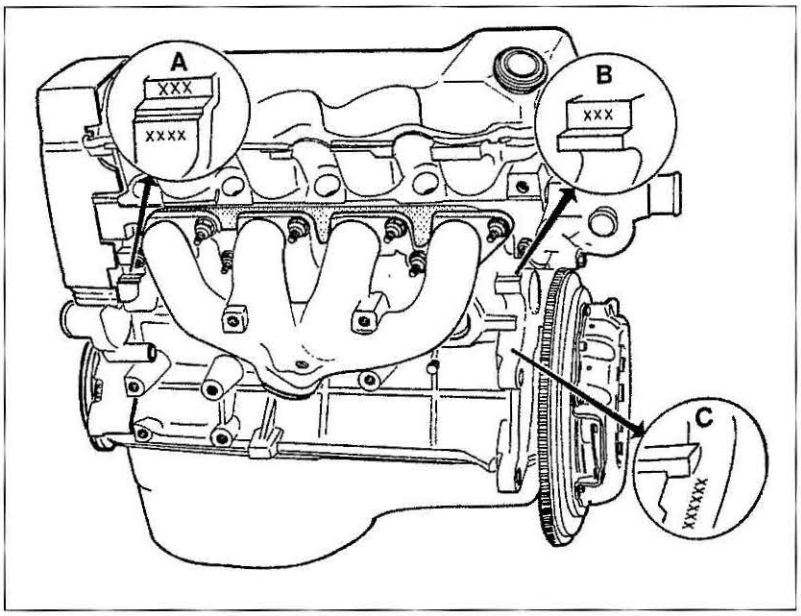
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similar boss just below the last fixing for the exhaust manifold carries the engine code number. You may also find another number stamped a little lower on the sloping face of the block where the bell-housing is bolted. If so it indicates that the engine has been remanufactured by Ford so you may find it has oversize bores and undersize crank journals. If these are on the limits, you won't be able to do much reconditioning so such an engine is best avoided if possible.

There are also a number of markings on the head. Like the block, the head will have the capacity cast in quite large figures. You will also find the date the head was cast. This is in a recess low down on the head near the block face and it is 'plain code', giving the day, month and year, eg 21.8 87.

The next marking needs to be looked for carefully. If, on a boss where the rocker cover fits, just above the No.1 exhaust port you find the marking T.25 or C.38, or both, beware. T.25 indicates that the bores in the head for the hydraulic followers are 0.25mm oversize while C.38 means that the camshaft bearings are 0.38mm oversize. Ford still lists oversize followers and camshafts in its parts list, but for how much longer is not known. The oversize parts are usually on special order only and are more expensive, such as £20 extra for an oversize camshaft. It is difficult to obtain a performance camshaft which is 0.38mm oversize. At the time of writing, Piper has none, Kent Cams has a few, but neither have any oversize followers. If you find these markings, the best bet is to look for a good second-hand head as a replacement.

Although we have covered rebuilding an engine in detail in this book, you don't necessarily have to strip down the engine completely before you can enjoy the fruits of mild tuning, if it is in good condition. Improving the engine's breathing with a free-flow air filter and a decent exhaust system, plus possibly a change of carburettor on an engine without fuel injection, will pep up the response and power quite gratifyingly without costing a fortune or putting too much extra stress on a unit that has already seen a fair amount of service.



▲ *Where to look for the markings on a CVH block. A is the engine number, B is the engine type code and C is a number on Ford remanufactured engines.*

However, before you go for things like a gas-flowed head and a high-lift camshaft on an old engine you are strongly advised to strip it and examine the parts, even if you do not go to the expense of reboring, new pistons and crank grinding. If wear is examined and measured properly then, and providing things are reasonably good, honing the bores, new piston rings, new bearing shells, a new oil pump, or at least a new pressure relief spring, new big end bolts, new head bolts and a new timing belt will give your engine an extended lease of life with extra power.

Remember, though, that we can't tell you here whether your engine is worn out or not. Only you, or someone with accurate measuring equipment, can decide if the parts are suitable for more service. The rule is, if in doubt, replace.

This applies particularly to turbocharged engines. The ease with which you can get more power out of a turbo CVH is almost

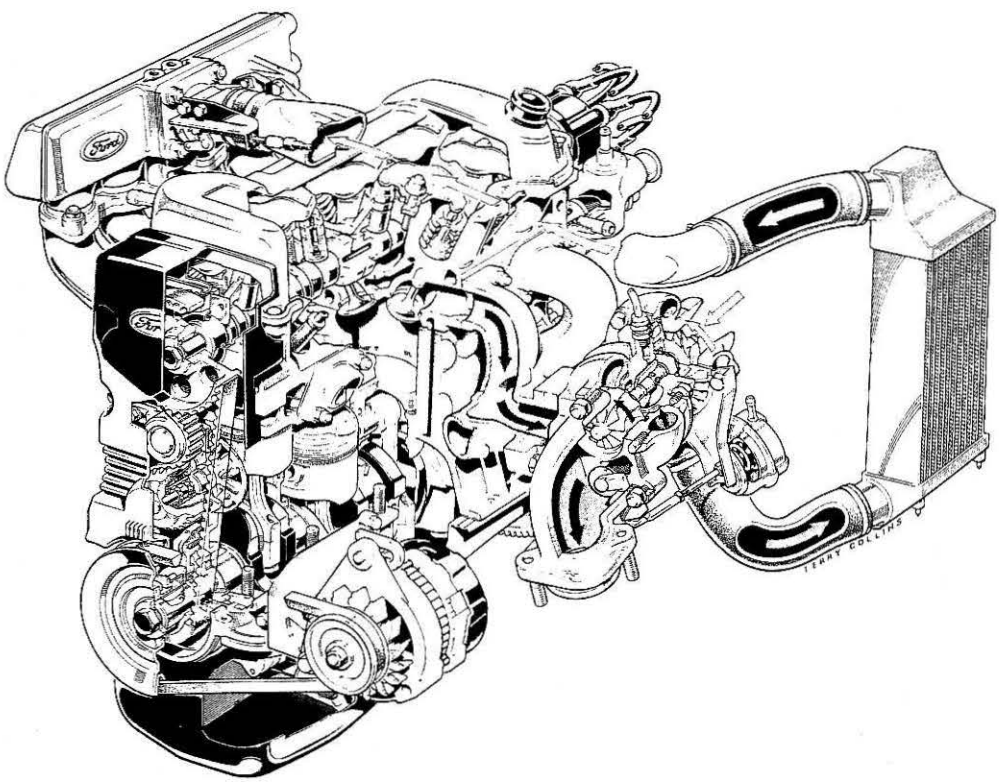
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frightening when it comes to the possibilities of disaster. You do not have to do much, if anything, to the basic engine. Ford strengthened the basic XR3i CVH engine for the Escort and Fiesta RS Turbos, to put out considerably more power. But, for longevity and freedom from trouble, Ford set the boost at 6 to 8psi and put safeguards in the engine management controls to keep it that way.

With a few spanners, a couple of screwdrivers and a fairly fat wallet you can change the actuator, fit a dump valve and bleed valve, a fuel pressure boost valve and have the chip in the electronic control unit remapped to do away with the boost limits, rev limits and temperature safeguards, all in weekend's work. You can then scream the thing up to 7,000 or 8,000rpm and frighten yourself silly with wheel spinning, neck-jerking acceleration until there's a very loud bang and the engine blows up. All you can do is console yourself that you have had a few miles of exhilarating motoring but the cost per mile would be hideous, and it is not our idea of very clever tuning.

Never play about altering the turbocharger or engine management settings, or fitting tuning goodies of unknown origin on an RS Turbo unless you know exactly what you are doing or you have sought the advice of an experienced tuner. This does not include a 'mate down the road' who knows someone who told him that all you have to do is tweak this and that. And don't have the chip in the ECU remapped on the cheap by someone in a backstreet garage with a PC and couple of discs of software.

Stay with the well-known and respected tuning firms, follow their advice and you should not go far wrong. They will have been in business for a long time, and



▶ *The layout of the standard CVH turbocharged engine in the Escort RS Turbo. For really high powers it needs either a larger intercooler or a charge cooler.*

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therefore have massive experience, and a reputation to keep.

Talking of RS Turbos, before you start planning what extras you are going to buy, have the engine set up properly on a rolling-road dynamometer by an experienced tuning firm. Dozens, if not hundreds of RS Turbos are running around putting out anything from 10 to 15bhp less than their potential because of tired actuators, tired plugs and HT leads, poor electrical connections to various senders in the injection system, and general lack of proper setting up and adjustment of the system. Ensure your engine is giving the best it is capable of in its present form before you start trying to raise the power above the figures quoted by Ford when the car was new. You might be very pleasantly surprised just how much this improves the engine's performance to start with.

As to what the tuning is going to cost, you can spend anything from a couple of hundred pounds to several thousand, depending on how much power you aim for and the present condition of the engine. Before starting, read through this book and get prices from catalogues or quotes from tuning firms and then add on at least 25 per cent for all the little things you have forgotten. That way, you will plan your expenditure and have a reliable and responsive engine on the road instead of having a collection of tuning goodies and not enough money to finish the job properly.

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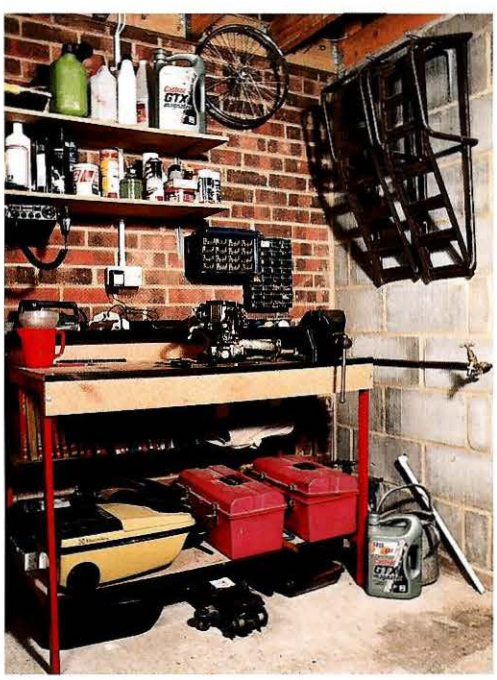
Chapter 1

Rebuilding and tuning at home

Rebuilding and tuning an engine at home is nothing like as daunting a task as restoring a car. You need far fewer tools and far less space. Even so, it is not something you want to undertake out in the back garden at the mercy of the weather so, before you start, make sure you have somewhere under cover and preferably private in which to work.

We say private because you will be leaving lots of parts laid out from time to time when you stop work, and if you have to share your working space with garden tools, deck chairs and the children's bikes, it is not conducive to methodical working which is the secret of successful engine building. Try to have at least half the garage reserved for the job, or maybe clear out the garden shed and use that. You do not need a lot of space, 8ft by 6ft is just about adequate although 8ft by 10ft is better if this is available because it leaves more room for the bench and a spare table for the sorting of parts.

You will need electricity both for lighting, if you are working after dark or even on very dull overcast days, and for using power tools although nearly all the work will be done with hand tools. A good strong bench with a fairly large vice is essential but try not to have to use the bench for the main engine dismantling and rebuilding because the engine will get in the way when you want to use the vice. An engine stand is ideal but, failing that, an old but sturdy kitchen table can serve the purpose. It need not be very large, but it must be strong because an engine, even a four-cylinder CVH, is surprisingly heavy.



▶ *Even if you cannot have the garage to yourself for the rebuild, at least clear one end, and get a sturdy bench.*



▶▶ *A decent-size vice, firmly bolted to the bench, makes many jobs so much easier.*

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If the legs are even a trifle wobbly, brace them diagonally with wooden boards. A piece of hard vinyl floor covering, but not the cushion type, tacked on the top makes the surface easy to wipe down, and you will be doing plenty of that. Suitable tables can be picked up for about £5 at car boot sales and in charity shops so there is no need to spend the earth on one.

You will need at least two, preferably three, baths for cleaning parts. Two should be quite large ones capable of taking things like the head and the crankshaft and, ideally, large enough to stand the block in even if only upright. You can pay quite a lot of money for parts cleaning tanks and, if you are likely to do a lot of restoration work, a proprietary tank is very nice to have. However, you can get the parts just as clean with open-top plastic baths standing on the floor. Have a look around garden centres and at boot fairs. It is surprising how many suitable plastic baths or tubs there are about. Even a couple of large baby's baths will suit. The only requirement, apart from not leaking, is that they are strong enough not to collapse if you rest a fairly heavy component against the side while you are cleaning it. Take a tip though; do not try to move plastic baths when they are full of cleaning liquid. They can go floppy on you at the slightest excuse and spill their contents all over the floor.

Two baths are required because one is needed for the initial cleaning of really mucky bits and pieces and the second is for the final rinsing off. When the first bath gets too mucky to use, the second bath is then used for the first clean while the first bath is refilled with clean fluid as the rinse. As well as the two main baths, a smaller one, such as an old washing up bowl, is very useful for small parts like pistons, con rods, valve gear and so on, and a fine mesh kitchen strainer is ideal for cleaning bolts and other little bits and bobs. You put them in, rinse the strainer around in the fluid and tip them out. Do not bother to buy special engine cleaning brushes as ordinary, cheap paint brushes from a DIY supermarket are fine for scrubbing the parts after they have soaked for an hour or two to loosen the old oil and muck.

A good supply of non-fluffy rags is essential, and a few rolls of paper kitchen towels will also come in very handy. Cleaning fluid has been mentioned, and you can buy proprietary degreasing fluid, some of which you mix with water and some you use neat, but they can be quite expensive. Where you are not counting the cost of your labour, and time is not of the essence, we are all for saving money where we can to spend on engine parts and good quality tools. Ordinary white spirit is quite cheap if you buy it in 25-litre plastic tubs from a paint or building supplies merchant. Even if bought in 5-litre plastic bottles from a DIY shop it is not very expensive and although it may not work quite so quickly as proprietary degreaser, if you leave the parts to soak with an occasional scrub, it will shift the most stubborn oil and grease deposits. If the bath gets really dirty after the first clean, and you have still got other dirty parts to deal with, leave the bath to stand overnight and most of the muck will sink to the bottom and you can then ladle off relatively clean white spirit from the top.

An old drip tray will also be found to be very useful as this can stand under an engine while it is still outside on the hoist for the initial cleaning-off of road dirt and whatever so you do not take more dirt than necessary into the garage. As an aside, we picked up all our cleaning baths, trays and quite a few other things quite cheaply over the years, from autojumbles at steam and commercial vehicle rallies. There always appears to be much more in the way of old garage equipment at these rallies than at car events.

Talking of engine hoists brings us to lifting the engine out of the car. There are

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two types that can be used. One is like a crane and has its own wheels so it can lift the engine free and be pulled away from the car with the engine hanging on it. This is very easy to use if you have got a flat, level, smooth surface like concrete or tarmac, but can be a little unstable on uneven or sloping ground. Unless the wheels are large, the crane is difficult to move on anything but a smooth surface and, when the engine is hoisted high enough to clear the front panel on the car, there is a lot of weight at a high centre of gravity. If the engine starts swinging, or hangs to one side because the ground is sloping, it can topple over when you start to move the crane. We generally use a set of tubular sheerlegs and a portable winch. It is not so convenient in that you have to push the car away from the engine once it has been hoisted up and you cannot move the sheerlegs to carry the engine into the garage, but it is a very safe method of raising an engine. To move the engine after it has been lowered from the sheerlegs we use a substantial trolley or a sack barrow, both of which, again, were picked up cheaply at autojumbles.

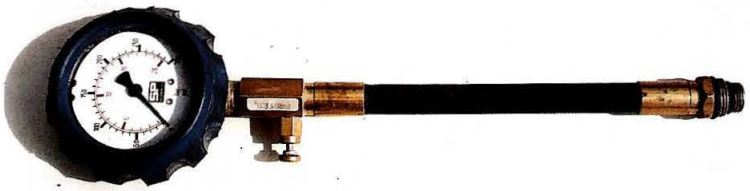
For the second way of lifting an engine out of the car you might be tempted to use one of your garage roof beams with a winch or block and tackle, but be very careful. Garage roof beams, even reinforced concrete ones, are designed to hold up the roof and the sides of the garage, not to take twice the weight of an engine right in the middle at the point of maximum bending stress.

Twice the weight? Yes, that's right. When the engine is suspended, the beam is supporting the weight of the engine. If you remember your schoolday applied maths, you will recall that for every action, there is an equal and opposite reaction. So, when you pull down on the winch cable to raise the engine, it is like a pair of scales. The beam is taking the weight of the engine plus an equal weight, or just slightly more because you are moving the engine, on the part where you are pulling. The fact that you have a block and tackle or winch between you and the engine does not make the slightest difference except to give you a mechanical advantage. The reaction on the beam is just the same as if you had a plain pulley with the weight of the engine on one end of the cable and your weight on the other. We have known garage roof beams break with very unhappy results.

Once you have the workshop set up with some garage equipment you will need a selection of hand tools. Unless you are absolutely new to working on a car you will already have a basic kit of spanners, screwdrivers, probably a socket set and so on, so we are not going to draw up a list of basic mechanic's tools. We have never known anyone to go out and shop from a list like that. You probably do as we have by starting with the basics and adding to your tool kit as and when the need arises.

One thing we would advocate though, is to buy the best quality tools you can afford. At autojumbles and in markets you often see tempting offers of things like huge socket sets of a hundred or more pieces, some of which you are never likely to use, all for not much more than £20. If you bought a similar set from someone like Facom, Britool or the Sykes-Pickavant professional range, you would probably pay four times that much. The cheap sets look great, and it may say something like 'Finest Chrome-Vanadium Steel' on the box, but finest is a matter of opinion and there are chrome-vanadium steels, and chrome-vanadium steels. Something has to be sacrificed to bring the price down, and that something is usually the quality of the steel alloy. The cheap sets are fine for occasional servicing jobs on the car but do not be surprised if, with hard use, the ends of the spanners start to gape, the sockets either round off inside or even split and the ratchets stop ratcheting. The same

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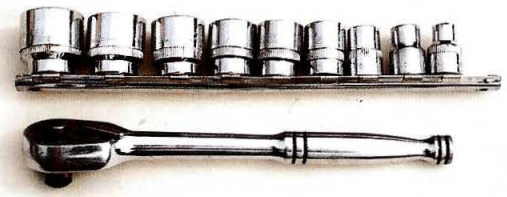
▲ *You will need a compression tester to check whether your engine needs an overhaul before tuning.*



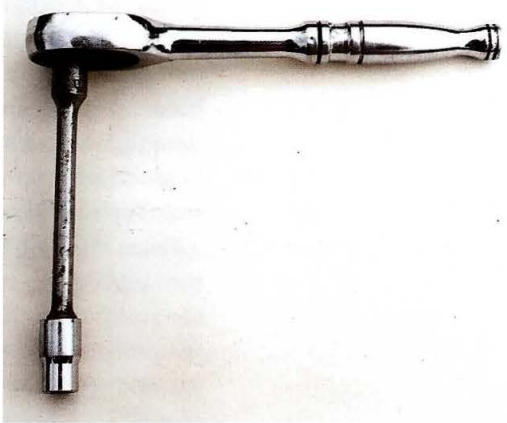
▲ *A long socket bar with some extensions and a selection of sockets is essential for loosening bolts that have been torqued to a high figure. Deep sockets are invaluable in some cases.*



▲ *A set of good quality spanners like these ones by Facom, will outlast several cheap sets, and they won't round off the nuts. None of the tools illustrated in this chapter is new, they have all seen several years hard service in our workshop.*



▲ *Most of the medium duty work can be tackled with ⅜in drive sockets and a medium duty ratchet.*



▲ *For small nuts and bolts a set of ¼in drive sockets with extensions and a small ratchet will get in where there is no room for larger sockets.*



▲ *In some places you may need a set of 'reverse Torx' sockets.*

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thing applies to cheap cross-head screwdrivers and sets of bits that fit into a handle. You are likely to end up with rounded-off nuts, bolt heads and screws that you have to drill out because a cheap screwdriver has slipped and worn the screw head. A full kit of tools can be very expensive, so buy the best quality of the minimum number of sockets and spanners you need and add to them later. Two things you cannot do without, are a good quality ratchet and a good quality long-bar handle.

Another essential tool is a torque wrench. The list of torque tightening figures in the specification chapter should be checked to make sure your torque wrench covers them and you may find you need two such tools – one large and one small. It is foolish in the extreme to go by guesswork when tightening main and big end bearing caps, flywheel bolts and cylinder heads, while even less-important bolts should be tightened to their proper torque for reliability and to avoid oil leaks.

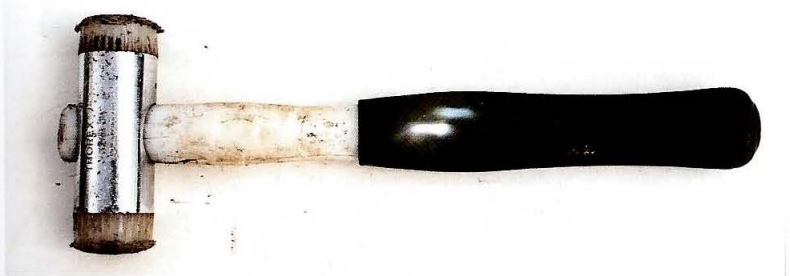
Other specialised tools needed will be a piston ring clamp, a tool for fitting new piston rings, a valve spring compressor and, unless you are having the block rebored and honed professionally, a cylinder bore hone. The less expensive sort that fits in an electric drill is fine. The hone is pushed into the cylinder before starting the drill, and switched off before pulling it out, otherwise the arms will fly out and get damaged. If you are planning on matching the port and manifold yourself, a proper riffler driver is more handy and faster to use than an electric drill.

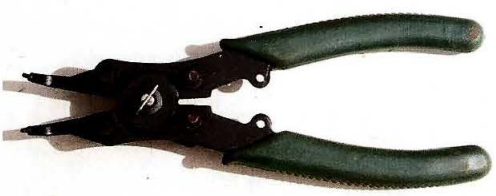
At one time these drivers, which look rather like a chubby power screwdriver, were available only as very expensive professional equipment, but in the past few years the makers of popular power tools like Bosch and Black & Decker have included them in their lower-priced range. Unless you are going to use one all day, every day, and provided you do not overload it by leaning very heavily on the rotary riffler file or stone to try to get the job done too quickly, these lower priced



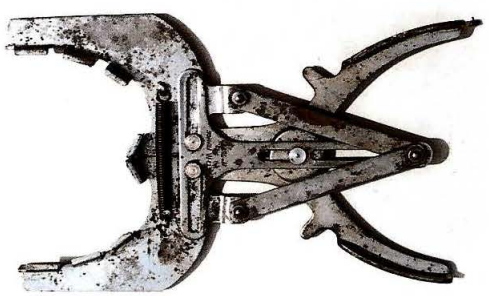
▶ *If someone has already rounded off nuts, special sockets (top) which grip the sides of the nut rather than the corners will often grip where a conventional socket (below) will slip.*

▼ *Don't be brutal when dismantling. Use a nylon or hide-faced mallet to free parts – not an iron hammer.*



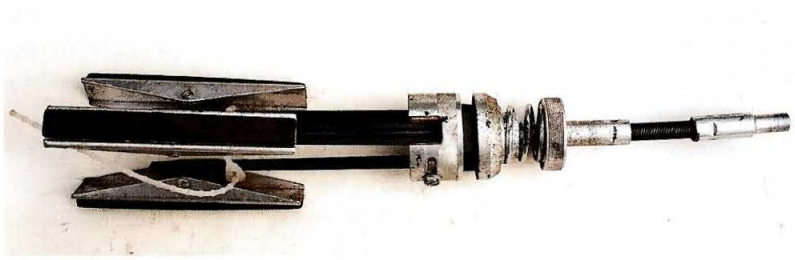


▶ *Taking out and refitting circlips is easy with a proper pair of circlip pliers. These have interchangeable jaws for different sizes of circlip. Digging with a screwdriver is frustrating and damages things.*



▲ *It is possible to fit piston rings by hand, but the proper tool is easier and less likely to break the rings.*

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▲ *If fitting new piston rings without reboring, a cylinder bore hone like this, which can be fitted in an electric drill, will break the old glaze quite easily.*



▲ *Some bolts on the CVH have to be torqued and then tightened through a set number of degrees. You can guess, but a gauge like this which fit onto your socket handle makes it certain.*

▶ *Here is something you cannot do without on an engine overhaul – a piston ring compressor.*



drivers will give good service. Although not really special tools, but very useful for getting tight things off, are a couple of tyre levers and a pair of hook-ended pry bars. You will no doubt find a use for other things like punches and drifts, but you are sure to accumulate these as you go along. Ford lists quite a few more special tools for use on the CVH but they are either designed to save time in the dealer's workshops and you can do the job without them even if it takes more time, or they are very expensive and not worth buying for a one-off or even two-off engine build. An example is the special tool for removing and replacing the gudgeon pins on CVH pistons. The charge for having new pistons fitted to your con rods is so small that it is not worth buying the special tool to do the job yourself.

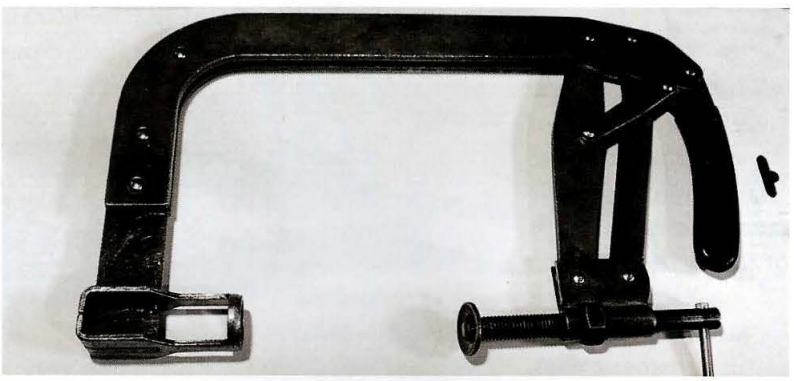
▶ *The valve spring compressor needs to have a deep throat and fairly long windows at the business end to get at the valve collets.*



▶ *We find a chain wrench the best tool for removing oil filters. It is much less messy than poking a screwdriver though the case.*



▲ *A torque wrench is essential for safe engine building.*



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Chapter 2

Looking for more power – what do we mean by tuning?

The meaning of the word 'tuning' has changed over the past 20 or so years. As used originally, it meant adjusting the carburation, ignition, valve clearances and so on, to get the engine running at its best, but without modifying or changing anything from the maker's original specification. It still has this meaning when used by people who offer services such as mobile tuning but this sort of work is now more generally classed as servicing.

Another form of engine tuning is usually called 'blueprinting', which is used when regulations for a particular class of competition do not allow the modification of certain parts of the engine from the maker's standard specification. To make parts interchangeable and to avoid impossibly high tooling costs, the dimensions on the production drawings carry tolerances, or limits, such as plus or minus ten thousandths, two thousandths of an inch, or even a quarter of a thousandth of an inch (or the equivalent in millimetres) depending on the importance of the fit. What the blueprinter will do is build an engine choosing parts on either their upper or lower limits, depending on what suits his purpose, to get the highest possible power without actually modifying any original components. This is a highly specialised form of engine building and is outside the scope of this book.

Tuning, as we use the term here, has come to mean changing or modifying parts of the engine, or its auxiliaries, to produce more power than when it came from the factory. Quite a large industry has grown up around this idea, and if you peruse the advertisements in magazines devoted to making standard cars go faster, you could be forgiven for believing that all you have to do is spend a lot of money changing various bits and pieces, or bolting on lots of go-faster performance parts, to produce a real tarmac-burning power house.

We are not decrying the makers of these performance parts and conversions. Indeed, they are an essential part of the tuning scene because they have brought power tuning, at least in its lower and medium stages, into the realms of DIY work. If you want a full-blown rally or race engine you still need to go to an engine builder who specialises in such work, but nowadays it is relatively easy to obtain a useful increase in power in the home garage with proprietary parts and a reasonable kit of tools. Some of the work may still have to be put out to specialists, such as gas-flowing a cylinder head, modifying a turbocharger or an engine management unit, but a considerable amount of money can be saved carrying out most of the work yourself.

Before becoming involved in advertisements and tuning catalogues, however, it is as well to have an idea not only what you are doing but also why you are doing it. The CVH engine in standard form, as it comes in the Escort, Orion,

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Fiesta or whatever, is designed and put together to be something of a compromise. In the ordinary family saloon it has to be quiet and smooth, docile enough for the average driver to be comfortable with it in traffic, but with enough acceleration for the car not to be a sluggard. It also has to be able to cruise happily with a minimum of fuss at motorway speeds pulling a car full of passengers and luggage. In addition to these, often conflicting requirements, it has to pass strict emission controls, be rugged and reliable enough to last for 80,000 to 100,000 miles without major overhaul and, most important of all for the vast majority of users, do all this while being as frugal as possible on fuel.

In the RS Turbo Fords some of these qualities, although perhaps surprisingly few, are played down, sacrificed if you like, to get more power and performance. It is a tribute to Ford's engine designers that the CVH achieved what it was intended to and has satisfied the vast majority of users.

However, there will always be enthusiasts who are not satisfied with the standard product, which is why the power tuning industry has grown up. Basically, all the power tuning modifications and bolt-on 'goodies' are aimed at either one or both of two things: increasing the engine's volumetric efficiency, and its thermal efficiency. It is therefore as well to understand what we mean by these terms.

Volumetric efficiency is the ratio of the capacity of a cylinder to the amount of air and fuel mixture which is drawn into it on the inlet stroke. Purists will say we have left out things like temperature and pressure, but the idea of volumetric efficiency was put very succinctly by one highly regarded tuner as 'how full you can get the pot while the inlet valve is open'.

Before any new mixture enters the cylinder the burnt gases from the previous power stroke have to be cleared out. At 6,000rpm, each complete revolution lasts 1/100th of a second. The inlet and exhaust strokes are each half a revolution, so the engine has only 1/200th of a second to push the burnt exhaust gases out and another 1/200th of a second to draw the new mixture in, or very slightly more when you allow for the valves starting to open and close slightly before and after top and bottom dead centre. If a camera shutter is set to 1/200th of a second and you watch how long the blades are open this will give an idea of how fast things have to happen in an engine. Anything we can do to improve the gas flow is beneficial.

Making it easier for the mixture to enter and for the exhaust gases to escape is usually known as improving the engine's breathing and it is the most important principle behind power tuning. In the lower stages of power tuning we usually start on the inlet side of the engine because, on a naturally aspirated, non-turbo engine we have only atmospheric pressure to push the mixture in, whereas on the exhaust side, we have the piston coming up to push the burnt gases out.

On naturally aspirated engines the inlet breathing can be improved by fitting less restricting air filters and larger carburettors, or arranging for the injectors to deliver more fuel to match the increased air, opening out the inlet ports and fitting larger inlet valves. On the exhaust side, larger valves are used less often in the lower stages of tuning, more attention being given to the exhaust ports and fitting a less restricting exhaust system. Matching head ports and manifold ports is also important, and this is dealt with in more detail when we come to rebuilding the head.

Fitting a performance camshaft with cam profiles which will open the valves further and hold them open longer, also makes a big difference but here you have to choose wisely because, as we will see later, camshafts which give a big increase in power at high revs often make the engine less

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smooth and less responsive at lower revs.

Turbocharging or supercharging an engine is another way of improving its volumetric efficiency. Some people get a little confused between turbocharging and supercharging because both come under the general heading of forced induction. On a naturally aspirated engine without forced induction, the piston creates a depression in the cylinder on its downward intake stroke. This causes normal atmospheric presume, roughly 15psi, to push air through the inlet manifold. It picks up its fuel to form the fuel and air mixture either from the carburettor or by fuel injectors squirting in fuel, usually into the inlet manifold.

With forced induction, air is compressed and pushed into the inlet manifold at higher than atmospheric pressure, and the increased pressure is usually referred to as boost. The fuel injection system, or the carburettor, is set up so that an increased amount of fuel is supplied, depending on the boost, to keep the mixture constant. If the compressor which supplies the boost is mechanically driven by the engine it is usually called a supercharger but if driven by a turbine rotor in the exhaust gas stream it is a turbocharger. The only form of forced induction used on CVH engines is turbocharging.

A question often asked is whether or not it is feasible to add a turbocharger to a naturally aspirated engine as an easy way of getting extra power. Yes, it is quite possible, and several firms offer conversions. On cars like the XR3i and 1.6 injected Escorts and Orions, either the existing Bosch K-Jetronic mechanical injection system can be used, or the electronically controlled KE-Jetronic system from the Escort RS Turbo can be fitted in its place. It is also possible to turbocharge a CVH fitted with a carburettor. This is covered more fully in Chapter 13.

Turbo engines can also be power tuned, often more easily in the lower stages of tuning than naturally aspirated engines, and the CVH is no exception. In the standard Escort RS Turbo, the maximum boost pressure is between 6psi and 8psi, and is controlled both mechanically and electronically by the engine management system. The boost can be increased by altering the mechanical control and changing the electronic chip in the electronic control unit. The new chip will also alter the fuel injection to compensate.

The way that improving volumetric efficiency can give more power is easy to appreciate, but fewer people appreciate the importance of thermal efficiency. If you again remember back to your school physics it may be recalled that energy can neither be created nor destroyed, but only changed in form. When we burn the fuel in the fuel and air mixture, the latent energy in the fuel is converted to heat which makes the mixture expand and push the piston down the cylinder so that the heat energy is changed to mechanical energy. The more heat we can convert to mechanical energy, the more power we are getting out of our fuel, and the conversion ratio is termed thermal efficiency.

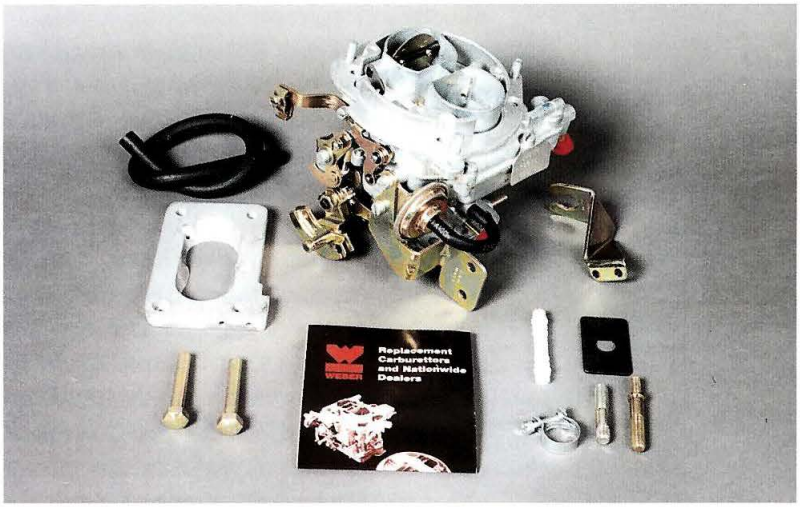
Unfortunately, the thermal efficiency of any internal combustion engine is not very high. On an average engine, only about 20 per cent of the heat obtained from burning the fuel is converted to mechanical energy. The other 80 per cent, less the small amount used for heating the car's interior, goes to warm up the big outside world by being dissipated though the cooling system, radiated from the cylinder head and carried away down the exhaust system.

Equally unfortunately, there is far less we can do to improve the thermal efficiency of our engines compared with improving the volumetric efficiency. We are very much in the hands of engine designers and fuel chemists. Over the years, general improvements in engine design and a greater understanding of what goes on

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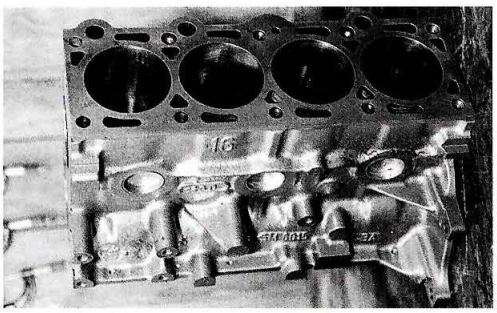
inside the combustion chamber when the mixture is sparked off has led to today's engines, including the CVH, being more thermally efficient than those of the past, which is why we get more miles per gallon as well as more power for the same engine size compared with cars of the 1950s and 1960s. The things which can be done to improve thermal efficiency, or at least maintain it as high as possible, are to pay careful attention to the timing and the quality of the ignition spark, improve the even distribution of the mixture between the cylinders and, with a carburetted engine, make sure that the fuel and air mixture is maintained at its proper ratio and atomised as thoroughly as possible.

Increasing the compression ratio or, more correctly, the compression pressure, can also improve thermal efficiency provided it is not increased to the point where we get detonation known as 'pinking', or auto-ignition as it is usually termed in the USA. On a naturally aspirated engine the compression ratio and pressure is increased by skimming the face of the cylinder head or fitting high compression pistons. A small amount of skimming is often necessary when rebuilding a high mileage engine because the face of the head is likely to have warped slightly, but any further skimming other than the minimum necessary to cure warping should be undertaken with caution. Too much can lead to horrible problems with the heads of the valves hitting the tops of the pistons, particularly with high-lift performance camshafts. The same goes for high compression pistons. On a turbocharged engine, the nominal compression ratio is considerably lower than on a naturally aspirated engine, and the compression pressure is increased by increasing the boost.



▲ *On non-injected engines, a change of carburettor can often give a dramatic improvement in response and pick-up as well as, often, more power. This is the Weber replacement for the Pierburg.*

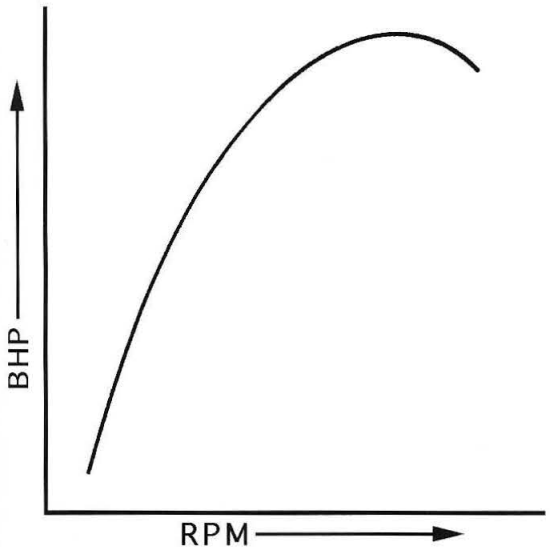
▼ *This block has been cleaned, rebored and honed, the top face checked for flatness and new core plugs fitted. It is all ready for building into a more powerful engine.*



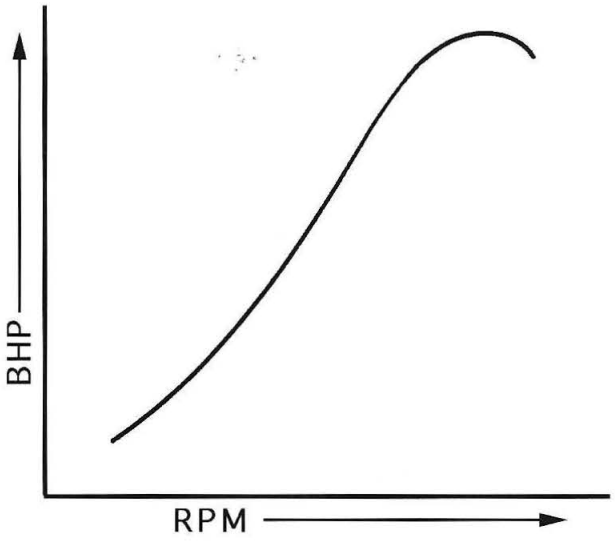
▼ *Poor plug leads, even though they may not look too bad, are often a cause of power drop at higher revs. High-quality leads changed every 15,000 miles might seem extravagant, but it will ensure that high-tension leakage does not cause the power to gradually drop.*



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▲ *A typical power curve for a standard engine. Top power may not be very high but the curve holds up well in the lower rev band giving easy driving without the need for constant gear changing.*



▲ *On this second theoretical power curve, power has been increased but it is all pushed into the top rev band. The lower part of the curve shows only a gradual increase until the revs build up.*

So far, we have talked about power because that is what interests the average enthusiast for tuning, but although quoting a high bhp figure by itself may sound impressive, it does not give the whole story. We need to know whereabouts in the engine rev range the maximum power occurs, and what the power output looks like over the rest of the rev range. The force pushing the piston down when the mixture in the cylinder burns does not produce power directly but it produces a turning force, or torque, on the crankshaft. Once the crankshaft starts moving, we can combine torque and power because power is defined as a rate of doing work, and depends on the torque.

The basic equation linking the two is:

$$\text{Horsepower} = \frac{2 \times \pi \times N \times T}{33{,}000}$$

where N is the rpm of the engine and T is the torque. The figure 2, the mathematical symbol π and the figure 33,000 are constant, so power is related to the rpm multiplied by the torque. The units in which rpm and torque are measured do not matter in this illustration. We can get more power by increasing either the rpm or the torque.

Improving the breathing increases the torque because the more mixture we burn in the cylinder, the greater force there is pushing the piston down. In practice, it is usually found that improving the breathing also increases the maximum rpm of which the engine is capable, but it does not do a great deal to alter the shape of the power curve, the curve produced by plotting bhp against rpm, except to lift it and extend it slightly in the top third. The maximum torque increases but stays more or less in the same place in the rev range so the car has much the same driving characteristics up the rev range, and it can be compared with putting in a larger standard engine with the same characteristics.

It is when we start moving the position of the maximum torque up, or down, the rev range that we alter the engine's characteristics and therefore the car's driving characteristics.

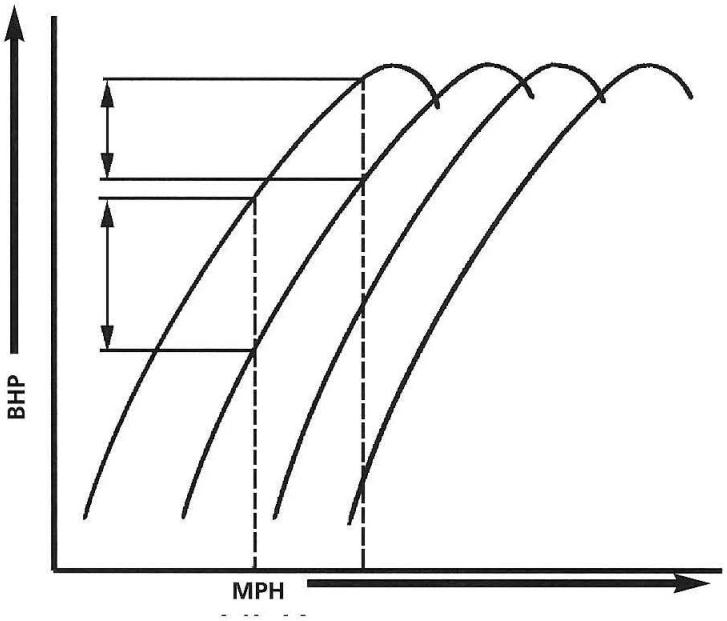
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Look at the theoretical power curves for two engines with widely different characteristics. The first is a real slogger, a lazy engine with plenty of torque in the mid rev range and a gentle taper off of power towards the top end. The maximum power may not be very high, nor the maximum rpm, but it is a serene and docile workhorse, the sort of engine that is quite happy with an automatic three-speed gearbox behind it. Unless you use the kick-down facility on the box it will probably spend all day purring along in top gear with no fuss.

Compare this power curve with one from the other end of the spectrum. Here, the engine has been designed and tuned for out and out power. The torque and power at low revs are horrible and if it ticked over at all under about 2,500rpm it would be like a camel with the hiccups. But what a different kettle of fish once you get into the top part of the rev range. The torque and the power shoot up but they are concentrated over a narrow rev band. It is a real screamer of an engine which will give the car a high top speed and, provided the driver has enough gears to keep the engine within the power band, searing acceleration. It's fine for sprints or circuit racing, but it would be a pig of an engine to drive in traffic.

We mentioned earlier that another way to improve breathing is to fit a camshaft with cam profiles that open the valves further and hold them open longer. Provided the engine can breathe well enough to take advantage of the cam profile, it is the shape of the cam profile that has a marked effect on the shape of the power curve. In standard form, the CVH has quite mild cam profiles and, as we will see in a later chapter, you can buy performance camshafts with varying cam profiles from 'fast road' to 'full race'.

Most fast road camshafts are designed so that the altered shape of the power curve is still suitable for the standard gearbox ratios and final drive ratio. It's when you go for the higher performance shafts that you need to consider whether or not a change of gearbox ratios and possibly final drive ratio will be beneficial. It can be interesting to obtain a power curve from the camshaft maker to see how it will affect your car's road performance. This is done by drawing a new graph, derived from the power curve but substituting road speed for rpm along the horizontal axis.



▲ *By substituting mph for rpm, a series of curves can be plotted, one for each gear. It gives a good indication of the drop in power when changing to a higher gear at low revs. The higher you go before changing up, the less the drop.*

Before you can do this it must be decided whether or not the wheels and tyres are going to be changed. Changing wheels and tyres is very popular among enthusiasts who modify Fords and, before you can start substituting road speed for rpm, you will need to know the wheel turns per mile of the tyres you are fitting, and whether the figure differs appreciably from that for the standard tyre.

You cannot work this out accurately from the outside diameter of the tyre, or from the static laden radius because these are fairly nominal and tyres alter their shape slightly at speed, so the manufacturers quote an average wheel turns per mile. This figure will be found in the tyre

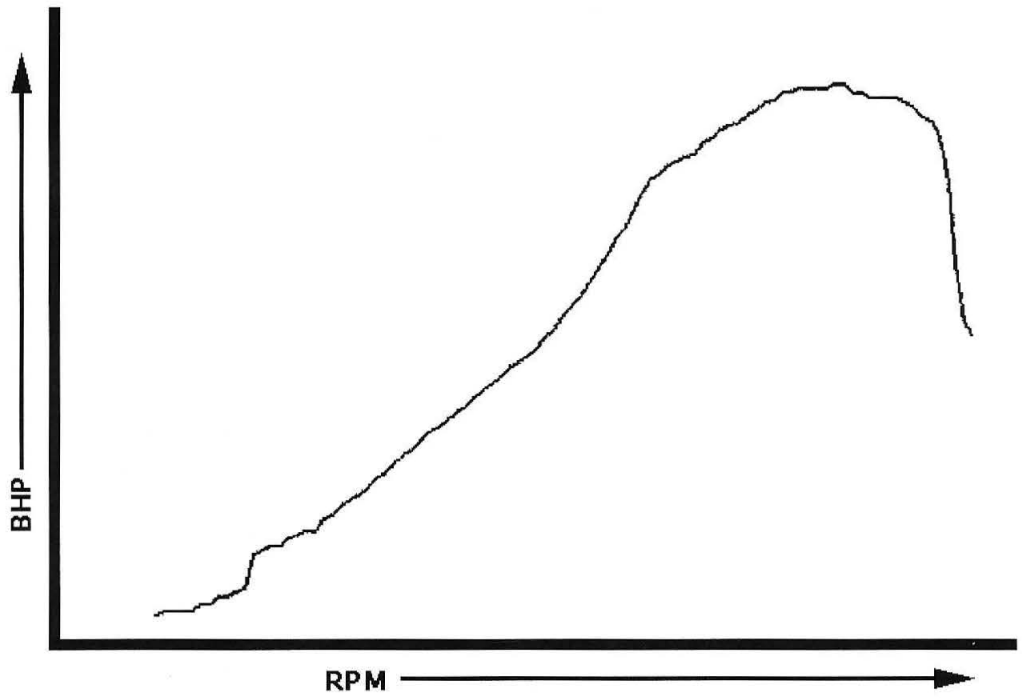
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maker's technical data book, and any agent for that make of tyre should have a copy. If not, ring the tyre company's technical department and ask.

As an example, we will use a Pirelli data book because we have it to hand, but most makers have similar publications. Suppose that, as many people do, you want to fit a larger diameter wheel with a lower profile tyre than the standard one on your car. For an XR3i, a suitable change would be from a standard 185/60 R14 to a 205/50 R15. This has a quoted wheel turns per mile figure of 897 compared with a figure of 910 for the 185/60 R14 so there is not a lot in it, only 13 in 897 or roughly 1.4 per cent therefore you do not have to worry about it. However, if you go the whole hog and fit something like a 255/45 R15, assuming you have the clearance for its 9 inch wide rim, this has a wheel turns per mile figure of only 856, a difference of nearly 5 per cent. Still not a lot but, if you are fussy, it makes a difference of 300 engine rpm at 6,000rpm compared with the standard wheel and tyre.

Now we can get down to drawing our new graph of bhp against road speed. The shape of the power curve is not going to alter, so all you need to do is convert rpm to mph. Assuming again that we have an XR3i, work it out first for the fourth gear ratio of 0.95 to 1 and the standard final drive ratio of 4.27 to 1. Assuming the engine is running at 6,000rpm, the final drive pinion will be registering 6,315rpm and the driveshafts – and thus the wheels and tyres – 1,478rpm. At 897 wheel turns per mile this works out at 1.64 miles per minute, or 98.4mph. As a slight diversion, the 856 wheel turns per mile of the 255/45 R15 tyres would make it 103.6mph. So, in place of 6,000rpm on the horizontal scale of the graph you enter 98.4mph. This gives the scale for the horizontal axis with zero at the origin.

If the standard power curve for your engine is also put on the graph it will be seen what difference in power the change of camshaft is going to make at any given road speed in fourth gear. The graph can be made even more useful by including the



▶ *A copy of a print-out from a rolling-road test on a mildly tuned engine. The original curve went up at a constant slope, but you can see how a change of air filter and exhaust has lifted the power about two-thirds of the way towards maximum revs. The sudden fall off at the end could be due to a breakdown in ignition, either plugs, leads or coil, to limit the maximum revs. A better ignition system might have taken the curve higher.*

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curves for the different gear ratios. Again the shape of the curve will be the same so all you have to do is substitute second, third and fifth if it is a five-speed gearbox, and move the curve along the horizontal axis by the difference. First gear can be put in as well if you like, but you would not normally stay in that gear long enough to make it worthwhile. If you want to see what difference a change of final drive ratio will make, just substitute that figure and move the curve again for each gear.

By substituting the curves for different camshafts you can get an idea on paper of what difference they will make to the performance of the car on the road. Remember it will be only an idea of what the maximum speed or acceleration will be because you have not taken into account mechanical rolling resistance or wind drag, which are much more complicated to calculate, but you can get a very useful set of comparison graphs.

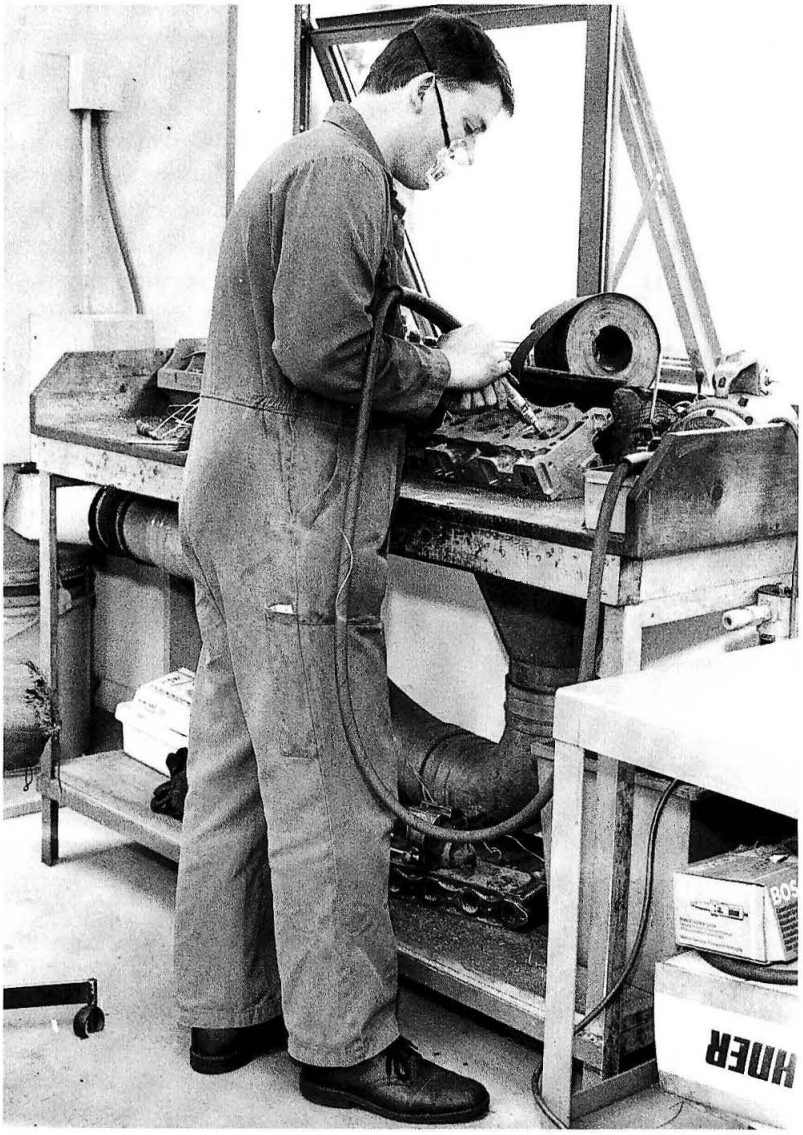
People who work out what final drive ratio or set of gearbox ratios to fit for racing on a particular circuit often use this method to decide what to fit depending on the length of straights and the estimated top speed, plus the severity of bends and the expected speed through them, so that the driver can select a gear to get all the power he can use at the right speed anywhere on the circuit.

Earlier in this chapter we mentioned opening out the inlet and exhaust ports and possibly fitting larger valves, all commonly lumped under the heading of having the head gas-flowed. If you have decided to have the head gas-flowed, or for that matter even if you have not, this could be a good place to bring in the question of unleaded fuel, whether you can use it or not in your engine, and whether or not it will give you the same power as the old four-star fuel or unleaded with a lead substitute.

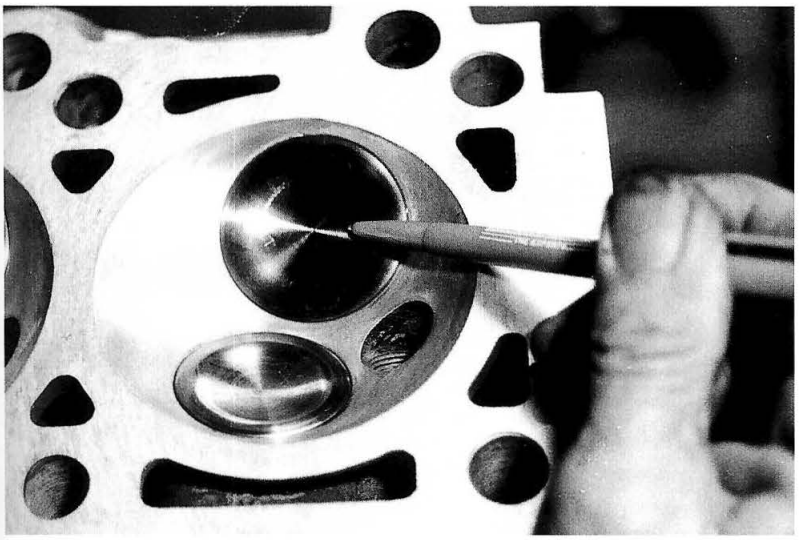
Lead compounds were first added to petrol way back in the 1920s as an anti-knock agent when compression ratios started to rise as designers looked for more power. In those days it wasn't unusual to have the cylinder head off every 10,000 miles or so to clean out the carbon and grind in the valves known as decarbonising or decoking. Even though engines were very lightly stressed and valve springs were weak compared with those of today, burnt exhaust valves and pocketed valve seats were not uncommon.

When lead was added to petrol it was found, almost as a bonus, that the valves and seats lasted much longer because when the lead compounds burnt they left

▼ *After attention to the air filter and exhaust, the next stage of improving volumetric efficiency is to have the head and ports gas-flowed and the head ports matched to the manifold ports.*



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◀ *On this gas-flowed combustion chamber the tops of the valve heads have been skimmed and smoothed to take away any rough spots which could lead to detonation.*

a deposit on the valve seats and valve faces which protected them. As a consequence, power could be increased and the valve seats could still be cut straight into the cast iron, and less expensive steel could still be used for the valves. Lead in petrol was abolished from general sale in the UK from 1 January 2000, and later CVH engines were prepared for this with hardened exhaust valve seats and better quality steel for the exhaust valves.

All these points are covered in greater depth later in this book but, before we go into detail about tuning to extract more power, we will deal first with checking that your engine, as it stands, is in a suitable condition to take that extra power without being a constant source of trouble or, worse still, knocking out its bearings and possibly throwing a con rod.

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Chapter 3

Is your engine fit for more power?

It is a false economy to try to save money by postponing an impending engine overhaul so that you have more to spend on tuning 'goodies'. You will not obtain the full benefit from the tuning parts you fit, and you are likely to find yourself with a lot of trouble and expense later on. Any tuning to increase power puts added stress on worn engine parts which may soldier on happily for quite a few thousand miles of light motoring but which do not like the added loads which go with extra power. Before long they are liable to cry 'enough' and pack up, sometimes with very expensive sounding noises!

As engine management systems become more sophisticated with electronic control of almost everything, it is easy to fall into the way of thinking that you need to plug in a computer before a worn engine can be diagnosed or any engine ailment detected. Don't believe it. Almost all electronic diagnostic equipment is designed to check out engine auxiliaries – fuel, ignition and engine management systems. When you get down to the basic lump, we have still got a crankshaft that goes round, con-rods and pistons that go up and down and valves that open and close, the same as we always had, and you can diagnose a lot of maladies with nothing more sophisticated than a



◀ *This engine looked very clean, and ran well, but was it fit enough to take extra power?*

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compression tester and piece of wood. Plus, of course, a little knowledge which we will give you now.

Let's have a look at knocks and rattles. We need to distinguish between, for want of a better description, light fairly high-pitched knocks and taps, more heavy, sharper knocks, and deep rumbling knocks.

Light clattering knocks from the top of a CVH engine, louder when it is cold but still there when it is hot, usually come from valve clearances that are too large because the valve operating gear is worn, a worn camshaft or hydraulic valve lifters that are tired and not closing the gap properly. They should give what is generally termed zero lash, or zero clearance, but, when they wear or get sludged up with old oil, it often is not the case.

Any overhead cam engine is more prone to camshaft wear than one in which the camshaft lives down in the block because it depends for its lubrication on oil being pumped up to it. One of the main, if not the main, causes of worn camshafts and sticking hydraulic lifters on CVH engines is sludged oil as a result of owners not changing the oil and filter frequently enough, particularly on older cars where some owners are not so fussy. You can spot a worn camshaft easily enough when you take the cam cover off because it looks worn and it has ridges on the sides of the cam faces where they have not been rubbing on the valve operating rockers. If the camshaft, rocker arms and hydraulic lifters are worn, there is not a cure except to replace them and be strict about your oil and filter changes in the future.

Moving down lower on the engine, there can be two types of knock when starting up. The first is quite sharp and lasts only for a few seconds, and the second is usually lighter and dies away as the engine warms up.

The first is nearly always wear in the big ends and probably the crankshaft journals as well. What happens is that, when the engine is left standing, the oil drains away from worn big ends and leaves them almost dry. When the engine starts up, they knock for a few seconds until the oil pressure builds up to keep them quiet. If an engine does this regularly there is an easy way to confirm the diagnosis. After the engine has been standing, say overnight, take one of the low tension leads off the coil so the engine does not fire, and crank it over on the starter a few times to build up the oil pressure. Three or four cranks of about 15 seconds each should be enough. Then pop the lead back on and start up. If the noise does not occur then you have confirmed the cause. Starting-up knock from worn big ends is often accompanied by an initial clatter from worn hydraulic valve lifters from which the oil has also drained, but it is not hard to distinguish between the two. Hydraulic lifter clatter is just that, a thin, clattery sound, whereas knock from worn big ends starved of oil for a few seconds is deeper and more serious sounding.

Some engines will soldier on relatively happily on light duties with slightly worn big ends and, if you can get the sump off without taking the engine out, you might be able to postpone an engine overhaul for a few thousand miles of shopping duties by putting in new shells, but do not bank on it. If you have tuned the top end to give more power, and you do a fair amount of sustained high-speed motorway driving, new shells on a worn crankshaft are not likely to last all that long. The time for a complete engine overhaul is very near.

The second type of starting-up knock, a lighter one which dies away as the engine warms up, is most likely to be piston slap. The pistons and bores are getting worn and, when they are cold, the piston skirts contract to give more clearance than there should be. As they warm up they expand, and the noise disappears. This is not such a pressing problem as big-end rattle because

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nothing is likely to break, but it is a sign that the pistons and bores are getting worn, even though the oil consumption may not be all that high. Excessive oil consumption is more likely to be due as much, or more so, to worn valve guides, stems and oil seals as worn bores. Piston slap is often found less on high mileage engines which spend much of their life on motorways than on engines that have always lived in towns and been used only on short journeys to and from work or the supermarket. Most engine wear occurs in the first few miles from cold before the engine has reached its full operating temperature. It is a typical symptom of an engine that has done only 30,000 miles in ten years with 'one careful owner'.

It is not a case of having to take the car off the road immediately, but attention to this should take precedence over, say, fitting a performance camshaft. If caught fairly early, before the bores are badly worn, a new set of pistons and deglazing the bores can often postpone a complete overhaul for 50,000 miles or so, but the only way to check is to have the head off and measure the bore wear.

Now we come to the heavier, sharper knocks, the classic one of which is a run big-end. Unless you have had a catastrophic oil failure it is unusual to get all four big ends fail at the same time. Usually, one goes before the others, quite often after a hard motorway thrash, and creates a racket that tells you to stop. With the engine ticking over, you can hear a sharp, deep knocking every second revolution of the crankshaft when the cylinder with the offending big-end fires, at the same frequency as with a misfiring spark plug. It often sounds less with the engine under light load such as gentle acceleration, but gets worse on the over-run. An almost sure sign is, with the engine ticking over, to pull off each plug lead in turn. If, when you take one of the leads off, the noise becomes much less, you have found the big end that has run.



▲ *An engine stethoscope will help to pinpoint knocks and rattles from any part of the engine. Be careful of moving parts and high tension leads.*

Can you get away with just a new set of big-end shells if you catch things early enough? Some people will tell you that you can, but it is taking a chance. Big-ends do not go simply because they feel like it. The white metal or lead-indium shell lining ran when it became too hot which was because it did not get enough oil. It is usually a sign of sludge in the oilways because no-one has changed the oil frequently enough, or a worn oil pump that could not keep up with high-speed demands, or both. If it is detected in time, before the crank journal is knocked about, a new set of shells, a new oil pump and a flushing of the oilways might give an

▼ *If you do not have a stethoscope, a length of rod held against your ear can serve almost as well.*



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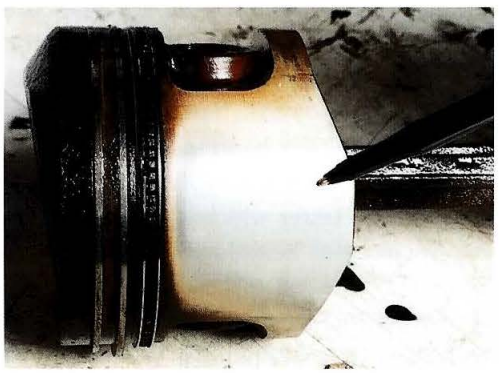


▲ *A 'wet and dry' compression test can tell you a lot about the condition of the piston rings and bores.*

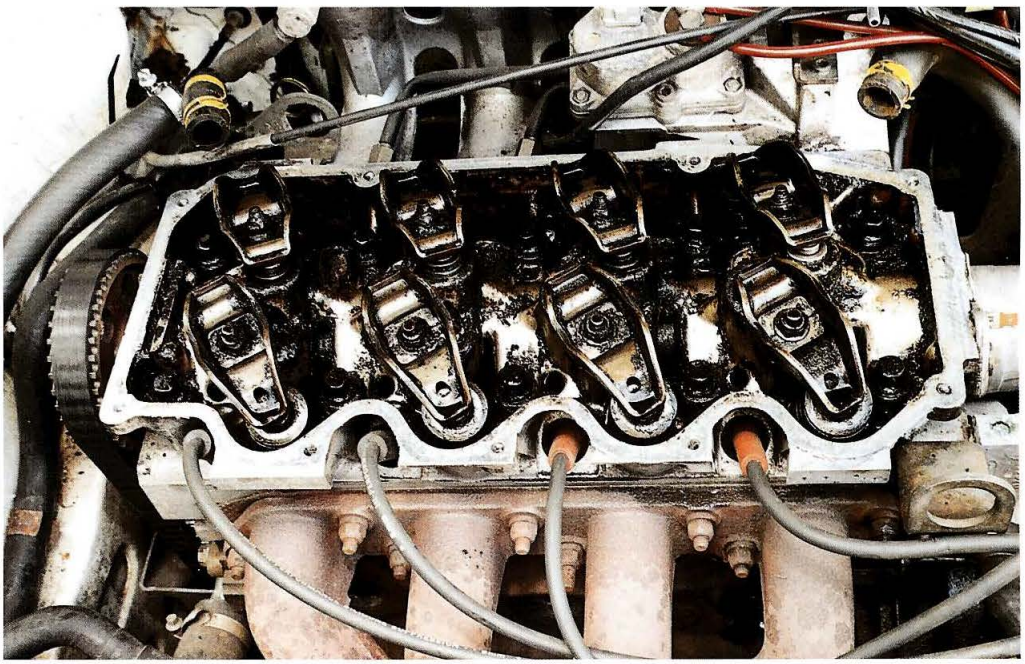
extended lease of life, but it depends on the surface condition and ovality of the crank journal. At best, this would be an interim measure, so do not be surprised if you try it and have the same problem soon afterwards.

Going back for a moment to our big-end knock on starting up, this is, as we said, more frequent on constant stop-start short journey engines, but it can also happen on high-mileage engines where the crank journals and big-ends are suffering from fair wear and tear. If this is the case, there may also be a deeper, more rumbling sort of sound, (the third type of knock we mentioned), when accelerating hard. With a combination of the two, this is most likely to be wear in the main crankshaft bearings. It is not so much a sharp knock but more of a rumble and a slight vibration that can be felt through the engine as much as it can be heard, and there is nothing that can be done about it other

▼ *Stripping down revealed that the rings were quite badly stuck in their grooves although the thrust face of the piston was a smooth, matt surface.*



▶ *Lifting the rocker cover revealed quite a large accumulation of black sludge, usually a sign of neglected oil changes.*



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than a complete engine overhaul.

Earlier we mentioned two diagnostic tools, one of which is a piece of wood. Find a length of heavy dowel rod or a piece of broomstick, place one end against the engine while it is running and put your ear or the bone just behind your ear on the other end. Knocks and rattles are amplified and transmitted through the wood and, with a little practice, you can move it about on the engine and tell where the knock is coming from. If you want to be more sophisticated you can buy an engine stethoscope to do the same thing, but a wooden rod can be just as effective. An experienced mechanic can diagnose all sorts of wear with this simple tool.

