SIERRA 2.3 DOHC 8v HYBRID

The 'I4' DOHC engine first introduced in the Ford Sierra and Granada models of late 1989 was only available in the Sierra in 2.0-litre 8-valve form.

While power output improvements can be made to the stock 2.0 8v engine, as documented in a separate article entitled 'DOHC tuning' and available from http://www.crustworld.co.uk/sierra/dohctuning.pdf, the engine output is ultimately limited by the availability and cost-effectiveness of off-the-shelf tuning parts.

For ultimate power output of a 2.0 8v engine, it is necessary to involve some form of customized engine management system and forced induction, either through turbo- or supercharging. Both of which are expensive and relatively complicated to sort out – necessitating exotic or rare kits (*in the case of turbocharging, Turbo Technics used to sell an aftermarket kit for the DOHC engine. Although rare with a handful believed to remain in operational condition, they do occasionally come up second hand - though prices are at a premium. At time of writing, there is no known supercharging kit for the DOHC commercially available*)

As discussed in the 'DOHC Tuning guide', beyond gasflowing, camshafts, exhaust, air filter and chip the next stages for improving the output of the DOHC engine 'in a cost effective manner' were to either fit the cylinder head from the 16-valve version of the same 2.0-litre engine found in a 1990's Escort RS2000, or fit the 2.3-litre variant found in a Ford Scorpio from the late 1990's.

While the 2.3 DOHC was also used in the Ford Galaxy MPV, it is used in front-wheel-drive format and as such is not as easily mountable into the Sierra's rear-wheel-drive chassis – engine mount and ancillary positions having been modified for the FWD package.

The Ford Scorpio was a RWD car, and as such the 2.3 engine is almost a straightforward 'slot in' upgrade for the Sierra.

With both options, there are one or two 'minor' considerations which must be borne in mind:

1. Engine Management on 2.3 Scorpios used the later Ford EEC-V system, which was also integrated with the Ford Passive Anti-Theft System (PATS). The Sierra loom must have this integrated, as the PATS system cannot easily be bypassed.

   Engine management on earlier Escort RS2000's was EEC-IV which if using the RS2000 16v cylinder head, should be used as it contains the 'RS' engine ignition and fuelling maps which helped the engine to 150BHP in the Escort.

   It is possible to use the RS2000 EEC-IV engine management system with the 2.3 Scorpio engine– though rewiring of the Sierra loom must still be undertaken to accommodate the different wiring schematics as both engines used E-DIS ignition system (a Distributorless Ignition System, featuring coil packs).

2. To reduce vibration, the 2.3 engine had a system of counter-rotating balancer shafts mounted in the sump. While it was applauded in the motoring press as being a very smooth-running engine, the increased depth of the sump means fouling of the Sierra crossmember and steering rack is certain to occur.

   The Scorpio crossmember will not fit the Sierra as the track is vastly different, so alternative arrangements must be made to raise the engine, or lower the crossmember (*affecting the suspension geometry in the process*).

3. Both Escort RS2000 2.0 and Scorpio 2.3 engine has different inlet and exhaust port shapes, and as such the 2.0 8v inlet and exhaust manifolds will not fit the cylinder heads of either engine. Considerable work must be therefore undertaken to accommodate the Scorpio manifolds, or adapt the Escort RS2000 ones for RWD application. Escort RS manifolds are not a direct fit on the 2.3 cylinder head either!

The 2.3 engine does show potential and there are one or two examples of tuned 2.3 DOHC 16v engines in existence that reach upwards of 190BHP using a combination of motorcycle throttle bodies, RS2000 cylinder head and camshafts, and aftermarket engine management systems.

However, the cost effectiveness of such development work to put a similar engine into a Sierra means the option will almost always be passed over in favour of more readily-available power – *at this point in time this means either a Cosworth-developed 2.9 24v 'BOA' V6, or the turbocharged 'Cosworth YB' 2.0 16v engine.*

An alternative to this is an 'interim' stage - using the existing Scorpio 2.3 DOHC bottom end mated to the Sierra 8v 2.0 DOHC cylinder head.

This hybrid combination would allow a 2.3 engine to be cost-effectively installed into a Sierra – utilizing existing manifolds, engine management and any investment already made in tuning.

The choice of 8v cylinder head should mean that the resulting engine, while showing an increased power output compared to a tuned 2.0 8v, retains the 2.0 8v's characteristic torque delivery throughout the rev range, rather than developing the "loss of low-down, gain in top-end" behaviour typically associated with 16v engines.

It is the aim of this 'How to...' to document the creation of a 2.3 8v DOHC hybrid for use in a Sierra.

1. Brief description of the 2.3 16v DOHC engine

Extracts are from Ford's own 'Description and Operation' guide provided to dealership technicians.

"*The most noticeable difference from the familiar 2,0 litre DOHC 16V is the height of the engine, which is caused by incorporating a housing for the balancer shafts. This construction technique together with the dual mass flywheel as used in the familiar 2,5 TCI diesel engine lead to particularly smooth and quiet running of the whole drive train.*"

"*In order to increase the smoothness and quiet running of the engine, a housing with two balancer shafts was developed. The balancer shafts rotate in opposite directions to each other and at twice the speed of the crankshaft, and in doing so produce vibrations which counteract those of the engine.*

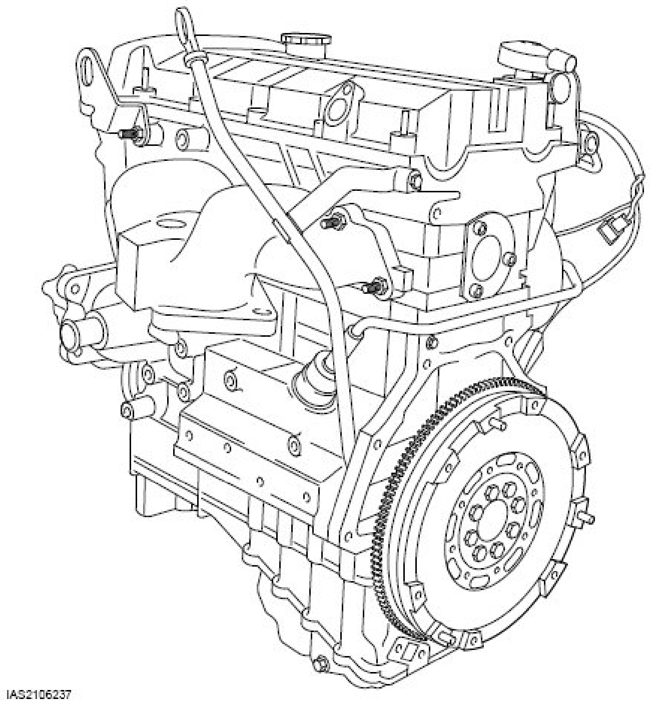
To prevent the oil foaming, plastic covers are bolted on the balancer shaft weights.

