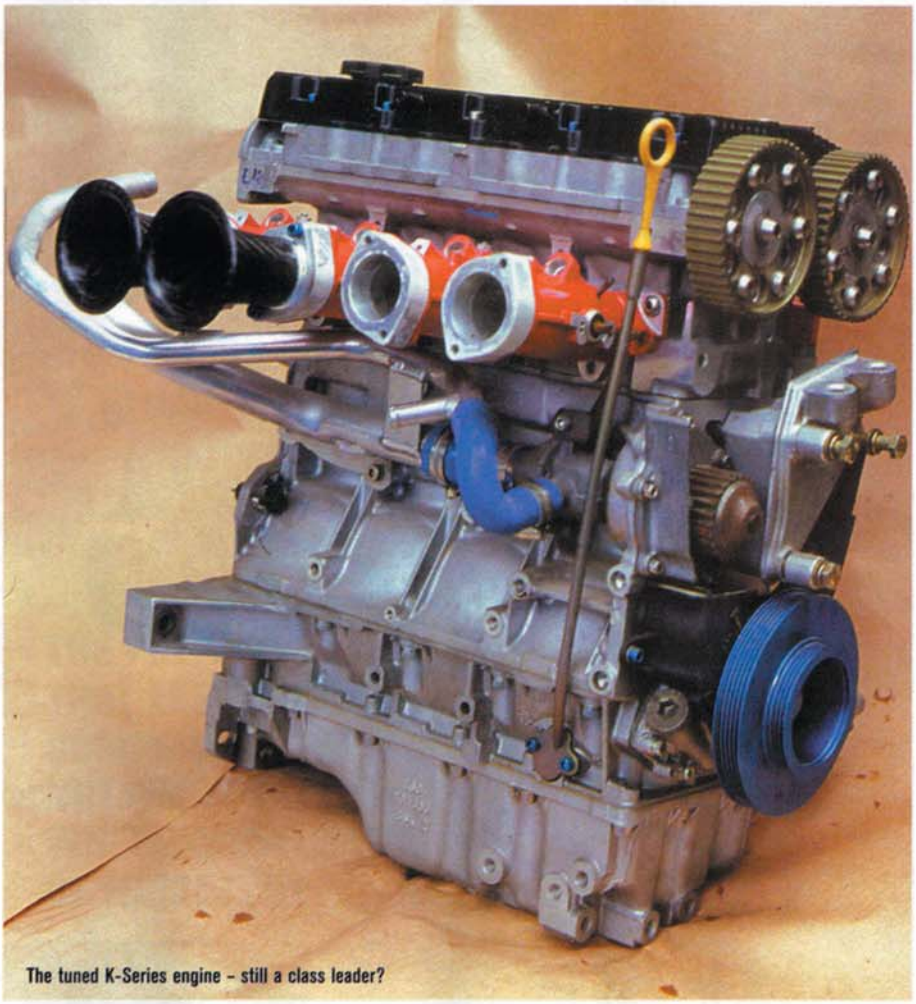
King K

Is the Rover K-Series engine the fragile unit many believe or has it been maligned by tuners failing to consider basic engine building principles?

Words & photos Simon Erland


The tuned K-Series engine – still a class leader?

Of the 17,000 Lotus Elises on the road, Lotus itself estimates 40 per cent have already been modified to some degree. Add to that all the Caterhams, rally Metros and MGs and the Rover K-Series represents one of the most significant engines in four-cylinder motorsport history. The credit for this goes to those manufacturers who realise that light weight in an engine is as important as power output.

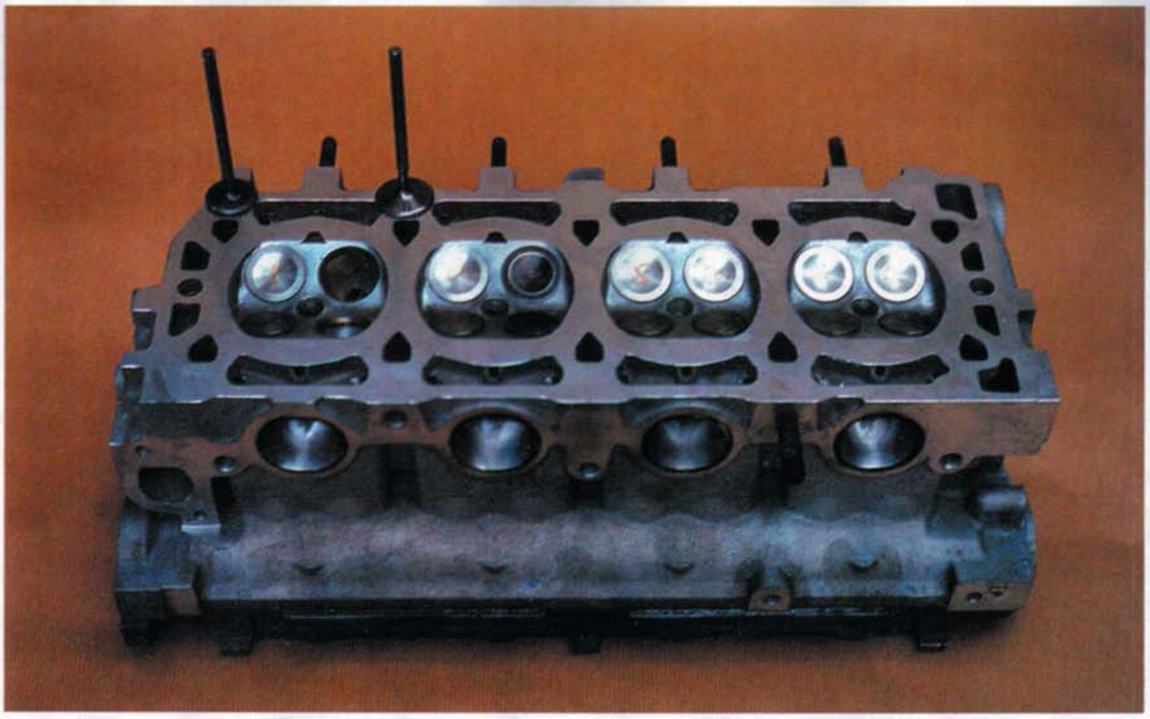
Unfortunately, as anyone who follows the letter pages of the automotive press will know, there is a widespread perception of the K-Series being fragile and all too breakable an engine that requires a huge amount of modification and expense to permit even relatively modest power upgrades reliably. Widespread are the stories of cracked liners, blown gaskets, spun bearings and all manner of woe.

But is the K-Series really so poor and, if so, why are leading sportscar manufacturers using it? Research has shown that the K-Series is far from a problematic engine and in fact, despite two minor design flaws – both of which have now been remedied – the engine represented a considerable advance in four-cylinder engine design at its launch. Its uniquely strong and sophisticated design offers huge weight benefits, so much so that even 20 years later no other manufacturer has caught up. It has also been a seminal influence on all other fours since, yet still remains significantly ahead of its rivals in its lightweight design, while many problems associated with the K-Series have been entirely due to poor engine building by some of those tuning the engine. People have been building problems into the K-Series.

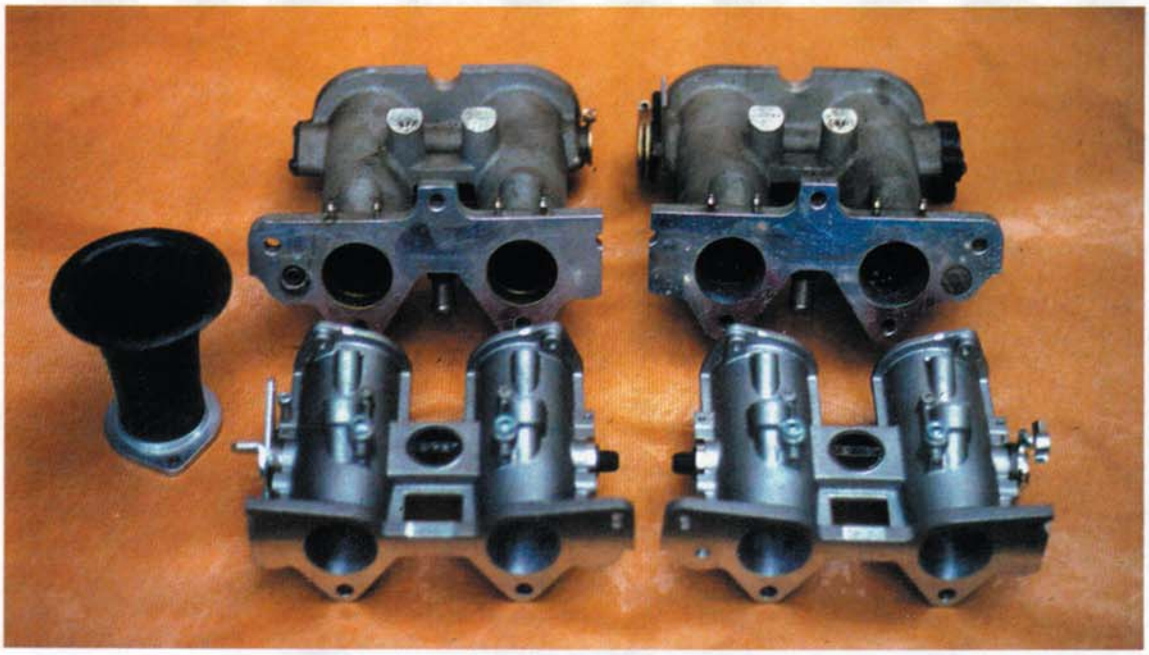
> "THE ROVER K-SERIES REPRESENTS ONE OF THE MOST SIGNIFICANT ENGINES IN FOUR-CYLINDER MOTORSPORT HISTORY"

