Hartech Engine Rebuilds (interim)

The well established problems afflicting a small number of the Boxster and 996 engines (IMS bearings, “D” Chunk failures etc) were relatively straightforward, fully understood by Hartech (and well publicised with common agreement) and our solutions have been proven reliable. However the more recent problems afflicting the 997’s and Cayman S cars (of cylinder scoring) are concerning a lot of people right now and the explanations and solutions are not simple and involve different contributory factors often acting together. Luckily we see more failures than anyone else to help us analyse causes and test solutions - not just for engines we rebuild - but also to see if there is anything we can do to help owners who’s cars are currently OK - to avoid the failures all together. Although our research is at a different level to any other independents we are aware of (and as a result our explanations and solutions are more comprehensive and involved) there is still some disagreement about the causes of cylinder scoring amongst others with a less experienced technical background (or a cheap short term solution to try and sell) resulting in this being a long and technically challenging explanation of the contributory factors leading to our solutions.

There are also so many clever academics that love to argue about almost everything posted on the Internet (but actually have never so much as held a spanner in their hands or designed, made or modified anything successfully) that anyone who knows their stuff disagrees with – that we make no apology for trying to explain in great detail (and covering all aspects of the issues that we expect others to argue about – in advance) to avoid lengthy defences in the future. So for those interested in the whole picture - this section starts right in the beginning to set the scene by looking at the background to changes at Porsche and in the “modern” World of car production and engineering that has resulted in some of the problems you are interested in reading about. If you are only interested in the technical information refer to page 7 where there is also an index to allow you to speed read the salient points if that is all you are interested in. Please be understanding if you find that some important issues have been repeated several times (on purpose) in the whole script (to avoid speed readers from missing what we regard as important points - by being too selective) while in other places you may at first think points are being repeated but actually discover that they also have some other influence – if you bother to read through the full explanation. If you simply want a short list of the main points and issues without any detailed descriptions, photographs, explanations or justifications – you can go straight to the very brief conclusion at the end on page 52

This is a big document full of lots of technical detail and can become hard to absorb in one session – but it is typical of Hartech’s approach to all their business to be thorough and to explain their conclusions in detail. There are plenty of people offering quick answers that are technically impossible or wrong (often to support a single solution they happen to be marketing) so this is written for those who want to find out all about the problems in great detail . It if was simple it would not have been a problem in the first place or quickly solved by the manufacturer – which it has not been – except to eventually re-design the whole engine concept (ironically incorporating many of the changes Hartech made to the engines years ago when they first set out to fix them). The modifications made by Hartech greatly improve the reliability and performance of the older rebuilt engines – prolonging their life at around half the cost of a new engine (that is the same technically as the original and so may fail again).

Index of the content with explanations and descriptions.

INTRODUCTION.

The M96 and M97 engine that came out in 1997/8 in the Boxster as a 2.5 (and later as a 996 3.4, 986 2.7 and 3.2) and was developed into the 996 3.6, 997 3.6 and 997 3.8 (and the Cayman 2.7 and 3.4) are all very similar – so much so that most engines could be fitted with a few different parts (or have a few small changes made in a machine shop) and be turned into any of the other examples (i.e. they are for most technical comments – identical).

So just how good are they? Very good indeed. Forget wide ranging Internet criticism about a very small number of failures – these engines have many features that top racing designers would like to see and tuners would usually modify standard engines to create (that the much revered older models did not incorporate) – resulting in superb performance for capacity, weight, fuel consumption and reduced emissions (necessary for modern manufacturers).

So why all the fuss? Unfortunately the combination of modern production methods, reduced emissions and increased performance combined with the Western World's rapid increase in repair labour rates/costs have all combined to make rebuilds potentially so expensive that many manufacturers are simply offering replacement engines instead – at huge cost – and not even supplying rebuild parts. Porsche probably decided that with their own guarantees in the first few years and a warranty available up to 9 years old – they had provided enough cover for any shortcomings in their new design (which most new similar products suffer to a greater or lesser degree - initially).

As a result most of these engines continue to perform all round better than their older stable-mates right up to very high mileages indeed (over 150k) – but unfortunately - amongst the very good engineering in these engines are a few minor weak areas (that probably in retrospect could have been designed a little better) that have resulted in a few failures that would have been impossible to intercept during development testing. Regrettably large scale manufacturers are often disinterested or notoriously slow at responding to these problems while design and manufacturing lead times (combined possibly with some poor engineering decision making) have rendered their solutions slow, expensive or unavailable and therefore unlikely to help owners with problems

This is not unusual because despite Porsche's well deserved reputation – even a small number of their older models had minor faults, like 911 gearbox synchro's, 3.2 Carerra piston ring wear, 944 number 2 big end, 16 valve cam chains, 964 head leaks etc … (with the same slow or sometimes non-existent manufacturers solutions provided) – but before the Internet and with many lower cost independent repair centres available – it didn't result in much criticism and when the cars were old enough to need rebuilds – owners accepted it (and the improvements some independents offered) as part of the cost of an older classic sports car.

With product lifespan being more influenced by fashion in our increasingly "throw-away society" it seems that longevity beyond say 10 years has become less of a concern to a manufacturer of new products than perhaps it used to be – leaving a small number of owners who didn't take up the rather expensive warranty (or whose cars are over 10 years old) with engine replacement costs they can neither afford nor justify – and spreading the resulting dissatisfaction widely and quickly over the Internet.

The good news is that there are still a few experienced and qualified engineers (spread thinly around the globe) with the interest, facilities and ability to provide affordable proven solutions quickly enough (in smaller more responsive organisations) - that have enabled failed engines to be rebuilt (often better than new) and/or provide products to safeguard against typical potential failures and protect owners and their cars.

One such director of Hartech Automotive is a qualified professional engineer and former director in charge of engine development (for a plc) and designed and previously manufactured racing engines (to GP success level). Hartech have responded (many years ago now) to what were (in his view) obvious weak spots and successfully provided numerous safeguards and repair options to enable owners to avoid problems or access affordable solutions. To implement this Hartech have over the last 10 years or so - heavily invested in a precision machine shop, two sterile dedicated engine rebuild rooms, specially manufactured parts (including oversized pistons, new IMS bearing conversion parts and stronger spindles, deep sump kits for Boxster racing, and Nikasil plated replacement cylinders) and a huge stores inventory (to directly control quality and speed up turnaround times). After a successful 1st season racing 968 models in the Porsche Club Championship in 2011 (during which they achieved 1st, 2nd, 3rd, 4th, 5th and 6 places, fastest laps and pole positions) - they are racing 2 Boxster cars (with M96 engine dirivatives) in 2012 – as a means of testing out weak areas and proving solutions etc.

The first problems and solutions were explained in detail in Hartech's buyers guide, containing numerous photos (www.hartech.org) section 4 "Boxster and 996 engine rebuilds, repairs and replacements" (written many years ago now), in which all the early assumptions and explanations (muted in that publication) have subsequently turned out to be correct and the solutions provided 100% reliable and satisfactory – being generally repeated everywhere else, resulting in Hartech becoming the UK's leading post '97 Porsche engine rebuild specialists with the most in house dedicated engineering facilities, technical solutions and options.

The New engine rebuild document adds to the popular Hartech buyers guide. This continues the story to update new problems, technical analysis, test results and new developments for the newer 996 models – the 3.6, 997 3.6, 997 3.8 and Cayman S 3.4 engines and the corresponding new solutions offered.

It must be remembered that while reading about various issues and failures – they are still very rare and not at all typical – but if an engine does fail it usually is in the areas covered and for the reasons discussed – so there is no need to become paranoid about the revelations and anyway – before we kick off describing the weak areas - there are a few salient points of advice we offer – to reassure readers that you can protect yourself against the worst scenarios.

(1) If you can afford a Porsche Warranty – it will provide a new engine in the event of an engine failure (although you should search the internet to see if other costs are added and if a subsequent second engine would also be covered). Generally this warranty is expensive and ties you to Porsche Main Agent prices and services to maintain eligibility and so is probably more suitable for owners of newer and more expensive cars (perhaps up to 4 or 5 years old).

(2) Hartech offer a different solution more orientated towards older cars (because it is less expensive and covers reduced prices for routine and failure replacements, free servicing, is monthly paid, costs less overall than similar Porsche cover and has no age, mileage or claim limit), while providing a total Maintenance Package – the first in the UK with a LIFETIME MAINTENANCE PLAN (now in its 11th successful year see buyers guide section) – despite Vauxhall's claims.

(3) If an engine fails under Hartech's plan the owner only pays for the repair parts cost – but is also offered the modification and/or replacement of other vulnerable parts (at minimal cost) to render the rebuilt engine fully protected against known typical weak spots for a bargain price and as a result not only guaranteed for 2 years (or 24K) but also likely to outlast any other solution.

(4) Rebuilds at full price (for those not on the Plan) start @ £2,200 (including gaskets, seals etc) plus repair parts + Vat (for part stripped engines only for acceptable situations) and £3500 (including gaskets, seals, oil, coolant, road tests etc) plus repair parts + Vat (for the whole job from receipt of the car to drive away finished).

(5) Hartech are the most successful post '97 Porsche engine rebuild specialists with a superb reputation for reliability and honesty and have the greatest experience and most options available for the models listed.

For more information please contact Grant or Baz.

Hartech www.hartech.org auto@hartech.org 01204 302809

ENGINE GUIDE - TECHNICAL

MORE RECENT ENGINE PROBLEMS AND SOLUTIONS (3.6, 3.8 & Cayman S 3.4 engines).

All of the original problems of cylinders migrating oval (increasing piston clearance, blow by and higher piston to cylinder face temperatures) that existed before in small numbers in the Boxster range and 3.4 996 engines (detailed in section 4) remain except that in the later engines with larger intermediate shaft (IMS) bearings – there are far fewer IMS failures – but as if to make up for that improvement - more piston damage and scored bores are occuring – at lower mileages than cracked liners appeared before (and therefore preceding that eventual failure) as those relatively critical piston to cylinder wall temperatures are slightly less well balanced and some are higher – reducing the oil viscosity while trying to support bigger and more torquey later engines with higher outputs.

CYLINDER SCORING

As a result the most recent and most common problem afflicts the pistons and corresponding cylinder scoring. Common signs are increased smoking and oil consumption (especially the rear near side exhaust tailpipe), sometimes – reduced performance (although not always) and a ticking noise resulting from the piston tilting and the top tapping against the cylinder head as it passes over top dead centre.

The question is often asked – why the later engines fail in this new area when the earlier ones were generally OK.

In offering an explanation – it is vital to understand that this range of engines were anyway built closer to a safe design limit (to increase performance, mpg and reduce emissions) and that testing for minor faults that only occur some years and several thousand miles after manufacture – in a very small number of engines – is practically impossible – and it is sometimes only in the public domain that some minor short comings emerge that manufacturers cannot fix (or may be unwilling to do anything about).

This is exactly the issue with these engines – that some changes made them work slightly differently (in such a small way they might not be expected to introduce a new problem) that was OK in most cases but never the less so close to the limit of reliability that a small number – when you combine all sorts of external influences and slight differences in usage etc result in a failure.

Piston scoring takes place very quickly after a very small rise in oil temperature at the cylinder wall lowers the viscosity so much it cannot support the gap between the piston and the bores and the increase in friction sets off a vicious circle of events that in a few seconds destroys the surface of the piston and cylinder bore.

PICTURE OF A SCUFFED PISTON AND SIGNS AT THE TOP EDGE OF THE PISTON TILTING AS A RESULT OF INCREASED PISTON CLEARANCE AND TAPPING AGAINST THE SQUISH BAND TOP OF THE CYLINDER HEAD.

THE PICTURE BELOW IS A GOOD EXAMPLE OF THE RESULTING CYLINDER SCORING.

This usually afflicts cylinder no 6, or 5 and 6 or 4, 5 and 6 – almost always from bank 2 (4, 5 and 6) only very- very rarely from the other bank 1 (cylinders 1, 2 and 3). Note (for future references) that the top is not scored – the bottom is and the scoring is in a slight oval pattern widest midway down.

The pistons are always badly scored on one side only (always the thrust side where the piston transfers the pressure between it and the cylinder wall into rotational movement turning the crankshaft under power). The other side has usually survived seizures but pistons often show signs of the coating material delaminating in patches (due to the high temperatures and pressures).

PICTURE SHOWING PISTON COATING DELAMINATION

Visually the result can be seen as scoring in the bore from a camera (or boroscope) placed though the spark plug hole – but always inside the engine the outer face of the piston (that cannot be seen with a camera) will be wrecked. Unfortunately we continually hear stories of customers with the classic symptoms taking their car somewhere to investigate (who know from the symptoms already that it will almost certainly have a scored bore and damaged piston) but who then inform the unfortunate owner that they need to look into it further before coming up with a diagnosis and proceed to remove the engine and partially strip it before confirming the damage. This unnecessarily adds the cost of the strip down to that of a new engine (or sometimes discounting it) but making it then less viable to remove the car and take it somewhere else where it can be repaired for less cost and where they could have included that work as part of the repair (like here at Hartech).

Our advice is therefore to never do more than to authorise anyone to look at the cylinder wall with a boroscope and then ask their options and costs before they entrap you in a no win situation for you and a total win situation for them.

THE BASIC CAUSE

The only factor that can cause this damage is that the pressure between the piston and the cylinder is too much for the oil film to separate the thrust faces enough to prevent damage. This would more commonly be described as the friction coefficient between the piston, the oil and the cylinder bore being worse. So it is important to understand a little about friction and the areas to investigate.

Factors affecting the friction between surfaces **** = points of particular importance.**

Dry surfaces

1. For low surface pressures the friction is directly proportional to the pressure between the surfaces. As the pressure rises the friction factor rises slightly. At very high pressure the friction factor then quickly increases to seizing ******
2. For low surface pressures the coefficient of friction is independent of surface area.
3. At low velocities the friction is independent of the relative surface velocity. At higher velocities the coefficent of friction decreases. ******

Well lubricated surfaces

1. The friction resistance is almost independent of the specific pressure between the surfaces.
2. At low pressures the friction varies directly as the relative surface speed. ******
3. At high pressures the friction is high at low velocities falling as the velocity increases to a minimum at about 0,6m/s. The friction then rises in proportion the velocity ^{2}.******
4. The friction is not so dependent of the surface materials ******
5. The friction is related to the temperature which affects the viscosity of the lubricant. ******

Static Coefficient of Friction

The static friction coefficient (μ) between two solid surfaces is defined as the ratio of the tangential force (F) required to produce sliding divided by the normal force between the surfaces (N)

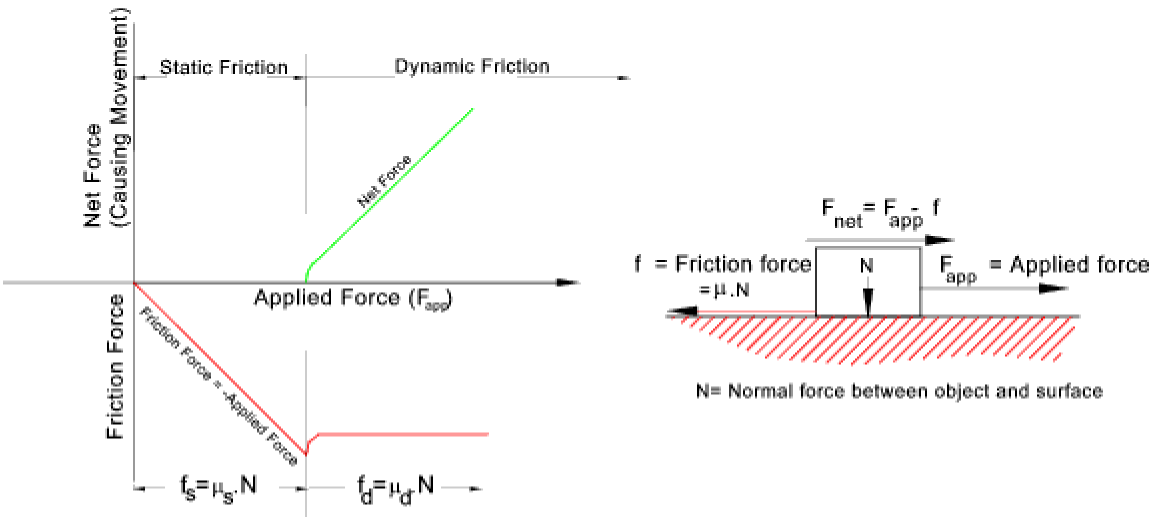
μ= F /N

For a horizontal surface the horizontal force (F) to move a solid resting on a flat surface

F= μx mass of solid x g.

Sliding Coefficient of Friction

When the tangential force F overcomes the frictional force between two surfaces then the surfaces begins to slide relative to each other. In the case of a body resting on a flat surface the body starts to move. The sliding frictional resistance is normally different to the static frictional resistance. The coefficient of sliding friction is expressed using the same formula as the static coefficient and is generally lower than the static coefficient of friction..



Friction Coefficients

The only way to determine the accurate coefficient of friction between two materials is to conduct experiments.

Coefficients of friction are sensitive to atmospheric dust and humidity, oxide films, surface finish, velocity of sliding ******, temperature ******, vibration, and extent of contamination ******. In many cases the degree of contamination is perhaps the most important single variable.

The friction values provided are obtained by different test methods under different ambient conditions. This factor can also affect the results. The way in which this theory links to these engines is directly in the temperatures at the cylinder wall (and corresponding oil viscosity), the loads and the quantity of oil present.

Although oil tests do reproduce various scenarios of temperature, pressure, speed and force they are all conducted with things like ball bearings running against other ball bearings or against flat faces, etc – what they do not usually do is build an example of the problem machine and test it under different conditions to establish causes and effects and even if they did the results would not necessarily cross refer to some other different machines.

So when a friction or lubrication problem occurs in a machine – it is often necessary for engineers to examine other contributory factors to work out what is the cause rather than fall back on the results of empirical tests. They then can relate standard phenomenon and scientific facts and trends to the conditions they find in the problem machine and try and make sense of all those factors to develop and test a solution.

This is exactly what we at Hartech have spent all our time doing in connection to this scoring problem and this is why our conclusions should be taken seriously. We may or may not have found the perfect explanation but we have gradually found several contributory factors, tested them, proven their validity and adjusted the engines where possible to improve the resulting weak areas – something no one else has made any comparable progress with.

Furthermore we are involved professionally with oil companies in testing and experimenting with causes and solutions and using track racing to quickly subject engines to new ideas and oil formulations (particularly with the latest “Nano oil technology”).

When trying to understand the causes of this new phenomenon of scoring (when the older versions were OK) it is clear from the above friction explanations that we needed to consider the impact of any adverse changes in temperatures (which we tested and found higher), forces (which are higher) and other similar factors that can influence the basic viscosity of the oil. We found a lot of areas in which these engines are contributing to the problem mostly affecting bank 2 of the engine where almost all the failures occur.

Usually when a piston seizes – both sides are damaged (because temperatures are similar all over the cylinder and crankcase) but the fact that only one side is damaged implies that one side is operating very close to the reliable temperature limits and that the additional pressure and temperature (and the resulting inability of the oil film to protect the opposing faces (i.e. reduction in viscosity) on that side (the thrust face) just tips that side of the system – over the edge and beyond recovery. There is therefore a big difference in the ability of the oil on that side to act as a reliable lubricant under the extra thrust load compared to how the same oil works on the other piston face and the only influencing factor will be the quantity of oil present to do the job of lubrication and it’s condition (i.e. the surface oil temperature being too high for the loads applied and too high a loading will then prevent the oil from separating the two faces that collide with each other rubbing the softer piston surface into tram lines and scoring the cylinder bore). However there are a lot of potential issues that can cause this reduction in lubricating property and several that can combine at one time in a particular - engine to create the symptoms for a failure.

BACKGROUND TO GENERAL CYLINDER AND PISTON SCORING

Historically (in any type of engine), any time a previously reliable engine has seized – it is almost always because either the piston has become too hot (through perhaps a weak mixture or incorrect ignition timing or poor sparks) or because the block has become too hot (because the coolant has leaked out, the water pump failed or the head gasket has leaked). These seizures usually affected both sides of the piston because the problem that resulted in too much heat (and the corresponding reduction in oil viscosity) was even all round the bore and the piston (and the coolant generally flowed all around the cylinder equally – keeping the same temperatures all round it) so it expanded and increased the piston face loads while the oil is too thin to support it. Always – if you knew of the problem and drove very slowly – there was a good chance to get away with it but if you continued to add piston face loads and heat by driving fast – the engine would fail. This engine is similar except that one side of the cylinder bore is running at very different temperatures to the other while the oil lubrication (that also acts as a coolant) has been minimised (explained more fully later).

We have seen similar piston damage (very rarely) in all preceding models (with different bore materials etc) but always associated with some other cooling problem like a failed water pump, leaking radiators or head gasket – never when everything else seems to be running OK – always when we know a reason for the piston temperature to be running higher than it was designed to run at – but these later engines are doing the same thing when there was no obvious reason for them running hotter than normal (except that everything in the engine is a little older than when it was new) and this seems sufficient (in some cases) to push the engine beyond its safe operating limits.

SAFETY MARGINS AND WHY NEW MODELS CAN INCORPORATE WEAKNESSES

To explain this further – usually with critical designs a "factor of safety" is used to calculate the amount above the calculated design limit the part will be made to be safe and reliable at. A factor of safety of 1.1 would for example add 10% to the calculated limit – making it 10% stronger or cooler etc than the engineers anticipated. Because of the need for light weight – aircraft have a small factor of safety (design limit) as weight adds to flying costs, fuel consumption and payload whereas bridges would have a higher one as weather is so unpredictable.