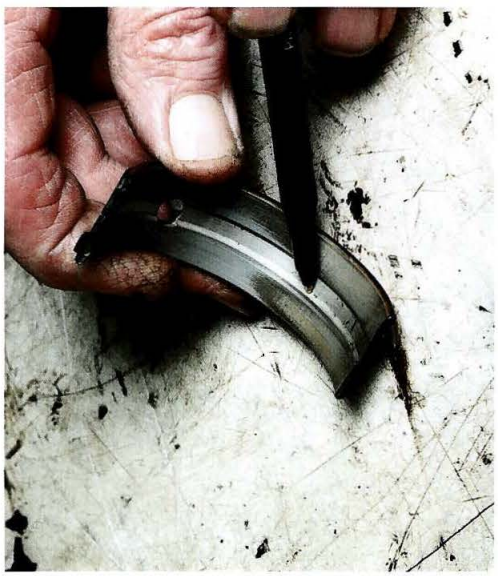
However, be very careful to keep the wood or stethoscope out of the way of the cooling fan and drive belts, and remember that a thermostatic fan can start up without warning when the engine is hot.

The other diagnostic tool mentioned is a compression tester which is an inexpensive but very useful item for determining the cause of a smoky engine. We need to distinguish between three types of smoke emitting from the exhaust. The first is white which you nearly always have when starting up from cold on those damp, misty autumn and winter mornings. If it disappears when the exhaust system heats up, it is nothing to worry about and is actually steam from the water which has condensed inside the hot exhaust pipe overnight. If it does not disappear and it has an acrid, sweet smell, it might be burnt anti-freeze where there is a blown head gasket that is leaking coolant into a combustion chamber.

The second type of smoke is black which you might see on bursts of heavy acceleration. If it is definitely black, and the inside of the tailpipe is sooty, this is due to over-fuelling, and is likely to be caused by a dirty air filter, a worn carburettor, or one that is not set up properly, a problem with the fuel injectors, or the management system.

The third type is blue smoke, usually most dense when the engine is revved up after it has been ticking over, and is usually more dense when the engine is hot and the oil is thinner. Blue smoke is burnt oil, and it comes either from worn valve stems, valve seals or valve guides, from worn

▼ *The bearing shells showed signs of wearing down through the thin coating of lead-indium, but no more than would have been expected from the mileage of over 80,000.*



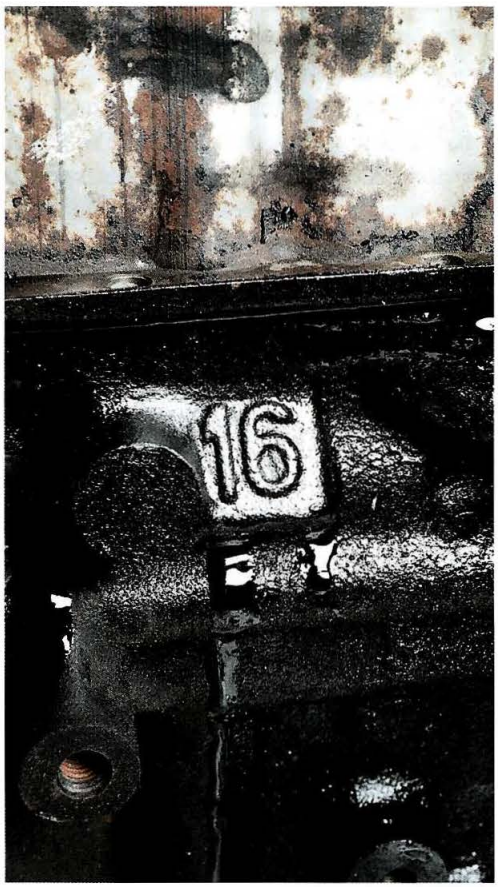


◀ *The crankshaft was just starting to ridge, but not too seriously for general motoring, and taper and ovality were within reason, but for extra power it needed a regrind.*

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bores, or sticking piston rings. To find out which, can be done by using the compression tester. The workshop manual will say what the compression pressures should be on an unworn engine, but here we are more concerned about the difference between what is usually termed 'dry' and 'wet' pressures.

The plugs are taken out, a low tension lead removed from the coil to stop a shower of sparks from the HT leads, and the compression tester is screwed into each plug hole in turn while the engine is cranked over for a few seconds. Assuming the compressions are more or less even, a note is made of each and then some oil is squirted down each of the bores and the compression readings taken again. If there is only a little difference between these readings and the first set, the pistons and rings are in good condition. Blue smoke from the exhaust is then probably due to oil being sucked down past the valve stem oil seals. New seals will help but, if the valve stems and guides are worn, the head will need overhauling.



▶ *The only way to identify the engine capacity accurately is to look for the cast figures on the block and head.*

If one cylinder is found right down on compression compared with the others and there is white, sweet-smelling smoke from the exhaust, it is an indication that there is a blown head gasket. It might also be possible to smell exhaust gases when the top of the coolant expansion tank is sniffed, or an oily film floating on the coolant may be seen. If the pressures on two adjacent cylinders are well down, the gasket has probably blown between them even if there is no white smoke.

When the pressures are more or less even, but the second set of readings after oil has been put in the bores is considerably higher than the first set, the piston rings are probably stuck and leaking. What has happened is that the oil has given a temporary seal to bring the pressures up again.

Dosing the bores with Redex, leaving it overnight to soak around the rings and then giving the engine a good run the next day, possibly repeated a few times, sometimes helps to free stuck rings but, failing this, the only answer is an engine overhaul. If dosing with Redex does bring the 'wet' and 'dry' compressions more equal, but you are still getting blue smoke when revving the engine after tick-over, look to the valve stem oil seals.

We cannot tell you whether or not your engine will run satisfactory with extra power, or how much it is capable of producing. If you are in doubt, seek the advice of an engine tuning specialist rather than a mechanic in a general garage because it is not really in their field. If you decide an overhaul is necessary, even if you do not want to go to the full extent of reconditioning, the next stage of doing things yourself is to take the engine apart and examine it for wear. This is covered in a later chapter.

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Chapter 4

Free-flow air filters

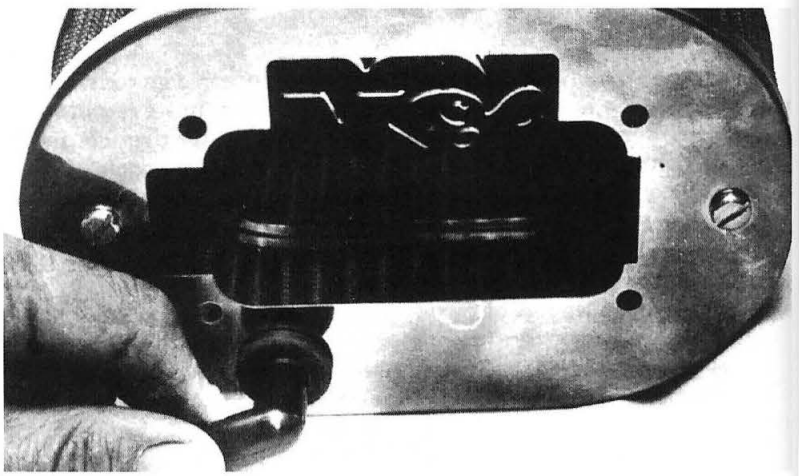
Fit a free-flow filter. It is a lovely alliteration of words, and it is the first step in tuning for a spot more urge. It is one you can easily take, even if you have only basic mechanical experience and, provided a few things are sorted out before starting, you should not have too many problems.

There are two main types of free-flow filter: cotton gauze and polyester foam. Good examples of gauze filters are K&N, Euro Web (which uses a similar element to K&N but in a cheaper case) and JR filters which are imported from France. K&N uses cotton gauze exclusively but on some other makes there might be a mixture of cotton and man-made fibres, some of which do not clean quite so easily. Two well-known names among foam filters are Pipercross and Megaflow. Both types of filter have to be sprayed with a special oil to get the best filtration.

Which type should you choose? Really, there is not much in it. Cotton gauze filters are robust and easy to clean and re-oil. Provided you do not do anything silly, like cleaning them with a wire brush, they have what almost amounts to a lifetime's guarantee. Foam filters are generally cheaper, and they can also be cleaned and re-oiled, but you have to be a lot more careful cleaning them because they can bruise quite easily. They have the advantage that specially shaped foam filters to go in awkward places are available although these are often more expensive than standard ones but, for general use, the need to renew foam filters occasionally is offset by their cheaper initial cost.

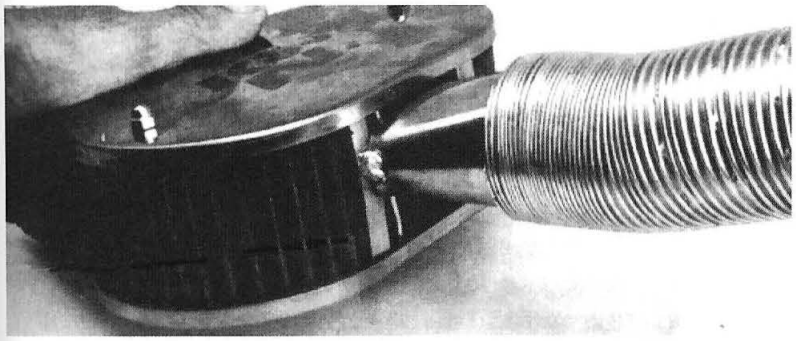
With regard to how free the air flow is, we have not made any direct comparison tests, and we do not know anyone who has but, certainly they all give a better air flow than the standard Ford set-up which is a balance between good filtration and silencing the suction noise from the air intake. Which brings us to the question of noise.

In almost all cases, a free-flow filter gives more induction roar than the Ford filter in its tin can or, with a fuel-injected engine, its plastic box. To some, a nice induction roar when you tread on the pedal is real music. To others, who like their car to be as smooth and as quiet as possible, it is a nasty noise they do not want. If you have not already done so, listen to an engine with a free-flow filter and if you do not fancy the increased induction roar, keep the Ford air-cleaner housing and, instead of the usual paper



▼ *With a K&N carburettor filter the engine breather can be fed into the base of the filter on the carburettor side of the element to avoid contaminating the element with oil fumes.*

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▲ *With a K&N pancake carburettor filter you can buy this adaptor to pipe warm air from over the exhaust manifold to avoid carburettor icing in winter.*

element inside, fit a free-flow element. There will not be quite so good a flow as with a complete free-flow filter, but it will be a lot quieter. No more noisy in fact, than the standard set-up. (We are assuming that you have a carburettor.)

Some say foam filters are more likely to catch fire than gauze filters. Any filter element will burn if soaked in petrol and a sheet of flame is blasted over it. In the early days of foam filters there were some quite spectacular flare-ups when engines with really wild cams had a coughing fit, or people had their ignition or valve timing hopelessly wrong, and old legends die hard. Nowadays, any additional fire hazard can pretty well be forgotten. All free-flow filters, reputable ones that is, are fire retardant. The oil which is put on them is specially treated to be flame resistant and, on foam filters, there is a layer of flame-retardant foam next to the carburettor intake. If there is a backfire, you are unlikely to know the carb spat back a sheet of flame until the next time the filter is cleaned and the scorch marks are found.



▶ *With a foam type filter you can use convoluted aluminium trunking to direct warm air to it in winter. This K&N air filter kit is for an Escort RS Turbo. If ventilation slots are cut in the bonnet the deflector plate can be fitted under them.*

If a free-flow filter is simply bolted on to a carburettor without thinking about it, you will suddenly find a piece of engine breather hose in your hand which used to go to the Ford air-cleaner can, but now there is nowhere to put it. You cannot leave it to spew oil fumes out over the road unless you are very anti-social, and it certainly won't pass an MoT test.

There are two ways to get round this. In the case of K&N and similar filters, there is an adaptor which pipes the breather into the air-cleaner case. There are two types, one where an adaptor fits around the edge of the casing and the other which uses an elbow pipe in the base. We much prefer the latter type because oil fumes are not blown straight onto the nice clean element. Whichever is chosen, our advice is to fit a slightly longer hose so that it can lead upwards into an upside-down U-bend before passing to the filter. Most of the oil which tries to come over will hit the top of the U-bend and drop back to the engine. The U-bend can be held together with a wire tie or, more neatly, a figure-of-eight clip. As an alternative, or as a secondary line of defence if you like, an oil trap can be fitted in the hose. The one from a carburetted XR3 is quite efficient, and it can be cleaned out from time to time.

You will not find an adaptor on a foam filter to take the breather pipe, so other arrangements have to be made. Pipercross produce a neat little oil filter trap which can be bolted on to a convenient part of the engine and the breather pipe led to it. They claim this will stop oil being spewed out into the atmosphere and will pass an MoT test. This trap can also be used with a cotton gauze filter. We have seen a breather hose led to a vented plastic bottle, but it does not look so smart.

With injection engines there is a choice of either fitting a direct replacement for the Ford panel filter or throwing away the complete Ford set-up and fitting a free-flow system in its place. There is not a problem

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with the free-flow panel filter which fits inside the Ford filter casing because nothing else is being disturbed but fitting the complete system calls for a little more work.

If the Ford system on an injected engine like the XR3i or Orion 1600i is discarded this leaves nowhere to mount the air-flow sensor or the fuel distributor because these sit on the lid of the panel filter box.

A popular replacement system is the 57i from K&N Filters. With this there is a large cone-shaped free-flow filter, trunking to connect it to the intake chamber and a second piece of trunking to provide the air intake to the filter. Also in the kit are brackets for mounting the filter, air flow sensor and fuel distributor which no longer have anywhere to fit. It is not a difficult kit to install, but it is more than a half-hour's job. The inner wing has to be drilled to take the various brackets which is not easy unless you take the sensor and distributor right off, in which case the fuel piping is disturbed. Care has to be taken with how things are mounted so that none of the pipes are put under strain or have any sharp bends. It is also as well to make sure the filter is accessible so that it can be cleaned and re-oiled without having to disturb the injection system every time. However, if the instructions are followed carefully it is a fairly straightforward DIY job.

Some prophets of doom say that 'next year, or the year after', when more stringent Brussels-inspired MoT tests for emissions come in, any alteration to the car maker's approved breathing set-up will bring a failure. We don't believe this is true but no-one can say for certain until the regulations are published, but those who are reckoned to be in the know, the 'informed sources' of the news journalists, believe if any more restricting regulations are introduced they will probably apply only to new cars and not be retrospective.

The last point we are left with is the possiblity of the carburettor icing in the winter. Unless the Ford filter housing is retained on an engine with a carburettor the free-flow filter cannot be swung over the exhaust manifold because it has not got a snout. Nor can you use the Ford thermostatic vacuum operated set-up which is inside the filter casing. However, K&N can supply an adaptor plate to take a length of convoluted aluminium hose which can be hung over the exhaust manifold. Pipercross say all you need to do is hang a piece of similar aluminium hose over the manifold and point the other end at the filter.

If your car has the thermostatic vacuum controlled hot or cold air valve in the filter casing, you will be left with a vacuum pipe if the filter casing is discarded. Do not leave it hanging loose or the engine will run weak because extra air is being sucked into the inlet manifold. Trace the pipe back, cut it off fairly short and seal the end. A convenient way to do this is to find a bolt that is a tight fit inside the end of the hose, coat it with rubber adhesive and screw it home. Make sure the adhesive is set before you start the engine to avoid any possibility of wet adhesive being drawn into the inlet manifold. The slow-running air bleed screw on the carburettor may have to be reset after blocking off this pipe, but the carburettor should be checked and reset if necessary in any case after fitting a free-flow filter. With fuel injection there should be no need for resetting. The air-flow sensor will adjust the fuel flow to match the better air flow.



▼ *Free-flow filters come in a variety of shapes and sizes to suit any installation. This is a selection from K&N.*

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Chapter 5

Fitting a better exhaust system

We are all familiar with big, chromium-plated exhaust tailpipes. As the saying goes, there's a lot of them about and, let's face it, they do look nice and, in most cases, you get a deeper exhaust note. Very satisfying. But do you actually gain much in the way of power?

We have not had the opportunity to do 'A' versus 'B' power checks on a car with and without a cosmetically nice tailpipe, but we have talked with exhaust makers who have and the answer is that a big tailpipe, chromium or not, gives nothing but looks and sound.

Change the rear silencer box, and you do start to see a little more power. With a modified CVH a different back box may well be needed together with a larger diameter pipe, but we will come to that later. With a naturally aspirated engine you will not achieve the full benefit from changing the back box unless something is done about the front box and the rest of the piping. The general consensus of opinion, backed by rolling road tests, is that for a road-going car, where you are looking for an uplift in power right across the rev range, this is as far as you need to go on an exhaust system. A highly tuned competition engine needs a highly tuned exhaust system, probably with a new manifold, but we will come to that in a moment.

Let's take the more usual case of someone who is looking for a livelier engine but does not want to deafen the neighbours with a raucous, rip-snorting exhaust or give himself and his passengers splitting headaches from resonance inside the car.

Earlier we said that in the simplest terms, power from an engine depends on how much air and fuel can be crammed through it in a given time. Yes, we know efficiency of the combustion chamber and all sorts of other things play their part but, if you do not get the air and fuel in, and make room for it by getting the burnt exhaust gases out, you will not have the power.

As we are talking about exhausts, it is taken for granted the engine has been fitted with an air filter that flows more air than Ford's standard effort. If it is an injection engine, the system will take care of the necessary increase in fuel flow and, if it has a carburettor, possibly some of the jets have been changed to match.

It is much easier to arrange for more air and fuel to be available than it is to get rid of the exhaust gases to make room for them, which is why you will not see the full benefits from the inlet side until something is done about the exhaust.

First of all, the big tailpipe. As we said, looks? Yes. Nice deep, powerful-sounding exhaust note? Probably. Extra power? Theoretically a little, but in practice not a lot.

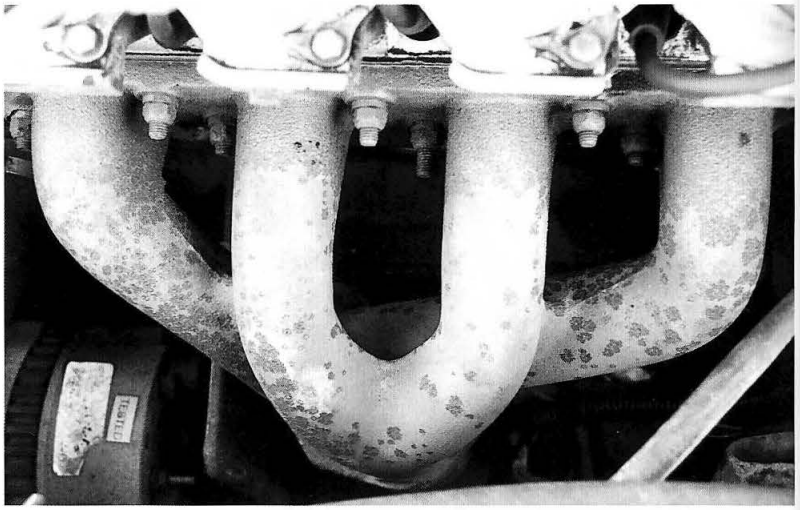
Putting things in the simplest terms (a dangerous thing to do when it comes to tuning, but it is easier to understand) Ford's standard exhaust system restricts the power because it limits the gas flow. The exhaust gases are pushed out of the exhaust port

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faster than they can pass through the silencer so they have to queue up, and this causes a build up in the engine, just like a traffic jam coming off a motorway on to an ordinary main road. The term for this is back pressure. Reduce the back pressure and more gas can be passed through. On all but the most highly tuned road cars it is as simple as that. In most cases, a useful increase in power can be gained without having to change the manifold.

If you are looking for maximum top-end power the manifold must be changed, but the standard cast-iron exhaust manifolds on Ford's transverse engines are not nearly as black as they are sometimes painted. If your car is fitted with a catalytic converter there is the added complication of the lambda sensor in the downpipe from the manifold. (Ford call this a HEGO sensor, standing for heated exhaust gas oxygen sensor.) With some fuel-injected engines there is also a pulsed air supply to the exhaust manifold.

Ford know as well as anybody that power, whether quoted in terms of bhp or just looked on as a reputation for lively performance, sells motor cars. Whoever designed Ford's crop of exhaust manifolds and downpipes for the CVH engine had to strike a compromise between efficiency, noise and emissions – and they did not make such a bad job of it at that. More power can be obtained with a tubular, four into two into one, custom-built manifold but you need to specify whereabouts in the rev range the increase in power is wanted.



▲ *Ford's standard exhaust manifold on the non-turbo CVH may not be the most efficient in the world, but it's much better than some of the company's previous offerings.*

We could quote formulas that some manifold designers use but, usually, most of the extra power will be at the top end, 5,500rpm plus. You will also have to put up with quite a lot more noise under the bonnet.

It depends what is wanted. If you want to be able to boast of a higher maximum bhp figure on a rolling-road than your friends, the so-called rolling-road shoot-out, by all means go for the full works, including a performance manifold. But if you are content with a general uplifting of the power curve from around 2,000rpm upwards without a high peak at the top, the standard manifold and downpipe on most CVH engines have quite a lot going for them.

If you have a turbo engine there is even more incentive for leaving the standard manifold as it is. Having a custom-built



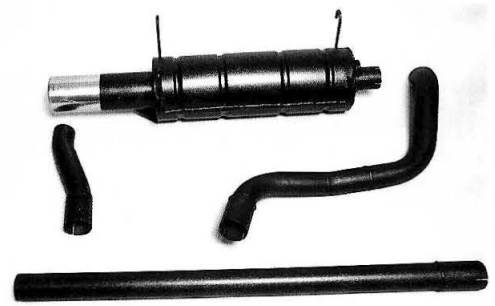
◀◀ *For comparison, here is Janspeed's four-branch tubular exhaust manifold for the CVH.*



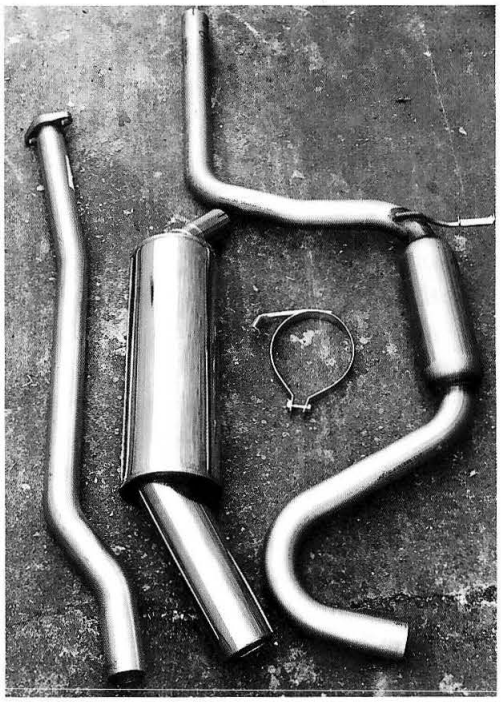
◀ *Janspeed's complete front end system for the CVH is a 4-2-1 design with two collector boxes. One joins 1 and 4, and the other joins 2 and 3. A second collector box brings the two pipes from the manifold together to feed into the main exhaust pipe.*

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▶ *A larger diameter pipe running back to a bigger expansion box and a large tailpipe will provide a more efficient exhaust than just fitting a big tail-pipe which is mainly cosmetic.*



▶▶ *This is the complete stainless steel large bore Mongoose system for the Escort RS Turbo.*



manifold made can be very expensive. You also have to be careful about how much the back pressure is reduced after the turbocharger on turbo engines or it may be found the oil seal in the turbo has a short life.

On newer Fords, and those not all that new nowadays, there is also the big tin can called a catalytic converter that legislation says you must have hanging in the system. Early 'cats' were pretty naff when it came to power efficiency. They cut down harmful emissions well enough but they were inclined to strangle the exhaust system. Like most innovations though, there has been a lot of development work carried out and the modern 'cats' are not nearly so restricting.

This is just as well, because if the 'cat' was fitted as part of the type-approval system when the car was first made, it would be illegal if it was taken off. Unless you were unlucky enough to come across a road-side emission check, you probably would not get caught until the next MoT. We know you can buy lengths of plain pipe which can be put in place of the 'cat', and even dummy 'cats' with nothing inside them are available. Selling them, apparently, is not illegal, but using them is!

You have to ask yourself if a performance manifold and downpipe, or pipes, is really worthwhile on a road-going car with a catalytic converter. If the car is fitted with Ford's EEC IV management system there is the added complication of where to fit the HEGO sensor. This is connected back to the engine management system as part of the mixture control, and no-one has explained to our satisfaction as yet, what effect taking out the 'cat' and the HEGO sensor will have on the EEC IV fuelling map. If the 'cat' and the HEGO sensor are removed it will do funny things to the mixture control unless the chip is reprogrammed to compensate, as explained later.

So, what it boils down to is, if you are looking for a general uplift in power across the rev range on most CVH engines, without going for a high peak maximum, start looking from the end of the downpipe backwards on cars without a 'cat' and from the rear end of the 'cat' backwards on cars so fitted.

You will still have a few decisions to make, and most exhaust makers offer a range of systems. Do you, for example, run a big bore pipe on a naturally aspirated engine, something like the 2½in diameter pipe on an RS Turbo, all the way from the downpipe to the rear wheels, and have all the silencing at the back end, or do you replace Ford's standard front silencer box with a larger straight-through performance box with a smaller box at the back?

In terms of power and efficiency, tests by

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exhaust makers have shown that there is not a lot in it. The governing factors are noise inside the car and ground clearance and these are things not all that many people take into account when they think about fitting lowered suspension. It is all very well modifying the wheel arches to get clearance for the wheels but modified wheel arches won't be a lot of help when you wipe your front silencer off on a 'sleeping policeman' ramp.

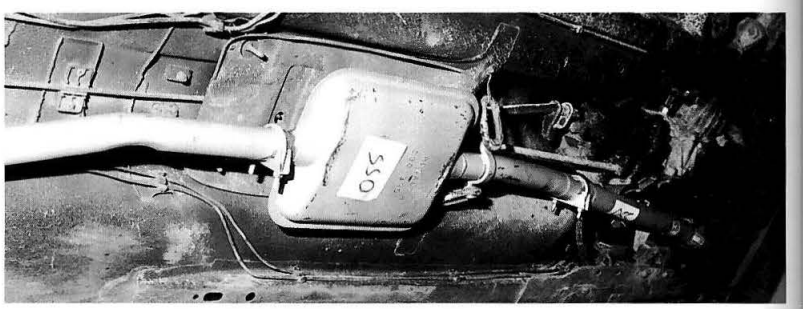
There's also the point that as the floor is lower, you are more likely to get a beat-back of the exhaust note through the floor if have a straight pipe from the downpipe back to the rear wheels unless you fit quite a lot of sound deadening. You are likely to experience quite a few decibels of noise resonance inside the car, even if only over part of the rev range or over-run. This is where you will have to talk to the people who make the system you wish to fit. To give the same degree of silencing but with less restriction and thus more power, a straight-through absorption type silencer must be larger in diameter than a more restricting one with internal baffles. This is something in the region of seven to eight inches in diameter, or the same cross section area if an oval pattern. If you want to lower the car, make sure you have the room to fit such a silencer.

It is possible to save ground clearance by going for a flatter straight-through silencer, but these are still more noisy under the car than a round one. The flat ones cut down on the noise sideways but not upwards, which is where it is going to rebound from the floor and give you internal resonance. This type does not have the same absorption to be as effective and you also have to watch out for price and quality. You may see two very similar straight-through front silencer boxes, one with a well-known name and one unbranded which is priced a lot lower than the other. Where the money has been saved is probably on the thickness or quality of the steel and on the quality and quantity of the absorption packing. You could find it getting very noisy inside a year. Choose from the range of one of the well-known and reputable makers and you won't go far wrong.

If you really want to go for the low, mean look then, provided you do not go so low that you wipe the pipe itself off, you will have to have a big bore piping right to the back as well as a really big rear end box to avoid attracting every policeman within earshot.

Ever since it became clear that 'cats' were here to stay and there was not a lot we could do about it, exhaust makers have been putting a lot of research and testing into systems from the 'cat' backwards, or from the downpipe backwards in the case of earlier cars. There are some pretty efficient systems about, but don't just buy on description or hearsay. Pick the make you fancy and have a word either with the makers or with one of their larger fitting agents to make sure you get the system that is suitable both for what you want in terms of power increase versus noise and, if you have lowered the car, ground clearance. You can still buy all the bits and pieces to design and make up your own performance exhaust to whatever formula you fancy, and several versions have been published in the past, but so much research has been done by exhaust makers that experimenting with home-brew efforts is not really worth all the trouble and effort.

Fancy tailpipe trims? Fit one by all means if you want to. They look good, but do not expect it to give you much in the way of extra power.



▼ *If the car is lowered you might like to consider a flattened first expansion box to give ground clearance. Even with a deflector shield above it, more noise is generated inside the car than by a tubular box and you may have to fit sound deadening material inside the floor.*

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Chapter 6

Going for a bigger engine

There is no doubt about it, the easiest and, quite often, the cheapest way to get more power is to fit a bigger engine. As the Americans say, there's no substitute for cubic inches or, in our case, litres. What is more, provided you are sensible about it and do not go overboard and try to graft something like an RS Turbo engine into a 957 Fiesta, it need not be all that difficult.

It makes things a lot easier if you keep like with like, although we will deal with more far reaching changes in a moment. By like for like, we mean swapping engines within the model ranges, particularly Escorts.

If you want to swap from ohv to CVH in a Fiesta, say from 1,100cc ohv to a 1.4-litre CVH, it is possible to put the CVH block on to the ohv's gearbox, but it is much more straightforward if you transfer the whole shooting match, engine, gearbox, manifolds, carb, gearchange linkage, sub frame, brakes, suspension and radiator. You will also want the auxiliaries such as alternator, starter, distributor and so on and you will have to do some wiring because things are in different places on the CVH from the ohv. If you can buy the 1.4 CVH still in its written-off or rusted-out donor it makes for easier installation as you can have it standing by the side of your car while the swap over is carried out. That way you can see where everything goes and you will have all the little clips, brackets and odds and ends for the CVH that can cost you a surprising amount of money bought separately from a dealer – if he has them all in stock.

We are sometimes asked about fitting a 1,800cc CVH from a Sierra in place of a 1,400cc or 1,600cc, which seems to be a fashionable bit of armchair planning at the moment. Well, on the basis that most conversions are possible, if you have the equipment and the money, we imagine it can be done, but among other snags, the spigot bearing will not accept the input shaft of the XR2i gearbox, and we are not certain about the flywheel and clutch even though the bellhousing will go on. The oil pump will not fit, and the mountings are wrong. You can spend an awful amount of time and money sorting all this out, as well as the problems of acquiring an 1,800cc engine or block in the first place.

Much easier, and probably a whole lot cheaper, is to use a conversion from one of the specialists, but we will be coming to that.

Moving now to Escorts, this is where it is better to keep like with like. Swapping around within the Mk 3 and the post-January 1986 Mk 4 ranges does not present many problems and, where changes are necessary, you can use items from the Ford parts bin or even from a breaker's. However, cross-swapping, between Mk 3 and Mk 4 raises a few more snags and, although it is possible, we would be inclined to think twice about it.

Inside the Mk 3 range, you can swap around between 1,300cc and 1,600cc with

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no real problems provided you take the appropriate inlet manifold and carburettor with you and, preferably, the exhaust manifold as well. The engines will sit straight on each other's gearbox but, once again, you will have final drive ratios to think about. If you happen to have one of the far less common 1,100cc engines, these had quite a low final drive ratio of 4.06 to 1, whereas the others were either 3.58 or 3.84. So, if you are swapping up from an 1,100 it will give better economy and less engine fuss if the gearbox and final drive are also taken over with the bigger engine. The drive shafts and mountings will fit OK. Watch out if you are offered a complete engine and gearbox from a van. Even the 1.6 had a 4.06 to 1 final drive and the others were lower still at 4.29. Good for acceleration, but fussy at higher speeds.

With regard to radiators, that from the 1,100 is not man enough for either a 1,300 or 1,600 engine but these engines used the same type so you can use one from either. We are referring here to carburetted engines, the XR3i radiator was different and, funnily enough, was the same as that used on the diesel.

On Mk 4 Escorts, you can swap parts around quite happily between the 1.4 and 1.6 engines except for the carburettor and the manifolds.

Can you put an XR3i or Orion 1.6i engine in a car that had a carburettor? Physically you can and, if you do not mind quite a lot of work, you can take over the K-Jetronic fuel injection system as well. It is a mechanical and not an electronic system, but remember that as well as taking the system and all its mounting brackets over, you have to change the petrol tank and piping and fit the injection fuel pump and accumulator. You will also have quite a few wiring alterations, too, when fitting the fuel pump, safety and speed sensing relays under the dash, as well as the wiring for all the engine sensors plus a few alterations to fit the throttle body controls. For the extra power obtained from an injected engine, you may think it is hardly worth the trouble, and if you have to buy the parts new we would agree. However, it becomes more feasible if you can find a smashed or rotted XR3i or Orion 1.6i going cheap and can have the whole car. With the help of workshop manuals, particularly the wiring diagrams, you can do a piece by piece swap. Servicing fuel injection systems is a specialised business, but there is a certain amount you can do yourself to trace troubles and the basics are covered in Chapter 9.

If you are offered a good XR3i engine by itself, and do not want the hassle of changing to fuel injection, the inlet manifold and carburettor from an XR3 can be used or, if you have an engine fitted with a Ford VV carb, go for a replacement Weber. Carburettor changes are dealt with in Chapter 8.

If you want to go beyond Ford's standard capacities for the CVH there are several roads you can take, depending on whether you have the standard block bored out and a longer stroke crank is fitted, go for the taller American CVH block, or throw away the CVH block and fit your head on to a Zetec block. We will look at these options in turn but they are really specialist jobs and not DIY conversions, so you will have to go to a tuner who offers one of these options.

First, using the 1,800 American 'tall block'. This is the way that Specialised Engines go about it. The American block was produced for very low emissions, and is only 0.70mm taller, but it has thicker metal around the bores so it can be bored out more safely than the 1,600 European block.

Specialised Engines take the bore out by 1mm to 83mm which, with an 88mm stroke gives 1,905cc. As it is, without doing much to the head, this will give you around 135bhp in naturally aspirated form with a K-Jetronic injection system. With gas flowing and bit of fiddling you can push

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this up to 150bhp. On an exchange basis, handing in your 1,600 and going away with a 1,900 will cost around £1,500 plus VAT. If you want to build the engine yourself, the completely built 1,900 block, bored and stroked, works out at a little over £1,000 plus VAT.

If you are doing this conversion on a turbo CVH, Ian Melville at Specialised Engines warns that you should choose your turbo with care. The standard RS turbo, he reckons, spins up too quickly although you should get over 200bhp with it. Fit the 2-litre Cosworth turbo for example, and he says you will see 220bhp comfortably. This can, with the right cam and attention to the head, produce up to 280bhp, but Ian warns this can be a bit of a tiring handful in traffic. The cost depends basically on the turbo you choose.

Dave Griffiths at Interpro takes a different approach. He is not all that keen on the tall American block, not so much because there is anything wrong with it, but he was enlarging the CVH before the American block was readily available and he prefers to stick with the tried and tested development he knows. What Interpro does is to take the standard 1,600 CVH block and bore it out by only 0.5mm. This, Dave says, leaves plenty of metal before reaching the water jacket. To go with the larger diameter there is a crankshaft with a longer throw, special longer con-rods and Mahle pistons. The final capacity is 1,820cc. Because of the longer throw crank, the inside of the crankcase has to be relieved by machining to give clearance for the big end bolts.

This method, he says, is popular with owners of RS Turbos because they can have their own engine converted which keeps the originality of the same engine number for cars which are fast becoming classics. If you take a standard RS Turbo engine to Interpro, they will convert the bottom end and refit a head supplied by the customer as many owners have already spent money on having the head attended to and have fitted a new cam. If you have not done this, they will do a basic amount of gas flowing to the ports and fit bigger valves.

The power obtained depends on what has been done to the head and whether or not the turbo has been changed, but with their own cam and some further gas flowing Interpro say there will be an output of 250bhp. With a different turbo you can go even higher.

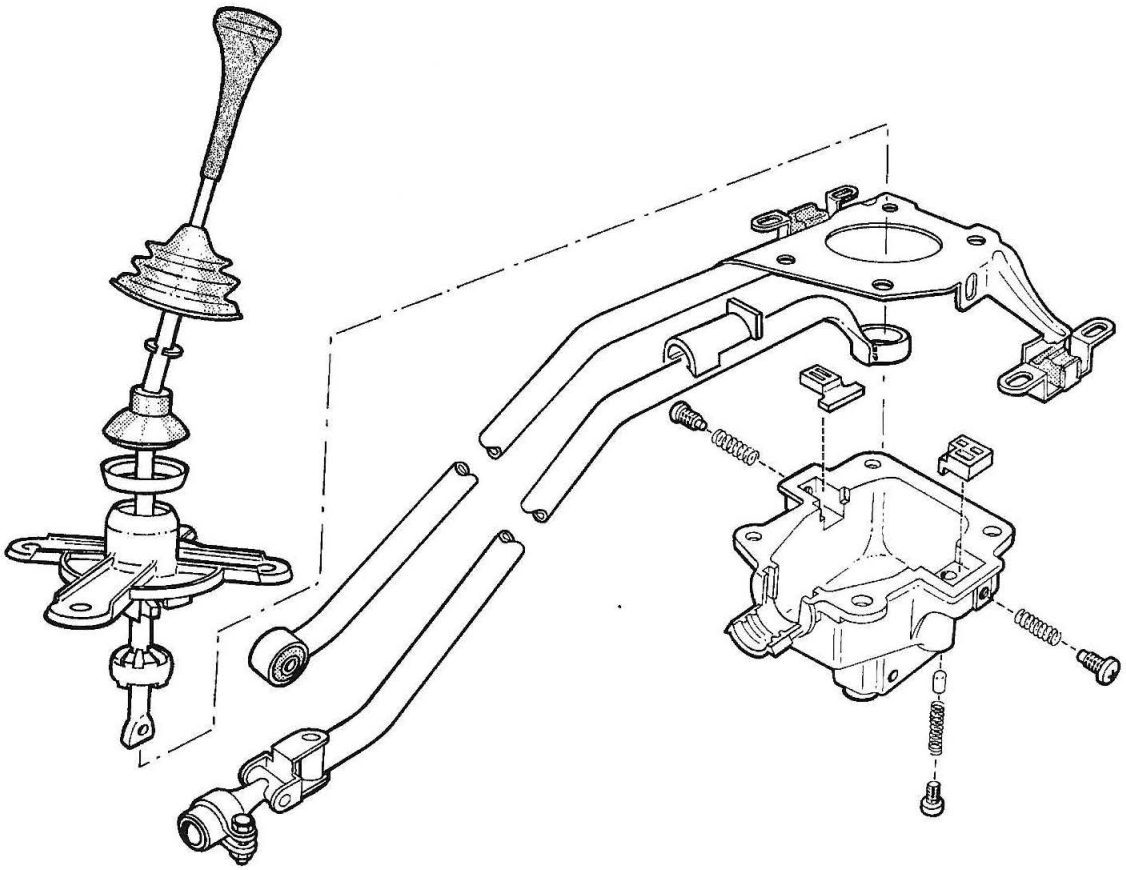
Power Engineering also stay with the standard 1,600cc CVH block but they bore it out a shade larger. David Power says that provided you have not got one of the very early CVH blocks, there is still plenty of meat left around the cylinders after the standard bore is taken up from 82mm to 82.9mm, 0.4mm more than Ford's standard tolerance. Like Interpro, Power Engineering use a longer stroke crank with their own steel con-rods and, again, Mahle pistons. The final capacity is 1,905cc, the same as Specialised Engine's American tall block.

With regard to power, again it depends on what has been done to the head, what cam is used and what the turbo is. The standard RS turbo, David warns, tends to have a lot of lag when you start pushing up the power, but he says that the engine is plenty strong enough to take up to 280bhp reliably.

You can also use the same conversion on a non-turbo engine with K-Jetronic mechanical injection and, if a 2-litre cam is fitted in the head, Power Engineering say there will be a considerable increase in power and response, although they are reluctant to quote figures because, again, it depends on what has been done to the head.

Lastly, there is a very different type of conversion which does not use the CVH block at all. It uses the Zetec bottom end with a CVH head but, as the Zetec block and bottom end was developed from the CVH, and is much tougher, this could be

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▲ *The earliest type of gearchange mechanism for a five-speed gearbox.*

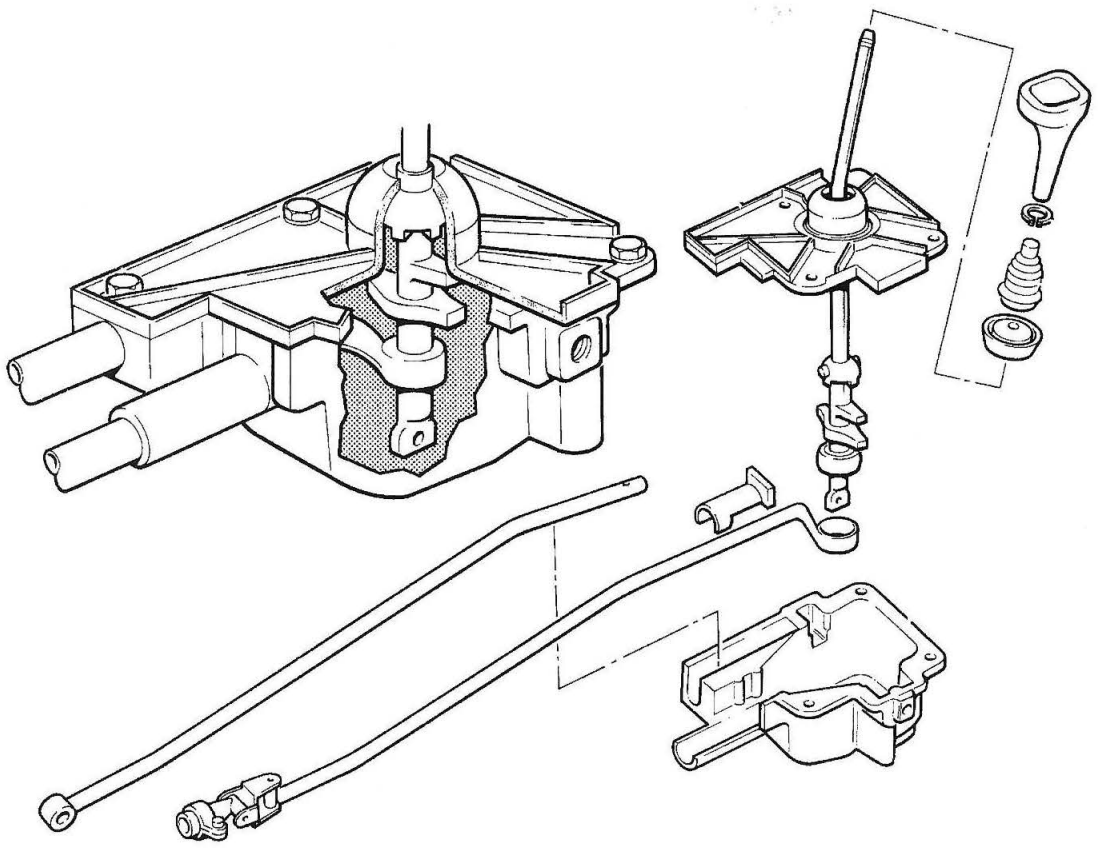
looked upon as a tuned CVH hybrid. However, don't run away with the idea that you can take any old second-hand Zetec engine, bolt a CVH head on it and magically gain loads of power. You can't – there is a lot more to it than that. It is really a conversion that is of more interest to owners of turbo engines than naturally aspirated, and it is definitely not a DIY job; you have to go to a specialist. Interpro, Severn Valley Motorsport and JA Developments are three firms that offer to do this work.

If your Fiesta or Escort has a four-speed gearbox you will no doubt want to think about fitting a five-speeder when you go for a bigger engine. We know it is not strictly engine tuning, but most people with four-speed boxes want to change to a five-speed when they tune their engine, so here is a run-down of what is involved. It is not difficult except in two cases. The first is the Mk 1 Fiesta.

For a long time, fitting a five-speed gearbox into a Mk 1 Fiesta was a big no for most people. Yes, there have been quite a few converted, but it has not been an easy job because of the cutting, hacking and welding-in of reinforcing plates that had to be carried out to get the five-speed box in the engine bay.

The trouble is that the five-speed box, either from a later Fiesta or from an Escort, has the fifth gear more or less bolted on the back of the four speed clusters so the casing is that much longer. When you try to

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▲ *In 1984, Ford changed to this type of five-speed gearchange mechanism.*

drop it in a Mk 1 Fiesta engine bay, the end of the gearbox hits the inner wing and chassis box section. It is possible to cut away the offending parts of the inner wing and side member, and weld in fairly heavy-gauge plate to restore the strength. But then you have to be very careful, not only about the quality of the welding but also about how abrupt you make the change in section of the side member and the thickness of the reinforcing plate. If you get things wrong, you could set up a stress concentration that either cracks the weld or the welded edge of the box section and splits the thing wide open again.

What most people wanted was a conversion that took a lot of the stress out of the side member so that after cutting it back to clear the five-speed gearbox, all that had to be done was weld in a closing plate of the same gauge as the rest of the metal. That is just what Norwich Fiesta Centre has done in its neat conversion kit. Included in the kit are instructions explaining how and where to hack away at the side of the engine bay to make gearbox clearance, plus a pre-shaped plate ready to weld back in to close the hole; all very straightforward.

If you do not have welding gear, or if you are a mite unsure that your welding is quite up to tackling a structural part, any competent welder can carry out the job for you without worrying about taking measurements to decide where to cut and how to make up the plate. It is not much

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different from 'cut and plate' rust repair.

To take a lot of the stress away from the cut-back side member, there is an extra tubular brace that runs from the front cross-member, where the front of the suspension tie-rod mounts, under the gearbox and it picks up on the inner mounting of the track control arm, or lower suspension arm, if you are not familiar with Ford's nomenclature.

The front of the tie-rod sits in a bracket that fastens to the cross-member with three bolts. You take off the old bracket and bolt on the new bracket in the kit. This carries both the front end of the tie-rod, and the front end of the tubular brace. At its back end, the tubular brace has a welded-on block which is threaded to take the pivot bolt that runs through the inner end of the track control arm. You take off the nut, tap the bolt back, hold the end of the tubular brace in position and tighten up the bolt again.

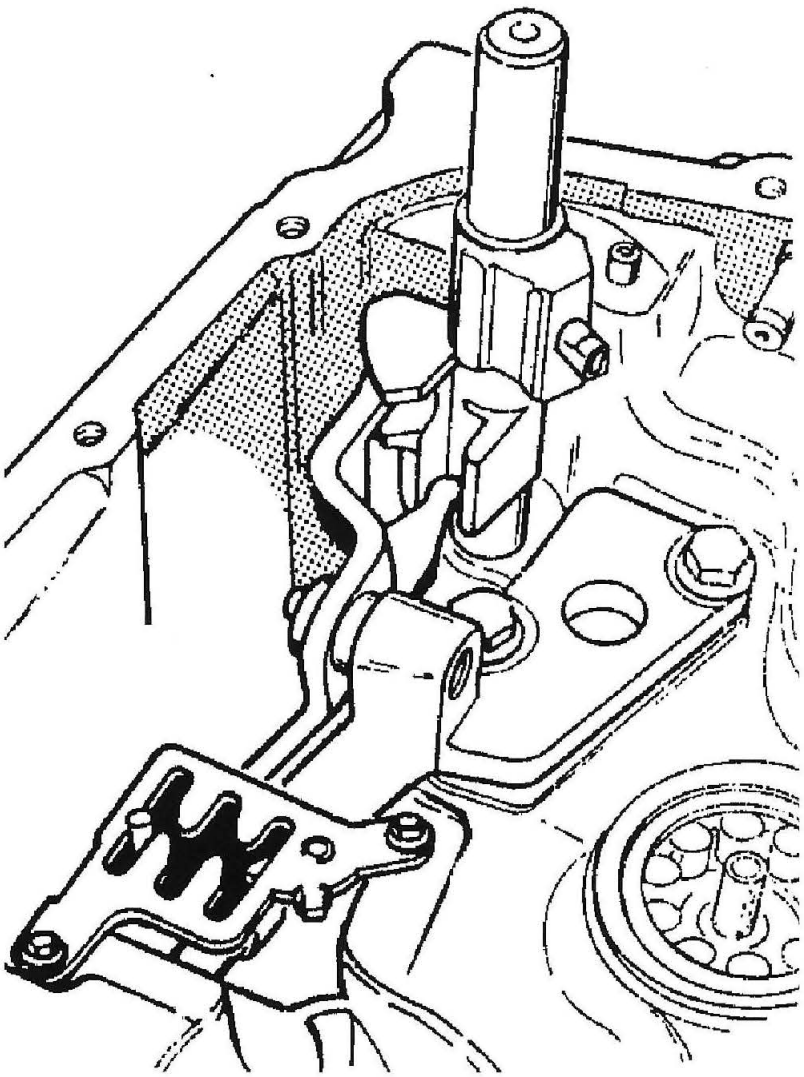
The original tie-rod cannot be put back because it would foul the five-speed gearbox, so included in the kit is a new tie-rod modified from a Mk 1 XR2's. The part where it bolts to the track control arm is cut off and a new plate welded in its place to bring the tie-rod out at a slightly different angle. We were a little concerned about this because the tie-rod controls the castor angle by locating the bottom end of the suspension strut, but Norwich Fiesta Centre assured us they have taken this into account and make up the modified tie-rod on a jig to ensure it holds the bottom of the strut in exactly the same position as did the old one. They say you should not even need to have the castor checked afterwards. What they do say is that you throw away the old Mk 1 front tie-rod bushes and use the Mk 2 bushes that come in the kit. There is not a lot of difference but they reckon that the improved composition of the Mk 2 bush material gives a better feel to the front end of the car.

OK, so now you are all ready to drop in the engine with its new five-speed box? Yes, in a manner of speaking, but there are a few more points you should think about before you start the job.

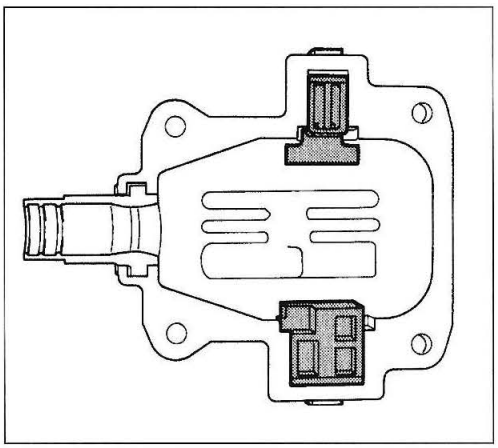
The first is to decide which five-speed gearbox you are going to use, and you have quite a choice of final drive ratios between the different capacity Fiestas and Escorts. It does not matter whether your five-speed box comes from a Fiesta or an Escort, or whether it originally had an ohv or a CVH engine sitting on top of it.

However, you have to be a little careful picking and choosing with older five-speed

▼ *In 1987, Ford moved the selector gate from the base of the gear lever and put it inside the gearbox.*



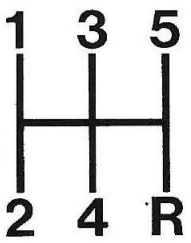
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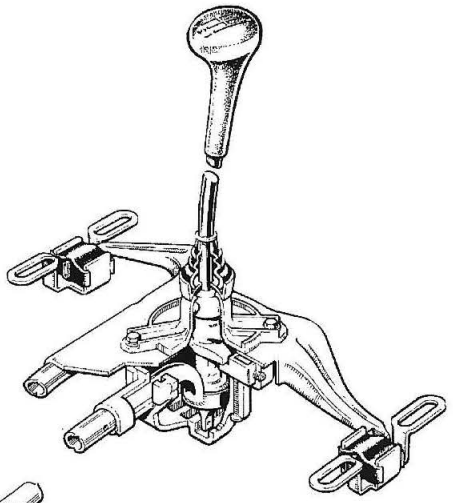


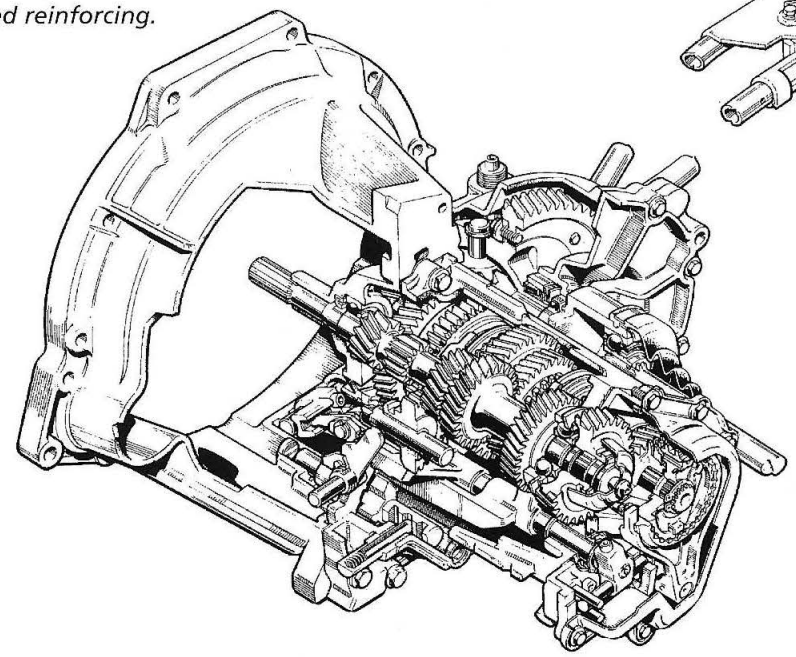
▶ *The pre-1987 selector plate under the gear lever. This cannot be used with the post-1987 gearbox.*

gearboxes if you are buying just the box and swapping gearchange linkages about because Ford altered the linkage twice in the 1980s, once in 1984 and again in 1987. If you are looking at an Escort in a breaker's, or buying from someone who is dismantling privately, do not put too much reliance on the car's registration date because quite a few cars built with the older style of linkage were not sold and registered until several months later. Check the gearbox and the linkage.

This is important because on the boxes from 1987 onwards, Ford moved the selector gate from the bottom of the gear change lever and put it in the gearbox. The reason was that when the older type of gate under the lever became worn, it was possible to clip reverse gear if you were a little careless making a fast change down from fifth to fourth. The Escort gear-change linkage does not fit in a Fiesta without a lot of messing about, so if your box comes from an Escort you will need to have a Fiesta five-speed change linkage. If







▶ *Ford's five-speed gearbox will fit any transverse CVH engine though chassis work is needed on the Mk 1 Fiesta. For rally or high power work the rubber mountings for the change linkage may need reinforcing.*

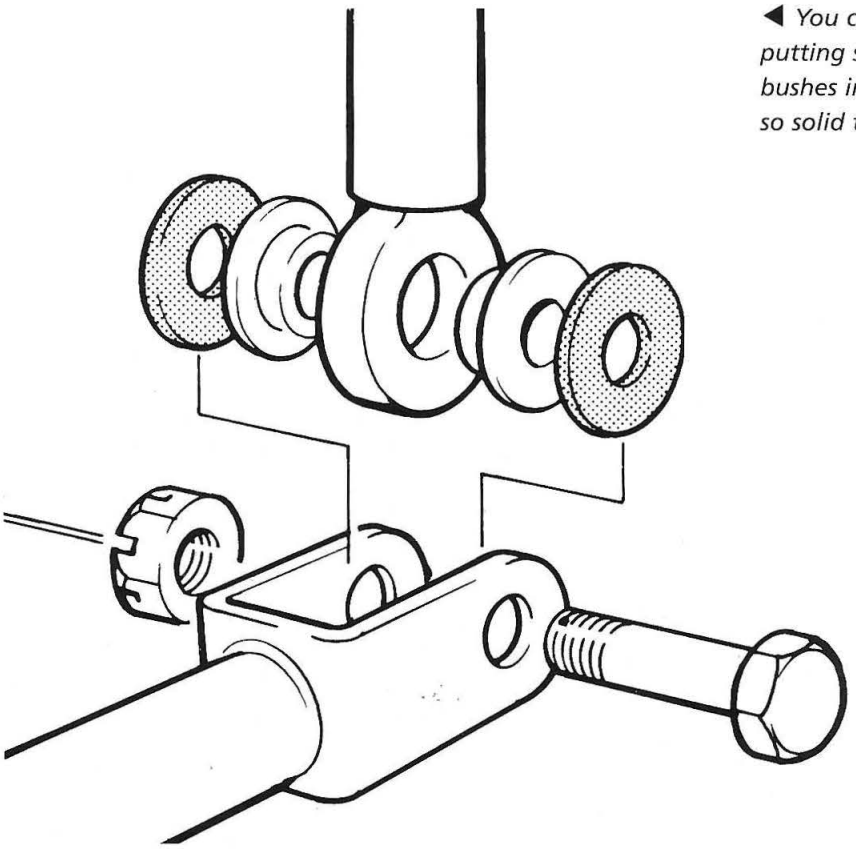
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an older style linkage is fitted to a later gearbox there will be two selector gates which will probably fight each other and you will wonder why you cannot get the thing into gear. If you go the other way and fit a later change linkage to an early box you will not have any selector gate at all, so your gear changes will be about as precise as stirring a Christmas pudding.

Make sure early and late linkages and boxes are kept together. It is quite easy to identify them when you look at the linkage. The housing which sits at the bottom of the gear lever on the older type of linkage, and carries the selector gate, is quite a chunky affair, whereas the later type, where the gate is in the gearbox, is much smaller and lighter. The mounting holes in the floor pan for the Mk 2 and Mk 3 Fiesta five-speed gearchange linkages are not in the same place as those for the Mk 1 four-speed linkage so, when the box is installed in the car, you have to offer up the back end of the linkage then plate and drill the floor to suit.

The other point to be watched is the drive shafts. The later 1,300 and 1,600 Fiesta drive shafts have larger hub splines than on 1,100cc and 950cc engines. They were also fitted with hubs that are identical to those on the Escort. If you are making something like an XR2 lookalike using an 1,100 as a base car the easiest and best way to go about it is to take over a 1,600 engine, five-speed box, front cross-member, drive shafts and hubs, all complete. That way, you make sure you do not have any last-minute mismatches when trying to put things together. If you cannot locate all the parts you need someone like Ray Wickens at Norwich, who can probably sort them out for you when you buy the conversion kit.

With other models there is far less of a problem. From 1989 all Fiestas except the 1,000cc and 1,100cc have five-speeders as



◀ *You can get a more positive gearchange by putting shim washers each side of the rubber bushes in the linkage rods, but don't make them so solid that they jam.*

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standard. Also, the 1.6 XR2 has a five-speed box which can be swapped straight over to the 1.3 and 1.4. The gearchange linkage for a five-speeder has to be changed but for 1986 on this bolts up as a complete assembly. For earlier models, your friendly parts man at a Ford main dealer should be able to make one up from parts in his stock bins.

The other problem is a 1,300 Escort built before March 1982. They are not all that thick on the ground now, but if you have one and want to fit a five-speed box, the drive shafts have to be changed, new brackets made up to move the engine over and the gearchange linkage bent and played with by trial and error. It is not straightforward and it is probably easier to take over a post-1982 subframe, drive shafts, suspension and so on.

Escorts and Orions from March 1982 onwards are much easier to convert. All you do is swap the four-speed box for one from a 1.4 five-speed model, complete with the gearchange linkage.

It all sounds very simple the way we have written about it and, in fact, engine and gearbox swapping on front-wheel-drive Fords is not all that difficult. Yes, you are going to find minor little problems like brackets you do not have and throttle linkages that don't match and, in some cases, if the car has a ballasted ignition coil and you fit a later one that works on 12 volts, you will need to do some rewiring. Check with a voltmeter when you switch the ignition on, and ask your Ford dealer if the coil you have taken over runs at 12 volts or is ballasted. Engine and box swapping may not be a job you can do in a spare Saturday afternoon, but Fords are great for this sort of thing – a grown-up boy's Meccano set.

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Chapter 7

Fitting a performance camshaft

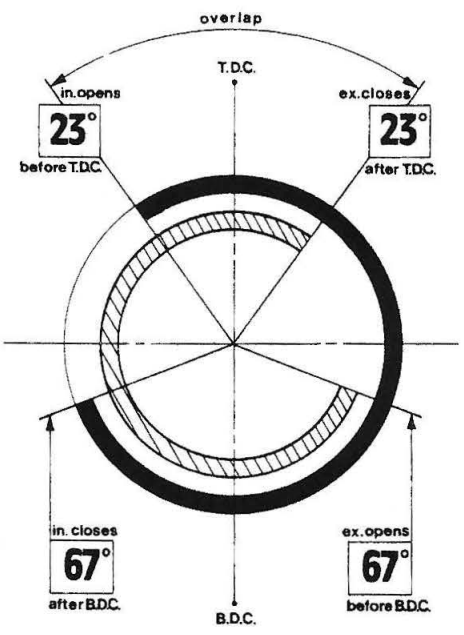
Unlike the Crossflow engine, where the camshaft lives down inside the block, or the Pinto where the camshaft comes out of the back so the head has to be taken off, changing a camshaft on a CVH engine is a relatively simple affair.

Camshafts for production CVH engines, even those in the XR3i and XR2 are designed for everyday give and take motoring where a smooth tick over, quiet valve gear and good fuel economy are the order of the day. Few ordinary motorists worry very much about acceleration and response provided the car is reasonably lively and they could not care less what bhp their engine develops. This is why people such as Kent Cams and Piper do a respectable if not roaring trade supplying performance camshafts to people who want more response and more power from their engines.

In anything to do with camshafts you have to talk horses for courses and horsepowers for course powers. If you are going for racing you will want the ultimate the engine can provide and this means more than just a camshaft change so you should probably go to a specialist engine builder. You will not have to worry about emissions because there is no MoT for racing cars, but you will be concerned about things like close-ratio gearboxes to keep the engine inside a narrow rev band, and hang the fact that it does not tick over smoothly at low revs.

For road use you have to strike a compromise. You want the engine to be tractable so that driving in traffic is not more of a hassle than it needs to be. You want quick response and good acceleration in the mid-rev range to make overtaking safer and, let's be honest, for the sheer pleasure of putting a bit more zing and zest into your driving. You also want a reasonable increase in power at the top end so it does not take for ever to pass a truck on the motorway without changing down and, most importantly, you want to be able to sail through the MoT emission test.

These may sound like very conflicting requirements and, some years ago, they were, but camshaft design has advanced



◀ *A typical valve timing diagram for a mild road camshaft. In a catalogue you would find this quoted as 23/67 67/23.*

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considerably since the days when you had to choose between a standard cooking camshaft and a wild stallion. With careful choice of the right camshaft you really can get the best of both worlds, even if insurance problems keep you down on cubic capacity, but remember that your insurance company must be told if you modify the engine from standard.

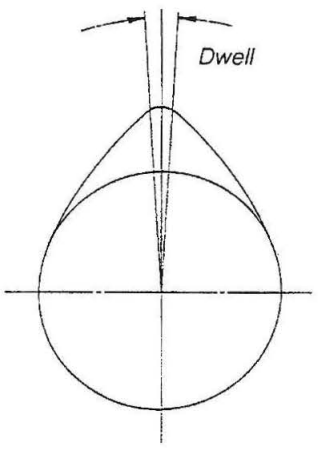
First, let's lay this bogey that an engine with a performance camshaft is difficult to get through an emission test. Provided the rest of the engine, including the carburettor or fuel injection system and the ignition system, are in good condition there is no reason why, with a modern performance camshaft, you should not get a comfortable increase in power with a good response and with tick over emissions that will satisfy the most nit-picking MoT inspector.

Before we get down to what profile camshaft to choose, we must look at some of the technical terms involved. As well as 'lift' and 'duration', you will find camshaft men talking about 'base circles', 'opening ramps', 'opening flanks', 'noses', 'closing flanks', and 'closing ramps'. You will also hear talk of 'valve overlap' and 'symmetrical' and 'asymmetrical cams', so it is as well to get these all straight in your mind before talking to camshaft suppliers and sending for their catalogues so you are not blinded by science.

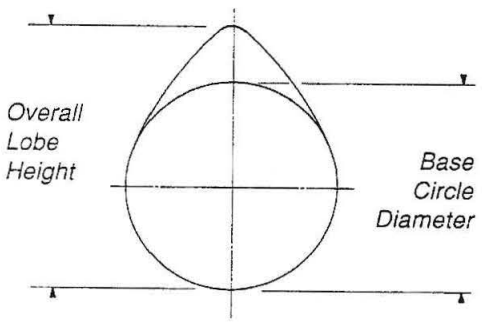
We will start with the base circle because the cam is built up on this. The base circle forms roughly 180 degrees of the cam profile and does not impart any movement to the cam follower.

Moving up the side of the cam we come to the opening ramp which is closely related to the opening flank. The ramp's job is to take up the valve clearance and start the follower moving in a controlled way that does not put a sudden shock into the valve system. On a standard touring cam the opening ramp plays an important part in keeping the valve train quiet, even with hydraulic lifters, but it does slow down the opening of the valve. When we are tuning for power, we require the valve to open as quickly as possible so, on a performance camshaft, the opening ramp is sharper.

Unfortunately this tends to make the operation of the valve gear more noisy. If you listen to an engine tuned to racing power, particularly if a probe stethoscope is used, the valve gear is usually much more noisy at tick over than a touring engine. Any noise with moving parts means wear, and the greater the noise the greater the wear but, on racing engines, the tuner will probably throw away the hydraulic lifters and fit mechanically adjustable ones because he is looking for every last ounce of power and the engines are stripped and checked far more often than fast road engines, sometimes after only one or two races. On a normal fast road engine few people would put up with either the noise or the increased rate of

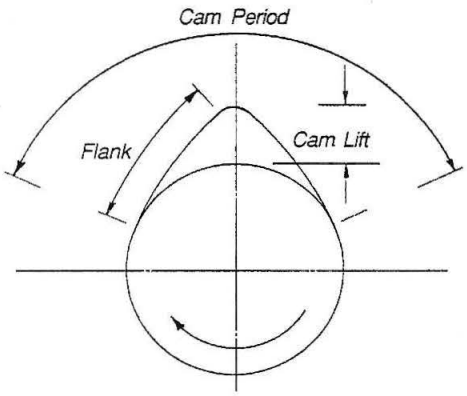


▶▶ *The width of the cam nose, or its dwell, determines the time the valve remains still at full opening before changing direction.*

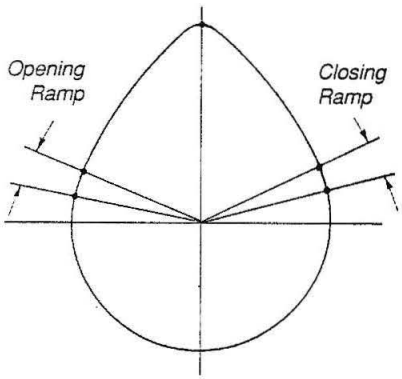


▶ *A cam's lift is the overall lobe height minus the base circle diameter.*

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◀◀ *A cam's period is the time the valve is off its seat from the start of the opening flank to the end of the closing flank.*



◀ *The opening and closing flanks lessen the shock load on the follower when the valve starts to move and when it comes to a stop.*

wear so the camshaft designer has to strike a compromise between fast valve opening, noise and wear.