Basic principles

It is useful firstly to look at the basic construction and compare it with other four-cylinder engines around at the moment. The brief for the K-Series was for a lightweight and efficient unit to power a plastic-bodied concept car called ECV3, with the first all-aluminium bonded chassis, then under development at Rover. Few people realise that this revolutionary concept was not only a Rover venture, but it was also conceived along with the K-Series engine and preceded the Elise by 15 years. The original engine had a top hung, wet liner, now replaced across the 1.4 – 1.8-litre range with a floating,



K16 head ported for Paul Ivey, with 29.5/26mm valves



Original VHPD throttle bodies (top) and replacement QED/Jenvey direct to head throttle bodies with carbon trumpet

half-wet liner. The early block was closed at the top, and this has sponsored one of the many myths about the K-Series – that the early 1.4-litre is a stiffer and better block. Some engine tuners look at the current block with its fully floating liner and immediately cry out in horror. The Rover design engineers however are quite clear – the blocks do have slightly different figures for stiffness, but the later block was designed to be as stiff in every required axis as the earlier block. There is absolutely no problem with this design. It is quite common for the top half of the liner to be laterally unsupported in V8 engines, and indeed, current IndyCar engines use this exact design. Nipping the liner beneath the head and a shoulder with only the lower half sitting in the block allows very efficient heat dissipation – essential for the use of low octane fuels in road cars and the high compression ratios of race engines.

"IT STILL REMAINS SIGNIFICANTLY AHEAD OF ITS RIVALS IN ITS LIGHTWEIGHT DESIGN"

The block and ladder frame that support the crank were a first for a mass produced engine. This arrangement is stiffer than conventional bearing caps, whilst again allowing the block to be very light. This is the area of the block that actually supports the crank and therefore carries all the loading imposed on the engine by the crank, and this kind of design had only previously be seen in fully-fledged race engines. The only engines which have caught up with the K-Series on this front are the 2.0-litre in the Honda S2000, the 2.0-litre from the Civic-R and the 1.9-litre VVTi in the Toyota Celica. All are copies of the K-Series in this fundamental area of engine design.

It is another frequently heard criticism of the K-Series that it has very narrow main and big end bearings. This is a feature of the fact that the engine is very compact with narrow centres of 88mm (only the Yamaha/Ford Puma and Toyota VVTi engines are narrower at 86.5mm). This again contributes to the lightweight →

nature of the block and has a further benefit in that the narrower the bearing surface area, the less the frictional loss in an engine. In the interests of power output alone, it is desirable to have a bearing as narrow as possible. In order to enable this, the loading on the bearings needs to be minimised by using a crank as stiff and accurately counterweighted as possible, and by careful associated design of the block – with the lowest possible reciprocating mass and a tight dynamic loading tolerance. All of this results in a complete engine that weighs, in standard form, just 96.5kg, including fluids. Compare this to a similarly equipped Honda S2000 engine with standard manifold, clutch and fluids at 158kg and the Toyota 1.9 VVTi engine at 137kg.

> **"THE BLOCK AND LADDER FRAME THAT SUPPORT THE CRANK WERE A FIRST FOR A MASS PRODUCED ENGINE"**

The Rover engine's compact size and weight are a significant advantage in a lightweight race/sportscar of the Lotus 7 type or the Elise. It is worth noting that a full race K-Series weighs just 78kg, including 7kg of fluids. It is a myth that the new Ford Duratec even comes close to the weight of the K-Series. Ford themselves gave us a standard weight of 127kg, without fluids, while Westfield claim a prepared weight of 92kg, without fluids, exhaust or clutch. A modestly prepared equivalent K-Series weighs 75kg – 17kg lighter or 23 per cent less engine weight. See figure 1 for a comparison of these engines output in terms of power to engine weight.

Figure 1

Engine	Power output	Power/engine weight
Ford Duratec 2.0-litre	140 bhp @ 6000 rpm	1.16bhp/kg
Honda S2000 2.0-litre	237 bhp @ 8300 rpm	1.5bhp/kg
Toyota 1.9-litre VVTi	189 bhp @ 7800 rpm	1.3bhp/kg
Standard K 1.8-litre	120 bhp @ 5500 rpm	1.25bhp/kg
K-Series VHPD	184 bhp @ 7000 rpm	1.91bhp/kg
K-Series R 500	235 bhp @ 8500 rpm	2.6bhp/kg
K-Series K2000	293 bhp @ 8500 rpm	3.9bhp/kg

Figure 2

Crankshaft	Initial level of unbalance (g/mm)		Final level of balance (g/mm) as balanced by Vibration Free	
	flywheel	nose	flywheel	nose
Steel crank make A - 1	773.5	313.8	17.1	15.1
Steel crank make A - 2	754.8	334.7	38.0	36.5
Steel crank make A - 3	764.3	328.4		
Steel crank make B - 1	747.3	106.9		
Steel crank make B - 2	783.7	362.0		
Steel crank make B - 3	748.7	301.7		
Steel crank make C	693.7	307.4		
Steel crank make D	227.1	68.2		
Std Rover iron crank -1	80.3	22.8	22.7	19.7
Std Rover iron crank - 2	79.3	11.5		
VHPD iron crank	360.2	25.7		

Figure 3

Flywheel	Initial level of unbalance (g/mm)	Final (g/mm) as balanced by Vibration Free
Steel crank make A - 1	238.4	3.65
Steel crank make A - 2	274.8	
Steel crank make A - 3	257.9	
Steel crank make B - 1	277.9	
Steel crank make B - 2	254.8	6.49
Steel crank make B - 3	279.3	
Steel crank make C - 1	708.5	65
Std Rover iron -1	115.0	
Std Rover iron - 2	112.3	

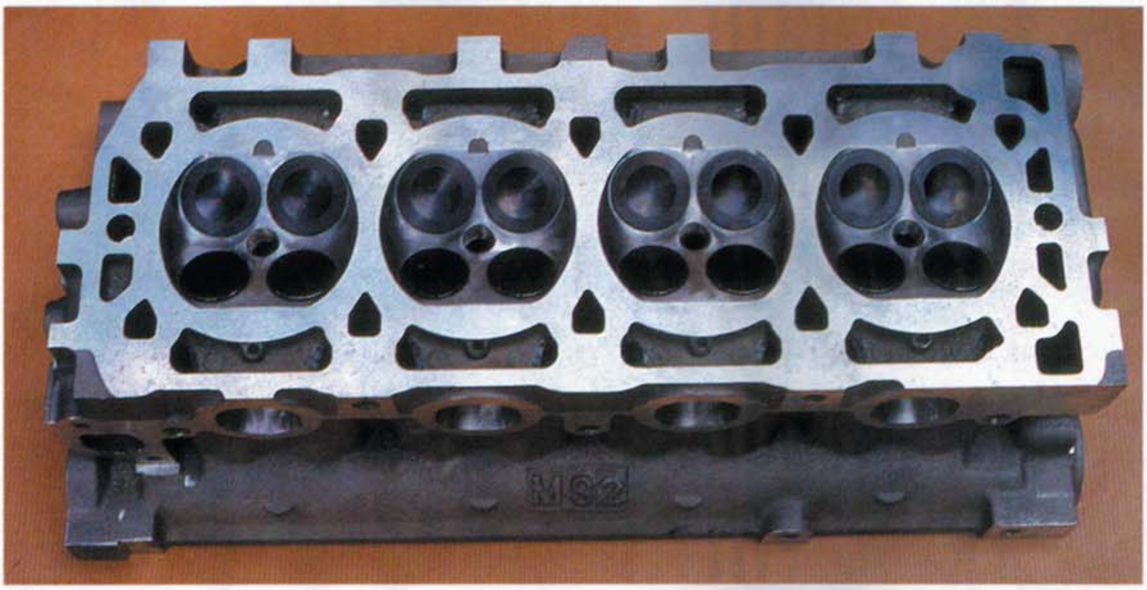
Blown gaskets

All this of course is on the assumption that the K-Series can do this reliably. As well as the commonly held perception of it being a fragile engine, there have been an enormous number of problems, from gasket and liner failure to complete bottom end failure. But why is this? There are a myriad myths and tales, but there is also some kitchen sink engineering being done by the tuning companies.