The balancer shaft housing is positively located on the cylinder block by two guide sleeves. These sleeves must not be interchanged, because one of them has an oil feed hole."

"*The cylinder bore has been increased to 89,6 mm.*

Further differences to the 2,0 litre engine are among others: modified stiffening ribs, modified oil gallery bores and larger coolant openings on the cylinder head sealing surface."

"*Stroke is 91mm*"



2. Brief description of the 2.3 8v DOHC hybrid

In order to make installation easy into existing Sierra DOHC environments, the engine will retain the existing Sierra DOHC 8v cylinder head which will utilize current EFi and ignition components.

This will mean there is no need to make any wiring adjustments to the existing vehicle loom which will make installation of the 2.3 engine a "plug in and go" job that can easily be accomplished in a single day.

The cylinder head is modified to reduce the effective compression ratio, and mated to the 2.3 16v DOHC cylinder block using the 2.3 cylinder head gasket.

To retain existing clearance over the cross member when used in a Sierra, it is necessary to remove the 2.3-specific balancer shafts and sump and replace them with a 2.0 8v Sierra sump and oil pick-up assembly.

Removing the balancer shafts requires a "filler" piece fabricating to seal a hole left in the crankcase.

The picture below shows a "mock up" of the engine, created before the start of the build process.

Note that the 2.3 balancer shaft assembly and sump is still attached in this picture.

3. Compression Ratio calculations

Because of the increased bore and stroke of the 2.3 engine, fitting the 2.0 cylinder head raises the compression ratio close to the "safe" limit for running with everyday unleaded fuel.

Put simply this is because the larger piston is trying to squish more fuel and air into the same 2.0 combustion chamber, and this can cause problems if left alone.

It is a given that the compression ratio is a function of the bore, stroke, cylinder head gasket thickness and aperture size, and the size of the combustion chamber in the head itself.

Using the following information, it is possible to calculate the effective compression ratio of the 8v 2.3 engine, and the extent of any modifications that must be made to lower it.

Bore: 89,60 mm / 8,96 cm
Stroke: 91,00 mm / 9,10 cm
Measured deck height: 0,10 mm / 0,01 cm
Head Gasket thickness: 1,50 mm (*used 2.3 gasket measured*)
Head Gasket aperture: 91,00 mm
Measured 2.0 combustion chamber volume: 48,00 cm^3

Formulae for calculating the volume of a cylinder: $\prod r^2 h$
For all calculations, the value of $\prod$ ("Pi") is 3.1415

Using the above formulae, the volume of each cylinder of the 2.3 engine (the "swept volume") is :

$$3.1415 \times (4.48 \times 4.48) \times 9.1 = 573.76\ cm^3$$

If this figure is multiplied by 4 (the number of cylinders) it will give us the total capacity of the engine: 2295cm³ This shows our math is right!

The formula for calculating the compression ratio of an engine is expressed as:

$$\frac{\text{(swept volume + clearance volume)}}{\text{clearance volume}}$$

"Clearance volume" is defined as the space remaining above the piston when it is at top dead centre.

In our case, it is the volume of the combustion chamber added to the volume of the compressed cylinder head gasket and the volume left at the top of the bore as the piston has a positive deck height in the bore – *that is, it reaches the top of it's stroke before it reaches the top of the cylinder bore in the block itself.*

Using the formulae for calculating a cylinder (*as the aperture in a head gasket is effectively a very squashed cylinder*) the volume of the compressed head gasket is:

$$3.1415 \times (4.55 \times 4.55) \times 0.15 = 9.75\ cm^3$$

The volume created by the positive deck height is:

$$3.1415 \times (4.48 \times 4.48) \times 0.01 = 0.63\ cm^3$$

If we add these two figures to the measured volume of a 2.0 combustion chamber, this gives us a total volume (the "clearance volume") of 58.38 cm^3.

Substituting these "real" numbers into the formula for compression ratio gives us the compression of a 2.3 engine with an unmodified 2.0 8v cylinder head fitted:

$$\frac{573.76 + 58.38}{58.38}$$

= 10.83 (*expressed as 10.83:1*)

This is a touch too high for comfortable use on regular 95-octane unleaded fuel, so it **will** be necessary to make some mechanical adjustments to the clearance volume to bring the ratio down to a more appropriate figure.

These adjustments could take the form of either machining material from the combustion chambers themselves, machining down the height of the pistons so increasing the deck height, or by fitting a "decompression plate".

Decompression plates are metal – usually copper or aluminium – with a carefully calculated thickness that supplement the thickness of the cylinder head gasket and work to increase the clearance volume by physically separating the cylinder head from the cylinder block by a given amount.

In the case of the DOHC engine and depending on the thickness of the plate used, this approach may require the use of adjustable camshaft sprockets to correct camshaft timing issues that use of a decompression plate will cause.

By substituting in larger numbers for the clearance volume in the above calculation, we can see what effect different clearance volumes will have on the compression ratio.

For instance, to achieve a 10.5:1 ratio, the clearance volume would need to be increased by 2 cm^3.

To achieve a 10.3:1 ratio, the clearance volume would need to be increased by 3 cm^3 (*bringing it to 61.38*).

To achieve a 10.1:1 ratio, the clearance volume would need to be increased by 4 cm^3 (*bringing it to 62.38*).

However it should also be noted that using after-market camshafts may raise or lower "real world" compression ratios achieved due to differences in valve timing.