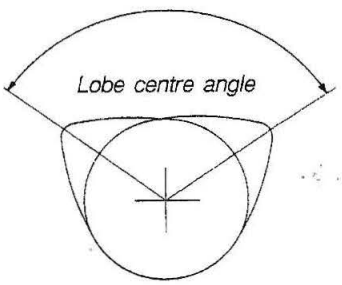
After the opening ramp, cam follower movement is taken over by the opening flank which accelerates the cam follower and pushes the valve open to its full lift position. The opening flank has far more work to do than most people realise and is a critical factor in profile design. It has to accelerate the rocker, spring cap, spring and valve, but it has only about half its length to do this because it also has to retard the follower before the valve reaches its full lift position. If it didn't, the hydraulic lifter could not recuperate fast enough and the rocker would bounce on the top of the cam lobe.

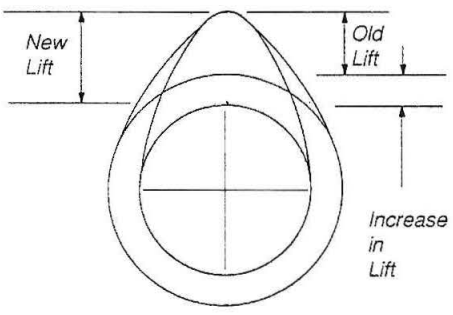
The nose of the cam, the pointed bit between the opening and closing flanks, is where we get maximum valve lift. It is also the part of the profile which is most highly stressed and which wears the fastest because it has the least area in contact with the follower.

Like people, different cams have different shaped noses. Some are quite pointed, some are rounded and others almost appear to be flattened at the tip. As well as giving the valve its maximum lift, the nose of the cam is also the part of the profile where the valve movement stops and changes direction. The length of time the valve remains fully open is called its dwell and the angle through which the cam turns while the valve is fully open is the dwell angle. Just to confuse things, dwell angle is not usually quoted in degrees of camshaft rotation, it is more often stated in degrees of crankshaft rotation. As the camshaft runs at half engine speed on a four stroke engine, the dwell angle in crankshaft degrees is twice the dwell angle at the cam profile.

Actually, this is not in order to confuse, the reason being the dwell angle is important when you come to set up the camshaft timing and it is easier to use degrees of crankshaft rotation than camshaft rotation.

◀◀ *The lobe centre angle, the angle between the inlet and exhaust cams, gives the overlap during which both valves are open.*





◀ *An existing camshaft can have its lift increased by grinding down the base circle diameter. This increases the difference between the base circle diameter and the overall lobe height.*

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After the nose has held the valve open, we come down the other side to the closing flank which first accelerates then decelerates the rocker until the closing ramp lowers it gently down on to the base circle again. The closing ramp is usually more gentle than the opening ramp because fast closing of the valve is nothing like so critical for performance as fast opening.

The other reason for having a more gentle closing ramp is to guard against the valve crashing back on its seat which would do neither it nor the seat any good. Sudden crashing back could also cause valve bounce because of the sudden reversal of energy in the spring and this would cause the valve to open again slightly, just when it was least needed and lead to misfires and burnt valve seating.

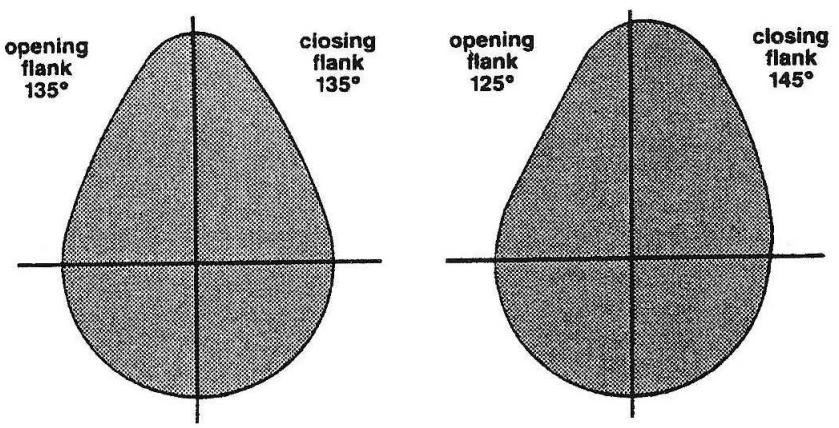
Next are lift and duration. Lift is fairly straightforward; it is the amount by which the cam lifts the rocker. Here, you have to be clear whether you are talking about cam lift or valve lift. On a direct-acting camshaft on top of the valves through bucket tappets, the valve lift is the same as the valve but, on the CVH you also have to take rocker arm ratio into account. The standard ratio of a CVH rocker is 1.65 to 1. In other words, the valve opens 1.6mm for each 1mm lift of the cam. At one time, higher ratio rockers were available for the CVH from some camshaft makers but we have not seen these for a long time.

Cam lift, as quoted by the camshaft maker, is the overall lobe height minus the base circle diameter. Some people try to check this by using a micrometer or vernier gauge but this is not a very accurate way of doing it because you can never be certain where the base circle starts and ends. The chances of arriving at an accurate base circle diameter are very slight.

If you must check what the maker says, or if you want to check the cam lift of an unfamiliar camshaft, the only way to do it accurately is to set it up in a lathe between centres and use a dial test indicator. You have to make sure that the DFT is set with its probe pointing exactly towards the centre of the camshaft and the easiest way to do this is to set the probe against one of the lathe centres before mounting the shaft. Checking in a lathe also lets you check the run-out of the centre bearing journal to make sure that the camshaft has not been bent. Camshafts are pretty stiff, but they can bend if dropped on a hard surface.

Some people check the cam lift by using a vernier depth gauge at the top of the valve cap to measure the valve lift and then divide by the rocker ratio. It will work with mechanical lifters set to zero clearance, but it is not very accurate with hydraulic lifters, and likely to be less accurate then checking with a DFT on the cam profile.

Duration is nearly always quoted as cam



▶ *You sometimes hear of asymmetric cams where the nose is offset to one side of the centreline. They can be used on Pinto engines, but seldom on a CVH.*

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duration but, in fact, it is measured in degrees of crankshaft rotation and is the number of crankshaft rotation degrees during which the valve remains off its seat. So if, for example, we have a cam duration quoted at 270 degrees, this is 270 degrees of crankshaft rotation. The camshaft runs at half engine speed, so in terms of camshaft rotation the figure would be 135 degrees. As a general rule, but not an infallible one, the longer the duration the less likely you are to get the engine to tick over smoothly at low speeds.

Fast road engines do not usually like an over-long duration. Typical figures for performance camshafts could be 270 to 280 degrees for a fast road camshaft and up to 310 or even 320 degrees for a full race shaft but the latter would be almost impossible to drive in traffic because the engine would hardly run at all, let alone smoothly, below 2,500 to 3,000rpm.

Lift, however, is a different matter and that brings us to increasing the lift of a cam by regrinding the existing profile. Many people find it difficult to understand that you can increase the lift by grinding something off as initial thoughts say that this will decrease the lift.

If, however, you think of lift as overall lobe height minus the base circle diameter, it becomes clearer. When you alter the ratio between the two, in other words reduce the base circle diameter by more than is ground off the lobe, the cam follower sits lower on the base circle and the lobe will lift the cam follower by a greater amount than before.

It is sometimes found on reprofiled cams that the parts between the cams, usually called the core, have also been machined. This is not just for looks, it is because the base circle has been taken down lower than the core and, if the core was not machined as well, the rockers could sit on this and not on the cam. A completely machined camshaft does not necessarily mean that it has been reprofiled. Some high performance cams are turned from new castings where the core has to be machined down to clear the cam base circles.



▲ *A complete Piper cam kit for a CVH engine.*

Increased lift will allow more mixture into the combustion chamber and give more power, but the more lift used the closer



◀ *With hydraulic followers you cannot check the valve timing accurately when building the engine. You need a vernier cam belt pulley with a scale to set the timing, either on the road or on a rolling-road, to get the best performance.*



◀ *With solid cam followers such as those on the RS 1600i engine, you can set the timing accurately during the engine build by using a timing chart mounted on the nose of the crankshaft.*

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things have to be watched. If you use too high a lift there is a danger that when they are fully open, the valves will touch the tops of the pistons with disastrous results. Things can get even tighter if the head face or the top of the block, or both, have been machined to take out bowing or warping, or if you have had oversize valves fitted. With some high-lift camshafts it is necessary to have the tops of the pistons machined or fitted with special pistons to clear the valves.

With a block and head that have not been machined, and with standard size valves, you should be able to rely on the camshaft maker to tell you that there is sufficient clearance. However, with a second-hand head or block you can never be certain whether or not the faces have been machined, so if the camshaft maker says that things could be a little tight it is as well to check with him before you go ahead bolting everything down.

Theoretically, the valves will not touch the pistons if there is only a small clearance, but parts flex and valves can bounce at high revs no matter how strong the springs or how many you use. Play it safe and make sure there is adequate clearance.

Valve clearance cut-outs in high compression pistons may be necessary, but they are not the most desirable things to have from the point of view of effective combustion. Any pockets in a combustion chamber tend to harbour mixture and this can cause detonation unless they are carefully designed. If you must use pistons with cutouts, be guided by the tuner and choose the make with care.

Other things you have to be careful about with high lift are valve spring coil clearance and clearance between the valve spring retainer cap and the top of the valve guide. With your new performance camshaft you will get a set of new valve springs, invariably stronger than the standard Ford ones, which will have been matched to the camshaft. They will not however, be matched to your engine because the camshaft maker has no way of knowing what you have done to the head. We deal with this aspect in the chapter on rebuilding the head.

To give an idea of the lift differences we are talking about between a standard camshaft and a high-lift one, Ford's standard camshaft on a 1,600cc Crossflow gives an inlet valve lift of 0.347in. On a fast road cam it is usually in the region of 0.380 to 0.382in and on a full race cam, 0.490 to 0.493in.

If you look at a valve timing diagram you will see that the inlet valve opens before top dead centre and the exhaust valve closes after top dead centre. The number of degrees of crankshaft rotation during which both valves are open at the same time is termed the valve overlap.

There are a number of reasons for arranging things this way. The inlet gases have inertia so they take a short time to get moving. Before top dead centre the piston is still on its way up so you might think that if the inlet valve opened before top dead centre the inlet gases would be pushed back in the manifold. However, the exhaust gases rushing out of the exhaust port create a suction effect inside the combustion chamber so the inlet gases actually start moving in even though the piston is still moving up.

The piston has not expelled the last remnants of the exhaust gases by the time it reaches to top dead centre and, if there were no incoming inlet gases, and the exhaust valve was still open, some exhaust gases would get sucked back in as the piston moved down. However, the inlet gases are well on their way by this time and before the the exhaust gases have time to slow down and change direction the inlet gases have pushed most of them out of the exhaust port.

You can see that the amount of valve overlap is a critical factor in engine performance. If there is too little, a lot of

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Part No.	APPLICATION	POWER BAND	CAM LIFT IN/EX	VALVE LIFT IN/EX	DURATION	TIMING FIGURES	INLET TIMING @ FULL LIFT	CLEARANCE	CAM FOLLOWER	VALVE SPRING
FORD 1300/1400/1600 CVH Hydraulic										
CVH 21	MILD ROAD – SPORTS	1500-1600	.238" (6.04)	.393" (9.98)	268° 270°	21/65 67/23	112°	.000"	CF28	VS48
CVH 22	FAST ROAD – SPORTS 'R'	2000-6500	.265" (6.80)	.437" (11.10)	274° 278°	28/66 68/30	109°	.000"	CF28	VS48
CVH 32	FAST ROAD – SPORTS	1000-6500	.272" .264" (6.90) (6.70)	.448" .435" (11.37) (11.04)	280° 273°	25/75 63/30	115°	.000"	CF28	VS48
CVH 33	ROAD/RALLY SUPERSPORTS	2500-7000	.290" .285" (7.36) (7.24)	.478" .470" (12.14) (11.93)	290° 285°	36/74 72/33	109°	.000"	CF29	VS42
FORD 1600 CVH Turbo Hydraulic										
CVH 31	MILD ROAD	1500-6500	.240" (6.12)	.396" (10.06)	270°	23/67 67/23	112°	.000"	CF29	VS22
CVH 35	FAST ROAD – SPORTS	2000-7000	.275" .267" (6.98) (6.78)	.453" .440" (11.50) (11.18)	278°	20/76 76/20	118°	.000"	CF29	VS22
CVH 35	FAST ROAD – SPORTS R	2500-7000	.275" .269" (6.98) (6.83)	.453" .445" (11.50) (11.30)	279°	24/75 75/24	116°	.000"	CF29	VS22
FORD 1300/1400/1600/CVH/RS 1600i Mechanical Profiles										
CVH 26	ROAD	1500-1600	.273" (6.93)	.445" .442" (11.30) (11.22)	261°	20/61 61/20	110°	.006" .008"	CF11	VS48
CVH 27	RALLY	3000-7500	.309" (7.84)	.487" .485" (12.36) (12.31)	290°	42/68 78/32	103°	.022" .024"	CF11	VS42
CVH 28	RACE	4000-8000	.324" (8.22)	.512" .510" (13.00) (12.95)	300°	47/73 83/37	103°	.022" .024"	CF11	VS42

CVH 22 AND CVH 33 are for carburettor models

Figures in brackets are mm

Standard valve springs may become coil bound with these camshafts

KENT CAMS PERFORMANCE CAMSHAFTS FOR THE CVH ENGINE

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PART No.	APPLICATION	POWER BAND	POWER INCREASE	DURATION	VALVE LIFT	TIMING FIGURES	FULL LIFT Atdc Btdc	VALVE CLEARANCE
CVHBP255	MILD ROAD All size engines	1000-5500	6 BHP	268 deg	.400"/10.16mm	22-66 66-22	112 deg	HYDRAULIC
CVHBP270	FAST ROAD For 1300/1400 engines Mild road cam in 1600	1200-6000	10 BHP	270 deg	.460"/11.68mm	25-65 65-25	110 deg	HYDRAULIC
CVHBP285	FAST ROAD INJECTION For injection engines	1500-6600	12 BHP	276 deg	.465"/11.81mm	32-64 64-32	106 deg	HYDRAULIC
CVHBP285C	FAST ROAD 1600 CARBURETTOR	2000-7000+	15 BHP	280 deg	.465"/11.81mm	34-66 66-34	106 deg	HYDRAULIC
CVHBP285T	FAST ROAD TURBO For std. boost	2000-6000+	15 BHP	270 deg	.458"/11.63mm	16-74 74-16	119 deg	HYDRAULIC
CVHBP285T2	HIGH BOOST TURBO For 14lb+ boost	2300-6500+	26 BHP	262 deg 270 deg	.465"/11.81mm 450"/11.43mm	17-65 69-21	114 deg	HYDRAULIC
CVHBP300M	RALLY CAMSHAFT	2800-7500		316 deg	.470"11.94mm	54-82 82-54	104 deg	.012"/.305mm .014"/.356mm
CVHBP320M	RALLY CAMSHAFT	4000-8000		352 deg	.443"/11.25mm	73-99 99-73	103 deg	.014"/.356mm .016"/.406mm

Standard valve springs may become coil bound with these camshafts

PIPER CAMS PERFORMANCE CAMSHAFTS FOR THE CVH ENGINE

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exhaust gas would be left inside the combustion chamber so there would be less room for the incoming charge. Too much, with the inlet valve opening too early, and you would get exhaust gases pushed into the inlet manifold. Quite apart from the danger of the hot exhaust gases igniting the mixture in the inlet manifold and giving a backfire the mixture, when it finally changed direction and came in, would contain exhaust gases as well as new mixture so the power would be down.

Too much overlap with the exhaust valve staying open too long would mean that some of the new mixture would escape out of the exhaust port and probably be ignited in the down pipe. In extreme cases there could be sheets of flame coming out of the tail pipe.

Valve overlap is governed by the positions of the inlet and exhaust cams relative to each other. If you look along a camshaft from the front it will be seen that there is an angle between the inlet and exhaust cams, called the lobe centre angle. The smaller the lobe centre angle, the greater the overlap.

When the camshaft grinder is re-profiling a shaft, or machining a performance cam from a new blank, it is not always possible to maintain the exact angular positions of the cams relative to the location for the belt sprocket. Even with a standard camshaft, production machining tolerances mean that this angular relationship is not always exactly as specified, but an engine in standard production tune is tolerant to small variations in camshaft timing.

Not so long ago, when a performance camshaft and a vernier sprocket were fitted you had to go through quite a long process using a timing disc on the nose of the crankshaft. This was not too bad with the engine out of the car but, with the engine in place it could be very awkward. You also had to measure accurately the point at which the valve started to open and at maximum lift. This was usually done with a specified valve clearance different from the running clearance. The introduction of hydraulic zero lash lifters which do not work until they have oil pressure superseded this method of timing unless solid mechanical valve lifters just for timing were substituted.

Makers of performance camshafts came to the rescue with a very simple device which killed two birds with one stone. It solved the problem of static timing with hydraulic lifters and it made camshaft timing so much easier because you no longer needed to use a timing disc on the crankshaft nose. This introduced a scale between the two adjustable parts of the vernier sprocket. The scale is set to zero and the camshaft timed according to the book just as if you were using a standard solid sprocket. Then, on the road, or a rolling-road if you are really fussy, the vernier sprocket is adjusted a degree or so at a time and the result tried. There is obviously a limit to how far you can go either way. With less tolerance the higher the performance of the camshaft, but the maker should tell you how far each way you can go safely. Usually, it is safe up to 5 degrees either way, but any necessary adjustment is more likely to be less, say 1 to 2 degrees at most.

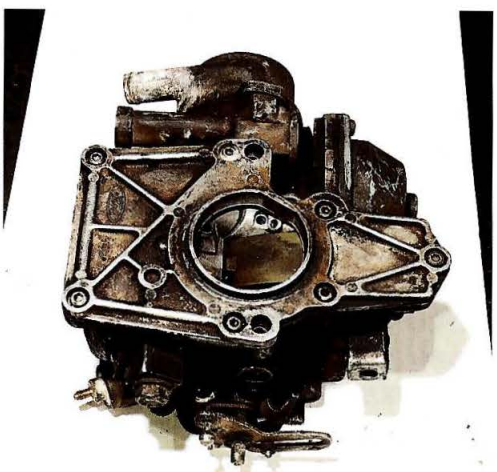
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Chapter 8

Changing the carburettor

You will come across a number of different carburettors on CVH engines depending on the capacity and the model of Ford to which it is fitted. You will also, no doubt have heard various stories about the almost infamous Ford VV carburettor fitted to some models, and how it is a constant source of trouble.

Unfortunately, most of these stories are true. The VV carburettor, VV standing for Variable Venturi, is quite a complicated design. When it is on song and set up properly it performs very well and gives a good combination of power and economy but its very complication is its downfall when it gets older. We have not come across all that many older VVs that are performing as well as they should. It has a second disadvantage from our point of view as it is not a tunable carb that you can play with to suit things like gas-flowed heads and free-flow air filters.



▶ *Ford's infamous VV (Variable Venturi) carburettor. If you have one of these, the best thing to do is to throw it in the bin!*

This is why most enthusiasts wanting to make carburetted CVH engines give more power will tell you to throw the VV away and fit a Weber. You will find a Weber carburettor listed as a direct replacement for the VV, in many cases the versatile 32/34 DMTL, and your local Weber agent can set it up with suitable jets and emulsion tubes to suit any standard model. The same carburettor, with different jets and settings, can be fitted to the 1.8-litre American-built CVH which was turned round to go in the Sierra. The DMTL takes the place of the dreadfully complicated Pierburg fitted by Ford and will give better response, better economy and more power. By the way, do not confuse the DMTL with the TLDM. Even though the same letters are in the designation, they are two completely different families of carburettor.

Weber lists performance carburettors for most models, jetted and set up to be used when you start tuning. You will find plenty of CVH engines in breakers' yards fitted with Weber carburettors as original equipment, and Webers have a reputation for being tunable by changing jets and various other parts. It is easy to get the wrong idea that you can take any Weber fitted to a CVH, swap a few bits and pieces and fit it to any other CVH, tuned or standard. It can be the case, but always consult your local agent to make sure you have the right jets and settings. You may have to get different throttle linkage brackets and possibly a spacer plate to let the throttle connections

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clear other parts. In some cases you may need a different inlet manifold.

We would not want to fit a second-hand Weber carburettor from a breaker's yard to a rebuilt engine without overhauling it. You can get overhaul kits for most Webers, and provided you go about things methodically, they are not difficult to take apart, clean and set up again with new gaskets and diaphragms. You get an instruction sheet with the overhaul kit but unfortunately these are quite abbreviated and not always the easiest of instructions to follow. Neither do they cover the setting up in much detail, so if you want to strip and rebuild a Weber from another Ford engine we advise you to refer to the Haynes book on overhauling Ford carburettors which adequately covers just about every type fitted.

Weber uses a combination of figures and letters in its carb designations, the figures giving the size of the chokes, or barrels, and the letters describing the type. On twin barrel Webers there will be a D, indicating double, while the letters and figures often have a slash dividing them, like 32/34. In this case it indicates that the first or primary venturi is 32mm diameter and the second is 34mm. Where both venturis are the same size Weber drops the slash and the second pair of figures so, for example, a DMTR carb with both barrels 34mm diameter is not a 34/34 DMTR, but a 34 DMTR. The letters stand for various changes in the type, some of which seem to be of interest only to Weber's design department. The ones that concern us on CVH engines are D, T, TL, M and A. The D, as we said, stands for double barrel, the T for transverse, meaning the float chamber is positioned and laid out to suit a transversely mounted engine and will not starve or flood the jets under acceleration or braking, and TL means that it is something of a compromise and will suit engines mounted either transversely or longitudinally. M in the designation means manual choke, and A refers to automatic choke. These figures and letters are stamped



◀ *The Weber DMTL is a direct replacement for the troublesome Pierburg fitted to the in-line CVH in the 1800 Sierra.*

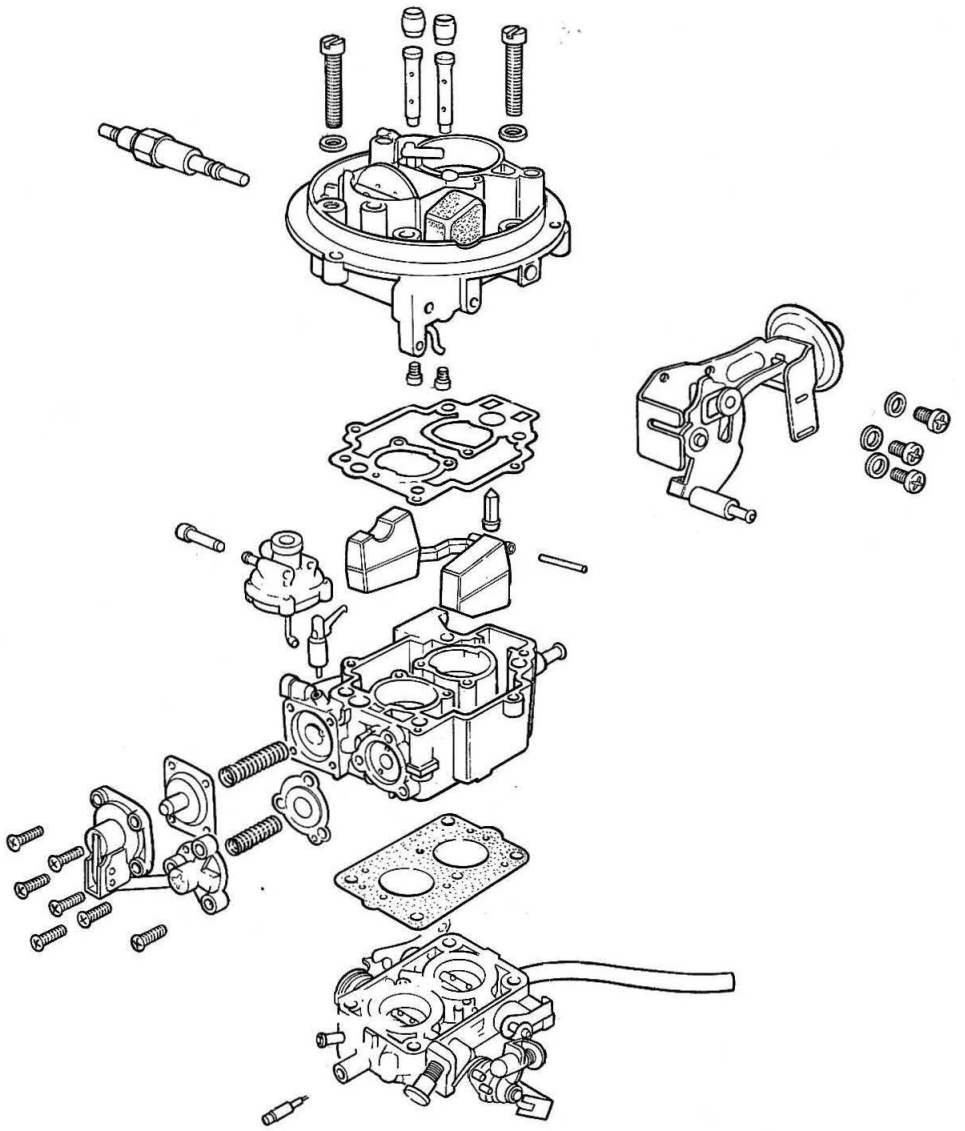
on the flange of the carb where it bolts to the inlet manifold.

However, not all Weber carburettors fitted as original equipment by Ford are necessarily the best for power and tuning. Between 1984 and 1986 Ford changed the Webers fitted to the CVH largely, we suspect, because of cost, partly to make it easier to control emissions and partly to give the engine characteristics which suit the average motorist as opposed to the power enthusiast. Take the XR2 as an example, if you look at Ford's power quotes for a CVH-engined Mk 2 you will not find any difference between pre-1986 and post-1986 versions. They are both quoted as 96bhp but, in our experience, the post-1986 versions do not give anything like that – 89 to 90bhp is nearer the mark.

Why? Because, without telling anybody about power, Ford made a carb change from a Weber 32/34 DFT to a Weber 28/32 TLDM. The TLDM is not a bad carb, no Weber is really bad, but it just does not give the power of the DFT. It has smaller barrels for a start, and it is designed to be a sort of maid of all work. The TL in its designation, as we said, stands for transverse or longitudinal, so it was originally designed to fit a wide range of engines around 1.6 litres. It is also cheaper than a DFT and very much a cooking carb; very good on economy and emissions, but it does not respond nearly as well to tuning with jet changes as do some other

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▶ *Weber's TLDM is not a bad carburettor but it is not suitable for tuning. You can swap it for a DFT, although be careful of the model, or fit a 34 DMTR.*



Webers. In short, it is Mr Average Motorist's carb, which is not exactly what you want when tuning a CVH engine. Ford did a similar thing on the 1.6 Escort and Orion.

So, what is the answer? You can do what quite a few people have and swap to the DFT from a pre-1986 Mk 2 XR2, but you have to throw away the inlet manifold that suited the TLDM because the flange holes in a DFT are not the same. You need either a manifold from a pre-1986 Mk 2 XR2 or one from a carburetted Escort XR3, which is the same thing.

The trouble is that DFTs off a pre-1986 XR2 are not exactly thick on the ground in breakers' yards, so you might have to shell out for a new one, and that is going to set you back about £375, plus whatever you have to pay for a manifold and some changes to the throttle linkage, say £400 as a round figure. That is quite a lot for an increase of about 6bhp.

You could use a DFT from a Mk 1 ohv XR2 but although this is basically the same carb as the DFT fitted to the CVH version, and the flange hole spacing is the same, there are

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differences in calibration, and not just to the jets and emulsion tubes. Some of the calibrated drillings in the carb body which govern things like progression are different which is why, if you look more closely at the designation of the ohv carb you will find it is a DFT6 whereas the CVH version uses a DFT4. The DFT6 will run satisfactorily on a CVH engine provided it has the right jets, but you possibly will not have the same smooth progression of power that comes with a DFT4. We have not had the opportunity to try it, but have a nasty feeling that there may be a flat spot.

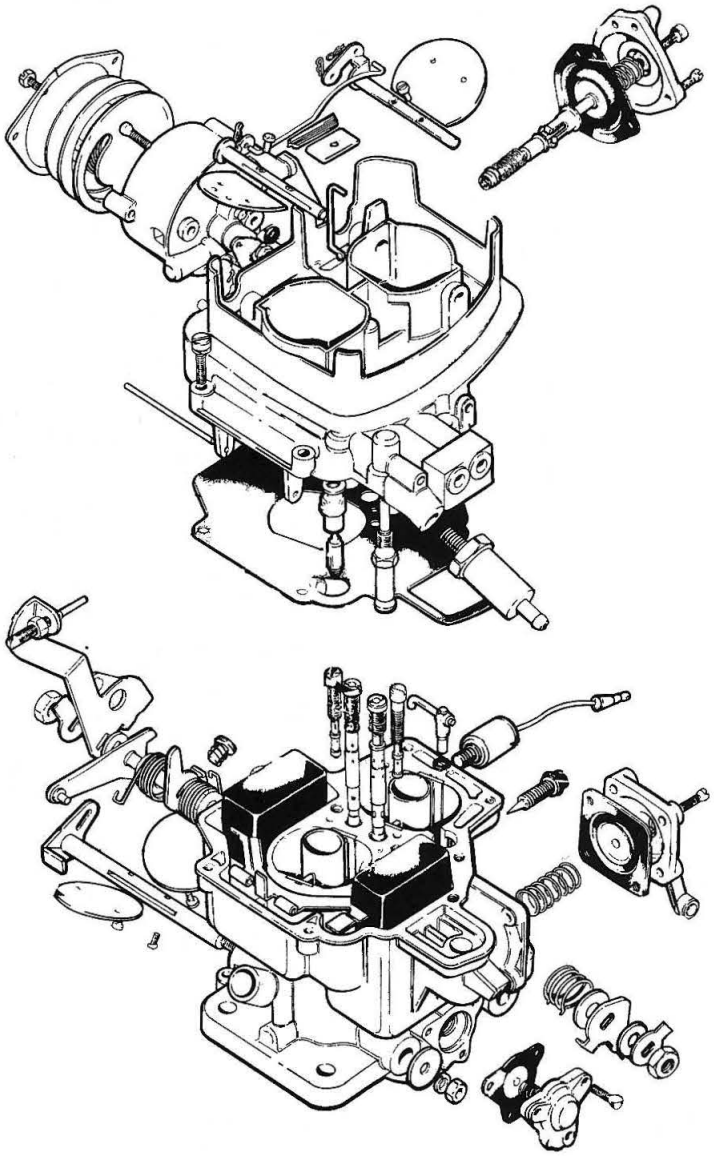
There is also the problem that many DFTs taken from pre-1986 cars will be quite worn by now. You can get overhaul kits for them, but these will not cope with things like worn throttle spindles and linkages and you could end up spending quite a lot of money for a carb that is not 100 per cent.

However, all is not doom and gloom. You can put the power back in your TLDM-carbed CVH and, what is more, put it into a condition that will lend itself to tuning such as coping with a free-flow filter, performance exhaust and a mild to mid-fast road cam, for a lot less than £400.

Webcon used to sell a kit for swapping back from a TLDM to a DFT, including the manifold. Then they looked at the matter more closely and decided that the DFT was not perhaps the best choice for someone who wanted to go tuning. Quite apart from the DFT being expensive, the awkward thing about these carbs is that they have fixed venturis. These are cast into the body of the carb unlike the venturis on serious tuning carbs like the DCOE and DCNF where they can be changed.

So, for tuning enthusiasts they looked around at the vast range of carbs that Weber produces in Italy and came up with the idea of using a carb that was originally developed for the 1.8-litre Lancia Beta, a 34 DMTR. Not only did it have a larger primary barrel than the DFT but it also had bigger venturis. What's more, it needed very little adaptation because the flange fitted beautifully on an XR3 manifold. There are actually two versions of this carb, the DMTR which has a manual choke and the DATR which has an automatic choke.

Thinking, probably rightly, that most people who like to tune Fords prefer a manual choke, Weber put up the DMTR as a kit, complete with a manual choke cable and an adaptor plate to take the standard Ford air filter, which is very different from the Lancia one. You do not have to use this plate if you want to fit a free-flow air filter intended for the 1.8 Beta, but you will need



▲ *The versatile Weber DFT was fitted to the XR2. It was also used on ohv Fiestas but with a different suffix number, so choose carefully if you buy second-hand.*

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it if you have already got one that is designed to fit a DFT.

There are three more bonuses with the DMTR. First, it is a much more tunable carb than the DFT. It responds better to changes in jets when you set it up on a rolling-road. It is also a most simple carb, although none the worse for that, and easier to work on than the DFT. The third big bonus however, is the price. As a kit, complete with the manual choke cable and brackets, it costs about £215. All you have got to find is a manifold to suit it, which is one from an XR3. At one time, Weber offered a suitable manifold, but this was not supplied by Ford and unfortunately, the source dried up. However, second-hand manifolds from XR3s are reasonably easy to come by from breakers.

You will also have to do a spot of fiddling about with accelerator controls, but they should not be too difficult to adapt, and you may have to lift the DMTR up a little from the manifold to get clearance between the throttle linkage and the manifold itself. However, Weber supply a couple of insulated spacer plates in the kit just for this purpose. Check this clearance carefully otherwise you might find you are not achieving full power or, worse, the throttle jams in the fully open position. If you have to use both spacers plus a tall free-flow air filter, check the bonnet clearance. You will also have to watch where you take your vacuum line for the ignition advance and retard, or any other vacuum line you need and you may have to experiment with T-piece connectors.

What do you get for your trouble? You get at least as much power as an XR2 with a DFT carburettor, probably more in standard form, and you have a carb that will respond better to tuning. Of course, if you want to go wild on tuning, with a really 'hairy' cam and a super gas-flowed head, this will not be the carb for you, but then you are moving into the realm of twin 40 DCNFs. You are also moving into an area of even more serious wallet depletion, plus bonnet clearance snags. It can be done, but specialist advice is desirable.

The following tables show the standard calibration for a 34 DMTR on a 1,600cc CVH engine in either a Mk 2 XR2 or an XR3. For comparison, a calibration table is included for a 32/34 DFT on a 1,600cc CVH engine from either an XR2 or an XR3.

If you want to go for really high powers on a tuned non-turbo CVH you can do away with the single carburettors and fit a pair of Webers, either 40 DCOEs or 40 DNCFs. There is a snag with the DCOEs. The O in the designation stands for Orizontali, or horizontal, indicating that they are side-draught carbs and there is not enough space to fit them on Escorts, Orions and Fiestas without quite a radical hacking and reworking of the air box for the heater and, even then, you will find fitting a decent air cleaner very difficult. The alternative, the DCNF, is a down-draught carb so you do not have quite the same cramped conditions although you might run into bonnet clearance problems and have to fit a power bulge on the bonnet top.

The temperature under the bonnet will also go up with the sort of power these carbs can give, on a suitably tuned engine, so to avoid fuel vaporisation problems, it might be advisable to fit cooling grooves in the bonnet. A number of tuning firms can supply suitable power bulges and plates with cooling grooves ready to weld into your bonnet once you have cut out the holes. You will also need a petrol pump with more flow than the standard one on a CVH but, again, tuning firms can come to the rescue with suitable electric pumps. A Facet can be recommended, but be careful which model you install. Some are designed to fit at the front of the car and pull the petrol up from the tank while others are designed to fit at the back, or underneath the car, and push the petrol up. The height you fit them in relation to the petrol tank is quite critical.

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Standard calibration of a 34 DMTR carburettor for a Mk 2 XR2 or Escort XR3 1,600cc CVH

	Primary	*Secondary*
Main jet	125	125
Air corrector	165	210
Emulsion tube	F30	F33
Idle jet	55	100
Pump jet	45	45
Needle valve	175	175
Float level	7.0mm +/- 0.25mm	7.0mm +/- 0.25mm

Standard calibration of a 34 DMTR carburettor for a Mk 1 XR2 1,600cc ohv

	Primary	*Secondary*
Main jet	120	110
Air corrector	190	190
Emulsion tube	F30	F33
Idle jet	55	100
Pump jet	45	45
Needle valve	175	175
Float level	7.0mm +/- 0.25mm	7.0mm +/- 0.25mm

Standard calibration of a 32/34 DFT 4* carburettor for a Mk 2 XR2 1,600cc CVH

	Primary	*Secondary*
Main jet	112	125
Air corrector	160	150
Emulsion tube	F30	F30
Idle jet	50	50
Pump jet	50	50
Needle valve	150	150
Float level	7.0mm +/- 0.25mm	7.0mm +/- 0.25mm

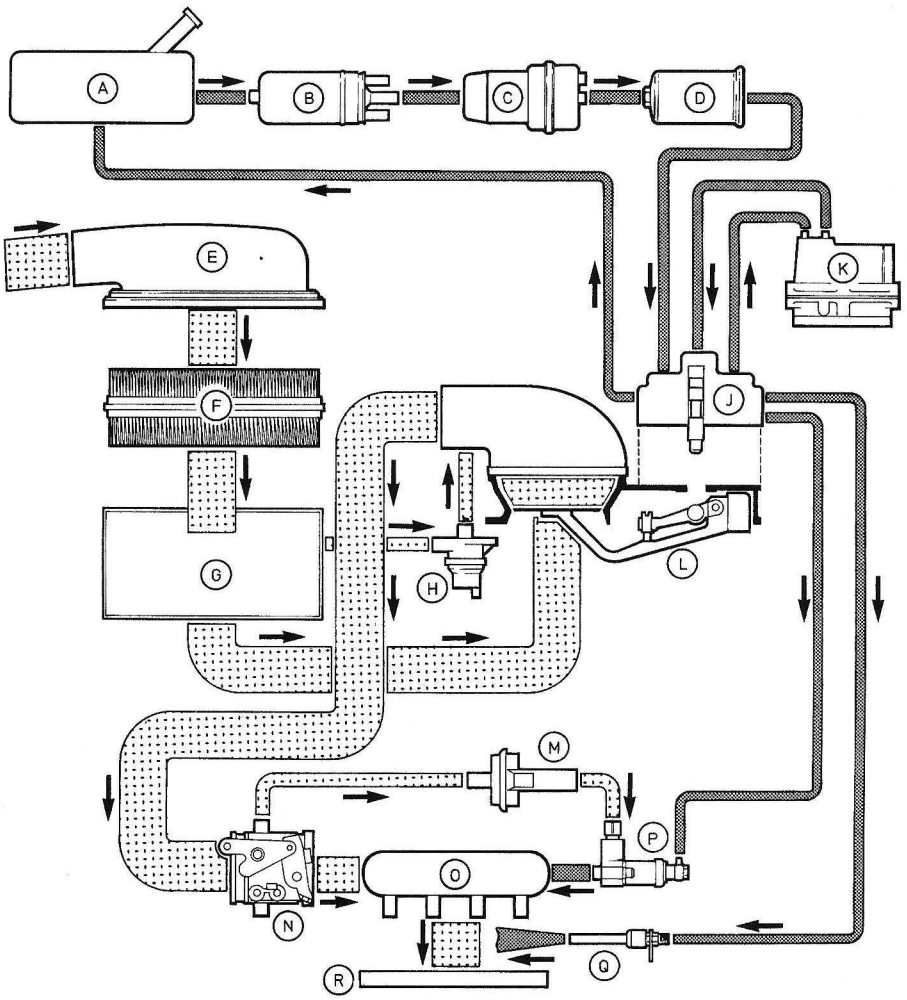
* The same calibration in a 34 DFT6 from a Mk 1 ohv XR2 could be tried but there may be problems with flat spots due to differently calibrated internal drillings which cannot be altered.

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Chapter 9

Dealing with fuel injection

Ford has used several fuel injection systems on the CVH engine. The most simple was the mechanical Bosch K-Jetronic which was used on the 1600i Escorts and Orions, and the XR3i. A related system, but with electronic control, was the KE-Jetronic as used on Escort RS Turbos. Towards the end of CVH production some engines with catalytic converters had Ford's EFi system. Although most 1800 CVH engines installed in Sierras had carburettors, a few had Ford's CFi system which was very similar to the



▶ *Diagrammatic layout of the Bosch K-Jetronic fuel system.*
A - fuel tank
B - pump
C - accumulator
D - filter
E - air intake
F - air filter
G - air filter box
H - shut-off valve
J - fuel distributor
K - warm-up regulator
L - air flow sensor
M - auxiliary air device
N - throttle housing
O - plenum chamber
P - cold start valve
Q - injectors
R - inlet manifold

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other systems but with a single central injector in the inlet manifold

Some people are puzzled by the differences in the systems and are unsure about how much they can do at home in the way of diagnosis and servicing. The overhaul of fuel injection systems is outside the scope of this book, and we do not intend to deal with each system in detail as this would need a book on its own. However, as it can be most frustrating to fit a newly rebuilt and tuned engine and then find it will not run properly because of a simple fault in the fuel injection, we will run through the basic principles with a few guide lines on these systems.

We will start with the K-Jetronic because it is the simplest and, usually, the easiest to repair when things go wrong. Except for the electric sensors, it is mechanically controlled with two main sections, fuel supply and air-flow measurement. Fuel is drawn from the tank by a high pressure pump to a pressure accumulator and a filter. The accumulator is there to do two things; it smooths out the pulses from the pump which it also helps to quieten it when the engine is running, and it holds a pressure in the system after the engine has been switched off to help prevent vapour locks and to assist with hot starting. Be careful of this residual pressure if loosening any injector pipes.

As its name suggests, the fuel distributor unit, which controls the amount of fuel being delivered to the injectors, distributes fuel under pressure to each injector. The injectors open automatically when the fuel pressure reaches a certain point and stay open while that pressure is maintained. The distributor has a control plunger to meter the amount of fuel delivered which is, in turn, controlled by an air-flow sensor with a moving plate sitting in the induction system between the air cleaner and the throttle butterfly. When the throttle is opened more air flows and there is also more fuel passing through so the mixture stays constant. Also, there is a pressure control regulator which puts a pressure on the opposite side of the control plunger so that it follows the air-flow sensor smoothly, and this control pressure is varied during warm-up by a warm-up regulator performing a similar function to an automatic choke on a carburettor. This weakens the mixture gradually from rich initial starting to a normal operating temperature mixture.

For cold starting there is an electrically controlled cold-start valve, rather like an extra injector, in the inlet manifold. Current to this is controlled by a thermo-time switch which allows extra fuel into the manifold for cold starting. As well as being sensitive to engine temperature, the thermo-time switch has an electric heating coil which is energised when the starter motor is operated. If the engine does not start reasonably quickly, perhaps because of an ignition fault, the heating coil shuts off the current to the cold-start valve so the engine does not get flooded with fuel. As well as the warm-up regulator, there is an auxiliary air-valve which allows an increased air flow during warm-up to maintain cold idling.

The K-Jetronic system is simple and robust, and most problems, such as poor hot starting, poor cold starting or rough idling, are due to faults in the cold-start valve, the thermo-time switch, the warm-up regulator or dribbling injectors. They can all be checked quite simply either by inspection or with a voltmeter. The Haynes Ford Escort Manual covers them all very well.

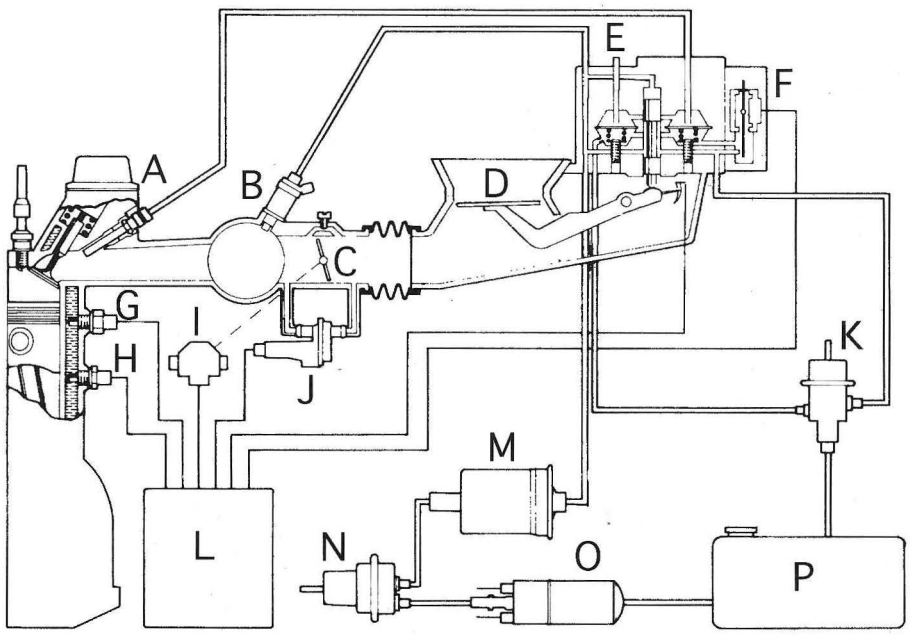
The air-flow sensor and fuel distributor do not give a lot of trouble except when people fiddle with them, yet they are a favourite target for DIY know-alls. If you find an air-flow sensor with a bent or kinked leaf spring, then someone has been inside and tampered with it. Ford dealers will not repair them and you will have to buy a new unit, but you might be lucky and find a fuel injection specialist who can repair it, or alternatively, look for a good second-hand one.

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Fuel distributors can be damaged by ham-fisted attempts to adjust the CO (carbon monoxide) level and, when they get old, they become sticky inside. The same DIY know-alls usually thump them with a big spanner or a hammer to free them and leave marks on the top cap. The manual repeats Ford's advice and says you cannot take them apart and clean them, and this is not advisable unless you know what you are doing but, if you can find someone who is familiar with them, they can be dismantled and cleaned which can save you a lot of money over an exchange unit.

The KE-Jetronic system is a development of the K-Jetronic with the E standing for electronic control. The main difference is that all the mixture corrections are controlled electronically by an ECU (electronic control unit) so you do not get a control pressure circuit and warm-up regulator. The mixture regulation is carried out by an electro-magnetic pressure actuator which takes pulses from the ECU in response to signals from the coolant temperature sensor and throttle switch. The air-flow sensor also has an electric sensor which measures the height of the plate and again sends signals to the ECU. Apart from bad electrical connections trouble shooting is very similar to the K-Jetronic and is also covered in the Haynes manual.

The K-Jetronic and KE-Jetronic are known as continuous systems because the injectors respond to pressure in the fuel line for their opening and the amount of fuel delivered is controlled by the fuel distributor. When problems occur, people often jump to the wrong conclusion that the electronic control unit is faulty. In practice, it seldom gives trouble but the signals to and from it can be distorted by bad electrical connections so they are always the first points to check. Next in line in trouble shooting are the various sensors which can be checked with an ordinary voltmeter with the correct voltages given in the Haynes manual. There is not a mechanically controlled fuel distributor unit like the one on the K-Jetronic so all the air-flow sensor has to do is send a signal to the ECU. Maintenance of the air-flow sensor is minimal and all that need be done is to ensure that the flap is not sticking or



▶ *Diagrammatic layout of the Bosch KE-Jetronic fuel system.*
A - injector
B - cold start valve
C - throttle valve
D - air-flow sensor
E - fuel distributor
F - pressure actuator
G - thermo-time switch
H - temperature sensor
I - throttle valve switch
J - auxiliary air device
K - diaphragm pressure regulator
L - electronic control module
M - fuel filter
N - fuel accumulator
O - fuel pump
P - fuel tank

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contaminated with oil, as it sometimes is. If it is sticky, clean it with a petrol-soaked cloth and check the voltages at the plug from this to the ECU.

Provided you go about things methodically, checking with a voltmeter, trouble shooting and maintenance of the K-Jetronic and KE-Jetronic are well within the scope of home maintenance and, with the appropriate manual, you can track down and cure most of the problems that occur.

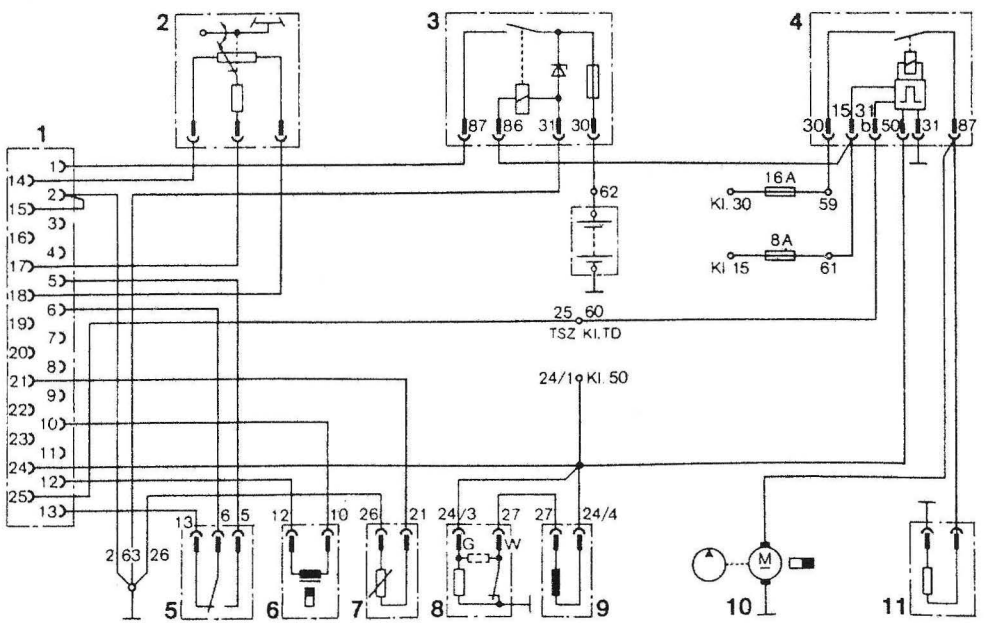
Ford's EFi fuel system fitted to some later CVH engines with catalytic converters is very different from the Bosch systems and far more complex electronically with sensors being so interrelated that any given symptom could indicate a fault in one of several areas. This makes home diagnosis without a computerised diagnostic tester so difficult that it can only be guesswork.

Running through the system very briefly, it starts with an MAS, (mass of air flow) sensor next to the air cleaner. This measures the mass of air passing through (density as well as volume) by measuring the current needed to keep a heated wire in the cold air flow at a constant temperature. From there, air goes to the throttle body on which there is a throttle position sensor.

On the fuel side, a pump submerged in the tank delivers fuel to a rail along the inlet manifold. The injectors go through this rail to receive fuel before they pass into the inlet manifold. The amount of fuel delivered by the injectors is governed by electrical pulses controlling the time they are open. Pressure in the rail is determined by a bleed return valve operated by vacuum in the plenum chamber so at low throttle openings (high vacuum) the pressure is less than at full throttle (low vacuum). Below the throttle body is the idle speed control valve. This is operated by the main control module and is governed by the readings from an engine-speed sensor.

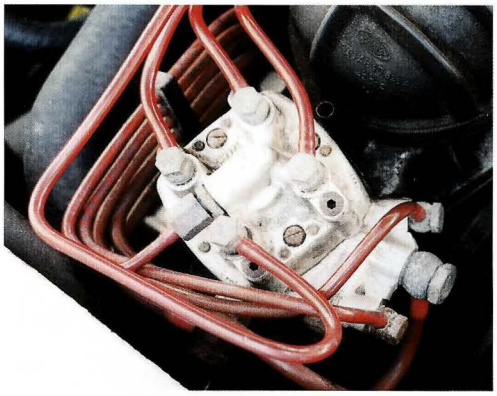
This is the only idle speed control and is not adjustable. What looks like a slow-running screw on the throttle body is set at the factory and sealed with locking compound. Do not try to adjust it; all you will do is break the end off your screwdriver.

There is also a coolant temperature sensor, a HEGO (heated exhaust gas oxygen) or lambda sensor in the exhaust downpipe



◀ *Component wiring diagram for the Bosch KE-Jetronic fuel system.*
1 - control module (situated behind the heater intake box)
2 - air-flow sensor potentiometer
3 - relay with overvoltage protection
4 - engine speed relay
5 - throttle position switch
6 - pressure actuator
7 - temperature sensor
8 - thermo-time switch
9 - cold start valve
10 - fuel pump
11 - auxiliary air device

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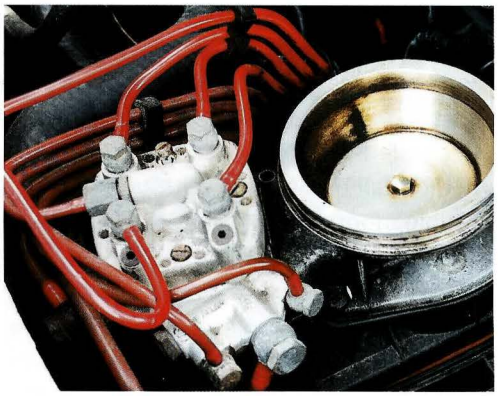


▶ *The fuel distributor on the K-Jetronic system. Beware if you find dent marks on the top as it usually means someone has been hitting it because it has been sticking. Despite what the manuals may say, these units can be taken apart and cleaned but it should be done by someone who knows what they are doing.*

to detect the amount of oxygen in the exhaust before it goes to the catalytic converter. If this is too high, it indicates a weak mixture (too much air going through) and, if it is too low, it indicates a rich mixture (not enough air to burn all the fuel), so the control module adjusts the opening time of the injectors accordingly.

To give the engine more fuel when it is cold, there is a pulsed air supply direct to the exhaust manifold. This fools the HEGO sensor so the control module keeps the injectors open longer to give more fuel. As the engine warms up, the pulsed air is shut off.

One rare but confusing fault, which is not a fault in the system itself, happens if the exhaust manifold gasket develops a leak. As well as allowing small amounts of exhaust gases to blow out, this can also allow air to be sucked in as the exhaust pulses from each cylinder. The result is a weak mixture reading on an exhaust gas analyser and on a dealer's diagnostic computer. Quite a few



▲ *Alongside the fuel distributor is the air-flow sensor bowl. This is also a target for fiddling by amateur mechanics.*

HEGO sensors were changed unnecessarily until Ford sorted out the real problem. Most Ford dealers are well aware of this, but it is worthwhile keeping in mind if a non-franchised garage says you need a new HEGO sensor because their gas analyser indicates a weak mixture.

The clever part of the system is that at least two sensors have to fail before the engine really goes off song because, if a sensor fails and the control module does not get a reading from it, it goes into LOS mode (limited operation strategy). It searches in its memory bank, averages previous readings from the failed sensor and adjusts the system according to those.

You will not get top-line performance, but the module is so good at this that some people do not notice the slight fall off in performance and economy from one failed sensor until it is picked up on a service check by a Ford dealer's diagnostic computer. If you suspect a slight fall off in performance, but cannot pinpoint it, have a diagnostic check carried out by a Ford main dealer. Even if you do not have such a problem, a diagnostic check on an EFi system every 10,000 miles is money well spent.

▼ *The air filter element lives in the plastic box which supports the fuel distributor and air-flow sensor.*



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Chapter 10

Electronic ignition systems

Like fuel injection systems, electronic ignition systems are not part of an engine overhaul, but it can be so frustrating to work on an engine and then find it does not run properly because of a simple ignition fault, so we will run through some basic checks.

The electronic ignition system fitted to CVH engines is far more reliable and efficient than the old contact breaker system and, in some ways, more simple. Yet this very simplicity often makes them puzzling to the average enthusiast. Hit-and-miss checking does not often find the cause of a problem unless you are very lucky. If there is not a good spark, or no spark at all, the easiest way to find the trouble is to settle down to a spot of systematic checking. For most systems you do not need a lot of expensive equipment – just a decent quality meter and a test lamp.

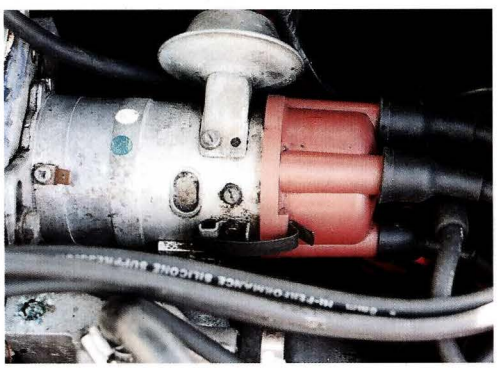
Before we start, a couple of words of warning. Modern electronic ignition systems generate far higher HT voltages than the old contact breaker systems. Do not try to test HT lead sparking against the engine by holding the HT lead in your fingers. HT spark testing has its place in diagnosis, but hold the lead in a large pair of pliers with insulated handles. The second warning is that no-one fitted with a heart pacemaker should test or work on electronic ignition systems. Even the magnetic fields around some programmed systems can affect a pacemaker and a high tension shock could be fatal.

On non-turbo CVH engines the electronic ignition system is not difficult to understand because it is similar in principle to the old contact breaker system. The most common system is the one fitted to the XR3, XR3i, Escort and Orion 1.6, 1.4 and 1.3 and the Fiesta 1.4. This uses a Bosch (or on earlier models Lucas), system with the amplifier mounted on the side of the distributor.

The early Lucas distributors often gave trouble and, if you have one, we would advise swapping this for the later Bosch distributor. It is a straightforward swap even though the Bosch has only two fixing lugs whereas the Lucas had three. You simply ignore the unwanted bolt hole.

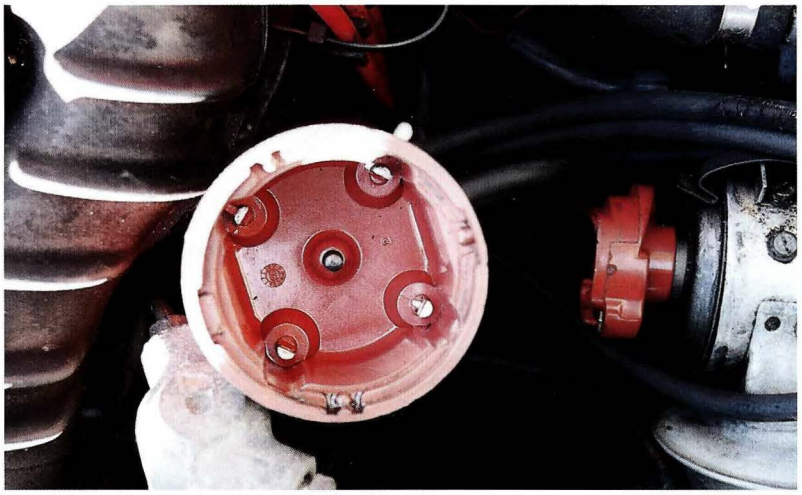
This system is very similar in principle to the Ford ESC type which was fitted to early 1.3-litre Fiestas and Mk 1 XR2s except that on the ESC the amplifier is mounted on the car body and not on the distributor. For fault finding we can treat both systems as the same.

First of all, as with any ignition system,



◀ *Later models of the CVH used this Bosch two-bolt distributor. Early models used a three-bolt Lucas distributor which was not noted for reliability. If you have an early one we suggest you change it.*

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▲ *Check the inside of the distributor cap for burnt studs, a poor centre contact or signs of tracking between the studs. If in doubt, replace.*

check that the battery is fully charged and the terminals are in good condition. An AA man once told us he could almost retire if he had a fiver for each time he had cured an 'ignition' fault by changing the battery or by cleaning and tightening the battery terminal contacts. If you are sure the battery and terminals are OK, check the



▶ *The centre contact and the arm contact of the rotor arm must be clean and bright.*



▶ *When removing or changing the distributor, check the condition of the O-ring which sits in this groove. If it is poor, you may have oil leaks.*

battery earthing strap where it bolts to the body. Then check the low tension connections to the coil and the distributor. Quite a few ignition problems are no more than bad connections.

If you cannot spot anything obviously wrong, check for an HT spark. As mentioned, use a pair of heavily insulated pliers, hold one of the HT leads about a quarter of an inch (6mm) from the engine block and get someone to crank the engine over. You should get a strong, blue, crackling spark. If you get nothing, or if the spark is yellow and very weak, you could have a fault with the HT leads, the coil or the distributor cap. Check the leads for condition, the distributor cap for cleanliness and possible signs of tracking (burnt paths between the towers, either inside or out) and check that the centre pick-up from the rotor is making good contact. Check the rotor arm for cracks or tracking.

For the coil, you need to use a multimeter. Switch the ignition to position II and check the voltage at the cable which connects with the positive low-tension terminal of the coil. If the wiring is original, it should be a black cable. The other low-tension cable going from the coil to the distributor should be green. Remove the positive terminal and check the voltage between it and the chassis earth. This system does not use a ballast resistor so you should get battery voltage. If you do not, check the wiring to the ignition coil as well as the ignition switch.

When there is battery voltage present, switch off, disconnect both low-tension leads from the coil, turn your meter to ohms and check the resistance between the low-tension terminals of the coil. This is the resistance of the primary coil winding. It should be quite low, between 0.7 ohms and 0.9 ohms. If that is satisfactory, check the resistance between one of the low-tension coil terminals – it does not matter which – and the HT terminal inside the tower. This

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is the resistance of the secondary coil winding and should be high, between 4,500 and 7,000 ohms. If readings are widely outside these figures, try borrowing another coil.

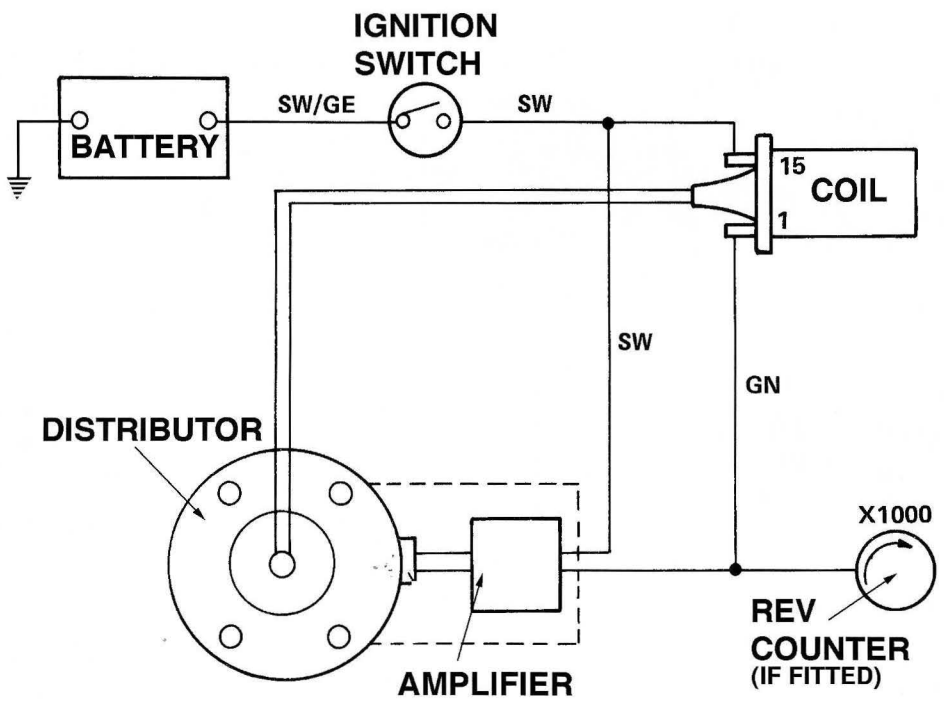
Providing everything is in order so far, take both low-tension cables off the coil and connect a 12-volt test lamp between them. Ask someone to crank the engine, and the lamp should flash as the low tension circuit is made and broken.

Should the lamp not flash, there is either a fault in the distributor, which is relatively rare or, more likely, in the amplifier. Amplifiers bolted to distributors are notorious for packing up if they become too hot inside, and this happens because they are not making a good contact with the distributor body. If a new amplifier has to be fitted, or a second-hand one for that matter, make sure the base and the area where it is going to make contact are clean, and smear the bolting faces with heat-conducting paste which can be obtained from a Ford main dealer. Amplifiers bolted to the car body are usually finned for cooling and are less likely to fail because of corrosion between them and the body.