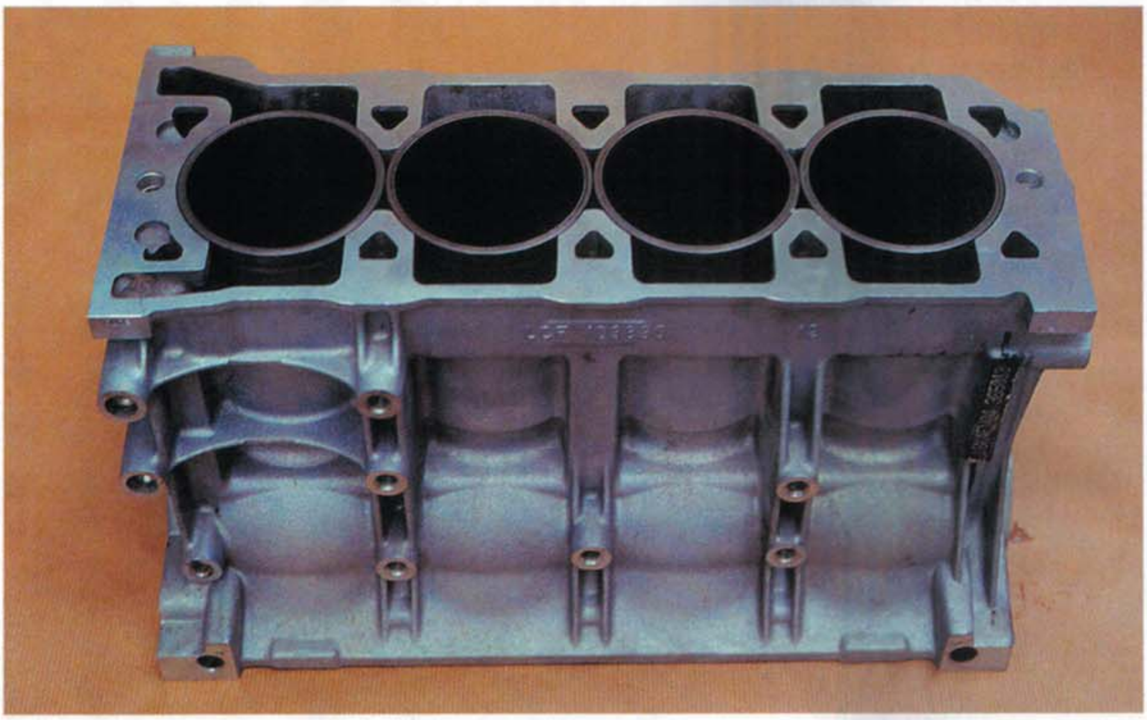
The most common problems on tuned K-Series relate to blown gaskets and cracked liners. Ironically, neither the standard gasket that has proved perfectly sound on the latest 2.0-litre BTCC K-Series engines, or the standard liner is at fault.

There were two principle causes of gasket failures. Firstly, the location of the thermostat in the coolant loop. The engine was designed principally as an efficient engine for small family cars seeing a large number of inner city journeys. To facilitate rapid warm-up, the thermostat is placed on the inlet side to the engine. This gives low emissions from start and good fuel economy and works well in its required purpose. It is, however, totally inappropriate for an engine seeing high revolutions and loads. The worst problems were seen in Landrover Freelanders and last year Landrover introduced a new PRT thermostat which opens with pressure as well as temperature. This has transformed the gasket failure rate on production cars. However, a →

For motorsport, use forged pistons such as this from Omega



MS2 big valve motorsport head with Paul Ivey 32.5/27.5mm high-performance coated valves



K-Series block showing open topped damp liner, now common in four-cylinder engine design

more effective solution on racecars is to move the thermostat to the output side of the engine. This allows it to measure the engine temperature quickly and sensitively, and is a complete solution to temperature-related failures.

Cracked liners

Secondly, the K-Series was designed and originally manufactured with steel dowels locating the head to the block. Unfortunately, these were replaced with plastic dowels in early 1.8-litre engines and were also used in most of the VHPDs (very high performance derivatives of the K-Series entirely unrelated as a commercial engine to Rover). This was a mistake and the dowels were re-specified as steel in 2000.

The temporary use of plastic dowels had the unfortunate consequence of misleading many into thinking that there was a problem with the liners themselves, as head shuffle became a problem in engines still equipped with plastic dowels. This was allowing the liner to rock in the block and eventually split – a result often seen on earlier engines when pushed hard, but never on engines equipped with steel dowels. This is the direct cause of the myth about weak liners, but few ever thought to question the plastic dowels and instead tried to find solutions by modifying the liners themselves. This, in turn, brought about many bizarre and totally unnecessary 'would be' solutions including liners soldered together to form a mono block, banded steel liners and blocks with the tops welded in to form a closed block. In fact, closing the top of the block will succeed only in interfering with the engine's cooling. All this when it was only the plastic dowels at fault.

> **"PEOPLE HAVE BEEN BUILDING PROBLEMS INTO THE K-SERIES"**

Even if the liners are totally sound, they are not without disadvantages. Chief is that the fit of the early liners into the bores was poor, causing a great deal of liner movement which, combined with the high rod angle of the 1.8-litre, caused significant piston skirt to liner friction. This is always evident on the bruised skirts from 1.8-litre pistons and therefore, as a matter of efficiency, if not reliability, the liners are better replaced by steel Chromoduro liners with a low friction, Lubrichrom coating. These will not move around in the bores and give the ideal five thou stand-proud. In 2003 the standard →

Rover liners were re-specified for better fit to the block and stand-proud. The tolerance on bore was also tightened and now there is only one liner grade. Similarly with the pistons, no longer are there grades A and B available.

A second disadvantage is that cast iron liners will always distort. This has been a significant problem with Honda's recent engines and may well also be in the new Toyota VVTi engine.

Bottom end failure

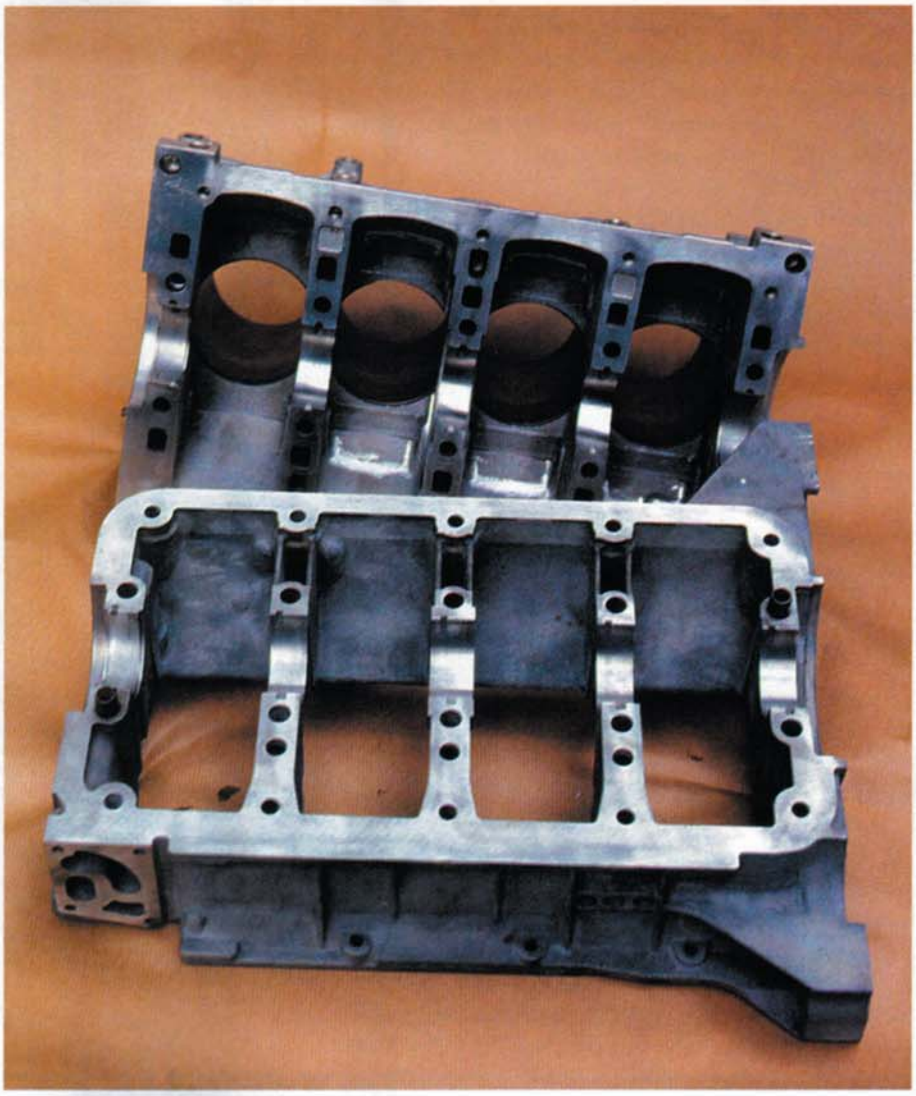
Another high-profile problem from which the K-Series is perceived to suffer is bottom end failure at high engine speeds, with spun bearings often sending rods through the block. Figure 2 is a table of crankshafts measured for dynamic unbalance, expressed in grammes/millimetres from a number of makers manufacturing steel aftermarket crankshafts for the engine, as well as the standard cast iron Rover crankshaft (all measurements taken by Steve Smith of Vibration Free). Smith uses techniques that give more sensitive measurements than anywhere outside of F1 operations and he works for a number of motorsport teams currently involved in F1, Cart, IndyCar and Le Mans endurance series.