If an engine had parts of the design that were say designed to a factor of safety of 1.5 those parts would be heavier and more costly to make than was strictly necessary – and so reduce performance while increasing fuel consumption unnecessarily (because some other part would always fail before it) and a competitors version would perform and therefore sell better. The 944 turbo was a good example because it is possible to double the power and torque with very few parts needing upgrading – but this also meant it was originally designed much stronger than it needed to be in standard form – wasting more potential performance in standard form and costing more to produce.

With performance always being a top priority for a sports car and fuel efficiency and low emissions being essential to export the product – designers have had to push the designs of all sports cars closer and closer to a low factor of safety and nearer to the limit while in many cases introducing new technology before long term testing can be completed. If in doing so one part is so near the limit that the slightest problem with its performance results in that part becoming vulnerable – you can have a complete engine failure as a result. However clever designers are, there is always a need to test out the calculations and theories to be certain all parts are still just within limit but in so doing there are bound to be some issues that cannot be tested except by reproducing the consequences of years of driving – so they become impossible to fully test out in time to meet production and sales needs – and some risk is then taken. The best way is to stick with the same basic design and test out different improvements within it – only changing one thing at a time over many years and testing it out on say a race circuit – then if it is still OK there is every chance that new part or idea will be satisfactory (a policy that the gradual development of the original 911's successfully followed from 2 litre through countless upgrades and increases in capacity to 3.6 litres and turbos).

However – if you need to re-design the whole engine (as Porsche did both to eliminate excessive production costs left over from "old fashioned" production designs and at the same time introduce liquid cooling to reduce emissions safely) there is a much greater chance that in one or two critical areas the designs are so close to the limit that the slightest deviation from everything being in perfect – as new – as designed condition – and a failure may occur.

This is really the story of the M96 engines and although Porsche slowly fixed some of the "weaknesses" in the M97 versions (like a stronger IMS bearing) we guess they assumed that some of their other new ideas were OK (like the combination of the Lokasil liner material, running temperatures and oil delivery - that worked OK up to and including the 3.4 996 engines) that were actually so close to the designed limits that they then became weaknesses when they increased the capacity or introduced variable valve lift (to increase torque and power) or the balance and maximum cylinder temperatures were slightly altered as well.

MORE THAN ONE CONTRIBUTORY FACTOR.

There is therefore no one reason for a small number of engines to fail in a predictable way – but instead a lot of minor contributory factors – any one of which or any combination of some of them – may push the piston to cylinder wall lubrication over the limit and cause scoring that didn't afflict the earlier versions. It is as if the engine was regarded as reliable enough in the smaller engine models and the manufacturers assumed a small increase in output would make no difference – nor would slightly altering the cylinder coolant flow characteristics – but (as other manufacturers have found out to their cost) sometimes the earlier engine was running close but just inside its safe working parameters and the slight increases or minor changes made later – just pushed some of the over it.

This is what was behind the emergence of a new problem of cylinder scoring with these later models – but it is an unusual failure – and difficult to find one good explanation. One thing that sets Hartech in a better position is simply that we have started repairing engines and trying ti identify the causes of various failures before almost anyone else and handled far more engine repairs than any other UK (and possibly World Wide) business. We also have our own machine shop in which to make and then test different issues and solutions (and the resources to afford to own a number of test cars at any one time). The benefit this provides is to see lots of failures with obvious causes and several of the same failures but clearly with different causes – all providing feedback to work out that there are actually several different contributory factors. This has enabled a clearer picture to emerge than those less able to test/ modify and manufacture parts internally can experience and has enabled Hartech to zone in on the main issues.

DIFFERENCES BETWEEN THE LATER AND OLDER ENGINES.

A good first step is to compare the differences between this engine and other earlier engines in the range to try and find any specific differences between the three models affected and the earlier models that were OK and see if those differences were the type that could lead to the problems encountered. (Before panicking and assuming all the engines made are going to fail it is important to understand that – statistically these failures are still very rare and therefore most examples are perfectly OK. It seems to us that a lot fail because we receive cars and engines to repair every day of the week –with one of perhaps two or three typical problems - but taken overall – Worldwide wide - there are relatively few).

It is also important to put a sense of perspective on the issue because any engine that is driven to its limits will eventually fail one day and when it does it will always find the weakest parts to fail first. The lighter the internals are made and/or the higher the power output or revs and/or the lower the production costs – in most cases the sooner such an engine driven to its limits will find those weak areas. Furthermore these engines have excellent power outputs and light weight internals and have been manufactured by more modern (and in many areas - lower cost production) methods than earlier Porsche examples (essential to keep prices within the realms of enthusiasts budgets) – but this does not automatically make them inferior – just pushes the envelope of limits nearer to daily operating conditions. So although failures are rare – when they do occur – they fall into specific areas.

It has also always been the case that many owners only can afford such a car after that have past the age of driving excessively fast and calmed down a lot more, plus – logically – the faster a cars top speed – the fewer people are comfortable driving at or close to it – so many expensive and desirable sports cars are actually never driven anywhere near their limits (which helps preserve their reliability). So as cars get faster and traffic and speed limiting devices get more prolific, there are fewer and fewer who push their cars towards their limits – but some still do and this is where the potential to get close to a failure starts more often. As it only takes a few seconds to score a piston and bore – even a cautious driver who occasionally opens the car up – can do some damage at that precise moment. I know that a sports car should be able to perform reliably at any level but while power has increased and internals have been made lighter – manufacturers still need to try and make the car drivable in the same slow (or probably even slower) traffic and control limits that most of us spend most of our driving time contending with – presenting a problem to designers – do they make the car poor to drive slowly but OK to drive fast (even though there is little opportunity to do so these days) or make it behave well slowly and lose out a bit at speed?

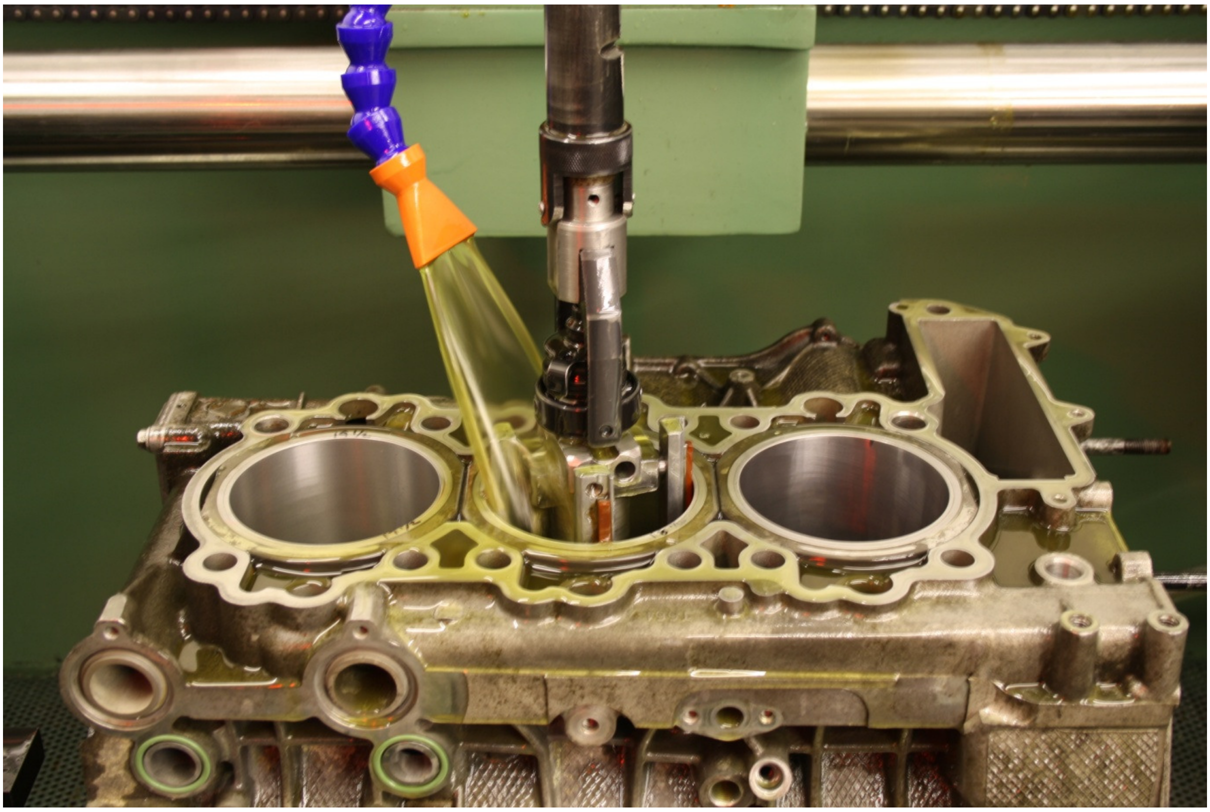
To some extent the switchable suspension is catering for this change but inside the engine those critical piston shapes and clearances have to somehow cater for 2 very extreme ends of a designers scale of limits and fits – and is not an easy compromise to make. The faster the car – the more difficult that balance is to get right.

OUR VIEW OF PORSCHE'S REACTION TO THE PROBLEMS. We feel it is not for us to comment on what Porsche regard as the right balance for their cars 9or an acceptable failure rate set against potential profitability) - but it seems they were content with the results for these engines manufactured since about 1995 as little seems to have been done to try and correct the weaknesses or provide affordable solutions - which has fallen to the few specialists with the experience and equipment to try and fill the void – like us – despite having minute comparative resources, smaller samples and little information about numbers and statistics (which Porsche have at their disposal through analysing their spares and replacement engine provisions).

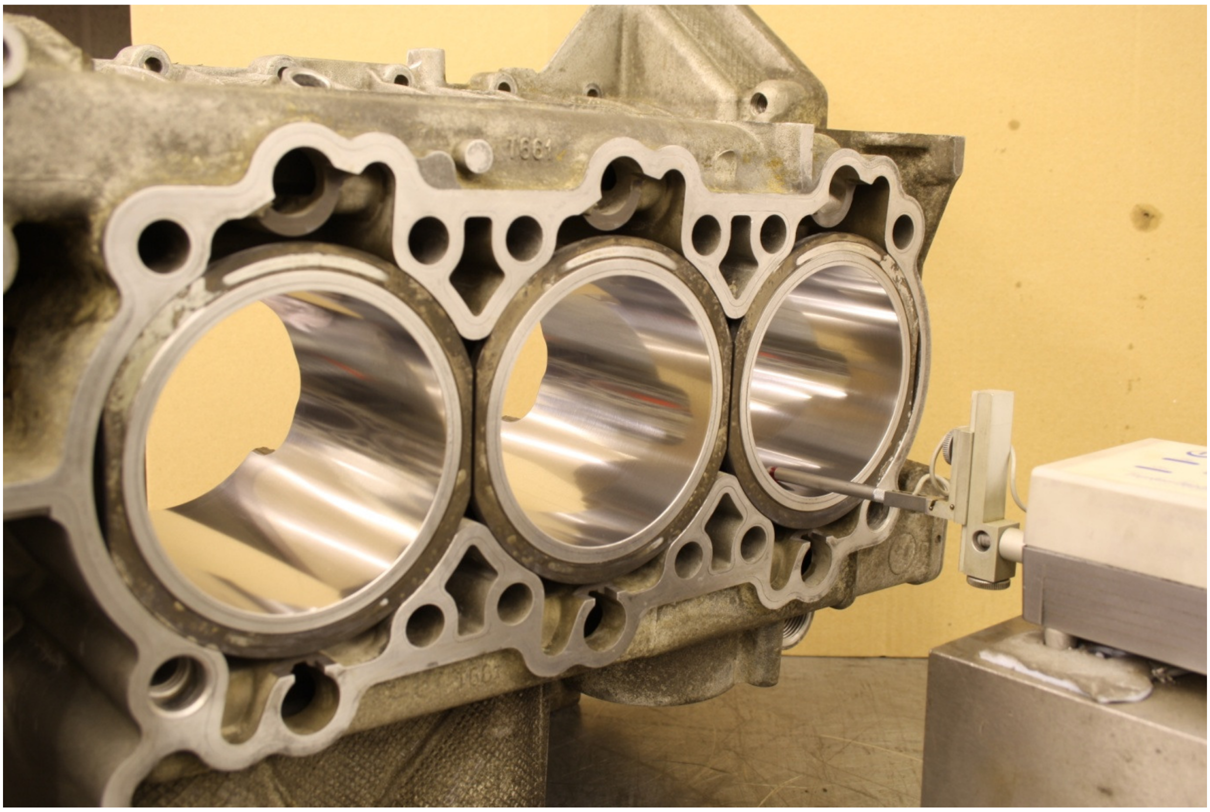
LOKASIL LINERS.

One new part of the design (with both early and late engines) is that the cylinders do not have cast iron liners, plating on the bore or a hard material cast into the alloy - but have a "cast in" composite liner that is then bored and honed (rather like more traditional cast in iron liners). However it is a new technology and with that comes some new technical challenges to overcome. The liners are not as strong or accurate as older cast iron liners and sometimes the liner moves during casting and then when it is bored out the thickness and corresponding strength varies around the circumference (some even seem to be marked with an X to identify the best side for the thrust face as if they were recognised as imperfect with the less than perfect areas being selectively located).

Another problem is achieving the right surface finish to that composite bore that is technically challenging and requires expensive test and production equipment. The bores have to be machined 1st with a diamond cutter in such a way that the tool does not dislodge the silicon crystals from the matrix but cuts them instead. Too fine a cut and you cut each crystal several times – thus making its bond weaker in the Matrix (and it may loosen and fall out later). After that (and leaving the exact right final bore thickness) a solid diamond honing head hones it with precise speed, feed and lift angles (in both directions) to an exact surface finish (with a machines usually costing a 5 figure sum see following photo of our machine).

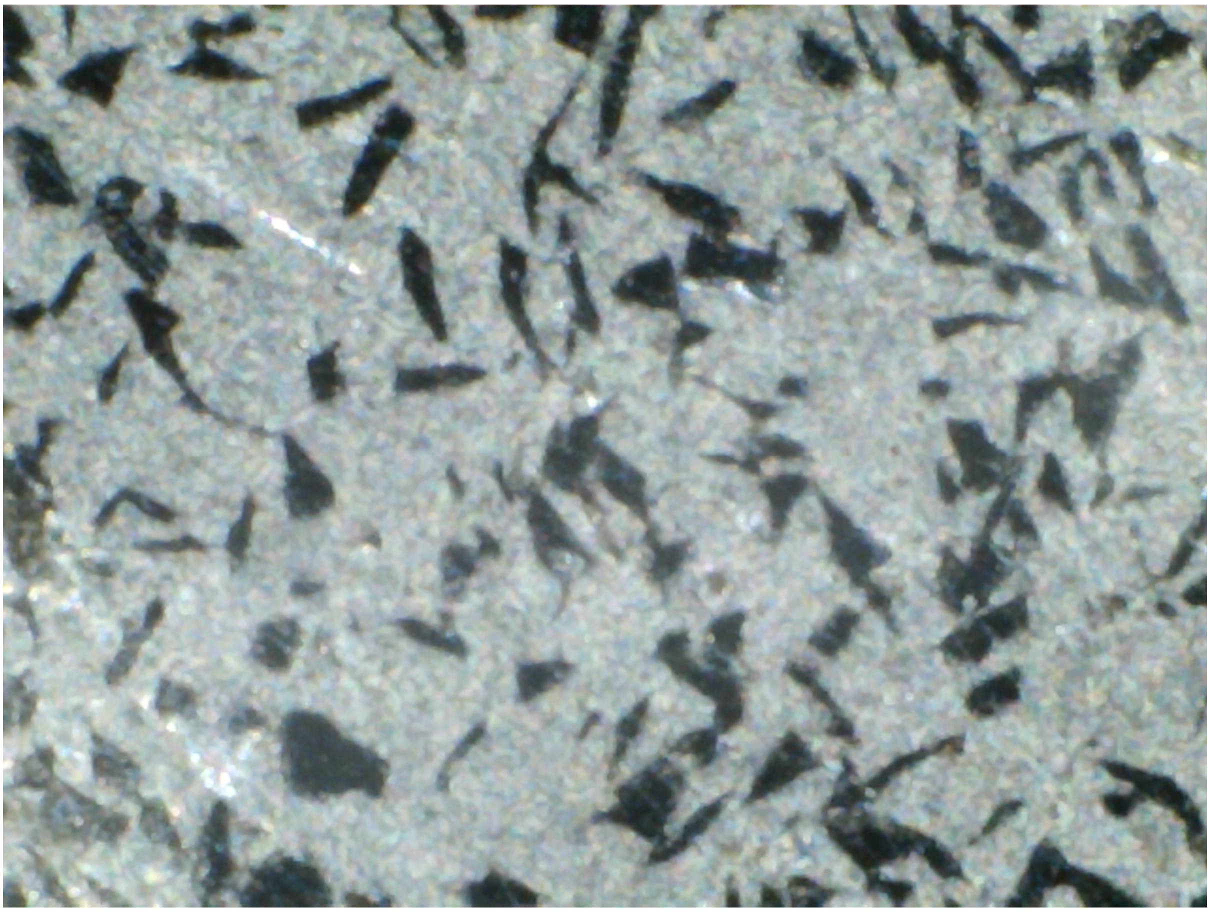


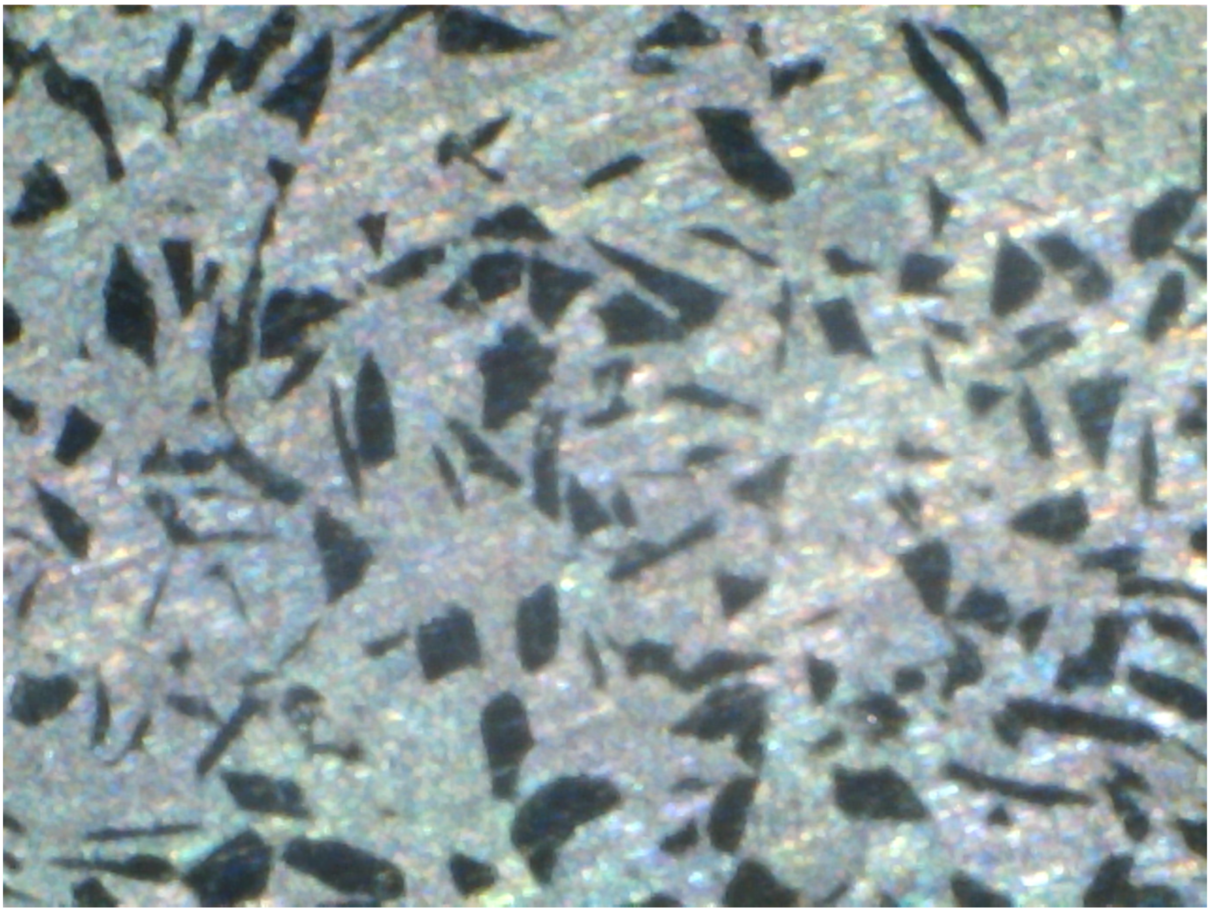
The surface finish is then tested with an expensive electronic measuring device (see next photos).



Then the remaining matrix has to be exposed to the right amount (tested by both a surface finish machine and electronic microscope).

The following pictures are taken with our own microscope used to compare the surface finish of our own re-bored cylinders (the first picture) and an original brand new Porsche supplied cylinder block (the second picture) . It shows the flakes of silicon embedded in the matrix and the degree of exposure of that matrix needed to create the right surface finish. This whole process is extremely challenging and demands a great deal of experimentation and testing – which involves driving cars and then re-stripping down the engines to inspect and measure the results – that we have been through and are reaping the benefits from.





This is why considerable investment is needed to reproduce the right bore finish – but properly done it makes a superb bore material. The piston has a normally reliable Teflon type coating applied (that was OK in the later 996 3.4 engines). Although LOKASIL is new technology it was perfectly Ok in the earlier models - so something else is causing the problem in the newer engines – not the basic bore material or pistons.

CYLINDER BLOCK HEIGHT AND OVERALL DIMENSIONS BEING THE SAME IN ALL MODELS.