Now let's move on to the ESC II system fitted to the Mk 1 Escort RS Turbos. You can carry out the same checks on the coil and try the flashing lamp test between the low-tension coil cables, but you cannot go very much further. If you do not get any results from the flashing lamp test and you can



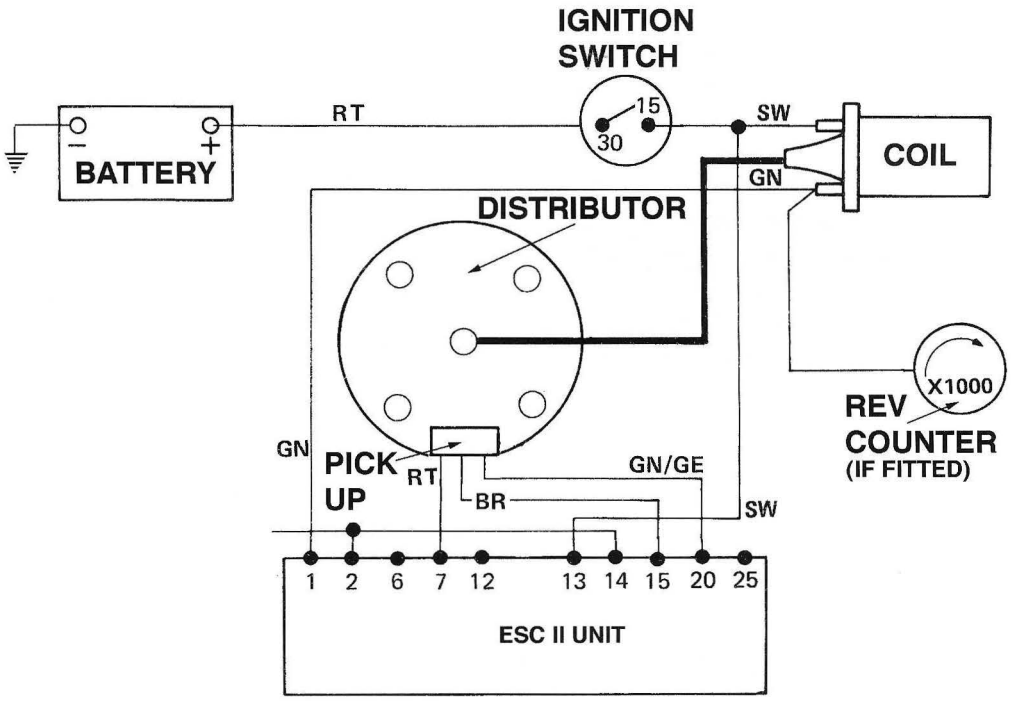
▲ *A set of top quality HT leads like these by Magnecor R100 Racing will make sure the sparks occur at the plugs and not along the way.*



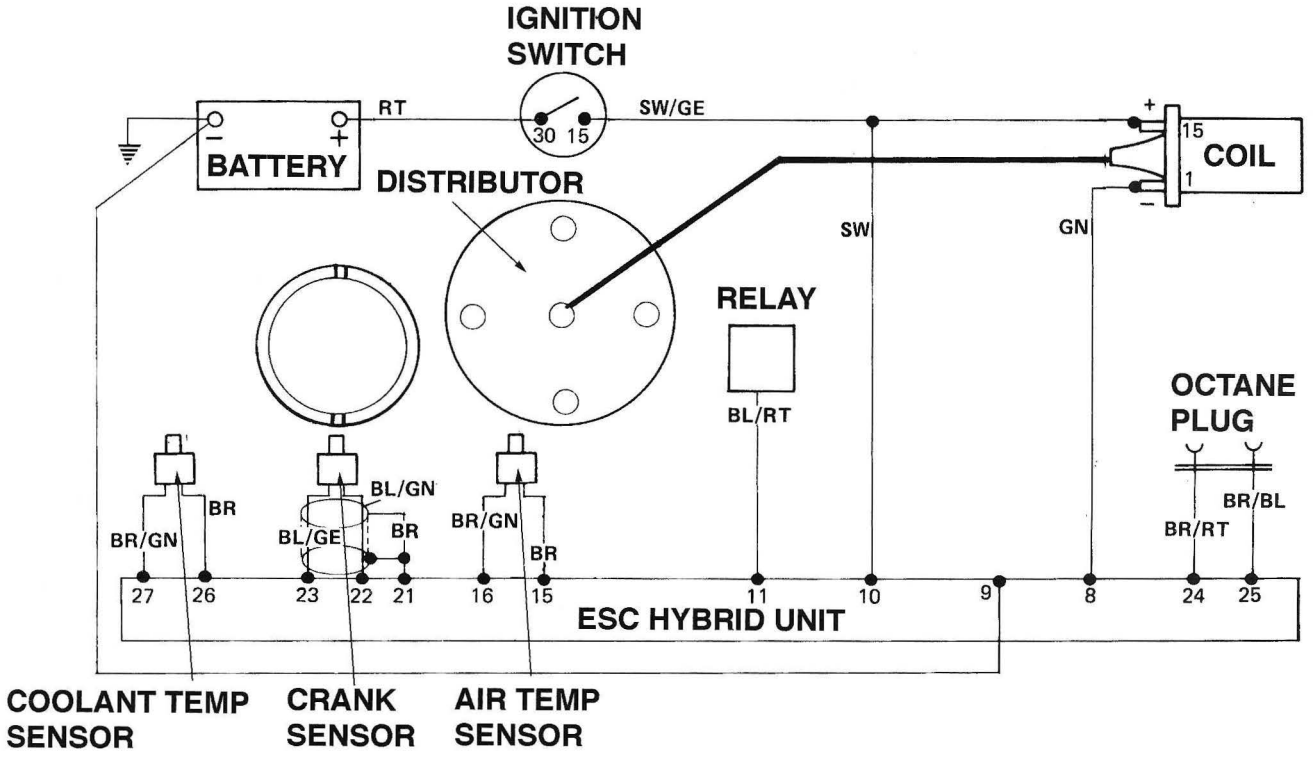
◀ *A wiring diagram of the most common type of ignition circuit you will find on CVH engines. It applies to the 1.3, 1.4 and 1.6-litre engines in the Escort, Orion and Fiesta.*

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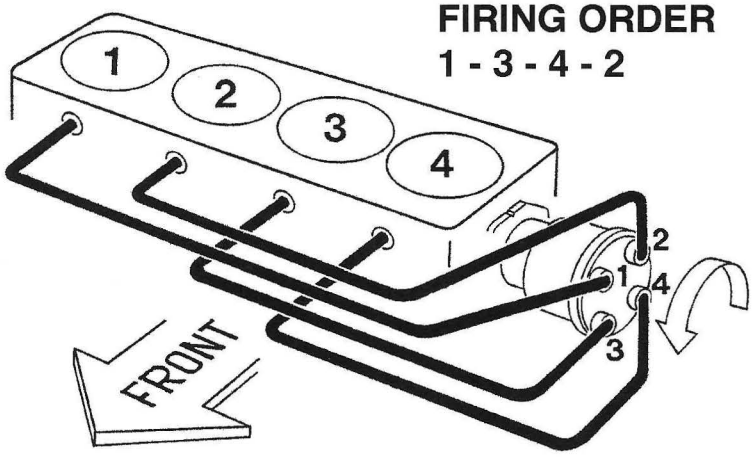
▶ *This is the wiring diagram for the Escort RS Turbo with Ford's ESC II module.*



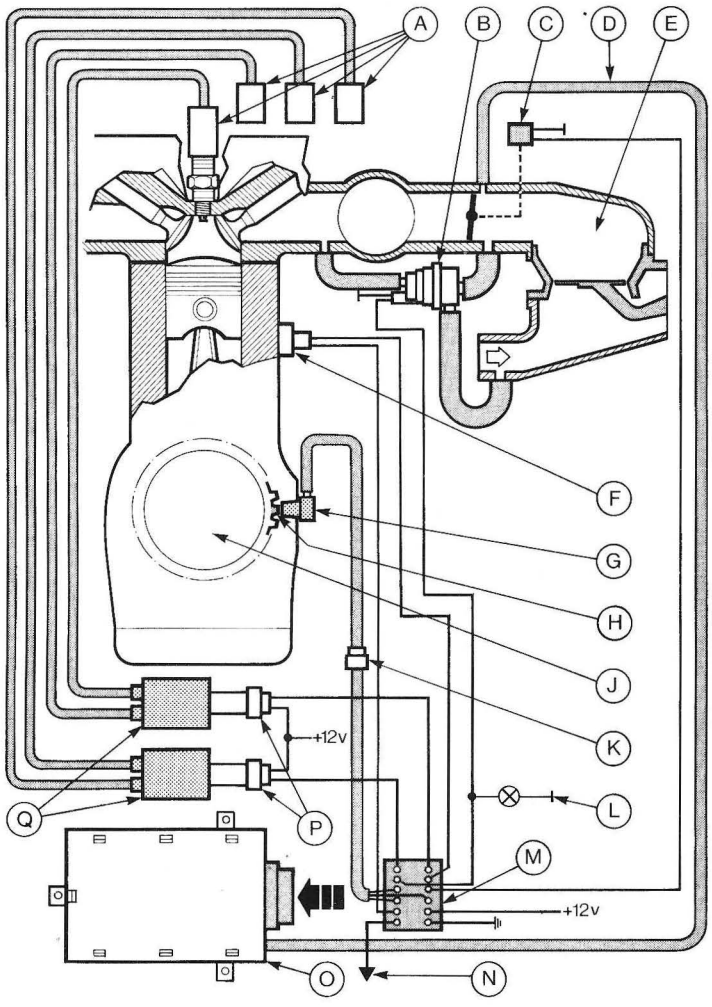
▼ *The 1.8-litre Sierra, with the in-line version of the CVH has Ford's ESC Hybrid unit with a crank angle sensor and other sensors for coolant temperature and air temperature.*



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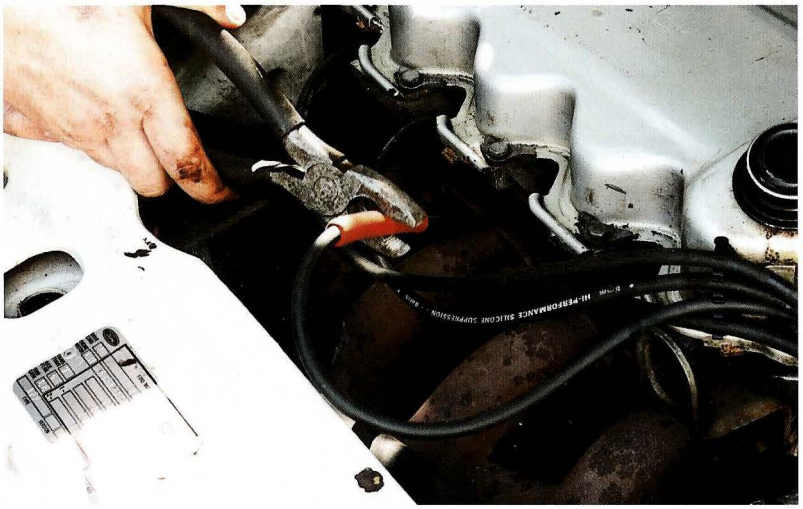
◀ *In case you have forgotten the firing orde it is 1-3-4-2 and the HT leads fit in the positio shown.*



◀ *Schematic diagram of the distributorless ignition system fitted to the Escort RS 1600i. I uses a crank angle, speed sensor and two ignition coils which fire either cylinders 1 and 4 or 2 and 3 simultaneously. The unwanted spark occurs on the exhaust stroke.*

A - HT leads
B - vacuum line
C - ring gear sensor
E - fuel injection distributor
F - temperature sensor
G - flywheel sensor
H - master tooth on the flywheel ring gear
J - flywheel
K - sensor connector
L - fuel indicator lights
M - multi-plug
O - ECU computer
P - ignition coil connectors
R - ignition coils

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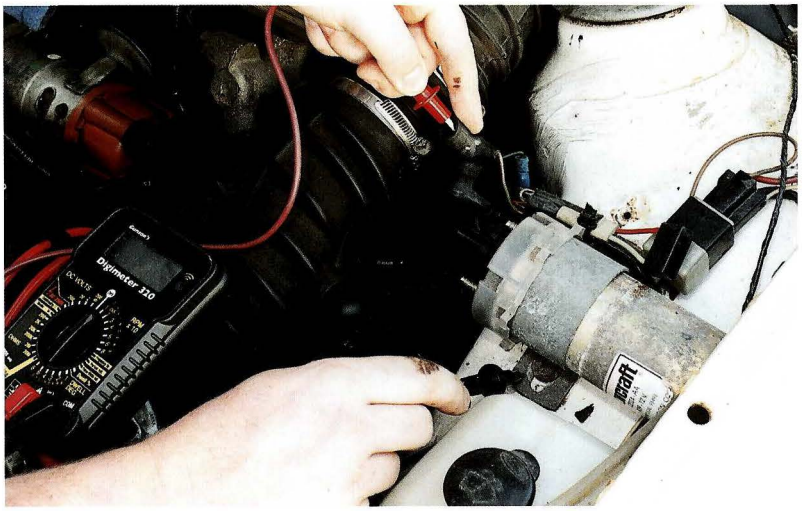
▲ *Use a heavy insulated pair of pliers if checking for a spark at the HT leads.*

borrow a distributor which you know is in good condition, you can connect the borrowed distributor in place of the one on the engine and spin the drive. If the lamp now flashes, suspect your distributor but if it does not, suspect the ESC module. The only way to check this is by substituting one known to be in good order.

The in-line CVH fitted to the 1.8 Sierra has an entirely different Ford system with an electronic control unit which is sometimes called an ESC Hybrid. This uses a distributor but you cannot advance or retard the ignition mechanically as the timing is by a crank angle sensor with a pick-up mounted to sense the flywheel position. The only way to alter the timing is by using the so-called octane plug which we will come to in a moment. Carry out the same checks for poor connections and battery voltage at the positive terminal of the coil. On the original coil this may be labelled 15, but possibly not on a replacement coil. Also check the primary and secondary resistances on the coil, but do not use the flashing lamp test.

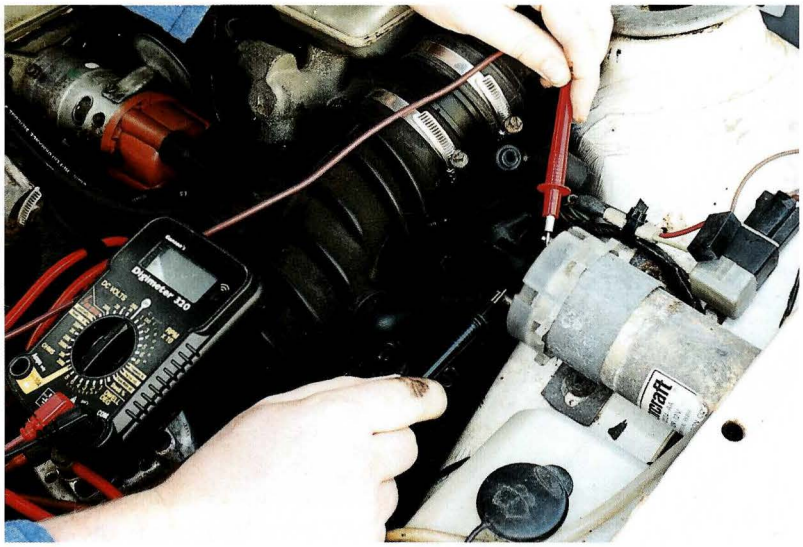
Instead, switch the ignition off, disconnect the multi-plug from the ECU and connect a voltmeter between terminals 9 and 10 on the plug (not on the ECU). Switch on and you should get battery voltage indicated. Repeat the check to test the voltage between terminal 9 of the ECU multi-plug and the negative low-tension terminal of the coil. On original Ford coils this may be labelled 1. Again, you should have battery voltage. If you do not get any voltage at all in these tests, switch the meter to ohms and check for any resistance between terminal 9 on the ECU multi-plug and the chassis earth. There should be zero resistance as terminal 9 should be earthed. If the voltage is considerably lower than battery voltage, or if there is any resistance between terminal 9 on the plug and the chassis earth, there is either a broken or badly corroded connection somewhere in the leads.

▼ *The first coil check is for voltage between the positive feed cable and chassis earth.*



The only test you can make on the crank angle sensor plug is to check the terminals for corrosion, and check across them with your meter set to continuity test. If you do not get continuity, try a replacement sensor and lead. The system also uses a coolant temperature sensor and an air-temperature sensor fitted in the underside of the air-filter casing. If the coolant sensor fails, the ECU will assume that the engine is overheating and will retard the ignition. The engine will still run, but at much reduced power. Should the air-temperature sensor fail, the engine may or may not run, but not properly. Ford lists different resistances at different temperatures for these sensors, but the easiest way to check them is by substituting a known good one.

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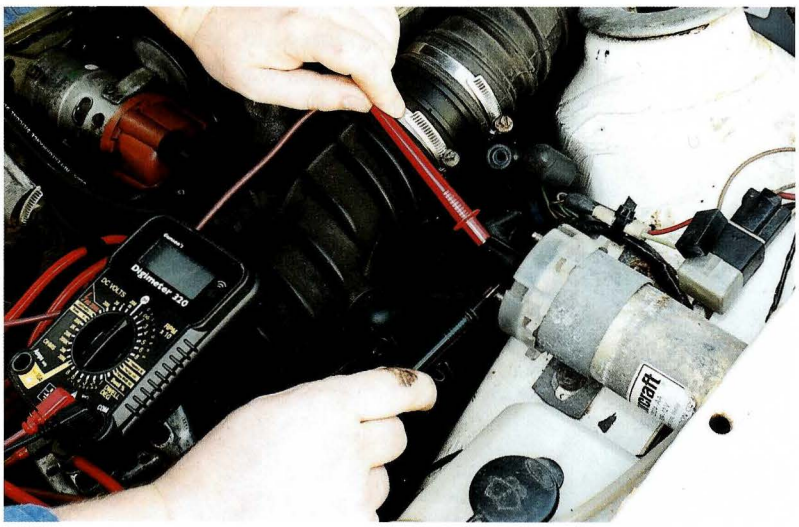


▶ *Checking the resistance of the coil primary windings. It should be quite low.*

We mentioned an octane compensation plug on this system, which is a plug in the leads near the coil. For running on 97 or 98 octane petrol, the plug is not connected to anything. For running on lower octane fuels you can get a special service harness to plug into this with wires that can be earthed to retard the ignition. To run on 95 octane unleaded, the blue wire should be earthed. This earths terminal 25 on the ECU and retards the ignition. When running on 91 octane, the red wire should be earthed, which has the effect of earthing terminal 24 on the ECU to give further retarding. If you still get pinking with either of these wires earthed, you can earth both of them which will retard the ignition still further, but will also cut down quite a lot on power. It is worthwhile, on a second-hand car to check what the position is if it is down on power and you cannot find any other cause.

Lastly we come to the fully programmed combined fuel injection and ignition systems such as Ford's EEC IV. Apart from checking all the wiring and connections, there is little you can do at home to diagnose faults in these systems without quite sophisticated diagnostic equipment and a so-called break-out box, a connecting box which plugs into the system and allows diagnostic readings to be taken while the engine is running. If you are experiencing ignition problems you may also have fuel injection control trouble, and the best bet is to go to a Ford main dealer or a specialist.

▼ *The resistance of the coil secondary winding should be much higher.*



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Chapter 11

Tuning and turbochargers

The 1.6-litre CVH engine as used in the Escort RS Turbo is based on the XR3i engine but with internal modifications to make it more suitable for turbocharging. The pistons are strengthened and reprofiled to lower the compression ratio from 9.5 to 1 to 8.3 to 1, the lobes are removed from the piston crowns, and there are modified second compression rings.

The head is taken from the XR3i engine with reworked inlet and exhaust ports as on the RS 1600i, but it retains hydraulic valve lifters instead of the mechanical ones of the RS 1600i. The combustion chambers and valve seats are the same as the XR3i but the exhaust valves are changed to sodium filled stems for better cooling, a practice which was quite common on piston engine aircraft engines during the Second World War. The head gasket is the same profile but with a thicker fire ring to cope with the higher combustion temperatures and pressures.

The connecting rods are unchanged but there are thicker gudgeon pins and the big end bearings are changed from aluminium-tin to a copper-lead alloy. The main bearings remain the same as, after durability testing, including the equivalent



Engine installation on the Escort RS Turbo.

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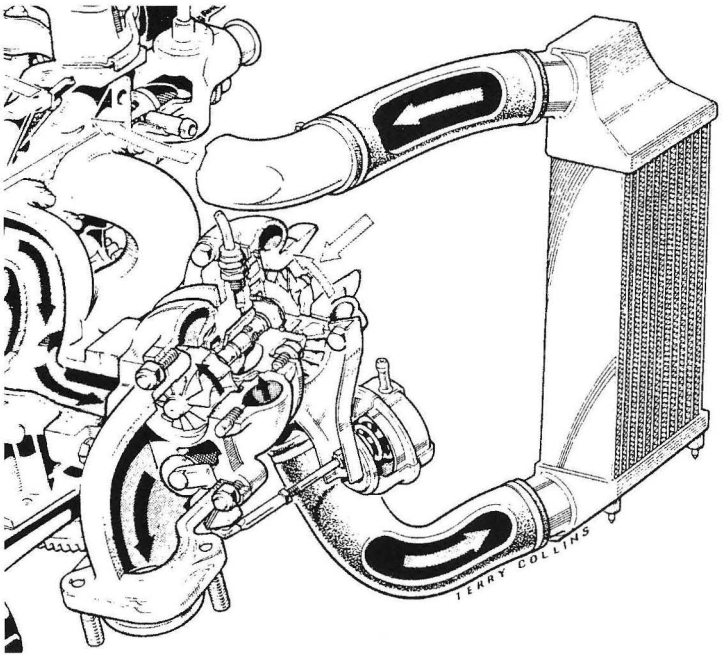
of 60,000km at maximum speed, Ford was satisfied the aluminium-tin bearing material was quite adequate. However, on a tuned RS Turbo engine running at high boost, we would advise fitting lead-indium or similar high-duty mains shells as well as big-end shells.

There are different inlet and exhaust manifolds, but the only change to the block and crankcase is an added boss to take the oil return from the turbocharger.

All the following parts are identical to those on the XR3i: inlet valves, valve stem oil seals, valve springs, cylinder head bolts, engine front cover, sump, including seals and gaskets, main bearings, oil pump and pick-up pipe, flywheel assembly, crankshaft, oil cooler and hoses, con rods, con rod bolts, camshaft and camshaft drive belt. Stripping and rebuilding is basically the same as for a naturally aspirated CVH as all the turbocharging parts are outside the engine.

For those who are not familiar with turbocharging, it is as well to run through the basic principles with particular reference to the RS Turbo engine. As we said in Chapter 1, the main aim of getting more power from an engine is to get more air and more fuel into the combustion chambers. On a normally aspirated non-turbocharger engine we do this by fitting less restricting air filters, bigger carburettors, gas-flowing the head with bigger inlet valves, increasing the valve lift and holding the valves open longer. The other approach is to have a turbocharger, a device which compresses the air before it goes into the inlet manifold so more air is forced in, and then the amount of fuel is increased to maintain the correct mixture.

To recap about the difference between a turbocharger and a supercharger, they both do the same job, and although a turbocharger is, in effect, a supercharger the word 'supercharger' is usually reserved for a mechanically driven compressor whereas a turbocharger is driven by the exhaust gases. It is called a turbocharger because it is driven by a turbine in the exhaust stream.



▲ *In standard form the RS Turbo uses an air-to-air intercooler.*

There have been, and still are for that matter, turbocharged engines fitted with carburettors, but not production Fords, although Ford once added a turbocharger to a carburetted XR3. It was really a forerunner of the RS Turbo by Ford's motorsport department at Boreham; a try-out, if you like, to see how the engine coped. It used a Garrett AIResearch T3 turbocharger together with the XR3's standard Weber 32/34 DMTL carburettor. For what might be termed field testing, Ford promoted a one-make rally championship where the turbocharger and fittings were offered as a kit to private entrants. The T3 turbocharger was really too big for the carburetted engine, but maybe Ford had the future in mind and ran it at very low boost to give about 125bhp. The championship ran for two years, 1983 and 1984, but Ford never sold the car as a production model through their showrooms.

Production turbocharging came at the end of 1984 with the launch of the Escort RS Turbo and the turbocharger really came

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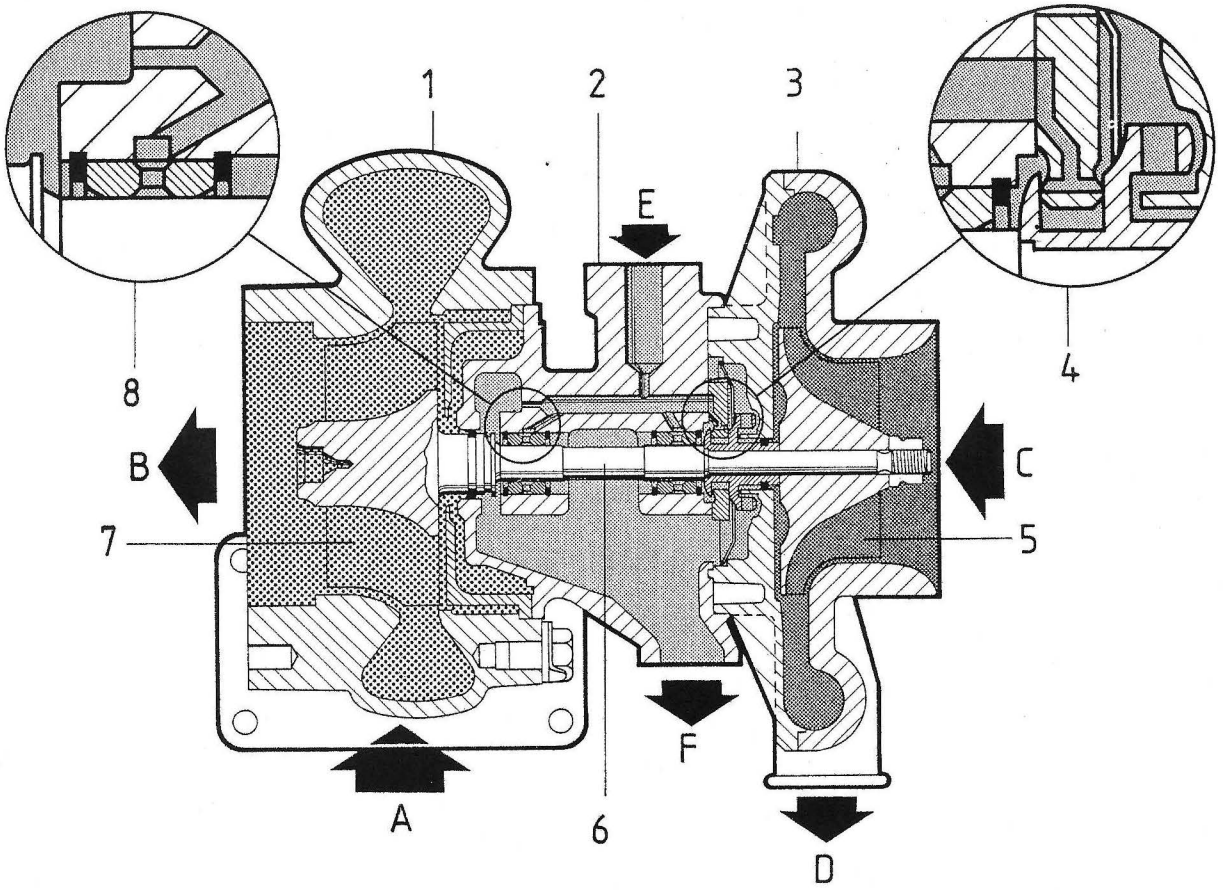
into its own with fuel injection, particularly electronically controlled injection, because with electronics it's so much easier to control the amount of fuel. This is why the RS Turbo used the Bosch LE-Jetronic (E for electronic) system instead of the mechanically controlled K-Jetronic as used on the XR3i. The car also had other changes such as the front suspension derived from the RS 1600i, but these changes are outside the scope of this book.

To get back to the turbocharger, basically it is a shaft running between the inlet manifold and the exhaust manifold. On the exhaust end there is a turbine rotor and on the inlet end there is a compressor rotor. As the exhaust gases spin the turbine rotor, the compressor rotor crams more air into the inlet manifold. When air is compressed it gets hotter, and the turbocharger itself runs pretty hot as well, but we do not want hot inlet air because it is less dense, in other words there is less of it in a given space. So, before it goes into the engine, it is cooled, usually by an air-to-air intercooler.

Put like that, it all sounds very simple and, in theory, it is. Where the complexities, and plenty of possibilities for tuning arise, is in the control of the turbocharger to make it give air compressed above atmospheric pressure, or boost as it is usually called, when we want it.

On the RS Turbo, control of the turbocharger is both mechanical and electronic. On the mechanical side there is a wastegate, a connection between the compressed air part of the turbocharger and the exhaust pipe, so that any excess pressure that is not wanted is by-passed, or wasted, and goes off down the exhaust

▼ *The oil seals on a turbocharger are piston-ring type to withstand the heat. It is possible for too little back pressure to cause leaks.*



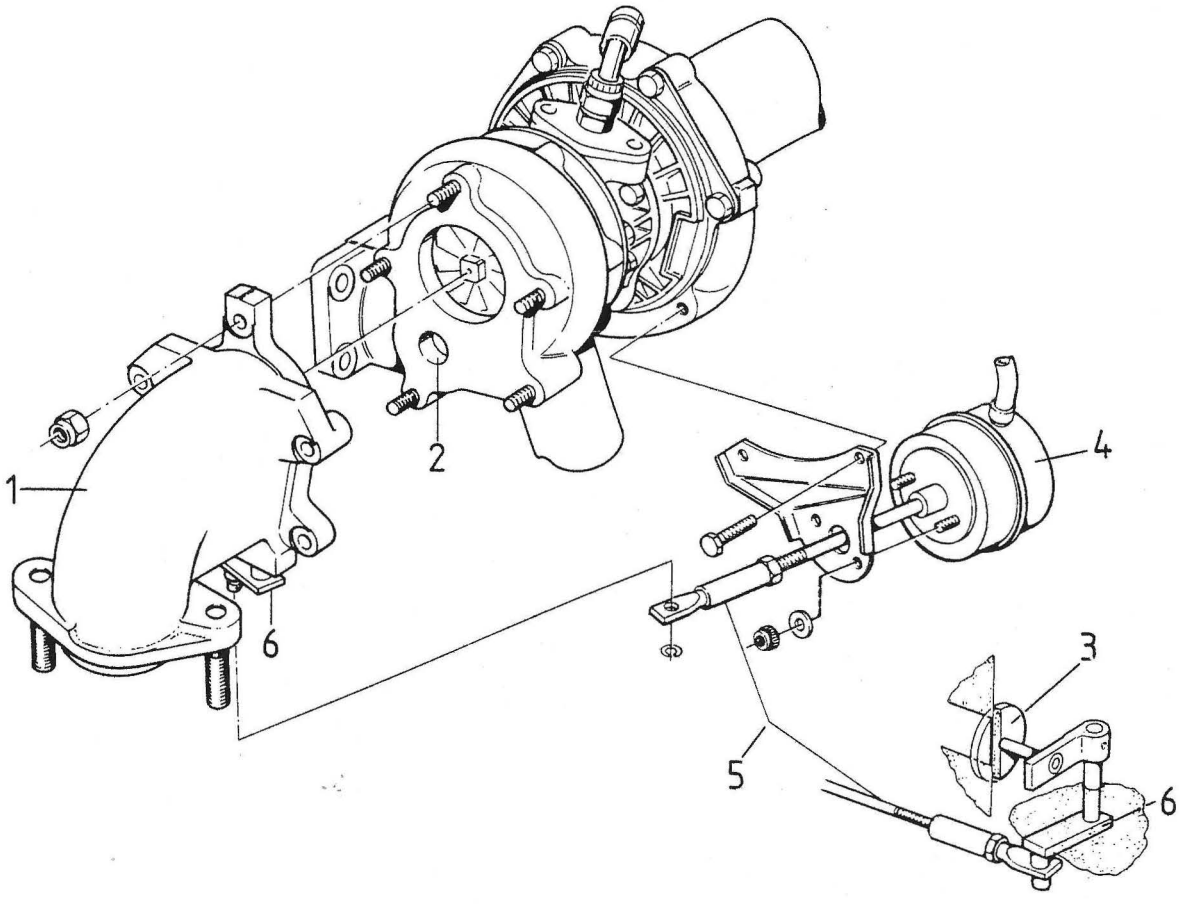
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pipe. The wastegate is controlled by an actuator which is also connected to a solenoid valve, usually called the Amal valve, which is controlled by the electronic control unit (ECU) of the engine management system. The Amal valve is directly connected to the high pressure side of the turbocharger and, depending on whether the valve is open or closed it will either vent off part of the boost to the inlet side of the compressor rotor (valve open), or direct it to the wastegate actuator (valve closed). When the engine gets to about 2,500rpm and above, the ECU supplies the Amal valve with a pulsed voltage, and the frequency of the pulses controls the length of time the valve is open, or venting to the inlet side of the compressor.

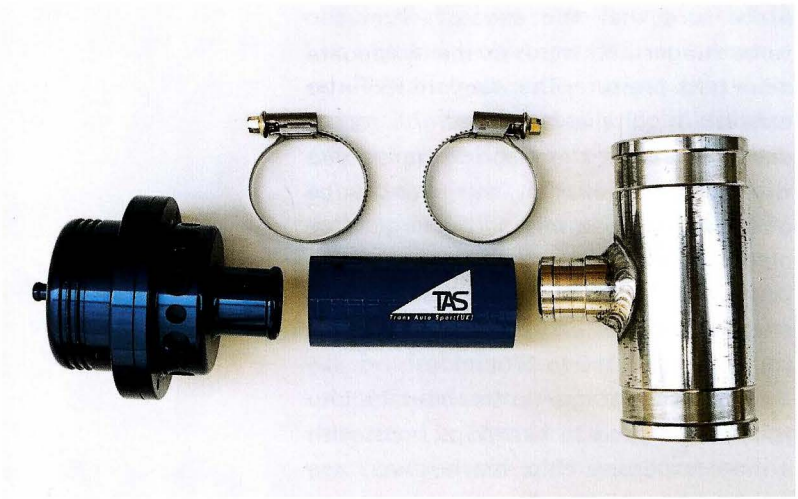
As the engine speed rises, the frequency is decreased, increasing the time the Amal valve supplies pressure to the wastegate actuator to increase the boost in the inlet manifold. At around 6,100rpm on a standard engine, the ECU is programmed to allow maximum boost to the engine by closing the wastegate.

There is yet another form of boost control which is a temperature sensor fitted in the inlet duct just before the throttle housing. This sends a signal to the ECU when the air temperature gets higher than about 68 degrees C. When it gets this signal, the ECU tells the Amal valve to direct pressure to the wastegate actuator and open the wastegate fully and then, a large part of the compressed air by-passes the inlet rotor so there is a drop in both pressure and flow, and the boost drops. Some ECUs are even programmed to cut

▼ *The wastegate actuator which limits the boost.*



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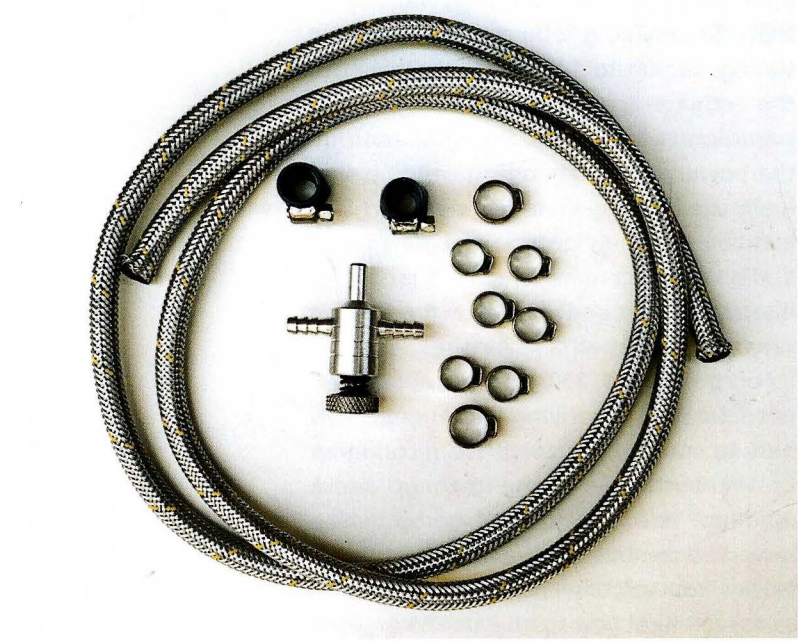


▲ *This is a dump valve kit which can be fitted to reduce back pressure on the turbo vanes when you snap the throttle shut and reduces turbo 'lag' when accelerating again.*

▼ *To go with the dump valve you need a bleed valve kit.*

the ignition completely should the temperature get out of hand. If you suffer from not reaching full boost, or ignition cutting as the boost rises, it is always worth checking the air temperature sensor and its wiring because, if it is faulty, or disconnected, the ECU will not allow full boost.

The turbine shaft runs at a fantastically high speed, and normal bearings would soon fail so, as well as being very finely balanced, the shaft runs on what is usually called a floating principle. This uses plain bearings with a high flow of oil so that when it is rotating the shaft does not actually touch the bearings, it floats on a continuous film of oil.



The oil supply to the turbocharger comes from the engine's main oil pressure supply with a return line to the sump. It is important on a turbocharged engine to stick religiously to Ford's oil and filter change intervals. With a tuned turbocharged engine, even more-frequent oil changes are worth considering. More turbochargers than enough have had their lives shortened by sludgy, mucky oil.

The oil seals in the turbocharger sit in grooves in the turbocharger shaft and are similar in design to piston rings. The pressure of the exhaust gases and the compressed charge air increases their sealing pressure and makes them more efficient. This is fine until you close the throttle. The turbine shaft is still spinning at very high revs and takes quite a long time to slow down, so it is getting back pressure from the closed throttle.

This is not terribly good for the bearings, and is quite a tribute to the turbocharger's design that they last as long as they do. For normal driving at reasonable revs, or when constantly opening and closing the throttle in traffic, the back pressure is not too bad, but constant snapping the throttle shut at high boost puts a big load on the bearings so, on a tuned engine, it is as well to do something about it.

This something is to fit a dump valve in the intake system. This gets rid of the high back pressure, dumps it in fact, so the back pressure on the turbine rotor is reduced. Many tuners say dump valves are not necessary, but they also have their advocates who claim two beneficial effects. They say a dump valve helps the life of the bearings and also means that the turbine rotor does not slow down as quickly so, when you open the throttle again, the turbocharger has less speed to pick up and there is a faster response – less turbocharger 'lag' as it is often called. Ford

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never fitted a dump valve as standard on the Escort RS Turbo, but various tuning specialist shops supply them. They cost around £85, or £135 if you have them fitted, and many owners think they are a worthwhile investment on a tuned turbo engine. Our view is that a dump valve can help, but possibly not as much as is sometimes claimed. One 'benefit' for many people who fit them, is that they make a nice power noise when they come into operation.

Which brings us neatly to tuning. Many people leave the engine as it is and concentrate on modifying the control of the turbocharger. Before spending a lot of money, however, it's worthwhile making sure that your engine is giving the sort of power it was designed to give as standard. As it left the factory, the RS Turbo engine was rated at 132bhp using 7.25psi boost, although with mass-production tuning some struggled to produce more than about 125bhp. Over the years, with general wear and the falling off that comes with age to actuators, many RS Turbos on the road, although well looked after, are actually giving around 100bhp with a maximum boost of about 2 to 3psi. A new actuator and the proper setting up by a turbo specialist will cost around £100 at the time of writing, and it is a good investment. You will notice a big difference with anything up to an extra 30bhp on tap.

The first stage in tuning for greater than standard power involves changing or reprogramming the chip in the ECU, pushing the boost up to 9 or 10psi, fitting a free-flow air filter element and a performance exhaust. Prices start at around £200, depending on where you go and what make of exhaust you have fitted. With a turbocharged engine, most back pressure that is going to occur happens between the turbocharger and the exhaust valves, so the design of a performance exhaust is not as critical as with a naturally aspirated engine. The main thing is to make sure that the exhaust from the turbocharger backwards does not add any more back pressure. The standard RS Turbo exhaust is quite a large one, 2.5 inches diameter, and at this stage of tuning you will probably be all right with just a change of back expansion box and a larger tail-pipe, but be guided by the tuning specialist who is doing the conversion. With a stage one chip, a filter and a matched exhaust you should see 160 to 170bhp.

For the next stage, up to about 190bhp you need to go up to 14 or 15psi boost with a more expensive chip, maybe two-stage boost with possibly a bleed valve to control the boost, a more expensive actuator and probably a full exhaust system. The exhaust system has to be chosen and matched with care because, if the back pressure to the exhaust rotor is reduced too much you can get oil leaks past the seal. This stage of tuning is where things start to get rather more expensive, between £500 and £600, but with an engine in good condition you ought to get 185 to 190bhp. A larger oil cooler is also needed because, as we said earlier, because turbos run very hot so does the lubricating oil.

This is about as far as you can go without modifying the engine, but we must stress that for anything other than very mild tuning, say up to 140bhp or thereabouts, the engine must be in really good condition to start with. Trying to push up the power on a high-mileage engine that really could do with new mains and big-end bearings, new piston rings, new water and oil pumps as a minimum is a recipe for disappointment and disaster in the form of very expensive mechanical noises.

For powers of 200bhp and above you need to start modifying the engine. It is best to start with a complete recondition of the bottom end and then go for a modified head, gas-flowed ports, maybe reworked combustion chambers and larger valves. You will also need a performance camshaft. Kent Cams and Piper RS are two

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popular makes, but some tuning specialists have their own designs. You will need a vernier cam belt pulley to get the valve timing spot-on, probably double valve springs, special valve-stem oil seals and anti-pump cam followers. You will definitely need a properly matched full exhaust system.

At powers above 200 to 210bhp, and sometimes even below this figure, there will be problems keeping the intake air cool enough so you have to do something about the intercooler. One of the things you cannot avoid when you increase the boost is increasing the temperature of the compressed charge and, as we have seen, the temperature sensing control by the ECU will retard the ignition and cut the boost if the temperature goes up too high. We also mentioned that the RS Turbo is fitted with an intercooler as standard to help bring the temperature of the compressed inlet charge down to below 68 degrees C or thereabouts. This intercooler is designed to cope comfortably with the increased temperature you get with a boost of 6 to 8psi, and it will still cope reasonably well when the boost is increased to around 10 or 12psi. At higher boost, the intercooler is struggling to take enough heat out of the charge, and the temperature sensor in the inlet duct tells the ECU to cut back on the fuel, retard the ignition, cut back the boost and, at the limit, cut the ignition altogether.

If it did not, you could get severe engine-destroying detonation. It might be possible to avoid this detonation by leaving the high boost and retarding the ignition still further, but if over-retarded to the point where the piston is actually on its downward power stroke before the mixture ignites, power is lost. It can also mean that, at high revs, the mixture has not finished burning by the time the exhaust valve opens and combustion carried through into the exhaust manifold which becomes so hot that it glows red, a similar symptom to using a camshaft with too great a valve overlap. Should this happen, do not ignore it, but seek the advice of a professional turbocharging firm before deciding what to do.

Above all, do not believe for a moment, anybody who says that fiddling with the wastegate actuator rod and the ignition timing will overcome this. Try it, and the next thing you know is that the boost gauge needle shoots up, the engine pinks like mad because it is running far too weak and too far advanced. Then you get expensive sounding noises, a cloud of smoke from the exhaust, and a very sick engine.

One answer, if you are not pushing too hard in the power stakes, is to fit a larger intercooler. Pace is probably the best known make, costing around £350 depending on the model chosen. One of the problems with fitting a larger intercooler of any real size is the space available. Ford ran into these problems in the development stages of the RS Turbo. On the Fiesta RS Turbo which has even less room to play with, they tried first of all mounting it in front of the standard radiator, but this did not turn out to be a very good idea, so they made the standard engine radiator narrower and mounted the intercooler alongside.

You can get an intercooler which is sort of half and half, partly in front and partly alongside. The electric fan gets in the way, but you can move that along quite easily. It doesn't seem to have a great deal of adverse effect on the efficiency of the standard engine radiator, and as an intercooler it's certainly a lot more efficient than the standard, and much smaller, Ford item.

With a bigger intercooler like this you should be all right with boost pressures up to about 12 or 14psi and still keep the charge air temperature down to below 68 degrees C which keeps the temperature sensor happy.

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The limiting factor in fitting a really big air-to-air intercooler is space, width wise. There just is not the room to fit a really wide intercooler and present a bigger cooling area to the wind. The only way you can get a substantial increase in intercooler volume is to make it deeper, and that means that the back part of the core is getting cooling air that is already warmed from passing through the front part. Obviously not the ideal set-up.

If you are looking for power above 200bhp and you want to obtain anything like value for money from your engine and turbocharger modifications, you will have to look at something better than a simple air-to-air intercooler to keep the charge air temperature down.

This is a charge cooler. A charge cooler is also an 'intercooler' in the sense that it is a cooler fitted in between the turbocharger and the inlet manifold, and an intercooler is also a 'charge cooler' in that it cools the charge air. However, very sensibly leaving niceties of description like this aside, most tuners use the name intercooler for a simple air-to-air radiator, and use the name charge cooler for something very different.

A charge cooler is a self-contained air-to-water cooling unit with its own radiator, water supply and electric pump. It is a much better heat exchanger than an air-to-air intercooler (some reckon four or five times as efficient), so that it can deal with the heat that is put into the air when it is compressed to give 20psi boost. What is more, it is fairly compact and you do not have the same space problems as with a large air-to-air intercooler.

The drawback is cost. You are looking at an extra £100 at least over a larger intercooler for a standard Pace charge cooler. If thinking about one of the modified Pace high-efficiency charge coolers with a top quality Bosch electric motor, such as the one modified by Turbo Systems, you can add another £100. Even so, there is little doubt that if you are looking for really high levels of boost, a charge cooler is the way to go. It should be noted though that the system depends for its efficiency on an electric motor and if that, or its associated wiring, fails, the charge cooler efficiency drops alarmingly.

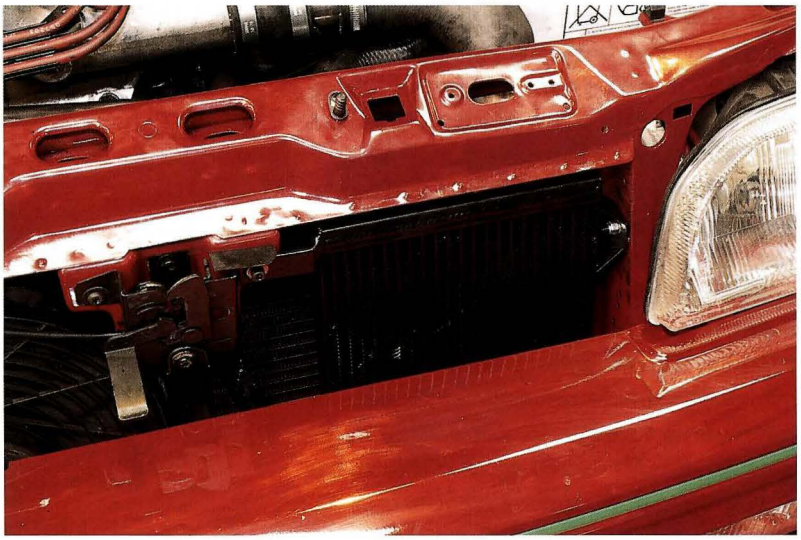
It might be possible to arrange some form of electronic interlink to the ECU to reduce the boost automatically should this happen, but we do not know of one. Cost is probably the deciding factor and there are two much cheaper warning systems available. You can have a green LED on the dash that lights when everything is working, or a red LED that lights should the motor or its electrical supply fail, plus, if you want, a warning buzzer. If we could have only one, we would go for the green light because it would do away with any worries that the circuit to the red light had failed. The disadvantage is that you may not notice a green light that goes out, whereas a red light that comes on attracts attention. Perhaps the safest answer is to go for belt and braces and have both. Cost? This would be in the region of £700 to £750.

There is another, additional, cooling system that can be fitted to improve the cooling of the turbocharger itself. Normally, the cooling water which



▼ *When an intercooler is no longer sufficient you can fit a charge cooler. This one is by Pace.*

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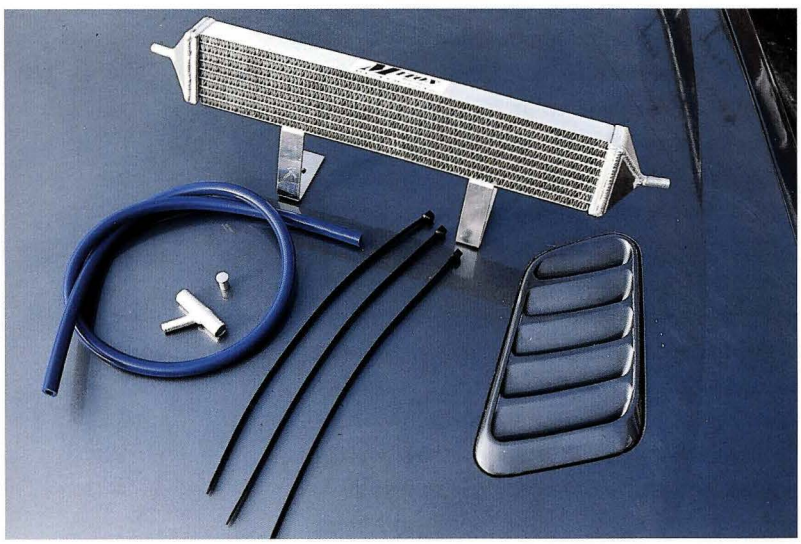


▲ *The Pace intercooler installed in a Fiesta.*

circulates round the turbocharger is piped into the engine's normal radiator cooling system, but there is a kit available from Miton Motorsport which rearranges the plumbing to give the turbocharger cooling water a radiator of its own. It is quite simple to fit and costs around £150.

For power above 225bhp, some tuners will recommend a modified turbocharger often referred to, quite loosely, as a hybrid turbo. Why hybrid? One of the definitions of hybrid in our dictionary gives 'of mixed ancestry', and that is just what the first hybrid turbos were.

They started in the late 1980s with people like Tony Mannock at Turbo Systems and Geoff Kershaw at Turbo Technics who wanted more boost than was provided by the standard Garret turbo fitted to the Escort RS Turbo. They took parts from different model turbos and, after a lot of testing and modification, persuaded them to work happily together at enhanced boost.



▼ *Where space is at a premium, Miton Motorsport offer this turbo coolant relocation kit.*

These days, most serious turbo specialists do not like the word 'hybrid' because it implies taking standard parts from the bin and just bolting them together. Generally they prefer to use the term 'modified turbo', because that is really what they are.

There is nothing new about hybrids in general design development. The often talked about but seldom used 'clean sheet of paper' is quite rare because it can push development costs too high. Even modifying existing parts to make a hybrid can involve so much development and testing that the final product becomes a new model in its own right. Garret's T28, for example, started with the idea of using a T25 with a T3 compressor rotor on a special shaft before it was developed into what it is today.

It might be asked, why modify a turbo instead of fitting a larger one, but just fitting a turbo from a bigger engine is not necessarily the answer. There might not be sufficient mass of air going through the exhaust manifold to drive it efficiently, and not enough air velocity to drive it at the speed needed to give the boost being sought. Quite often, the power can be lower than with the standard turbo.

Turbochargers need to be matched to an engine. In that respect they can be thought of in a similar way to camshafts. No-one in their right mind would put a full race camshaft in an otherwise standard engine and expect it to work properly. In the same way, you cannot just bolt a turbocharger from a Cosworth Sapphire on a Fiesta and expect to get tarmac-scorching power. Things like the air-flow sensor and the throttle body just will not let enough air

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through and there will be horrible back pressure on the turbine rotors.

Turbocharger rotors work very hard for their living. They run at anything from 100,000 to 150,000rpm, and the one on the exhaust side has to cope with searing hot gases mixed with soot, unburnt fuel and various additives that go into petrol.

The other thing they have to cope with is the simple truth that the more air you push into an engine the more exhaust gas comes out. The more exhaust gas that goes through the turbo housing, the faster the exhaust rotor tries to turn, as does similarly, the intake rotor.

Without getting too technical about air flow and air compression, the faster air flows, the more 'solid' it becomes. When you increase the boost by modifying external controls and altering the chip in the ECU, you can get to the point where the increased flow of exhaust gas is trying to drive the exhaust rotor faster and faster, and the compression rotor on the other end of the shaft cannot cope with it. This has got very little to do with actuators and things like dump valves – it is purely a question of gas flow and rotor speed. There is also the fact that, at very high speeds and volume, the flow of gas across the rotor blades changes its character.

If too high a boost is given at high engine revs and you will experience a phenomenon known as rotor stall which results in the turbocharger receiving a horrible shock loading and creating a sudden back pressure on the pistons and cuts the power. It is a bit of a Catch 22 situation really, because you need to slow the turbo rotors down a little at maximum engine rpm and a high exhaust gas flow, but you require all the rotor speed and response available at lower exhaust gas flows when accelerating.

Months, years even, of development and testing went into modifying turbochargers to find the answer to this problem although, in theory, it is quite a simple matter. The exhaust rotor blades are cut back a few degrees which makes them less efficient at top rpm without upsetting their performance too much at low and medium rpm. This is of course, turbine rotor rpm, not engine rpm.

It sounds simple enough, and it is all pukka according to the theory of air flow over a rotor blade but, like a lot of things, there is a world of difference between theory on a computer and hard metal in the workshop. It is not so much a question of knowing what to do, but how to do it. You do not, for example, strip the turbo down, take a file and start hacking away. Get it wrong and you could end up with so much turbo lag you could make a cup of coffee while it responds.

Nor do you necessarily modify the turbo by the same degree for different engines, even for two examples of the same engine but in different stages of tune. The turbo should be modified, taking into account the capacity of the engine, its compression ratio, what other modifications have been made to improve the gas flow through it, the power expected to get from it and the rpm at which it is hoped to gain this power.

When all this has been done correctly, the turbo is put under a lot more load and stress than when it was standard and fitted on a standard engine. One of the things that happens is that the axial load, or end thrust if you like, on the turbine shaft goes up. On a standard turbo the thrust bearing is not completely circular, but 270 degrees, or three-quarters of a circle. This is tied up with oil flow among other things. You cannot have metal to metal contact at that sort of rpm and load or the turbo would not last five minutes.

When end thrust is increased a larger bearing area is needed, so one of the things that is often done on a modified turbo is to fit a full-circle thrust bearing, commonly called a 360 degree bearing.

Making these bearings, and choosing the right mix of aluminium bronze and trace

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element alloy, is a very specialised and highly skilled job calling for machining that makes normal so-called precision engineering look like hacking away with a handsaw. This is not measured in thousandths of an inch, or even tenths of thousandths, but is almost working in microns, as the oil flow has to be right.

That is why, on top quality modified turbos, you get a new, 360 degree thrust bearing. On some cheap modified turbos there may be what is called a 360 degree bearing, and true, it is a full circle, but it may not be all one piece. It is not unknown for some modifiers to take two new bearings, cut 90 degrees out of one, fit this in the gap of the other, and hold them together with a sort of circlip arrangement.

A couple of centuries ago, Dr Johnson wrote warning about taking price alone into account when buying, and earlier last century Sir Henry Royce wrote that the quality is remembered long after the price is forgotten. They could both have been writing about modified turbos.

As well as matching the turbocharger to the engine, the inlet air flow, both through the air-flow sensor and through the throttle body, has to be matched to the capacity of the turbocharger. Don't guess about these points, and don't necessarily modify things just because someone else has done it that way. Always seek the advice of the firm supplying the modified turbocharger.

By the time you get to this stage, or maybe even a little before it, so much extra air will be pushed into the engine that a lot more fuel will be needed to mix with it. If this is not provided it can run very weak at high boost so there is engine-destroying detonation or, possibly worse still, it will run so hot inside the combustion chamber that piston melt-down occurs.

This is the reason why some people will recommend larger injectors are fitted or, rather, injectors with bigger holes in the nozzles. Fuel rail pressure can be increased because the amount of fuel that an injector will inject depends on fuel pressure as well as nozzle size. This can provide a solution, up to a point, but it might also introduce problems that were not there before you started.

Injectors with large nozzles work fine when squirting in loads of fuel; that is what they are made to do. They are not so happy though, when asked to squirt in much smaller quantities of fuel for slower running, light throttle cruising and idling. They do not respond all that readily to the electronic pulses which tell them to regulate the fuel flow for low engine speeds and slower air flow. It is a bit like trying to regulate a garden hose to water a window box. You are quite likely to get a very rich mixture at lower revs, with fluffy pick-up when starting to accelerate, and rough, rich idling to the extent that it will not stand any chance of passing the MoT emission test. You could even get such a rich mixture trying to start a cold engine that it floods and it will not go at all.

Not everyone has such problems, but the higher you go in the search for power, with more air flow and higher boost, the more likely you are to run into them. This is why those reaching up into the higher ranges of power that their engine is capable of delivering think in terms of adding extra injectors. With the CVH engine in an RS Turbo, the usual set-up is to fit a fifth injector.

The basic idea, and it works very well with the right control equipment, is that the car runs on standard injectors for idling, cruising and moderate acceleration. There is no need to change ECU programming, no starting problems, no idling problems and no emission test problems. The extra injectors and the control unit for them are sound asleep and not interested in what is going on at this stage, but when you tread hard on the accelerator, it is a different matter. The

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control picks up signals from sensors which tell it what is going on, so it wakes up and instructs the extra injectors to get busy and squirt in more fuel to match the much greater air flow that is coming in from the extra boost or the modified turbo that has been fitted. One point to get clear here is that extra injectors, even if the control unit told them to start injecting, will not give extra power unless the amount of air going in has been increased to match the extra fuel. Once the limit of the air the turbo will deliver has been reached, all you would have is a very rich mixture, so the drill is: extra boost first, then extra fuel to match it.

What sort of extra injectors do you need? Here we have to distinguish between high impedance injectors fitted to an RS Turbo, and low impedance injectors such as those fitted to a Cosworth. High impedance injectors will deliver about 300cc of fuel a minute, but you can get a useful increase in power by adding a high impedance fifth injector without having to go mad on the turbo side. If a high efficiency hybrid turbo has been fitted it might need a single low impedance injector, a pair of high impedance injectors, or even a pair of low impedance. In theory, it is possible to get 350bhp plus bhp from an RS Turbo with proper turbo and injector matching, provided the rest of your engine will stand up to the extra strain but that sort of power is strictly for competition use and the modifications can easily cost more than the car itself. Like all tuning equipment, do not just bolt it on and hope for the best. Consult a turbo specialist to get proper matching.

When it comes to fitting the extra injectors and the control unit, it is not all that complicated. We talked with Richard Lamb at ERL who make the MF2 (Map Fueller version 2) control unit, and he told us that while you need a little more than a household tool kit, and your average bolt-on-new-parts garage mechanic might be a bit lost, any competent fitter who's used to working on turbo engines should not have any problems.

First of all you need the extra injector or injectors, and Richard told us that quite a few people have been very happy buying second-hand injectors and having them cleaned and reset, which can save you a lot of money over new ones. The manifold has to be drilled, machined and tapped to accept the extra injectors and, while it is ideal to put a single injector in the middle of the manifold, or two equally spaced along the manifold, there is no need to worry if the spacing is not all that spot on. The air flow at the high boost at which the extra injectors start working is so high that uneven distribution of the extra fuel along the cylinders is very seldom a problem.

Then the extra injectors have to be piped into the fuel line. With a single extra injector there is no problem. A T-piece is fitted in the fuel line, a new piece of pipe and connectors are installed and that is it. With two extra injectors it is best to make up a new fuel rail, or possibly adapt a second-hand standard one, and then pipe that back to a T-piece. According to Richard, there is no need to fit a fuel line pressure boosting pump. Provided your existing fuel pump and pressure regulator are in good order, you should be OK. You are not looking for extra pressure to force more fuel through standard injectors, but are just needing more fuel flow to feed extra injectors at standard pressure, and the system is nowhere near its flow limit on a standard set-up.

The control unit comes with a mounting bracket and can be bolted anywhere convenient under the bonnet. Included in the kit are looms to connect the electrical system to the power unit to pick up signals from engine management sensors and to feed signals to the injectors. This loom has standard Bosch end connectors. There is also a pressure activated switch which fits to the inlet manifold to tell the control

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▲ *If you fit extra or larger injectors you may need a fuel pressure booster.*

unit when the extra boost comes along. This is fitted to give 2D (two dimensional) mapping where using signals from existing engine management sensors, the throttle angle sensor and the MAP air-flow sensor. Alternatively, the system can be wired to operate independently to give 3D mapping, and the unit has a stabilised 5-volt output terminal to drive an MAP sensor if the system does not have one. This wiring makes installation a little more complicated, but not terribly so.

The standard MF2 box will control up to four extra high impedance injectors or two low impedance injectors. If fitting more than two low impedance injectors an extra driver box is needed which is quite simple to wire in.

The chip in the MF2 is programmable to suit different installations, but Richard says the unit is based on an 'open architecture' design which means that you do not need any special equipment, not even a computer interface. All that is required is a small screwdriver and a knowledge of what you are doing.

Closely allied to extra injectors is water injection which is dealt with in Chapter 13.

Lastly, a few words about looking after your turbocharger, modified or unmodified. We have already mentioned the importance of regular oil changes in a turbocharger's life. The life of the seals, which is the same as the life of the turbocharger, can also be shortened by a restricted air cleaner which can make the turbocharger try to compress air it does not have. On a standard turbocharged engine, pay attention to the state of the air cleaner and renew it sooner rather than later. On a tuned engine, take the advice of whoever does the tuning or supplies the parts, about what type and size of air filter to use.

Apart from that, keep an eye on the boost gauge. With modified turbocharger control you will see a tremendous difference, a rise from about 6psi to something approaching 1 bar, or about 14.7psi, more if you also fit a modified turbocharger. If fitting the modified parts yourself, keep an eye on the boost gauge and stay strictly to what the supplier recommends. Do not try to get a boost beyond what is said in the instructions by 'screwing things down a bit' or you are likely to blow things up with a lot of very 'expensive' noises!

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Chapter 12

Adding a turbo

If your pride and joy has a naturally aspirated CVH you will have now read the chapter on tuning turbo engines with a twinge of envy for the people who have one.

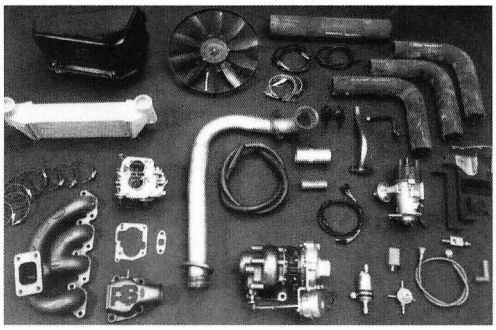
So is it possible to turbocharge a naturally aspirated CVH? The answer of course is yes, and it has to be, otherwise we would never have had the RS Turbo. But, and there has to be a but, there is the question of which gives the best value for money, turbocharging your present engine, fitting a complete second-hand turbo engine, or even selling the car and buying a turbo version? In the long run the decision has to be yours, but we can tell you what is basically involved in fitting a turbo and, roughly, how much it is likely to cost.

In the chapter on turbocharging we mentioned the pre-RS Turbo tuning kit from Ford for rally work. It was put together in 1981 by Ford's motorsport people at Boreham and Dunton, possibly part of the development programme for the yet to be announced RS Turbo. It was intended to be an RS dealer fitment and was sometimes called the 'World Championship' kit although Ford called it the Escort Turbo Rally kit and organised a short-lived championship for this one-make class.

Buyers received a turbo, manifold, intercooler, new inlet and exhaust valves, anti-pump-up hydraulic lifters, fuel pump and filter, different distributor (the Bosch one later fitted to the XR3i) and various bits of wiring and controls. They also came with a different carburettor, a Weber 32/34 DMTT (double barrel, manual choke, transverse turbo). The main difference between this and the naturally aspirated 32/34 DMTL being a sealed top cover and sealing at the ends of the throttle spindles because the carburettor was pressurised by the turbo.

The advent of the XR3i and, later, the RS Turbo, killed the kit completely, and you are most unlikely to find one nowadays. Even if you do come across one second-hand, it is no good going along to a Weber agent and asking for a DMTT carb, or even an overhaul kit. All he will find when he calls it up on his computer will be a big NLA; no longer available.

However, Turbo Systems has resurrected the kit in replica, with a DMTL carb modified for pressurisation, although they prefer to fit it themselves rather than sell it as an over-the-counter package. The reason is, that although fitting it is relatively straightforward physically,



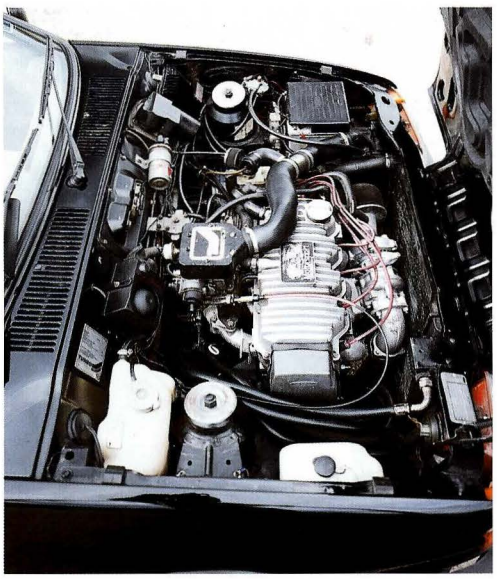
◀ *Ford's first offering for turbocharging a CVH was this kit for private rally entrants. It is no longer available but you might possibly find a car with one fitted.*

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setting things up afterwards is not. If you are not careful you can easily get engine-destroying detonation. Provided the engine is in good condition, and that means really good, it does not have to be stripped down. It must be a later CVH engine with lead-indium bearing shells, not an early one with aluminium-tin shells, although very few of these are likely to be still in good enough condition for turbocharging without a complete overhaul. The conversion runs on standard compression ratio, which is all right so long as you limit the boost to about 6 or 7psi. Go much higher without lowering the compression ratio and you will almost certainly destroy the pistons.

Fuel-injected CVH engines are generally more easy to turbocharge than those with carburettors, mainly because Ford did all the development work on the RS Turbo.

At one time, Power Engineering used to offer a turbo conversion for injected CVH engines using a special hybrid turbo which they developed in conjunction with Garrett. The conversion also used a charge cooler instead of an intercooler (air-to-water instead of air-to-air) mainly because they were looking at much higher boosts than 7psi and there was not really room to get a big enough intercooler in front of the engine with sufficient air flow across it. The conversions also went the whole hog with lowered compression ratios, special pistons and specially mapped chips and certainly produced a lot of power, but because of the small volume of the specialised parts needed the cost was very high, and it was uneconomic.



▶ *A later conversion of a CVH to turbocharging, by Turbo Technics.*

Turbo Systems also offer a turbo conversion for injected CVH engines but, on those like the XR3i and Orion 1600i they do not usually discard the K-Jetronic fuel injection system unless the customer particularly wants an RS Turbo look-alike system. They can fit various items of electronic wizardry and sensors which they have developed to keep the turbo under control and married happily to the K-Jetronic mechanical injection system.

Severn Valley Motorsport also offer a CVH conversion with nearly all the items coming from the Ford parts bins, or from the owner second-hand, although in that case there is no warranty on the owner-supplied parts even though they are inspected as closely as possible without actually stripping them down.

Severn Valley throws away the Bosch K-Jetronic mechanical fuel system and fits in its place the KE-Jetronic electronically controlled system as used on the RS Turbo. At one time they used to discard the old wiring loom as well, including all the relays and other bits and pieces and substitute RST looms and control boxes, almost rewiring the car, but their auto electrician has since developed a way of splicing a new front-end loom into the existing system which saves the customer quite a bit of money in labour charges.

The company is not keen on the idea of pressurised carbs so on a carburetted engine they convert it to fuel injection, and here there is a choice that they like to talk over with the customer. Obviously something has to be done about the fuel pump and tank because the injection system works at a much higher pressure

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and also needs a return line. One possibility is to fit the tank and fuel pump from an XR3i or a 1600i Orion, or the carb-type tank can be modified to take a return line and use a high-pressure proprietary pump with a swirl pot in the system. With regard to the management of the turbo you can have either the KE-Jetronic or Ford's EFi system. Again, it is a question of talking things over.