For example, the longer the inlet valve stays open during the compression stroke, the lower the effective compression. *This is because compression can only begin once the cylinder is fully and completely sealed!*

4. Parts requirements

During the course of the conversion process, the following parts – sourced either new or second-hand – will be required *as a bare minimum*.

1 x 2.0 8v oil pick-up pipe, with securing bolts
1 x 2.0 8v oil pick-up pipe gasket
1 x 2.0 8v oil splash shield
4 x 2.0 8v crank main bearing cap bolts with stud on the top and suitable nut
1 x 2.0 8v oil sump, with securing bolts
1 x 2.0 8v "front sump mounting plate" (NOTE: *this is not available from Ford without buying a cylinder block – so will have to be sourced from an engine in a scrapyard*)
1 x 2.0 8v lower front timing chain cover
1 x 2.0 8v oil pump chain
1 x 2.0 8v oil pump chain tensioner arm and spring
6 x 2.0 8v DOHC manual flywheel bolts (*assumes flywheel and clutch will be transferred from an existing 2.0 engine*)
1 x 2.3 DOHC cylinder head gasket
1 x DOHC timing chain (*this is a common part between 8v and 16v engines*)

However, as I already had the necessary sump, pick-up pipe and big-end bearing cap bolts from the dismantly of a donor 2.0 8v engine, my "shopping list" from the Ford dealer was somewhat different and is shown below.

Included in this list are the timing chain components, the manifold gaskets, fuel injector seals and adaptors and a new set of main- and big-end bearings.

Note that your individual shopping list will vary depending on the condition of your donor 2.3 engine.

While replacing the bearings isn't essential, it does make good sense when the engine is already in a suitable state of dismantly to allow the additional work to be done with little additional effort.

Qty	FINIS Code	Description	Vehicle	Cat	CD Price
1	7079279	CHAIN - TIMING	Sierra DD 1989-1993	DD	26.34
1	1022214	ARM - TIMING CHAIN TENSIONER	Sierra DD 1989-1993	DD	22.42
1	1662847	TENSIONER - TIMING CHAIN	Sierra DD 1989-1993	DD	24.03
1	7079280	CHAIN ASSY - OIL PUMP DRIVE	Sierra DD 1989-1993	DD	14.82
2	6179653	GASKET	Sierra DD 1989-1993	DD	9.26
1	6172113	GASKET - CYL. HEAD FRONT COVER, DOHC (8V)	Sierra DD 1989-1993	DD	2.54
1	6778601	GASKET	Sierra DD 1989-1993	DD	0.25
1	6191988	GASKET - OIL PAN, DOHC (8V)	Sierra DD 1989-1993	DD	0.00
1	6172130	GASKET - INTAKE MANIFOLD	Sierra DD 1989-1993	DD	8.47
8	6134936	"O" RING'	Sierra DD 1989-1993	DD	9.76
4	6171202	ADAPTOR	Sierra DD 1989-1993	DD	4.72
1	6988500	COVER ASSY - CYLINDER BLOCK FRONT, DOHC (8V)	Sierra DD 1989-1993	DD	24.91
8	1018960	BOLT - CONNECTING ROD	Scorpio FE 1994-1998	FE	10.24
8	7010052	BEARING - CONNECTING ROD, STD	Scorpio FE 1994-1998	FE	26.72
5	6162846	BEARING - CRANKSHAFT MAIN, CYLINDER BLOCK STD/CRANKSHAFT 0.02MM U/S	Scorpio FE 1994-1998	FE	26.15
5	6162855	BEARING - CRANKSHAFT MAIN, CYLINDER BLOCK STD/CRANKSHAFT 0.02MM U/S	Scorpio FE 1994-1998	FE	21.90
1	3505673	SEAL ASSY - CRANKSHAFT OIL	Scorpio FE 1994-1998	FE	9.68
1	1019030	GASKET - CYLINDER HEAD, SCORPIO 95, DOHC 2.3	Scorpio FE 1994-1998	FE	27.71
1	6166200	"O" RING'	Scorpio FE 1994-1998	FE	0.85
2	1592026	ELBOW, SCORPIO 95, DOHC 2.0 EFI (136PS)	Scorpio FE 1994-1998	FE	2.78

5. Checking crankshaft, pistons and cylinder bores

If the condition of the donor 2.3 engine is unknown and it hasn't been heard running, it should be stripped down and crankshaft, pistons and cylinder bores all be checked for excessive wear and machined accordingly before any modification work is done to it.

Replacement of the bearing shells and piston rings is always recommended while the engine is in a state of complete disassembly – this should return the engine to a "known state" and prevent the necessity for further work once the initial build is completed though it does add to the cost – a set of piston rings for the 2.3 engine are over £100!

Useful note!
If the engine has been heard running and on examination it has been determined that it produces an oil pressure and cylinder compression figures that are all "in specification", it may not be necessary to replace either bearings or rings as the view could be taken that they are in a good, serviceable condition and the overall state of the donor engine can be described as "healthy".

However should a donor engine exhibit low compression, while this may be attributed to a cylinder head gasket failure or valve seating problems, it may also mean a worn cylinder bore or broken piston ring and the cylinder bores should be carefully examined to determine if they are damaged before proceeding with the build of the 8v hybrid.

Although there is no reason why excessive wear or other damage cannot be removed from a cylinder bore by machining to a larger size, oversize pistons are not available from Ford or any of the common aftermarket engine component manufacturers because the engine was never intended to be remanufactured.

As such, if a cylinder bore exhibits excessive wear or other damage, the engine block should be discarded in favour of a better item – although custom oversize pistons can be made to suit a re-bore, the cost is prohibitive and rises above £500.

It may be possible to rectify very light damage – for instance, feint scoring or even slight surface corrosion – present on a cylinder bore, though the presence of a "lip" at the top of the bore strongly suggests bore wear is present and the lifespan of the block is severely limited without machining and the fitment of expensive aftermarket custom pistons.

If damaged by corrosion or any other interference, the piston rings should be replaced as a complete set.

Scoring or cracking on the crank journals can be taken care of via usual machining methods and the use of oversize shell bearings on reassembly – the oil pump should be checked and re-built as a matter of course if scoring is found on the crank journals as an oil pressure problem may have been the root cause.