They are all developments of the original Boxster 2.5 engine – almost identical design and internals, same overall sizes (block height etc) but the capacity and a change to variable valve lift has greatly increased the torque and power outputs (particularly at low revs) adding to piston to cylinder wall loading.

The 3.6 and 3.8 engines have a longer stroke but the same block and piston to gudgeon pin height – so have shorter con rods. This in turn increases the load on the cylinder wall – even if the combustion pressure was the same (although it is also higher – doubling the slight influence). Furthermore - as the pistons have gradually got bigger but the external block dimensions have remained the same - the channels and space for coolant to flow around has been reduced along with the size of the coolant feeder holes. The amount of spray oil to lubricate the bores is also the same despite the circumferential area it has to support increasing with bore size (and hence less/unit area) – all very small changes that when combined - simply increase the likelihood of failure.

Older examples provided the most cylinder/piston wall loading at higher revs – so the problem was more likely to occur for owners driving their cars aggressively and more sympathetic drivers changed gear at lower revs when their engines were more lightly loaded. However - because the torque at low revs is so much greater with these later engines the load on the piston/cylinder wall is much higher - even when a driver is not revving the car high (or therefore thinks he is not driving aggressively or near limits) simply enjoying good performance without realising the consequences – and so we find that a greater number of "more modest" drivers are experiencing this failure than before. Furthermore it is a strange fact of piston wall lubrication that the most difficult revs to protect from "piston scuffing and bore scoring" is often at very low revs (where the later engines are also producing more torque). This is for a similar reason that moving a heavy object by sliding it can prove hard to get going – but as soon as it starts moving – it is easier to keep moving and the faster you can slide it – the easier it seems to become as the resistance seems to decrease.

So something in this equation - with each new model - of gradually increasing the piston face load at lower revs (while many other facets of the original satisfactory design remain similar or the same) – has gradually pushed the safe operating limit of some of the cylinders lubrication capability - nearer to that experienced in normal driving use and therefore has increased the small number of failures that result. Because the accumulation of lots of different minor changes are needed before a failure occurs – there are some cheap short term solutions that may well work for a while (or even may work for a long time in some engines) – but that for other reasons are not good long term answers (like fitting steel liners) that the industry has largely discarded for good technical reasons long ago and for which the extra bore clearances needed and the differential expansion of steel and the alloy block gradually leads to future problems again – so owners need to carefully consider all the contributory factors to understand that it is only by analysing the situation scientifically and making a number of changes wherever there is a justifiable reason – that the rebuilt engine will be better protected in the long term regardless of whatever else may deteriorate in time.

ANALYSING GENERAL TECHNICAL PROBLEMS AND WEAKNESSES.

LUBRICATING THE CYLINDER WALL.

Assuming there is sufficient oil present - whenever a piston to cylinder problem occurs it is nearly always due to the localised temperatures becoming too high to keep the oil viscosity low enough to keep a friction barrier between the 2 metal parts – the load being able to squeeze too much oil out of the gap before it can be replenished through lower oil film strength (assuming there is sufficient there in the first place). You can see this if your car has an oil pressure gauge by observing the oil pressure at tick-over as the oil and engine warm up – where you will see the oil pressure falling as it gets hotter and thinner. So – both the cylinder wall temperatures AND how the cylinder walls receive oil (and how much) are factors. Some engines have oil sprayed in through spray jets (usually as much to lubricate the little ends and cool the pistons as lubricate the cylinder walls) while others rely upon splash lubrication from the rotation of the crankshaft and con rods (and/or the intermediate shaft) to spread oil all over the bores. This particular engine range has several areas in which the design prevents the rotating parts of the engine from splashing oil everywhere – by lowering the oil level below the crankshaft and masking off those areas. This leaves the cylinders more or less to be lubricated by the oil mist that occurs when an engine is running and the return overspill from the spray jets as the movement of air inside the engine block distributes it everywhere.

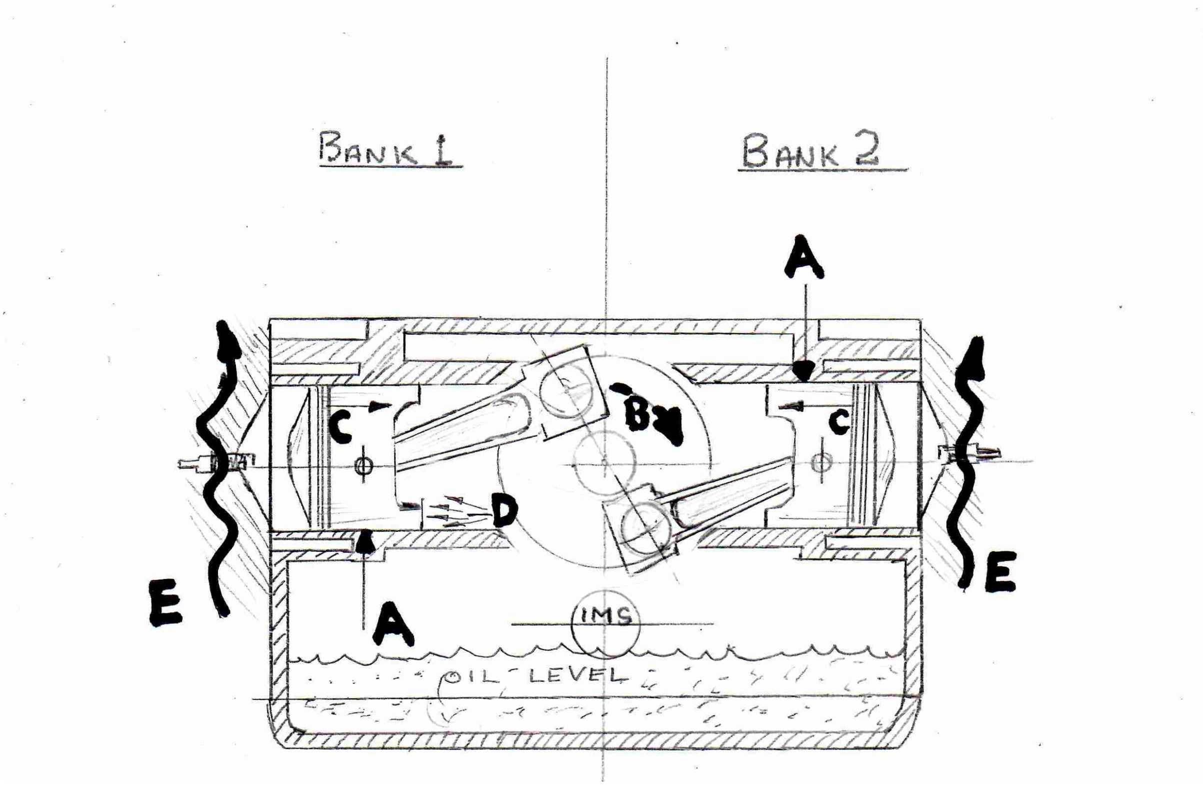
This is important because - In much the same way that if you were trying to cool a hot piece of metal with a hose – it will cool quicker if the water jet is fast and solid than if it was just a fine spray of less quantity - the reduction of splash oil to lubricate the cylinders results in the smaller quantity of oil present and the cylinder wall and pistons being hotter than in more traditional engine designs. This reduction in the quantity of oil on the cylinder walls may slightly reduce the resistance of the piston scavenging it from the cylinder walls and lead to a minute improvement in power and lower fuel consumption and is therefore desirable IF it does not go too far to reliably lubricate and cool the critical engine components. However lower friction and a better viscosity (through providing more oil) may also increase efficiency and provide a positive payback and even if it didn't - we think most owners would prefer a 100% reliable engine than a few pence more MPG and another bhp – given the choice. The earlier engines survived this design well but in our view it must have been close to the limit of reliability which the newer versions are closer to. Hartech's technical director is well used to the problems of OIL mist lubrication in two stroke racing engines and remembers well how quickly such systems move from running Ok to complete seizure – so in this respect he is aware of this problem potentially afflicting these later higher performance engines.

THE ENGINE LAYOUT AND RELEVANT ISSUES RESULTING.

Sorry about the poor quality of our sketch (no time to do better) but it is sufficient to explain the salient points. Look at item marked "A" and you can see from this that to rotate the crankshaft "B" clockwise the pressure of combustion pushes the pistons down "C" and that to turn the crankshaft the thrust face on bank 2 is on the top and on bank 1 is on the bottom – and this then is where the highest load occurs.

The wiggly line "E" shows that the coolant enters both banks at the bottom – so bank 2 coolant is hotter on the thrust side than bank 1 – hence the oil viscosity will be lower. You can also work out approximately where that maximum thrust will occur because the maximum cylinder pressure occurs after top dead centre and as the fuel burns it continues to increase while the piston is moving down the bore. The greatest mechanical advantage is when the angle between the rod centre line and the tangent at the crank pin is the same (90 degrees to the radius - approximately as drawn) – but by this point – although the pressure has been increasing the volume it occupies has been reducing (as the piston moves down the bore) so there is reasonably constant force on the piston at and around the 90 degree angle point – where the highest cylinder and piston face loads then occur. This is also where the evidence of the worst amount of scoring occurs in all the cylinders we see.

The sketch also shows the oil level being lower than the crankshaft and how spray jets lubricate the little end and bore "D". Bank 2 also has the spray jets in the same place at the bottom (not shown on the sketch as the rod is in the way). Because gravity will naturally pull oil spray downwards and because both spray jets are located at the lower end of the cylinder – the bottom will naturally get better lubrication – once again favouring bank 1.



The older air cooled 911's also had similar spray jets but there was a significant difference because they were located in the top of the cylinders (not the bottom) so gravity would tend to make the spray hit more of the top of the cylinders and also fall to cover the bottom. Because the crankshaft shells were wider (and the associated crankcase casting width) it was possible to angle the jets more towards the centre of the bore to equally spread out to all the bore area when the piston falls and moves the air downwards. The air cooled engines also had the cool air directed at the top of the cylinders therefore the combination of the top being cooler and the jet spray falling under gravity – balanced the resulting spread and temperatures more evenly. Meanwhile the air cooled cylinders resisted going out of shape well due to the air cooling fins holding the bores round – and therefore kept piston to cylinder clearances small while these liquid cooled engines - being "open deck" - allow them to go oval – increasing bore clearances by around 0.1mm to 0.125mm (4 to 5 thou) by around 60K miles.

Ask any engine reconditioner if 5 thou bore wear would be a problem to reduce reliability and they would probably laugh in your face. It will always increase blow by and surface piston temperatures and also blow away some of the oil that should be present – increasing the friction and heating the oil to reduce its viscosity while it has less in the area to cool the piston anyway. (Of course it is not actually "wear" of the Lokasil bore material but "creep" making them oval (like a baked bean tip squeezed in on two sides) – so when we re-round cylinders to convert the engines back to a closed deck design – we return the clearances to normal and they don't vary again thereafter. Before anyone questions why the side that reduces in diameter doesn't pinch the piston remember the sides of the piston are relieved and the top is made smaller – so there is not actually any problem with the sides of the pistons being free even though the cylinder bore at the sides is closing in on it).

All this is why BANK "2" IS USUALLY THE SIDE TO FAIL (by some 97%).

Some of these differences also existed in the earlier engines that did not have a scoring problem. However if you took any previously reliable engine and gradually made all the parts lighter or smaller (or gradually increased the output without any other changes) eventually you would reach a point at which a previously reliable engine would suddenly start to fail – in small quantities at first and then – if you continued with the same policy – in larger quantities. To solve the problem you would identify the issues causing the problems and improve them – by making some parts stronger – others better lubricated – others to run cooler (or more at the temperatures they used to run at). What you are asking for trouble doing – is to increase output and leave everything else the same – or even worse to increase the output and at the same time reduce the effectiveness of some of the original design criteria – that might have made the previously reliable versions – less so if it had also been introduced to them.

To sum this up – while these later engines are basically very similar to the earlier examples but with higher output – in some areas rather than adjusting the engines to handle the extra output better – some other changes actually made them more prone to failure – hence the problem this section is concerned with.

There are then several issues in the new engines that have pushed the boundaries just a little over the safe limit in some areas – that will almost always affect bank 2 first. We address some of these other possible contributory factors by making appropriate changes to reduce a future repetition. To understand these other issues fully it is necessary to understand a lot of unconnected facts about engines and cooling them as these factors are often misrepresented on Internet Forums.

SOME RELEVANT BASIC ENGINE SCIENTIFIC ENGINEERING PRINCIPLES

(repeating some of the information provided earlier but expanding its significance)

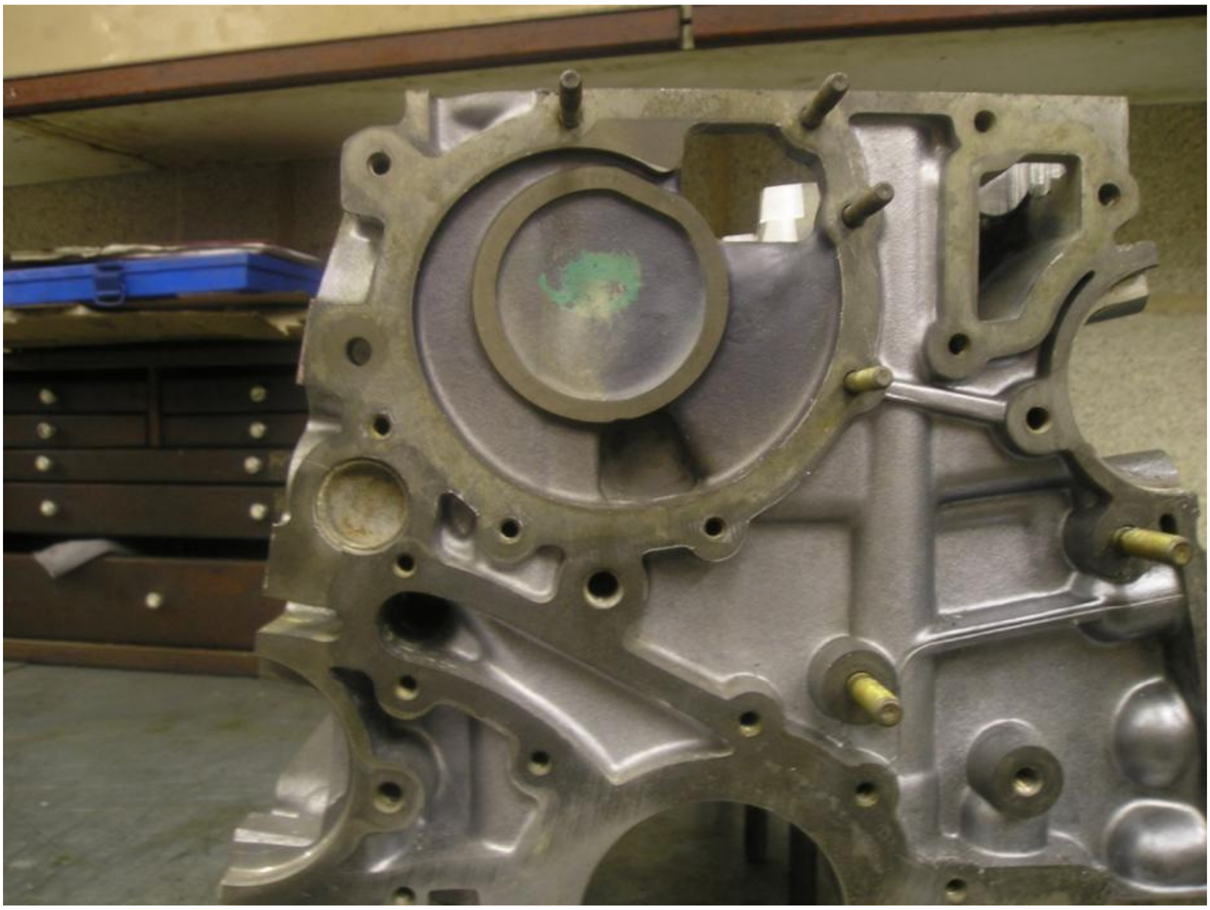
Cooling (or heat transfer) takes place when the temperature between two things in contact is different. The bigger the temperature difference between them - the greater the heat removed from the hotter part and the greater the cooling. The best cooling - to provide even temperatures - comes from pouring the coldest coolant against the hottest area first – (called Contra-Flow) – because as the coolant picks up the heat and the temperature rises (reducing its cooling potential) it gradually comes into contact with the less hot areas. These engines have the right “contra flow” design (in one sense) because the coolest coolant enters the cylinder heads on the exhaust side (the hottest side) and flows upwards to the inlet side (the cooler side) so providing contra flow conditions. However the “THRUST SIDE” of the piston is the side that squeezes against the cylinder wall to transfer the linear motion of the piston into rotating motion of the crankshaft through the con-rod and is therefore more highly loaded (see sketch page 19). However on bank 1 the thrust side of the piston is also on the bottom (which receives the coolest coolant first). On bank 2 the thrust face is on the top and is furthest away from the coolest coolant – so on bank 2 the thrust faces will always run hotter. How much hotter depends mainly upon the flow rate because if the flow rate is slow as the coolant passes upwards to the top of the cylinders – it will pick up more heat - and the temperature gradient will be higher. Since it enters the block at the same temperature it follows that the slower it travels through the cylinder block the greater the temperature gradient and the hotter the top of the cylinder (the thrust side on bank 2) whereas the flow rate makes no difference to the cooling of the thrust face on bank 1 because the coolest coolant directly hits the thrust face first before it picks up any other heat. But the earlier engines are OK so what difference is there in this latest batch?

Unlike older designs - the coolant flow is not going through each cylinder one after the other but instead is split and a smaller amount is fed individually into different parts of the engine – the restrictions controlling the individual cylinder coolant speed then slow it down.

The original air cooled 6 cylinder (911) engines had air pumped into the top of the cylinders and heads equally (so each cylinder and head was cooled the same) so this left the other bank running with the thrust loads on the hottest side – but they had less torque to handle and the air flow was more proportional to engine speed than a centrifugal coolant pump and of course no thermostat to reduce flow rates so cooling air speed was always high at high revs – immediately the engine was driven hard - providing a quick cooling response – whereas in contrast a liquid cooled engine with a thermostat will always be slower to open the thermostat and increase coolant flow when the engine is driven harder – delaying the extra cooling effect.

Cooling is also influenced by the flow speed and volume. In this regard these engines are different to earlier classic designs (like the 944 and 968 and most water cooled engines designed around the same 70's/80's era). The quickest way to cool a hot piece of metal is flood it with fast flowing cold water – not less quantity flowing more slowly.

These older engines had all the coolant from the pump fed into the cylinder block at one end (see photo below of a 944 turbo cylinder block where all the coolant is fed into the first cylinder through the square holes).



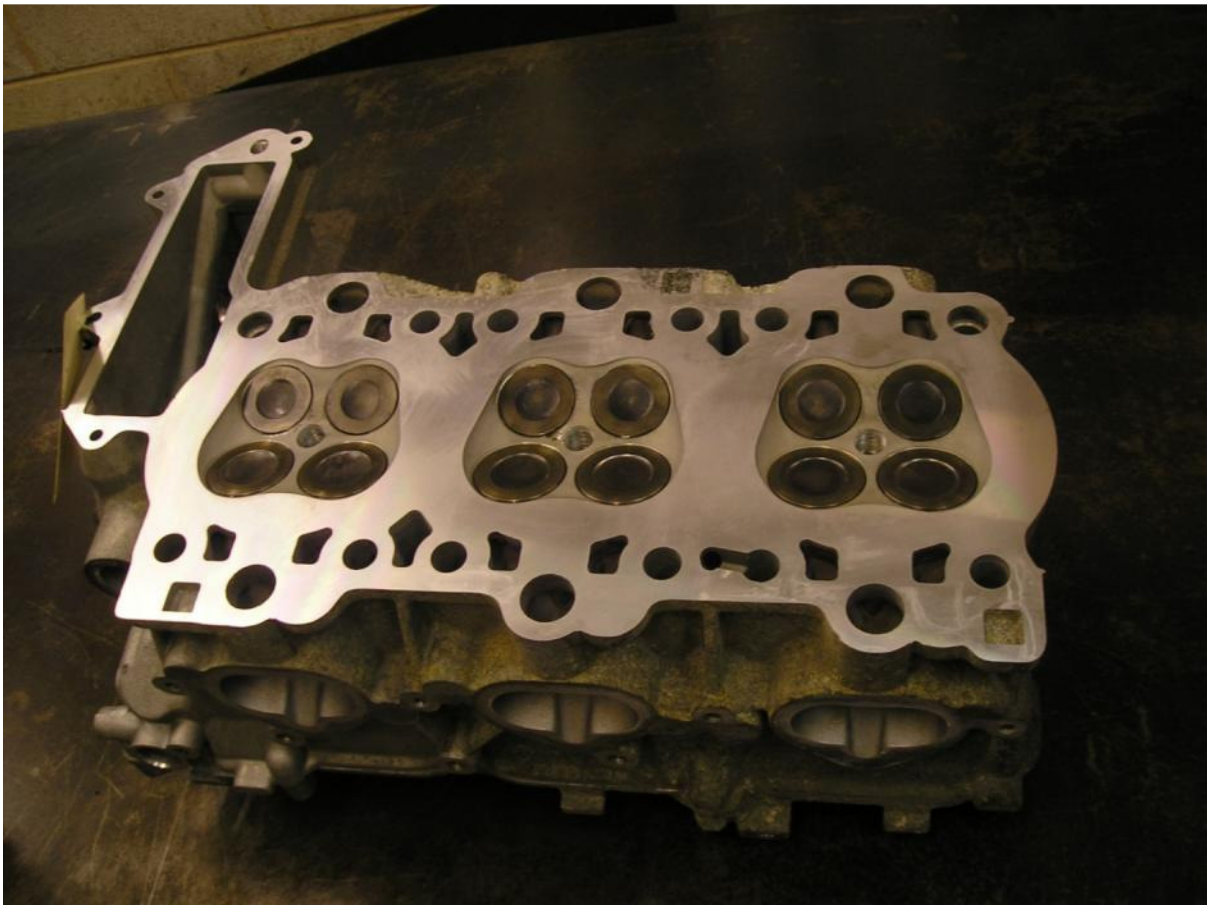
Despite lots of connecting holes from the block casting to the head casting in this 944 engine – few people realise that the head gasket forced all the coolant to travel along the block from the front to the back (resulting in each individual cylinder running at different temperatures as the coolant heated up on its passageway backwards and then it passed forwards across the cylinder head – getting hotter as it flowed resulting in different head temperatures as well. Consequently any tuned examples would usually give problems with head sealing near the front and piston seizing problems near the back. Tuners of the era would often alter that coolant flow direction and volume of similar engines to equalise the cylinder and head temperatures otherwise the amount of tuning is limited by the reactions of the hottest cylinders. The coolant speed through the standard road cylinder blocks were usually the full speed from the pump throughout controlled only by the engine speed and thermostat.