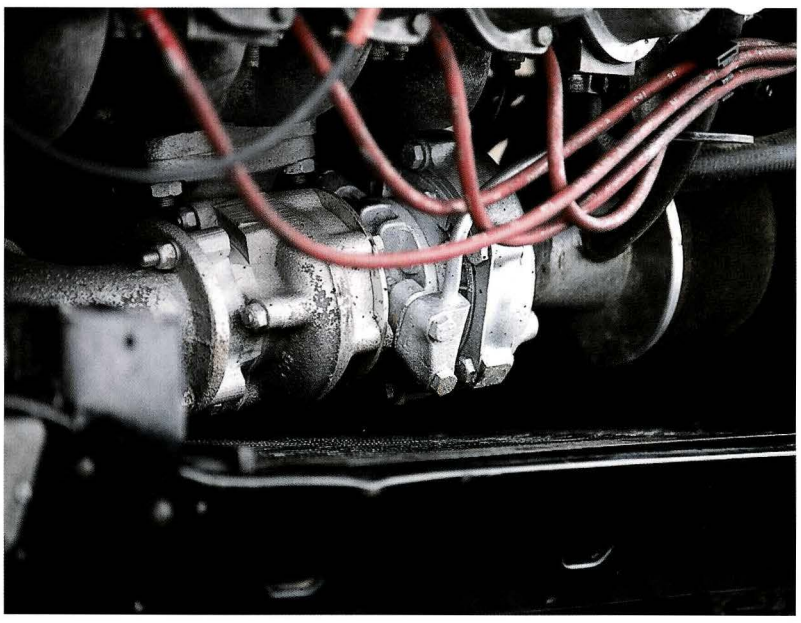
With regard to the cost of converting a CVH engine to turbo, it varies according to what is wanted and is being started with, and how much is done yourself. We have been quoted prices in the region of £1,680 to £2,000, provided the base engine is in good condition.

Can the job be done yourself by getting hold of bits from a scrap or crashed RS Turbo and fitting them to the CVH engine in your car? The answer is yes, provided you know what you are doing and you stick pretty closely to Ford's RS Turbo specification. It is in trying to mix and match, particularly with turbocharger control systems and mechanical injection systems that the home converter is likely to run into trouble. If in doubt, convert to the KE-Jetronic.

Adding a turbo to a naturally aspirated engine that already has quite a few thousand miles behind it puts a lot of extra stress on it; even keeping the boost down to 6 or 7psi, which is why both Terry Mannock and Kevin Kemp lay a lot of emphasis on engine condition. If you are undertaking the job yourself, make absolutely certain your engine can cope.

What sort of power can you expect? You ought to see around 148bhp, but watch the ignition advance curve and have this checked on a rolling road without screaming it up to maximum power, at least until the engine has settled down, to prove just how much has been gained. It is easy, with a cheap and cheerful remapped chip, to get far too much advance in the mid-rev range at cruising, and this will do the engine no good at all. Before you start, cost things out properly. It may be found that you have to buy all sorts of extra bits and pieces so you end up spending very nearly as much as having the job done for you, plus a lot of work and hassle, and no warranty.

Remember, whoever does the job, that the CVH is basically quite an old design engine and if you do not fit lower compression pistons you will probably need to use 98̊ octane petrol to be sure you are not suffering from detonation, possibly even what is sometimes called 'inaudible detonation' because this sounds more like quiet tappet noise and does not ping out at you like pinking. Premium unleaded 95 octane is therefore not high enough. Most lead replacement petrols are 97 octane at best, possibly lower, and Super unleaded is getting scarcer, so you may well have to use an octane booster.



▶ *The Garrett T3 turbo, which is used for most conversions.*

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Chapter 13

Water injection

It might appear to be something of a paradox that injecting water into the combustion chamber, or the inlet manifold, can be a way of getting more power from an engine. After all, water is supposed to put out fires, not help them burn. Here, we are not using water as a flame quencher, but using its ability to absorb heat, particularly when it changes from a liquid to a gas. Water is a very stable liquid and it takes about six times as much heat to vaporise it as it does to vaporise petrol.

This is a very useful property when dealing with turbocharged engines because too much heat in the combustion chamber caused by too high a boost can destroy an engine very quickly, as it can lead to pre-ignition and uncontrollable detonation. The idea of using the heat-absorbing property of water as an anti-knock agent is not by any means new. It was used on aircraft engines, Rolls-Royce Merlins in particular, during the Second World War where the pilot had a 'panic button' which would override the supercharger governor to give a big emergency increase in boost. At the same time, water, actually a mixture of water and antifreeze because the temperature is below freezing at high altitude, was injected into the inlet manifolds to keep



▶ *A complete water injection kit from ERL.*

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the combustion temperatures within reason and prevent pre-ignition and detonation which would result in temperatures high enough to melt the piston crowns.

On turbocharged car engines, combustion chamber temperature and piston temperature are kept under control in three ways. The first is that in standard tune the compression ratio is lower than in a naturally aspirated engine, and the boost is kept low enough to avoid pre-ignition and detonation. These are both uncontrolled burning, explosion if you like, of a pocket of mixture inside the combustion chamber.

Pre-ignition, as its name suggests, happens when the combustion chamber, or usually a small part of it, gets so hot that it ignites the compressed fuel and air mixture before it is ignited by the sparking plug, and well before top dead centre. This puts a tremendous shock loading on the piston which is still trying to complete its compression stroke against a burning, expanding mixture.

The term detonation is usually used for an uncontrolled explosion after the sparking plug has ignited the mixture. What happens is that a flame front rushes from the sparking plug across the combustion chamber and compresses the mixture in front of it as it goes. If the temperature in the combustion chamber is too high, the compressed pocket of gas in front of the flame front ignites and explodes spontaneously instead of burning in the controlled way it should. The American term for this is auto-ignition. This detonation adds to the heat inside the combustion chamber so there is a vicious circle of cause and effect.

Under these conditions in a turbo engine with heavy boost, the combustion chamber exhaust temperature can become as high as 1,100 degrees C unless it is controlled. When it is realised that the aluminium alloy from which most pistons are made melts at about 660 degrees C, you can understand why, on some over-boosted engines, you can literally get melt-down.

The highest temperatures do not usually occur at maximum power output but at around the point of maximum torque. The reason for this is that at maximum power at near maximum revs the combustion is so fast there is hardly time for detonation to happen or, at least, a lot of the force is taken out of it. At or around maximum torque, combustion chamber temperatures can get far too high for the health of the engine, even at standard boost.

What does Ford do about this? They arrange the fuelling map in the ECU to give an over-rich mixture in the critical engine load and rev range, with the excess fuel used as a cooling agent to hold the temperature down to about 850 degrees C. This is still far too hot for the piston, so the temperature of the piston crown is held down to a safe level, (550 degrees C is usually the designed aim), by heat being conducted through the metal to the underside of the piston crown and the skirt where oil quenching carries the heat away. Another reason why you need an oil cooler.

All this works fine on a turbo engine in standard tune even although you do not get the most efficient conditions for power and fuel economy because of the over-rich mixture. It's when you start to upgrade the power on a turbo engine that nasty things can happen and it is so easy to push up the torque and power of a turbo engine. In the simplest terms, all you need is a different actuator to delay the wastegate opening, more fuel pressure and a new chip in the engine management box. You can go from the normal 6psi boost of a standard Escort Turbo up to 12 or 15psi boost with no problems except, that is, inside the combustion chamber.

Things are not helped by the fact that all this increased boost, or compression of the intake air if you like, pushes up the air

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temperature. We mentioned that an intercooler between the turbo and inlet manifold is put there to take some of the heat out of the compressed air to make it a little more dense so you can burn more fuel at the correct air-to-fuel ratio and thus get more power, and to keep the air temperature sensor happy. What many people do not necessarily realise is that the intercooler also plays a vital part in helping to keep pre-ignition and detonation more or less under control by maintaining combustion chamber temperatures within reason.

Another way to keep temperatures down would be to increase the size of the water jacket around the head, force coolant through it at a prodigious rate with a high pressure pump and fit a huge radiator, but you can imagine what that would cost. So, what is sometimes done is a spot of fuel dumping. With increased boost, fuel is quite literally dumped into the combustion chambers to help cool them at the critical point in the rev range, usually, as we mentioned, at around maximum torque.

Unfortunately, there is then another vicious circle created. Because the mixture is far too rich, it burns more slowly so the ignition cannot be advanced to the point where you would like it for maximum torque, or the engine would pink like fury. So power is lost because the mixture is too rich to burn efficiently, more power because you cannot time the ignition to its most efficient advance, and fuel is wasted because it is used as a coolant as well as a fuel.

There is yet another drawback. All this excess fuel may be helping to keep temperatures under control, but it is also washing the bores quite effectively to give you greater bore wear and diluting the oil that is cooling the pistons so it is more likely to burn and get carbon in it. The oil companies have stepped in and helped matters by developing high grade synthetic oils which withstand this ill-treatment better than straight mineral oils, but the whole thing is a delicate balance of fuel mixture, combustion pressure and combustion temperature.

Get just one part of the balance wrong by fiddling with actuators and fuel pressures based on the advice of ill-informed 'saloon bar experts', and it could be goodbye to a highly tuned engine.

We also mentioned earlier that the internal combustion engine is a pretty inefficient piece of machinery all round when it comes to converting the energy in petrol to mechanical energy and power at the flywheel. Well over half this energy is thrown away in heat, but, until something better comes along, we're stuck with it.

So what can we do about it? Quite frankly, as end users, not all that much and we are very much in the hands of the specialists. In the long term, we are relying on engine designers to produce combustion chambers with the right shape and swirl, and the sparking plug in the right place to lessen the chances of pre-ignition and detonation, on fuel chemists to produce fuels with better latent heat properties so they burn a little less hot and on oil chemists to give us oils that will better withstand fuel dilution and high piston temperatures. When we buy a turbo power-increase package, we rely on the tuning firms to get their sums right and build their electronic management chips so that they control the wastegate, the fuel pressure and the cooling fuel dumping at the correct critical points.

We started this chapter by talking about water injection and how this can help. Basically, by injecting water mist into the inlet manifold at the right time, things can be arranged so that it gets carried into the combustion chamber where it absorbs heat by becoming changed into superheated dry steam. It is about six times more efficient in absorbing heat while it is doing this than fuel dumped in for cooling.

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If it helps that much, why do we not all have it as standard? This is mainly because although the principle is well over 50 years old, it was not really necessary on cars until people started pushing turbo engines to much higher powers than their designers ever intended. Also, until the advent of reasonably priced sophisticated electronic engine sensing and control, it was far from easy to inject the water at exactly the right time when it would do the most good.

Now that such control systems are possible, water injection is starting to be reintroduced after being in the doldrums for half a century. What it will not do is increase the all-out maximum power of the engine. What it can do, if it is properly designed and fitted, is to allow the fuel control part of the engine management chip to be programmed to deliver the most efficient fuel mixture right across the rev range instead of an over-rich mixture for cooling at critical points, and allow the ignition timing to be advanced around the point of maximum torque because the correct mixture will not burn so slowly as an over-rich mixture.

The equipment is easy enough to fit as it uses water from the windscreen washer bottle. The alcohol of the screen-wash liquid does not hurt at all, and indeed, may even help. Although it is physically easy to fit, the electronic control of the water injection and the management system of the fuel and ignition, have to be set up properly to obtain the full benefit.

The end result is that you should get quite an appreciable increase in torque at and around its maximum point which will lessen the steepness of the power curve to make it more plump and give you more power where it is most likely to be used.

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Chapter 14

Head gaskets

As they leave the factory with standard power outputs, and if the head has not been disturbed, Ford head gaskets are pretty reliable. It is when power is uprated or, sometimes, when the head has been off for a top overhaul, that problems can occcur. If this happens, or if you find a blown head gasket when stripping down an engine, don't just put another head gasket on and hope for the best as it will probably blow again. And never, ever, use jointing compound to try to stop it blowing again; it's useless. Find out why the gasket blew, put things right, and you should not have any more trouble.

Cylinder head gaskets depend on proper clamping between the head and the block and this is not simply a matter of doing things up tight. Proper clamping depends on the flatness of the head and block faces, the type of gasket and bolts used, the way they are fitted, and how these are pre-loaded.

As mentioned in Chapter 19, Examining the parts, we are sometimes asked how much bowing is permissible on a head or block face and also, if the head comes off for a top overhaul and shows slight signs of bowing, why should it be likely to leak when it goes back if it did not leak before it came off? The answer to the first part of the question is, ideally, none. Certainly, on an uprated engine, or a turbo engine, there should be no warping or bowing at all.

The answer to the second question is that it was not bowed before it came off. When a head is in service it gets alternately hot and cold, many times, usually with uneven heating along its length, so it develops internal stresses in the metal. Because it is clamped down by the head bolts, these stresses cannot relieve themselves so they wait until the bolts are undone. Then the head bows or warps.

Next, the gasket. You can buy genuine Ford gaskets as well as other reputable proprietary gaskets, and you can buy cheap pattern gaskets. Our advice is to give the cheap ones a miss. They may be all right but, if they are a lot cheaper than ones made by well-known companies with a good reputation, the lower price had to come from somewhere, usually from lower quality. When it comes to boosting engines to considerably higher power than standard, particularly turbo engines, even a reputable or a Ford standard gasket may not be sufficient. You may need to go to a Group A gasket which is available from most specialist tuning shops.

Whichever gasket you use, treat it carefully. It is, or should be, made to quite high precision so that it squashes down by a known amount under a certain clamping force to give a perfect seal, yet still retaining enough elasticity to prevent leaks when the head and block heat up and expand. Do not let it get bent or kinked. Keep it in its packaging until you need to use it and, when it is fed down over the locating dowels, make sure it does

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not catch and raise burrs which will stop the head seating properly.

Before fitting the head, check that the holes in the gasket have proper clearance round the bolt holes so there is no chance of the bolt catching the gasket as it goes in. If the holes do not line up accurately you may have the wrong gasket. Consult your Ford dealer or specialist tuner. Genuine Ford gaskets for CVH engines have a number of 'teeth', from one to four, cut in a tag on the edge to identify them for different capacities of CVH engine. It is possible you may have the wrong gasket for your model CVH engine.

For really high powers you might have to use either Wills or Cooper rings, with special gaskets. These are special rings which take the place of the fire ring on a normal head gasket and fit in machined grooves at the top of the bores. The difference between the two is that Wills rings are hollow and rely on gas pressure inside to give them flexibility when they are squashed whereas the Cooper rings have a spring inside. Each has its champions, and we're not going to pick between one or the other. You will have to take the block to a specialist tuner for machining, so ask his advice about which type he favours for a particular engine.

The machining has to be done very accurately so that the ring sits down into the block exactly the right amount. When the head is torqued down, the ring has to compress to its working thickness and, at the same time, the special gasket, which is cut to fit round the rings, has to be clamped down and compressed tight enough to stop oil and water leaks. It's quite a critical business. When fitting the rings and the gasket, follow the instructions religiously.

When it comes to head bolts on CVH engines, always use new bolts. It might seem an extravagance, but there is a very good reason for this. When it comes to holding the head clamped down on a high performance engine, any old bolt that fits isn't good enough. The head bolts on a CVH are what are generally termed stretch bolts. When tightened in the correct way, to the correct torque, the bolts stretch slightly but not enough to take them past their elastic limit. Think of them, if you like, as being very strong springs clamping the head down to the block. When the head heats up in use, it expands and the bolts stretch just a shade more while still exerting sufficient clamping pressure to keep the gasket firmly in place without blowing.

The reason you should use new bolts each time the head comes off is that after they have heated and cooled, expanded and contracted a few hundred, or even a few thousand times they tend to lose their elasticity. They are fine until you disturb them, and they still look perfectly good when you take them out. For other less demanding applications they might be, but, if you use them again as cylinder head bolts they will not exert the same clamping force when they are stretched again and, what is more important, they will not have lost their elasticity by the same degree as each other so, even though you tighten them identically, the head will be unevenly clamped and the chances of blowing a gasket will increase.

If uprating the power much beyond standard, a specialist tuner may advise that higher grade bolts than standard are needed. This is not just to relieve you of more money as the higher grade bolts will be made from a different steel alloy and will exert a greater clamping force than standard bolts, but only if tightened in the correct way. The torqueing down sequence will be the same, but the figures for torqueing and tightening may be different from standard bolts.

Whether you use standard or higher grade bolts, the tightening method will be similar. Use a torque wrench to tighten down to a figure considerably lower than

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the final clamping force, then put the torque wrench away and finish tightening by one or two sequences of tightening each bolt through a certain number of degrees using a socket. With standard bolts this is usually a double sequence of tightening through 90 degrees each time, and you can judge a right-angle turn pretty accurately by eye with paint dots and by watching the socket wrench bar. With higher grade bolts, it may or may not be 90 degrees and, if it isn't, it will be difficult to judge by eye so in this case a small dial gauge to fit on your socket bar is needed which will indicate by how much it has been turned. These gauges are not expensive, so use one instead of trying to guess.

We emphasise again that there is an essential precaution you must take before fitting any type of head bolt. The threaded hole in the block must be absolutely clean and dry. If it is mucky with grit this will prevent a proper torqueing down because friction is added to the natural twisting movement of the bolt which gives a false torque reading. If there is any water or oil in the hole, there is a distinct danger that a hydraulic lock will occur when the end of the bolt hits the liquid and it will not tighten down properly. If compressed air is available, clean the bolt holes with an air blast, but wear goggles and keep your face out of the way because any muck or water in the hole will be blown out with considerable force. If you do not have an air line, go down the holes with a rod and a non-fluffy piece of rag until you're sure they are clean and dry. Ideally, you should run a suitably sized tap down the threads afterwards to make sure they are clean.

If the head or the block, or both, has been refaced, consult the specialist tuner that did the work and ask if the bolt holes in the block need to have the threads deepened. If the head was badly warped, it is just possible that the bolts might bottom in the hole before being tightened down fully and, once again the torque figure will be wrong because the bolt will not be exerting the correct clamping pressure at any given torque figure.

Always use plain washers under the head of the bolts, never lock washers and, once again, just any old washer will not do. The cheap, stamped-out washers you find in DIY shops or in boxes in accessory shops may be fine for other uses but for cylinder heads, are useless. They will have burrs on them, and will be made of cheap mild steel that squashes and picks up on the underside of the head bolt. Proper head bolt washers should be hardened and ground flat, and there should be a chamfer on the hole on one side to accommodate the fillet radius at the head of the bolt. Remember, always fit the washer with this chamfer towards the bolt head.

When it comes to torqueing down, you hear all sorts of stories that the threads should be dry, or oiled, or coated with copper lubricant, or not coated. We follow the recommendations of ARP, a highly respected American bolt and fastener manufacturer in America who make bolts for the space industry as well as motor racing. They say that the threads should be clean and either lightly oiled or lightly coated with a good quality anti-friction lubricant. That way, the resistance you get when you torque down is the resistance of the bolt material itself, not bolt material plus an unknown amount of thread friction.

If you are going for a highly boosted RS Turbo, the tuner may advise that studs should be fitted instead of bolts. What's the advantage? For cylinder heads, studs have two advantages. The first is that there is far less chance of damaging the threads in the block because when the head is tightened down, the force on the block threads is a straight pull, not a combination of pull and twist as with a bolt. The second is that the stretch on the stud is exerted while it is stationary, not

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turning, with the torque applied to the nut so that the stud stretches without being twisted. The studs are shouldered, and the block usually has to be machined and retapped to accept them. They are not necessary on a mildly tuned engine but are recommended on very highly boosted racing or rally turbo engines. If you have them fitted, take care not to raise burrs on the gasket by catching it on the stud threads when it is fed down. Some fussy tuners prefer to lay the gasket on the block face before they fit the studs in the block. The studs do not have to be tightened down very hard in the block, and ARP say that firm hand-tightness is sufficient although, being 'belt and braces' people, we prefer to lock a couple of nuts on the top threads and just check with a spanner that they are reasonably tight. Do not overdo it though. With clean and lubricated threads, ground washers and high quality nuts, the studs will not turn or pull out when torqued down.

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Chapter 15

Can you take the 'cat' out?

Catalytic converters to reduce exhaust emissions came into general use in 1992. This was much to the disgust of people who wanted to tune their engines with a performance exhaust and manifold because a catalytic converter, or 'cat' as it is usually called now, is far from being an ideal component in a performance exhaust system. What is more, when the time comes to renew it, and they do not last for ever, they are expensive.

So, if your car has a cat, can you legally take it off and fit a normal silencer or a performance system? The best people to answer this were the Vehicle Inspectorate (VI), the branch of the Department of Transport which interprets the MoT regulations, so we asked them for clarification.

It will no doubt surprise a lot of people that, at the time of writing, there is nothing in any regulation which says that your car has to be fitted with a cat, nor is there likely to be. However, there is a but, and a big but, attached to this. Depending on when the car was first used, and a few other important provisos, it has to pass one of five exhaust emission tests.

The important dates are all 1 August, because that was when the registration letter changed until 1999, and it is easier for the examiner to date the car. Any car first used before 1 August 1975, does not have to pass an emission test except a visual check for smoke, so that will not apply to any CVH engine. Between 1975 and 1 August 1992 it has to pass what is usually known as a 'non-cat test'. This is 4.5 per cent CO (carbon monoxide) before 1986 and 3.5 per cent CO after 1986. In both cases, the HC (hydrocarbon) level is 0.12 per cent, or 1,200ppm (parts per million). Any CVH engine, provided the fuel system and ignition are in good condition, should have no difficulty with this.

Now we come to the 'killer' date, 1 August 1992. This was from when most cars were fitted with cats, because it was the date decided by the European Union for testing cars fitted with what it calls an advanced emission control system. The test here is in two parts, one at idle speed and one at a raised engine speed, usually between 2,500 and 3,000rpm.

At idle speed, there is not a test for HC, but the allowable CO emission is slashed right down to 0.5 per cent. On the raised engine speed test, the allowable CO is a measly 0.3 per cent, and the allowable HC is cut back to a very mean 0.02 per cent, that is 200ppm. There is also a lambda test which is the fuel-to-air mixture. The tester does not use the lambda sensor in the car's system, but it is done with a probe in the tailpipe which measures the air-to-unburnt fuel ratio. The computer on the test equipment divides this by 14.7, the usually accepted optimum value. The answer must be 1.00 plus or minus 0.03.

The reason we called 1 August 1992 the killer date is because, without a cat, no

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CVH engine stands the slightest chance of passing these tests. So does this mean that if your car was first used on or after that date it has to be fitted with a cat to get through the emission tests? Not necessarily, as there is yet another 1 August date; 1994. When the EU laid down the regulations, the UK put up a good case that there were plenty of cars first used after 1 August 1992, but fitted with older engines that were never designed to pass the advanced emission control system test.

The UK was granted a derogation, or concession, that if these cars were first used before 1 August 1994, they would pass an MoT on the same test as 1986 to 1992 cars, 3.5 per cent CO and 1,200ppm HC at idling speed. As we said, a good CVH engine should achieve those levels easily without a cat.

To find out if your Ford is one to which this concession applies, you will have to refer to a book issued by the Vehicle Inspectorate which lists all the cars which the manufacturers say should be able to pass a more stringent test. The cars are classified not by the date of the first registration, but by engine code.

If your car was first used between 1 August 1992 and 1 August 1994, and the engine code is not on the list, you are in the clear. You can remove the cat and still sail through a non-cat MoT emission test.

This book is called the In-Service Exhaust Emission Standards for Road Vehicles, and it is published by the Department of Transport. You do not have to buy it, as there is a copy in every MoT test station equipped to carry out a cat test. All you have to do is drop in and ask to see it.

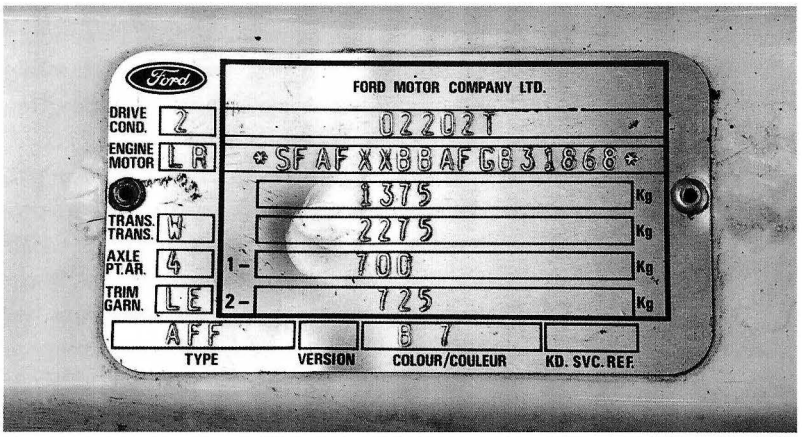
This leaves those cars which were first used after 1 August 1994, or first used between 1 August 1992 and 1 August 1994, and which have an engine code that is listed in the book. At this point it is a good idea to define what the Vehicle Inspectorate means by 'first used'.

The usual place for determining first used is the V5 registration document. However, Ford went through periods of having quite a big vehicle park of finished cars which were not delivered to dealers for some months. Add to this the time the car may have been standing at the dealers before it was sold and registered, and there could be a considerable time lapse between the date the car was built and the date on the V5.

In that case, the MoT station has to refer to the VIN number, which has a code on it giving the build date. First used is taken to mean either the date on the V5, or a date six months after the car was built, whichever is the earlier. In some cases, this could mean a big difference in the severity of the emission test.

Even if this does not let you out, do not despair. There is another way of legally getting rid of the cat and passing the MoT on the much less severe non-cat emission test. There is a loophole in the regulations, and it could have been written specially for people who like to tune their Fords with a modified rebuilt engine.

While we were talking with the Vehicle Inspectorate, the subject of modified engines came up. The VI told us that some people are putting it about that if you modify your engine by fitting a gas-flowed head, different exhaust and a reprogrammed chip, the engine is no longer to manufacturer's standard so the



▼ *The VIN plate is the first place the MoT examiner will look to determine the age of your car.*

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more stringent MoT emission tests do not apply. It would be nice if they were right, but they aren't. If someone tries to spin you this line, don't believe them, says the VI. It is a load of rubbish.

They referred us to their MoT Inspection Manual, the book by which MoT examiners work. In Section 6.4, on page 5, there is a paragraph headed 'Vehicles fitted with modified engines'. It reads:

'If an engine has been modified in any way, it still has to meet the exhaust emission requirements according to the age of the vehicle.'

That seemed effectively to squash any barrack-room lawyer's talk about modified engines. However, there is a small seam of gold on the same page. Further down there is another paragraph which is headed 'Vehicles fitted with a different engine'. As it is important, it is quoted in full:

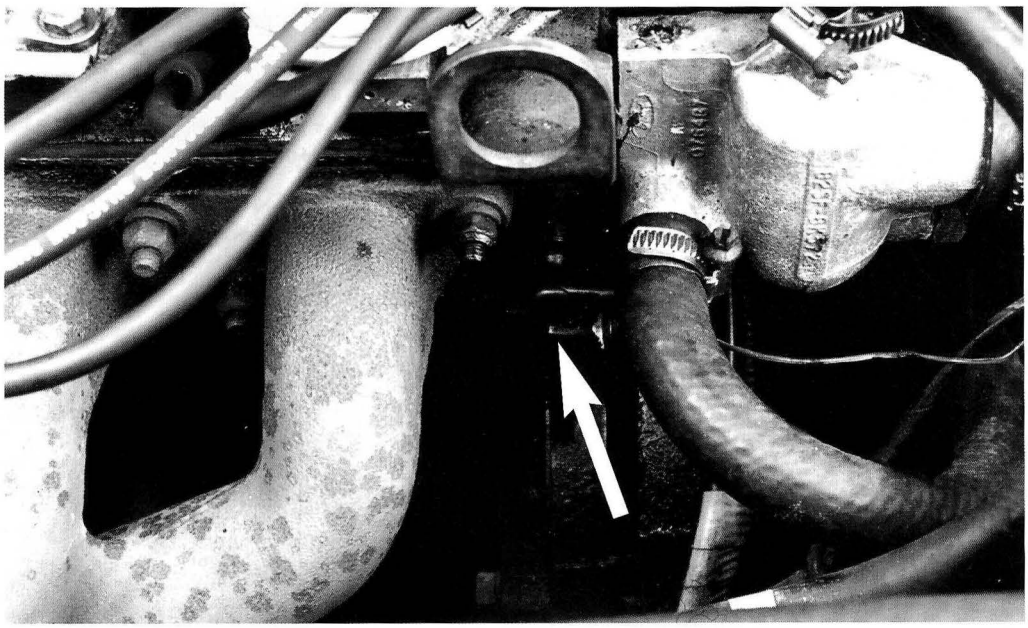
'Test according to which is older, engine or vehicle, eg: a 1995 car fitted with a 1991 engine (of whatever make), test to 1991 standards for emission purposes. Note: The onus is on the vehicle presenter to prove engine age.'

We went back to the paragraph about modified engines and asked for clarification. Suppose, we said, someone has a car first used after 1 August 1992, but which is fitted with an engine that was originally built either before 1 August 1992, or between 1 August 1992 and 1 August 1994 but is not listed in the emission standards book. Which emission test applies? The very stringent cat test which cannot be met unless you have a cat fitted, or the far less stringent, pre-August 1992, non-cat test, which should be child's play for any decently tuned engine?

Back came the answer: The less stringent test applies.

Just to make absolutely sure, we returned to the paragraph about modified engines and suggested that the last part should read: '. . . according to the age of the vehicle or the engine'. The Vehicle Inspectorate agreed we had a point. The date which applies refers to the age of the vehicle, or the age of the engine, whichever is older.

Does the converse apply? Suppose someone has a car, first used before 1 August 1992, and fits a rebuilt engine, modified or not, with a build code listed in the book, or which was built after 1 August



▶ *If you have rebuilt an older engine and want the pre-cat MoT test the examiner will check the engine build code. It is deep down under the exhaust, so pick it out in white paint so he can read it.*

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1994. Which emission test applies? The stringent cat test or the easy non-cat test? Answer? In this case the age of the vehicle is taken, and the non-cat test applies.

What determines the age of the vehicle? The code on the VIN plate. And what determines the age of the engine? The build code on the block. So, if you do not want a catalytic converter, and can show that your modified engine is built with a block dating before 1 August 1992, or between then and 1 August 1994, and the build code is not listed in the emissions book, you can forget about a cat and pass the MoT on the easy non-cat test.

Similarly, if you have a car on which the VIN plate says was 'first used' before 1 August 1992, and you fit a 1997 or whatever engine, it will still be tested to non-cat standards no matter what the engine build code is.

What are the chances of the Vehicle Inspectorate plugging this loophole? In our humble opinion, and after talking with them, pretty slim. Compared with the thousands of cars being tested, the number to which this loophole applies is very small. It just would not be worthwhile adding yet more complications to a regulation which is complicated enough to give MoT examiners plenty of headaches as it stands.

So there you have it. If you want to throw away the cat, or do not want to fork out hundreds of pounds for a new one, rebuild your CVH with a block dated before 1 August 1992. If you do not want to do that, look into fitting a rebuilt pre-1992 engine and sell your later engine to someone with a pre-1992 car.

There are a few other things you will have to take care of. For example, make sure the mixture is right, because you will have done away with cat back pressure. You might have to get the mixture checked on a rolling road, and have the chip reprogrammed. You will also have to find somewhere to fit the lambda sensor because your engine management box will still need a signal from it but that should not be too difficult though. Janspeed, for example, make several performance manifolds with a boss to take a lambda sensor. If it does not have one, they will fit a boss for you.

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Chapter 16

Tuning with chips

Talk to most people about changing the engine management chip on an EEC IV system and, ten to one, the first thing they will ask is 'how much extra power will it give?' Oh yes, it is possible to push up the power quite a lot by changing the chip, but, and it is a big but, if those who produce the new chip do not know properly what they are doing, you can end up with an engine that has such a peaky power curve that you cannot use top gear under about 50mph.

However, it is possible simply by plugging a modified chip into the engine management box to improve pick-up, response and acceleration plus a little bit more at the top end. Therefore we will look at the popular and easy way to fit fuel and ignition modifying chips like Star Chip and Superchip.

When Ford designed its EEC IV engine management system they had to strike a compromise, like all those who design cars for a mass market. The engine had to develop sufficient power so that the car didn't get a reputation for being a sluggard compared with the competition. It also had to develop power in the important mid-rev range so that it was nippy in town traffic and safe to pull out and overtake without needing a mile and a half to pass a big truck.

It had to do all this with a relatively light right foot because Mr, Mrs or Miss average motorist does not push the pedal to the metal to accelerate or overtake. They want reasonable acceleration at mid-throttle. We say reasonable because if the acceleration were too fierce, two things would be likely. First, the average shopping driver would not be able to judge it properly resulting in too many front-end shunts and consequently the insurance premium for the model would go sky high. Secondly, fierce acceleration burns fuel so the car would gain a reputation for being very thirsty in town traffic. Ford's sales people would not be very happy with either of these facts. Added to this, the engine has to pass constantly more stringent emission tests.

Fuel economy is, of course, a big selling feature so here, the designers devised quite a cunning little bit of programming. They arranged things so that the fuel supply to the injectors was cut off on the over-run. This meant that every time the driver lifted his or her foot, the fuel cut off and in give-and-take city and suburban motoring this can save a surprising amount of fuel. Next time you are out in commuting traffic count the number of times you lift your right foot in a mile, both to change gear and to slow down, and you will get an idea of the possible savings.

Then there are the Government 'standard' fuel economy figures that manufacturers have to provide with all new cars at a constant 56mph, 70mph and urban cycle. These are rolling-road test-bed figures and may not have a lot in

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common with actual driving on the road but they provide a comparison between models and the general buying public take a lot of notice of them, so standard chips are programmed to give the best looking results.

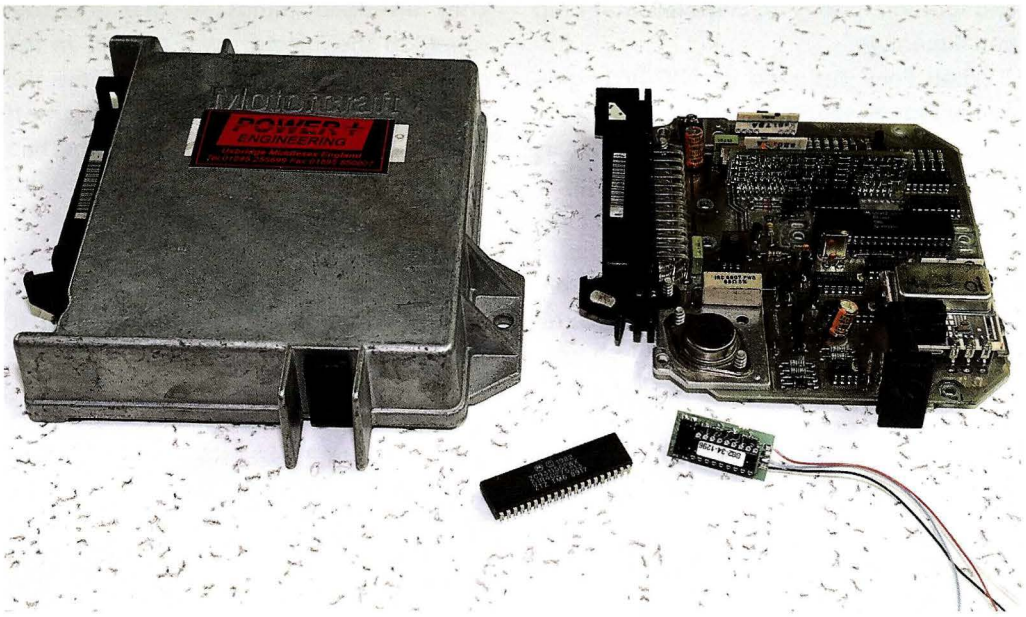
Top-end power, acceleration and economy are all conflicting requirements and, all in all, Ford did a pretty good job of balancing them out for the masses of drivers who buy their cars. But, for enthusiasts, people who like driving for the fun of it, things could be better. We want a quicker response when we accelerate, with no flat spots, and we want better torque in the mid- and upper mid-rev range.

If we can get more power at the top end as a bonus, so much the better but, let's face it, how often during an average day's driving do we get a chance to use 6,000 plus rpm in top? We would go for a hairy turbo with bags of boost, peaky cams, water injection, big exhaust and spend a lot of money on the engine build. Hang the fact that it would not tick over under 2,000rpm. It would be lots of fun, but we could want another car for everyday motoring where we'd swap some of the top end power for better performance and driveability lower down.

That is what you can do with chipping a non-turbo engine. Let's look at driveability chips for the EEC IV system. As by-the-way, EEC IV stands for electronic engine control model Four, colloquially known as 'eek-four' and is nothing to do with the old Common Market EEC, or EU as it now is.

Two very popular chips are the Superchip and the Star Chip which is made by BBR Engineering and supplied by Webcon. These two are not the only makers of this type of add-on chip; Collins Engineering among others also produce chips which are similar, although each maker has their own ideas about how the system should be modified, so it is a question of reading their claims and making up your mind.

All are simplicity itself to fit to any EEC IV system which includes many post-1984 Fiestas and Escorts. The engine management module on the EEC IV system has a plastic cover under which is a diagnostic edge connector socket that is covered with white grease to stop the terminals corroding. This grease is cleaned off with switch cleaner and then a Superchip, Star Chip or whatever make you fancy, is plugged into this socket. This fools the other electronics inside the box so that, instead of taking all their instructions from



◀ *This is a processor from Power Engineering for an Escort RS Turbo. It allows the ECU to function normally under higher boost pressures, can modify the ignition table and shut down the engine should the boost rise too high. It is expensive, but gives optimum performance and could save an expensive engine from blowing up.*

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the internal Ford chip they take some from the externally added chip.

Having said that, what difference does the plug-in chip make? The companies that make them obviously will not give away the fine details of how they modify the engine management system but, by and large, what they do is to modify the fuel injection and the ignition timing at different points in the rev range to smooth out the little hesitations and slight flat spots that have been programmed in for the best possible Government specific fuel consumption figures forced into the system.

This is not to say you get worse economy on the road, but economy when you are driving with a modified chip is much more dependent on the way you drive than with a standard Ford chip. Obviously, if you are going to use the better acceleration by slamming your foot to the floor, more fuel is going to be burnt although not as much as with a standard chip driven in the same way. If, however, you use the better response and acceleration more sensibly, you can improve overall fuel figures because this lets you be lighter footed for the same performance. Also, you should see better economy when motorway cruising.

Like all manufacturers, Ford improves its products, and the early EEC IV systems were noted for a bad flat spot when picking up from the over-run after the fuel had been shut off. For this reason, Superchip programmes its chip for these cars to do away with the over-run fuel cut-off. The later EEC IV systems are much better in this respect and it is possible to overcome what little flat spot remains without actually doing away with the fuel cut-off. For these later systems, neither Superchip nor Star Chip do away with it but smooth it out by modifying the fuel map of the system.

What about more top-end power? Yes, these chips will give it to you, anything around 8 to 10 per cent is claimed, although this is not their primary purpose which is to improve the mid-range torque and response.

Although these chips are easy to fit, you cannot just get hold of one, new or second-hand, and plug it in willy-nilly to any EEC IV system. If you look at the engine management boxes on these systems there is a part number, and this differs from model to model and sometimes from year to year on the same model where Ford has introduced variations in the programming.

When you buy the chip you have to quote the number on the engine management box. With a Superchip, the selling agent will then be able to programme the Superchip to suit that particular system. With Star Chip, the ordering is slightly different as not all Webcon agents are set up for programming so you have to quote the box part number to them and they will order the correctly programmed chip for you, which usually takes two to three days.

When any of these plug-in chips are removed, the EEC system reverts to standard but you have to be very wary if you are offered a chip second-hand, say from a crashed car or, for that matter, if you want to change your car. If the part number on the engine management box is different from that on your car, the chip will not be suitable. You might think you could buy both the chip and the engine management box from a crashed car and fit them as a pair to yours but this can still run into snags.

When we asked our local friendly Ford dealer about swapping EEC boxes we learned that, in most cases, engine management boxes with different part numbers are not directly interchangeable, even for the same model car. They can be fitted, and the engine will probably run, but the system will not be working properly. In a few cases, with early EEC IV systems, the box has been superseded by a

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later one and, in certain examples, this is a direct replacement but, in others, some of the sensors also have to be changed. Unless you can clear it with your Ford dealer that a different number engine management box is suitable for your car, the only safe way if you are offered a second-hand plug-in chip is to determine that it was programmed and fitted to an engine management box with the same part number as the one on your vehicle.

Until quite recently, people with pre-EEC systems and a K-Jetronic fuel injection system, XR3i, 1600i and the like, or with a carburettor, could not take advantage of a plug-in chip because the K-Jetronic fuel system is not electronic and the 'black box', or blue box in most cases, (the one behind the dash that is a swine to get at unless you take the dash off), controls only the ignition and, in any case, it does not have a plug-in diagnostic port.

However, although you cannot alter the fuel injection with an added chip, you can now improve the ignition mapping because Superchip has brought out its Ikon Race programmable ignition control chip which connects directly to the coil. There are four versions, two for engines with a distributor and two for distributorless systems, so there is a chip to suit just about any car with a negative earth ignition system.

They can be programmed with suitable software and an adaptor on an ordinary PC, so that a Superchip dealer can programme it to suit your engine. If you are into computers and home tuning, and want to sport out an extra £60, you can buy the programming software plus an adaptor interface to plug into a PC, preferably a lap-top so you can work at the car instead of dashing in and out to and from the computer. You can alter the programming on these chips as many times as you like, and they will swap from one car to another provided the two cars have similar ignition systems.

So does plug-in chip tuning mean that free-flow filters, performance exhausts, performance camshafts and the rest are on the way out? Not a bit. What the chips do is to bring the engine up to a better performance in its standard mechanical tune. If you alter this in the traditional way, tell the person who is programming the chip and they will be able to give you a smoother response and better driveability with almost any stage of mechanical tune.

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Chapter 17

Can you run older CVH engines on unleaded fuel?

We can moan and protest all we like, but the fact remains that four-star leaded petrol has disappeared from our garage forecourts. Our masters in Brussels decreed that from 1 January 2000, the ban on selling leaded petrol applied in all EU countries, and that includes the UK.

But why should some engines need leaded petrol? The answer goes right back to the 1920s when petrol was very crude compared with today, when an octane rating of 60 to 65 was common and, to cope with it, engines had a compression ratio around 5 or 5.5 to 1. Ignition was not very often advanced beyond top dead centre. They peaked at about 1,800 to 2,000rpm, were also horribly inefficient from a fuel economy point of view even though speeds were low, and the power to capacity ratio was pathetic by today's standards. Annual mileages were usually very low, in the order of 3,000 to 4,000 miles, and if the engine lasted for four years before a complete overhaul everyone was happy.

Then, in the late 1920s and early 1930s, engine designers started improving the breathing and pushing up the compression ratio to around 6.3 to 1 but the big trouble was pinking. Cars usually had an advance and retard lever and drivers were expected to retard the ignition every time they came to a hill.

The answer from the petrol companies was to raise the octane number of their petrol and they found that the easiest and most effective way to do this was to add compounds of lead, usually tetra-ethyl lead. There was even a petrol branded as Tetra-Ethyl which claimed to banish pinking. There was also an unexpected bonus from adding lead compounds. Previously, engines had to be taken apart about every 10,000 miles or so to have the valves reseated and ground in. What was happening was that with the higher combustion temperatures, the valves were actually welding themselves to the soft cast iron seats momentarily each time they closed. This raised pips and dug craters which made the valves leak so the hot exhaust flame did even more damage. A complete engine overhaul at 20,000 miles, often with valve seat inserts, was usual.

With the addition of lead compounds to petrol it was found that valve and valve seat wear was reduced quite dramatically and, with improved engine oils, engine life between overhauls was considerably extended. It was found that when they burned in the hot exhaust flame, the lead compounds deposited a protective layer on the valve faces and valve seats which practically eliminated the welding effect. There were of course far fewer cars on the road than today, and no-one even thought about harmful exhaust emissions other than carbon monoxide which could kill in an enclosed space.

Research during the war on aircraft engines brought even higher octane petrol so compression ratios could continue to

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rise and there things more or less stayed until, a few years ago. Then, environmentalists showed that exhaust emissions in general and those from leaded petrol in particular, were harmful and had an accumulative effect with increasing traffic density. Legislation was forced through to compel all new cars to have a catalytic converter in the exhaust system to reduce the toxic effect of emissions. Catalytic converters cannot be used with leaded petrol because the lead compounds destroy the catalyst, so sales of leaded petrol would have dropped anyway as older cars were taken off the road, but the environmentalists could not wait for this to happen so leaded petrol was forced out of existence by legislation.

Additives, usually complicated organic compounds, which take the place of lead as an octane booster, do nothing for the valves, so engine makers have had to put in hardened exhaust valve seats and use better quality steel for the valves.

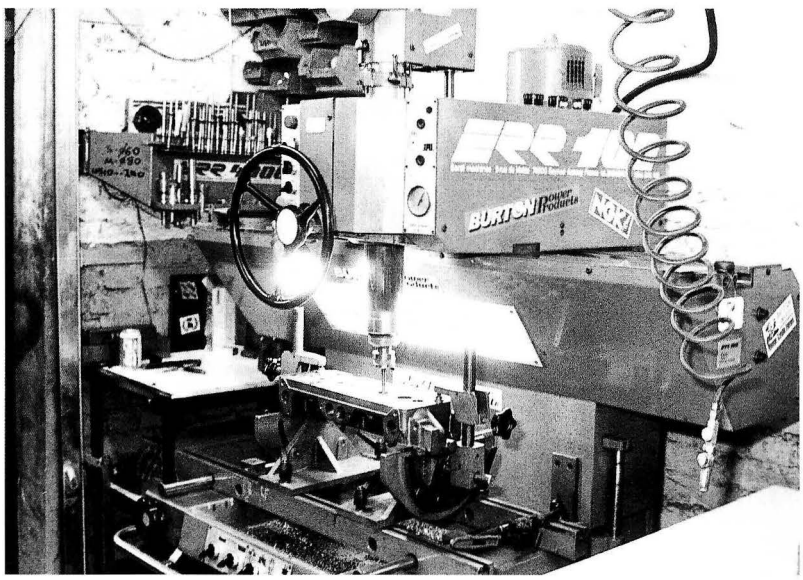
This has left owners of older engines designed to run on leaded petrol right back in the position of the early 1930s, except that with higher engine speeds and higher compression ratios the burning away of exhaust valve heads and pocketing of the seats was very much accelerated. Running for 2,000 to 3,000 miles on unleaded petrol can be enough to ruin the cylinder head.

No CVH engines built before the mid-1980s are suitable for running all the time on unleaded petrol. The first thing you notice if you try it is a fall off in power because the valves are not seating properly, followed by spitting back when you accelerate and, before long, a very sick engine.

It is as yet, too early to say from experience whether lead replacement petrol (LRP) which has taken the place of four-star, or the various additives which can be mixed in with unleaded petrol, really protect the valves and seats in highly tuned engines. Our view is that if you are rebuilding an older engine, or you have an older head where a lot of money has been spent on gas-flowing, have the head converted to run on unleaded.

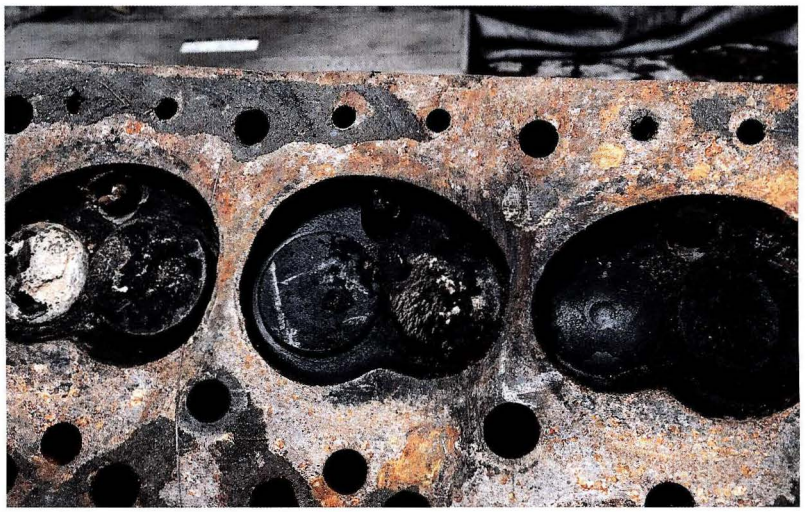
Converting a head to run on unleaded fuel goes right back to the early days of engine overhaul and involves having the old exhaust seat faces machined away and hardened inserts put in their place. With these, and possibly better quality exhaust valves, you will be set up to run happily on unleaded petrol. Inlet valves do not mind whether there is lead in the petrol or not, the incoming air and fuel mixture helps to keep them cool, and they do not have searing hot exhaust gases to cope with while they are off their seats.

To find out what is involved in a head conversion, we went along to Burton Power Products, in Ilford, London. Our first question was whether any CVH head can be converted or if there are exceptions. The answer was yes, almost any head can be converted, with a couple of provisos. One is that the valve seats have not been so badly damaged by running on unleaded petrol that the head has become scrap. The second is that the valve guides should be in pretty good condition. The guides are used to locate the cutters for machining and, if



▼ *At Burton Power Products, the cylinder head is mounted on the bed of this machine where the cutting head floats on air and the cutter is located by a mandrel in the exhaust valve guide.*

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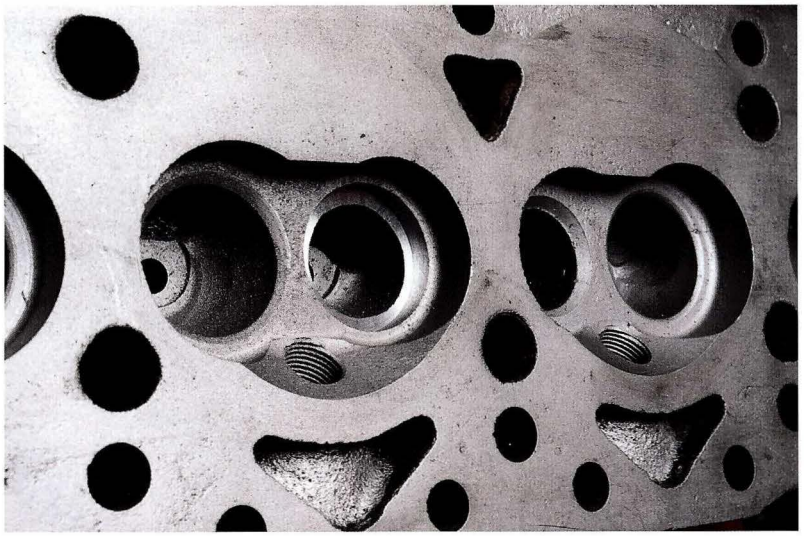


▲ *This is what can happen if you run an older engine on unleaded petrol. The exhaust valves start to pocket and, like the one in the centre, burn away, usually starting next to the sparking plug.*

▼ *Here the head has been cleaned and the exhaust valve seat machined back to accept a hardened steel insert.*

these are sloppy, the machining will not be true. Worn guides need to be machined out and new guides or inserts pressed in their place before any machining for seat inserts.

After cleaning and attending to the guides as necessary, Burton mounts the head on the bed of a machine where the cutting head actually floats on air so that the mandrel in the valve guide positions the cutter absolutely accurately. Other companies use a cutting jig that bolts to the head itself. The old exhaust valve seat is machined away to very close tolerances, and the valve insert is then frozen in dry ice to shrink it before it is hammered into place. When it warms up, it's about a 0.005in interference fit, so it does not move even when the head gets hot. The inserts themselves are made from high quality material which will withstand pocketing and pitting without the protection of lead. After the insert is in place, the valve head diameter is measured and the insert is cut to the angle recommended by Ford to give a perfect seat.



You may be wondering why we said the inserts are hammered in rather than pressed in but they are not just welted in willy-nilly with a big hammer. A special size mandrel is located in the valve guide and the insert is then hammered down by hand so that the person doing it can judge by the feel of the hammer blows exactly when the insert goes solid and sits on the bottom of the machining in the head. With a press, it would be so easy to put too much or too little pressure on, neither of which would seat the insert properly.

Except, possibly, for very highly tuned engines running on unleaded with octane boosters, only the exhaust valves and seats need attention to use unleaded petrol because they run so much hotter. The inlet valves and seats last OK.

Even with a conversion, you are still faced with the problem of octane rating. Already, 98 octane super unleaded is difficult to find at filling stations, and to use 95 octane premium unleaded petrol in an engine with a compression ratio suited to 97 octane four-star you will have to retard the ignition by about 3 to 4 degrees to prevent detonation. It will give a loss of power, typically between 3 and 5bhp at peak power, probably a little less lower down the rev scale.

If running an uprated turbo, or a highly-tuned non-turbo engine with special high compression pistons, you may have to use some form of octane booster additive, but the specialist tuners are the best people to ask about this as it will vary from engine to engine depending on the state of tune and

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▶ *The insert is shrunk in a box of dry ice before fitting it to the head.*



the shape of the ignition advance curve.

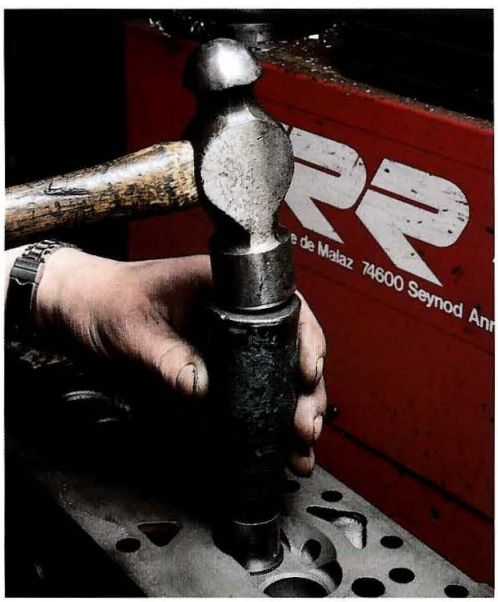
Large numbers of cars, including many Fords, made from the mid-1980s onwards had engines with hardened exhaust valve seats preparing for 1992 when the compulsory introduction of catalytic converters meant that unleaded petrol had to be used. The handbooks for these cars recommended they use four-star fuel because the ignition timing was set for 97 octane. They will run fine on 98 octane super unleaded, and all that is required to run on 95 octane unleaded is to retard the ignition timing three or four degrees.

Realisation of this cut the demand for LRP considerably and, when you add the large number of four-star burning cars that found their way to the breakers in 1999, the demand for LRP could well drop. If it drops below what filling station managers regard as economic, they will not stock it. The pour-in additives will be available but, if demand for those drops as well, the number of filling stations that stock them will get fewer and fewer until, eventually, they may be available only at specialists.

We said earlier that some older CVH engines made before cats became mandatory already have hardened valve seats and can run on unleaded. Back in August 1989, Ford issued a *Technical Service Bulletin* listing those engines which have hardened valve seats.

All CVH engines made after January 1985 have hardened seats and the heads are not code marked. Some built before then have them, and these heads are identified by the letters LPG stamped on a boss on the cylinder head just above No. 1 exhaust port. CVH engines built before January 1985 which do not have the head code marked LPG are not suitable for running on straight unleaded petrol.

▼ *Inserts are driven into place with a mandrel which locates in the valve guide.*



▼ *Before machining, the cutter, which is shaped to give the correct Ford multi-angle seat, is set to the right diameter for each valve.*



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Chapter 18

Dismantling the engine

We will assume you have taken the engine out of the car and stripped off the accessories such as distributor, alternator and bracket, oil filter and, in the case of fuel injected engines, the oil cooler behind the filter. This is held by a threaded sleeve and a threaded bush, so make sure you keep both of them safe. We will also assume you have drained out the old engine oil and that you are left with just the basic engine. It is a moot point whether you leave the manifolds on at this stage or take them off. Most manuals tell you to leave them on so they give you something to grip to break the seal when you lift off the cylinder head, but if you buy a second-hand engine for reconditioning it is unlikely that the manifolds will be on, so we assume they have been taken off.

If you have an engine stand with a CVH adaptor plate then by all means use it because it makes handling the engine much easier, but if not, don't worry. It is perfectly straightforward to strip and rebuild a CVH on the bench, as we did for our photographs, or even on an upturned sturdy wooden box.

Before you start pulling things apart, give the engine a good clean down with paraffin or white spirit. You will still end up with plenty of oil and mess on the bench from the old oil inside, but there is no reason to add to this with oil-caked road grit from the outside.

The actual order of taking the engine apart is not critical, but most people start at the front and top end. The Ford book tells you to start by undoing the bolt holding the front crankshaft pulley, then take off the timing belt covers, then the tensioner and belt. If the sparking plugs are still in place you might get enough resistance against compression to undo the front pulley bolt, but it is tightened to between 100 and 115Nm (74 to 85lb/ft) and after several years the 'crack' undoing torque can be considerably higher. Usually, a sharp jerk or thump with a piece of pipe as an extension on your long socket bar will jar it free but, if not, you might have to wedge the flywheel ring gear teeth with a bar to stop the crankshaft turning.

After you take off the rocker cover you can either undo the ten cylinder head bolts and lift off the head complete with the camshaft, followers and rockers to be dealt with later, or you can take out the rockers, camshaft and followers while the head is on the engine. The procedure is the same in either case, but we prefer to put the complete head to one side, still assembled, to be dealt with later. There is less chance of getting rockers, spacers, valves and other parts either mixed up or lost.

To remove the head, whether or not you still have the camshaft and rockers in place, undo the cylinder head bolts in the reverse order of tightening (see diagram). To lessen the chance of head warping you should crack each bolt free and then go round again loosening them in sequence.

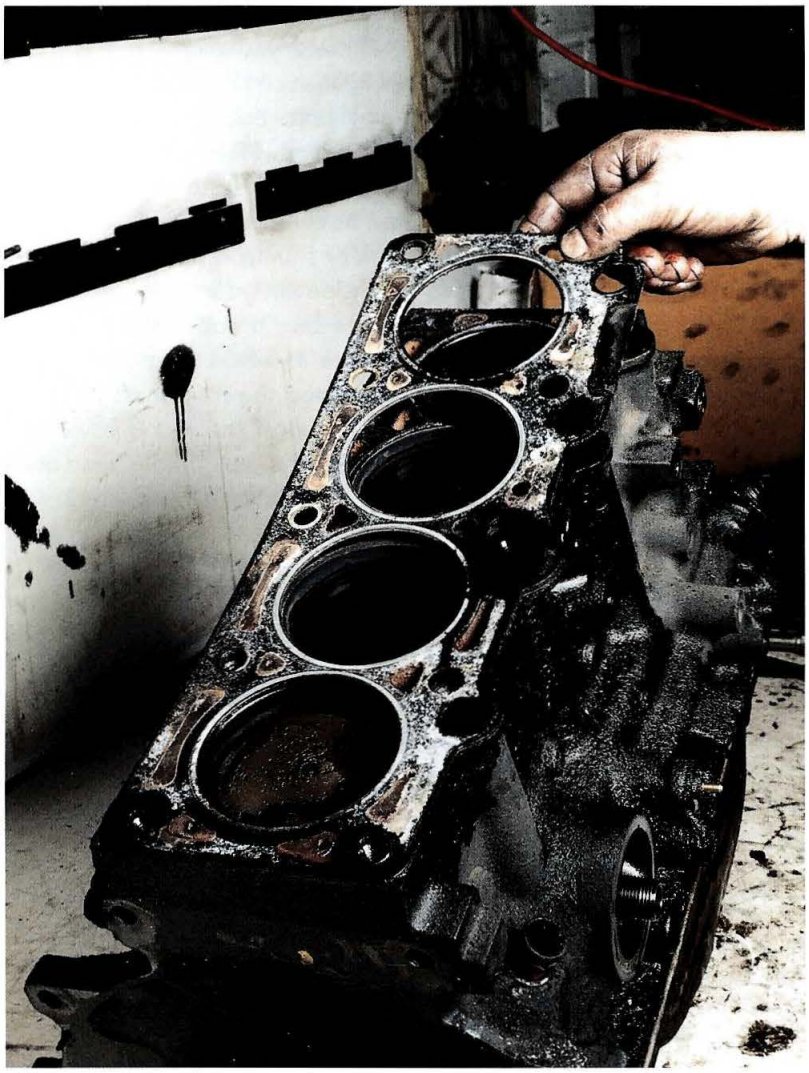
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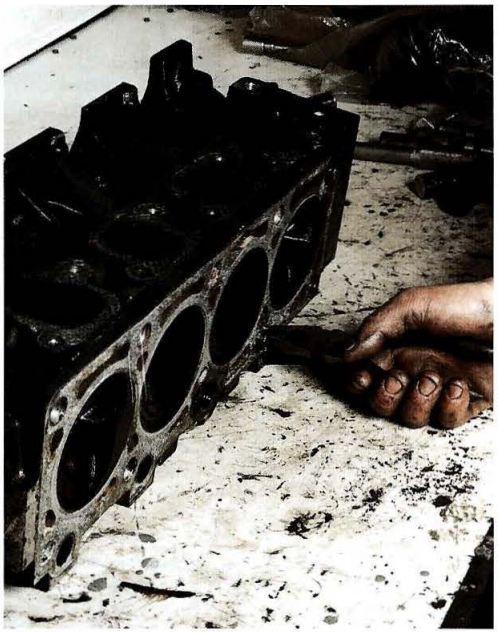


▲ *You will need a long bar handle as well as an extension to loosen the head bolts.*



▲ *You can't tap the head sideways to break the seal because of the dowels. It has to be lifted.*

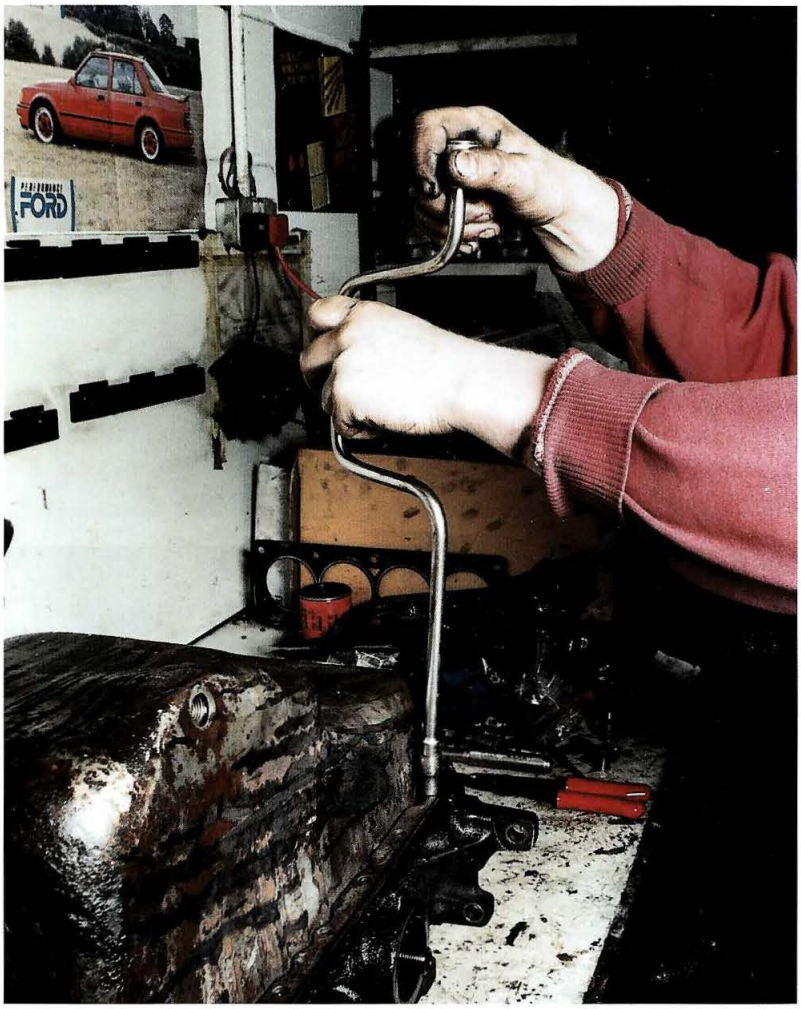




▲ *Pull the head-locating dowels out with a large pair of pliers.*

◀ *With the head taken off and put safely to one side, examine the head gasket before you throw it away, to look for any signs of blowing or water leakage.*

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▲ *If you have taken out the head-locating dowels you can stand the block upside down to undo the sump.*

There is no need to keep the old cylinder head bolts for using again because, as explained earlier in Chapter 14, they are special 'stretch' bolts. Therefore, always use new ones and, although you can buy cheaper 'pattern' bolts we always recommend using genuine Ford items.

Unlike some engines with cylinder head bolts, you cannot tap the head of a CVH engine sideways to break the seal once the bolts are out because it is located on hollow dowels. This is why some people like to leave the manifolds on until after the head is off the block as they give you something to grip. Usually a few sharp thumps with a wooden or hide-faced hammer will jar the head free but, if it is really stubborn and refuses to budge, refit the manifolds as a last resort.

The next stage is to undo the clutch and flywheel bolts. The ring gear will probably have to be wedged with a large screwdriver or tyre lever to stop the crankshaft turning but even then, you may have difficulty because the flywheel bolts are really tight and sealed with locking compound. Sometimes a sharp jerk on the handle of your long socket bar will free them but, failing this, you may have to



▶ *Lift the sump off and put it aside for cleaning.*

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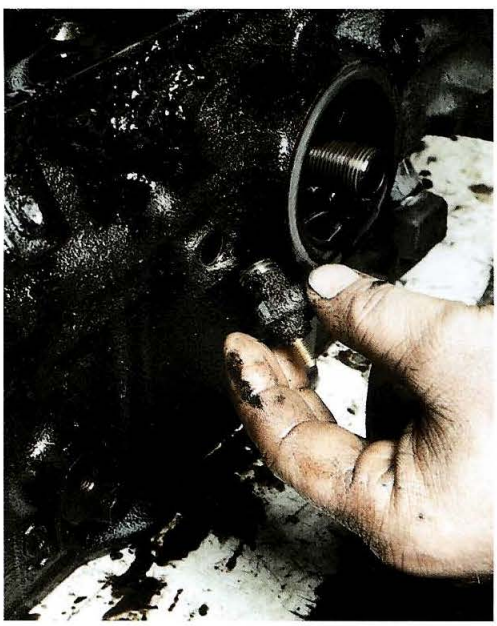
wait until you take the sump off and wedge a block of wood inside to stop the crankshaft turning.

With the flywheel off you can remove the rear oil seal carrier and dig the oil seal out. Unbolt and take off the water pump, and then pull off the crankshaft belt pulley. There is a special puller for doing this, but usually it can be removed by levering round it with two large screwdrivers or similar levers. If not, most two-legged proprietary pullers will fit. Unbolt and take off the oil pump complete with its intake after unbolting the intake from the cylinder block. Undo the oil pressure transmitter.