When completely stripped, the engine components should be examined and checked for excessive wear with reference to the appropriate sections in the Haynes (or similar) workshop manual and replaced or machined as appropriate bearing in mind what has already been written about the cylinder bores and aftermarket piston availability.

Here we see an example of one of the cylinder bores in the 2.3 block I obtained for my conversion. This engine had been standing in a scrapyard and then garage for nearly 2 years following a cylinder head gasket failure, and water had entered the bores leading to corrosion of the bores and piston rings.

All four bores were unworn but corroded and were salvaged using a couple of domestic nylon pan scourers to remove the light surface corrosion and then a glaze-breaking tool mounted in an electric hand drill to dress (or "hone") the surface – roughening it sufficiently to help replacement piston rings bed in, and remove any final stubborn corrosion left behind by the nylon scouring pads.

The photograph overleaf shows the block after it had been stripped, cleaned and degreased, painted with black engine lacquer and the bores had been honed.

Having checked, cleaned and dressed the cylinder bores, attention then turned to the crankshaft and the bearing journals. As can be seen from the image below, the journals were in pretty good shape – no visible scoring, cracking or other indication of wear – and it was decided that the crank could be re-used "as is" with just new main and big-end bearing shells fitted.

As the old bearings showed no major or concerning signs of wear, it was decided to replace them with identically-sized shells, and check the running clearances with "Plastigauge".

However, given the state of the cylinder bores, the pistons weren't in quite as good condition as the crank as the following photograph shows.

Moisture had caused corrosion in the piston rings, which had combined with oil present and more moisture to create a rusty "gunge" that glued the piston rings together and effectively stuck them in the grooves.

The damage was not as severe as it looked. Having removed the rings, gentle use of the nylon pan scouring pads and a suitable degreasing agent brought the pistons to an almost "good as new" condition.

Cleaned, the pistons were fitted with new piston rings at a cost of £120 for the engine set before being refitted into the engine block.

6. Preparation of the 2.3 16v cylinder block

In order to be used successfully in the Sierra, the 2.3 cylinder block must be modified to accommodate the complete removal of the balancer shaft assembly.

As can be seen from the three photographs below, while the majority of the standard 2.3 sump is the same size as the 8v 2.0 sump held against it for comparison purposes, the front section is vastly different and will foul the Sierra steering rack and cross member.

However, it is not quite as simple as just changing the sumps – it is necessary to firstly block up the oil feed to the balancer shafts in the block (*to not do so will result in a massive loss of oil pressure*), install a "fillet" piece to make good a section of the block machined away at the factory to provide access for the balancer shaft drive chain, and fit the 8v oil pickup tube, oil splash shield and front sump mounting plate.

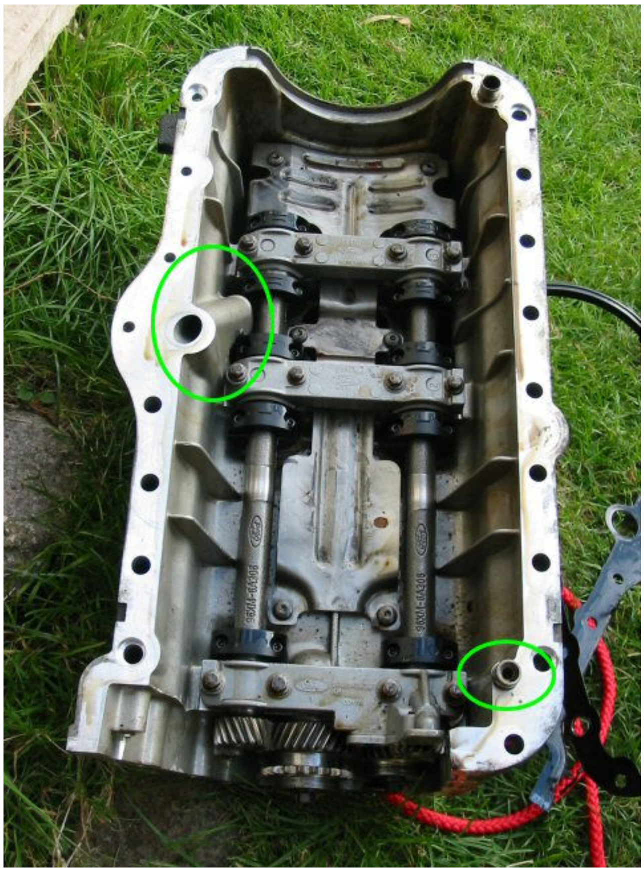
In this section, we will cover these modifications. *Step-by-step strip down, cleaning or re-assembly procedures are not given – it is assumed that anyone following this guide has sufficient mechanical knowledge and the appropriate workshop manuals for the DOHC engines to be able to complete this work without guidance.*

Safety First!
An engine stand is an invaluable tool here as it allows the engine to be rotated completely, easily and safely as it is worked on. Appropriate engine stands can be hired from tool hire shops – check your *Yellow Pages* for more information. It is NOT recommended to work on an engine outside of a vehicle without an engine stand – to do so you run the risk of personal injury should the engine fall or be lifted improperly.

The 2.3 sump is secured to the bottom of the cylinder block via long 8mm hex-headed bolts. Unscrew all of the bolts, separate the sump from the cylinder block and recover the gasket.

The photograph below shows the removed 2.3 sump, complete with counter-rotating balancer shafts.

Note the integral oil-pickup pipe (circled, left) and the oil feed for the balancer shafts contained in the locating dowel (circled, lower right)

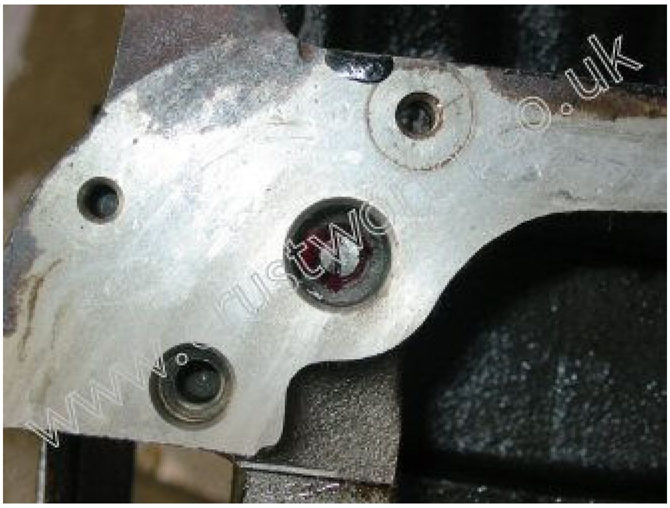


The first job after stripping down and cleaning the engine components is to seal the oil feed to the balancer shafts. This is located in the hole for the front sump locating dowel.