Thermostats originally were usually fitted on top of the cylinder head and therefore controlled the hottest temperature – opening more as soon as the engine as a whole ran hotter and increasing flow through the radiator immediately (as in the 924 range) providing quicker response.

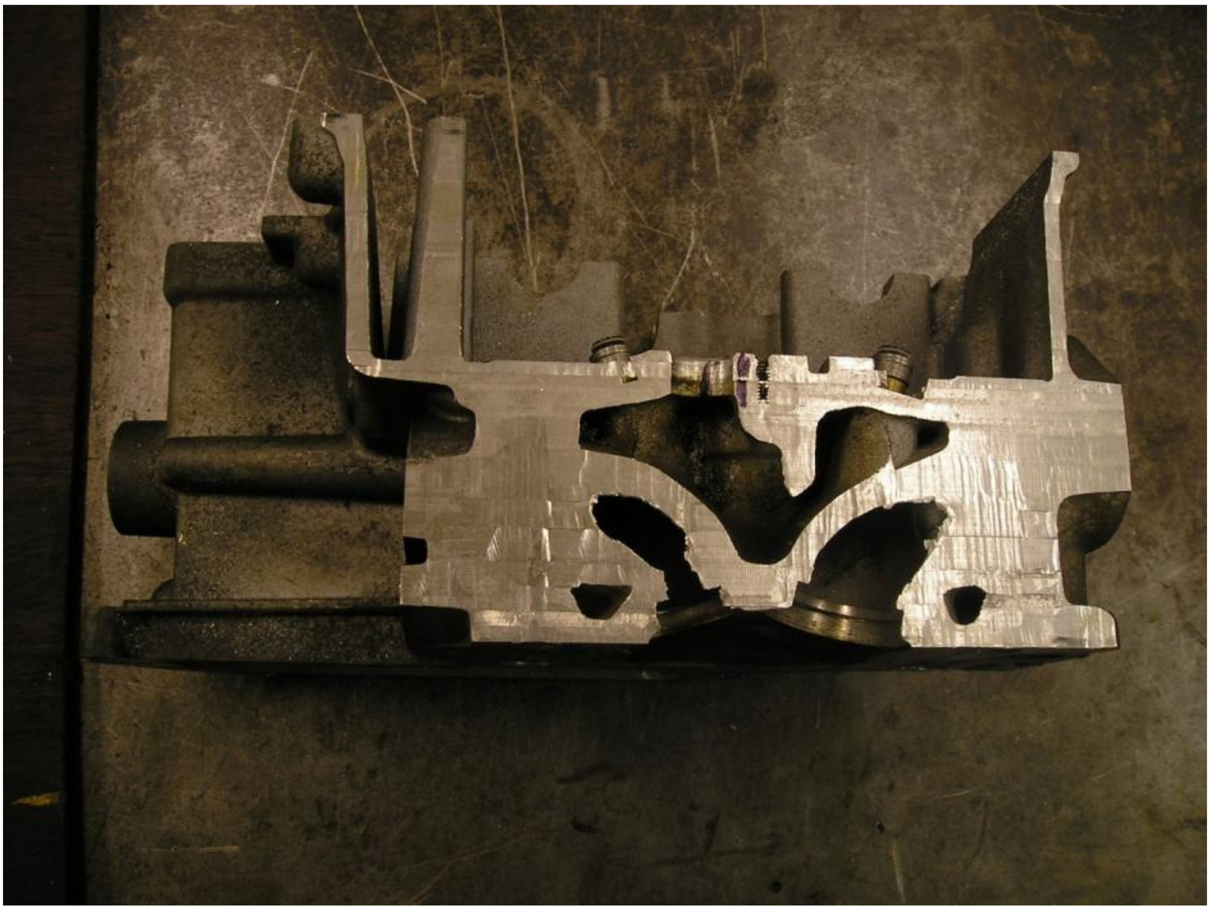
The 944 and 968 range moved the thermostat to the coolant inlet of the engine (after the coolant had been cooled by the radiator) rather than the outlet of the engine (before it reaches the radiator). It therefore controlled the temperature of the coolant going into the engine – not out of it – so if the cylinder running temperature was raised (by faster driving) the flow rate initially remained the same as the coolant passed into the radiator for cooling first and the thermostat was slower to open because the coolant was already still cooled somewhat by the time it entered the thermostat housing and engine and the thermostat took longer overall to respond. This proved OK when all 100% of the coolant was passing directly into the cylinders first before travelling on up to the cylinder heads but with split coolant delivery the response is slower and internal temperature rises are higher for a short while until the thermostat has opened enough to increase coolant flow to compensate.

Now the potential cooling surface area of the outside of a cylinder is many times greater than the same potential cooling surface area of the cylinder heads – so much more heat is removed from the cylinder area (in the cylinder block) by this 944 typical system than from the cylinder heads that therefore run much hotter. The actual temperature of the outer surface of the cylinder wall is not necessarily the same as the coolant temperature. Basically the slower the coolant speed the nearer the temperature of the cylinder wall will be to the coolant – but the downside is that with the slower the coolant speed – as the coolant passes across different parts of the interior – the higher that coolant temperature rises while it is "passing through" and the greater the difference in the cylinder wall temperature in different parts of the cylinder block.

When you look at a cylinder head it is quite clear why they are more difficult to cool (see photo below).



Most of the area in contact with the burning fuel is steel valve heads or a spark plug and nearby are the inlet and exhaust ports (as can be seen from the section below in which the only coolant volume is above the sectioned inlet and exhaust port and a long way away from the combustion area at the bottom – apart from two tiny coolant passages of little cooling consequence).



There is relatively little room to flow coolant near aluminium that is directly being heated up by combustion – but on the other hand there is nothing like the same lubrication challenge as the valves merely slide up and down in bronze guides and the oil lubricates (and cools) the camshaft area directly. You rarely hear of problems in that area due to the engine running too hot whereas piston seizures are almost always the consequence of cylinders running too hot. So - of the two – the cylinders need more attention to cooling than the cylinder heads.

Pre 1990, more traditional engines (incl. 924,944/968 etc) usually had all the coolant passing 1st into the cylinders and then on to the heads and were therefore running quite high coolant speeds, taking a lot of heat out of the cylinders (and consequently from the cylinder wall, the oil between the piston and the cylinder wall and the pistons themselves) resulting in relatively cool cylinders – but by the same reasoning hotter cylinder heads resulting in temperatures varying in different cylinders. To minimise detonation resulting in the hottest cylinder - many tuners would split the coolant flow supplying about 70% to the cylinder head and 30% to the cylinder block (because it is easier to cool).

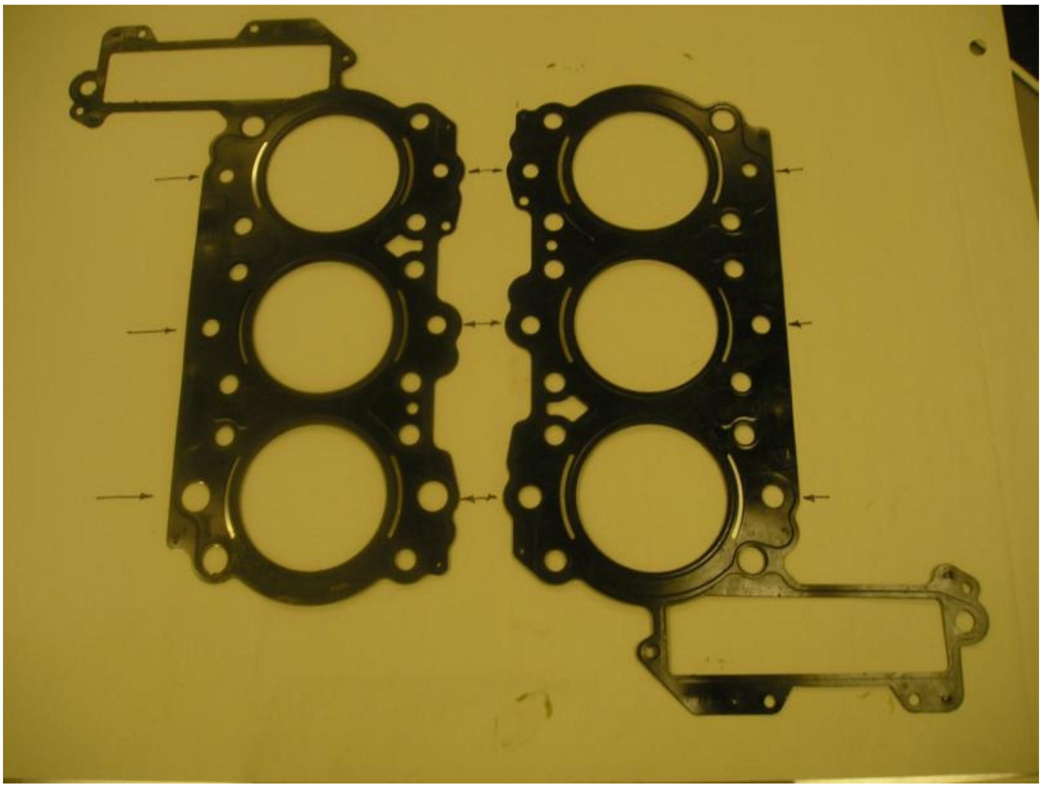
The M96/97 engines are completely different. A good feature of the design is that the coolant is fed individually into each cylinder area (all 6 separated) and also into each head area – through cast in tubes in the cylinder block and cast in holes in the cylinder heads (and/or different hole sizes in the head gasket) - balancing the temperatures much more evenly and allowing the tuning to safely run nearer control limits (as the cylinder temperatures are better balanced and not restricted by one cylinder being the hottest and most vulnerable).

PICTURE OF a typical BLOCK TOP (machined out to fit a Hartech liner) that shows the hole that feeds coolant upwards to the cylinder head (near the 50P coin) and the tiny slot in front of it (that is all that feeds coolant into the cylinder block to cool the cylinder walls and the piston skirts).

By altering the inlet and outlet slot sizes from the tubes that feed the coolant into the cylinders – this split enabled Porsche to control the flow rates into all 6 cylinders individually. To refine that control further, models up to and including the 996 3.4 also had different sized holes in the head gaskets connecting the feeder hole to each individual cylinder head as well (getting larger as the feeder tube flow reduces – towards the clutch end), the biggest being the number 6 cylinder head feed hole in bank 2. Hole diameters are 11.2mm (cylinder 1 & 4), 12.8mm (2 & 5), 14.8mm (3) and 20mm (6) making cylinder 6 feed hole area 3 times the flow capacity of cylinders 1 & 4.

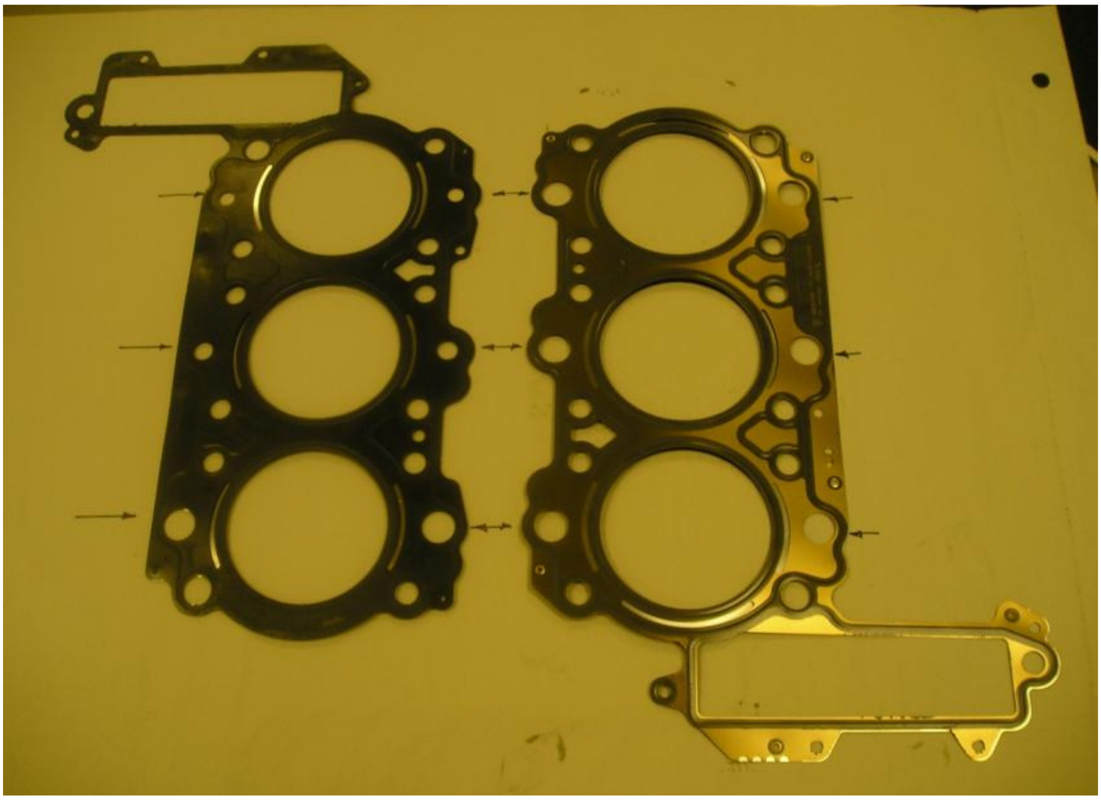
The following photo shows the two "hands" of a 3.4 head gasket (2.5, 2.7 and 3.2 Boxsters were similar) laid out as it fits on to the engine with arrows showing the coolant feed holes to each cylinder area and how they differ in size. The largest feed hole is at the bottom right of the left hand side gasket and it can also be seen that as the coolant travels along to each feeder hole from the top to the bottom- the feed holes get progressively bigger (and the area that controls the flow rate is proportional to that diameter increase squared).

The opposite gasket is on the right hand side to that. If it was turned over so it mirrored the left hand side gasket you can see that the hole that is the biggest on the left hand side gasket would be adjacent to the smallest hole in the right hand gasket. So if the same head gasket was being used for both sides – it would reduce the coolant flow for the same cylinder by about 66%.



An independent specialist (that we repair engines for) actually had this experience when they mistakenly fitted the wrong gasket to the wrong side of an experimental supercharged engine (apparently the gasket had been supplied in the wrong package/part number) and by doing so innocently swapped the coolest feed (intended for the hottest cylinder) for the smallest feed and the result was a similar seizure and cylinder scoring – demonstrating the importance of this asymmetric arrangement.

The next picture below shows the 3.4 gasket used above still on the left hand side set against a 3.8 gasket (the same as a 3.6 and 3.4 Cayman S gasket except for the bore diameter) on the right hand side that clearly has all the coolant feed holes the same size (so it can be fitted to either side of the engine). By this change only one type needs to be manufactured and stocked and production numbers double and unit costs drop – but in so doing the fine control to the coolant flow rate to each individual cylinder (that the original gaskets provided for in the older engine types) has been reduced resulting in a different temperature distribution that could result in some cylinders running hotter than others where they were previously better balanced.



These larger holes allow more coolant to pass into the heads (and therefore less into the cylinders which must then run hotter) so by standardising the feed hole sizes to save production costs the control of individual areas of some cylinders is not as good (and they will run hotter than the older versions), creating more hot spots promoting the idea of a cooler thermostat to compensate.

Proper testing of the results of these differences in feeder hole and slot sizes is both complex, expensive and time consuming for a manufacturer (and almost impossible for a small independent business like ours) but we needed to do something about the increasing number of failures – so initially we had to use our experience and knowledge of fluid dynamics to estimate what they would have achieved – and assumed they had tried to reduce the flow in the cylinders to increase it in the heads and also different feeder slot and hole diameters to equalise the temperatures.

To find out what they achieved we have measured all the coolant passages (and calculated the flow areas - to assess likely coolant flow rates in different parts of the engine) and these showed dramatic changes to the more traditional flow rates (probably about 90 % feeding the cylinder head and 10% feeding the cylinder block) and various minor changes to the areas feeding coolant to each cylinder and head depending on their location.

Eventually when considering huge investment in solutions we felt we simply must test the outcomes so to check our calculations we fitted temperature sensors into the cylinder blocks and cylinder heads of two 3.4 996 cars we had bought for the purpose at the outlet point where the two flows meet up to travel back to the radiator and to measure the radiator temperature drop, made a plug in wiring loom and connected it to temperature gauges mounted in the cabin. We then undertook road tests with someone recording results at different driving speeds and rates. The two engines had different internal coolant flow (one standard – one modified) and were run first with standard and then with the new lower temperature thermostats.

The results proved that basically the standard 996 3.4 engines have equalised the running temperature of all areas by dramatically reducing the volume of coolant passing into the area where it can do the most cooling (the cylinders), dramatically increased the volume of coolant passing into the cylinder heads and balance the gradual reduction in feeder tube flow rates (as the coolant is diverted into stage cylinders) by altering the coolant feeder slots and head gasket hole diameters accordingly.

This seems like a brilliant idea on the face of it – to run all the internal parts of the whole engine at the same temperature (and there was not a problem over engine temperatures in any of the models up to and including the 996 3.4 as a result).

We think their plan was that if before (in older designs) there was a "hottest" cylinder that was still running perfectly OK then instead of lowering the temperature of that one to a more average figure – instead they could raise all the other cylinder temperatures up to that higher level – perfectly safely - by fitting a higher temperature thermostat. Sounds logical however it is never the less a major change in what was done traditionally – which was basically to run the cylinders much cooler than the heads and with faster coolant flow rates passing each part in sequence. But the earlier examples were OK so something different must have afflicted the 3.4 Cayman, 3.6 and 3.8 engines to change this previously reliable coolant layout and distribution (of which the alteration to the head gasket to cylinder head hole diameters seemed a likely candidate) so we set out to understand what was going on and seek differences that would explain or support why these new problems have emerged.

The theoretical benefit of this more equalised engine temperature is closer control of lean mixtures and emissions (as very highly tuned more traditional racing engines often had to be run with different compression ratios, fuelling and even ignition timing to optimise performance) – and the corresponding ability to run more power reliably as there is not one weak cylinder holding back the tuning - but there are several potential downsides.

However – to achieve this balance it is not necessary to reduce the flow to the block by about 90% (which is roughly the proportional to the area of the smallest flow control spots). Coolant is anyway flowing through the block much more slowly than if all of it was passing through each cylinder (as there is only now 1/6th of the total amount going towards each cylinder anyway) and is therefore allowing a greater temperature difference between where it comes into the block and where it exits. The piston thrust side on bank 2 is the top of the engine and on bank 1 is the bottom – so although the average temperature inside the cylinders and the heads is the same from side to side and front to back – the thrust side of the engines is not a mirror image side to side and so bank 2 will still be running much hotter on the thrust side of the piston than bank 1.

The rate of cooling is also a function of the temperature difference – so if hotter coolant passes into a radiator – it will take more heat out than when it was cooler. The thermostat being on the return side allows this temperature increase inside the engine (particularly when a driver opens up the throttle and suddenly increases the cylinder and piston temperature) to be much slower to cool again (as the coolant has to travel through the radiator and be cooled before the thermostat feels a difference and then only a slight difference because it has already been cooled somewhat (due to the higher temperature difference)– resulting in a slower response to cooling the fast rise in piston temperatures immediately during sudden power runs.

What affect all this can have depends somewhat upon the actual temperatures we are dealing with.

If the running temperatures were designed to be like older engines (or were more similar to say the GT2, GT3 or turbo engines) they would be lower than they are in these std engines and the thermostats would be set to open @ around 70 to 80 Deg Centigrade (or 176 Fahrenheight) or less. But the standard thermostats that we tested start to open at around 86 deg C (187 deg F) and are not fully open until around 99 deg C (210 Deg F).

Now the problem starts at last to focus on an explanation. The less powerful versions of this engine range run OK at these higher temperatures (unless there was an additional specific coolant problem) but Porsche found it necessary to reduce the thermostat rating in the more powerful and more torquey turbo and GT3 engines (like older designs ran on anyway). Despite this the more powerful 3.6 and 3.8 engines (and the 3.4 Cayman S) have more torque (approaching turbo ranges) yet retain the original std thermostat (when it would be more logical to expect them to run a little cooler at least) and the cylinder head gaskets changes reduce the balanced engine temperatures that now result in higher cylinder wall temperatures and slower response to cooling sudden temperature increases.