The levels in the right hand columns represent the levels of balance achieved by Smith. A level of 40g/mm represents the required level for an engine spinning to 9500rpm. Crank A – 1 in the table was balanced to inside the 2001 F1 specifications (a required level of 26g/mm). It is worth noting that the cranks measured in the left hand column came from a variety of sources, both direct from their manufacturers and from intermediate tuning companies who had balanced elements both individually and as an assembly. Also included is a number of standard Rover iron cranks. Figure 3 shows a similar table for flywheels.

Balancing and blueprinting are both relative terms. All engines, from Ilmor V10s to Rover K-Series engines are balanced and blueprinted to a specified, required level. This level depends upon the engine's use and its maximum speed of rotation. If an engine is outside its balancing tolerance it will vibrate, like an oscillating hammer, and the faster an engine rotates, the more violent the hammering. Any rotating mass will do this – the tolerance simply reflects a maximum limit.

The fact that some of the cranks and flywheels measured come from engines that had been built by specialist tuners is cause for concern and is the cause of all the bottom end problems the K-Series has been suffering. Put simply, some suppliers and engine builders have been using components that are wildly outside the tolerance limits for a standard factory engine and then exacerbating the problem by raising the rev limit. This is why many tuned →

"SUPPLIERS AND ENGINE BUILDERS HAVE BEEN USING COMPONENTS THAT ARE WILDLY OUTSIDE THE TOLERANCE LIMITS FOR A STANDARD FACTORY ENGINE"



The Rover K-Series exhibited seminal bearing ladder construction – an idea now widely copied by Honda, Toyota and BMW

Original forged rod (top) and replacement motorsport rod, both showing Vibration Free's balancing corrections engines are so rough when compared to a standard factory engine. They rev more freely with less advance in the mapping and feature lightweight flywheels and clutches but, put back-to-back, the modified engines are rough. The degree to which these engines actually see this unbalance depends upon the relative position of unbalance of flywheel and crank. Opposite and they will cancel these forces out to an extent. But if they coincide they combine, and I have seen resultant bearing loads as a result of these forces top 120kgf at 9200rpm. Compare this with a standard factory crank and flywheel that measure 6.7kgf at 9200rpm.

At best these engines will be highly stressed, lose power, wear more rapidly, be noisy and more difficult to drive – particularly when using a race clutch. At worst, the bearing loads become so much as to squeeze out the bearing oil film, resulting in seizure and total failure.

Throughbolt design

Another major issue that is significantly misunderstood is the design concept of the longbolts that hold the engine together. The torque setting of 34Nm and the metallurgy of these bolts were designed very carefully to allow them to stretch with the movement of the block that will happen in any engine. This design allows the loading of the block to be evenly distributed throughout the structure, reducing the effective stressing of the block. These bolts have proved themselves capable of handling close to 300bhp in the new K-Series BTCC engines without any problems. However, it is common for these bolts to be replaced with stiffer, aftermarket bolts. Not only does this imply a complete misunderstanding of the design concept of the engine but worse, Rover's own stress analysis shows that the use of these bolts will cause fatigue failure of the block due to effective point loading. To make matters worse, often these non-OE bolts are torqued beyond 34Nm without the crank path being align bored. This causes distortion of the crank path, bearing crush and loss of power.

The real problem with the K-Series has been that it is the first truly optimised engine to see mass production, and few of the tuning companies or individuals involved have had the knowledge or experience to handle it. Most of these companies were only previously experienced with the older generation of iron block engines and their techniques and practices are only appropriate for this older generation of engines. Clearly, it is these practices and the general lack of adequate tolerances that have caused the K-Series engine to fail so often.

And this is not just a problem with the K-Series either, but also many of the other newer generation engines from other manufacturers used in lower motorsport series such as F3, BTCC etc. Unfortunately it is considered a K-Series problem only because these engines see a much higher level of tune – BTCC engines are limited to a modest 8500rpm, F3 to a mere 6000rpm. Also, the sheer number of K-Series engines used in motorsport dwarfs the numbers of all the other engines put together, so there are many more to go wrong, and most are in the hands of individuals rather than sponsored teams.

Quite simply, the K-Series is a remarkable engine, arguably the best four cylinder around and uniquely suited to motorsport. Far more so in fact than the heavy Japanese copies with their over-engineering and certainly more so than the 2.0-litre Duratec with its archaic and flimsy bearing cap design. The K-Series deserves more recognition for the engine that it is, but it has been badly let down by companies trying to tune it incorrectly. What is unbelievable is that the companies involved, particularly the sportscar manufacturers, have not gone to the Rover design engineers for any help or advice. Given proper respect and understanding, it is unbeatable as a four cylinder and is still ahead of all its rivals, but when tuned it must be treated with the respect and care with which it was designed. With a host of new developments, including a heavy-metalled crank and new 2.0-litre versions – currently producing almost 300bhp and 190lb.ft of torque on a plenum – it seems that the best is still to come from this exceptional engine.

Comparison between original oil rail and longbolts and aftermarket replacements (behind) which can be used to cause crank binding and fatigue failure of the block

For greater efficiency and reliability, Lubichrom-coated Chromoduro liners (left) should be used to replace the standard Rover 80mm iron liners

"THE K-SERIES DESERVES MORE RECOGNITION FOR THE ENGINE THAT IT IS"

King K

Rover’s K Series — a lightweight, technically advanced easily tuneable four, or an unreliable and fragile lump?

Two years ago, I bought from the Commercial Director of the Lotus One Make motorsport series my Lotus ex-racer. Dave Cooling had recently left Lotus to pursue his own business, but was and remains very close to the company. It was on the drive to the factory, where I had been invited to meet some of the Lotus engineers, that Dave regaled me with stories of how much trouble they had had with the K Series engine – with vibration, with bottom end failure and endless blown gaskets. He revealed that they had thought very hard about junking the K and replacing it with the Honda S2000’s 2 litre engine, which as Dave said, would give a “reliable” 237 bhp.

On arrival I was met by Myles Lubbock, chief engineer on the One Make Series, and his right hand man John Danby, both of whom knew that I had done a lot of work on the K Series engine in pursuit of a bullet proof 350 bhp supercharged engine. It was immediately clear from the moment that I met them, that they were having all sorts of problems. In fact, they were at their wits ends and had very little respect for the engine. Myles, a very serious and able engineer, told me of their problems and efforts to understand them, even of doing a tranche of tests with vibration sensors mounted all over the block to measure what he considered to be the engine’s weakest feature. His assertion was that the engine was made out of very poor quality metal and the block suffered from enormous distortion. He thought the engine very fragile, and I suspect more trouble than it could possibly be worth. They were also having immense problems with gasket failure, and even as recently as last November when I spoke to Tony Schute, head of the Elise development program at Lotus, it was plain that Lotus had an engrained belief that the K would suffer gasket failure in any engine over and above the 190PS VHPD specification within an unreasonably short period of time.

Lotus are not the only people to have a similar experience. Another car manufacturer specialising in road/track day racers produced a flagship model a couple of years ago boasting trick throttle bodies, a steel bottom end and 230 bhp / 9200 rpm specification. The car is a stormer, regaled as being quicker in a straight line than the McLaren F1, but has gained just as vivid a reputation for fragility, notably for putting rods through the block. I myself have met five owners of cars whose engines have done just that, Dave Andrews tells me of more, and all the journalists from the mainstream motoring magazines relate stories of great car – until the engine goes. Similarly, there are engine builders up and down the country who look upon the K as all too breakable in their experience, and the letters pages of this magazine have, in their time, been full of stories of cracked liners, blown gaskets, spun bearings, and in fact and all manner of woe.

Is the K Series really so poor? And if so, why are some of the leading sports car manufacturers using it? I firmly believe not, and rather that it is in many ways the best four cylinder engine around despite its age. During the last three years, I have done a great deal of research into the engine and particularly bottom end loading, in which period I have been lucky enough to be able to call upon the advice and opinion – sometimes very colourful, of the design engineers for K at Powertrain Ltd – MG Rover Engines. In this time it has become very evident that the engine is very sound, its basic design having had just two minor flaws both now remedied, and that the problems that have beset K, are entirely due to poor engine building by many of those tuning the engine – people are building problems into K!