Using grease packed in the feed hole to catch swarf, a thread is cut using an M8 x 1.25 tap.

NOTE: Other tap sizes may fit the hole equally well – I discovered that the thread size was identical to that used on DOHC exhaust manifold studs and, having a few old ones "knocking about" in my toolbox, I fashioned a blanking plug from a cut-down exhaust manifold stud.

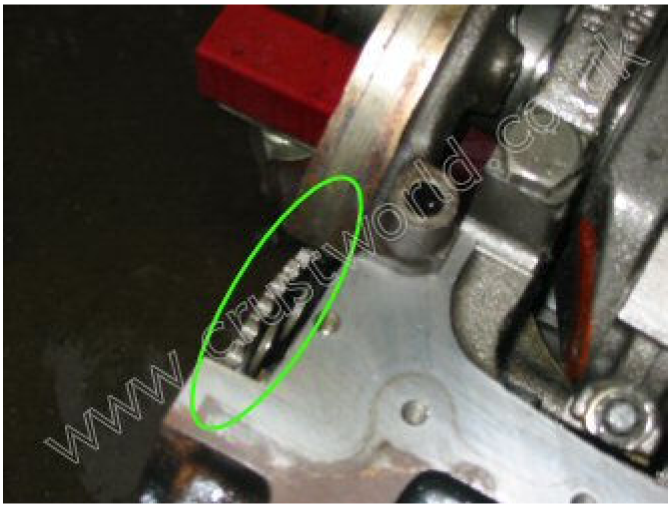
The freshly-cut thread is cleaned out, and a blanking-plug smeared liberally with thread-locker, is screwed in.



The balancer shaft oil feed blocked off, the next task is to install the 8v front sump mounting plate and create the fillet piece that will block the hole left by machining at the factory to accommodate the balancer shaft drive chain.

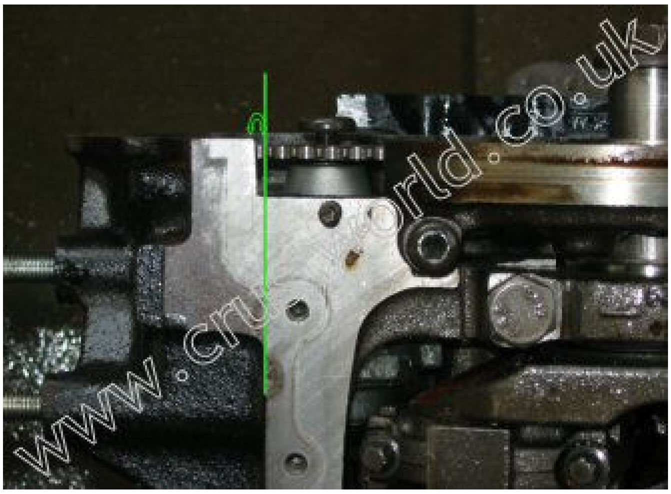
The recommended course of action with relation to the fillet piece is to make a pattern – possibly from wood, or even plastiscene – and get an engineering company to machine up an aluminium or steel equivalent that will fit the gap perfectly.

The photograph opposite shows the gap (circled) that the fillet piece needs to fill once the front sump mounting plate is installed.



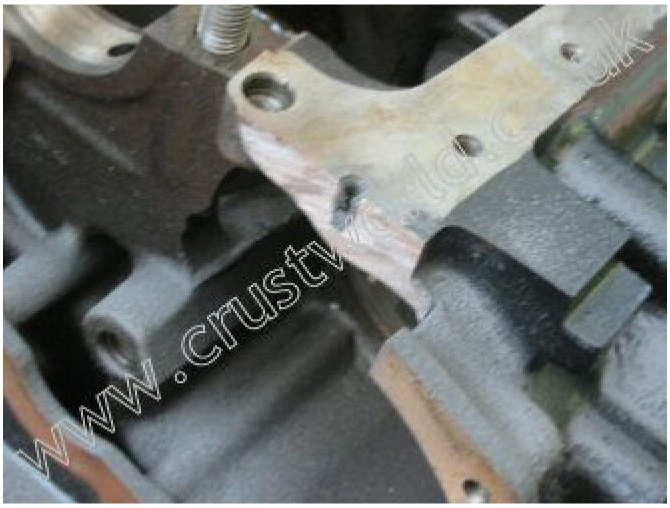
Comparing the same section of the 2.0 (top) and the 2.3 blocks (bottom) reveals an interesting similarity.

It seems that the bulk of the fillet could be cut from the 2.0 block and transferred across – though an alternative solution would have to be found for filling the gap to the left of the green line highlighted on the 2.3 block, below.



By taking a hacksaw to the 2.0 block and grinding the resultant off-cut carefully with a bench grinder, a filler

piece was created that fitted better than expected – the gaps surrounding it being taken up with 'Loctite' silicon-based flange sealant.
While this is not the preferred method of creating a fillet to replace the machined-out section of the 2.3 block, it has been surprisingly acceptable so far with no leaks. It is held firmly in position by one of the front lower timing cover bolts, and the adhesive action of the flange sealer.



Above, the section removed from the 2.0 block and below, sealed into position on the completed engine.

The filler piece created and front sump mounting plate bolted into position, the final stage in modifying the 2.3 block is to install the 8v oil pick-up pipe and oil splash shield.

The oil pick-up pipe is secured to the underside of the cylinder block by two torx bolts. You will need to fit a new gasket, but note that it seems the bolt holes are already tapped to accept a bolt – which is curious as the engine was never intended to have an oil pick-up pipe!