We also observed some other (admittedly minor) changes with the later engines. The feeder slots feeding coolant into the cylinders were slightly smaller (so you might expect the cylinders to run even hotter – but we suppose they had proven OK in the previous smaller engines) but a major change was to do away with the minor differences in the two different head gaskets and supply one that could fit both sides (and therefore had all the feeder hole sizes for each cylinder head the same instead of all being different by up to 3 times in area for different cylinder heads as they were before). So although cylinder 6 (in the older up to 3.4 996 engines) had the largest feed holes – changing the head gasket feeder holes all to cylinder head hole sizes to make then all the same size – will have allowed more coolant to flow into cylinders 4 and 5 and less into cylinder 6 (the most common one for failures).

Having established some fundamental differences that could explain why the later engines run hotter cylinders despite having larger capacities and (therefore waste heat generated to dispose of) the failures and starting to post our thoughts on the Internet (in response to owners questions) their response was often - “Why then are they OK from new”? as very few fail until they have covered 15K or are over three years old.

This is always difficult to explain when lots of the same products are OK but a small number fail. Is it poor design, poor manufacturing control, poor assembly, inappropriate use, deterioration of service quality and care? It is very hard to come up with factual answers – but we needed to if we were going to continue to modify and rebuild engines that will be more reliable than the originals.

The answer we feel is that they run a less well balanced cylinder temperature between different cylinders and so one or two cylinders are therefore running much nearer the safe temperature limits. It seems they have changed the balance of coolant in the engine (for the minor commercial benefit of replacing 2 head gasket types with one) that has now raised the temperature of some individual cylinders and anything then that deteriorates slightly and deviates from an "as new spec engine" can push that limit over the edge in some cases and cause the piston and bore damage in specific areas that are running the hottest – that we refer to as "seizure marks".

TYPICAL SEIZURES/SCORING

It is probably appropriate to clarify now that usually a typical "seizure" is when the piston gets too hot and grows too big to impact on the bores and the oil is so hot it can no longer keep good lubrication between the piston and the bore, friction increases and lowers the viscosity still further until the soft aluminium of the piston tears and jams the piston solid (sometimes freeing off as it cools down). With these Porsche pistons one side looks just like this but the other side is usually OK forming the conclusion that the thrust side is acting similarly to a normal seizure (too much pressure on the thrust face for the ability of the amount of oil present to keep lubricated at the localised temperatures present) while the other side is cool enough to resist tearing even though the tears on the thrust side will be forcing the piston over and harder on to the non thrust side by then. There must clearly be a big temperature difference between each side of the piston.

Consequently the driver rarely even feels the experience – just notices later - increased oil consumption, perhaps a tapping noise and possibly reduced performance. The piston damage increases the clearance between that piston and the bore – so it rarely repeats the problem and anyway will be achieving lower compression and therefore never creating as much heat or power so never running as hot again. It may indeed therefore be the case that when we find all three cylinders with scored bores (and damaged pistons) that the problems each occurred on different occasions.

Others have decided that this problem is caused by the piston rings acting against the Lokasil bores. This seems to ignore the fact that piston rings can be pushed in below the surface of the piston and also that the part of the piston where they are fitted is machined smaller than the thrust face lower down and so neither the piston in the ring area nor the rings are pressed against the area of the bore that fails – any more than by the ring pressure that is reasonably consistent around all of the bores (slightly higher at the open ends). The piston rings cannot impart any more force to the "thrust area that always scores" than anywhere else around the circumference – so is clearly not the right explanation.

BEHAVIOUR OF HOT LIQUIDS

Localised coolant boiling is a known problem discovered years ago when tuning standard road engines for racing because coolant (like water) starts to boil when the surface temperature is higher than 100 deg C (in air) but the rest of the water nearby can still not be boiling (as can be seen when boiling water in a saucepan). These steam bubbles are a problem because they form a barrier between the hot metal surface and the denser coolant – allowing local hot spots and many racing cars (and specialists like us) will use equipment to vacuum bleed engines before a race (or rebuilding a road car) to expel all the air bubbles and improve cooling and reliability – or drill specially located holes to allow the air/steam to escape upwards and encourage coolant to reach the hot cylinder walls again. What few may realise is that if the heat source is from say one side of the container –

then the bubbles start when the average temperature of the coolant in that vicinity is at a much lower temperature (around 60 deg C in water and 71 in the coolant mix recommended – 88 in 100% undiluted coolant). This is because the heat at the surface is dissipated locally and the bubbles there reflect the minute surface layer area temperature not that of the coolant mixture nearby as a whole. Similarly whereas water boils ambient @ 100 Deg C the coolant mix boils @ about 102 and 100% coolant @ 105. This means that new properly mixed recommended coolant can still bubble well below the standard thermostat setting but our new low temperature thermostat starts opening at just before that temperature (at ambient pressure). Both bubble at a higher temperature if the pressure is Ok but also both will still form air bubbles and the higher the thermostat setting and the lower the coolant speed the more will form under sudden high engine outputs.

So although the average cylinder temperatures in these engines are more even between each cylinder - they are also more uneven (and hotter) than perhaps similar engines across an individual cylinder – having a bigger temperature difference between the cool side and the hot side (and much hotter than older designed water cooled Porsche cylinders and more modern – more powerful or racing GT versions), have much slower coolant flow (slowing response times to cool sudden power runs), and a thermostat position that also slows response times and a new head gasket that does not differentiate between the differences in bank 1 and bank 2 anymore = a problem if things start to get too hot (and our previous dyno tests have proven that it can take only 3-4 seconds between running perfectly OK and a scuffing/seizure of this type (while the engine has covered say 450 cycles and 900 piston strokes)).

You would think that this explanation was sufficient to convince anyone of the basic cause of scoring but - believe it or not there are also quite a lot of other reasons why this particular design is vulnerable – all adding up to provide a variety of potential causes any one of which (or more probably several combined) that could lead to a failure.

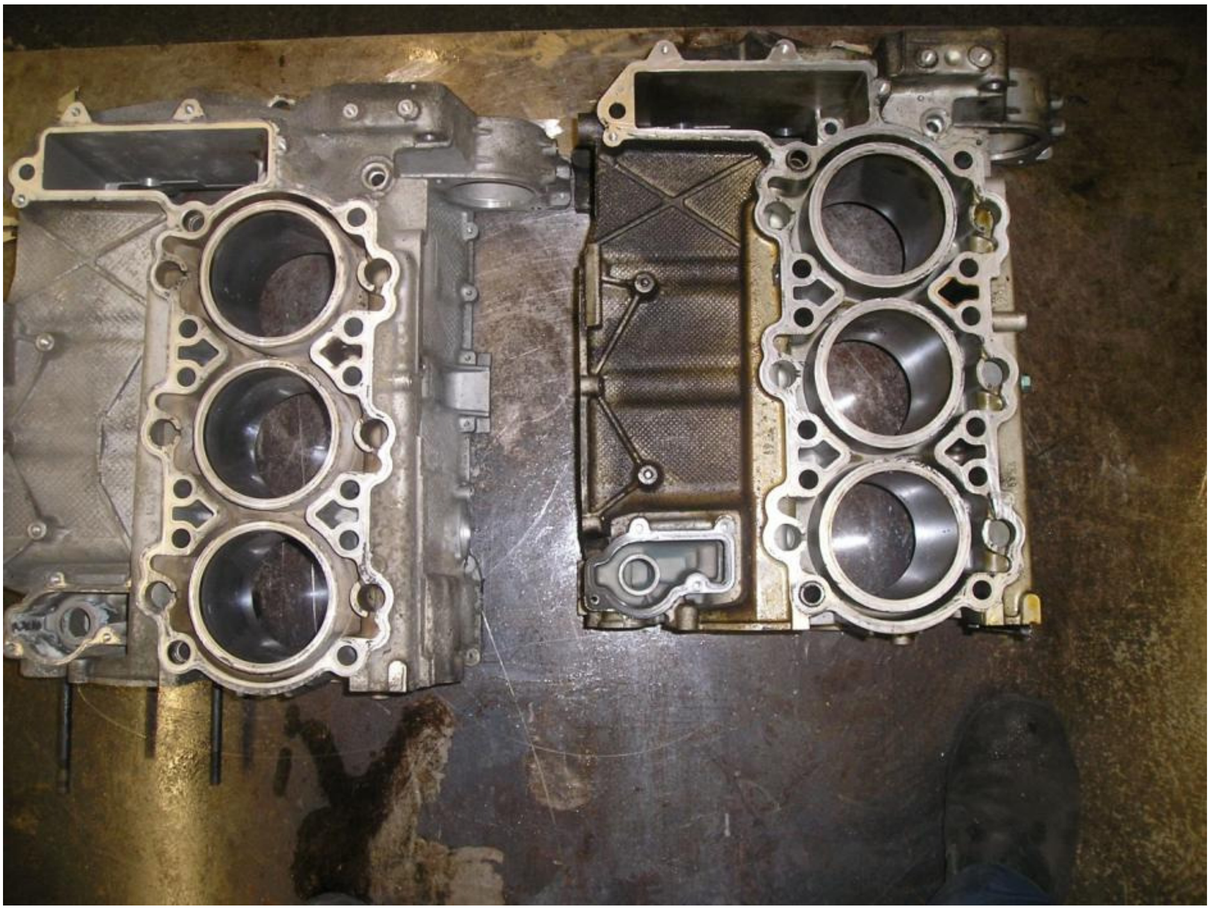
The Lokasil cylinder material is a brilliant lubricating surface with long life and low wear but will not transfer heat as well as solid aluminium (as used in Alusil or Nikasil bores used in the older Porsche engines and the turbo Gt1 and 2 and GT3 engines). This is because it is more porous. That porosity means there are gaps in between the metal and relatively small contact patches between the material in microscopic form. That very porosity helps lubrication but slows heat transfer.

The pistons also have very little contact area to transfer heat through (being full racing “slipper” pistons designs to reduce).

OPEN AND CLOSED DECK ISSUES

There is also yet another problem with these engines that could be a contributory factor. The cylinder bores are ”open decked” design – consisting of basically a metal matrix composite cylinder (similar to the traditional cast iron liners) cast into a thin aluminium outer sleeve and unrestrained at the top.

PICTURE TOP OF 3.2 Boxster S and 3.4 BLOCK



Section 4 of this buyers guide describes in detail how that results in gradual “creep” and the bores go oval in the thrust direction by up to or over 0.2mm (0.008”) and then can crack. This increase in ovality has four detrimental effects on piston temperature (1) Blow by of hot burning gasses past the piston increase and burn or overheat the oil film, (2) the contact area between the piston, the oil and the cylinder wall (through which the heat is dissipated) reduces as only one half is sufficiently in contact with the bore at any one time, (3) the piston rings are unable to bend into an oval shape (don’t wear either) so don’t do their job properly (4) when the engine has stopped the pistons sit on the bottom face of the bores (through gravity) and the oil tries to drop or flow down to the bottom of the bore. A tight clearance will keep some oil in the gap in between the piston and the bore (due to surface tension) but if the gap gets too big it will allow the oil to slide away leaving the top of the piston (the thrust face on bank 2) relatively dry for the next cold start-up. Some owners have a bad habit of starting a car with some throttle to let it rev to circulate splash oil quickly to all the internal parts (as most wear takes place on start up and older cars often had splash lubrication then). But in this engine layout there is very little splash oil anyway and big bore clearances leaves the top of the pistons quite dry – so it might be better to start with no throttle (for a few seconds) to allow some oil mist to reach the upper cylinders before any loading or piston speed increases.

The later engines also have another difference that may or may not be significant. We have already explained that more traditional engines relied on the crankshaft splashing oil up the bores to lubricate them. Although in reality there was mainly “oil mist” fulfilling this function – there was plenty of it and the oil level in the sump was usually higher than the crankshaft webs and they did provide splash oil especially to lubricate the “dry” cylinders on cold start up (before the oil level drops as the oil is circulated around the engine and become more of a mist than a liquid). Indeed the amount of oil lifted up the bores by the crankshaft in the 944 S2, 2,7 and 968 block needed some blanking plates to prevent so much being thrown up into spaces in the crankcase – that it lowered the actual sump level too much.

The crankshaft in these newer engines is not only highly screened from contact with oil (by the crank carrier that most engines don’t have and also plastic baffle plates) but the oil sump level is also lower than the bottom of the crankshaft webs – so there is little or no “crankshaft splash oil” anyway – relying mainly on mist oil distribution from the engine to lubricate the bores (and therefore much less in volume than previous engine designs). There are spray jets fitted to each cylinder but these will only lubricate the bores once sufficient has been sprayed up into the piston crown area (to lubricate the little end and cool the piston) to spread out to the bore area – again a potential problem on initial cold start up while the piston rises and falls to distribute the oil sprayed into the crown area to the cylinder bores.

It seems that any potential contribution to a critical problem is always worse on bank 2 and ironically the spray jets that are fitted to these engines continue that trend because they are both orientated to the bottom of the cylinders (and therefore opposite the thrust side on bank 2 but on the thrust side of bank 1) – adding yet another weakness to Bank 2.

It is also an interesting fact that the crankshaft webs on the later models are slightly wider and the resulting overhang of the crank carrier (that holds back oil from being splashed up into the bores) is greater – slightly reducing the amount that may be splash fed to the bores) if indeed any ever is. This may not seem very significant until you realise that the rotation of the crankshaft naturally splashes drip oil to the non thrust side of both cylinder banks – but any splash oil will then drip down onto the thrust side of bank 1 but away from the thrust side of bank 2. It is important to recognise that the oil in an engine also acts as a significant coolant medium. It collects heat to be cooled by the oil cooler later and therefore any reduction in the quantity present in the upper cylinders will leave the pistons and the cylinder wall hotter than when more splash oil was present in older more traditional designs.

Now we have a compelling story to begin to explain why this particular design – while good theoretically and good when everything else is new and spot on spec – can cause problems when general things deteriorate with age and use and run closer to the limit – especially since Porsche have combined the need for greater cooling in the bigger and more powerful engines with a reduction in coolant distribution control to each cylinder and cylinder head to enable one common head gasket to fit both banks. These changes combined with a large number of other factors influencing the condition of one older engine with another (and one driver care and style with another) then account for why some fail and some don't and in almost any investigation into the lubrication of the cylinders in which you compare the distribution of oil to bank 1 with bank 2 – you find that bank 1 gets more oil or better lubrication to the thrust side than bank 2 (WHERE ALMOST ALL THE FAILURES OCCUR) and as we have already established – that bank 2 runs hotter for several technical, tested and proven reasons and heat and load reduce viscosity and increase friction.

THE CHANGE OF BOILING POINT WITH PRESSURE

Amongst the "other contributory factors that can deteriorate with age" we can add another very important scientific fact. We have already explained that coolant (like water) boils at a specific temperature in air – but if contained in an enclosed container and put under pressure will only boil at a higher temperature (and this is why when you undo the radiator cap too quickly it can suddenly result in the coolant boiling and scalding you) – because you have lowered the pressure below the boiling point – even though it was OK when held under the pressure of the pressure cap.

The expansion tank is there to allow coolant to expand with heat and (assuming it was overfilled to start with) to blow out excess coolant and air until the remaining air gap is just right to allow the engine to reach the necessary temperature and pressure to run without boiling.

Anything that then results in the loss of coolant (without it being replaced) will increase the air gap on cooling and the next time the engine is run it may not then reach the same pressure and will therefore be running closer to the temperature it will boil at when running at a lower pressure (and remember they start boiling or creating air bubbles at a much lower temperature).

Now we know that there are several common contributory factors to loss of coolant in these engines – weeping (and eventually leaking) radiators (through premature corrosion), cracked expansion tank bottles, leaking bleed caps, weeping water pumps. Any one of these problems will result in lowering the running pressure and with it moving the critical temperature closer. Coolant radiators also run behind the air conditioning condensers – and as both get clogged with leaves and dirt their efficiency reduces – once again raising coolant temperatures and reducing response times.

On top of all that (as if the problems were not already great enough) – the radiators are at the other end of the car to the engine and so the delay in the radiators fixing a sudden increase in coolant temperature (or bubbling or boiling) is greater than in a more conventional layout (and bubbles of air are notoriously difficult to bleed from the coolant pipe layout front to back as it rises and falls creating air pockets and even leaves the engine at a lower level than it flows at inside – trapping potential air pockets).

Apart from expecting to find that the balance of temperatures inside the engines is not as good as the previous versions - most of the other factors that contribute to eventual failure are gradual deterioration of minor issues which all put together cause the result and to those we can also add deterioration of oil quality (being in too long or too thin), deterioration of coolant condition, skinning affect in which the inside of both the radiators and cylinder castings become coated (reducing heat transfer capabilities), water pump impellor to rear face clearance increasing with wear (which reduces lower speed coolant flow rates)– etc etc.

PUTTING THOSE ISSUES TOGETHER

All in all these points – the individual technical differences are – on their own – quite minor (and this is why many discount them as irrelevant) but if you put them all together and consider each as yet another potential issue on bank 2 – it changes to become are pretty convincing argument.

These engines have a design that has many good features (but that would result in some areas of the engine getting closer to a critical operating temperature in some places due to more temperature imbalance between the cylinders inside the engine than the older designs), a good bore material that unfortunately will tend to run hotter cylinder wall temperatures, a bore that creeps oval (increasing piston temperatures), a thermostat in a position to delay it being able to cool sudden increases (and radiators too far away to help quickly), a reduced coolant flow and layout that slows responses to temperature increases, and a thermostat that is basically set hotter than we think it needs to be to compensate for the other deterioration of various original settings and allowing critical temperatures to be reached too easily and localised bubbling/boiling to insulate the piston temperature from the cooling effect of the coolant nearby and a reduction in oil spray/splash cooling and lubrication through masking the crankshaft discs and the intermediate shaft (that could have supplied good splash lubrication – being in the sump oil deck height). Probably the changes would have worked OK if a lower temperature thermostat had also been fitted to reduce the individual HIGHER TEMPERATURE CYLINDERS BACK DOWN TO WHAT HAD ALREADY BEEN PROVEN TO BE A SATISFACTORY RUNNING TEMPERATURE IN THE OLDER CARS.

We also cannot help wondering if the extended periods between oil changes and the "never needs changing" coolant (despite a manufacturer suggesting a 5 year maximum for safe usage) also contribute to this problem in some way. The increased piston to cylinder clearances resulting from gradual ovality would need a thicker oil to provide sufficient support as well – which is not specified (but which many independents change to).

PRIMARY CONCLUSIONS

In conclusion it would seem that the increased piston thrust loads between the piston and the cylinder bore that has a relatively small amount of hot oil to lubricate it - combined with less accurate distribution of temperature control inside the engine and higher cylinder temperatures - has resulted in the more vulnerable side (Bank 2) running closer to critical operating temperatures and eventually fail in some case where age and other contributory factors separate one example from another.

TEMPERATURE GAUAGE ACCURACY

Having absorbed all this there is one question we would expect the more observant of you to raise – that your car running temperature is not as high as the figures our test showed – but this is unfortunately because – according to all our tests and fully checked out temperature gauges etc –

the dashboard temperature dial reads a lower temperature than is actually measured inside the engine (by 6 to 8 deg C) and is actually showing nearer to the temperature the coolant leaves the radiator (or enters the engine) than where the sensor is fitted in the engine. This may be to avoid worrying owners seeing temperatures near or at the boiling point of water and although it is entirely up to the manufacturer to display any temperature he feels appropriate – it possibly disguises the need to investigate slight temperature rises that may be contributory factors leading to a damaged cylinder – caused by some slight deterioration of a parts or parts of the car.

WHY IT IS IMPOSSIBLE TO TEST EVERY ASPECT OF A NEW DESIGN BEFORE PUBLIC SALE

Because most cars are perfectly OK and so few fail, it would probably be impossible to test enough cars for long enough to find out by what proportion various contributory factors combine to cause the damage. In time some common factors may emerge (and we are looking for just such symptoms) but for now there clearly are logical, practical and technical reasons why a small number of these more powerful and more torquey engines fail. Good maintenance may help, attention to oil and coolant condition may help – but driver care may also come into the equation because we would expect a driver who warms up a car before driving it aggressively and then takes a minute or two building up to full throttle driving (to allow the thermostat to open enough to control local hot spots inside the engine) to avoid damage whereas in contrast someone who mercilessly drives at full throttle whenever they can – especially suddenly changing from slow driving to very fast in a few seconds - to experience the most problems. To be fair however it may well be that just using a lot of throttle at low revs (when the water pump and car speed are low and hence the air speed through the radiator is low) may also bring the problem closer or it may indeed start on cold start up due to the lack of oil around the cylinders (exacerbated when bores migrate oval and hot oil seeps away from the stationary piston on cooling).

Everyone seems to be looking for just 1 explanation for the continuing unreliability of a small number of newer engines (that it would be reasonable to expect Porsche to have eradicated by now) but in our view there is not ONE isolated problem – but instead quite a large number of small problems – each of which is normally running very close to a safe design limit (but just inside it) and therefore reliable for most cars and owners.

Whenever in the past a manufacturer has increased either the capacity or power output (or both) of a previously exceptionally reliable engine they have eventually reached a point at which weak spots showed up – that were sometimes fixed by the manufacturer – sometimes by independent specialists but more often remained as a feature of that engine that the public slowly came to recognise.

Because earlier engines with much the same overall technology and materials did not suffer this particular problem – and since different types of failure clearly have different contributory factors – it is likely that several small problems combine to create a failure in some engines while others are OK.

To test out all the potential problems would need hundreds of cars with different solutions driven around by the general public for many years before it would be possible to determine which factors were more significant than others.

Since it is therefore practically impossible to prove any one cause - Hartech's approach is to continually seek to examine failures and understand contributory causes and whenever an explanation unearths a weak area – try and rectify that during a rebuild. As a result a rebuilt Hartech engine featuring ALL the options available – changes and improves the marginal factors of safety in a whole range of different areas – some of which may well be more relevant than others.