It is useful firstly to look at the basic construction and compare it with other four cylinder engines around at the moment. The brief for K was originally for 3 and 4 cylinder aluminium engines that would be both lightweight and efficient, to power an all-plastic concept car called the ECV3, then under development at Rover’s secret Gaydon research centre. The 3 cylinder was dropped and the K eventually emerged in 1.1 and 1.4 litre, single and DOHC forms. The original engine had a top hung wet liner, now replaced across the 1.4 – 1.8L range with a floating half-wet liner. The block on the early 1.4 was closed at the top, and this has sponsored one of the many myths about the K, that the early 1.4 is a stiffer and better block. Some engine tuners look at the current block with its fully floating liner and immediately cry out in horror. I haven’t, prior to publication, managed to elicit from Rover precise figures for torsional stiffness for the two blocks. However, the engineers are quite explicit – the blocks do have slightly different figures for stiffness, but the later block was designed to be as stiff in every required axis as the earlier block. There is absolutely no problem with this design. Indeed, it does make me wonder about the experience of some criticising this block design when it is quite common for the top half of the liner to be laterally unsupported in V8 engines. For example, the current Nascar engines use exactly this design and no one would think to criticise them for this concept. In fact, nipping the liner beneath the head and a shoulder with only the lower half sitting in the block allows very efficient heat dissipation – essential for the use of low octane fuels in road cars, and the high compression ratios of race engines. It is a well established design and there were absolutely no compromise in the stiffness of the second generation block.

The block and ladder frame that support the crank were an absolute first for a mass produced engine. This arrangement is in fact immensely stiffer than conventional bearing caps, which allowed the block to be very light. This is the area of the block that actually supports the crank and therefore carries all the loading imposed on the engine by the crank. It is where stiffness is actually required in an engine. This design was only previously seen in fully-fledged race engines – F1, Nascar, etc. and had never before been seen in a 4 cylinder. It is one of the design elements that makes the K such a sophisticated and efficient design. Far more so than, for instance, all current Ford 4 cylinders including the Yamaha/Ford 1.7L in the Puma and the very new all-aluminium 2.0L duratec, plus the likes of the much vaunted Honda 1.8 VTEC. The only engines which have caught up with the K are the 2.0L in the Honda S2000 and the 1.9 VVTi in the Toyota Celica. Both are copies of the K Series in this essential area of engine design.

To touch on another area that I shall explore later more fully, it is another frequently heard criticism of the K that it has very narrow main and big end bearings. This is a feature of the fact that the engine is very compact with narrow centres of 88mm. Only the Yamaha/Ford Puma engine is narrower at 86.5mm. This again contributes to a lightweight block, but I would say to those who consider that the resultant narrow bearings are a weakness, to look at any of the current F1 engines. Having seen a stripped down 1997 supertec engine I can tell you that the F1 engine bearings are not huge and like the K's, are certainly a lot narrower than the older generation of much tuned Ford engines or any of the new generation of 4's, with the exception of the Puma engine with its bike heritage. The fact is that the larger the bearing surface area the greater the friction loss in an engine. Therefore, it is in the interest of power output to have as small a bearing as possible. In order to enable this, the loading on the bearings needs to be minimised. This in turn is achieved by having as stiff a crank as possible, by accurate counterweighting in the crank and careful associated design of the block, by having as low a reciprocating mass as possible and specifying a tight F_3 dynamic loading tolerance. It is worth noting that the K's tolerance for the latter is half that for the Ford, Alpha and Mercedes engines I have tolerances for, and for that reason the K is a well balanced engine with low resultant F_3 bearing loads. Most Ford engines are particularly poor in this respect.

Loads imposed on the block by the rotating mass and fluid forces – combustion loading, will cause any engine to flex whether it is an old iron dinosaur, such as a Chevrolet V8 or Ford Zetec, or the modern aluminium block in a Puma, or the K. The problem is to manage these stresses. The K does this by, instead of using a series of bolts to close the cam carriers-to-head and head-to-block and block-to-ladder, one long bolt which goes right the way through the engine. The metallurgy of this bolt has been very carefully designed and the torqueing at 34Nm brings the bolt to its yield point. Effectively the point at which the bolt will stretch with the block under its cyclic loading, to distribute these loads very evenly throughout the block, and allows the block to be relatively unstressed within the design parameters for performance for the engine and also allows the block to be lighter than it otherwise would. The design and metallurgy of these bolts is critical to the whole design and loading that the engine sees, which has, as we shall see, has implications for some of the aftermarket tuning going on with non OE bolts.

All of this tends towards an engine that weighs in, as standard, fully dressed at 96.5 kg. Compare this to the Honda S2000 engine similarly equipped with standard manifold clutch and fluids at 158 kg and the Toyota 1.9 VVTi engine at 137 kg. The Rover engine's compact size and weight are a significant advantage in a lightweight race/sports car of the Lotus 7 type or the Elise. Note, a full race K Series weighs 78 kg including 7 kg of fluids. Compare these figures for output in terms of power to engine weight. See Table 1.

Engine	Power Output	Power / Engine Weight
Ford Duratec 2.0L	140 bhp @ 6000 rpm	1.16 bhp/kg
Honda S2000 2.0L	237 bhp @ 8300 rpm	1.5 bhp/kg
Toyota 1.9 VVTi	189 bhp @ 7800 rpm	1.3 bhp/kg
Standard K 1.8L	120 bhp @ 5500 rpm	1.25 bhp/kg
K VHPD	184 bhp @ 7000 rpm	1.91 bhp/kg
K R 500	235 bhp @ 8500 rpm	2.6 bhp/kg
K Peter Carmichael	250 bhp @ 8500 rpm	3.0 bhp/kg

However, this tells only part of the story because most of the Japanese engines like the old 1.8 VTEC and the new I VTEC engines are all short stroke, big bore engines, all of which have a relatively narrow power band. The K with its 89.3 mm stroke produces a lot more torque and spread over a wider engine speed range. This makes the K's power to weight ratio all the more remarkable in the context of lightweight sports/race cars, and given its more advanced construction than all but 2 or 3 of its most recent competitors, it is clear that the K has a very strong claim to be the best 4 cylinder engine around. In fact, given the huge weight penalties of the Japanese engines and the backward design of the new 2.0L Ford – indeed most of the engines around at the moment, the only clear competitors to the K's crown are the motorcycle derived engines, none of which have the ultimate power output potential of the K.

The limitation of any normally aspirated engine, that is an engine that is using engine speed to pull the fuel mix into the cylinders and hence produce power, is piston speed. Piston speed is a function of both engine speed and stroke. To put the K's ability into perspective the Honda S2000's 2.0 litre engine the one that the Lotus people on the one make series aspired to, revs to 9000 rpm as a production engine. With a 75 mm stroke this achieves a piston speed of 4966 ft/min, with its longer stroke the K achieves this at 8500 rpm, something the standard K bottom end is perfectly capable of, with the sole modification of forged pistons. The R500 engine achieves a piston speed of 5390 ft/min at 9200 rpm, a figure that the Honda engine would only match were it to be revved to 10,000 rpm. The point is that big bore short stroke engines are conceived to make high engine speeds possible, the penalty is poor torque, the Honda 2.0 litre S2000 producing just 151 lb/ft @ 7500 rpm, a figure easily eclipsed by the 1.8 litre K equipped with Piper's 1227 cams which will give a very similar power output to the Honda engine. So, the Honda is not such a special engine. It does have a very strong and stiff block, being a copy of the K Series' design, but suffers from its enormous weight of 158 kg in standard form fully dressed (figures from the Vemac Car Co.) more than 60 kg heavier than the standard K. The only really attractive part of the Honda's design are the roller cams which do reduce friction in the valve train but in every other respect the K is a more efficient and effective design than the Honda.

All this of course is on the assumption that the K can do this reliably, and the truth is that not only is there a perception of a fragile engine but there have been an enormous number of problems, from gasket and liner failure to complete catastrophe with the bottom end and on everything from the numerous privately modified engines, to the flagship model of that sports car manufacturer, who's engines are famous for spinning big end bearings, and putting rods through the block. This amongst both owners and all the motoring press, even the weekly press who recently judged the car's performance so highly.

So what is going on here? Well, there are an awful lot of myths and housewives tales told about the K, but there is also some kitchen sink engineering being done by the tuning companies. The only way to put this straight is to look at the engine, element by element.