The oil splash shield is a shaped metal plate that bolts onto studs integral with the securing bolts on main bearing caps number 3 and 5. As the 2.3 has no need for a separate splash shield, the main bearing cap bolts do not feature the integral studs for mounting the 8v item against, as can be seen from the following picture showing the 2.3 crank assembly (*taken before stripping)*.

At this point, if it has not already been undertaken, it is an ideal time to check the state of the main bearing journals as this can be done relatively easily and without replacement of any further parts.

In building my 2.3 8-valve engine, I chose to fit new big-end and main bearings as the history of the engine was unknown – despite the bearing shells appearing not excessively worn or otherwise damaged.

The new upper main bearing shells are inserted into the cleaned and prepared engine block.

If fitting new, or simply checking the condition of existing shell bearings, it is highly advisable to check the running clearances of the bearings using "plastigauge". This is a compressible plastic element that is inserted into the bearing before assembly. The bearing is tightened up, then the cap removed without disturbing the bearing – this reveals the squashed plastigauge, and the width of the "squish" can be compared against a card scale to determine the running clearance of the bearing and check it is within specification.

It is important to have bearing clearances that are in specification. Incorrect clearances could lead to overheating and binding problems if the bearing is too tight and low oil pressure and excessive noise when running if too loose.

The running clearance of number 1 main bearing is checked using "plastigauge". The width of the compressed element is compared against the card scale, showing the bearing is "in tolerance"

Bearings checked and reassembled correctly (*note to use new big-end bolts*), the next stage is to fit the 8-valve crank main bearing cap bolts to the main bearing caps in positions 3 and 5.

The photograph above below shows the correct main bearing cap bolts inserted and torque down, and the following photograph shows the 2.0 8v oil pick-up pipe and oil splash shield secured to the 2.3 cylinder block.

Having checked the bearings and fitted the oil splash shield, pickup pipe and sump mounting plate onto the block, the next stage is to fit the 8-valve Sierra oil sump.

A light smear of gasket cement is applied to the underside of the cylinder block to help the sump gasket seal (above)

The cleaned 8v Sierra DOHC sump, complete with new gasket prior to fitting (below)

Using a straight-edge to align the rear face of the sump with the rear face of the cylinder block, the sump is fastened down using 10mm nuts on the four locating studs and 10mm bolts along both sides.

Finally, with the 2.3 cylinder head gasket laid in place, the "short engine" is ready to accept the 8-valve DOHC cylinder head.

7. Preparation of the 8v cylinder head.

As discussed in section 3, it is necessary to make some mechanical modification to the engine to reduce the compression ratio from 10.83 : 1 to something a little more suitable for running on everyday unleaded fuel.

While the use of a decompression plate is an acceptable method of doing this (*for more information, contact Ferriday Engineering at www.ferriday.co.uk*) it may lead to some valve timing issues necessitating the use of relatively expensive adjustable timing chain sprockets to counteract the effect of moving the cylinder head further from the crankshaft.

In building my 2.3 hybrid, I decided that I wasn't going to go down this route as I was going to gasflow the cylinder head as per the DOHC tuning article at the same time.

Having a scrap 2.0 8-valve cylinder head in the workshop, it was used to experiment with the amounts of material that could be successfully ground out of the combustion chambers in order to lower the compression ratio without affecting the strength of the cylinder head itself.

My main area of interest was in the shaping of the combustion chamber itself:

By machining away the material opposite the spark plug, I discovered I could safely remove the required $2cm^3$ of material to bring the compression ratio down to 10.5 : 1 without affecting the strength of the casting – test holes drilled subsequently revealed the aluminium alloy is surprisingly thick at this point.

(above) with the head up-side-down and carefully levelled, the combustion chamber is slowly filled with water to determine its volume. Usually the combustion chamber will be sealed with a Perspex sheet acting as a "head gasket" so the volume can be accurately determined without surface tension or fluid spills giving false readings.

(below) test holes drilled to establish the thickness of the head casting

Test on a scrap cylinder head completed, a good spare head was stripped and cleaned. In line with the advice given in the DOHC Tuning article, the valve throats were "ported" and polished...

Showing the early stages of polishing the walls of one of the inlet tracts

...and based on the experiments with the scrap cylinder head, the combustion chambers were ground out and sized as evenly and closely to $50cm^3$ as possible.

Combustion chambers completed – note the chamfer around the edge of the combustion chamber to give a better "squish band" and prevent the production of hotspots around the edge of the head, and the modified swirl wall next to the inlet valve and spark plug.

Grinding completed, the final stage in cylinder head modification was to clean the head to eliminate traces of swarf, ensure the head gasket face was clean and lap and refit the valves with fresh valve stem oil seals.

NOTE: If a cylinder head is used that has been previously machined ("refaced") to restore the head gasket surface to true, additional material may need removing from the combustion chamber to ensure the desired compression ratio is reached. In these circumstances, it is highly recommended that a decompression plate is used to obtain the correct compression ratio as removing too much material from the cylinder head *will* weaken it.

8. Final assembly, installation and running in.

Cylinder head modifications completed, the final stage is assembly onto the modified 2.3 "short engine".

Although the 2.0 and 2.3 cylinder head gaskets are remarkably similar, the 2.3 cylinder head gasket *must* be used with the 2.3 cylinder block, irrespective of the cylinder head that is used. This is because the fire ring aperture in the gasket is correctly sized not to protrude into the cylinder bore – the 2.0 gasket has a much smaller aperture: the fire rings will protrude into the combustion chambers and will overheat, burn and subsequently fail.

Because the cylinder head interface design is identical across all 2.0 8-valve and 2.0 / 1.3 16-valve engine designs, there are no issues to bear in mind when fitting the cylinder head beyond ensuring the correct gasket is used for the cylinder block and the surfaces are spotlessly clean.

The 8-valve cylinder head in place on the 2.3 short block. Note the fillet piece to block the hole left in the block by the drive chain for the balancer shafts (circled)

Once lifted into position, head bolt tightening sequences and torques, are the same as for the 2.0 8-valve engine. In fact, the entire re-assembly procedure beyond this point exactly mirrors that of the 2.0 8-valve engine and the appropriate portions of the Haynes (or similar) manual can be followed to complete assembly of the camshafts, timing chain, fuel rail, inlet and exhaust manifold assemblies.