Having completed a wide range of time consuming (and financially expensive) tests with two 3.4 996's we have now replicated those with similar tests of 3.6 and 3.8 engines (that are on-going). Furthermore our quest for answers and solutions does not stop here. Already tests have been undertaken in test engines (for between 6 and 12 months) on other new ideas and solutions (not yet released) designed to reduce costs and increase reliability and two other significant new ideas are presently in their first stage of testing (one that can be done while an engine is stripped and another that may help stop scoring all together before it is too late).

As each is proven to help the outcome by reducing temperatures or improving lubrication it will be introduced – but unlike many small independents we do not release new ideas for them to test at their cost and expense and only do so after extensive internal tests and analysis so new additional solutions may gradually make future engines even better than the excellent reliability already achieved.

READING ALL THE EVIDENCE IS PROBABLY OFF PUTTING – BUT THERE IS NO NEED TO BECOME DISCONSOLATE ABOUT THE PROBLEM BECAUSE PLENTY CAN BE DONE TO BOTH REPAIR DAMAGED ENGINES (AND EVEN AVOID DAMAGE OCCURING!) ALLOWING YOU TO CONTINUE TO ENJOY A FABULOUS RANGE OF OTHERWISE SUPERB SPORTS CARS WITH CONFIDENCE.

AND BECAUSE Hartech have a solution to each and every problem mentioned **above BOTH TO AVOID ENGINES FAILING and to REPAIR THEM ECONOMICALLY IF THEY DO.**

(1) For engines not yet failed – THERE IS NOTHING WE CAN DO YET WITHOUT STRIPPING AND REBUILDING THE ENGINE TO ALTER THE BALANCE OF COOLANT FLOW AND MINIMISE INCIDENCES OF FAILURE – EXCEPT THAT WE CAN OFFER A LOWER TEMPERATURE THERMOSTAT THAT WILL MINIMISE OR HOPEFULLY ELIMINATE THE PROBLEM. This basically runs the engine cooler by about 12 to 15 degrees Centigrade (21 to 27 Degrees Fahrenheight) and (at a temperature more similar to that which most racing engines (and more traditional older designs of sports engines) are run at. It makes no difference to the interior heating system and actually slightly increases power output but the main benefit is that when the car is driven under full power – even though the system as a whole is still comparatively slow to respond to sudden coolant temperature increases – the thermostat has now fully opened before the original normal running temperature has been reached (which increases coolant speed) and protects the pistons by lowering their temperature of the hottest ones and by this increasing the oil film strength.

With this new thermostat – warming up times are almost identical but as the new thermostat reaches a general running temperature of around 82 deg C (180 Deg F) it stays there while the original would continue to rise to 95 to 100 Deg C (203 to 212 Deg F).
Although it is possible to lower the temperature the fans switch on at (to cool the radiator more in standing or slow traffic) we do not find this necessary or a handicap as the new thermostat is so wide open by then as soon as the car is driven fast - the radiators lower the temperature immediately.

During our testing (using two standard and modified cars with different thermostats) we recorded temperatures every minute in different running conditions and speeds and these show that the original thermostat results in temperatures as high as 100 Deg C (212 Deg F) in some parts of the engines. These tests were actually carried out in Winter and unfortunately on days when the ambient temperature was just below zero. In such conditions the air naturally cools both the radiators and engines casings better and more quickly than in hotter ambient conditions and so to find such very high temperatures is quite surprising but fully supports the theory we had come up with that encouraged the tests in the first place and confirmed everything we had suspected.

Although the oil cooler is situated on the bank 2 side (and many others assume that causes that side of the engine to run hotter) Porsche have adjusted the side to side coolant flow to compensate and if anything the bank 1 side runs slightly hotter (a fact that also proves it is probably the difference in the location of the thrust face being on different sides of the cylinder on bank 1 and bank 2 and the relatively slow coolant speed that causes the thrust side of bank 2 to run hotter than the thrust side of bank 1 and in so doing confirms why it is the extra torque delivered combined with greater cylinder temperature variation caused by using common head gaskets - that is running some cylinders closer to their limits than with the older engines and hence the new "weak spots").

Without stripping and modifying the engine - we can do nothing about the new common cylinder head gasket (that results in some areas running hotter than others nor the difference in temperatures being more than it used to be inside the previous models) – but by lowering the overall temperatures – this critical areas move away from such high temperatures and return more inside a safe operating limit.

Replacing a thermostat involves the loss of the original coolant. This is no bad thing anyway as some manufacturers prefer it to be replaced every 5 years and most engine failures are around or after that age – but the re-bleeding is a long drawn out procedure and so it is quite an expensive preventative measure (but still worth doing in our opinion). One way to mitigate that cost is if the car needed a new radiator or two anyway (or a water pump) since both would require new coolant and re-bleeding anyway – rendering the cost of the new thermostat relatively smaller.

(2) For engines that have already failed (with scored bores and damaged pistons) we have more than one solution.

(a) Because we already manufactured replacement cylinders to repair engines with cracked oval bores - when the first scored bore engines came our way we were able to bore out the old liner (as if it was a cracked one) and fit the same replacement cylinder/liner and a new standard Porsche piston (and we manufacture for stock liners for 8 different models now).

(b) This worked OK but had two disadvantages – the cost is high (but still cheaper than a new engine) and the engines still ran as hot as before. We then opened out the coolant channel to change the split of coolant between the head and the cylinder to increase the amount of heat being taken out of the cylinder and run the surface temperature cooler – which proved satisfactory and so we did this to all the other cylinders – for the same preventative future proofing reason.

PIC HARTECH CYLINDER LINER

(c) Although the scoring is too deep to hone out and fit another standard piston it is shallow enough to bore and hone out the original cylinder a little larger and fit a slightly bigger piston (of high quality manufacture and the same basic design as original including the facing material to suit Lokasil). To achieve this Hartech have contracted a highly reputable manufacturer to provide these for all models affected on an exclusive basis and they are currently under test for 997 3.6 and 997 3.8 engines (as they are the most affected models) and pistons for other models are in manufacture but testing (and therefore availability) will follow later in 2012). Once proven they will lower the cost of a rebuild considerably – but the advantage will be greatest when two or three cylinder bores are affected – because the other methods would require two or all three cylinders being machined out and replaced plus two or three new pistons anyway).

PHOTO NEW PISTONS for 3.6 and 3.8 997 engines.

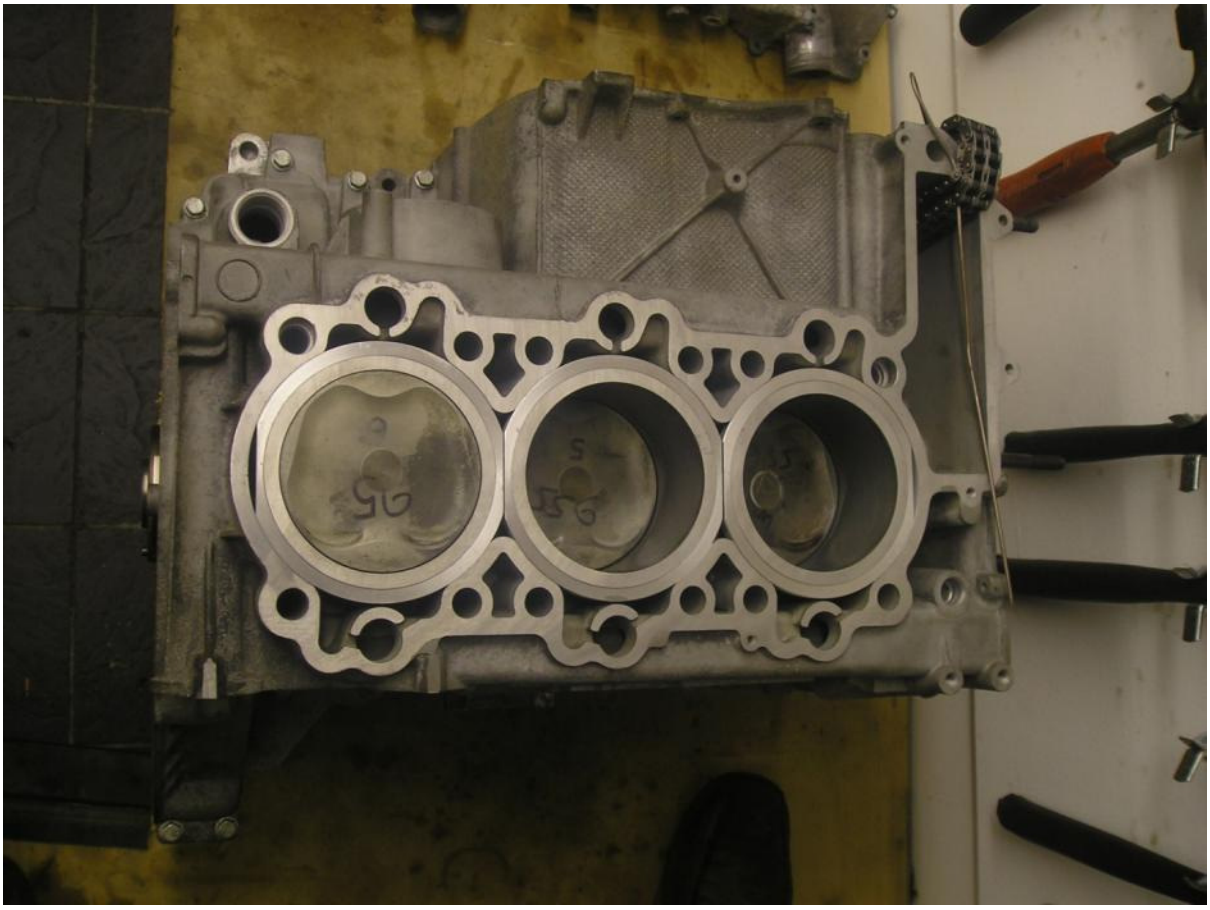
We have had difficulty in reproducing the same bore finish as the original standard Lokasil bores and this has resulted in the purchase and installation of a lot of new very expensive equipment and further testing of several of our own cars (and some customer cars under agreements if the outcome is not favourable).

(d) It is also possible to replace the two halves of the crankcases with new Porsche crankcases and rebuild with new Porsche pistons – but this is the most expensive option (although still cheaper than a new engine). We insist that all engines rebuilt are fitted with the new thermostat (for obvious reasons).

An additional option offered is to re-round the remaining oval bores and to fit them with restraining rings – or in the case of fitting slightly oversized pistons we insist that at least that bore (or those bores) are restrained so that they will not be the cause of a future failure. This converts the cylinders to a closed deck design – much exploited by Porsche in describing the benefits of the series 2 engines that are of that design from new and in their own words – improves cylinder sealing, reduces blow by and increases life expectancy while reducing running temperatures".

We allow customers to decide if they want the other standard bores that are fitted with standard pistons and already oval – to be re-rounded and restrained but any failures of the cylinders or pistons that are not re-rounded - resulting from ignoring this process - will not – in all fairness - be covered under our guarantee.

PHOTO RESTRAINING RINGS fitted to the tops of each re-rounded cylinder.



We can also alter the coolant flow balance so that the cylinders now run cooler than the heads (by about 5 deg C). This means that this modification together with a standard thermostat would result in the cylinders running cooler than before and the heads running very slightly hotter (a better compromise), but when fitted with the lower temperature thermostat both the cylinders and the cylinder heads run cooler and the cylinders slightly cooler than before with the earlier engines that had no related problems (but advisable due to the increased cylinder wall thrust loads applied).

In addition to these specific solutions to the main new problems afflicting some of these models – we also continue to offer additional modifications and replacement to “FUTURE PROOF” the engines - to make the engine more robust than it was before or than a new one at a relatively small additional cost (largely covered in section 4). Please contact us for more details and quotations. So although we are used to boring out a scored liner and replace it and the piston to affect a repair at a much lower cost than a new engine and also make changes to improve the weaknesses that we think are contributory, we are also investing heavily in ways to reduce the repair costs in the future – because we believe this to be a problem that will afflict a lot of engines (although still statistically small overall).

Because the cost of this investment is relatively - very high for us – we are not prepared right now to explain or describe in detail every cause or future development we have up our sleeves or in test – for pure commercial reasons – but present developments include re-ground and re-hardened crankshafts with wider undersized shells (presently under test), different oil pump gears (to increase flow and cooling and recover damaged oil pump housings), baffled deeper sumps (for track use), re-built IMS shafts with new bearing carriers (for both roller and HIVO chain models).

This scoring problem usually occurs between about 25K and 50K. If the engine survives until a radiator leaks, a water pump fails, a cylinder head cracks or anything else occurs to cause overheating – then that may well also initiate this unfortunate failure by pushing the hottest area inside the engine over the limit.

In addition to this there is a purely manufacturing machining problem we have also previously identified (one that we correct during reconditioning) where a small step in the otherwise flat machining of the top of the cylinder block can cause cylinder head gasket leakage and overheating the cylinder through reduction in cooling (that has caused this very problem in a car/engine received for repair in 2010 after only 17K) but is much less expensive to repair.

REITERATING THE INNACCURACY OF THE TEMPERATURE GAUAGE – A WAY TO TEST IT OUT BUT ALSO EXPLAINING THAT EVEN THEN THIS DOES NOT READ CYLINDER WALL TEMPERATURES AND WHY

The Internet has thrown up a useful confirmation of our findings and we were grateful to a contributor called “GT4” when he showed how to read the coolant temperature by another system (by re-setting the existing digital air con control unit on the pre face lift 996’s) the results of which confirmed that our own test readings (that showed higher engine coolant temperature readings than the dash board temperature gauge) were right.

But even then you should not be fooled into assuming the cylinder coolant temperature is even the same as that shown on the gauges (even after adjusting for inaacurate readings). Why – well you will remember that instead of 100% of the coolant passing each cylinder to cool it – only about 1.5% to 4% passes each individual cylinder and then mixes with the majority of the coolant that goes through the cylinder head before travelling on a relatively long journey back to the radiator and even later reaching the thermostat and back inside the engine again.

This means that if there is a sudden temperature rise inside the engine (as a result of suddenly driving much faster) it is the cylinder walls that will try and transfer this heat first (because the coolant in the cylinder head is far less effective being further away and masked by other parts and thicker casting areas) and because the coolant in the cylinder area is travelling relatively slowly - that temperature rise will be higher. The coolant from the cylinders then mixes with about 80% of the coolant going through the head (the temperature of which will not yet be affected) – so the temperature of the resulting mixture will be only slightly elevated as it travels back to the radiator (where it is then cooled) before even reaching the thermostat. The result must be a system that results in much higher immediate cylinder wall temperatures and much hotter pistons - because it reacts much more slowly to dissipate that sudden increase in cylinder temperature than more traditional engine designs.

Now the change in cylinder head gasket design has made that balance different in the 3.4 Cayman, 3.6 and 3.8 engines by about 50% - or put another way – the amount of coolant (as a proportion of the rest going through the cylinder heads) has been reduced in those engines compared to a 3.4 engine – by about half – less through the block and more through the head.

This must mean that the temperature rise it has to handle is higher, the proportion of it mixing with the coolant coming out of the cylinder head is less and the resulting mixture going on to the radiator is cooler – thus creating a further delayed response in quickly bringing those temperatures down again (because the thermostat can only react to the whole coolant mix temperature and not the rise just in the cylinder area).

Now if we go back to looking at the difference in the actual coolant temperature readings (between the dash board gauge and either the air con digital signal or our test gauges) – we find that whereas they rise from cold almost together – once the dash board gauge reaches about 80 degrees it becomes very slow to read any sudden rises (that the other instruments pick up immediately) and starts to lag behind the true reading as the temperature rises further.

It means that owners don't realise that during some dramatic changes in driving – temperatures are rising and falling very quickly and to high maximums – and bearing in mind that this rise came about from a very small amount (that was in the cylinder block) mixing with the cooler majority that is in the head – when we see a sudden rise of 10 degrees C in the mixed temperature (using the digital or test gauges) – the rise in the small amount of cylinder coolant temperature must be many times higher than that and certainly could be in that area of boiling and creating air bubble screening (all of which our tests confirmed).

Now the pistons have a PTFE type MOLYCOTE coating (which some 3.4's have and some don't but has not been a problem in 3.4's) that has always delaminated on the pistons that have not seized - in engines that have scored bores.

So our conclusion still is that the biggest change in these later engines (and most influencing factor) is the change in the head gasket design that has altered the coolant flow ratios and speeds resulting in higher cylinder wall temperatures while the pistons are transmitting higher cylinder wall loads and the consequence is either that the additional load and heat gradually de-laminates the coating that then jams against the pistons rings (causing scoring) or the increased load/unit piston face area is too much for the oil film to support (which all our research and discussions with tribology experts agrees with) is more likely . This is why we made changes to the coolant flow when we rebuild the engines and also verifies the benefit that fitting a lower temperature thermostat to engines that are presently Ok will have – by helping to compensating for the slow reaction time of the cooling system (because it then starts off at a lower temperature) and allow the slow reacting cooling system to recover back to a sensible running temperature before it has risen far enough to cause damage and generally preventing the temperatures from reaching the heights they previously did.

DRIP DRYING

However we cannot be absolutely sure at which precise moment the cylinder damage damage occurs (and cannot think of a way to test for it reliably). So we don't know if it is during driving hard, after a sudden stop or on initial start up after a period of inactivity. To minimise whichever alternative is the culprit - we suggest starting with no throttle for a few seconds from cold, not to give a car full throttle immediately after slowing to tickover at say lights etc and to ensure the engine is fully hot before driving flat out.

It may be that the ovality that creeps up on the cylinders increases the gap at the top of the cylinder so much (as the piston sits at the bottom through gravity) that the surface tension affect of the piston and hence the oil film being too far away from the cylinder wall to prevent it draining down to the bottom of the cylinder – resulting in a dry start up and a puff of smoke from the oil at the bottom that has migrated through to the bores as the engine cools down (which has become a typical feature). If so it is difficult to think of a way to avoid the problem – except when we rebuild the engines as a closed deck design – restoring the correct piston to cylinder wall clearances.

Finally - we at Hartech - are now being recognised for the effort and quality of research we are putting into this problem by major specialist oil suppliers and are presently involved with them in testing and analysis of existing and new oils and additives to try and find a simple solution to avoid the problem altogether (and it does look encouraging).

DANGERS OF THE EDITORIALS AND THE INTERNET

Technical journalists are very much in the hands of the engineers explaining their theories and often unwittingly publish research that is of poor quality (or technically must be wrong) that the general public have no way of reading selectively and often get fooled into making poor decisions as a result.

There is also a good and bad side to the Internet (as with most things) and just as the Internet forums showed up the temperature difference in the dashboard gauge by using another part of the an existing system – it has also become a platform for others to exploit the widespread nature of this problem by offering their own solutions and technical expertise – that are often misleading or wrong.

This is why we have written this huge document – so everyone Worldwide – can analyse our findings and conclusions and if they so wish - challenge them properly.

SOME EXAMPLES.

It has been said that the scoring is cause by the piston rings.

This must be wrong because the scoring occurs on the thrust side of bank 2 and piston rings have no way of applying a force selectively to one bank or any one part of the bore. Furthermore the scoring takes place in the lower half of the cylinders and below the level that the rings actually touch the bores and never in the top where the rings do touch.

Readers may also not be aware that the top of a piston (where the rings sit) is machined smaller than the rest of the piston and so never touches the bores at all and the rings sit in a groove that is deeper than the ring so there is no load whatsoever transmitted from the piston to the ring on the thrust face or on to the cylinder bore. There is slightly more pressure exerted from a ring where the open end sits but this is not controlled by any pegs and is randomly distributed.

If the problem was the rings it would affect bank one as much as bank 2, would be anywhere round the circumference and scoring would occur higher up the bores and not at the bottom (where the rings never reach).

We would agree that if the thrust face of bank 2 is running hotter than anywhere else and the oil is therefore critically unable to support the piston loads – then the rings could damage the surface – but this would only be possible where the rings slide up and down and not in a different place all together (where it actually occurs). Sorry but this argument about the rings being the cause - must be wrong.

STEEL or CAST IRON LINERS.

The industry long ago improved the performance and lifespan of engines by getting away from the old tried and trusted steel/iron liner. To be fair it does not make a bad cylinder system if the liner is cast in place – but does wear prematurely and is not as good if it is pressed or shrunk into an aluminium block due to differential expansion of the metals resulting in poor interference fits and cylinder head sealing problems. We have already had to repair and replace steel liners from 2 different UK sources with our own superior alloy cylinders with Nikasil plated bores (as used in most air cooled 911's, 996 and 997 turbos and GT3 engines prior to the generation 2 engines).

PISTONS.

It has also been said that the problem is the pistons changing from cast to forged designs or being inferior. Frankly this falls into the category of failing to think out ALL the relevant issues again because not only have forged pistons been proven to be superior but any faults in the pistons would apply equally to bank 1 and bank 2. Furthermore pistons have been manufactured for so many years they will work perfectly well if all the other parameters are in limit.

Furthermore we have seen cast pistons fail in exactly the same way in 996's and Boxsters when some other fault existed (like lack of coolant or a damaged coolant pump).

Sometimes – to prove a theory – it is quicker to adjust a parameter you think is the main cause and see if that does produce the expected failure. As part of our testing and development we did exactly that (even though the cost to us in first modifying an aspect of the engine – then building, driving under test and then stripping and repairing the engine in question was huge) and actually managed to reproduce scoring using both forged and cast pistons. This achieved 2 objectives – it confirmed the primary cause and at the same time refuted the type of piston being the cause. Anyway - if the pistons were faulty it would also affect more than the small percentage failing through scoring.

Mature readers will see through the reasons why some competitors try and find different explanations to this problem than us when they cannot or do not offer the same solution as a new alloy Nikasil cylinder, changes to temperature distributions, re-rounding of cylinders (of which we are still the only people Worldwide to solve the problems of how to do it), don't offer a method of changing the cylinders to a closed deck design (much vaunted by Porsche themselves in their new generation 2 publicity), do not usually have their own IN HOUSE machining capability and don't employ graduate engineers with proven history and background in racing engine design, manufacture and problem solving.