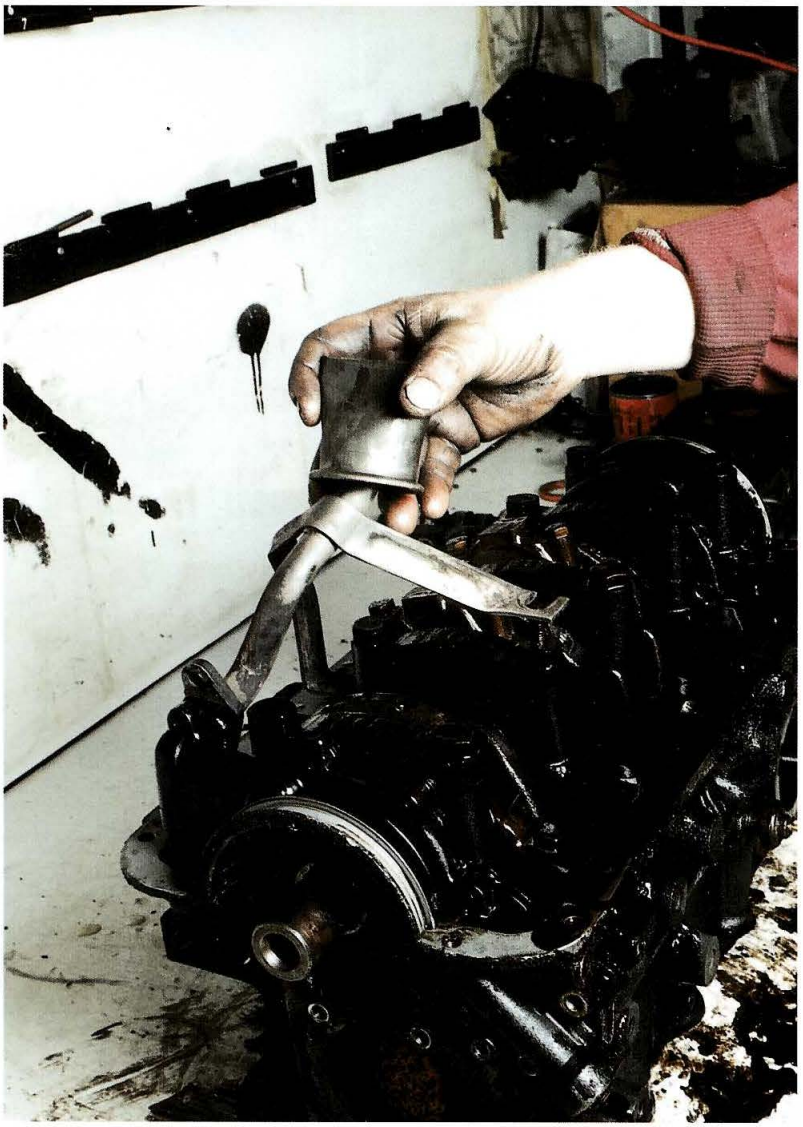
Take out the two hollow dowels which locate the head. They may be tight but they will come out if you grip them with a Mole wrench and twist. This will damage them, but new dowels are cheap enough and must be removed in order to clean the top face of the block properly.

If you are fussy turn the engine on its side and support it on two lengths of wood to save sludge and other muck running up inside the crankcase when you remove the sump, but it is easier to turn it upside down over a drip tray, or even clean the sludge off the bench afterwards. If you have it on an engine stand, put a drip tray underneath to prevent any sludge and old oil going over the garage floor. If someone has felt the need to use a jointing compound on the gasket the sump can be surprisingly tight after you take the bolts out, but a couple of blows with a nylon-faced mallet will usually free it. If not, use a screwdriver to lever them apart but, if you do, check the face of the sump

▼ *It is a good plan at this stage to take out the oil pressure switch so that you can later squirt white spirit through the gallery to clean out the sludge.*



▼ *Unbolt and take out the oil pick-up pipe.*

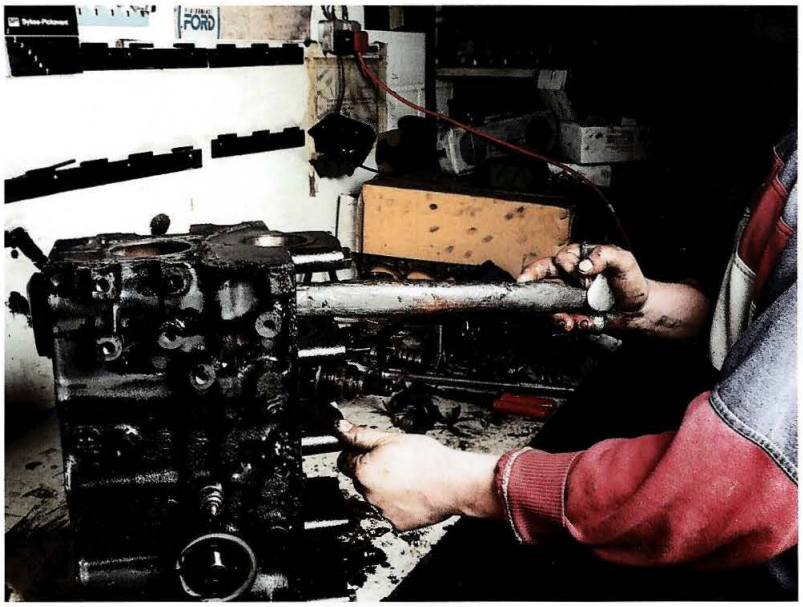


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▲ *Turn the crank to get at each con-rod and undo the cap bolts.*

▶ *If the con-rod caps do not want to come off give them a sharp tap sideways with a hammer handle or soft-faced mallet.*



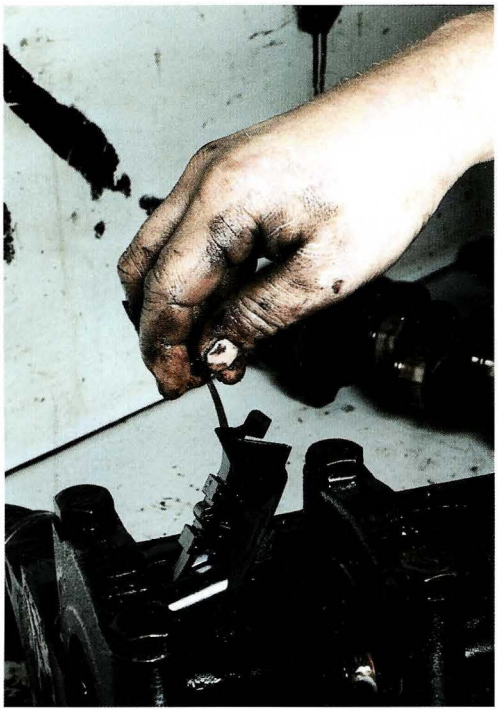
▲ *Turn the block on its end and push the con-rods through with the handle of your hammer. You may have to give them a tap to get the rings past any ridge in the bores.*

▶ *Once the rings are through you can pull the piston and con-rod out from the engine.*





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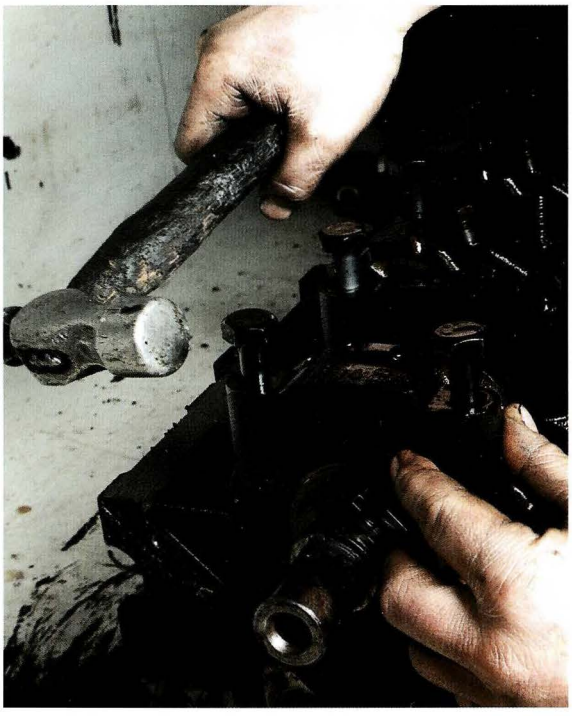


▲ *You may find that the front oil seal housing and pump are very tight even after you unbolt them. Wriggling, plus a few gentle taps from a hammer, will free them.*

◀ *Lift out the ventilation baffle which just clips into place.*

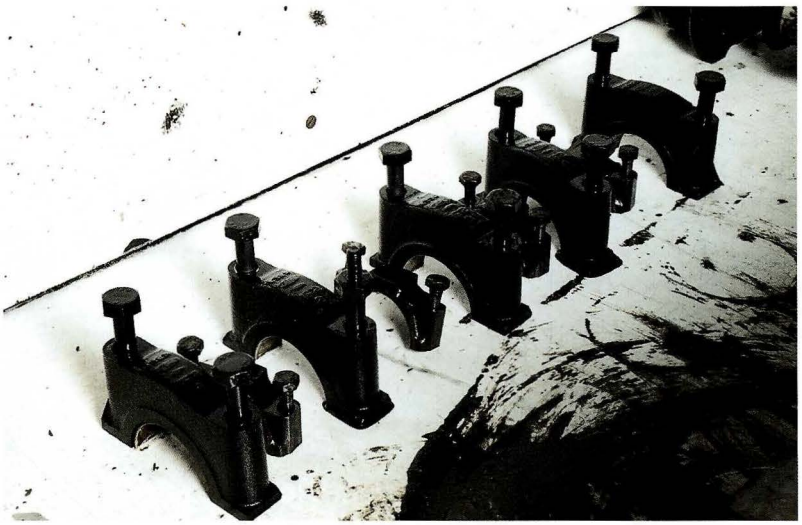


▲ *Once the front cover is free it will lift away easily.*

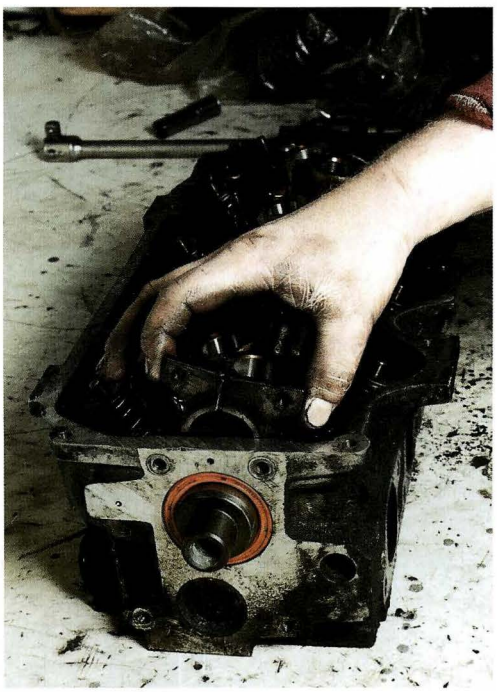


▲ *You may also find that the main bearing caps do not want to budge, even after tapping with a nylon-faced mallet. If so, give a few gentle taps sideways with a hammer but don't hit hard and be careful not to damage them.*

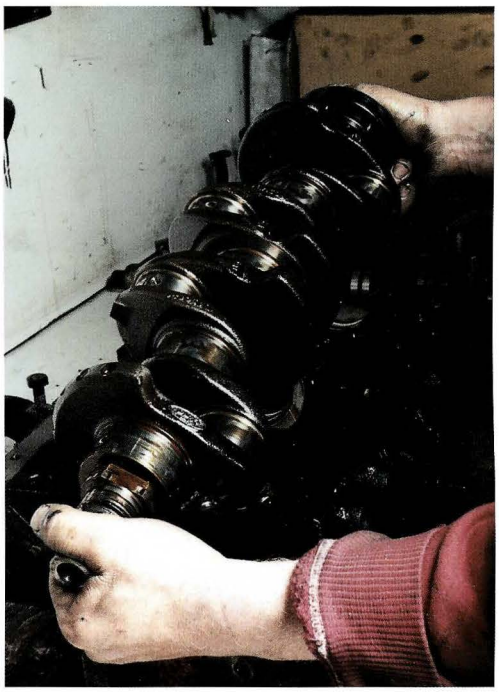
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▲ *Keep all the bearing caps in order until you can check their markings to make sure where they fit.*



▶ *Turning to the head, unbolt and lift out the camshaft thrust plate.*



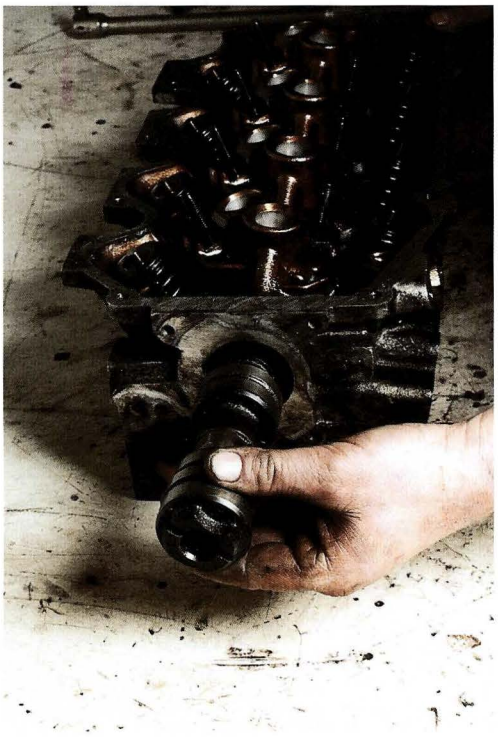
▲ *The last job on the bottom end is to lift out the crankshaft.*

afterwards to make sure neither you, nor the person before you, has distorted the bolting flange. If you find distortion, make a note to dress the flange up again with a hammer and dolly.

Before you take the con-rods and pistons out, run a scraper around the top edge of the bores to remove the ridge of carbon. It makes it easier for the piston rings to come out of the bores. Now lay the engine on its side and, dealing with one con-rod at a time, undo the big-end bolts and take off the end cap. You may have to give it a light tap with a hide-faced hammer to free it. Then push the rod and piston up the bore, giving it a tap with the handle of your hammer if necessary, to get the rings past the ridge at the top of the bore. Refit the cap to the rod before you lay the rod and piston aside, and check the identification numbers on the sides of the cap and rod to check you have the cap on the right way round. They should be numbered 1, 2, 3 and 4. There is no need to save all the bearing shells because you will be fitting new ones but, if the crankshaft is not being reground, save one pair of shells as a check as to whether they are standard or undersize, if the shaft has already been reground. If they are undersize, the degree of reduction will usually be marked on the backs of the shells but you may just come across the odd set that aren't, so by saving one pair the markings can be used to identify them when you buy the new ones.

Once the con-rods and pistons are out you can turn the engine upside down

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▲ *The camshaft comes out from the back of the head.*

again to undo the main bearing caps. Before taking the main bearing caps off, note that they are numbered and also have an arrow cast on them pointing towards the front (timing belt end) of the engine. The main bearing cap bolts are very tight and will probably come undone with a loud crack, but don't worry about it, that is normal. With the caps off you can lift the crankshaft out and put it somewhere safe where it is not going to topple over and get damaged. Take out the main bearing shells, again saving one pair to check whether the shaft is standard or undersize, and remove the two half-thrust washers. Lift out the engine ventilation baffle with its retaining spring, and the bottom end of the engine is now in pieces.

Turning back to the head assembly, start dismantling by taking off the eight rockers. If not badly worn they can be used again, but only if you keep all the parts – top guide, rocker and bottom spacer plate – in order. The easiest way to do this is to use



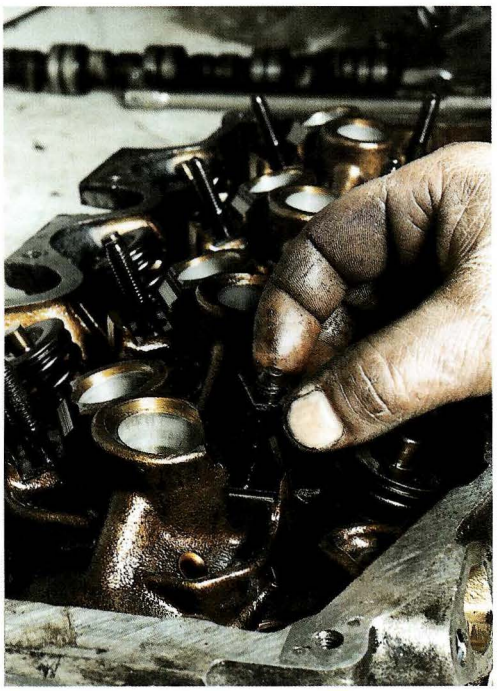
▲ *Ford has a special tool for compressing the valve springs, but most deep-throated compressors will suit.*



◀ *This is a very handy proprietary tool for pulling off Ford valve stem oil seals. If you do not have one, you can do the job with a screwdriver, but it is awkward.*

two lengths of fairly heavy wire and thread the guides, rockers and plates from the inlet side on one and those from the exhaust side on the other. Bend the ends of the wire to stop them falling off and label the wires 'Inlet Front' and 'Exhaust Front'. Use tie-on labels as they stay in place better than stick-ons. Then lift out the hydraulic cam followers, or tappets as some people still call them, and again keep

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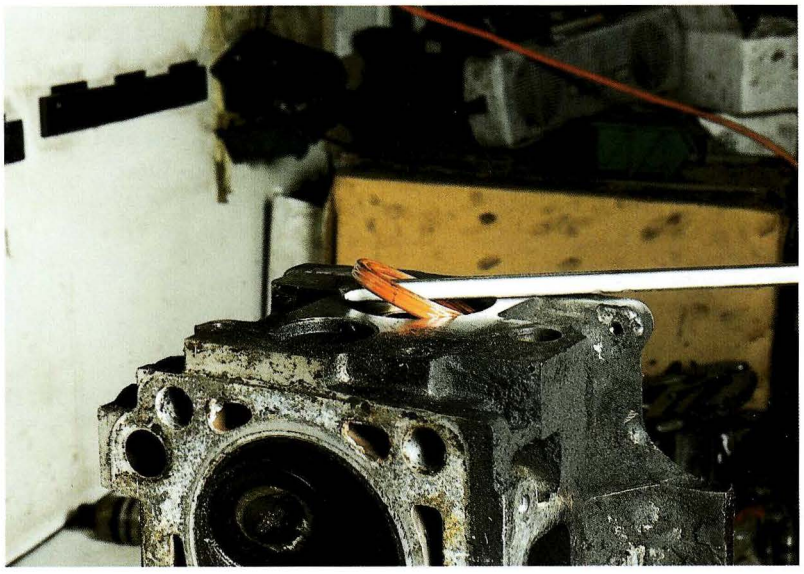


▶ *After unbolting the rockers take out and save these small spacer plates.*

these in order if you want to use them again. It may be found that one or two seem as if they do no want to come out but all you can do is keep tugging until they do. The reason they feel tight, as if something is in the way, is that after a high mileage, and with a worn camshaft, the bottom ends of the followers can become burred over slightly. There is nothing that can be done about it because you cannot get at the bottom ends to take any burrs off, but it is a pretty sure sign that you need new followers. If you want to retain them, keep them in order. You cannot thread these onto anything, so put them in two trays with one end marked 'front'. Personally, we prefer to renew them, even if they do not have burrs on them as they tend to become 'lazy' after high mileages.

Wedge the camshaft drive pulley with a large screwdriver through one of its holes while you undo the bolt to lift it off. Then undo the camshaft thrust plate after which you can carefully draw the camshaft out from the back (distributor) end of the head. Take care that you do not scrape and damage the camshaft bearings when you draw the shaft out. The bearings are machined directly into the head and, if they are damaged, the only answer is another head.

Ford has a special valve spring compressor that fits on the top of the head, but you can use an ordinary G-cramp type of spring compressor provided it has a reasonably deep throat. Keep the valves in order using holes bored in a suitable length of wood, but do not bother about the valve springs as it is false economy to try to use them again whatever some books may say about comparing poundages with new springs.



◀ *Prise out the old oil seals with a screwdriver and the head is then ready for cleaning.*

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Chapter 19

Examining the parts

You cannot examine parts for wear while they are covered in oil and muck, so the first job is to clean everything. The lazy way to do it and, we must admit, the easiest and least messy answer, is to take all the parts to an engineering firm and get them cleaned in a power degreaser, but you can do the job at home just as well if you take time.

The best method is to use two large baths. Deep metal baths are best if you can find them, but a couple of baby's plastic baths make good and cheap substitutes. Proprietary degreaser is good, but expensive unless you buy it in 40-gallon drums, and the fumes tend to get down your throat, so we use about five gallons of white spirit or turps substitute which is surprisingly cheap if you get it from a builder's merchant or household paint warehouse. Even 5-litre bottles from DIY supermarkets are reasonably cheap. White spirit has two advantages over paraffin for cleaning engine parts. It dries fairly quickly and it does not promote rust whereas paraffin takes ages to dry and does promote rust. Even so, it is best to wipe a thin film of clean engine oil over the parts once they are dry, and keep them covered so that dust does not settle on them.

Put a couple of gallons or so in each bath, one as a soak and one as a rinse, put all the small parts in the soak bath and leave them overnight. Then clean them with a stiff bristle brush and transfer them to the rinse bath. Give them another scrub in this and you will be surprised how clean they become. Dry them and put them somewhere safe where they can be covered over with a sheet to save dust and grit settling on them while you clean up the garage.

Most of the parts will need no more than scrubbing in the white spirit but some, the block, head and crankshaft, will call for special attention. To make sure the oilways are clean and clear of deposited sludge you need a large syringe. A garden syringe with a 'squirt' rather then a 'spray' nozzle is ideal. The oilways on the head and crankshaft are open, so squirt a syringe full of white spirit through them in both the soak and rinse baths. Quite a lot of black oily sludge will come out, particularly if the engine has seen a high mileage.

Before starting on the block with white spirit, take the core plugs out of the water jacket and clean out as much of the rusty sludge as possible. Poking and scraping with a screwdriver and long pieces of stiff wire will shift much of it and you can hose through afterwards. A power washer is ideal, but a garden hose with a high pressure nozzle will flush it out pretty well.

Some people make quite a fuss over digging out Ford core plugs which look like small tin lids. When you know how, taking them out is very simple. Put a flat-headed punch inside the core plug at one side and give it a sharp blow with a fairly heavy hammer. The core plug will spin

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▲ *Before you clean the block take out the core plugs. Give the plug a sharp blow at one side with a drift and hammer.*

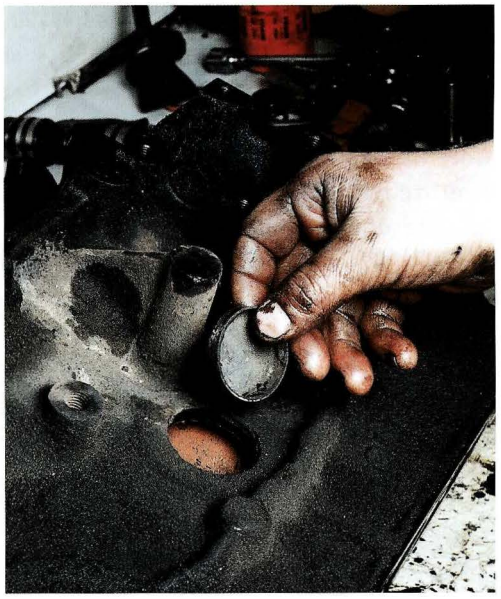
round in its hole and can then be levered out with a pair of gas pliers or a Mole wrench.

The oilways and oil galleries through the block have screwed caps sealing the ends, and although most of the old oil and sludge can be removed by squirting through the gallery where the oil pump fits, and through the feeds to the main bearings and up to the head, most serious tuners take the plugs out of the galleries to make a thorough job of it. They then fit new plugs afterwards with just a smear of jointing compound – making sure that none gets into the galleries.

When everything is clean, and the bench is also clean and dry, you can start



▲ *The core plug will spin round in its housing so you can get your drift under the rim.*



▲ *Just a sharp pull and the old core plug will lift out easily.*

examining the parts to see what has to be renewed or reconditioned.

First, the block. We will assume there is not any physical damage to this so the things to check are the bores and the top

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face. The block is a fairly substantial lump of iron and it is unlikely that the top face will be warped, but check it with a straightedge just in case. How much warping is allowable? The ideal answer is none, and if you are tuning the engine, especially one that is turbocharged, that should be your limit. However, if you are rebuilding the engine for a new lease of life and not completely reconditioning to new standards, and you can just see a suspicion of daylight under the straightedge, you should be OK. If, however, you can get a 0.005in feeler gauge under the straightedge, the block should be refaced, but only by the barest minimum to produce a flat surface. Remember you may have to allow for refacing the head as well which we will come to shortly.

Next, the bores. The first thing to check is whether or not the engine has already been rebored larger than standard. Sometimes, if it has, you may find markings on the top of the piston such as +0.29, +0.50, +10, +20 and so on, the actual markings depending on the make of the piston. Occasionally the nominal standard bore is shown in millimetres and the oversize in thousandths of an inch so, on a 1.6-litre engine you may have a peculiar mixture of 79.96mm plus 0.020in oversize, usually referred to as standard plus 20 thou. Sometimes, however, oversize pistons are not marked so it is a wise precaution to check them, or have them checked, with a micrometer or vernier calliper so you know what you are dealing with.

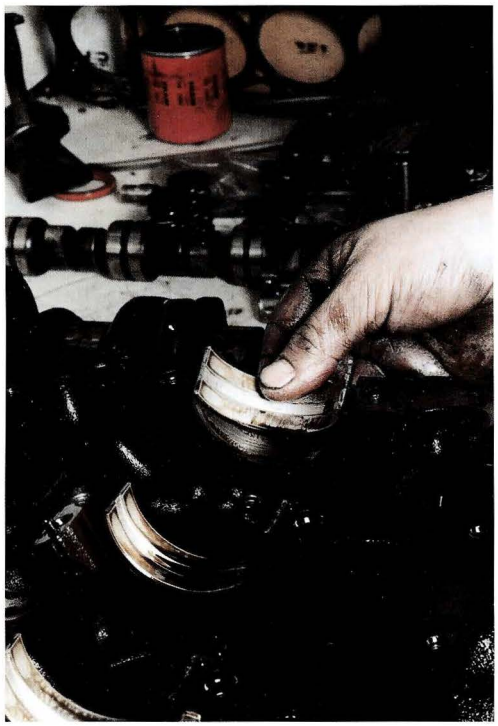
You may find yourself in the unfortunate position of having an engine that has already been rebored to its maximum recommended oversize. If the bores are in good enough condition to get away with just a hone and new rings, fine. If, however, they are too badly worn, or if you are going for high power and need an as-new bore condition, the only answer is to have the block linered back to standard or find another block that will take a rebore. In this case it is best to consult one of the specialist tuning firms. They sometimes offer a part exchange scheme on blocks that have already been bored out to their maximum.

Assuming, however, that the block will take another rebore if necessary, continue with your examination. There will undoubtedly be a ridge at the top of the bores and a ring of carbon as well. Clean the carbon off with fine wet-and-dry rubbing paper so you can check the actual wear. Here again you have to differentiate between reconditioning to new and rebuilding for, say, another 50,000 to 60,000 miles general motoring. Few people

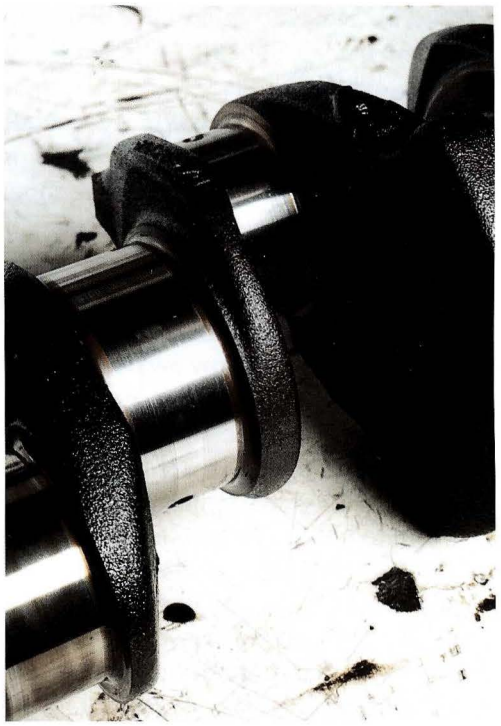


▼ *If you can use the services of a local engineering works they can clean the main components for you at a reasonable cost in their big tanks.*

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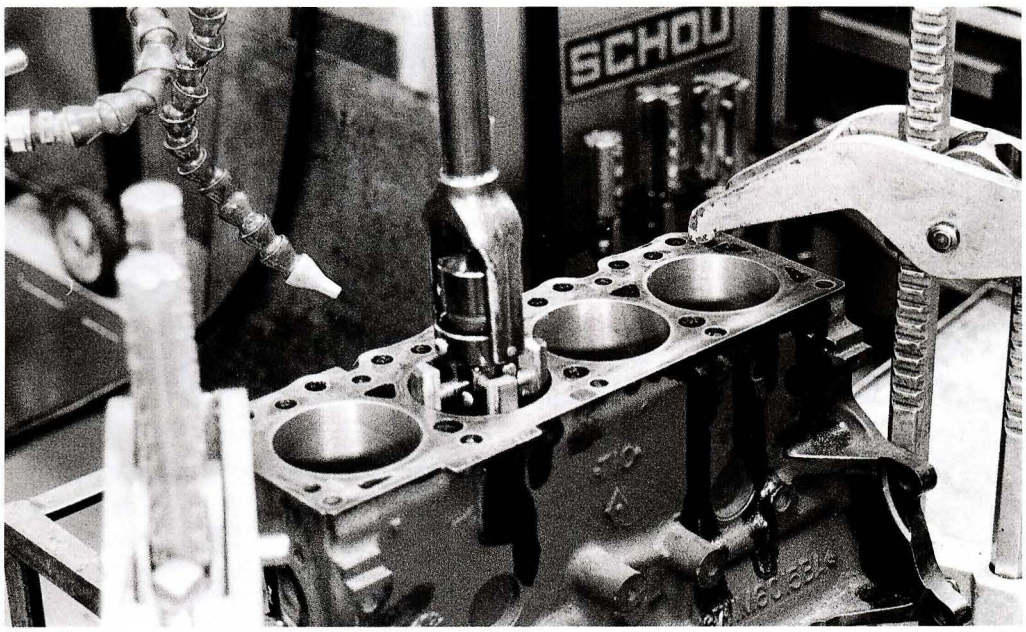
▶ *The state of the old bearing shells will be a good guide to the condition of the crankshaft. These shells are not badly worn, but have gone too far to take much more in the way of extra power.*



▶▶ *Examine the crank journals for scores and ridges and if you find any it is time to have the shaft reground.*

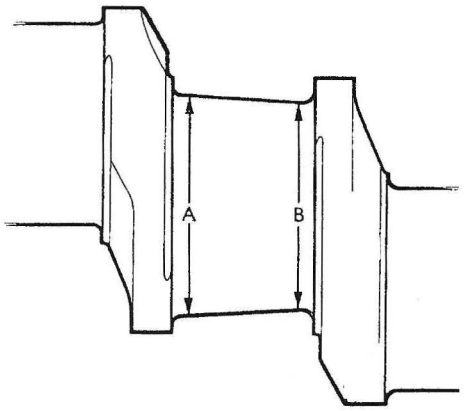
have internal micrometers at home for checking bores, so it is dealt with here by rule of thumb. For an engine that is not going to be tuned beyond, say, a mild to fast road camshaft and a free-flow air filter, you will probably be OK if you can see rather than feel the ridge, but if it catches really hard on your fingernail then think seriously about reboring. If reconditioning to new standards or tuning seriously, then we would say rebore as a matter of course.

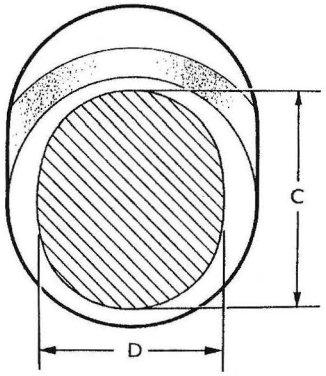
If you decide not to rebore, then it is essential to hone the bores to break the mirror-like glaze. If you don't, your new piston rings will not bed in and you will



▶ *Even if you don't have the block rebored you will have to hone it to break the hard glaze. This block is being honed on a machine but you can get bore hones to use in an electric drill that are quite reasonably priced.*

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◀ *If you have a micrometer or accurate vernier gauge you can test the journals for taper and ovality. Taper, on the left, is the difference between A and B. Ovality is the difference between C and D.*

burn oil. We have known people break the glaze the hard way with wet-and-dry rubbing paper and loads of paraffin, but with the expansion of the DIY engine market in the past few years you can buy cylinder bore hones quite cheaply in most well-stocked tool stores that cater for engineers rather than general ironmongery.

The hones have a flexible shaft drive so they self-centre in the bore, and you drive them with an ordinary electric drill. Put the hone in the bore before you start the drill and stop the drill before you take it out. Set your drill to a medium to fast speed and move the hone slowly up and down the bore taking care that it does not come out at the top or bottom. Use plenty of paraffin as a lubricant to carry away the honing dust, stopping every minute or so to feed in more. An old brush is useful for this. Do the honing over a tray or the paraffin will make a terrible mess on your garage floor. Carry on until all the mirror-like glaze is gone and you are left with a satin-smooth matt surface. Wash the block afterwards with white spirit to get rid of the honing dust. For the last clean of the bores, wipe them round with a rag moistened with automatic transmission fluid. It helps to pull the last traces of honing dust out of the bore surfaces.

If the crankshaft journals show any signs of ridging your new bearing shells will not last very long. The shaft needs regrinding. You can get quite a good idea of the state of the journals by looking at the old big-end and main bearing shells. If these show a smooth, even, slate grey surface the chances are that the engine has been reasonably well looked after with fairly regular oil changes and the crankshaft may be useable again as it stands. If, however, the bearing metal is worn away so you can see areas of copper or base metal, the engine has either covered a very high mileage or it has been neglected and the chances are that the crankshaft journals will also be worn.

The only way to make sure is to measure the journals for taper and ovality with a micrometer or vernier gauge. Nowadays quite reasonably priced dial read-out vernier callipers are available, usually made in the Far East, which are much easier to read than the older type with scale divisions. They are accurate and will last a long time provided you take care of them.

On a newly reground shaft the ovality of main and big-end journals should be less than 0.0004in. Taper should be less than 0.0005in but even on a used shaft the taper ought not to be significantly more than this. You probably won't find any taper on the main journals but if this is much more than 0.0005in on a big end journal, either it has been reground, and not very accurately, or you have got a bent con-rod.

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The bearing shell will also probably show signs of excessive wear on one side. It does not take much bend in a con-rod to wear out a bearing shell and crankshaft badly, anything in excess of 0.0005in over its length will accelerate wear rapidly. Con-rods cannot be checked while still on their pistons, and we will deal with the whole assemblies in a moment. For now, just make a note that more investigation may be needed.

You are much more likely to come across ovality than taper on the big end journals. On a high-mileage engine the ovality is bound to be more than that allowed on a reground shaft and, yet again, how much you can tolerate depends on the use to which you are going to put the engine. For normal road use you might be all right with up to 0.0008in ovality. We have known engines with this amount put back into service with new bearing shells and run happily for thousands of miles as long as they weren't thrashed. On the other hand we have also known lightly tuned engines with this sort of ovality knock out new bearing shells in less than 5,000 miles. If tuning for power, play it safe and have the shaft reground whatever the ovality.

Ford allows four stages of grinding for big end journals: 0.25mm, 0.50mm, 0.75mm and 1.00mm undersize and supplies bearing shells to these undersizes. However, if going for really high power on a turbocharged engine for competition work, we would be wary of taking a shaft journal down to the maximum undersize. The added strain on a crankshaft when you push for really high power is tremendous, and they have been known to break. For competition we would advise either a new standard shaft or a second-hand standard one that will take the first undersize regrind of 0.25mm. When you have your shaft reground do not take it to your friendly engineering shop round the corner under the railway arches but to one of the well-known tuning firms. You will pay a little extra but they know all about the importance of things like fillet radius on a highly stressed shaft and allowance for over-thickness thrust washers, if these are needed.

When your shaft has been reground, ask the firm to balance it together with the flywheel. Some people say you should always have the clutch included in the balancing and, on a racing engine, we would agree. But racing engines get stripped down and rebalanced pretty

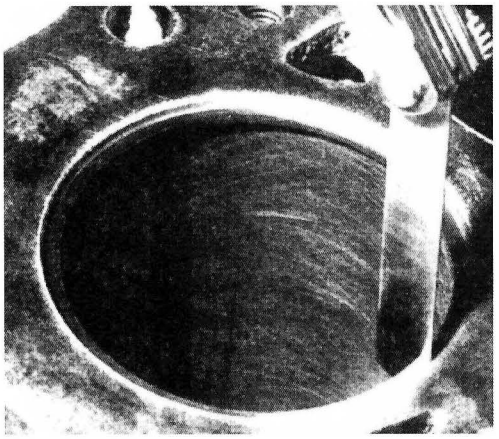


▶ *A piston ring tool will remove rings that are not stuck but you may have to break out rings which are heavily carboned. Remember to clean the grooves and try the new rings for side clearance.*

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frequently. On a road-going engine you will not want to go to the trouble of taking the engine apart for rebalancing every time you fit a new clutch. On a high-revving road engine we prefer to have the shaft balanced with its flywheel and then have the clutch balanced separately on a balanced slave shaft and flywheel. Most tuning firms will do this for you and, if you have to fit a new clutch, the new one can be balanced on a balanced slave shaft and flywheel. If your crankshaft is worn or ground undersize to the point where you are looking at replacing it, remember that the oil pump fitting at the rear end is different on pre-January 1986 engines.

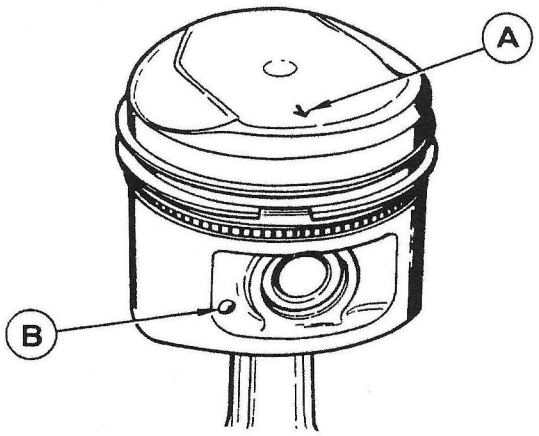
Whether or not you separate the pistons and con-rods depends on how far you are going with your rebuild. On the general overhaul of an engine that was in reasonably good condition before you stripped it, and if you are not having it rebored, you may decide that the pistons and rods are fit for further service. There are several pointers which will help you judge. The first is any evidence on the big-end bearing shell and crankshaft wear that you may have a bent con-rod. The second is the thrust face of the piston. It should have a perfectly smooth, slate-grey surface. If it is scored or unevenly worn, think seriously about a rebore and new pistons. The third is the condition of the ring grooves and the lands between them. You may find that some of the rings are stuck in their grooves but, provided they come free fairly easily, this is not serious. What is serious is any burning away or damage to the lands between the grooves in the piston or grooves worn so wide that an unworn ring is loose and wobbles. Unless the grooves and lands are in good condition the engine will burn oil at a prodigious rate. If you find any piston faults there is a real probability that the bores will have worn as well, so a rebore with new pistons is called for. Therefore, if going for any stages of tuning beyond the mildest, it is false economy not to go for a rebore.



◀ *Always check the ring gaps, even on new rings. Errors in packaging are rare but have been known.*

On a general 'extended life' overhaul, with no indications of serious piston or rod wear, there is no need to separate the rods and pistons but you will need new piston rings. For these, the grooves will have to be cleaned out. You can buy special tools for cleaning ring grooves which have a series of cutters to fit different width grooves, but the old rings serve just as well and cost you nothing.

Snap one of the old rings and use the sharp edge to clean all the carbon out of the grooves in the piston. Take care with this job because the carbon will be quite hard even after soaking in white spirit and it is very easy to be over enthusiastic and widen the groove so that the new ring will be a very loose fit. If this happens, the ring can actually pump oil up into the combustion chamber.



▼ *If you have new pistons put on your rods check that they have been put on the right way round. Ford pistons have both an arrow (A) and a dimple (B) to indicate the front or timing belt side.*

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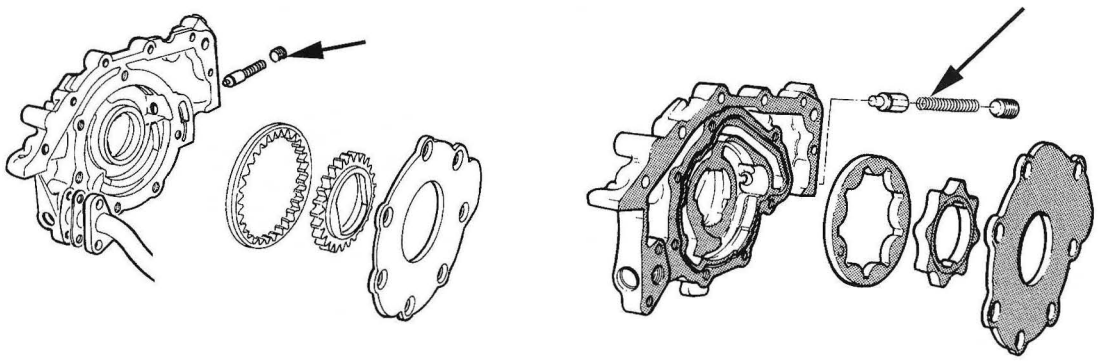
You should have your new rings before you start cleaning the grooves, and keep trying a new ring, rolling it round the groove to make sure it is completely free but not wobbling. When you're happy with the ring grooves, give the piston a clean with a soft brass brush, one made for cleaning suede shoes is useful for this, rinse it off, dry it and put it aside where it won't get damaged. Do not use a hard steel wire brush for cleaning pistons, they can score the surface too much.

If you are having the block rebored, take along the old pistons and rods, complete with the big-end caps so that the firm which does the reboring can fit the new pistons on to the rods for you. The gudgeon pins are an interference press fit in the ends of the rods. They have to be taken out with a press and the ends of the rods heated on a hotplate before the new gudgeon pins are pressed in. Tuning firms will have a jig for this which ensures that the pins are central in the rods and do not stick out one side to score the bores. When you get them back, check to make sure that the pistons have been fitted the right way round. There should be a marking to indicate the front of the piston, and the big end cap is marked with an arrow to indicate 'front'. On Ford pistons there is also a small pip cast by the side of the gudgeon pin to indicate front. Front, as we mentioned, being the timing belt end of the engine. The firm is unlikely to have made a mistake, but it has happened, and halfway through re-assembling the engine is not the ideal time to discover it.

You are most unlikely to find any wear on the camshaft belt drive pulleys except, possibly on the tensioner pulley. These sometimes get grooves on the outside and, if so, they will cause wear on the new belt. If you find grooves, replace it with a new or better condition one. The pulley must be free to rotate easily on its spindle. If you have the type of tensioner that uses a spring, renew the spring as a matter of course.

The oil pump is the heart of the engine, and it does not pay to take chances with it. Before January 1986, CVH engines were fitted with a gear type pump. From that date this was replaced by a rotor type. The two pumps look very similar on the outside, but they are not interchangeable because, as we said, the fitting to the end of the crankshaft is different. Both types are still current service parts from Ford dealers. Ford does not give any wear limits on the gear type pump but, if the gear teeth look obviously worn, or if there are signs of scoring and grooving inside from lack of regular oil changes, renew the pump. On the later rotor type, Ford gives a clearance dimension between the outer rotor and the casing of 0.060 to 0.190mm. (You are unlikely to find an exact Imperial equivalent feeler gauge, but the nearest standard sizes are 0.003 and 0.007in.)

▼ *Ford used two types of oil pump, the gear type (left) and, after January 1986, the rotor type (right). They are not interchangeable. Always renew the pressure relief valve and spring (arrowed) and, if in doubt about wear, the complete pump.*



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Between the inner and outer rotors, Ford's clearance tolerances are 0.05 to 0.18mm (0.002 to 0.007in nearest standard Imperial feeler gauges) and the rotor end float relative to the mating face should be between 0.014 and 0.100mm (0.001 to 0.004in). Again, if there are any signs of scoring, renew the pump. If you are retaining either type of pump, a safe precaution is to renew the by-pass pressure relief valve and spring. Failure is rare, but it has been known to happen with disastrous and expensive results. Most tuning firms stock higher pressure relief springs if you feel safer with one.

Water pumps usually either work or leak but, even if yours was working before the engine was stripped, still examine it for roughness when you turn the gear pulley and look for excessive sludge build up. If in doubt, renew it.

Check the flywheel clutch face for grooving or signs of 'crazy paving cracks', sometimes called 'Chinese writing cracks', caused by overheating from a slipping clutch. Also check the starter ring gear teeth for wear. It may be possible to have the flywheel face skimmed and the ring gear replaced; consult a tuning shop.

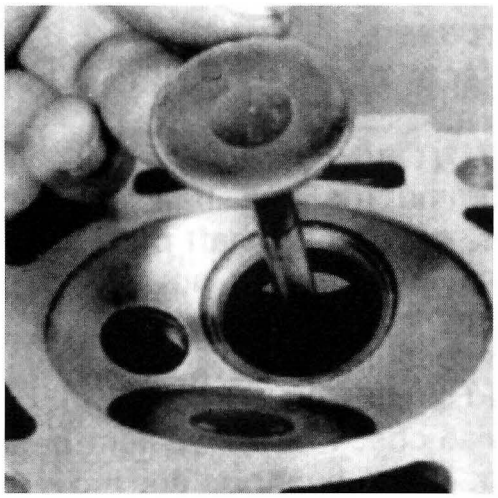
That just about covers the bottom end of the engine, so we will turn our attention to the head. Decarbonising follows the usual procedure of getting rid of all the old carbon with scrapers and wire brushes, after which give the head a good wash off in white spirit.

The first job is to check the head face for any warping. Use a straightedge and feeler gauges. Ford's maximum allowance for head face distortion is 0.04mm (0.001in) measured over 26mm (1in); 0.08mm (0.003in) measured over 156mm (6in) and 0.15mm (0.006in) measured over the entire length. If you find distortion greater than this, have the head refaced. The maximum amount of refacing before there is a danger of the valves hitting the pistons is 0.30mm (0.018in).

The valve guides will probably be worn and, as they are cast in the head, you cannot replace them at home. Take the head along to a tuning firm to have the guides bored out and copper inserts put in. It is possible to buy the special drill and mandrel to do this at home but it is not worth it because the valve seats will need recutting after the guide inserts have been put in. Ford valve seats are cut to three angles, which cannot be done at home without a special cutter, and you will spend more on special tools than it costs to have the whole job done outside.

If having the head gas-flowed with larger diameter valves, the firm that puts inserts in the guides will do this and supply the larger valves as well, but if you are just overhauling with standard size valves, these need cleaning up and checking.

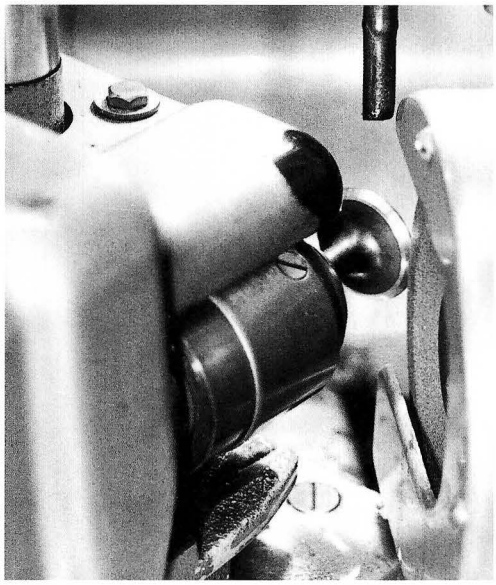
The easiest way to clean valves is to mount them in the chuck of a drill, run the drill at a slow speed and use an old, sturdy, fairly blunt knife as a scraper. Finish off with emery cloth under the heads, but not on the stems. If the valve stems show any signs of ridging, the valves need to be replaced but, if they are just polished and do not wobble in the new guide inserts, you can have them refaced. The Ford manual tells you not to grind in valves, but that's because new Ford valves have the seats coated with a special compound to



◀ *After cleaning the valves check for play in the guides. If they wobble, but the valve stems are OK, have the guides fitted with inserts.*

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▶ *You can have valves with good stems lightly faced to get rid of slight pitting.*



help bedding in. However, if the valves have been refaced there is no harm in a light grinding in with fine compound to make sure they are bedding properly.

If the rockers show none, or very little, signs of wear at their contact with the valve stem they can be used again, but if they have become hammered and worn from clattering because of sticky or lazy hydraulic followers, it is best to renew them. It may be tempting to try stoning out the wear but it is hardly worthwhile. Unlike some makes, you cannot strip and clean out Ford hydraulic followers but the cost of renewing them is relatively small compared with the total cost of overhauling the engine, so we would recommend getting new ones. It is not likely that the bores in the head for the followers will be worn, but check just in case before you spend a lot of money on the head.

It is also unlikely that you will find any loose or damaged studs where the rockers bolt down but, if you have to renew any, there is a special procedure. The studs are locked in either by compound or nylon locking inserts. To remove the old stud use either a stud box or two nuts locked together on the threads and warm the stud with the flame from a small blowlamp. Do not use a welding torch as the flame is much too fierce. Once the stud starts to give, unscrew it with a continuous movement and then clean out the hole with an M10 (10mm) tap. Clean all traces of oil or grease out of the hole with petrol, dry the hole and screw in the new stud, again using two nuts or a stud box, with one continuous movement. The new stud will either have its threads coated with compound, or will have a nylon locking insert, and if you stop the compound will start to set or the nylon will lock and you will have difficulty getting the stud screwed right home. Once again, if putting the head out for work to be done on it, it is easier to let the firm doing the rest of the work renew any damaged studs. Some tuners offer a complete exchange head, the price depending on whether or not you want the replacement head gas-flowed and to what stage.

▼ *If the face of the flywheel is scored like this it will quickly wear out a new clutch. Either have it refaced or look for a better one.*



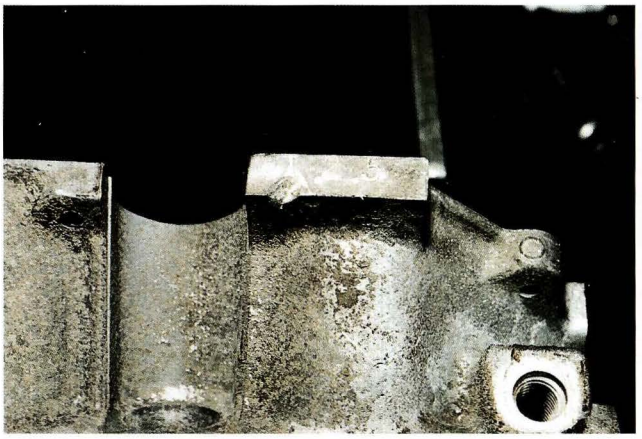
▼ *The engine capacity is cast on the side of the head as well as on the block.*



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▲ *Somewhere on the side of the head will be a casting date. It can be a good guide as to whether or not it is suitable for running on unleaded petrol.*



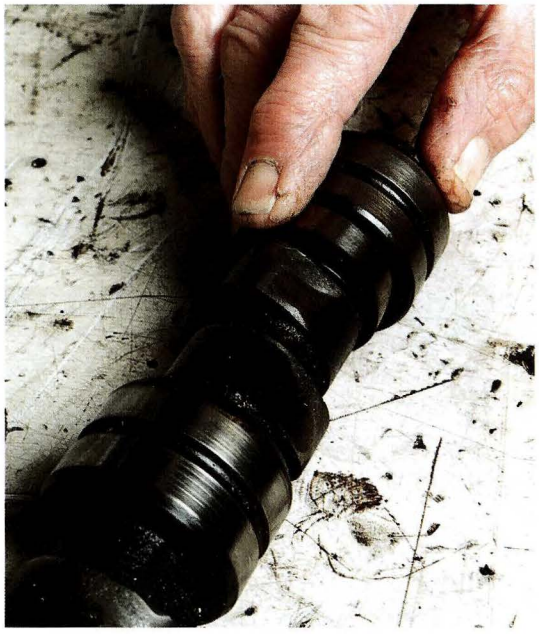
▲ *If you find T 2.5 or C 3.8 stamped on a boss on the head beware these denote oversize cam follower bores and camshaft bearings.*



▲ *If the valve faces show signs of pitting or deep wear, reject them and fit new valves.*



▲ *Another reason for rejecting a valve is a ridge at the top of the stem.*



◀ *The nose of this cam has worn badly and has probably gone too far for reprofiling.*

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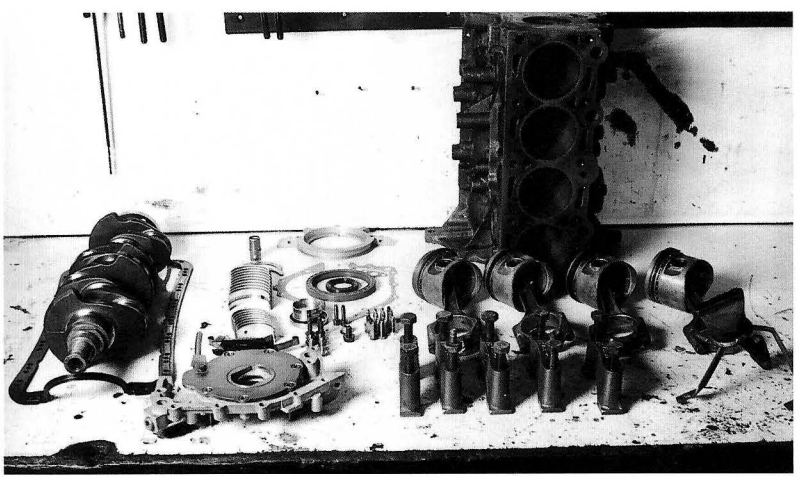
Chapter 20

Building the block

With all the parts cleaned and checked, you will be aching to get the engine together again but, before you do, spend some time on dry runs to check that everything fits just as it should. These checks, combined with scrupulous cleanliness, are the secrets of successful engine building.

You might think that not all the checks being recommended are necessary and that we are preaching a text book counsel of perfection. If you have bought new parts, or had them reconditioned, you should be entitled to think that they will go together with no problems and with all the correct fits and clearances. You would not find this sort of dry checking carried out on production engines, or on most commercially rebuilt exchange engines in standard tune. But, you are spending a lot of time, and quite a lot of money, building an engine that is better than standard, and the higher you go in power tuning, the more important the checks become.

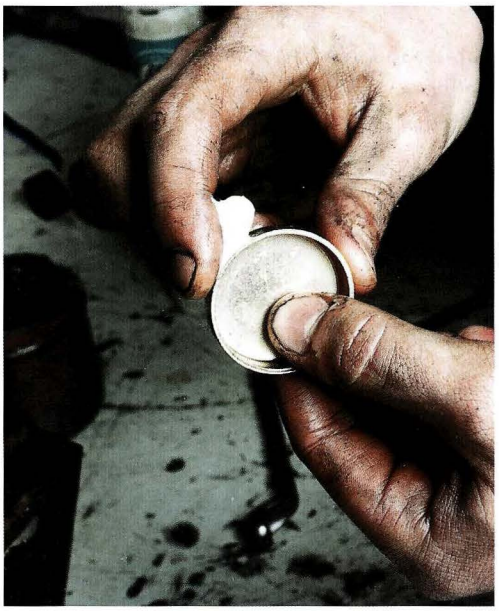
▼ *It is best to gather all the bits and pieces together before starting to build the block, then you will not forget anything.*

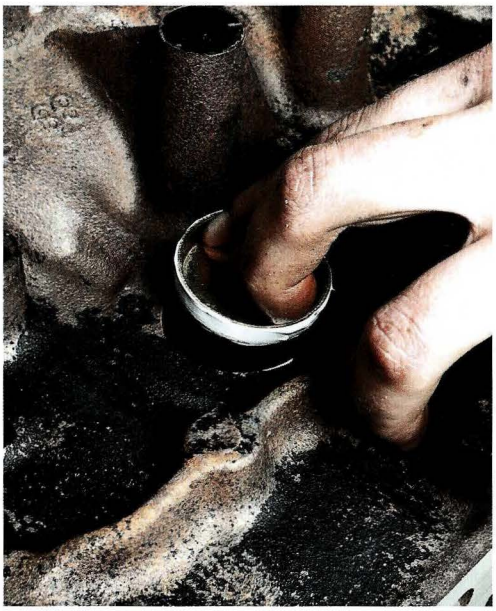


Start with the block and check again that as much as possible of the loose muck in the water jacket has been washed out. Then fit the new core plugs. As with taking them out, fitting new Ford core plugs successfully so they do not leak is simple once you know how. Do not just put them in place and hammer on the edges to drive them in as they are unlikely to go in straight, but even if they do this would damage the edges and the plug will not seal properly.

Use a jointing compound, available from Ford dealers, but there are a number of proprietary brands on sale at most accessory shops. We tend to use the Ford product, but any good, non-setting compound should be suitable. Find an old socket which is a reasonably good fit inside the 'lid' of the plug and remember that the plug will close slightly when it goes in so do not choose one that is too tight. We usually put an old short extension in the socket because it makes it easier to hold. Coat the inside of the recess on the block and the edges of the core plug with compound, fit the socket in the plug and use it as a mandrel to tap the plug home. Go lightly at first to make sure the plug's going in square and then drive it home until the edge is level with, or very slightly inside, the face of the hole in the block. Wipe away any surplus compound that oozes out.

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◀◀ *Coat new core plugs liberally with jointing compound.*

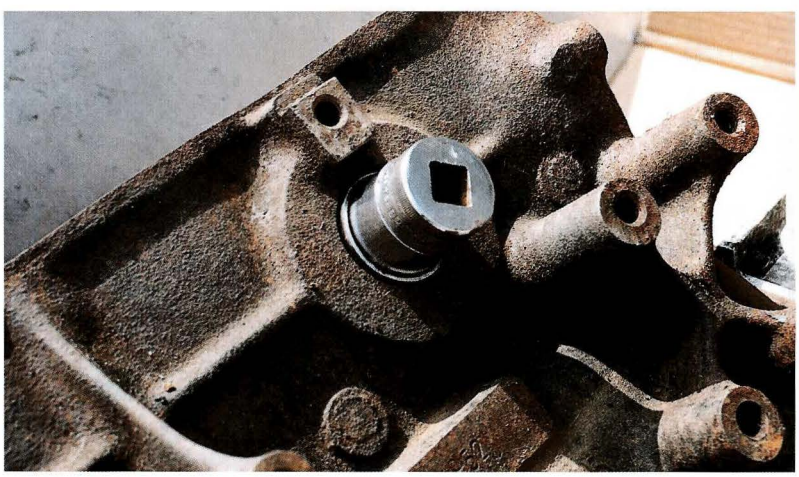
◀ *Push the coated core plug into its hole.*

Although you cleaned the block thoroughly, or had it cleaned, check it again just to make sure. If you sent the block for reboring, and did not take the oil gallery plugs out, there is a fair chance that some of the cleaning fluid used in the reborer's cleaning tank may still be lodged inside the oil galleries. This is a powerful degreasing compound designed to break down old oil deposits, and it is not very friendly to new oil. Take the gallery plugs out and give the galleries a good squirt through with a syringe full of petrol. You may be surprised at the colour of it when it comes out. Even if you did take the plugs out before sending the block away, still give the galleries a squirt through, just to be on the safe side. Then make sure that the inside of the crankcase is spotless. Even after a deep tank degreasing you can still get small pockets of sludge or honing dust lodging in nooks and corners. Remove any with a brush and petrol and, if you have a compressor, dry off the inside of the crankcase with compressed air. If you have to use rags, make sure they are not fluffy. Indeed, fluffy rags like yellow dusters ought to be banned from engine

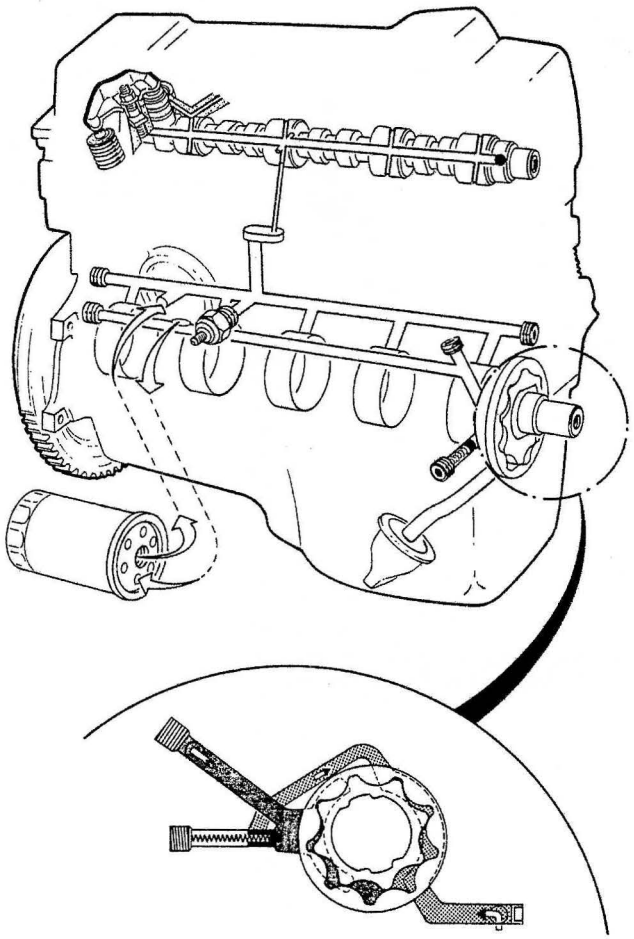


◀◀ *Drive it down flush with a suitably sized drift.*

▼ *If you do not have a large drift you can use an old socket to drive the new core plugs into position.*



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▲ *There are four oil gallery plugs, apart from the pressure relief valve on the pump.*

workshops. They leave fluff behind on every sharp edge or point.

Oil gallery end plugs are not expensive, so to be safe we always fit new ones with just a smear of jointing compound on the threads. Make sure there is not too much compound that will find its way into the gallery. Wipe off the surplus compound and throw away now the rags you used for this and for cleaning surplus compound off the core plugs. That way you will not use them to wipe things like pistons and bearing shells.

You may think that the bores are clean, but go over them again with a rag moistened with clean automatic transmission fluid or power steering fluid. This is one of the best things we know of for getting the last traces of honing dust out of the microscopic grooves in the bores.

With the bores absolutely clean, check the fit of the piston skirts in the bores. If your block was bored in a tuning shop, the person who did the reboring and honing should have measured each piston and honed the bore to suit. If they have done this you usually find the pistons numbered in pencil or felt-tip pen on the tops. Even if they did, and particularly if they didn't, check the fits now. If a piston gets tight and seizes up the first time you turn on real power, it is a bit late to go back and ask.

The professional tuner's way of checking piston fit is to use long feeler gauges about half an inch wide. The top of the feeler has a hook for attaching a small spring balance. The feeler and the piston, without its rings, are pushed down the bore and the pull to lift the feeler out is measured.

Different tuners work to different clearances. Some like a close fit, 0.0009 to 0.0010in (0.023 to 0.043mm). An engine with these clearances will be fairly tight when new and will need careful running in for at least 500 to 600 miles and, even then, top power should be introduced gradually in stages as the engine beds down and frees off.



◀ *Whether your crankshaft is reground or not, make sure it is perfectly clean and squirt plenty of oil in the holes.*

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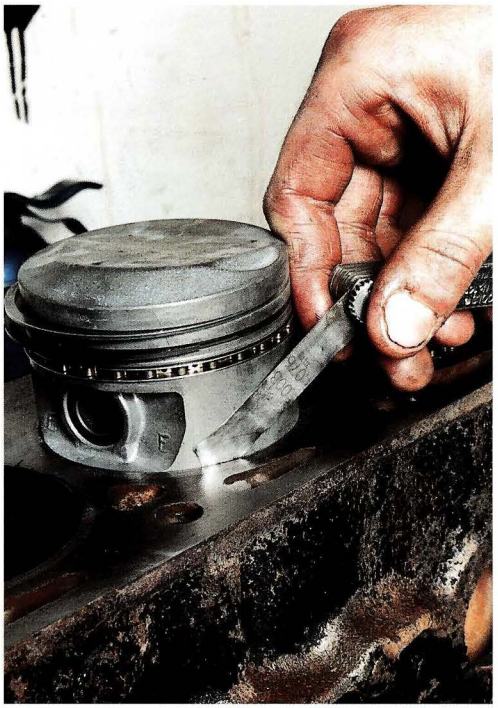
Other tuners hone to a wider clearance, 0.0020 to 0.0025in (0.048 to 0.064mm) on the basis that not all that many of their customers will run-in the engine properly, and a wider clearance is better than a piston which goes tight and picks up in the bore.

These two clearances represent a pull of 7lb and 11lb on the spring balance with a 0.5in wide feeler blade. If you are working to metric figures the width of the blade is 12.5 to 12.7mm. These are fairly standard widths for long piston feelers.

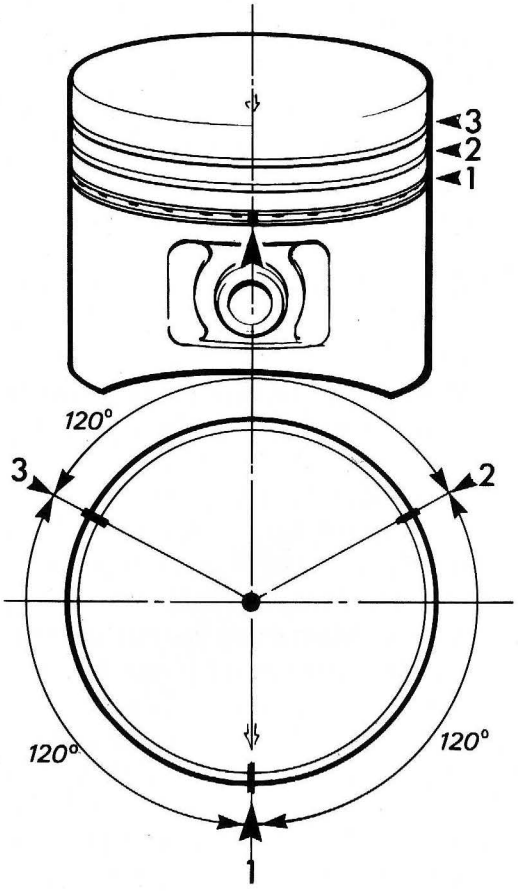
You may not think it is worthwhile buying a set of feelers and a spring balance just for one engine rebuild, and if the bores have been honed you can get a very good idea of the piston fit using ordinary feeler gauges at the top of the bore to measure the skirt clearance. The clearances quoted are for standard pistons and they all go by the board if using special high-expansion alloy pistons. These have much higher clearances and whoever does the final honing of the bores must work to the maker's specifications, or you will be wasting a lot of money.

There is another job that has to be done before you can put the pistons safely to one side, and that is measure the ring gaps and side clearances. Yes, we know that the gaps as the rings come from the packet should be right, and in these days of computer controlled machining it is a long time since we have found one that is too tight, but it has happened. You can also check the rings at the same time to make sure they are the right ones. The people who pack them work at high speed and do not often make a mistake, but they are human and again, it has happened.

Check the side clearances before you check the gaps because if they are not right you can take the rings back and exchange them. If you file the ends to correct the gap, and then find the side clearance is wrong, the supplier will not accept them.