As I previously stated, there are, or were, two minor problems, design features of the basic engine which did give rise to problems when the engine was tuned. The first is the positioning of the thermostat in the cooling system. You must remember that the engine was not conceived to boast 350 bhp, or propel Lotus race cars around the race track. It was first designed as an efficient engine for lightweight front wheel drive cars, typically the Rover Metro and the current Rover 25, with good fuel consumption and low emissions from start-up when the car was likely to see a large number of very short inner city journeys. It was thus designed to give very rapid warm up by placing the thermostat at the coolant inlet to the engine, where the thermostat measures the cooled water from the radiator. This is a very unusual coolant path design, but is very effective in its required purpose.

It was a system never designed to cope with the demands of a high revving race engine let alone a cooling system where the radiator is a long way from the engine, witness the Elise. The problem arises when the engine is put under heavy load, causing high engine temperatures which are not immediately read by the thermostat, because cold water in the radiator and hoses has to pass the thermostat first. This can cause enormous thermal gradients across the engine, causing both distortion of the head and block and also gasket failure. The vehicle which actually suffered most from this was the Land Rover Freelander. Apparently, the typical owner for this vehicle is the middle class housewife and mother who uses it for large numbers of short shopping trips to the supermarket!! Being heavy and 4x4, the 1.8 litre K's tend to be pushed very hard from cold. This results in the engine getting very hot before the water can circulate and open the thermostat. Result – blown gasket. Early last year, Rover introduced a new thermostat, the PRT thermostat that will open with pressure as well as temperature, the result is that it opens much more quickly and prevents this thermal shock across the engine. Warranty claims on the once troubled Freelander have now fallen to zero, and the thermostat is now fitted to all 1.8 L K's as standard. However, while this is a very effective solution for any road car, a far more effective solution for any engine used on the track, and in fact any Elise with its problematic long coolant hose runs is to move the thermostat to the output side of the engine. Both Elise Parts.com and QED do inexpensive remote thermostat housings for this purpose. When one of these units is employed the thermostat is measuring the engine temperature and is therefore able to control the coolant temperature quickly and sensitively.

Removing the thermostat altogether, as currently practiced by Lotus, is no solution, firstly because engine warm-up becomes protracted, with all the implications for premature engine wear and secondly, because the engine temperature is at the mercy of the pump speed, if engine speed falls, the coolant in the radiator will cool disproportionately, then as soon as engine speed builds and engine temperature with it, the pump speeds to sends a mass of very cold water from the radiator suddenly to the engine. There is no thermostat to even this process out so the engine is repeatedly subjected to thermal shock. Bad for the head, bad for the block, and sooner or later the gasket will go. Fit the thermostat to the coolant output and all cooling gasket problems will disappear, it's as simple as that. Witness Simon Scuffam who has made this single coolant modification to his 220 bhp Elise, and runs in 2 hour races – non-stop and has no problem with gaskets – ever. Tony Shute take note. Since Lotus have added an oil/water cooler to their K Series engines it amazes me that they have not made the modification to the thermostat location since it is such a small external change to make.

To digress for a moment, the other engine component carried over by Lotus that makes little sense to me is the right-hand side engine mount. This huge rubber bush, called the hydro mount was a replacement for an earlier simpler smaller bush in the front wheel cars, to make these Rover saloons more refined. It is surprising to see it carried over to the MGF. Frankly, it is bizarre to use it in the Lotus. The bush is so floppy that it allows a truly massive amount of engine movement in the chassis. This undoubtedly hurts traction, but worse, causes huge weight transfer when cornering. The last thing anyone wants in a race car and I am sure the principle if not the only cause of the sudden over-steer that the Elise suffers from. A very effective replacement engine mount with a choice of two polyurethane buses each with different shore hardness's is available from Elise Parts.com. I would recommend this to all Elise owners, but again am amazed Lotus have not tackled this themselves. Lotus suspension engineers have I know, always pointed to the 61/39 weight distribution as the root of the Elise's handling limitations, and although this is not ideal there are many cars that have similar figures but are not so easily provoked, for example the Radical SR3.

The second problem with the engine has also now been resolved, but was partly responsible for creating some of the myths about the integrity of the block and liners. The K Series was designed and originally manufactured with steel dowels, to locate the head to the block, as all engines should be. Unfortunately, Rover had a large number of replacement gaskets, gaskets replaced as a result of the previously mentioned problems, being damaged by clumsy mechanics at Rover main dealers who were catching the new gaskets on the steel dowels protruding from the blocks or head. It seems incredible but such were the gasket warranty failures, that the steel dowels were replaced by plastic ones. The design engineers recognise this now as a mistake and the dowels were re-specified as steel about two years ago. All replacement gaskets now come with replacement steel dowels to retrofit to the entire K Series family.

The problem with these plastic dowels was that they were not such a problem, not in Rover's own cars at any rate, in the same way that the thermostat could be, however in engines that were regularly revved hard and to the rev limit, head shuffle became a problem. There was clear evidence on the engine from my Lotus of relative movement between head and block when I stripped the engine down. The plastic dowels were nearly severed and the long bolts exhibited clear witness marks at the point where the holes in the head for these bolts open up to become an oil way. This problem is easily and effectively solved with Rover's own steel dowels and with the new PRT thermostat resolve the only two significant problems with the basic engine.

The plastic dowels have had one unfortunate consequence in engines so equipped, by causing problems for the liners and misleading many into thinking that there is a problem with the liners themselves. The liners are in fact totally sound and quite capable of coping with the cylinder pressures associated with the clutch of 250-255 bhp normally aspirated engines around. On only one of these engines so specified, Jason Krebbs' Caterham, have I found a failure, and that because one of the drivers on a track day test for this magazine managed to buzz the engine to 16,000 rpm – recorded on the data logger, causing just one liner to split. Apart from that, I have not managed to identify any substantial problems with the standard liner apart from a small batch of liners supplied by their manufacturer GKN, which suffered from some porosity. These were quickly identified and eliminated by Rover many years ago.

The problem of head shuffle associated with engines still equipped with the plastic dowels can cause movement between head, gasket and liner, and can allow the liner to rock in the block, come away from the fire ring, and eventually split. This was often seen on the earlier engines when pushed hard, but not ever on engines equipped with the steel dowels. It is however the cause of the myth about weak liners in the K. Anyone who has an engine with the plastic dowels which must be most of the unmodified Elises, should take the opportunity to fit a properly ported head, the steel dowels that come with the new gasket and can then have absolute confidence in the liners.

To build a blue printed normally aspirated engine, to the highest specification, or a forced induction engine, with associated high cylinder pressures above the 90-95 bar to which the standard iron liners are specified. It would be well to fit steel liners. By far the best ones available are the Cromo Duro liners, made to F1 standards they are quite exquisite to look at, Lubricrom coated and with modified outside dimensions to fit the block to a much tighter tolerance. The liners themselves exhibit 3 times the hoop strength of the standard items. The coating ensures they will out last other liners by multiples, but they must have titanium nitrided top and oil rings. Cromo Duro liners, despite their quality are about half the price of other steel liners and are available from Cromo Duro or Eliseparts.com.

The block and head in the K Series are made of the alloy LM25. The crank bearing ladder and cam carrier a derivative, LM24 designed for die casting. LM25 is a very adequate metal used in the better mass produced engines today. The only two alloys which offer an advantage are A357 and A354, the latter having better heat dissipation qualities, being alloyed with copper, and A357 having a lower iron and a higher magnesium content giving a higher torsional strength. Until recently it was also alloyed with Berylium. This has now been banned as those who follow F1 will know, A357 is therefore the alloy used in F1 engines, LM25 is a very adequate second choice.

So if the design of the block, and the alloy are not the cause of the problem, what was causing all this vibration and distortion that so exercised Miles at Lotus?

Below is a table of crankshafts measured for dynamic unbalance – F_3 forces, expressed in gram/millimetres from a number of makers manufacturing steel after market crankshafts for the engine as well as standard cast iron Rover crankshafts, as measured by Steve Smith of Vibration Free. Steve uses a machine and methods which are very much more sensitive than any used outside the in-house F1 operations. He works for a number of the best motorsport teams including F1, Cart, Nascar, Le Mans and also does some of the very fine work on satellite systems. Simply, his machine and methodology achieve a sensitivity that is not common.