WHY HARTECH STARTED TRACK RACING IN 2011.

Yet another difference between us and others is that - we are now being recognised for the effort and quality of research we are putting into this problem by major specialist oil suppliers and are presently involved with them in testing and analysing existing and new oils and additives to try and find a simple solution to avoid the problem altogether (and it does look encouraging).

If the logistical problems for a manufacturer to test out new products quickly enough is virtually impossible – it is by a huge factor even more impossible for a small independently funded private business. However on way to increase stresses and temperatures and test out issues and solutions more quickly and safely is through racing the product.

To assist in this process – as part of a longer term plan - Hartech took part in the Porsche Club Motor Racing Championship for 2011 (for the first time). Although our employees had previous success in motorsport/tuning/design and manufacture etc – no one had any experience of actual circuit racing cars and so it was a difficult learning curve to run 2 cars competitively while trying to pick up enough experience to compete with others with 20 or 30 years experience.

With the business expanding at a rapid rate to cope with the ever increasing demand for engine rebuilds – we thought it would be too much to combine that with entering racing with our own new cars in one go – but instead chose a slightly slower way to get the experience we lacked more quickly.

Sponsoring 2 968's (to at least start out with cars that have benefitted from many years of Worldwide modifications and alterations) we still found it challenging to set them up properly - despite which we achieved several 2nd, 3rd, 4th, 5th and 6 places, had some pole positions and ran second and fourth in the Championship for most of the season and achieved a 1st in the last event at Silverstone.

Now that we have picked up some valuable experience (but recognising there is still much more to learn) the second part of the plan is coming into place with the building of 2 Boxster racers for the 2012 season (to enable us to learn how to set them up competitively and push the limits of the M96 engines as far as possible and find out about future weak spots and test out solutions etc). Driven by 2 former Club Champions – they should provide an ideal mobile test bed for many of the issues involved in the larger 996 and 997 engines. Already 3 potentially interesting new solutions to existing problems are being built into these cars and if they prove successful under the rigorous race conditions we will encounter – this will shorten the testing time before we can add them to the already impressive number of rebuild options that we have available.

These results will also be relevant to 911 variants but although the 3.4 996 is allowable for the first time in the 2012 Championship, we think racing one of those would be a step too far - because we have only one year of racing experience behind us – and we want to find our way gradually and primarily be testing and pushing engines to their limits. We have a whole new model to try and fine tune into a race winning car and although the last 2 seasons of the BRSCC Boxster race series (and their inclusion in the Porsche Club Championship in 2011) already provides some feedback to shorten development time - and despite the fact that we already have had involvement in building the engines and making racing sumps etc fitted to their race and Championship winning cars - it seems like less of a step to build our own Boxsters than a car not yet raced before in the UK. However the Boxster and 996 share so many common parts and technology - we hope to run a 996 later in the season – or - when and if we have managed to get the Boxsters competitive.

After that – just as soon as the 3.6, 3.8 or Cayman S are allowed to compete – we hope to move up to those and continue to test and experiment with our progress and solutions – not being intimidated by the results being open to public scrutiny – but proud to demonstrate our capabilities and show our confidence in the work we do and our whole approach to addressing these failures.

FUTURE DEVELOPMENTS

There are several modifications we have been testing for 12 months that we will soon introduce to lower some rebuild costs – but the most relevant recent development has been in the analysis of the performance and quantity of oil from the spray jets on the cylinder walls.

This has split into 2 distinct directions.

NANO OIL TECHNOLOGY.

The oil industry has admitted that standard lubricant technology is no longer adequate to meet the challenges that the motor industry face by using smaller, lighter and more powerful engines. In searching for new solutions – Nano technology has emerged as the fore runner.

This is a new development that basically applies a whole new idea to lubrication. By adding a variety of different Nano constituents to oils – the resulting performance improves by a huge factor in lubricity, film strength etc.

Nano constituents are small particles (so small that if you compared the size of a melon to that of the earth – a Nano particle would be the same proportion smaller than the melon as the earth is to the melon – unimaginably small (under 100nm).

They act rather similar to you trying to move a large machine on a flat surface covered in oil (in which the weight would still prevent it from moving) and then throwing a lot of very small ball bearings under the machine – in the oil – to create a rolling mechanism inside the oil film.

Several different Nano materials have been tested but one of the most promising seems to be Tungsten Disulphide (one of the most lubricious materials in existence) and some Nano particles can even be magnetised to sit in the minute hollows in the microscopic surface of metals – to provide a permanent low friction surface.

In the most severe tests - oils including Nano particles out-perform the best competition oils by a factor of about 3 to 1. They are presently very expensive but may just compensate for the slight deficiencies we have identified in the newer engines and render them acceptably reliable in the future. It seems to provide a lower coefficient of friction combined with higher film strength and much lower wear rates (exactly what is needed to compensate for cylinder wall temperatures being so high and reducing the viscosity of the oils below that which the high torque and reliably be managed between the piston and the cylinder wall).

Because we not only seek out improvements to engines we are rebuilding but also look for ways to help owners avoid problems in the first place – early in 2011 - we became involved in the testing of Nano additives (getting condition results properly tested at formal intervals in which the content of wear particles is measured by volume and proportion) to establish our own conclusions.

In all tests so far the results have shown a reduction in the friction coefficient and wear rates – and of specific interest is the simple fact that this reduction in friction also has a spin off benefit in that the oil does not get as hot, which in turn keeps the viscosity higher and the engine oil cooler so engines not fitted with a tickover control mechanism – will then tickover at higher revs and the oil pressure delivered at tickover increases even when the revs are the same (due to lower temperatures in the oil and the higher viscosity resulting.

It is this last fact that may enable a newer type of Nano oil to eradicate the incidences of cylinder bore scoring in the future and we are actively as involved as possible in testing this out (even though it will reduce the numbers of engines we would eventually rebuild). We think the interests of our customers and Porsche owners are of greater importance than our turnover and anyway expect numbers needing repair to grow as the cars age even though some may be better protected by the addition of a better quality “Nano” oil.

MILLERS OILS RACING CONTRACT.

While we have been testing out Nano engine oil separately - Millers Oils had already produced a Nano gear oil with great results and a well earned and justified award for the “Most Innovative New Motorsport Product” in 2011.

With their philosophy very much embedded in racing research (and with involvement in many top racing teams) and their recognition of the professional and highly technical work we have carried out, our recent success at the race circuits and the ability to manufacture and test out our own products and modifications – it has resulted in a joint venture to use and test their latest products under strict test conditions in our Boxster racing team for 2012 under contract.

We are delighted to become involved - as it provides a direct link to the most sophisticated research and test facilities available and the feedback will help to verify and support our own results and modifications in the future and hopefully result in a road suitable Nano oil for the engines presently vulnerable to cylinder scoring. Together with our low temperature thermostat – this may provide a reliable preventative measure at modest cost to eradicate or significantly reduce the problem.

To achieve this our two Boxster race cars will run with Millers latest oils (including Nano derivatives developed for road cars), sending samples back to their laboratory for test and putting them through the most arduous of conditions as we try and run at the front of the Championship with two cars and two former Champions.

NEW SPRAY JETS.

Although our rebuilt engines have been extremely reliable – we have always been looking into the potential causes and testing our solutions (in case we have not yet picked on every possibility).

It is an odd fact that there are lots of issues that make the newer engines slightly less well lubricated on the cylinder walls than the older versions that were perfectly OK. The fact that the spray jets are fitted to the bottom of the cylinders in m96 engines (but the top in air cooled 911's) may be significant, the outputs are higher, the cylinders less stable and more prone to increased bore clearances, the cooling is in the opposite direction and the amount of oil on the vulnerable bank 2 thrust side is reduced.

This is something we thought we might be able to do to something about by fitting a second set of spray jets that spray the oil directly to the exact area of the cylinder wall where all the scoring takes place (on the top of the bores in bank 2 and the bottom in bank 1)

It was a difficult task as the cast alloy crankcase journals are comparatively thin – but we have managed to make tooling to suit and have fitted a test engine with extra jets that our photos prove spray the oil directly on the exact area and shape of the scoring – on bank 2.

Our test engine also has them fitted to bank 1 for one very good reason. We assumed that supplying extra oil to 6 new spray jets (each with 2 outlets) would lower the oil pressure on tickover (since the amount of oil spraying out would be similar to very worn crankshaft shells). We were not overly concerned if the pressure had not dropped too far (as engines like the 3.2 carerra run with no measurable oil pressure on tickover anyway which works because the load is minimal) and if it dropped say 10 psi we think it could be worth it if the extra oil on the bores eradicated the problem all together.

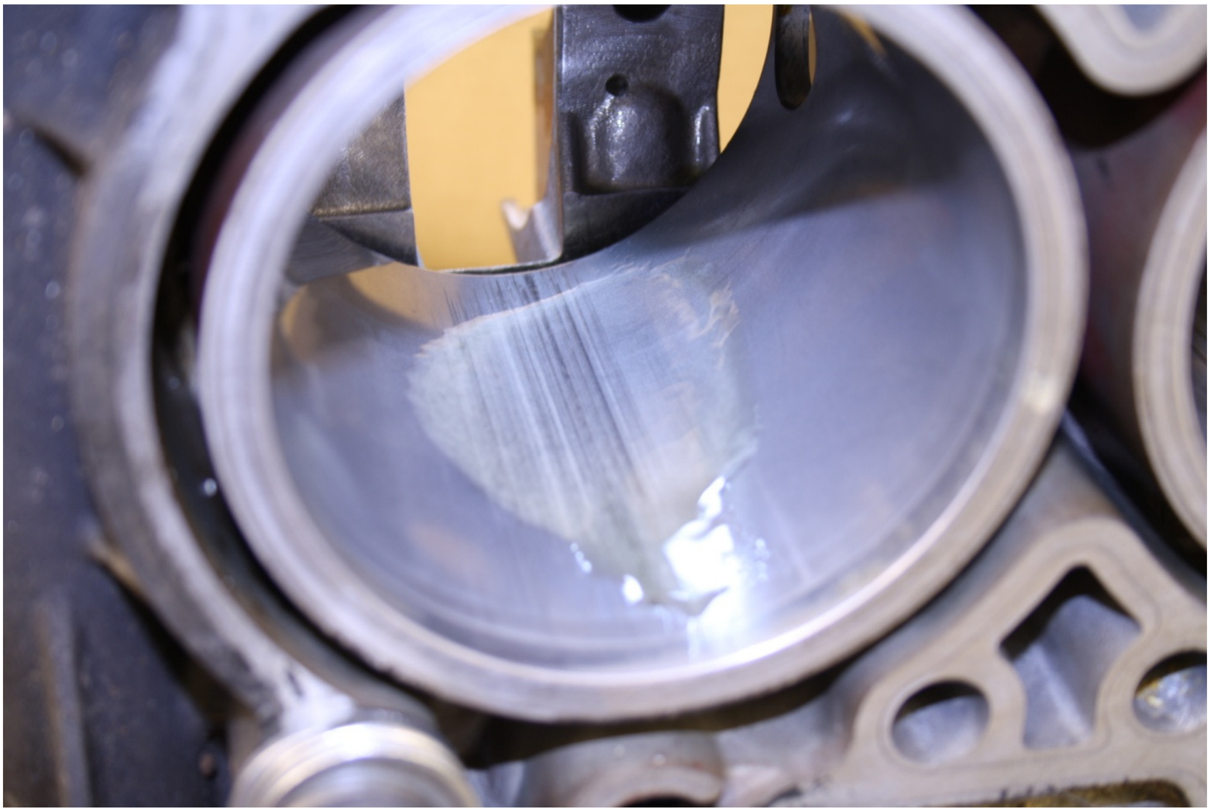
The jets worked OK but to our surprise the oil pressure on tickover increased by half a bar – which we admit was unexpected.

After consultation with our Millers Oil experts they were not at all surprised as they said that whenever they have changed to a better oil (or added a more slippery ingredient) the reduction in basic friction has reduced the oil temperature and in turn that has increased the oil pressure on tickover.

It seems at the moment that these additional oil spray jets have not only improved the lubrication to the bores but seem to have confirmed that the basic amount normally present was relatively low and causing some additional friction, heat and lower oil viscosity – which was exactly what we considered was an additional contributory factor if the scoring in the first place.

It is early days with this particular modification at present – so we can only report that it seems like a good additional solution and if it continues to prove worthwhile will eventually be another additional modification that we can carry out during a rebuild.

The following photo shows oil after spraying through the new spray jets into the area it had previously been scored. If there was a piston there it would spread that oil film across the whole are of the scoring on its way down – thus ensuring there is sufficient to cope with the loads and at lower oil temperatures and therefore greater viscosity. You can see how the oil spray jet distributes oil across the surface – but the photo is from simply squeezing oil through the jet and allowing it to run down – when we do it under pressure the view is much more conclusive that it does spread the oil all across the surface – but we cannot manage to take a photo that shows this perfectly under pressure as the mist blocks the view and spreads oil everywhere including the camera lens.



However this will not be the only factor. We still believe that the small number that fail mean that most of the engines survive OK – and that there are only ever small differences in several different areas that can result in the viscosity of the oil becoming too low in some circumstances and under some driving conditions – in some cars resulting in cylinder scoring.

Although some competitors are claiming one simple cause and fix – most engines rebuilt with new parts, new oil, new coolant and new pistons may survive for some years (because the new engines did as well) and it will only be after some considerable time that the actual causes and solutions can properly be analysed by eventual feedback when they fail again.

Our view is that we have identified numerous contributory factors all of which both logically and technically explain why these engines are particularly vulnerable and we incorporate several different modifications – all of which contribute towards a satisfactory solution by improving the general technical capabilities of the engine and the safety margins.

Of all of these – for engines that have failed the re-rounding of cylinders and converting to a closed deck design, the lower temperature thermostat and the new oil spray jets (still under test and yet to be released) are probably the most beneficial but we continue to develop new ideas and seek out ways to render the engines as reliable as their predecessors rightly gained a superb reputation for.

TRYING HARDER THAN ANYONE ELSE TO HELP OWNERS WITH PROBLEMS.

There is no other business operation that we are aware of that has dedicated so much time or and invested so much money – or for so many years – in solving these problems in cost effective ways that give the owners a variety of solutions (to suit their needs and circumstances) and that are prepared to advise on the outcomes on the Internet (for all to see) and who have already successfully rebuilt anything like as many engines that are running around reliably ever since.

Our business has invested in machinery and organised a production line approach with full technical records and analysis to speed up repairs and control quality with all the manufacturing of special parts and modifications undertaken in house with our own staff and under our control and the results are guaranteed.

One of the top motoring technical journalist recently visited us (following similar visits to the other UK engine rebuild specialists) and commented afterwards that the whole operation, the level of technical excellence, the equipment and the lengths we have gone to in order to offer the best and most reasonably priced set of repair options –is on a completely different level to anything anyone else if offering.

BRIEF LIST OF CAUSES, EFFECTS AND SOLUTIONS WITHOUT ANY TECNICAL BACK UP OR EXPLANATIONS.

EXISTING ISSUES THAT MAKE ALL THESE ENGINES DIFFERENT to previous Porsche designs.

The coolant flow to each cylinder is reduced (so a greater temperature difference across the cylinders top to bottom).

The thermostat is fitted to the inlet – increasing engine running temperatures compared to traditional engines with the same thermostat setting but on the outlet.

The radiators are a long way from the engine slowing reaction times to sudden temperature increases.

The radiators are partially blocked by the air conditioning condensers and often with leaves and can corrode and then leak.

The temperature gauge reads lower than the actual temperature.

The piston spray jets are in the bottom of the cylinders (favouring bank 1) unable to lubricate the thrust face of bank 2 as well as on bank 1.

The coolant enters under the cylinders (favouring bank 1)

The cylinders gradually go oval in the thrust direction increasing blow by and piston temperatures.

The coolant outlet is lower than the highest point of the crankcase potentially trapping bubbles allowing temperatures at the cylinder walls to rise.

The head gasket controls the balance of coolant to each cylinder and the cylinder heads.

Oil and coolant change intervals have been increased reducing oil condition and effectiveness.

As a result the cylinder walls run hotter than traditional engines and as the mileage increases the cylinder ovality increases and so does the cylinder wall temperature and oil viscosity drops.

ISSUES THAT RENDER THE Cayman S, 3.6 and 3.8 engines different to the 3.4's and Boxsters.

The head gasket now fits both sides but has larger coolant holes to the cylinder heads, reducing the proportion of coolant to the cylinders and changing their balance that then run hotter.

The connecting rods are shorter increasing cylinder wall loads and friction.

The torque developed is higher increasing piston to cylinder wall loads especially at low revs – increasing friction.

The oil spray jets are the same size as before and therefore the ratio of oil in the cylinders to surface area is reduced.

The space for the coolant to circulate in the cylinders has been reduced.

The crankshaft is wider (reducing any spray oil to the cylinders buy entrapment).

FINAL CONCLUSION.

We often find that when we explain a particular issue or solution on the Internet or in our buyers guide, some people immediately say we are wrong (for all sorts of different reasons and motivations) yet the answer to their point is often contained within the original script (that they missed) or is at odds with accepted scientific or engineering principles that we then take hours explaining to defend our position (and we are rarely found to be wrong). So we have written this section to try and cover everything we can anticipate being raised as a result and to enable readers to at least get the full picture before they start trying to confuse others by arguing about the content, causes and conclusions.

Although these engines are similar to the older air cooled 911's there are several changes that make them different and they are also built and run closer to design limits – but in most cases perfectly OK (as the older engine's design limits were basically higher than they needed to be).

There are also numerous reasons why bank 2 will suffer 1st if a problem emerges – all of which relate to the quantity, temperature and condition of the oil at the upper cylinder wall being unable to cope with the friction generated and resulting in contact between the piston and the bore causing scoring.

Although earlier designs didn't usually suffer this problem – the increases in power output combined with the reduction in cylinder block coolant flow and balance, the direction of the oil spray jets and the quantity of oil present - have pushed the later engines even closer to that limit and as a result some fail when mileages get higher, bore clearances increase, piston coatings wear thin, oil deteriorates, radiators leak, etc, etc – i.e. some engines with some driving conditions – just slightly go over that safe limit for a few seconds and this then results in the scoring we are concerned about.

Many others claim alternative explanations but none of these explain why the scoring is only on the top of bank 2. Indeed if you think there is some other alternative cause – please ask yourself why it would not then apply to the other bank before raising the issue. Conversely – ALL our explanations herein (many and varied) point to why these failures only occur – where they actually occur – on bank 2 and link the design changes in the later engines (and their increased torque) to the generally accepted reasons for scoring (or scuffing) to occur.

Consequently – all our solutions are relevant and viable – and we can adjust and modify several items around those weaknesses to improve the future reliability of the engines we rebuild – accordingly.

We are continually testing out different potential contributory factors and the results are being professionally researched by independent specialists, while we also pursue our own tests in the harshest conditions we can reproduce in trying to win races against other Porsche models, drivers and businesses.

We can find no evidence that anyone else has put similar resources, new re-designs, tests or effort into explaining and solving this particular problem – in fact the content of this section demonstrates both the highest level of technical and engineering capability and direction and the determination of Hartech to offer the very best answers and solutions available Worldwide.

If you have a problem – this should - at the very least – encourage you to contact us to discuss what we can do for you – there is nowhere else that can combine as much experience, knowledge, or who has built anything like as many engines successfully nor is as involved in testing them and continuing to manufacture new and innovative solutions IN HOUSE nor who backs up their business with as many guarantees and Maintenance solutions to enable Porsche owners to enjoy their cars – whatever their shortcoming – with pride and confidence.

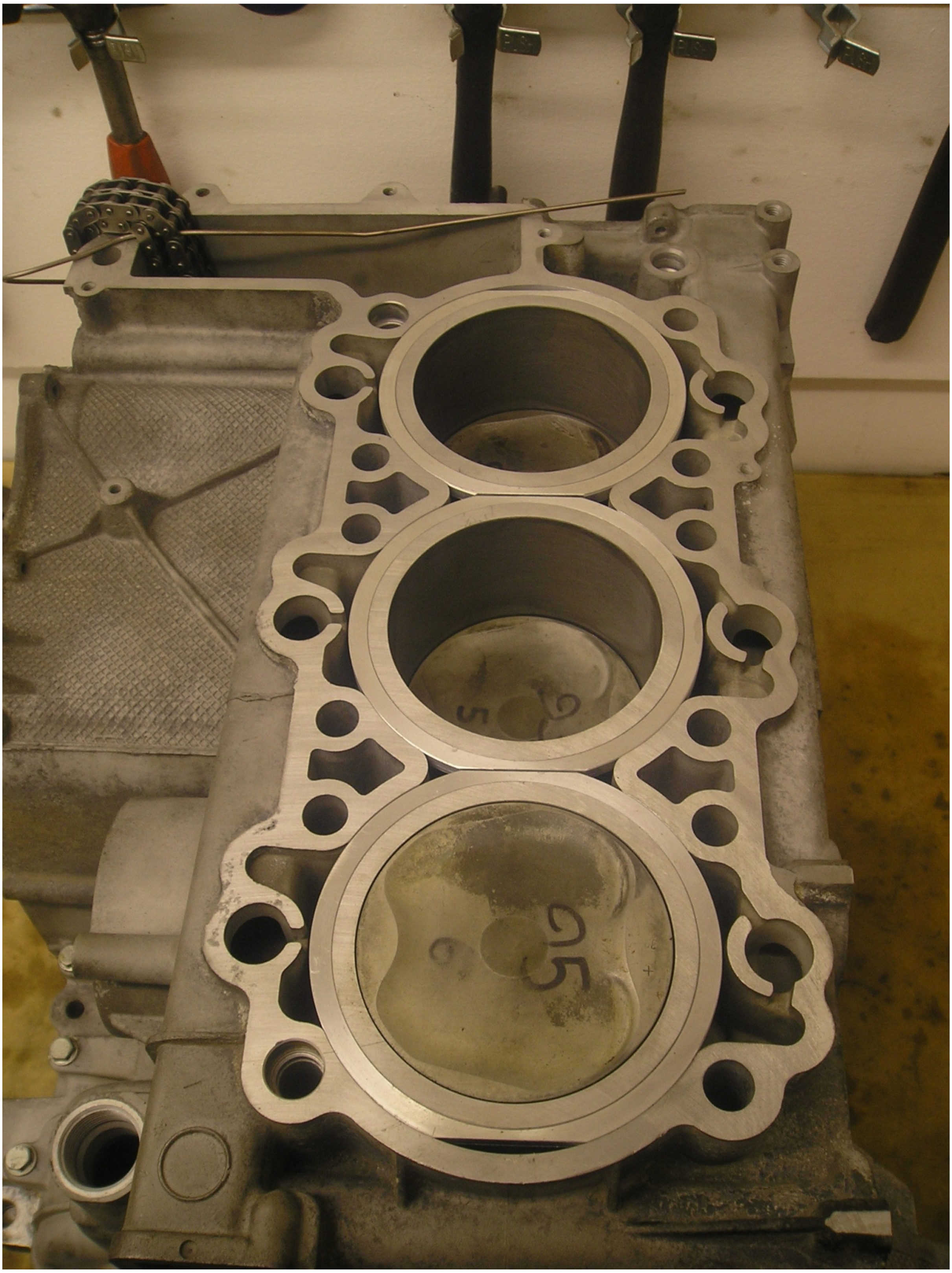
Supplement February 2012

The Reason why modern engines tend to have Alloy Cylinders Instead of Traditional Iron Liners.