Nearing completion, camshafts and timing chain assemblies refitted

Complete and ready for installation – all covers, inlet manifold, injectors and fuel rail and water pump fitted.

A quick "word" about fuel injectors:
16-valve DOHC "I4" engine variants all use the same fuel injector, a Bosch unit rated at 205cc/min when running fuel pressure of 3bar.

Difference in capacities is accommodated through the EEC-V engine management system varying injector duration (*that is, the time for which the injector "squirts" fuel*) depending on the engine capacity the particular management system revision is intended for. For instance, the 2.3 engines utilize slightly longer injector duration than the 2.0 variants.

The EEC-IV engine management system in "open loop" configuration does not do this, injector duration is fixed. Even operating in "closed loop" configuration, where injector duration is dynamically adjusted within set parameters, the standard 2.0 Sierra 8-valve injectors rated at 191cc/min (*or 19lb/hr to use the American method of injector sizing*), will not provide sufficient fuelling for the increased capacity of the engine at the normal fuel pressure.

Rather than increasing the fuel pressure to force more fuel through the injectors, it is recommended that larger injectors are fitted and the fuel pressure remain unaltered and within safe operational limits to prevent damage to the fuel line or pump, or dangerous high-pressure leaks.

Increasing the injector size will provide the correct fuelling for the engine to perform optimally, especially on cars fitted "closed loop" EEC-IV systems with the Oxygen / HEGO sensor in the exhaust - the engine management system will automatically adjust the injector duration to give correct fuelling.

However, it should be noted that on cars operating in "open loop" mode, that is without an Oxygen / HEGO sensor in the exhaust, that the ECU will be unable to compensate if too large an injector is fitted and this will actively *reduce* the output of the engine due to excessive amounts of injected fuel adversely affecting the combustion process.

Over-fuelling – the condition that exists when more fuel is injected than can be burned - will damage the engine in the long term as unburned fuel will wash the light film of lubricating oil off the cylinder walls and cause accelerated cylinder or piston ring wear, effectively undoing your hard work in fitting the 2.3 bottom end in the first place! ☹

Personal experience has shown that 250cc/min injectors to be too large for the application, even when the fuel pressure is reduced to give a lower rate of fuel injection (comparable to 235cc/min) and at the time of writing, I am experimenting with 210cc/min injectors from the Vauxhall 2.5 and 3.0 V6 engine as used in the Omega and Vectra models but am unable to give any data relating to these at this time beyond the observation that they are perhaps a bit too small judging by the flat spot experienced in the mid-range – this project is still a "work in progress"!

As such, at the moment the best advice I can give for owners of cars operating in "open loop" mode and without Oxygen / HEGO sensors is to not initially fit fuel injectors larger than about 230cc/min and have the fuelling checked carefully across the rev-range of the engine to ensure that the fuelling is correct before tuning further. This can be done by any rolling road tuning specialist and is *not* the same as having the CO emissions checked for the MOT!

With regards to the final assembly of the 2.3 8-valve engine and fitting into the car, you may find the following information helpful:

- ✓ All DOHC "I4" engines use the same water pump
- ✓ Using the Sierra 8-valve DOHC flywheel will enable you to re-use the Sierra DOHC clutch: ideal if your conversion is being done on a budget as an existing one can be retained. *However ensure that the clutch is in good condition!*
- ✓ When fitting the flywheel, use *new* flywheel bolts of the same type that were on the 2.0 (*i.e. for a manual*

or automatic flywheel) if you are keeping the 2.0 flywheel.
- ✓ Always use a new crankshaft pulley bolt when fitting the crankshaft pulley – they are "fit once" items and can't be re-used without risking damage to the engine.
- ✓ If fitting the later-type metal lower timing chain cover (*as I did*), you will find that Sierra 8-valve DOHC lower cover securing bolts are too long. This is because the cover is thinner than the plastic item originally used on the 8-valve Sierra. The solution is to either pad the bolt heads out with suitable washers, buy the later type of bolt which is shorter, or shorten any existing bolts you may have using a hacksaw (*when I did mine, I chose to do the latter*).
- ✓ Ensure you fit a new "spigot" or clutch pilot bearing into the 2.3 crank. Most 2.3 engines were fitted into Scorpio's with automatic transmission and as such never had the clutch pilot bearing! The blind hole is still drilled in the crank to accommodate it, and a new bearing should be fitted before the engine is installed in the car.
- ✓ It is a reasonable idea – though not a mandatory one – to leave securing the camshaft cover until the engine is in the car. *This way, when the engine is being turned over for the first time on the starter motor to build oil pressure before initial starting, oil can be observed spraying onto the camshafts from the lubrication bars that run overhead. At this point, once there is known to be oil pressure at the top of the engine, the cover can be carefully bolted down with a new gasket and smear of gasket cement to aid sealing.*
- ✓ Fit the sparkplugs last – especially if you're cranking the engine a lot to circulate oil and build oil pressure!
- ✓ Replace the standard 085 / 440-amp battery with a heavy-duty item. The standard 085 battery will struggle to produce the power necessary to turn the engine over against the higher-than-normal compression on cold days or when the engine is hot if standard 2.0 camshafts are retained (*they will produce the most compression due to more conservative valve timing*).
- ✓ Once the final build-up is complete, the standard owners workshop manual steps covering removal and refitting of the existing DOHC engine can be used – only instead fit the 2.3 8-valve hybrid in place of the engine that came out!
- ✓ Ensure you have appropriate tools for removing the engine and lifting the new one back in. With an assistant to help you if necessary. ☺
- ✓ Allow two days for the removal of the existing 2.0 DOHC engine and the fitting of the 2.3 in its place. You may take less time than this – I took two days with meal and drinks breaks in the autumn with reduced daylight hours!
- ✓ Re-fill the cooling system *slowly*, paying particular attention to removing any trapped air. As you are refilling the system, squeeze all hoses to encourage air to escape and allow the water to settle in the expansion tank before topping it up further. *As a guide, the cooling system takes between 7.0 and 7.3 litres depending on model so expect to put this back in before you turn the key!*
- ✓ If you're fitting aftermarket camshafts, my advice is to run the engine in for 500 miles or so before fitting them. *Most performance camshaft manufacturers specify a minimum engine speed for the first twenty minutes or so to make sure the camshafts properly "bed in" and to minimise the chances of any accelerated wear later – personally I find running a newly rebuilt engine at such speeds a bad idea in the first moments of its life when you need to be concentrating on dealing with any other problems that may present themselves but at the end of the day it's up to you.*

Once you are sure everything is connected, tightened and filled up, with a final check over for leaking coolant or disconnected cables or hoses, reconnect the battery and start the engine. This may take some time and when the engine first starts it may run rough and noisily for a few minutes until it settles down and oil circulates properly to the hydraulic tappets.