Crankshaft	Initial level of unbalance gm/mm		Final level of balance gm/mm as balanced by Vibration Free	
	flywheel	nose	flywheel	nose
steel crank make A n°1	773.5	313.8	17.1	15.1
steel crank make A n°2	754.8	334.7	38.0	36.5
steel crank make A n°3	764.3	328.4		
steel crank make B n°1	747.3	106.9		
steel crank make B n°2	783.7	362.0		
steel crank make B n°3	748.7	301.7		
steel crank make C	693.7	307.4		
steel crank make D	227.1	68.2		
std Rover iron crank n°1	80.3	22.8	22.7	19.7
std Rover iron crank n°2	79.3	11.5		
VHPD iron crank n°1	360.2	25.7		

The levels in the right hand columns represent the levels of balance achieved by Steve. A level of 40 gm/mm represents the required level for an engine spinning to 9500 rpm. Crank A n°1 in the table was done for me to inside the F1 specification, a required level of 26 gm/mm. It is worth noting that the cranks measured in the left-hand column came from a variety of sources both direct from their manufacturers and from tuning companies who had balanced elements individually and as an assembly, and also a number of totally standard Rover iron cranks. Below is a similar table for flywheels.

flywheel	Initial level of unbalance gm/mm	final gm/mm as balanced by Vibration Free
steel make A n°1	238.4	3.65
steel make A n°2	274.8	
steel make A n°3	257.9	
steel make B n°1	277.9	
steel make B n°2	254.8	6.49
steel make B n°3	279.3	
steel make C n°1	708.5	65
std Rover iron n°1	115.0	
std Rover iron n°2	112.3	

Balancing and blueprinting are relative terms, all engines, Ilmor V10's to Rover K Series engines are balanced and blueprinted to a specified required level. This level depends upon the engines use and its maximum speed of rotation. If an engine is outside its balancing tolerance it will vibrate – like an oscillating hammer, and the faster an engine rotates the more violent the hammering. Any rotating mass – crank assembly will do this, the tolerance simply reflects a maximum limit. The graph below shows how required levels of balance are derived. The lines on the graph denote the use to which the engine will be put, the lower the line the better the engine. The vertical axis denotes the vibration a system exhibits, against engine speed on the horizontal axis.

[graph placeholder]

Point D exhibits the point that a factory balanced K Series crank is toleranced to for a 7000 rpm rev limit. Point C is the intersection with an engine speed of 9500 rpm that is required of a modified K to make this rev limit possible. This equates to a required tolerance of 40 gm/mm. Point A indicates the tolerance of the aftermarket cranks as measured to an engine speed of 7000 rpm and B the same cranks to an engine speed of 9500 rpm. In other words all the steel crankshafts are at least 10 times out of tolerance for a standard engine and more that 20 times out of tolerance for an engine with a raised rev limit. It is a similar story for the flywheels measured. Points A and B mark a tolerance that is appropriate only for agricultural diesel engines!

Now it is worth pointing out that a tolerance represents merely an “acceptable level”, and that any engine builder worth his name will realise that the tighter the tolerance the better. A badly balanced engine causes vibration, this stress within the reciprocating elements and engine block, noise and heat. All this is lost power. A recent test measured a 5 litre V8 on a dyno, then balanced and blueprinted the engine to a race tolerance, without the addition of any non OE parts, subsequently the engine was found to have gained 12 bhp on the dyno, why, because internal stresses were minimised.

The fact that some of the cranks and flywheels measured, come from engines that had been built by specialist tuners, indeed one from a car manufacturer, is nothing short of breath-taking and is the cause of all the bottom end problems that the K has been suffering. Quite simply suppliers and engine builders have been using components that are wildly outside the tolerance for a standard factory engine and exacerbating the problem by then raising the rev limit. This is why all these tuned engines are so rough when compared to a standard factory engine. They rev more freely with less advance in the mapping, lightweight flywheels and clutches, but put back-to-back, the modified engines are rough. The degree to which these engines actually see this unbalance depends upon the relative position of unbalance of flywheel and crank. Opposite and they will cancel these forces out to an extent, if they coincide they combine, and I have seen resultant bearing loads as a result of these F_3 forces top 120 kgf @ 9200 rpm, this compares with a standard factory crank and flywheel measuring 6.7 kgf @ 9200 rpm.

At best these engines will be highly stressed, lose power, wear more rapidly, be noisy and more difficult to drive – particularly on a race clutch, at worst the bearing loads become so much as to squeeze out the bearing oil film, resulting in seizure and total failure.

A good example of the consequences is Mark Waldron’s experience with his carbon fibre turbocharged Elise, much featured in CCC. For three years he used an engine tuned to 300 bhp with a standard iron crank, and although I believe the crank’s balance was not improved to cope with the increased rev limit of 8500 rpm, which would have lost him power, the engine nonetheless was successful in carrying Mark to the championship three years running. This is great testament to the strength of the basic engine. Nonetheless last year Mark sought to build a 400 bhp engine with a 9000 rev limit, and commissioned a bespoke steel crank. Figures for this crank are listed in the table. It was similarly poor, and combined with the raised rev limit, the crank caused the engine to fail catastrophically on its first race!

Similarly MG racing have found that their 1600 supersport WRC car had been suffering high levels of vibration causing, all manner of failures. This also had a specially commissioned steel crank. The engineer at Rover responsible for crank design suggested that the crank was measured on the standard factory balancing machine. It was again found out to be wildly out of tolerance. Now the factory balancing machine is not a particularly sensitive machine and is calibrated only to a tolerance for a mass produced engine specified to a 7000 rpm rev limit, however not only is this machine consistent it is clearly much more sensitive than the machines the aftermarket steel cranks are being balanced on.

It is not my intention to discuss balancing procedure in this article, and I refer to Dave Walkers column on Vibration Free elsewhere in this magazine. However briefly most of the balancing machines used by the aftermarket tuning companies are of the old Italian CEMB and CAMM machines. These are often insensitive and poorly maintained, so much so that it is a waste of time mounting a crank to them, and completely inappropriate for a highly toleranced modern alloy engine like the K. There are also a number of modern and expensive Schenck machines in use. These are often not that sensitive either when challenged and are frequently end driven, which confuses sensitivity and residual imbalances, and causes the unequal unbalances end-to-end on a crank. This is apparent as the difference given between figures for nose and flywheel ends in the tables. However, these machines should be capable of acceptable results. The fact that they are not is due to either setup, design, or methodology, I do not know which. One of the crank manufacturers has recently accepted that it has a problem with their machine, but it has taken a long time convincing them.

The fact that these engines are being built with the reciprocating elements so badly balanced, makes an absolute nonsense of any claim to blueprinting, and as I have attempted to show with the graph for required levels of eccentricity the standard crank’s tolerance is not adequate for an engine with a higher rev limit.

This then is a major issue, so what is the attitude of the tuning companies to this problem? Well I suspect that a number, including the sportscars manufacturers are blissfully unaware of the issue, the balancing machines being used are simply so insensitive that they are not reading the problem. However I have given these results to some companies who have accepted the validity of the data, and yet they have not changed their procedures. Why is this? Well I got a number of answers. Common is “that these engines are only involved in club motorsport and to take the engine building to a higher level is unnecessary and expensive.” This attitude is both intellectually and procedurally totally unacceptable. The design and production engineers involved with F1 and Nascar engines with whom I have discussed the K Series are utterly appalled, as are Rover’s own design engineers, and secondly it is not expensive, a pulley, cam sprocket, pump, crank, flywheel + clutch cover costs less than £100 to balance to F1 spec. Pistons and rods more, rods because they are so difficult to balance, but it is not expensive.

The other claim I hear is that people accept the data but deny there is a problem. On those engines where the flywheel and crank combine to cause the highest bearing loads, 9000 rpm seems to be the limit beyond which failure happens, although the Lotus One Make series lost approximately 15 engines out of the 60 built when revved to just below 9000 rpm. This happened on downshifts, the engine was limited to 8000 rpm.

There are however a number of other problems that result from a badly balanced engine. Firstly broken oil pumps. A steel pump is a useful precaution on a race engine to replace the cheap sintered original, but it's a sticking plaster solution to the problem. The cause of failure is engine speed and an out of balance engine. Similarly with alternator problems caused by resonances, bolts working their way loose on the engine, clutches and ring gears shattering sending shards of metal through the bell housing. All quite apart from the efficiency loss, the increased wear, and just plain simply a foul engine, but then people will never really appreciate that until they have a properly balanced engine to compare.

As a final note on the subject, I have not yet come across a standard iron crank that has broken in a 1.8L engine despite some being revved to 9000 rpm. A standard crank and flywheel do need their balance improved to be properly toleranced to this higher rev limit, however the fact that some have managed this engine speed without failure and the steel cranks and flywheels have been the cause of so many spectacular failures, suggests strongly to me that there is no good reason to use any of the current steel cranks, particularly as all those available are not sophisticated designs or address any of the other issues such as improved big end oiling.

The issue with the iron crank is that it is under-counterweighted. The confines of the compact block and the limitations of production machining have combined to produce an effective counterweight to the piston and rods that is less than ideal. All the steel cranks suffer the same problem. Determining the correct counter weighting for an engine is always a theoretical approximation depending on the engine configuration. Straight sixes, V12s, flat sixes are, for instance, perfectly balanced engines. 90^0 V8s are a good compromise. However remove two cylinders and you have a nightmare. V6s are compromised engines with very careful crank design and damping to make them acceptable, tamper with them at your peril. The angle on a V engine is also critical in determining the state of balance, witness the problems with increased vibration that the F1 teams have to contend with as they move from 72°V to 90° and 110°. Forces that result from the centrifugal effect of the rotating masses and the inertial forces due to the reciprocating masses, are cancelled or partially compensated for by the use of counterweights however in a straight four the solution can be only partial because of engine layout. The long accepted optimum was to have effective counterweighting for 100% of the centrifugal forces (F_1) due to the rotating masses, added to 50% of the axial inertia forces (F_2). the balance of these latter forces is compensated for by designing adequate stiffness into the block in the cylinder axis.