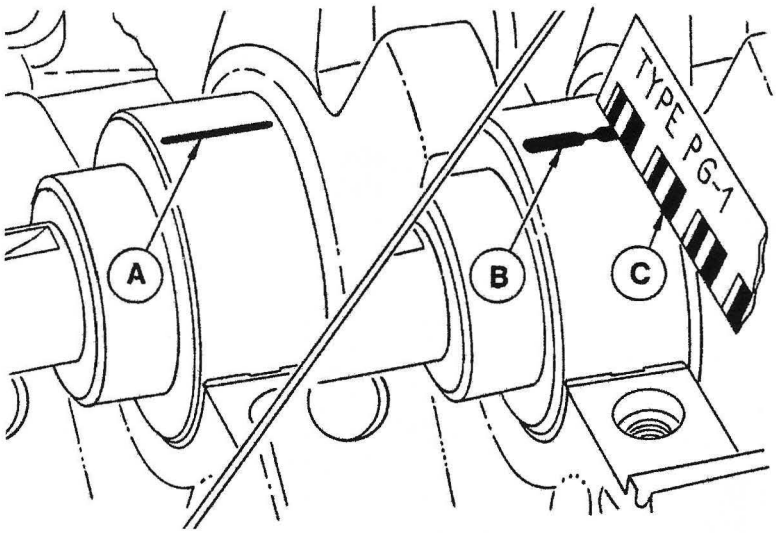


◀ *You can still check the piston clearance with an ordinary feeler if you do not have a long feeler and tension gauge.*



◀ *The best way to install the piston rings. The oil control ring slot is over the end of the gudgeon pin, the slot of the scraper ring is 120 degrees anticlockwise from it and the slot of the compression ring 120 degrees clockwise.*

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◀ *To use Plastigage, cut a length of the plastic wire and lay it on the crank journal (A), then bolt down the bearing cap which will squash the plastic so that you can measure its width (B) against a gauge (C) to read off the clearance from a chart. You can use this method on both main and big end bearings.*

Then check the side clearance of each ring in its piston groove with feeler gauges. The clearance may be marked on the packet but, if not, a good rule of thumb clearance is 0.001in to 0.003in (0.025 to 0.075mm) for compression rings and 0.002in to 0.004in (0.050 to 0.102mm) for plain oil control rings. If using special oil control rings of the multi-ring wavy sort, clearances do not apply because you cannot check them. Most manufacturers of rings of this type make them to fit the standard oil control groove in the piston, but check when you buy them as it might be necessary to have the piston groove machined.

To check the ring gaps the rings have to be off the pistons, and the pistons may have come back to you with them fitted. The easiest and safest way to remove and replace piston rings is to use the tool designed for the job. You can buy these in many tool shops, and they are not very expensive. Alternatively, you can take rings off and put them on using your fingers. It is not something we would recommend though because it takes a lot of practice to be certain of not breaking a ring but, if you want to learn the art, practice taking the old worn rings off to get the hang of it. Use the middle fingers and thumbs of each hand, the middle fingers round the back of the ring to support it and the balls of your thumbs against the ends of the rings. With practice you can open up the ring just enough to lift it off or put it on the piston, but be warned, the edges of the rings can be very sharp and can dig into the balls of your thumbs, so don't blame us if you have to stop work to reach for the sticking plaster.

Push each ring in turn down the bore into which it is going to work and square it up using an upside-down piston. Then measure the gap with feeler gauges. If you are using special exotic rings the maker may specify a particular clearance, and this will be marked on the packet. With standard rings, or if you do not have the packet, a good working figure for the gap is 0.009 to 0.014in (0.23 to 0.36mm). We usually work to a sliding fit with a 0.012in feeler because it is a handy size. If the gap is a shade on the wide side do not worry too much. In theory you can lose a little power from blow-by, and carbon gets deposited behind the ring more easily. In practice, a slightly wider gap will not make any noticeable difference. Too small a gap on the other hand, can be disastrous. The ring expands as it gets hot and if the gap closes up before it has finished expanding it will dig into the wall of the bore and score it.

In the unlikely event that you have found a gap which is too small you must do something about it. This needs a small vice, like an instrument maker's, with undamaged smooth jaws, and a small, very fine file. A big bench vice with serrated

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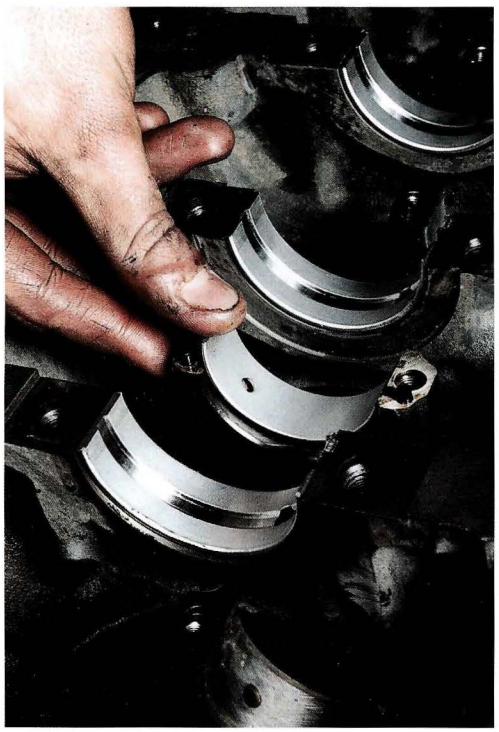
jaws is useless for this job as it will probably break the ring, while plastic or fibre work protectors are soft enough to let the ring turn in them. Hold the ring in the vice with about ⅛in showing and file the end slowly and deliberately with a clean file. Keep the end of the ring square, and stop every four of five strokes to check the gap again. Clean any swarf off the ring before trying it down the bore. When you are happy that the piston and ring clearances are all OK you can put the pistons safely to one side while you get on with the other checking.

Next comes the crankshaft and bearings. When you get your crankshaft back from the regrinders it will be smeared over with oil and possibly wrapped in waxed paper or plastic. The oil is put on to prevent any surface rust forming from moisture in the air, but it also attracts any dust that may be about, and this is something you can well do without.

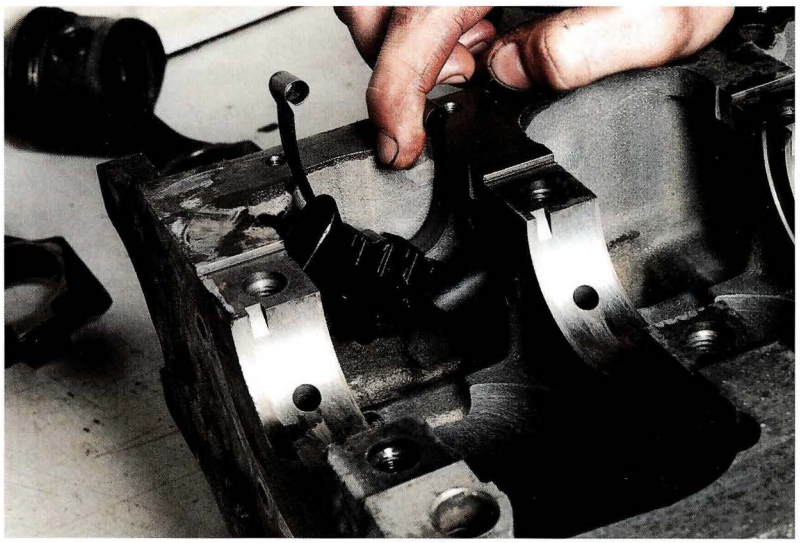
Give the crank shaft a good clean, finishing off with a rag moistened in petrol, and squirt a syringe full of petrol down the oil holes just to make certain there is no muck left in them. Once again, it is never a waste of time to check the fit of the main bearings or the big end bearings on the journals. There are three ways to check the fit of the bigends: one, an old engineer's rule of thumb method, the second the old precision engineer's method and the third, much easier and more scientific.

The rule of thumb method is to hold the crankshaft horizontal in the vice – use vice jaw protectors and clamp the crank by the webs not the journals. Clean off a con-rod and piston, and its bearing shells and assemble it on the journal to which it is going to fit. Make sure you get it the right way round. Torque it up to the correct figure and then hold the rod and piston horizontal. It should drop gently under its own weight. If it needs the slightest touch with a finger to get it started but then falls gently it is probably OK but keep it in mind because it means the shells are a shade on the tight side and the engine will need running in carefully. If it needs a push to get it started and it stops and sticks on the way down check again that there is not even the slightest particle of grit behind the bearing shell which can make it go

▼ *Wipe the housings and shells and lay the main bearing half-shells in the block.*



▼ *Before you fit the crankshaft and rods, clip the crankcase ventilation baffle in place. You will not be able to put it in at a later stage.*



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tight, and try again. If it still sticks, the journal may be ground just a tad oversize and needs checking with a micrometer. If, on the other hand, the rod slams down and swings about like a pendulum at the bottom, it is too loose and the journal has been ground too far undersize.

The precision engineer's method is to use something seldom found outside a toolroom these days, engineer's blue. This is a very fine thin marking paste and you may have a job to get it, but a good toolshop may be able to order it if you want to try it. It should come in a tube rather than in a tin, to prevent any dust getting on it. Wash your hands before

▶ *Give the shells a liberal dosing of clean engine oil.*



▶▶ *Lower the crankshaft gently into position taking care not to dislodge the bearing shells.*



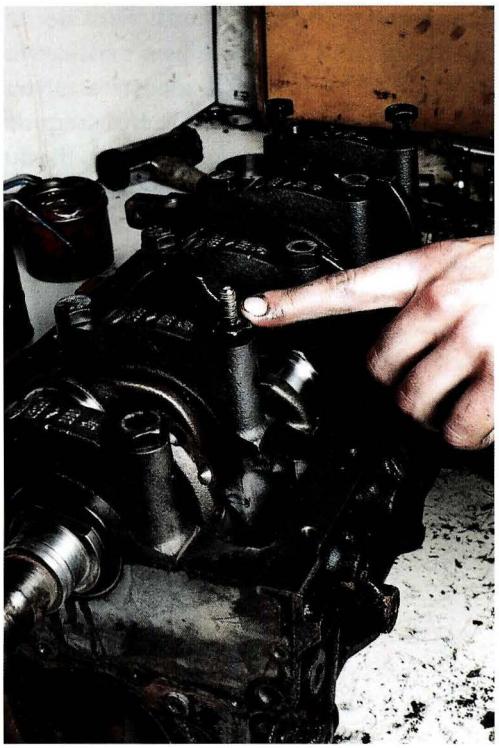
▶ *If you did not fit the half-thrust washers before lowering the crankshaft you can fit them now and rotate them into place.*

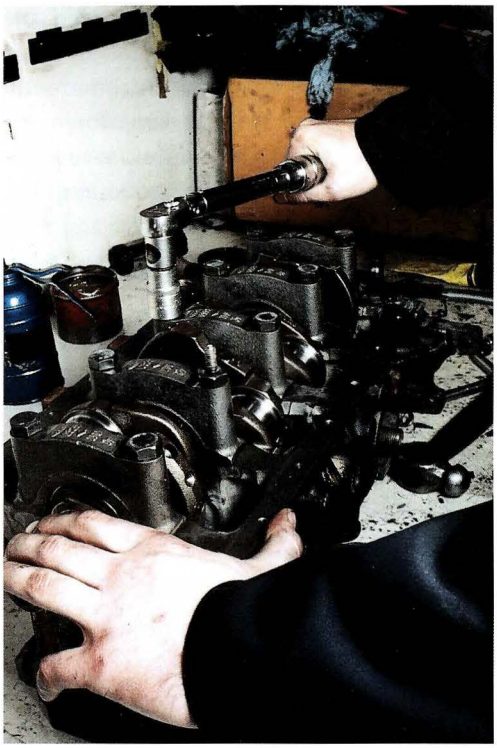


▶▶ *After fitting the bearing shells and dousing them with oil, fit the main bearing caps taking care to place them in the correct order.*



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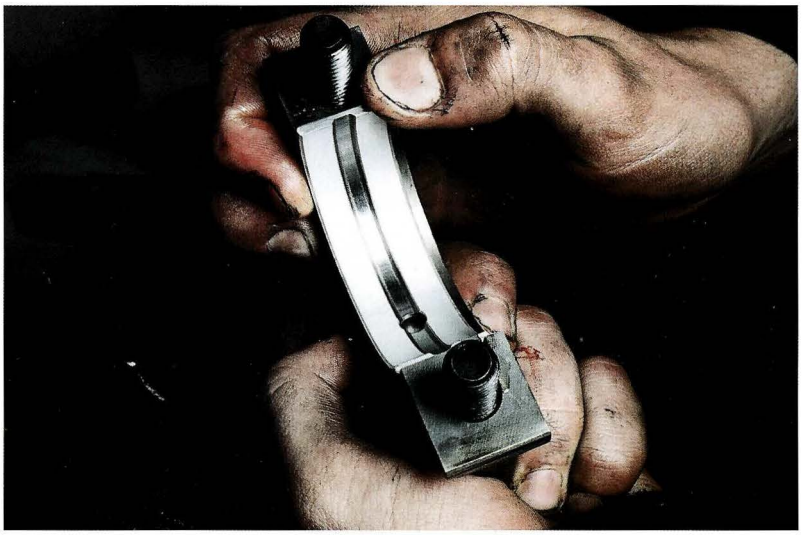




◀◀ *When you fit the main bearing bolts remember that one has an extension to hold the bracket for the oil pick-up pipe.*

◀ *Torque down the bearing-cap bolts and keep turning the shaft to make sure it is free.*

▼ *Fit the big end half-shells to the rods, lining up the tag on the shells with the recesses in the rods.*

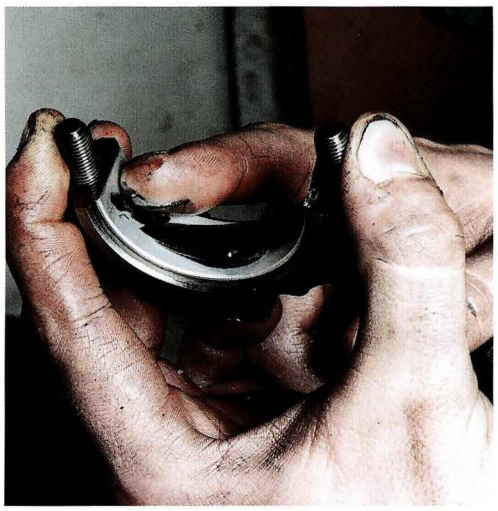


using it because it will attract dust and grit and these are the last things you want in your bearings. To use it, mount the crankshaft horizontal in the vice and smear a very thin layer of blue evenly over the journal. Bolt up the con-rod and bearing shells to the correct torque and turn the rod round on the shaft a couple of times. Stop it with the rod hanging vertically so you can undo it without turning it at all. The blue should have transferred to the bearing shell as a nice even coating all over the surface except, possibly at the extreme edges where there's a fillet radius on the journal and the bearings allow for this. If it is darker one side than the other it means the journal has been ground with a slight taper, so check it carefully with a micrometer. The taper should not be more than 0.0005in (0.013mm). If you find light high spots in the blue it means that there are very slightly proud high spots on the journal, so once again check carefully with a micrometer. If the micrometer confirms either taper or high spots take the shaft back to the person who reground it. You can check the fit of mains bearings, one at a time with the other bearings in place to support the shaft, in the same way.

The most scientific, easiest and safest method of checking bearing clearances is to use a product known as Plastigage. Produced by the Perfect Circle Corporation in Hagerstown, Indiana, USA, it is available as a handy kit in the right sizes and sufficient quantity to check an engine. If

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▶ *Instead of oil on big end shells we like to use a graphite compound to help bedding-in on the first start-up.*



you have difficulty finding it locally, Burton Power Products Ltd of Ilford keep it in stock.

Using it, say to check the clearance of a big end, is simplicity itself. You cut a length of the appropriate Plastigage to the exact length of the big-end journal and lay it lengthways along the journal. Then you bolt on the connecting rod and bearing shells and torque up to the correct figure. Be careful not to rotate the rod at all while you do this. When you undo the rod, the Plastigage will have squashed down to a flat strip. Without taking it off the journal, measure its width against a series of marked widths on a gauge, rather like a large bar code. The width of the bar which matches the width of the gauge indicates the clearance. It will also tell you if the journal is tapered because, if it is, the strip will be flattened more at one end than the other. You can check mains clearances the same way, using the other bearings to support the shaft while you check one, and it is the easiest and most accurate method we know for doing the job. It is almost foolproof too, but not idiot-proof, so follow the instructions on the packet carefully.

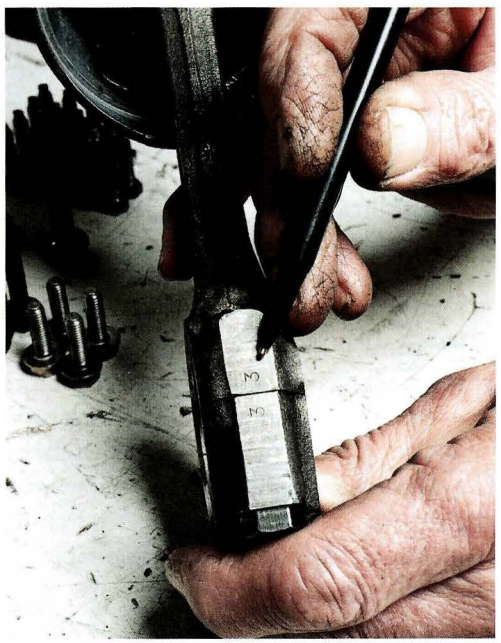
Now, at last, you are ready to start the actual assembly of the bottom part of the engine. Start by putting back the ventilation baffle and make sure that its spring retainer holds it firmly in position. Do this now, before you forget it, because it is annoying, to say the least, to discover you have forgotten it after the engine has been assembled and you have to take it all apart again because the baffle wil not go past the con-rods.

Make sure the bearing housings in the crankcase and the shells themselves are perfectly clean, and fit the bottom shells in

▶ *Remember that the big end caps have an arrow which must point towards the front, or timing belt, end of the engine.*



▶▶ *You should already have checked that the numbers on the caps and rods agree.*



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place. Either use a light smear of grease to hold the two end thrust half-washers in place before you lower the crankshaft down or, as some builders do, put them in and rotate them into position after the shaft is in place. Dribble plenty of clean engine oil on the bearing shells and lower the crankshaft into position. Fit the shells into the bearing caps, coat them with oil and fit the caps in place making sure you have them in the right order and with the arrows pointing towards the timing belt end of the engine. Tighten the bolts down a little at a time to make sure everything is bedded in and then tighten to the correct torque of 66 to 74lb/ft (90 to 100Nm). Turn the shaft from time to time to make sure nothing is binding.

Next, check the crankshaft end float. If you have a dial test indicator you can use this on the flywheel mounting face of the shaft but, if not, use feeler gauges between the thrust washers and the machined thrust face on the shaft. Use a bar to lever the crank endways to check the clearance and rotate the shaft to check it at 180 degrees. The end float tolerance us quite generous, 0.0035 to 0.0118in (0.09 to 0.30mm). In the unlikely event that the end float is too small you can rub the non-bearing surface of the thrust washers down by making them absolutely flat with a piece of emery cloth laid on something perfectly flat such as a surface plate or a piece of plate glass. If the end float is too great, you can order over-thickness thrust washers from your Ford main dealer or tuning shop.

Now space the ring gaps evenly around the pistons so they are 120 degrees apart, coat the rings generously with colloidal graphite bedding-in paste and fit a piston ring clamp. Before you tighten the clamp make sure the ends of the oil control garter ring are butting up together when the gap is closed and not overlapping. Although we are quite happy to use plain engine oil when fitting main bearings, we like to use a colloidal graphite assembly paste on big ends and pistons because they take quite a hammering when the engine first starts up and the graphite helps them to bed in smoothly. We use Graphogen, but there are other makes. As well as putting paste around the rings, smear some down the bore.

Before you start putting the pistons in, turn the crankshaft so that the webs are horizontal, halfway between top dead centre and bottom dead centre. Turn the engine over so that the cylinder head face is uppermost and, if you are working on a bench, use some blocks of wood to make sure the bearing caps do not ride on the work surface. Put the rod and piston in its appropriate bore and tap the piston through the clamp with the handle of a hammer until it just goes free, with the top of the piston level with the top face of the block. Make sure the piston is facing the right way round. As mentioned earlier, there are two indications, one of which, or both, should be noted. There will be an arrow on the top of the piston and there will most likely be a raised dimple on the recessed part of the piston by the end of the gudgeon pin bore. Both of these must face the front, or timing belt, end of the engine. Also make certain that you lay the big-end bearing caps out in the correct order so that they go back on their mating rods.

When all the pistons are in, lay the block gently on its side and pull the con-rods down to line them up with the crankshaft journals. Fit the shells to the bearing caps, coat the shells with graphite and fit the caps, checking again that they are the correct mating caps and are the right way round, with the numbers on the rod and cap together. Do the bolts up reasonably tight until you have all the pistons and rods in place, then turn the engine over on to its cylinder head face and torque down the big-end bolts to 22 to 26lb/ft (30 to 36Nm). If you are working on a bench and not an

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▶ *Smear plenty of graphite compound in the bores to help the rings bed down.*

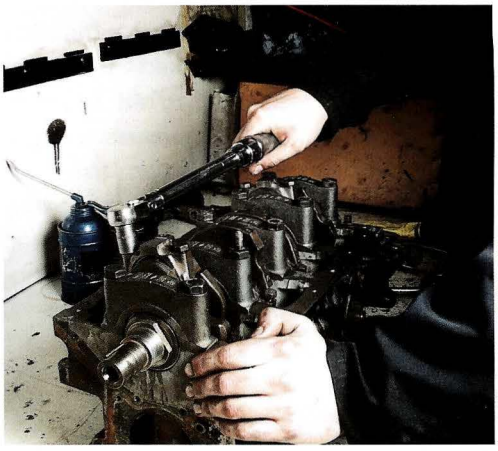


▶▶ *Use a piston-ring clamp and tap the pistons down into the bores until they are flush with the top.*



▼ *This is the brand of graphite compound we use, but there are others.*





▲ *With the engine on its side, push the pistons down the bores to fit the big end caps, then stand it upside down and torque down the bolts.*

engine stand, turn the engine over so that the pistons are at top dead centre and make sure that they do not project above the top face of the block. Some high compression pistons do, and in which case, either work with the engine on its side or support it underneath with strips of wood to make sure the pistons are clear of the bench. Be careful when you torque up big-end bolts because it is easy to pull the engine off the strips of wood and damage the tops of the pistons.

As you torque up each rod, turn the engine over to make sure that everything is free. With all the pistons and rods in place, you may find the engine is a little too stiff to turn by hand using the flange at the back of the crankshaft, so screw in a couple of old flywheel bolts and use a lever to turn it over. Everything should turn smoothly and freely with no tight spots. It

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does? Good, you're halfway towards building a successful and reliable engine.

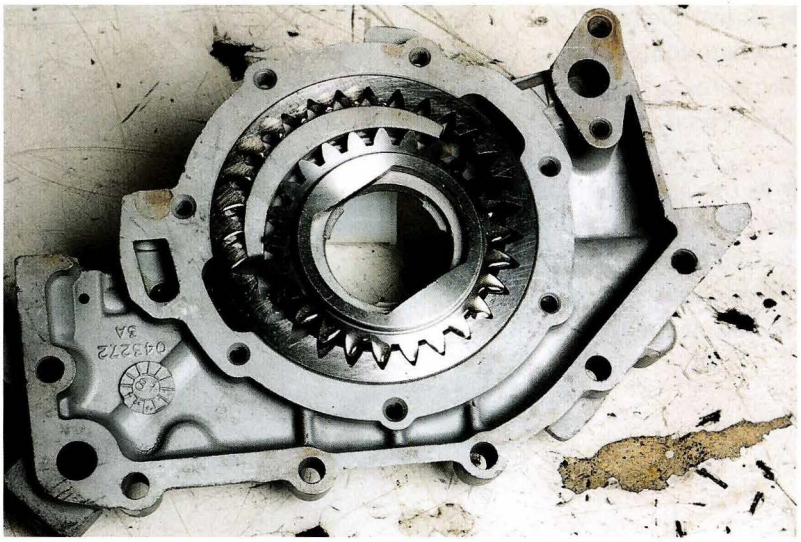
Fit the oil pressure switch now, while you remember it, and then get the oil pump. It is assumed that either you are fitting a new pump or have checked the old one and are happy with it. At the risk of repeating ourselves, do not take chances if you are the slightest bit unhappy with the old pump. It is the heart of the engine, and a heart transplant at a later date will probably mean new bearings and maybe crankshaft and camshaft as well.

If using the Ford special tool to fit the front oil seal, fit the seal after the pump is bolted on. The tool can be ordered through Ford dealers, but it is quite expensive for a one-off job, and there is another way of doing the job which we will come to in a moment.

Whether you use the tool or not, prime the pump with clean oil before fitting it, and turn it over by hand to distribute the oil around the gears. This makes sure there is no delay in getting oil to the bearings during the first vital few seconds of start-up.

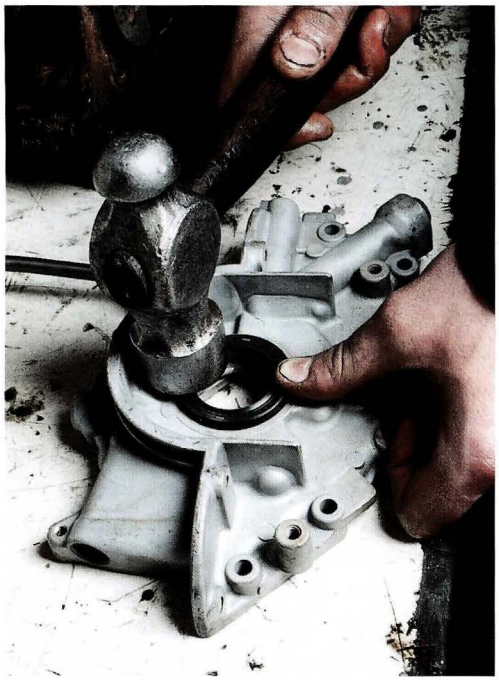
You may or may not still have the Woodruff key in the nose of the crankshaft. If you have, you must take it out before fitting the pump or you will ruin the oil seal. We have seen people mess about with pliers and Mole grips trying to get Woodruff keys out, and damaging the shaft in the process, but there is no need. The simple and easy way to do it is to put an old screwdriver or blunt chisel against one end of it and give it a sharp blow with a decent-sized hammer. The key will pop straight out without damage to anything except itself, so all that is needed is a new key.

If using the Ford oil seal tool, bolt the pump in place without the seal, using a new gasket. Do not use jointing compound

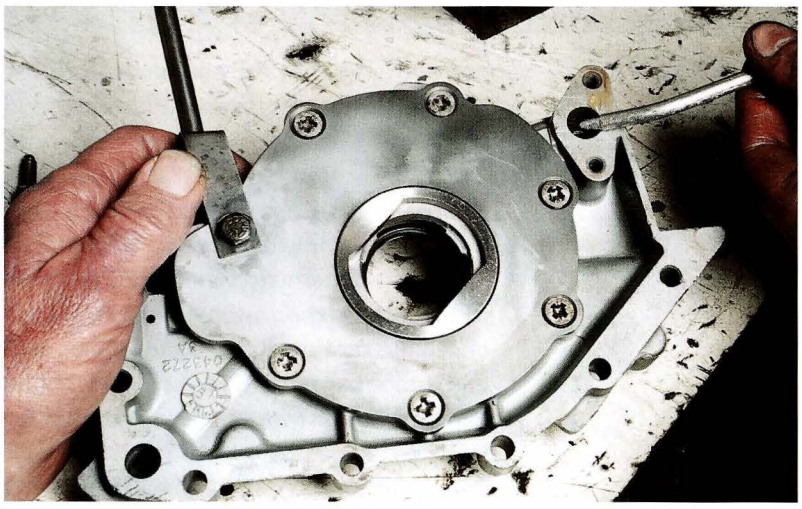


▲ *This is the earlier gear-type oil pump. It is not interchangeable with the later rotor-type.*

◀◀ *Carefully tap the oil pump seal into position after greasing the recess, making sure it goes in square.*

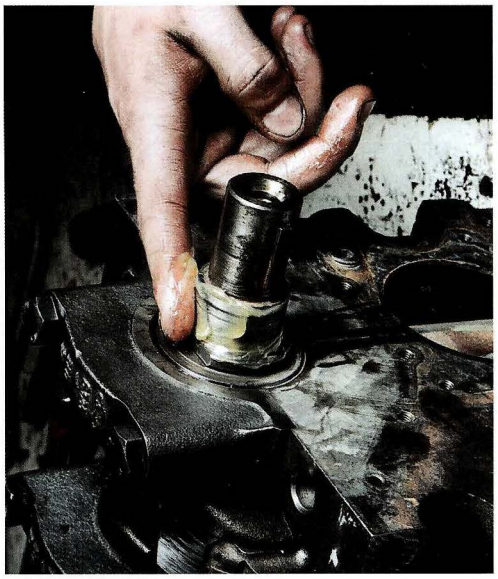


▼ *Prime the oil pump with plenty of clean oil before fitting it.*



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▶ *Most professionals just grease the nose of the crankshaft before fitting the pump but you may like to wind adhesive tape over the step first.*



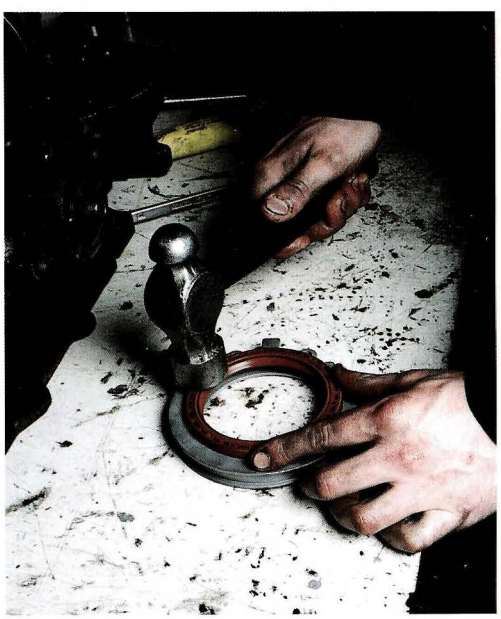
and in fact, there is no need to use jointing compound on any gaskets on a CVH engine other than when fitting the sump, and we will come to that in a moment. Put the new gasket in place with just a light smear of grease and there will not be any leaks. Make sure that the flats of the driving flange on the crankshaft engine line up properly with the pump, and tighten the bolts. Lightly oil the recess in the pump and the part of the shaft on which the gearing runs, fit the new seal into the Ford tool, place it in position and use the belt pulley retaining bolt to draw the seal into position.

If not using the special tool, fit a new seal to the pump before you bolt it to the engine. Grease the inside of the recess lightly, push the seal in position making sure it is square, and gently tap it home with a hammer, moving around the seal as you go to make sure it goes down straight.

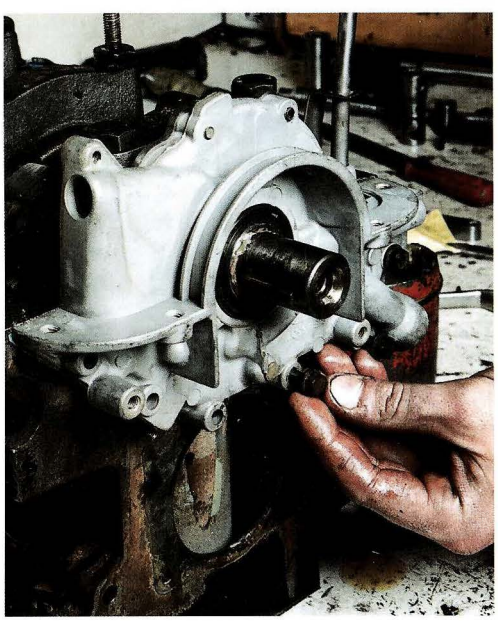
There is a step on the end of the shaft which the oil seal has to pass over, and unless you do something about it, the chances of ruining the seal are quite high. We know many experienced engine builders who just grease the end of the shaft and slide the pump and seal in place, but unless you are experienced it is best to do away with the step. Use the masking tape to build up the end of the shaft so that the step becomes a gentle slope, grease it well, and carefully slide the pump on with the inside of the seal sliding up the masking tape ramp. Bolt the pump in place, take the masking tape off and tap a new Woodruff key in the shaft.

Never, under any circumstances, fit the pump without the seal and then try to fit

▼ *Fit the oil seal to the rear cover, again using grease to help it go in squarely.*



▶ *Ease the oil pump over the nose of the crankshaft and make sure the seal is not cockled before fitting the bolts.*



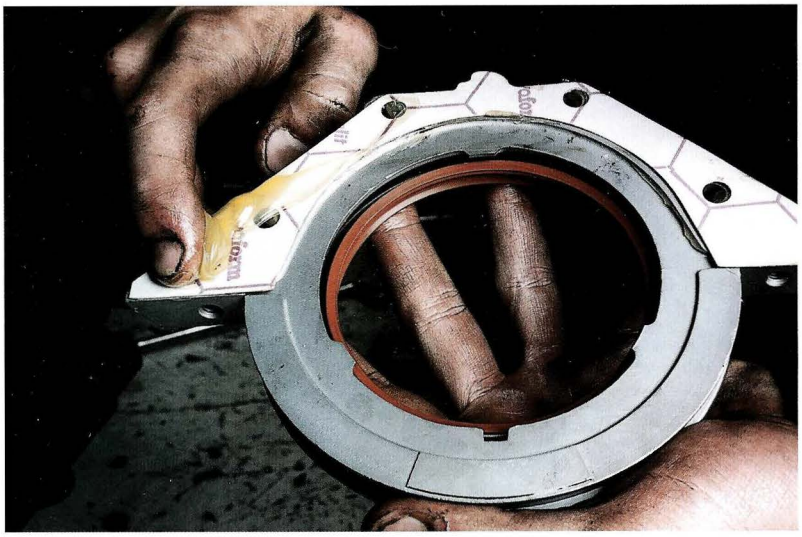
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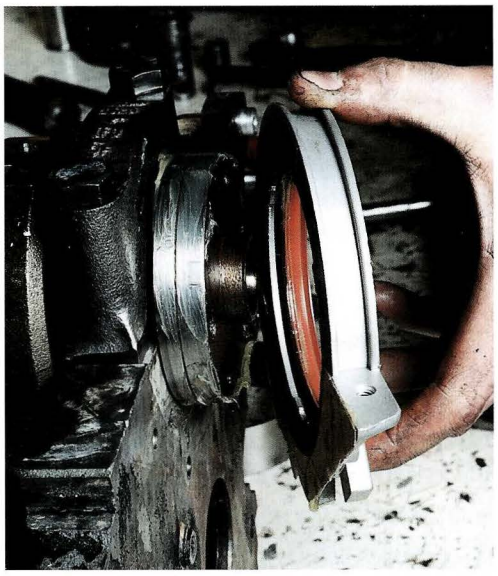
the seal afterwards by drifting it home with a piece of tube. This is a sure recipe for leaks.

Next fit the cam belt pulley guide, (Ford call it a thrust washer), with the concave side towards the oil pump, that is with the domed side outwards, and grease the end of the shaft before fitting the drive belt toothed pulley. There are two reasons for this. It is often a tight fit, and the grease stops it binding while you are putting it on and, without grease it can be extremely tight to get off in the future, as you may have found out when you dismantled the engine. Fit the toothed pulley with its flange outward and, as it is probably tight, use the fan pulley and retaining bolt to draw it on. Take the fan pulley off again because it is easier to fit the drive belt without it in the way. Bolt on the water pump, again with a smear of grease on the gasket, and then turn your attention to the back end of the engine.

Ford specify a special tool similar to the one for the oil pump seal, to draw in the rear crankshaft oil seal and again, you can order one if you really want to, but the job can be done without it. We would, however, advise you to use a much more simple aligning tool which can be obtained from most engine building shops.

Grease the recess in the rear oil seal carrier and, as with the oil pump seal, push the oil seal in square and tap it home gently with a hammer. The aligning tool needed is just a plain thin-walled tube. Treat it with care because if it becomes distorted it is then useless. Grease the inside of the oil seal, stick the gasket on the carrier with a smear of grease and push the aligning tube through the seal. Feed the carrier and tube over the end of the crankshaft making sure everything fits fully home. Line up the carrier with the mating face for the sump and tighten the bolts. It is possible to do the job without the aligning tube but the clearances in the bolt holes make it very easy to get the carrier slightly off centre which can lead to oil leaks.



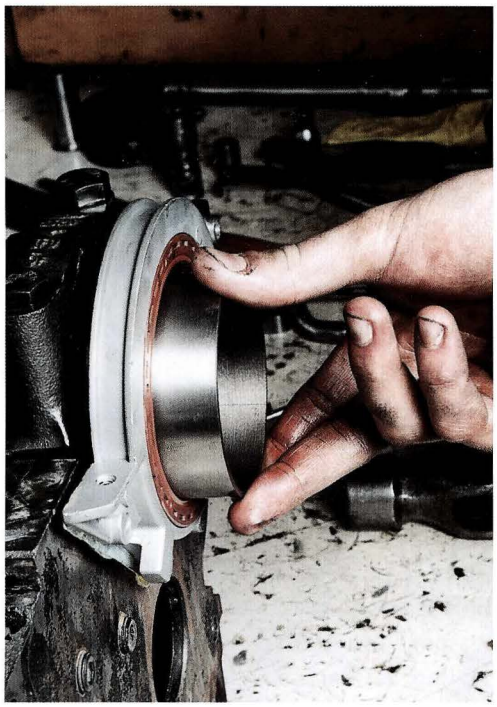


▲ *You do not need jointing compound on the gaskets, just a smear of grease is all that is necessary.*

◀ *Use grease again when you slide the rear cover into position.*

You can fit the flywheel now or later, but we prefer to fit it at this stage because the bolts are done up to a high torque and once the sump is in place it is difficult to stop the crankshaft turning. Before you fit the flywheel, fit the rear engine adaptor plate on its dowels. The flywheel will go on only one way because one of the bolt holes, marked with a small drilling, is offset. When Ford tells you to use new bolts in the flywheel, they mean it. If the bolts come loose you will get a terrible vibration and, if you do not stop the

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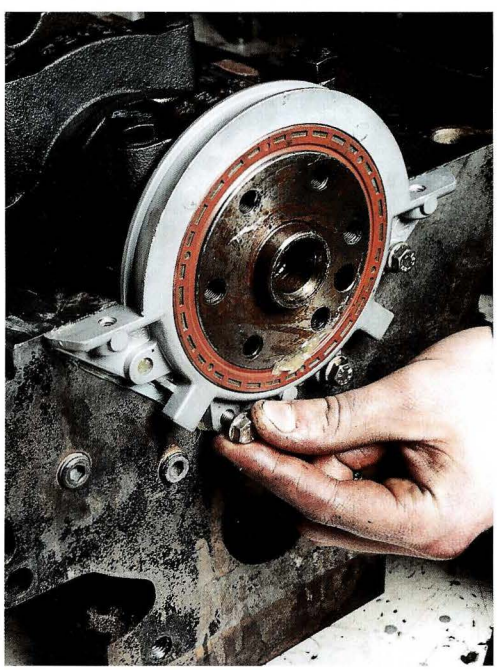
▶ *This is about the only special tool you will need; a sleeve to centralise the rear cover before bolting it tight.*

engine quickly it can do a hideous amount of damage. Coat the threads of the bolts with Loctite sealer before fitting and tightening them evenly to a torque of 60 to 68lb/ft (82 to 92Nm). You cannot get an accurate torque figure if the crankshaft turns while the bolts are being tightend, so wedge a block of wood between one of the rear webs and the side of the crankcase to hold it.

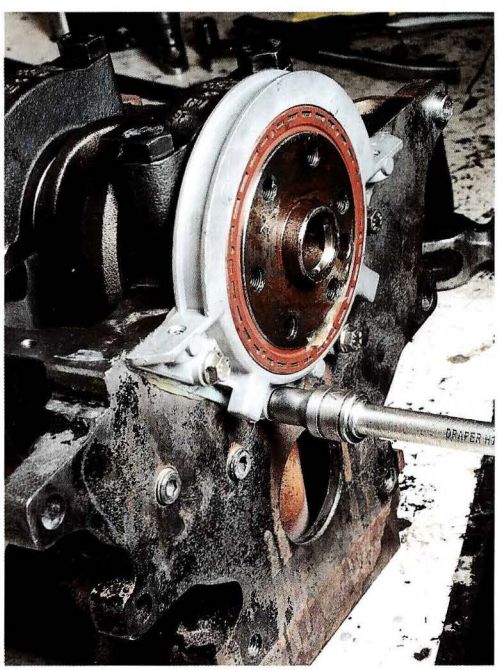
Depending on whether you have an early or late type of gasket set, you will either have a one-piece sump gasket or separate sealing strips for the oil pump and rear oil seal carrier plus two gasket strips for the sump, one each side. Before fitting either type, smear some jointing compound across the joins between the oil pump and the rear oil seal carrier and the sump face of the crankcase. (See the accompanying drawing.)

The one-piece gasket just fits in position with a smear of grease but, if you have the earlier type, fit the sealing strips to the oil pump and the rear oil seal carrier first. Then fit the two side strips. They are meant to overlap the ends of the other sealing strips, so do not think they are too long, and do not cut them.

If the side strips have been stuck down with grease they will probably stay in position, but it is easy to get the holes out of alignment when you lower the sump on. The best way to make sure the gaskets do not move is to use a couple of studs each



▶ *With the rear cover centralised, fit the bolts finger tight first, to hold it. Normally you would do this with the sleeve in place, but we took the sleeve away for the photograph.*

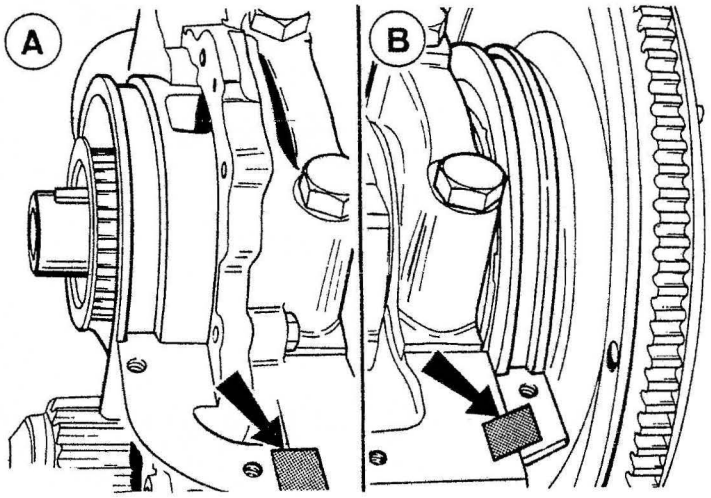


▶▶ *When you are happy that the rear cover is central, tighten its holding bolts.*

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side screwed in loosely, and take them out once a few sump bolts are engaged. If you do not have any studs of the right thread, use four fairly close-fitting lengths of round bar or studs that are slightly too small and will lift out easily. When you lower the sump down, make sure that the little pips on the face of the sump engage in the holes in the gasket, or you are sure to get leaks.

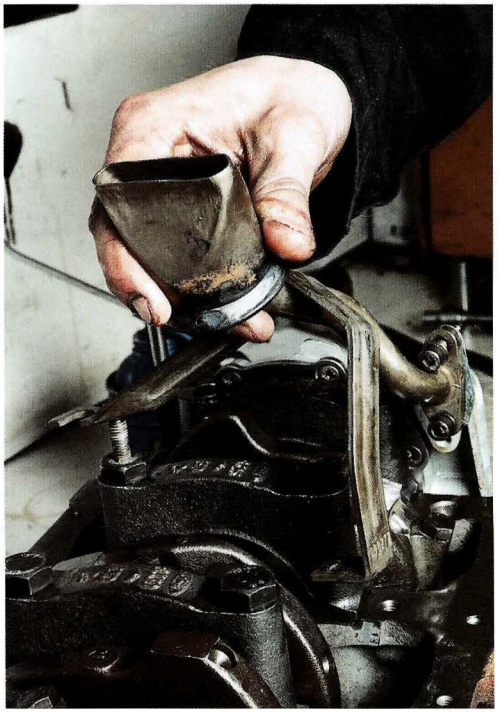
In Ford's manual, it tells you to torque down the sump bolts in two stages, and then gives you the same torque figure for both stages. It sounds silly, but what they mean is that as you torque down further bolts, the sump gasket compresses and the earlier ones you torqued become slightly loose. To make sure you do not get any leaks, tighten the sump bolts evenly a little at a time. The order of tightening is not critical, but do not tighten all along one side first and then tighten the other side. Go in a sort of criss-cross pattern and then finally go round again making sure that all the bolts are tight. The given torque figure is 6 to 8lb/ft (8 to 11Nm) for a multi-piece gasket and 4 to 6lb/ft (5 to 8Nm) for a one-piece gasket. Fit the drain plug now, before you forget it, and use a new sealing washer. You should, indeed, use a new sealing washer each time you do an oil change.



▲ *Before you fit the sump gasket put dabs of sealant across the joins between the two end covers and the block.*

Now stand the engine up on its sump and make sure the top face of the block and the tops of the pistons are absolutely clean before fitting the cylinder head. If you have a compressor, clean out all the cylinder head bolt holes with a blast of





◀◀ *Fit a new gasket to the oil pick-up pipe with just a light smear of grease to hold it in position.*

◀ *When fitting the pick-up pipe make sure the joint face seats squarely before you fit the bolt and nut to the support brackets.*

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▶ *The last job underneath is to fit the sump gasket and sump, and bolt it down.*

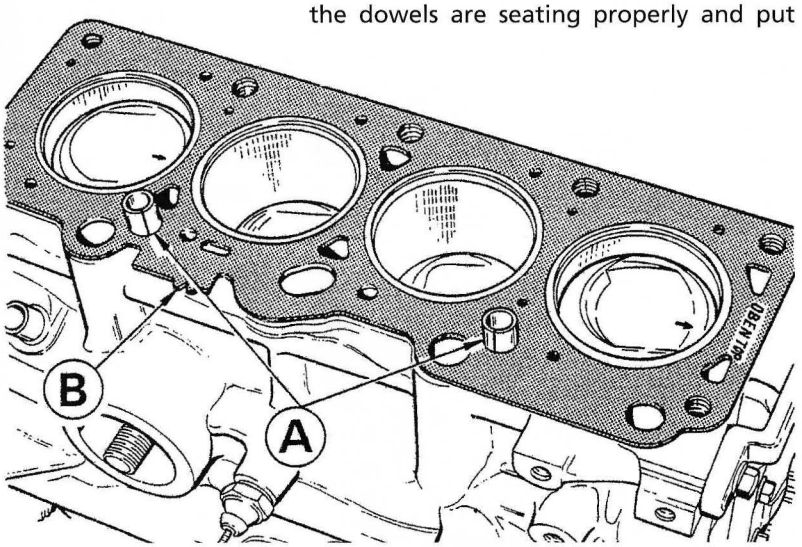


compressed air, but mind your eyes when you do this because if there is any muck in the hole it will fly out like a shotgun pellet. If any muck is left in the holes the bolts will not torque down properly, and if there is any oil or other liquid in them you can get a hydraulic lock before the bolts go fully home. You will think it is torqued down correctly, but it is not.

When everything is clean and dry, fit new locating dowels for the head, make sure the dowels are seating properly and put the gasket in place. Fit the gasket dry, without either grease or compound. Make sure you get it the right way up. One face is marked OBEN – TOP. It is assumed you have already assembled the cylinder head with its valves and camshaft, but before you fit it, turn the engine so that the piston of No. 1 cylinder is about ¾in (20mm) down from the top so there is no chance of the tops of the pistons hitting the valves. This will also bring it into a handy position for timing the camshaft when the head is on. Run a dribble of engine oil around the edge of each piston, lower the head down on to its locating dowels and fit new bolts.

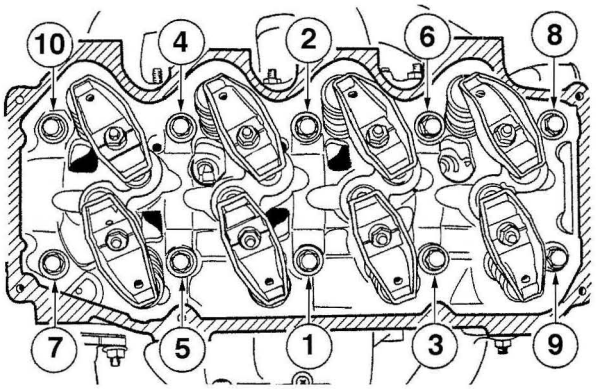
The head bolts are torqued down in four stages and it is important to tighten them in the correct sequence as shown in the drawing. Tighten first to 18lb/ft (25Nm) then go around again tightening to 40lb/ft (55Nm). Now mark the same side of each bolt head with a dab of quick-drying paint. Typewriter correcting fluid is ideal for this, or you could use marking crayon or, at a pinch, chalk. Now go around in sequence without the torque wrench tightening each bolt through 90 degrees and then go around again tightening a further 90 degrees. When finished, check that all the paint marks are pointing in the same direction so you know you have not missed a bolt. As an alternative to marking the bolt heads you can use an angle gauge fitted on your socket bar, as shown in Chapter 1.

▼ *With the engine back up the right way, fit the head locating dowels (A) and the head gasket. Ford gaskets for different size engines are identified by teeth at B.*



Before you can fit the timing belt you have to bring the crankshaft and camshaft to time, so start by setting the camshaft so that the pointer on the pulley lines up with the TDC mark on the front of the cylinder head. Then turn the crankshaft until the small pip on the crankshaft belt pulley lines up with the mark on the oil pump casing. This is usually in the same position as the crankshaft keyway. Take the shortest route when you turn the crankshaft. If you go the long way round there is a distinct chance that a piston will hit a valve.

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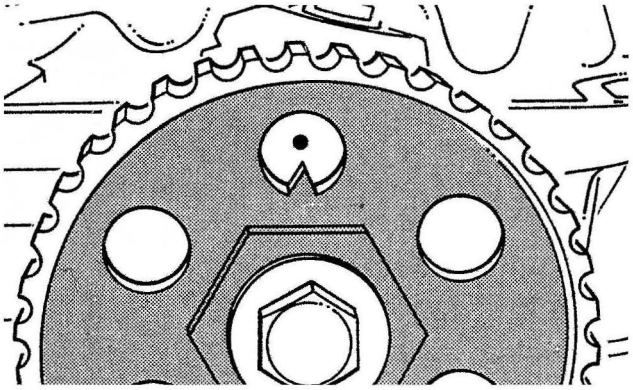
▲ *The tightening sequence for the cylinder head bolts. Follow the torqueing-down procedure accurately.*

Fit the belt tensioner loosely and push it over fully to the left. Older tensioners had a spring on them but the later ones don't, and Ford says there is no need to fit a spring. Fit the timing belt, starting at the crankshaft pulley and go anti-clockwise straight up to the camshaft pulley and back down over the right-hand side of the tensioner and over the water pump. Push the tensioner over to the right to give the belt an initial tension, then turn the crankshaft one full turn, 360 degrees, clockwise – that is the normal direction of rotation – to settle the belt.

Check again that the timing marks on the camshaft pulley and the crankshaft pulley line up with their marks and then turn the crankshaft back through 60 degrees to bring it to the belt tensioning position. To save measuring 60 degrees, it is the same as three teeth on the camshaft pulley. If you have, or can borrow, the Ford tension gauge, now is the time to use it, but if not, tension the belt until you can just turn the longest run through 90 degrees with your thumb and finger without straining your muscles too hard. If you have to alter the tension, turn the crank through 360 degrees again and check the tension, doing this every time you have to adjust the tension. As a final check by hand, push the belt inwards in the middle of the longest run of the belt. You should get a deflection of about 10mm with reasonable finger pressure. Finally, bring the engine back to its timing marks yet again to do a double check.

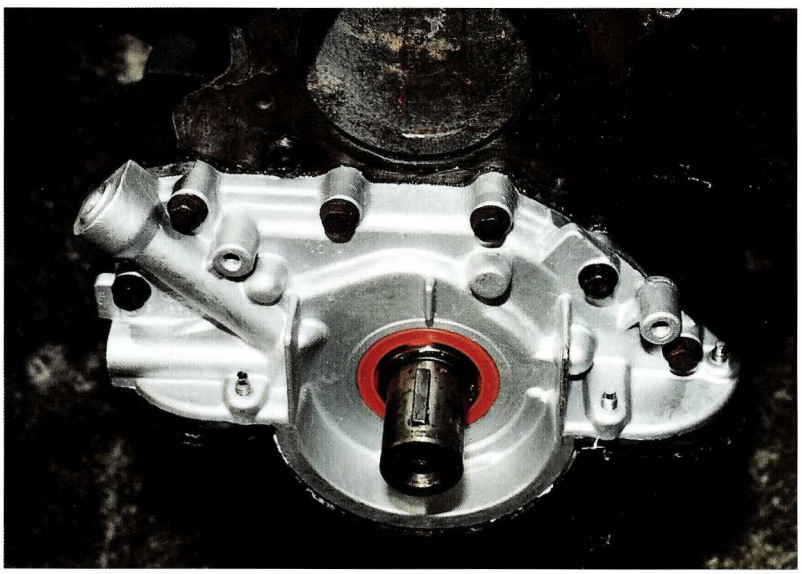
If fitting a performance camshaft with a vernier adjustment pulley, it should have a degree scale engraved on it. Follow the camshaft maker's instructions for optimum timing but remember, after slackening the adjustment screws, to turn the centre part attached to the camshaft, not the outer part which carries the timing belt or you will upset the crankshaft position.

Leave the engine at TDC with No. 1 cylinder at the top of its compression stroke. It is easy to do this while the rocker cover is off as you can watch the camshaft to make sure that neither of the valves is



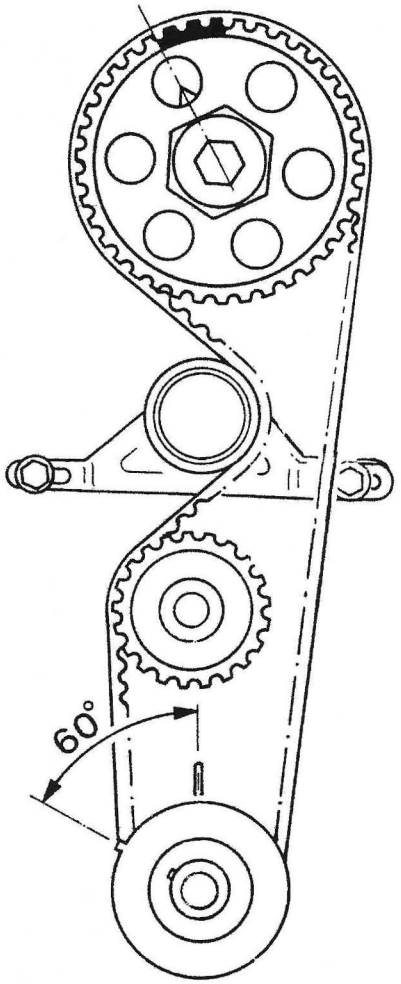
▲ *Before you lower the head in position, bring the camshaft to time with the pointer on the belt pulley opposite a small hole in the head.*

▼ *Bring the crankshaft to TDC by lining up the belt pulley key with this mark on the oil pump casing.*



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▶ *When checking the belt tension, the crankshaft needs to be turned back through 60 degrees. This is the same as the camshaft pulley turning back by three teeth.*



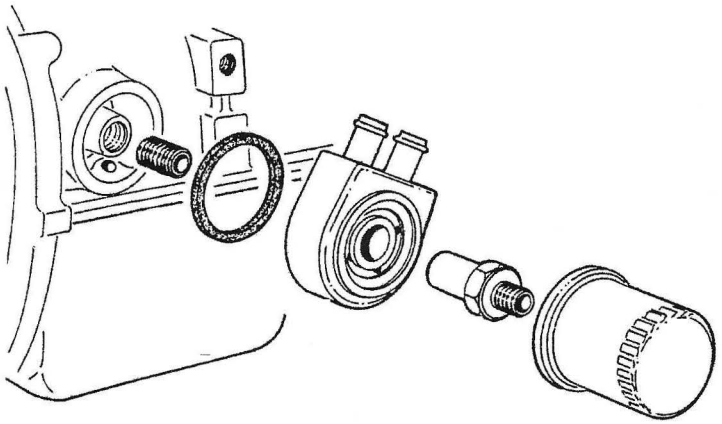
open, and this is a big help when you come to fit the distributor.

Fit the belt covers, two-piece on early engines and one-piece on later ones, fit the crankshaft V-belt pulley and tighten the bolt. While you are about it you might as well fit the water pump pulley at this stage. Fit the rocker cover, again with a smear of grease on the gasket, and the same with the fuel pump. Whether or not you fit the alternator, distributor and engine mounting brackets at this stage or later is up to you, but as timing the distributor is the same whether you do it now or later, we will run through it here.

You should already have the engine set with No. 1 cylinder at the top of its compression stroke, so turn it back until the pointer at the front is opposite the correct mark for the number of degrees before top dead centre applicable to your engine, usually 12 degrees BTDC. Before you fit the distributor, check the O-ring at the drive end and, if there is any doubt about it, fit a new one. We usually fit a new one anyway.

There were two makes and two types of distributor fitted to the CVH, but you need only consider the type. Always use the later type which has only two fixing bolts and which fits on earlier cylinder heads satisfactorily; you just leave one bolt off. Fit the rotor arm and turn it until it points to the firing position for No. 1 cylinder which is roughly at the 10 o'clock position (see drawing). The offset dog on the drive end should now be more or less in the correct position to engage with the slot in the end of the camshaft. Push the distributor home and fit the holding bolts finger tight. If using the distributor which came with the engine you may well find two punch marks, one on the distributor and one on the head, which were put there after the ignition was first timed, so you can line them up again. If you have a different distributor, do not trust the punch marks as they may not be accurate, so set the distributor in the middle position of the elongated holes in the fixing lugs. This will be accurate enough to start the engine, and you can set the

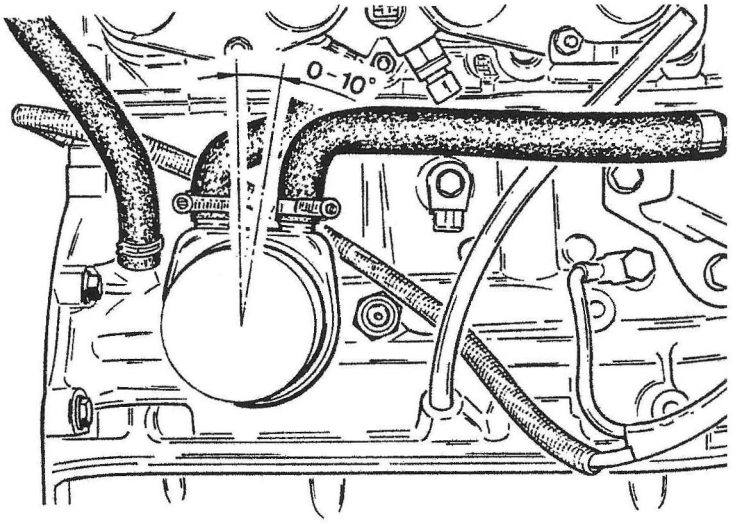
▼ *If you are fitting an oil cooler it bolts to the oil filter housing with a hollow stud.*



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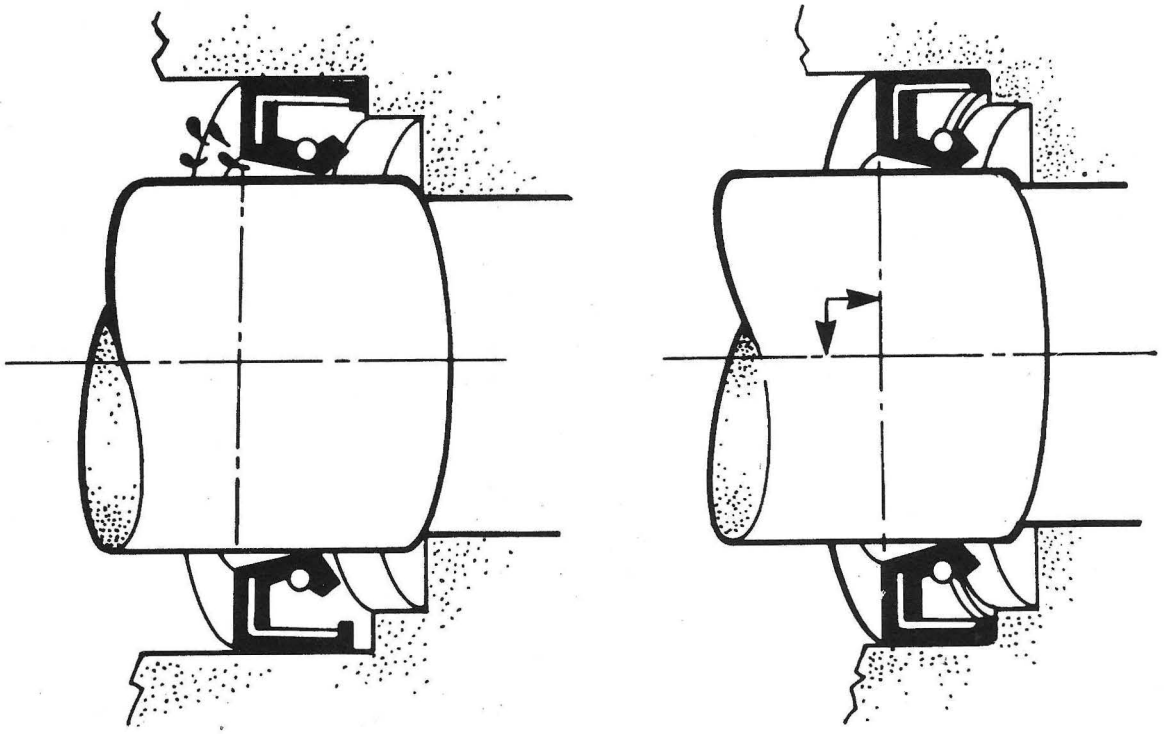
timing accurately with a strobe lamp once it is running.

Whether or not you fit the other auxiliaries such as starter motor, manifolds and so on before the engine goes back in the car or after, is up to you. If leaving it as it is for now, fit cardboard covers over the inlet and exhaust ports and hold them with masking tape, mask off the water inlet and outlet pipes and screw in an old set of sparking plugs so that no dirt can find its way inside the engine. You can, if you want, fit the new plugs, but we prefer to fit old ones until the engine is in the car then, if you break a plug when lifting the engine in it does not matter. If you want to paint the engine, now is the time to do it. Wipe the outside over with petrol because there are bound to be traces of oil about, and let it dry thoroughly before painting it. If you are not yet ready to fit the engine back in the car, wait until the paint is dry then put it in a safe place in the garage where you will not keep tripping over it, and cover it over with a large plastic bag.



▲ *The oil cooler adaptor must not be turned anticlockwise. It must be upright or, at most, 10 degrees clockwise.*

▼ *Oil seals must sit squarely in their recesses, as on the right. If they are tilted, as on the left, we guarantee they will leak.*



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Chapter 21

Building the head

Rebuilding the head might sound an easy enough job, and it is, provided you take a little care. We will assume the head has been cleaned thoroughly, the valve guides attended to and the ports either gas-flowed or cleaned and matched to their manifolds. Once again we want to repeat what we said in the Introduction.

If you have not yet started on the head, and if you did not do it before, check for any markings which indicate that it has either oversize cam follower bores or oversize camshaft bearings, or possibly both. The markings are T.25 for 0.25mm oversize follower bores and C.38 for 0.38mm oversize camshaft bearings. We have known people spend a lot of money on having a head gas-flowed only to find later that they have difficulty getting the oversize camshaft and followers.



▶ *The valve seats on this head are worn and pitted, and need refacing. The valve guides are also slightly worn and need sleeving.*

If you forgot to take the manifolds in when you took the head for valve guide inserts and valve seat grinding, or if you have gone for an exchange gas-flowed head, the ports will not be matched so now is the time to do it, not later when the grinding dust is going to get all over the valves and camshaft. Before starting on the ports though, fit new core plugs using the method we described in Chapter 20 Building the block.

We pointed out the importance of matching the ports and manifolds in the chapter on basic tuning, but we did not go into detail so we will do that now. The main thing you must avoid is a step in the join which will impede the gas flow and set up back eddies.

Really fussy tuners who are going for top power in competition classes where very little modification from standard is allowed, often dowel the manifolds to the head before port matching so the manifolds do not move with the bolt clearance. On a fast road car it is being a touch extreme but, if you want to have it done, the manifolds are bolted to the head and then a couple of holes are drilled through the flanges and into the head

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▶ *Before any work can be done on the head it must be cleaned thoroughly.*

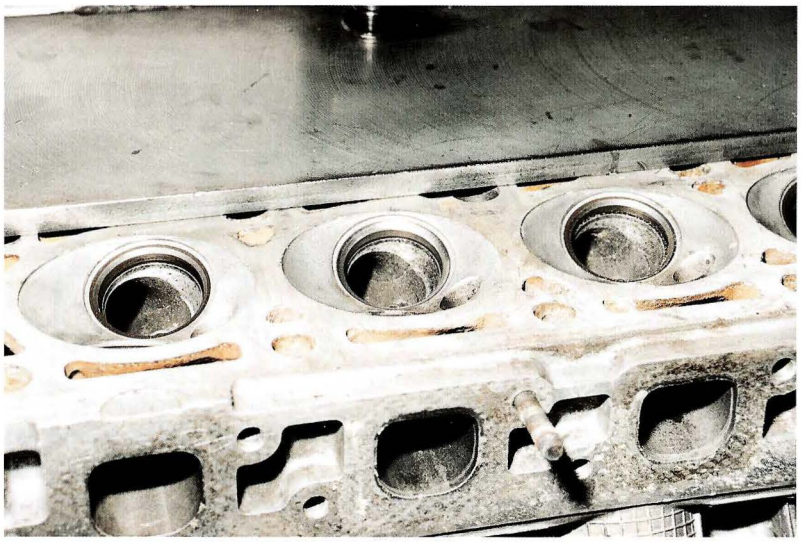
being very careful not to go into the water jacket. This is why we said have it done, not do it at home unless you feel supremely confident that you know exactly where the water jacket in the head is.