For the first few minutes, do not rev the engine excessively – despite degreasing and using clean oil on the rebuild, there *will* be dirt and other contaminants in the oil that have been languishing deep inside the block that are best served not being blasted round the inside of the engine. Plus you need to be busy squeezing hoses to ensure that any air trapped in the cooling system escapes as the engine warms up gently, not revving the pants off it in delight.

Try to run the engine until the thermostat opens and the cooling fan cuts in. There will be odd smells as new gaskets warm through, oil burns off the side of the engine and as any skin or blood left behind evaporates! At that point, allow the fan to bring the engine temperature down and then stop the engine. While it's cooling and oil drains back to the sump, check it over to make sure bolts and hoses have remained in place and nothing's leaked.

So once your engine is fitted into the car and is running, what about any running in period? This is especially important if new pistons, rings and bearings have been fitted during the course of the rebuild.

Advice on running in will vary from engine builder to engine builder and can sometimes be contradictory.

What I did was to drive very gently, avoiding any engine speeds above 2000-revs and excessively labouring the engine for the first 150 miles, keeping a close eye on coolant and oil levels the whole time, after which I changed the oil from the engine using a proprietary engine oil flush in the process, fitted a new oil filter and refilled the engine with clean 5w30 oil.

After that point, the engine was run semi-normally – still avoiding excessive labouring (*for instance, trying to go up a hill in fifth gear*) and enthusiastic over-revving (*so leave the chav in the Saxo alone – he'll wait for later*) but gradually increasing the maximum engine speeds by approximately 1000-revs with every additional 100 miles travelled.

The general consensus was that this was reasonable given that no machining of the crank had taken place, and that the bores were only lightly honed to accept the new piston rings. *You should find that it is entirely realistic to do too – the engine will produce sufficiently increased amounts or torque low down in the rev-range to make around-town driving almost relaxed without the need for high engine speeds!*

After 500 miles had passed, the engine oil was changed again for fresh 5w30 along with the fitting of a new filter. At this point, the running in period was deemed to have been completed.

If your own engine has not been machined in any way, the main or big-end bearings not been disturbed, nor had new piston rings, you could reasonably take the view that a running in period is not needed and that beyond an initial oil change after a relatively short period of time to remove any dirt remaining in the crankcase, the engine can be driven as "normally" as you see fit.

Conversely, should the crank journals and cylinder bores have been machined and new pistons fitted, a running in period in excess of what I undertook may be needed. The engineering company who perform the machining work for you will advise what they see as realistic in this instance.

And we're done!

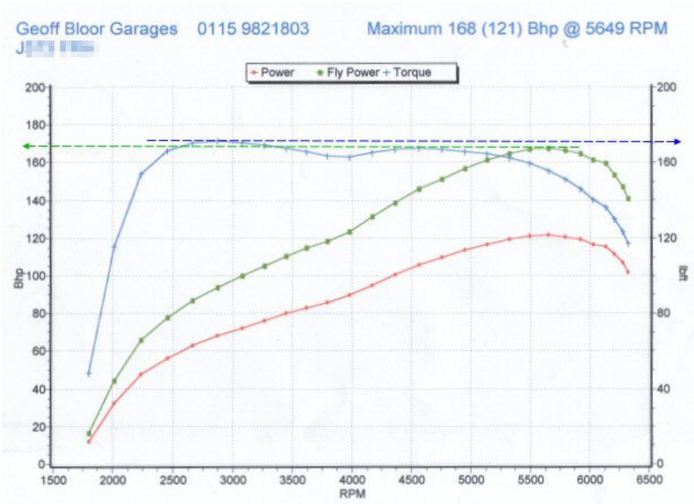
Like it was meant to be there and little to visually distinguish it from a standard 2.0 DOHC – the 2.3 8-valve DOHC hybrid

9. The results: 2.3 8-valve power output

To build my hybrid 2.3 8-valve engine cost me in the region of £600.00 once all components and expenditures were taken into account.

After the running-in period was completed, I took the car to a local tuning company and had the engine output measured on a rolling road dynamometer.

They recorded a maximum power output of 168bhp and 171lb f ft (231Nm) of torque, with the power being delivered consistently and smoothly through the rev-range as can be seen from the graph below



To put this into context, period Ford literature states that the 12-valve 2.9 EFi V6 engine used in XR4x4 Sierra and many executive Granada models produced 150bhp and 230Nm of torque.

So the 2.3 8-valve engine here produced a power output greater than an engine 600cc and two cylinders larger!

In obtaining this figure, besides the 2.3 8v engine itself, the following modifications were made to the car:

- Piper BP285 "ultimate road" camshafts
- Ported and gas-flowed cylinder head
- Collins Engineering "powerchip"
- Bosch 250cc/min injectors
- Janspeed 4-2-1 exhaust manifold and unbranded "black diamond" sports system
- K&N 57i cone filter on modified air intake
- Bosch "super-4" sparkplugs
- Extralube ZX1 friction reducing oil additive.

So, was it worth it? I have to answer with an unqualified "yes" – the 2.3 8-valve setup retains the prior investment made in tuning the 2.0 DOHC engine, and produces a *very* rewarding driving experience: relaxed on the motorway, yet nimble around town, and with a hidden depth of power that just seemed to want to keep on going when you open the throttle...