The alternative is to compensate for 100% of both forces however the nature of the resultant forces is to load the engine structure in the axis of the crank. The best compromise giving the least possible loading of the block is this magic formula of 100% F_1 + 50% F_2. Thus it can be seen that the design and stiffness of the block and the torquing of its fasteners are a very careful calculation that comes from an assessment of the loads being imposed on the engine by the rotating and reciprocating masses. Also the forces of combustion.

A deviation of 5% from this ideal counterweighting is considered unacceptable in a high speed engine. For a while this well established rule was ignored in race engines, in order to achieve a lighter crank and hence a more responsive engine. This has now been discredited as an approach to crank design because the engine becomes so stressed that bending and hence friction losses become unacceptable. Today the most sophisticated cranks, F1 cranks, have the most carefully calculated counterweighting using heavy metal to keep mass only where it is dynamically required. Crankshaft technology has advanced enormously in just the last 3 to 4 years.

Determining the required counterweighting for an opposed crank is normally considered a simple mathematical exercise, however in motorsport the use of what is called a single piston test, where a crank is sectioned and the required counterweighting empirically measured, is used to achieve a very much more accurate figure. Some work has been done on this at Vibration Free to determine how the available K Series cranks perform. All these cranks are under-counterweighted, in the iron crank this is purely a production limitation because of the limits of production machining on the crank and the available space in the block. There is less excuse for the steel cranks, their design moreover reveals a series of missed opportunities. Under-counterweighting in production 4 cylinder engines is common. For instance, without doing a single piston test it is impossible to be definitive, however the new Ford 2 litre duratec has a crank only 700 g heavier than the K's and yet piston and rod assemblies that are each 200 g heavier! It is very difficult to think that this is not a severely under-counterweighted crank and together with its antiquated block design, the engine is an unlikely candidate for performance tuning.

In the K this under-counterweighting produces a bending moment over each web in the block of just less than 1000 kg @ 9200 rpm, which is testimony to the strength and effective design of the block. I know however that Rover are looking at some very sophisticated production measures to improve this in the future.

This demonstrates how a design engineer makes choices about how loads imposed by the crank are managed within the block. In the K this loading and those imposed by combustion are carried by the long bolts, which are designed to stretch as the block distorts under load. All engines have to manage this distortion and loading, it is the design that stipulates how. This highlights another of the unfortunate practices that is currently going on within the aftermarket tuning companies. The replacement of the long bolts by thicker and stiffer material. These are designed not to stretch, under for the most part, the totally misconceived idea that the OE bolts in the K are a weakness in the engine. The original bolts because they have been so carefully designed, transfer loading throughout the engines structure in a very even way. This avoids point loading, and it is hugely successful in the engine, in fact it is one of the K's essential design precepts. The effect of the replacing the OE bolts with stronger ones whether or not their torquing is changed, is to stress the webs between the crank and the bolt path. Rover's own stress analysis shows that this will lead to fatigue failure of the block. I cannot say how long that will take or what the cycle will be but, given the loading of the engine this will be the result. This is dismaying partly because there are so many engines about with these bolts now, but also because for the most part these bolts are totally unnecessary, and have come about because of a complete misconception of the engine and how it has been designed.

The only possible need to change these bolts would be in the cause of forced induction engines running significantly over 300 bhp, because of the very high cylinder pressures generated by turbo or supercharging. In such cases it is not enough to re-specify the bolts, a systematic re-appraisal of the whole engine structure is required. First effort must be made to remove as much stress as possible from the block. The first candidate is to redesign the crank by adding counterweight. It was with this in mind that the single piston tests were done at Vibration Free and I have in preparation a sophisticated crank heavy metalled and with significant anti-windage provision which has been conceived to significantly de-stress a 350 bhp supercharged engine to levels, excepting combustion forces, lower than a standard 118 bhp K Series engine. This crank was designed to make forced induction engines over 300 bhp possible, but the crank through a number of design features will have significant advantages for naturally aspirated engines.

The other cause of stress that can be significantly reduced is thermal distortion by the use of ceramic coating. CTG have a new coating for aluminium heads and pistons, now being widely adopted in WRC cars, which is extremely effective. Cam Coat also have such a coating, but also offer a coating for steel valves, as well as low friction coatings for piston skirts. Any K Series engine will significantly benefit from these measures, but given their low cost, coating valves and pistons I regard as an absolute must, giving considerable anti-detonation and oil temp benefits as well as reducing thermal stress throughout the engine.

An aspect of engine building significantly ignored is block preparation. In older iron blocks a great deal of effort is put into blueprinting the deck height and the crank bores. The design of the K means that the essential dimension is from the crank is to the shoulder that the liners sit on. To this end it is meaningless to worry too much about the upper block surface, what is important is that that surface is straight and that all the cylinder liners have a standproud within tolerance. The weakest tolerances on the K are for the location of the liners within their bores and the liners standproud which is given as 0 to 4 thou. The former is the less important but solved by the higher specification of the Cromo Duro liners the latter is better adjusted to a 3 to 4 thou tolerance. With this improved tolerance for the gaskets to work within, it is worth noting that although the Raceline MLS gasket is the best available and essential with a forced induction engine, the standard gasket is very adequate in normally aspirated engines provided that the head is doweled properly to the block with steel.

The other blueprinting measure that is important to consider is to line bore the block. For two reasons, the newer engines are machined on a very much more accurate machine that Rover has recently acquired, however any block, but particularly an aluminium block will 'relax' with time. Line boring to achieve an absolutely straight bore not only allows use of shells of uniform thickness but trues the bores of any distortion from this ageing process. To my knowledge only Roger King practises this measure, though like a badly balanced crank, deviation in the bore of as little as 25 micron is enough to cause power loss. It is a relatively inexpensive procedure and essential on any properly engineered build.

So then my answer to Miles at Lotus was that the K Series is a very strong engine with a significantly more sophisticated design than almost all its competition but alone amongst these last in fully taking advantage of this to minimise weight. With suitable appreciation of the engine's design concept, it is clear that it is possible to tune to uniquely high engine outputs, but that the engine is significantly sensitive to poor quality aftermarket components and inadequate engine building. The fact is that many of the tuned engines are significantly out of tolerance for a standard engine, truly I suspect there are not more than a dozen of the tuned engines about that would pass the factory quality control tests on the production line for a basic 1.8 litre, limited to 7000 rpm! which is shocking! This includes the so-called the VHPD engine with its lightweight flywheel, which is not a factory engine.

Had Lotus confined their modifications to dowels, moving the thermostat, and the replacement of the uniquely light cast pistons, which are very vulnerable to engine speeds over 7500 rpm, to Omega's excellent forged pistons, balancing the bottom end to a required level suitable for 8000 rpm, they would have found the engine robust and totally reliable in their race series. Additionally they would have avoided the significant expense of steel rods and crank, which were not merely unnecessary but the cause of failure. The standard liners would also have been more than adequate in an engine of just 210 bhp. In short overwhelmingly all the problems were built into the engine by the engine builders.

If that is not bad enough, it may well be that the unfortunate experience Lotus had with this series contributed to their decision, widely briefed to the weekly motoring press to replace the K in the next generation of the Elise with Toyota's 1.9 VVTi engine. This engine boasts 190 bhp but has such an inaccessible power band and so little torque because of its short stroke that, given its huge weight it is difficult to see any revised Elise keeping pace with a standard S2 Elise on an average B road in the hands of anything less than a professional driver. Given additionally the problems that such increased engine weight will cause the cars handling, it is very difficult to understand why Lotus would even consider this move. The only rational possibility is the need to export the Elise to the USA which would be facilitated by Toyota's engine being federalised for 2005 emissions standards. However, Rover have made it clear to me that Lotus need only ask for the K to be so licensed, for that to happen, in much the same way that Ford the new owners of Land Rover asked for the K V6 in the Discovery to be federalised early last year. The Discovery was launched with a compliant K V6 in the autumn of last year.

Who knows what Lotus will do, but it is difficult not to think that using any engine other than the K will be a huge mistake. Quite simply the K is a very remarkable engine – quite the best four around. It deserves very much more recognition for the engine that it is. However, it has been let down badly by the companies trying to tune it – in fact, murdered! – and it amazes me that these companies, particularly the car manufacturers, but also MG's WRC team, have not gone to the Rover design engineers for any help or advice at all. This surely has been the biggest mistake. Given proper respect and understanding it is unbeatable as a four cylinder, and with new components coming including a 2 litre K Series, titanium rods and especially the heavy metalled crank, there will be even more clear water between the K and any other rival.

As this goes to press, Minister and Lotus Sports have sent engine sets to Vibration Free for balancing.