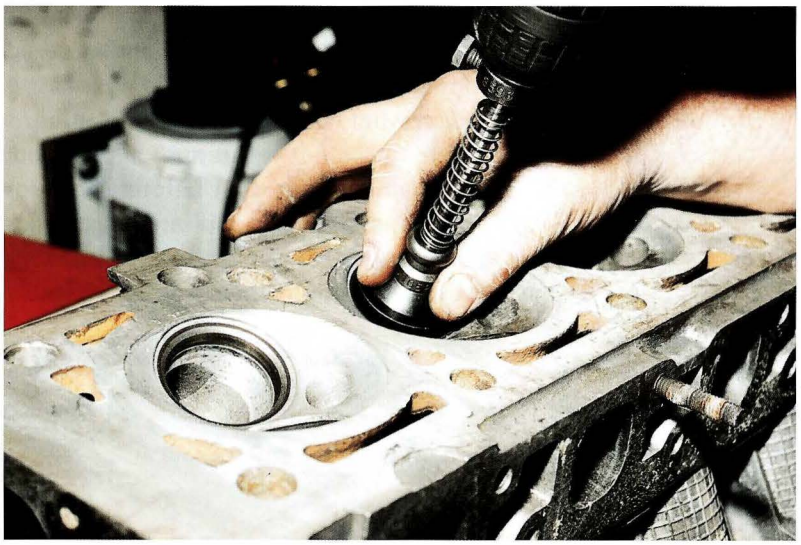
After drilling, the manifolds are taken off, the holes in the head are reamed to be a press fit for the dowels and the holes in the manifolds reamed to be a close clearance fit on the dowels. After the dowels are fitted, you can enlarge the bolt holes in the manifolds very slightly to make sure that the manifolds are being located by the dowels and not binding between the dowels and the bolts. If you don't, you may find that the manifolds do not bolt up to a proper gas-tight joint.

You need power riffler files to grind ports and the manifold. Small shaped grinding stones are OK on cast iron, but we much prefer to use riffler files instead of stones on aluminium, so there is no chance of grinding dust being embedded in the aluminium surface where it can hang about until it comes free and goes off into the engine to continue grinding things you do not want ground. You can fit the riffler files in an ordinary electric drill, and they will work, but not at their best because they are designed to be run at much higher speeds. You really need the proper tool, which looks rather like a large power screwdriver. These used to be only in the province of professional tuners and toolroom workers and were very expensive. The professional models still are, but within recent years most of the popular power tool makers have brought out home rifflers at very reasonable prices. They may not be robust enough to stand up to everyday professional use but, if you treat them with care and don't let them overheat, they will last a long time.

Before you can start you must know where to riffle and, as you cannot see the match of the manifold and head port very well when it is bolted up, you need some guidance. Dealing with the inlet side first, we want the head ports to be very slightly larger than the ports in the manifold, so the first step is to smooth any roughness on the edges of the manifold ports without taking off more metal than you have to. Avoid making a sharp bevel at the edge. Wherever you have to take metal off, taper the chamfer gradually back into the manifold.

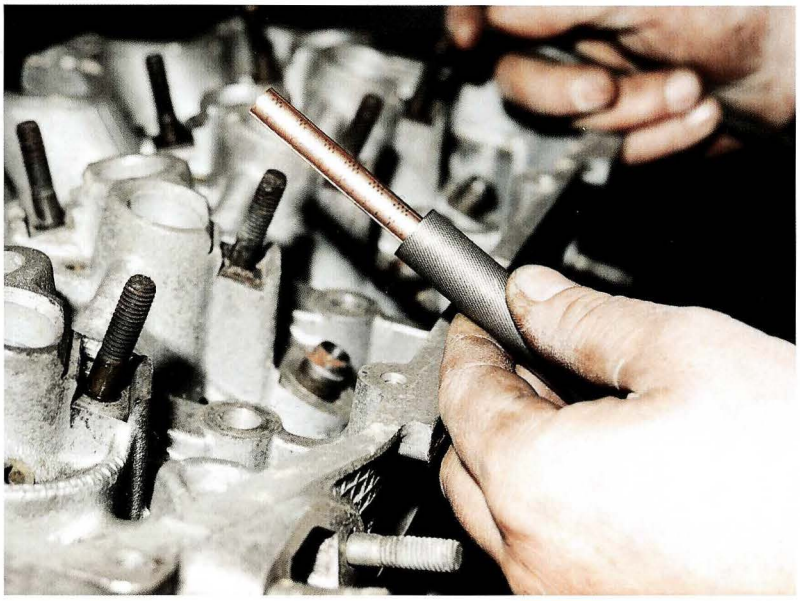
When satisfied, cut a piece of card wide enough and long enough to cover the ports, fit it against the head and smear the faces of the manifold with blue marker





▲ *Attention to the guides starts with reaming them out, using a cutter located on the old valve seat.*

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▲ *The copper sleeve is first placed in a tubular mandrel.*

which you can buy in the better equipped tool shops. Bolt the manifold on using your piece of card as a gasket and, when it is unbolted you will have the outline of the manifold ports neatly marked on it. Lay the card on a flat piece of wood and cut the holes out carefully with a scalpel blade. (Scalpels and blades are available quite cheaply from art shops.)

Lay the card back on the head and look to see whether or not any of the edges of the head ports stick out into the gas flow.

▼ *The mandrel is held over the reamed guide and the insert driven down.*



If they do, riffle them back, again making a gentle chamfer, not a bevel, until the head port is slightly larger than your template. There is no need to overdo it; 1 to 1.5mm larger is quite enough, although do not worry if the head port is already larger in places by slightly more than this. Having made sure there is no step between the manifold and head to obstruct the gas flow, you have to try the gasket to make sure this does not stick down into the enlarged holes. Match the holes in the gasket to the head ports so that you do not get a rim of unclamped gasket edge.

On the exhaust side you need the opposite state of affairs with the manifold ports slightly larger than those in the head. This has a double advantage. As with the inlet side, it gives a step-free flow to the gases going out, and it also helps to stop back pressure from driving burnt exhaust gases back into the combustion chamber.

It is not widely realised that the burnt gases can get back into the combustion chamber, but they can because when fighting against a fast outflow of exhaust gas from the combustion chamber when the exhaust valve opens, the back pressure tends to push earlier burnt gases back along the wall of the exhaust pipe and manifold. You then have a sort of sausage roll effect with the exhaust gases which are being pushed out by the piston rushing in a fast stream down the middle of the pipe like the sausage meat, and the much slower but very much unwanted back pressure gases creep back along the walls of the manifold like the pastry. If you have the ports in the exhaust manifold slightly larger than those in the head, these back pressure gases meet the step where the manifold joins the head and are deflected into the main stream of outgoing gas which carries them back down the pipe. You don't need much of a step, 2mm is ample, and even 1mm helps. What is important is to fit the port holes in the gasket to the larger port holes in the

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▶ *The sleeve is driven down until it is flush with the bottom of the guide leaving the excess sticking out of the top.*



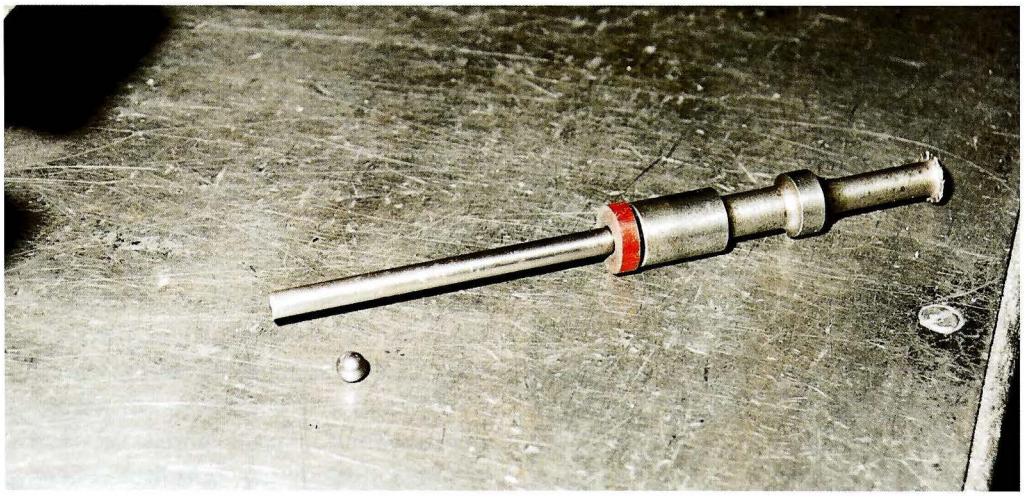


manifold, not the smaller port holes in the head, otherwise there is a rim of unclamped gasket exposed to the searing hot exhaust gases, a condition which can start the gasket burning and, eventually, a manifold leak.

Be very careful if you have a tubular performance manifold. It is easy to get too enthusiastic and grind away so much of the flange that one of the pipes parts company with it. Only the flange itself should be ground and, if you have any doubts about it, consult the people who made the manifold. It's just possible they can change it for one with larger ports.

When satisfied with the matching of the ports, give the head a thorough clean to get rid of any trace of grinding dust, and do not forget to clean out the manifolds as well. This is particularly important with the inlet manifold as any metal or grinding stone dust left in there will be drawn into the engine on the first inlet stroke. The next step is to fit new core plugs using the technique described in the previous chapter on rebuilding the block.

If you have a low-mileage head with the valve seats and guides in good condition it may be decided that you do not need to



▲ *The exposed part of the sleeve is broken off flush with the top of the guide using this tool, before burnishing.*

◀ *This accurately ground and hardened steel ball is driven down the bore of the sleeve to burnish it to size for the valve.*

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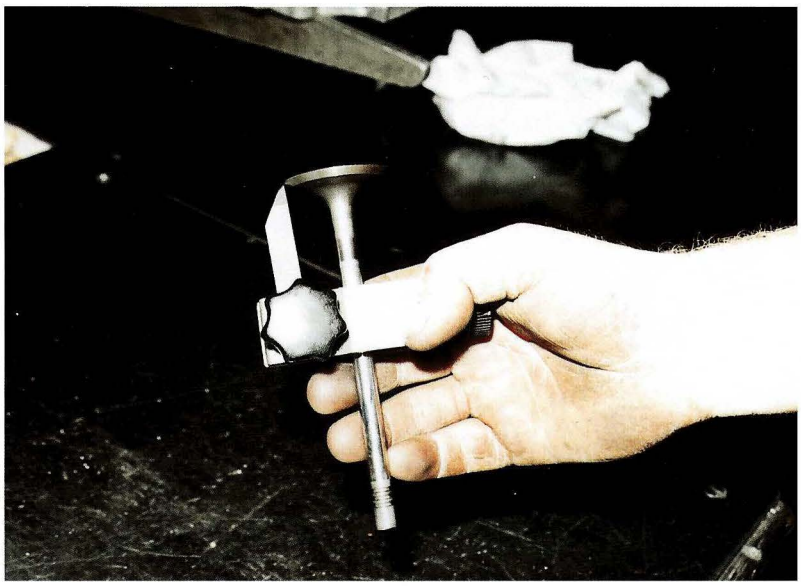


▲ *Burnishing the sleeve stretches and elongates it slightly so the top is faced down with a spot cutter.*

have guide inserts or to have the seats recut. All you may consider is necessary is a light grinding-in of the valves. We cannot tell you whether or not your valve seats need recutting but, as a rule, if a dozen or so strokes with a valve grinding tool and fine grinding paste does not give you a clean grey seat, think seriously about having them recut. What is usually found is that the seat is a slate grey over most of its surface but there are pits and pin holes in the surface.

Some books will tell you to get rid of these with coarse grinding paste and then switch back to fine. This may be all right for a run about town 'cooking' engine but it leads to pocketed valves which restrict the gas flow, but we do not have any coarse grinding paste in our workshop. If you have any pretensions towards increased power, and the seats do not come up clean first time, have them recut. Take the head to a tuning firm which will machine them at the Ford-specified three angles with a special cutter, not to a small local workshop which uses a grinding stone with just one angle. The engine will still run well enough with the seats cut at a single angle, but you will not get anything like the best gas flow.

▼ *For cutting the new seat, the diameter of the valve is measured on this jig.*



If you had the head gas-flowed with larger valves it will probably come back to you with the valves and springs ready assembled and if you are fitting the valves yourself, there are a couple of important points to watch. The first is whether or not you grind in new valves. Most tuners will tell you that the quality of their seat machining and the accuracy of the valves they supply makes even the lightest grinding-in unnecessary, and in most cases they are right. New Ford valves should not be ground in because the seats are coated with a fine layer of material which helps them to bed down quickly to the recut seat. There remains the awkward case if you have had the seats recut because the guides have been sleeved but are thinking of using the original valves again, or maybe just the inlet ones, because they're in good condition. If you want to do this, ask the firm that did the sleeving and seat cutting as to how much they will charge for refacing the valves and compare this with the cost of new ones. Do not grind-in an old valve against a newly recut seat. You will spoil both, which is a waste of effort and money.

The second point concerns valve springs. You would be foolish not to fit new valve springs after a complete head overhaul but take care if you are also fitting a high-lift

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camshaft. It is possible for the cam to push the valve so far open that the valve spring becomes coil bound, with the coils tight up against each other before the cam reaches the point of maximum opening. If this happens, something is going to break. We dealt with performance camshafts in Chapter 7, and you should have asked the camshaft supplier if you need to use special springs, or if you have to have the spring seats in the head spot-faced deeper to allow the cam to push the valve fully open before the spring becomes coil bound.

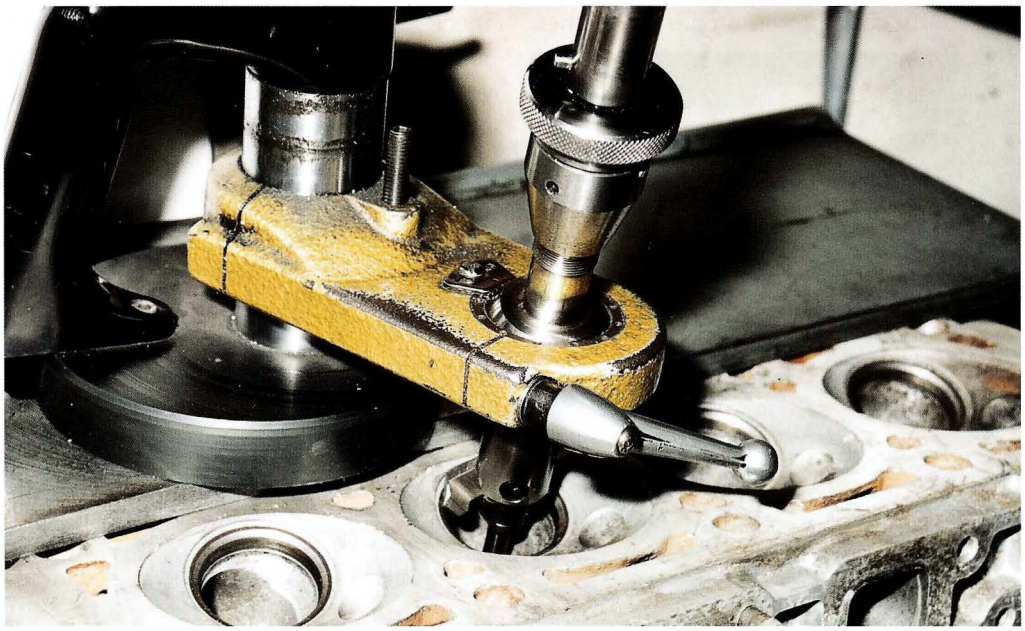
If so, the tuning firm which is doing other work on your head can spot-face the seats and then fit shims under the springs to get the optimum setting, so as to give maximum poundage in order to keep the valve stem against its follower without bouncing and without the coils binding at full opening.

Once you have all this sorted out, fitting the valves follows the usual practice. Ford dealers use a special tool which fits on the head for compressing the valve springs but, as we said in the chapter on dismantling, any good quality proprietary compressor with a fairly deep throat and a slim head will suit. The same one, indeed, that you used for taking the valves out. Fit new valve stem oil seals before you put the valves in place, and smear them with a little engine oil to help them bed down. We like to put a smear of graphite bedding-in compound on the valve stems to help the valves settle down during the initial starting-up period.

When you fit the valve spring collets a light smear of grease helps to hold them in position while releasing the pressure on the spring. When they are all in, put the head face down on the bench and hit the



▲ *The jig is then used to set the fly cutter on the refacing machine.*



◀ *The mandrel which carries the fly cutter is located in the newly sleeved guide. The cutter refaces the seat to the three angles specified by Ford.*

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▲ *After a thorough clean to get rid of any cutting swarf, the valves, oil seals and springs are fitted.*

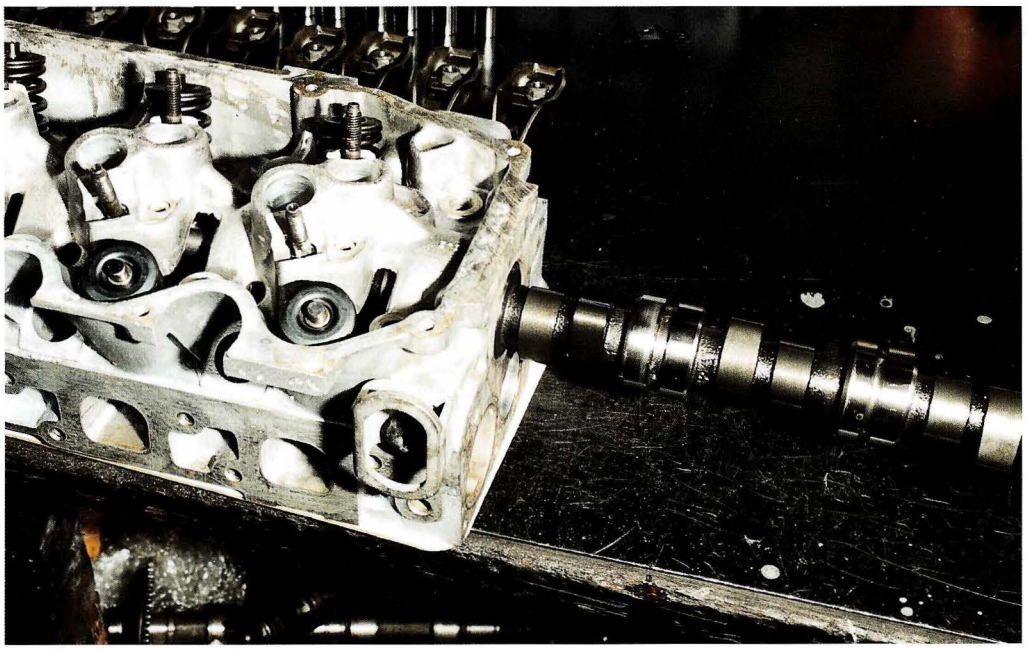
top of each valve fairly hard with a nylon or hide-faced hammer to bounce the valve slightly and make sure that the collets bed into their seats on the valve stem. If you fitted the collets properly there is no chance of a spring flying off, but keep your face out of the way because of the remote possibility that yours is the one in a million chance where the collets look OK but one is riding out of its groove.

At this stage we like to fit the camshaft front oil seal. We know the manuals say fit it after the camshaft is in place, using the special tool, but at least one well-known specialist engine builder does not use it. They do as we do and tap the oil seal into its recess in the head using a good coat of oil to help it in and, going around and around it, tapping gently with a hammer until it is flush with the surface. When fully seated it sits just a shade lower than the surface so you need to finish off with a fairly wide drift. If done carefully you should not get any oil leaks.



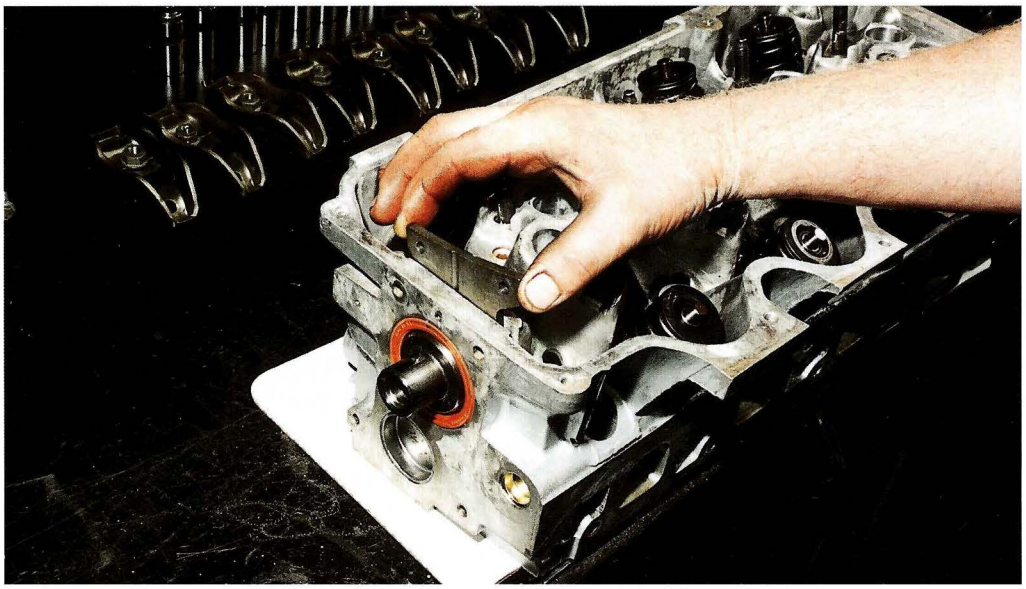
▲ *With a smear of grease to help it, the camshaft oil seal is tapped down into position.*

Now run some engine oil around the



▶ *The camshaft is fed in from the back (distributor end) of the head taking care not to catch any of the cams on the bearings.*

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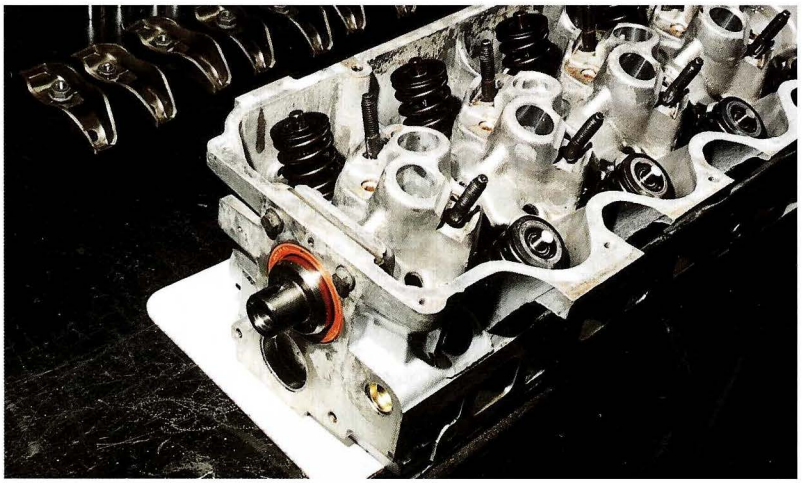


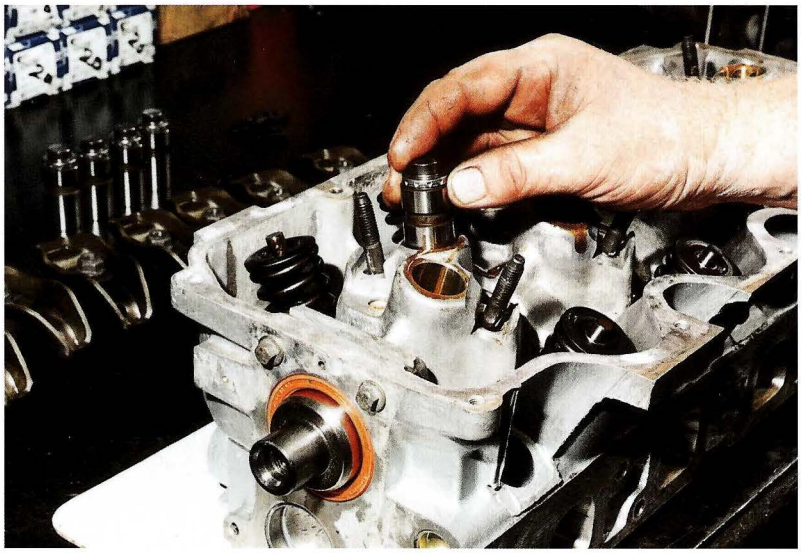
◀ *The camshaft may have to be tapped gently back and forth a little to let the thrust plate drop into place.*

▼ *With the thrust plate bolted in position, turn the camshaft a few times to make sure it is free.*

inside of the camshaft bearings and feed the camshaft in gently from the opposite end to the seal, taking care not to catch the sharp edges of the cams on the edges of the bearing housing. If you are unlucky enough to catch one, take the shaft out again and check you have not raised a pip on the edge of the bearing which will prevent the camshaft from seating properly. If you have, remove it with a scraper. Once the camshaft is home fit the thrust plate and check the camshaft end float. You may have to tap the camshaft gently back or forwards to get the thrust plate to drop into position. The specified end float is 0.002in and 0.006in (0.05 to 0.15mm). You probably won't have a 0.002in or 0.006in feeler gauge in your set, it will probably start at 0.005in and jump to 0.008in. Therefore, if the 0.005in slides in freely but the 0.008 won't, it's fine.

If you can just force the 0.008in feeler tightly into the gap, do not worry unduly, a thou or so too much end float will not hurt, but too little will. If the 0.005in does not go in, an experienced fitter may judge by feel if there is enough end float, but if





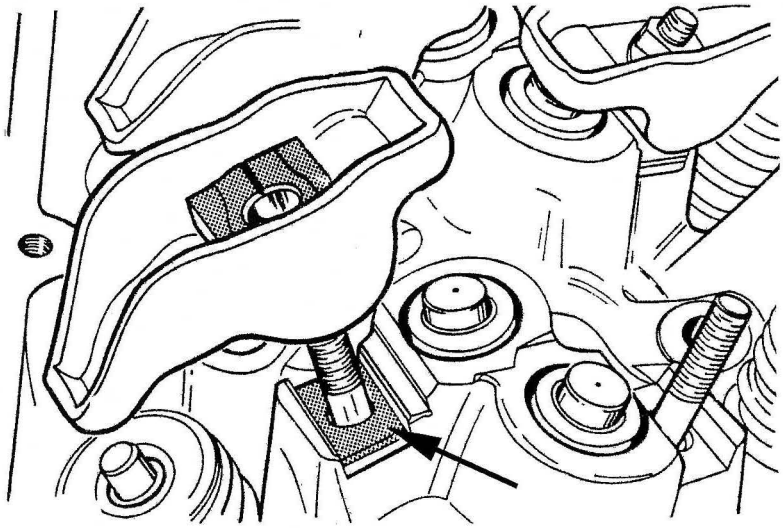
▶ *The hydraulic cam followers are coated with cam lube before being pressed down into position.*

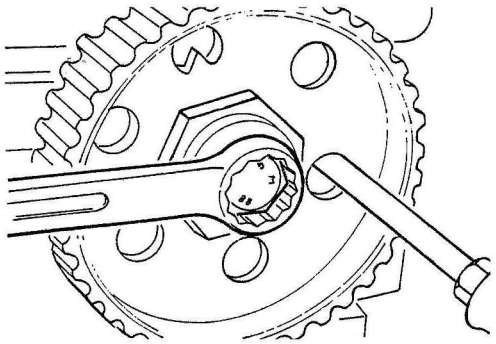
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▲ *The last job is to bolt on the rockers with their spacers and plates with the head ready for fitting to the block. There are no tappets to adjust.*

you have any doubts, either go to a well-stocked tool shop and buy a 0.002in feeler blade or ask someone with a dial test indicator to measure the end float for you. If it is less than 0.002in and the thrust plate feels tight when you put it in, you can either rub the plate down slightly using emery cloth on a flat surface, or take it along to a Ford dealer to see if he has a slightly thinner one. It will not be listed as thinner, but the manufacturing tolerance is 0.1965 to 0.1972in, only three-quarters of a thou, and you may have both a camshaft and thrust plate that are on top tolerance. This is known to people who build





▲ *Wedge the camshaft belt pulley with a stout screwdriver while you torque up the bolt.*

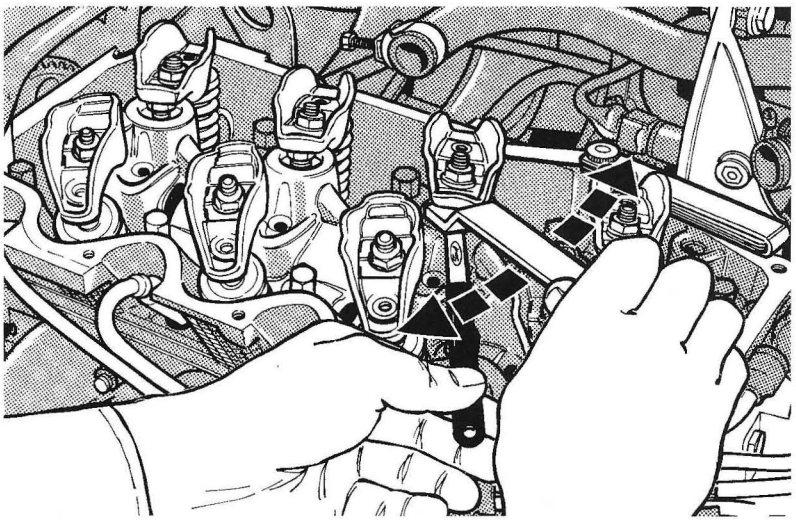
'blueprinted' engines as selective fitting. If you do not already have a key in the end of the camshaft, fit one now and then rotate the camshaft to make sure it is free. It may be too tight to turn by hand because there is nothing to get hold of, so either fit the belt pulley temporarily or use a pair of grips, with a rag as protection, on the boss of the shaft and key.

Oil the hydraulic valve lifters before you fit them in their original bores, but do not use engine oil. Either get a small bottle of hypoid gear oil and coat them liberally with this, or use some of the cam lube that came with your performance camshaft; it helps ease the initial loads on first starting up.

Fit the spacer plates, rocker arms, or cam followers as they are often termed, and the rocker arm guides and tighten the holding nuts to the correct torque. It helps to turn the camshaft as you fit each arm so that the base of the cam is pointing towards the arm as you fit it, and support the head on blocks of wood while the shaft is turned to make certain that none of the valve heads hits the top of the bench. The hydraulic lifters give zero lash, so there are no tappets to set. Fit the belt pulley and lock it against the head with a screwdriver through one of its holes while you tighten

◀ *Do not forget this small spacer plate under the rockers or you will never get a quiet engine.*

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▶ *The CVH in the RS 1600i Escort used mechanically adjusted rockers. There is a special Ford spanner for adjusting them but, be warned, they are very tight.*

and torque up the bolt. Turn the belt pulley to its timing mark, with its pointer level with the small depression in the head, then you will not forget to do this when bolting it onto the engine.

When finished, fit a new temperature sender, again so you do not forget it later, rub everything over with an oily cloth, put the head safely aside and cover it over until you are ready to fit it on the block. Remember to store it on its side, or on blocks of wood, to make sure none of the valve heads hit the bench where it is stored.

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Chapter 22

Power and clutches

Tuning an engine for extra power can often lead to clutch problems, but much of the time, people don't refer to them as such, although they describe the symptom. Slip, spin, squeal and judder might sound like a firm of estate agents or solicitors, but they are the four main symptoms of something starting to go wrong inside the bellhousing.

First on our list is slip. This is when the engine speeds up without much acceleration and you have that nasty feeling in the pit of your stomach that a big expense is looming on the horizon.

Sometimes you have slip just because the clutch is reaching the end of its life after long service of fair wear and tear. But a lot of premature slip occurs because the clutch cable is out of adjustment. Ford's clutch operation is all mechanical, so you do not have any hydraulic cylinders to mess about with and, in the old days of simple machines like rear-wheel drive Escorts and Cortinas, clutch adjustment was also simple. There was a threaded rod and two nuts on the release lever at the bellhousing. You checked the specified free play and adjusted the nuts until it was right. A ten-minute job.

Then Ford went and made it even more simple by fitting a pawl and ratchet self-adjusting mechanism at the top of the clutch pedal so you did not even have to check it. The only trouble with this is, that because you do not have to check it, or at least you are not supposed to have to, it sometimes misbehaves itself so that the release bearing is pushing against the diaphragm spring a lot of the time. Turn on the power, and the clutch slips. The answer is to strip and clean the self-adjusting mechanism – it is not all that difficult to take off once the cable has been disconnected. Look for broken springs, worn teeth and a sticking pawl. If you find any, renew them.

Next we come to spin, the opposite of slip, where the clutch does not disengage properly, and you get a graunching sound when you engage first or reverse gear from rest. Again, this can be caused by bad cable adjustment, but it can also be caused by troubles inside the bellhousing. One of the most common is that the centre plate, the one with the friction linings on it, is not freeing itself properly from the flywheel and the pressure plate. It can be one of three reasons why it is not doing this. One is that there is a slight oil leak from the engine through on to the clutch. If you get a lot of oil coming through it can cause slip but, in its early stages, an oil leak quite often causes the clutch to stick and spin because it can become quite hot and the oil burns to a sticky resin-like stuff that gums things together. Slip comes later when the oil burns itself to carbon.

If you find this sort of thing when you take a clutch out, don't just clean up the flywheel and slap a new clutch in or you are likely to get the same problem again in a few hundred miles or so. Investigate the

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source of the oil leak, which is almost always a worn crankshaft rear oil seal, and cure it.

A second reason for spin is that the clutch centre plate is warped. It does not often happen and, to be honest, we do not know the reason why a few do warp and the rest don't. All you can do is check that everything else is all right and renew things as necessary.

The third reason is that the centre plate is sticking on the splines of the gearbox shaft because the splines, either in the plate or on the gearbox shaft are worn and ridged. Before fitting your tuned engine back to its gearbox take a good look at the splines on the end of the gearbox shaft. Try the new centre plate on them and, if it does not slide freely, look for signs of ridging on the shaft splines. Once again, on a very high mileage car, this can be fair wear and tear, but we have come across a couple of cases at relatively low mileage and, in each case, the owner had fitted a cheap pattern clutch made somewhere east of Suez, where the splines in the centre plate were too sloppy. Each time the drive was taken up, the centre plate jerked on the shaft and eventually wore a ridge. We have heard of people trying to clean up ridges with an oil stone, and have even seen it advocated in print but, in our opinion, that is only storing up trouble for the near future. If you have been getting spin and find the clutch shaft is ridged, the only safe answer is to strip the gearbox and fit a new clutch shaft.

Our third clutch enemy is squeal. This is almost always the sign of a worn release bearing that shows itself as a high-pitched squealing noise when taking up the drive either from standing still or, to a lesser extent, when changing gear. Sometimes it occurs all the time you have your foot on the clutch pedal and, if so, something had better be done about it because it means the bearing is on its last legs.

Release bearings do not give a lot of trouble so they get pushed into further service when they should be renewed. Before diaphragm spring clutches came in, most clutches had a plain carbon block as a release bearing. Diaphragm clutches use a thrust ball race which lasts much longer but, unlike a carbon block which you can see needs renewing when it wears thin, a ball race release bearing cannot be seen to be worn.

In the Ford manual it tells you to spin the bearing and listen for any roughness, but the only time this can be done is when the bellhousing is off. Our advice is, that when fitting a new clutch, fit a new release bearing as well. It is a piddling little expense compared with the other parts of the clutch, and a real pig to get at afterwards, to put it mildly.

But what should you do if you get squeal from a worn bearing with a relatively new clutch because some clown did not fit a new bearing when replacing it? After you have gone to all the trouble of taking the bellhousing off to renew the bearing you are in a quandary, on the horns of a dilemma, or some similar uncomfortable place.

Just because you have the bellhousing off to fit a new bearing, do you spend a lot more money renewing a part-worn clutch with maybe a quarter of its life or more left? It could well need renewing in a year or two, possibly less, and you will have all that dismantling to do again.

Therefore, the sensible answer, indeed the only answer with a tuned engine, is yes, replace clutch now. While things are in pieces, bite the bullet and renew the lot – release bearing, clutch cover and centre plate and, while you are about it, check the face of the flywheel for scoring or 'crazy paving', a series of fine cracks that look just like crazy paving and are caused by the surface of the flywheel getting too hot.

Can release bearing problems be

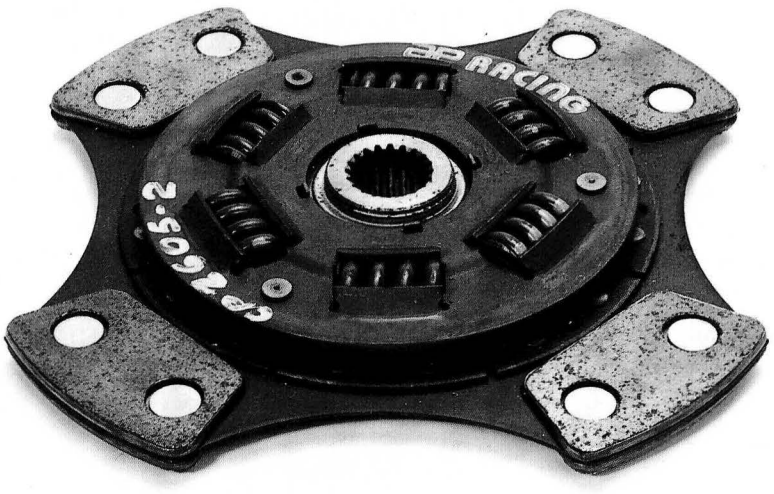
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avoided by fitting an uprated one? No, it is not worth it, even if they were readily available. Provided you renew the release bearing when you renew the clutch, and don't misuse it, Ford's standard item will do pretty well anything you ask of it. Indeed, in the front of its catalogue, AP Racing says that for everything except formula type machines you should use Ford's standard release bearing with competition clutches.

Almost all release bearing troubles come from inconsiderate driving, lack of mechanical sympathy, or just plain brutal treatment, whichever you like to call it. Two things are typical. One is resting your left foot on the clutch while driving. Yes, everyone knows you should not do it, but you will still find people who do.

Much more frequent, and maybe less obvious that you are punishing the release bearing, is sitting in a queue of traffic, or at the traffic lights, with the car in gear, and your left foot on the clutch. In normal use the release bearing is operating for about two to three seconds each time you change gear. So, if you sit in traffic for even a couple of minutes with your foot on the clutch you have used up a lot of gear changes. Knock it into neutral and take your foot off.

▼ *The paddle type of competition centre plate. This will probably have cerametallic friction material and needs a specially hardened flywheel face.*



Lastly we come to judder, kangarooing or jerking when you let in the clutch in first or, often more marked, in reverse gear. Now and again you will find this is caused by soggy engine mountings or bushes in the transmission stabilising rod, so check these first because they are easier to deal with than a clutch.

A warped clutch centre plate will also give judder, sometimes accompanied by a fluttering or a pulsing up and down of the clutch pedal. A more usual reason, though, is that the cushion springs in the centre plate, the ring of coil springs around the centre spline, have either gone soft or broken. They can go soft because the clutch has become too hot, usually because someone is in the habit of slipping it on the pedal too long on take off. Once it starts to judder, you slip it even more to try to get a smooth take off, and that only makes things worse. The answer is to be more considerate to your clutch.

If you find cushion springs that are broken, the usual cause is letting in the clutch far too fiercely so you get a jack rabbit start. This sort of thing might be all very well on the grid of a racing circuit where fighting for a half second advantage into the first bend but, if you practice doing this at a traffic light grand prix, you only have yourself to blame if you get juddering.

By the way, when fitting the centre plate, make sure you have it the right way round. One side should be marked FLYWHEEL SIDE or, if it came from one of Ford's German suppliers, SHWUNGRADSEITE.

So far, we have been talking about 'bog standard', out-of-the-bin, clutch parts from Ford. And this is all you need with an engine in standard tune or if you have just given it a pep-up with a K&N filter, a performance exhaust and a mild fast-road cam. When starting to look at more serious power you

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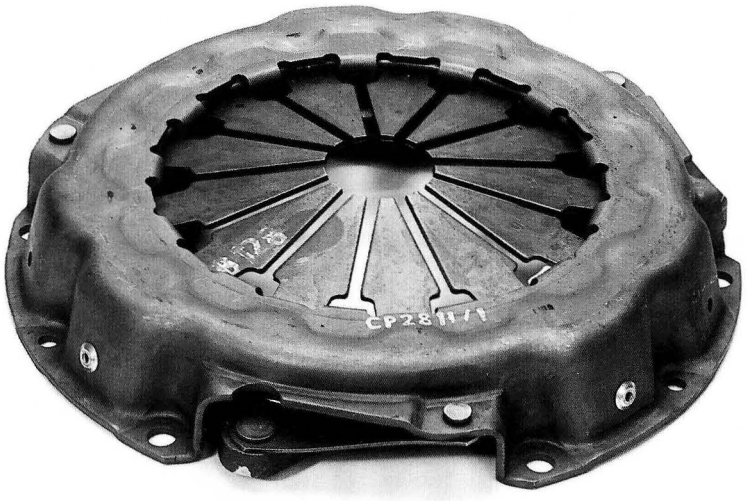
should consider more serious clutches.

Favourite in the clutch uprating stakes is AP which keeps a competition department in Coventry, telephone 01203 639595. They have the answer to just about all uprated clutches from fast road to Formula One. You will not find AP competition products as part of the normal Ford parts holding at many Ford main dealers, or even RS dealers, and you will usually have to go to one of the tuning specialists.

AP offers a range of competition clutches to suit pretty well anything you are likely to do to a road car. The first stage in uprating is to fit a different centre plate. In some cases, for mild uprating, this will look just the same as the normal plate except that it will have a different friction material on it. The next stage up is the so-called paddle clutch. It has this name because the friction material is not circular but is made in a series of pads or segments fitted to arms from the splined centre so that it looks like a paddle wheel, or a starfish.

You can have paddle clutches with cushion springs and they can come with solid centres. In almost all cases for road use you should, go for the ones with cushion springs which provide a smoother take off. The solid centre ones are really intended for circuit racing. There are paddle clutches with anything from three to seven paddles, depending on the application, so be guided either by AP, or the specialist dealer, about which type to fit for the amount of power you have given your engine.

Paddle clutches are nearly always fitted with a cerametallic friction material. Cerametallic is a portmanteau word made up from ceramic and metallic and is a material that withstands far higher temperatures than the normal friction material available over the counter at Ford dealers. Cerametallic materials are not recommended for road use with a



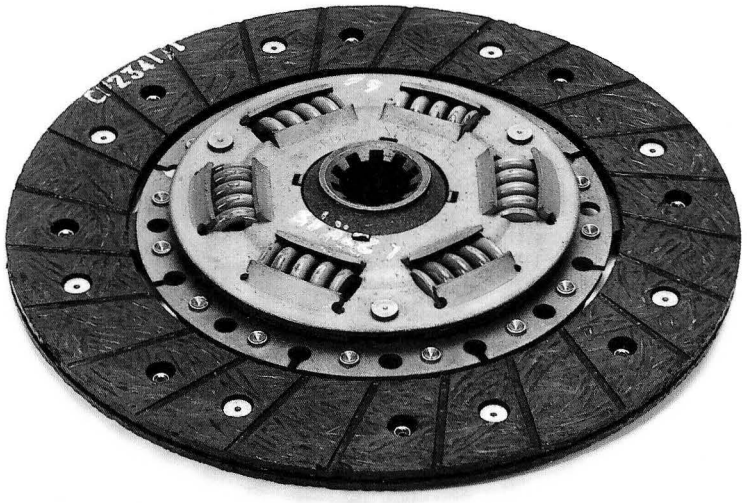
▲▼ *Two types of uprated cover plates from AP. Which type of cover you use depends on the amount of torque your uprated engine develops.*



standard flywheel because they can wear the surface of the flywheel quite quickly. If you really want to use this material you need a different flywheel.

It is also advisable with higher powers to use a heavier clamping pressure with cerametallic clutches, partly because the reason you fit one is that you

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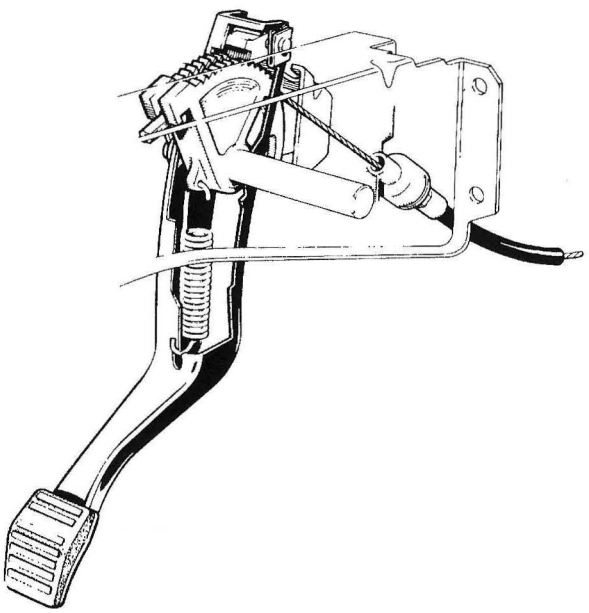


▲ *An uprated centre plate for road use will not look very different from standard but it will have a different friction material and cushion springs.*

have a lot more torque than standard to put through it, and partly because the material likes high pressures.

With what you might call mild stages of tuning, AP recommend that although you need to have an uprated centre plate you do not really have to go to the extra expense of a higher pressure competition clutch cover. The cheaper standard one from Ford is still man enough for the job. However, this applies to the milder types of uprated centre plate where the friction material thickness is the same as on the standard Ford clutch. When you start moving up a grade or two the friction material is thicker, so you need a different clutch cover to accommodate it. You cannot buy a standard clutch to do this, as it has to be a competition one.

So, to sum up, Ford's standard clutch set-up is pretty good and it will take a lot of punishment, including mild engine tuning, without complaining, provided you treat it properly and do not abuse it. When you get further up the ladder of higher power, look seriously into fitting a competition clutch. But do not just pick one out of the catalogue because it takes your fancy. Seek expert advice about the type to fit, either from a specialist tuner or from AP's competition department.



◀ *Quite a few clutch problems can be traced to the self-adjusting mechanism not working properly. When uprating an engine it is always advisable to take out, strip and clean the adjuster and renew any worn parts or weal springs.*

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Technical specifications and data 1.3, 1.4 and 1.6 litre engines

General

Type Four-cylinder, in-line overhead camshaft

Engine code
The code consists of three letters or digits, the first giving the capacity and the second the type. The third is a factory assembly code.

1st letter:
J = 1.3 litre
F = 1.4 litre
L = 1.6 litre
R = 1.8 litre

2nd letter:
U = carburettor engine
R = K-Jetronic injection
N = turbo

Capacity:

1.3 litre	1.296cc
1.4 litre	1.392cc
1.6 litre	1.597cc

Bore:

1.3 litre	79.96mm (3.15in)
1.4 litre	77.24mm (3.04in)
1.6 litre	79.96mm (3.15in)

Stroke:

1.3 litre	64.52mm (2.54in)
1.4 litre	74.30mm (2.92in)
1.6 litre	79.52mm (3.13in)

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Compression ratio:	
1.3 litre	9.5 to 1
1.4 litre	9.5 to 1
1.6 litre	9.5 to 1
1.6 litre Turbo	8.3 to 1
Firing order:	1-3-4-2 (No. 1 at the timing belt end of the engine)

Cylinder block

Material:	Cast iron
Number of main bearings:	5

Cylinder bore diameter (production):

1.3 litre and 1.6 litre

Standard class 1	79.94 to 79.95mm (3.1472 to 3.1476in)
Standard class 2	79.95 to 79.96mm (3.1476 to 3.1480in)
Standard class 3	79.96 to 79.97mm (3.1480 to 3.1484in)
Standard class 4	79.97 to 79.98mm (3.1484 to 3.1488in)
Oversize class A	80.23 to 80.24mm (3.1587 to 3.1590in)
Oversize class B	80.24 to 80.25mm (3.1590 to 3.1594in)
Oversize class C	80.25 to 80.26mm (3.1594 to 3.1598in)

1.4 litre

Standard class 1	77.22 to 77.23mm (3.0424 to 3.0428in)
Standard class 2	77.23 to 77.24mm (3.0428 to 3.0432in)
Standard class 3	77.24 to 77.25mm (3.0432 to 3.0436in)
Standard class 4	77.25 to 77.26mm (3.0436 to 3.0440in)
Oversize class A	77.51 to 77.52mm (3.0538 to 3.0542in)
Oversize class B	77.52 to 77.53mm (3.0542 to 3.0546in)
Oversize class C	77.53 to 77.54mm (3.0546 to 3.0550in)

Cylinder bore diameter (service)

1.3 litre and 1.6 litre

Standard		79.965 to 79.975mm
Oversize	0.29mm	79.245 to 80.255mm
	0.50mm	80.465 to 80.475mm

1.4 litre

Standard		77.245 to 77.255mm
Oversize	0.29mm	77.525 to 77.535mm
	0.50mm	77.745 to 77.755mm

Main bearing shell vertical inner diameter:

Standard		58.011 to 58.038mm (2.2839 to 2.2850in)
Undersize	0.25mm	57.761 to 57.788mm (2.2740 to 2.2751in)
Undersize	0.50mm	57.511 to 57.538mm (2.2642 to 2.2653in)
Undersize	0.75mm	57.261 to 57.288mm (2.2544 to 2.2554in)

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Crankshaft

Main bearing journal diameter:

Standard	57.98 to 58.00mm (2.2827 to 2.2835in)
Undersize 0.25mm	57.73 to 57.75mm (2.2728 to 2.2736in)
Undersize 0.50mm	57.48 to 57.50mm (2.630 to 2.2638in)
Undersize 0.75mm	57.23 to 57.25mm (2.2531 to 2.2539in)
Main bearing running clearance:	0.011 to 0.058mm (0.0004 to 0.0023in)
Thrust washer thickness:	
Standard	2.301 to 2.351mm (0.0906 to 0.0926in)
Oversize	2.491 to 2.541mm (0.0981 to 0.1000in)
Crankshaft endfloat:	0.09 to 0.30mm (0.0035 to 0.0118in)

Big-end bearing journal diameter:
1.3, 1.4 and 1.6 litre

Standard	47.89 to 47.91mm (1.8854 to 1.8862in)
Undersize 0.25mm	47.64 to 47.66mm (1.8756 to 1.8764in)
Undersize 0.50mm	47.39 to 47.41mm (1.8657 to 1.8665in)
Undersize 0.75mm	47.14 to 47.16mm (1.8559 to 1.8567in)
Undersize 1.0mm	46.89 to 46.91mm (1.8461 to 1.8468in)
Big-end bearing running clearance:	0.006 to 0.060mm (0.0002 to 0.0024in)

Camshaft

Number of bearings:	5
Drive:	Toothed belt
Camshaft thrust plate thickness:	4.99 to 5.01mm (0.1965 to 0.1972in)
Cam lift (inlet and exhaust):	
1.3 and 1.4 litre and 1.6 litre with Ford VV carb.	5.79mm (0.2280in)
1.6 litre with Weber carb. or fuel injection	6.09mm (0.2398in)

Inlet cam length (heel to toe):

1.3 litre, 1.4 litre and 1.6 litre with Ford VV carb.	38.305mm (1.5081in)
1.6 litre with Weber carb. or fuel injection	38.606mm (1.5200in)
Exhaust cam length (heel to toe):	
1.3 litre, 1.4 litre and 1.6 litre with Ford VV carb.	37.289mm (1.4681in)
1.6 litre with Weber carb. or fuel injection	37.590mm (1.4799in)

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Bearing journal diameter:		
	No. 1	44.75mm (1.7618in)
	No. 2	45.00mm (1.7717in)
	No. 3	45.25mm (1.7815in)
	No. 4	45.50mm (1.7913in)
	No. 5	45.75mm (1.8012in)
Camshaft endfloat:		0.05 to 0.15mm (0.0020 to 0.0059in)

Pistons and piston rings

Piston diameter (production):		
1.3 litre and 1.6 litre		
Standard class 1		79.910 to 79.920mm (3.1461 to 3.1465in)
Standard class 2		79.920 to 79.930mm (3.1465 to 3.1468in)
Standard class 3		79.930 to 79.940mm (3.1468 to 3.1472in)
Standard class 4		79.940 to 79.950mm (3.1472 to 3.1476in)
Piston diameter (service):		
1.3 and 1.6 litre		
Standard		79.930 to 79.955mm (3.1468 to 3.1478in)
Oversize	0.29mm	80.210 to 80.235mm (3.1579 to 3.1589in)
Oversize	0.50mm	8.430 to 80.455mm (3.1665 to 3.1675in)
Piston diameter (production):		
1.4 litre		
Standard class 1		77.190 to 77.200mm (3.0412 to 3.0416in)
Standard class 2		77.200 to 77.210mm (3.0416 to 3.0420in)
Standard class 3		77.210 to 77.220mm (3.0420 to 3.0424in)
Standard class 4		77.220 to 77.230mm (3.0424 to 3.0428in)
Piston diameter (service):		
1.4 litre		
Standard		77.210 to 77.235mm (3.0420 to 3.0430in)
Oversize	0.29mm	77.490 to 77.515mm (3.0531 to 3.0540in)
Oversize	0.50mm	77.710 to 77.735mm (3.0617 to 3.0627in)
Piston to bore clearance (service):		0.010 to 0.045mm (0.0004 to 0.0017in)
Piston ring end gaps (fitted):		
1st and 2nd rings		
Oil control ring		0.030 to 0.50mm (0.0118 to 0.0197in) 0.40 to 1.40mm (0.0158 to 0.0552in)
Ring gap position:		Ring gaps must be staggered evenly around the piston circumference. This also applies to intermediate ring gaps relative to the garter spring gap. The intermediate ring gaps must be offset 120° from the garter ring gap.

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Gudgeon pin

Pin length:		66.20 to 67.00mm (2.606 to 2.638in)
Pin diameter:		
Colour code	white	20.622 to 20.625mm (0.8119 to 0.8120in)
	red	20.625 to 20.628mm (0.8120 to 0.8121in)
	blue	20.628 to 20.631mm (0.8121 to 0.8122in)
	yellow	20.631 to 20.634mm (0.8122 to 0.8124in)
Clearance in piston:		0.005 to 0.011mm (0.0002 to 0.0004in)
Interference fit in connecting rod:		0.013 to 0.045mm (0.0005 to 0.0018in)

Connecting rod

Big-end bore diameter:		50.890 to 50.910mm (2.0035 to 2.0043in)
Small-end bore diameter:		20.589 to 20.609mm (0.8106 to 0.8114in)
Fitted big-end bearing shells, vertical inside diameter:		
Standard:		47.916 to 47.950mm (1.8865 to 1.8878in)
Undersize	0.25mm	47.666 to 47.700mm (1.8766 to 1.8779in)
Undersize	0.50mm	47.416 to 47.450mm (1.8668 to 1.8681in)
Undersize	0.75mm	47.166 to 47.200mm (1.8569 to 1.8582in)
Undersize	1.00mm	46.916 to 46.950mm (1.8471 to 1.8484in)
Clearance, big-end bearing journal to bearing shell:		0.006 to 0.060mm (0.0002 to 0.0024in)

Cylinder head

Material:	Light alloy
Maximum permissible head distortion:	
Measured over 26mm	0.04mm (0.001in)
Measured over 156mm	0.08mm (0.003in)
Measured over entire length	0.15mm (0.006in)
Minimum combustion chamber depth after refacing:	
1.4 litre	17.40mm (0.685in)
1.3 litre and 1.6 litre with Ford VV carb. or fuel injection	19.60mm (0.772in)
1.6 litre with Weber carb.	19.10mm (0.752in)
Valve seat angle:	45°
Valve seat width:	1.75 to 2.32mm (0.689 to 0.0913in)
Upper correction angle (production):	30° inlet and exhaust
Service correction cutter:	15°
Lower correction angle (production):	77° inlet 70° exhaust

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Service correction cutter:		75° inlet 70° exhaust
Valve guide bore:		8.063 to 8.094mm (0.3174 to 0.3187in)
Camshaft bearing bore in head:		
Camshaft bearing	No. 1	44.783 to 44.808mm (1.7631 to 1.7639in)
	No. 2	45.033 to 45.058mm (1.7729 to 1.7739in)
	No. 3	45.283 to 45.308mm (1.7828 to 1.7838in)
	No. 4	45.533 to 45.558mm (1.7926 to 1.7936in)
	No. 5	45.783 to 45.808mm (1.8025 to 1.8034in)
Valve lifter bore in head:		22.235 to 22.265mm (0.8754 to 0.8766in)

Valves, general

Operation:	Rocker arms with hydraulic valve lifters
Valve lift:	
1.3 litre, 1.4 litre and 1.6 litre with Ford VV carb.	inlet 9.56mm (0.376in), exhaust 9.52mm (0.374in)
1.6 litre with Weber carb. or fuel injection	inlet 10.09mm (0.397in), exhaust 10.06mm (0.396in)
Valve spring free length:	47.2mm (1.859in)

Inlet valve

Length:	
1.3 and 1.6 litre	134.54 to 135.0mm (5.299 to 5.319in)
1.4 litre	136.29 to 136.75mm (5.369 to 5.387in)
Head diameter:	
1.3 and 1.6 litre	41.9 to 42.1mm (1.650 to 1.658in)
1.4 litre	39.9 to 40.1mm (1.572 to 1.579in)
Stem diameter:	8.025 to 8.043mm (0.3161 to 0.3168in)

Exhaust valve

Length:	
1.3 litre	131.17 to 131.63mm (5.168 to 5.186in)
1.4 litre	132.97 to 133.43mm (5.239 to 5.257in)
1.6 litre	131.57 to 132.03mm (5.183 to 5.201in)
Head diameter:	
1.3 litre	33.9 to 34.1mm (1.335 to 1.343in)
1.4 litre	33.9 to 34.1mm (1.335 to 1.343in)
1.6 litre	36.9 to 37.1mm (1.453 to 1.461in)
Stem diameter:	7.999 to 8.017mm (0.3151 to 0.3158in)

Valve timing

1.3 litre and 1.6 litre with Ford VV carb.	
Inlet valve opens	13° ATDC
Inlet valve closes	28° ABDC
Exhaust valve opens	30° BBDC
Exhaust valve closes	15° BTDC
1.4 litre	
Inlet valve opens	15° ATDC

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Inlet valve closes	30° ABDC
Exhaust valve opens	28° BBDC
Exhaust valve closes	13° BTDC
1.6 litre fuel injection	
Inlet valve opens	8° ATDC
Inlet valve closes	36° ABDC
Exhaust valve opens	34° BBDC
Exhaust valve closes	6° BTDC
1.6 litre with Weber carb.	
Inlet valve opens	4° ATDC
Inlet valve closes	32° ABDC
Exhaust valve opens	38° BBDC
Exhaust valve closes	10° BTDC

Lubrication

Oil type and specification:	Use recommended oil from Ford dealers or see oil manufacturers' charts
Oil pump type:	
Pre-1986	Gear type driven by crankshaft
1986 onwards	Rotor type driven by crankshaft
Minimum oil pressure at 80°C (176°F):	
At 750rpm	1.0bar (14.5psi)
At 2,000rpm	2.8bar (40.6psi)
Oil pressure warning lamp operates:	0.3 to 0.5bar (4.3 to 7.2psi)
Relief valve opens:	4.0bar (58psi)
Oil pump clearances (rotor type pump only):	
Outer rotor to body	0.060 to 0.190mm (0.002 to 0.0074in)
Inner to outer rotor	0.05 to 0.18mm (0.0019 to 0.0070in)
Rotor endfloat	0.014 to 0.100mm (0.0005 to 0.0039in)

Torque tightening figures	**Nm**	**lbft**
Main bearing caps	90 to 100	66 to 74
Connecting rod bolts	30 to 36	22 to 26
Oil pump to crankcase	8 to 11	6 to 8
Oil pump cover bolts	8 to 11	6 to 8
Oil pump pick-up tube to block	17 to 23	12 to 17
Oil pump pick-up tube to pump	8 to 11	6 to 8
Oil cooler threaded sleeve to block	55 to 60	40 to 44
Rear oil seal carrier bolts	8 to 11	6 to 8
Sump with multi-piece gasket:		
Stage 1	8 to 11	6 to 8
Stage 2	8 to 11	6 to 8

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Sump with one-piece gasket:		
Stage 1	5 to 8	4 to 6
Stage 2	5 to 8	4 to 6
Flywheel to crankshaft	82 to 92	60 to 68
Crankshaft pulley bolt	100 to 115	74 to 85
Cylinder head bolts:		
Stage 1	25	18
Stage 2	55	40
Stage 3	Tighten by a further 90°	Tighten by a further 90°
Stage 4	Tighten by a further 90°	Tighten by a further 90°
Camshaft thrust plate	9 to 13	7 to 10
Camshaft sprocket bolt	54 to 59	40 to 43
Timing belt tensioner bolts	16 to 20	12 to 15
Rocker arm studs in head		
Plain stud	10 to 15	7 to 11
Stud with nylon insert	16 to 23	13 to 17
Rocker arm nut	25 to 29	18 to 21
Rocker cover screws	6 to 8	4 to 6
Timing belt cover bolts	9 to 11	7 to 8
Sump drain plug	21 to 28	15 to 21
Oil pressure switch	18 to 22	13 to 16
Engine to manual gearbox	35 to 45	26 to 33

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Useful names and addresses

The following addresses and telephone numbers were believed to be correct at the time of going to press. However, as these are subject to change, particularly telephone area codes, no guarantee can be given for their continued accuracy.

AP Racing, Wheeler Road, Coventry CV3 4LB. Tel. 024 7663 9595. *Competition clutches, brakes and other equipment.*

Burton Power Products Ltd, 623 Eastern Avenue, Ilford, Essex IG2 6PN. Tel. 020 8554 2281. *Performance components, engine tuning, machining.*

Collins Performance Engineering Ltd, Unit 6, Greenfields Industrial Estate, off Back Lane, Congleton, Cheshire CW12 4TR. Tel. 01269 279604. *Performance components, engine building and tuning.*

ERL Ltd, Iroko House, Bolney Avenue, Peacehaven, East Sussex BN10 8HF. *Water injection and fuel management control.*

Interpro Engineering Ltd, Unit 16, Walker Way, Thornbury Ind. Est., Thornbury, Bristol BS35 3US. *Performance components.*

Janspeed Engineering Ltd, Castle Road, Salisbury, Wiltshire SP1 3SQ. Tel. 01722 21833. *Performance exhausts and tuning components.*

Kent Performance Cams Ltd, 1-4 Military Road, Shorncliffe Industrial Estate, Folkestone, Kent CT20 3SP. Tel. 01303 48666. *Performance camshafts and associated components.*

Pace Products Ltd, Bury Road, Chedburgh, Nr Bury St Edmunds, Suffolk IP2 4NU. Tel. 01284 850960. *Intercoolers, charge coolers and aluminium radiators.*

Piper RS Ltd, 2 St John's Court, Ashford Business Park, Ashford, Kent TN24 0SJ. Tel. 01233 500200. *Performance camshafts, exhausts and associated equipment.*

Power Engineering Ltd, Unit 8, Union Buildings, Wallingford Road, Uxbridge, Middlesex UB8 2FR. Tel. 01895 255699. *Tuning specialists, performance components, engine management chipping and exhausts.*

Severn Valley Motorsport Ltd, High Street, Ironbridge, Telford, Shropshire TF8 7AD. Tel. 01952 432139. *Engine building and tuning, performance components.*

Specialised Engines Ltd, 15 Curzon Drive, Grays, Essex RM17 6BG. Tel. 01375 378606. *Ford engine rebuilding specialists.*

Superchips Ltd, 2-12 Homestall, Buckingham Industrial Park, Buckingham MK18 1XJ. Tel. 0990 143005. *Performance chips.*

Turbo Technics Ltd, 17 Galowhill Road, Brackmills, Northampton NN4 7EE. Tel. 01604 705050. *Performance turbocharger specialists.*

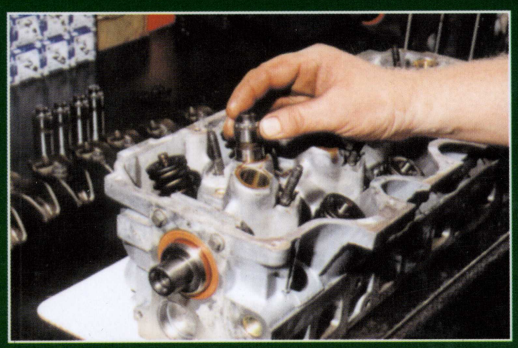
Webcon Ltd, Dolphin Road, Sunbury-on-Thames, Middlesex TW16 7HE. Tel. 01932 788805. *Weber carburettors and fuel injection systems.*

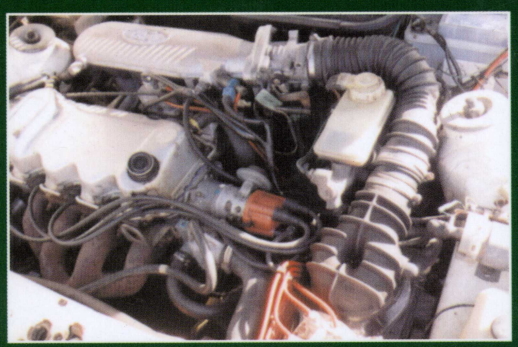
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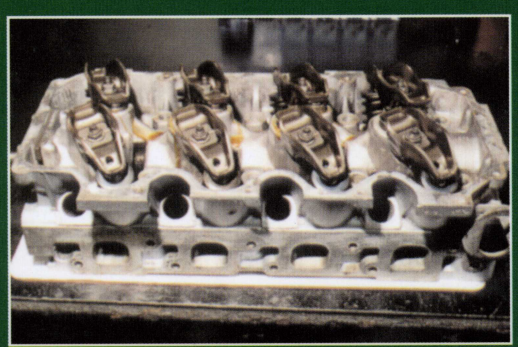
CAR/DIY £17.99 / $36.95

Rebuilding and Tuning

Ford's CVH Engine







The Ford CVH engine (Compound Valve angle, Hemispherical combustion chamber) has been used as the standard power plant in many well-known Ford models including Fiestas (1.4, 1.6, XR2i and RS Turbo) Escorts (1.4, 1.6, RS1600i, XR3, XR3i and RS Turbo) and Orions (1.3, 1.6 and 1600i). It has also been built in the USA as a 1.9-litre engine, the so-called tall block version.

This book includes a brief history of the CVH engine followed by hints, tips and advice on rebuilding and tuning it in the home garage, describing what can be undertaken by the enthusiast and what should be put out to specialists. The general principles and theory of tuning are explained, and the modifications and adjustments that can be made to an engine and its ancillaries to increase power or improve economy are detailed in step-by-step sequences.

Topical matters, such as unleaded fuel and catalytic converters, are dealt with regarding their effects on power and performance as well as the legal implications relative to the age of the car or engine block. Fully illustrated, mostly in colour, the book also covers the following:

- Tools required
- Air filters and exhaust systems
- Fitting a performance camshaft
- Changing the carburettor
- Fuel injection and electronic ignition systems
- Turbocharging
- Water injection and head gaskets
- Tuning with chips
- Dismantling the engine and examining the parts
- Building the head and block
- Clutches
- Technical specifications and data
- Useful names and addresses

Peter Wallage has spent all his working life in and around cars and the motor industry. He worked in the design offices of Rolls-Royce and Scammell, then for a design consultants before turning full-time to motoring journalism in 1964. Now freelance, and an acknowledged expert on Ford technical matters, he works with his son John as photographer, contributing to numerous motoring journals.

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