With the problem of cylinder scoring and owners and customers seeking the cheapest solution - has once again come the traditional quick cheap fix of steel (or more accurately “iron”) liners fitted to Porsche engines.

The reasons that this is not the best answer are many but relate to a wider problem engineers have in designing modern high performance engines.

Most readers know what a piston looks like and would understand that the top is a round alloy disc (this is the part that the fuel mixture pushes down on when it is ignited and is expanding) with sides that are round and extend down the cylinder bore (see following photos).



Because the expanding fuel starts off burning when the piston is near the top – the heat is not yet near the round cylinder bores and is only reaching the piston crown (top) and cylinder head. As the piston descends heat reaches the cylinder bores as well – but for a shorter length of time – but because both these and the heads are liquid cooled (and the piston is not) the piston crown is by far the hottest piece of alloy reached by combustion and therefore expands the most.

The heat from the piston is dissipated through the piston rings, the oil mist that is in contact with it and the faces of the piston as it rubs against the cylinder wall. Because the top is the hottest part – this expands the most.

To prevent the top from expanding so much that it gets bigger than the cylinder bore – the piston is machined smaller at the top – in fact the part where the piston rings are (and above the rings) is machined so much smaller that it never normally touches the cylinder wall. The front and back of the piston pushes against the cylinder wall to transfer the pressure pushing it down into a force down the con rod to turn the crankshaft – so this area is machined to touch the cylinder wall but is also tapered (to allow for the gradually reduction in temperature further away from the heat source – at the top).

The sides of the piston do little as they don't apply any pressure and because the rubbing of the piston against the cylinder wall actually also causes friction (which adds to the heat and reduces power through friction losses) they are usually cut away.

If the taper is too much the piston rocks and allows pressure above to blow hot gasses past the piston rings and congeals oil and carbon around the area that there is a gap between the piston and the cylinder wall. If it has too little taper – it will expand too much and jam (or seize) against the cylinder wall – damaging the engine.

The piston then – ends up tapered smaller towards the top (even smaller above the bottom piston ring) and oval around the circumference – a very complicated shape designed to be a perfect fit when everything has expanding fully and is running at maximum operating conditions.

This is where the problem emerges – because everyone driving on public roads is forced to spend a lot of time driving at the same speed as the car in front, the conditions and limits allow or within the law. The average speed of most road cars is actually around 30mph regardless of how fast the car has the potential to reach.

Now the heat inside an engine developing the sort of power to drive at 170mph is massively more than for a small compact family car with a maximum top speed of say 110 – many times more heat energy required – in somewhat similar proportions to the maximum power output – often 3 or 4 times as much as the smaller car. Consequently the piston of the more powerful engine has to be designed with more taper and ovality – to prevent it from expanding too much at full power – but this means that when it is being used "most of the time" at normal speed limits and in traffic – the piston is much too tapered to work as well as one designed for a lower range of temperatures and performance.

This means that most high performance road engines are rarely driven near enough their designed limit to expand the pistons enough to fit well in the bores and the space left gradually fills up with carbon and congealed oil sludge (see typical photo below). The more powerful the engine the greater the expansion between running at average speeds and the maximum potential and although owners may never drive their Porsches over – say 90mph or even never on full throttle – the designers still need to make the piston capable or continuous running nearer 170mph.

You can see from this typical picture above how the diameters near the rings (and the sides below it) are totally coated in carbon (because they are machined too small to reach the cylinder bore) and you can also see that the actual contact area where the piston is pushing hard on the cylinder wall is really quite small. Just like a stiletto heel making a depression in a floor because the load (or weight) is concentrated over a small area (compared to a shoe heel) rather than being spread over a wider area - this increases the force trying to squeeze out the oil film that is keeping the piston and the cylinder bore from rubbing against each other (causing scoring or a seizure).

Because the piston is hotter than the cylinder – some clearance must exist between them to allow for this expansion rate and then – when the engine is cold (or being used mildly) this clearance is more than it needs to be to run ideally – because it has to allow for the sudden expansion of the piston when a driver changes from driving slowly to flat out – while there is a delay in the cylinder expanding as well. The designer has to account for the idiot that sets off from cold (while the cylinders are cold) and immediately goes full throttle to maximum (and there are some about!).

Cast iron is a good cylinder material because it has a hard surface – holds oil well and is cheap to manufacture – but it has half the coefficient of liner expansion of aluminium (and a 1/3rd lower coefficient of thermal conductivity). Used in relatively modestly powered engines (or engines with a consistent output) it can still make a useful cylinder bore material – but as sports car engines have increased their power output to typically double the amount they had perhaps 40 years ago – this differential in the heat the piston experiences and the greater range of expansion it must cope with (and still run reasonably OK in the cylinder bore) resulted in making cylinders and cylinder blocks in aluminium – so the rate of expansion of the cylinder bore was much more similar to that of the piston and the initial clearances could be made much smaller as both the piston and the cylinder bore will expand and contract more closely than one with an iron liner (and more quickly as the iron liner will take longer to catch up – needing even greater initial cold clearances).

But aluminium would have too soft a surface to stand up to the friction and pressures – so the solution was developed to apply some hard (but thin) component to that alloy bore. Typical methods have been hard chrome, Nikasil, plasma coatings, laser alloy with silicon, thin layer PVD coatings, electric wire thermal spraying etc. Other solutions were Alusil (in which the silicon powder was mixed in to the alloy when casting the block) and Lokasil (in which the liner was pre-formed in a matrix bonded material – cast in like an iron liner – but with greater expansion potential).

Manufacturers usually quote the reasons for changing from traditional iron liners to aluminium alternatives as "lighter engines, good machinability, good recycling potential, lower fuel consumption, reduced emissions (through tighter bore clearances and better heat dissipation), better thermal balance, better thermal conductivity (cooling), faster warm up times and the ability to run with reduced coolant quality". They rarely mention the problem of the range of differential expansion that a very high performance engine must cover and how this is greatly handicapped if iron liners were still in use – but this is the main reason we would not use them in any high performance engine design – because while it is OK to own and drive a car capable of reaching 2 and a half times the maximum speed limit – for most owners between 90% and 100% of the driving hours they experience in that car are no different to an 850cc or 1 litre small car they are forced to follow and at that level the pistons are relatively slack in the cylinder bores (even though the problem is less significant with alloy bores). They would be far worse if they were replaced with an iron liner.

Another problem with iron liners is the difference in longitudinal expansion because the cylinder head gaskets are now made from three pieces of thin steel and they have little tolerance to take up any mismatches. A liner needs a shoulder somewhere to sit on to prevent it sinking when the head gasket is tightened and then – when the engine is hot – there is a difference between the liner to cylinder head face heights that an alloy liner will not experience (as it is made of the same material as the cylinder block and expand and contract together). Most engines that still use iron liners cast them into the block with ribs so they are forced to expand with the alloy block (as the photo below of this Honda Civic block – being bored out to fit racing liners for 1/4 mile sprinting – reveals showing the ribs in the cast iron being gradually machined out. In this case allowance was made for the differences in heights (hot and cold) and sealing rings were fitted etc to compensate – and the engine would only ever be used for short bursts (sub 10 seconds).

So for engines with relatively low output, or running at a constant output, cast in liners can still be useful but for engines with the potential for high outputs that never the less may be used more often than not for mild applications – the problem of designing a piston to cope with both extremes is made easier and better if the piston and bore are made of similar metals and the results more long lasting.

To make iron liners work at all you need a much larger initial cylinder clearance and this will result in some smoking while for 90% to 100% of the driving time the cylinder and piston ring gaps will be so large that the blow by will increase and the lifespan will be reduced. It can be a cheap solution for those disinterested in the engine being rebuilt correctly or in its lifespan or long term performance.

Already evidence of this poor solution has come to our attention in rebuilding failed engines fitted with iron liners (as the iron liner in the following photo clearly demonstrates – having turned after assembly from the position to fit the gudgeon pin shown on the RHS) potentially allowing the piston skirt to catch the edge of the assembly hole. Similarly another engine with a thicker liner had. problems.

However – although fitting an iron liner (which we could easily do well) is cheaper than fitting a Nikasil alloy liner (as we do for cracked and scored pistons) – the new solution we are currently testing in several engines (of simply re-boring the existing Lokasil bore) is even less expensive as the additional cost on top of the new piston is simply that of a rebore. As previously reported though – that re-boring has taken a lot of expensive equipment and machinery and a lot of learning and not getting it right initially – costing several builds and rebuilds for inspections and adjustments.

Because we do not release new solutions until they have covered many satisfactory test miles – and although the most recent versions have proven 100% reliable – we are still not ready to release it to the general public (but are making good progress). When we are satisfied with this solution it will be both the least expensive and best available – cheaper than an iron liner but retaining the original design criteria even when including the other improvements and modifications we would insist on carrying out at the same time - so avoiding the need for even those on miniscule budgets from resorting to the unsatisfactory iron liner alternative.

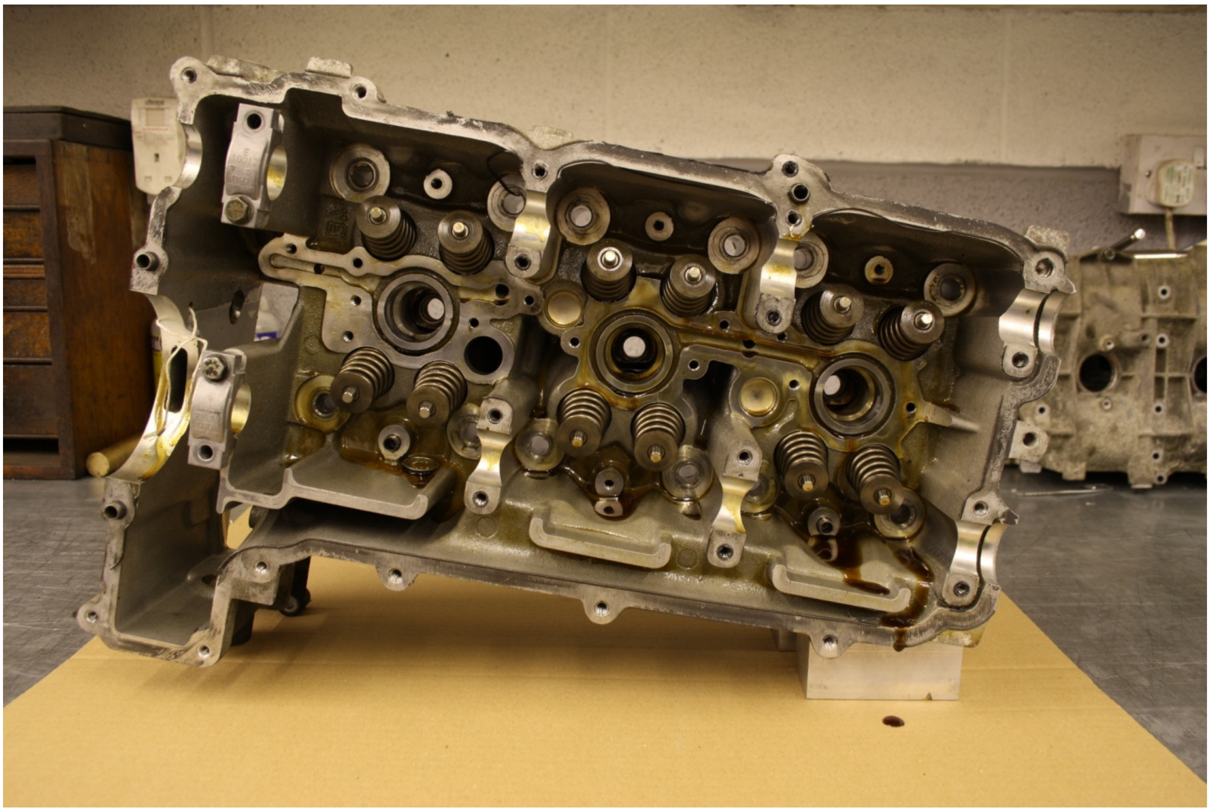
SMOKING ON START UP.

Some engines (even rebuilt ones) have a tendency to occasionally smoke on cold start up for a few seconds. This problem of initial smoking (while the difference in the piston and bore sizes is so large) would not be so noticeable in most conventional engines because the cylinders usually point upwards and oil that sits around the piston and bore when the engine is resting – naturally drips downwards and into the sump. But with the cylinder being horizontal – much more collects in the bottom of the bore and is exposed on the next start up.

Even with alloy cylinders (or liners) there can be some initial smoke on start up with horizontally opposed cylinder designs because the pistons have oil holes internally to allow oil to reach and lubricate the rings from inside and when the engines are resting – that oil drips onto the horizontal bore and has nowhere to drip away to – tending to run up the cylinder bore and escape on the next start up – but this is insignificant to oil consumption if the engine has alloy cylinders as they have tighter initial bore clearances and quickly run at the correct tolerances – the smoking only lasting a few seconds. We say insignificant because while there is no harm in an engine burning a small amount of oil (after all 2 strokes have run like that for years with around 25/1 one ratios of fuel to oil - the equivalent of a litre every 100 miles without too much harm) – permanently running a very powerful engine – capable of huge performance – designed originally for alloy bores - with iron liners – is basically very poor re-engineering.

This is however not the only cause of “start-up smoke” because it can also be contributed to by worn valve guides and stem seals and the angle the car is parked at.

In this case the engine has been designed to allow the oil that is pumped into the cylinder head camshaft journals etc to flow back via the chain housing though a 5 degree slope in the casting (see photo below).



The drive at the home of one of our staff is steeper than this so if the car is parked at a similar angle to the photo – you can see that oil will become trapped in the right hand lower area of the 2 valves and springs. With each head being the opposite way around to the other – this cannot be avoided whichever way the car is parked (as there will always be one head this way around), nor is it different in a Boxster to a 996/7 even though the engine faces the other way around. It also seems to vary with the position the engine stops at – whether the exhaust valve happens to be open on the lower cylinders or not. If it is then there is less of it inside the guide and more overhang so it can tilt allowing oil to seep into a worn seal and down the valve shaft into the exhaust port where – on start up – fresh oil will quickly burn/smoke. We have tested this theory on the angled drive in numerous different cars - many of which we have later rebuilt and checked (together with the results) and it does seem to explain some of the start up smoking (which would obviously be worse on a worn out engine).

Similarly – although the sump level is below the bottom of the cylinders – it is possible on a steep slope for that sump level to reach the lower cylinder (or at least to coat the crankshaft webs at the lower end to throw a lot of oil at the bores on start up) and this can also cause a puff of smoke on start up. It tends to be less of a problem if a 996 or 997 are parked facing downhill (or a Boxster uphill) because one end of the engine has the additional sump length to accommodate the IMS chain drive and so oil seeps across into that additional space making the level less likely to rise enough to reach the cylinders. Always parking downhill in a 996 or 997 seems to almost eradicate this problem.

Finally – rather like the old 924 that would rarely start after a hot run and a half hour rest because the pistons had cooled and shrunk in size while the iron cylinder block was still hot (because the hot coolant was no longer circulating – preventing sufficient suction to move the throttle paddle to fuel the car) a liquid cooled alloy engine will keep the cylinders bigger after a hot run – for longer than if it was air cooled (when it naturally still convects air around the fins) – and the extra piston clearance resulting can promote a brief puff from the oil that collects in the space left between the piston and bore until it the block also cools down some more.

Because the 996 3.6, 997 and Cayman S engines can suffer scored bores and we cannot be certain exactly at what point the initial scuffing starts – we have made our special oversized pistons with repositioned oil holes in such a way that they slightly increase the amount of oil that drips onto the cylinder bore – on resting the engine - to ensure there is sufficient oil there on start-up to avoid any possible damage. This sometimes results in a brief puff of smoke which we feel is preferable to a scored bore but has no impact on overall oil consumption or performance that we can measure.

Hartech rebuilt engines carry numerous tested solutions that no one else offers - to reduce running temperatures, increase cylinder stability, improve lubrication and reliability – however present test results suggest that the new re-bored and oversized piston solution (when available) may need slightly longer running in (for at least 2 thousand miles) since it will effectively have the same new pistons, bores and clearances as a new car.

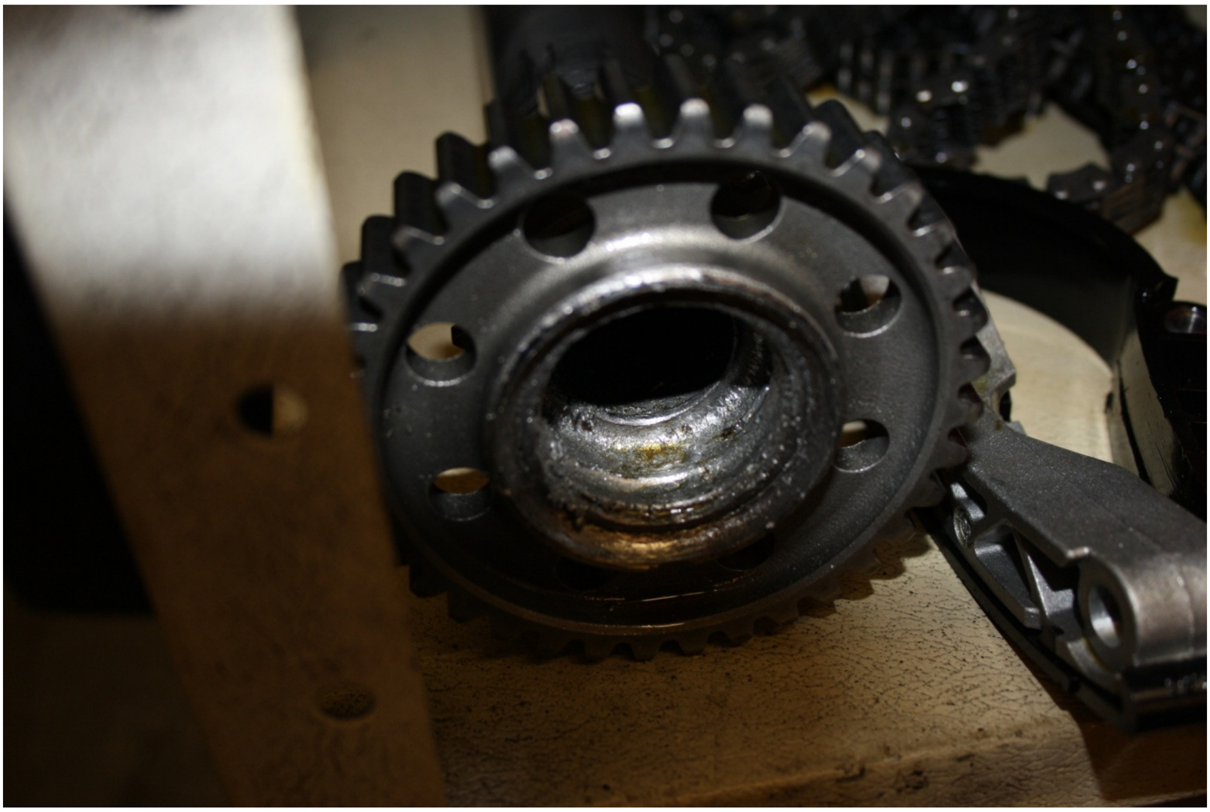
These are some of the latest things under test to find out the best advice after rebuilds. It may be (for example) that the inclusion of additional spray jets may negate this long period by greatly improving the lubrication between the piston and cylinder but it may also be necessary to delay the use of Nano oil additives (that we may later come to rely on for general use) until the rings have bedded in (as we have noticed during testing that it can take between 1200 and 2000 miles to run in the piston rings and also clear out the oil sludge from the exhaust system (that collected there due to the original fault of a scored or cracked cylinder – in one case taking 3500 miles to fully get rid of a faint smell of burnt oil).

You can probably imagine that all these issues and testing takes a long time and considerable investment – but we remain determined to provide – not only the very best technical solutions – but also the most cost effective – that only this level of technical excellence and commitment can achieve.

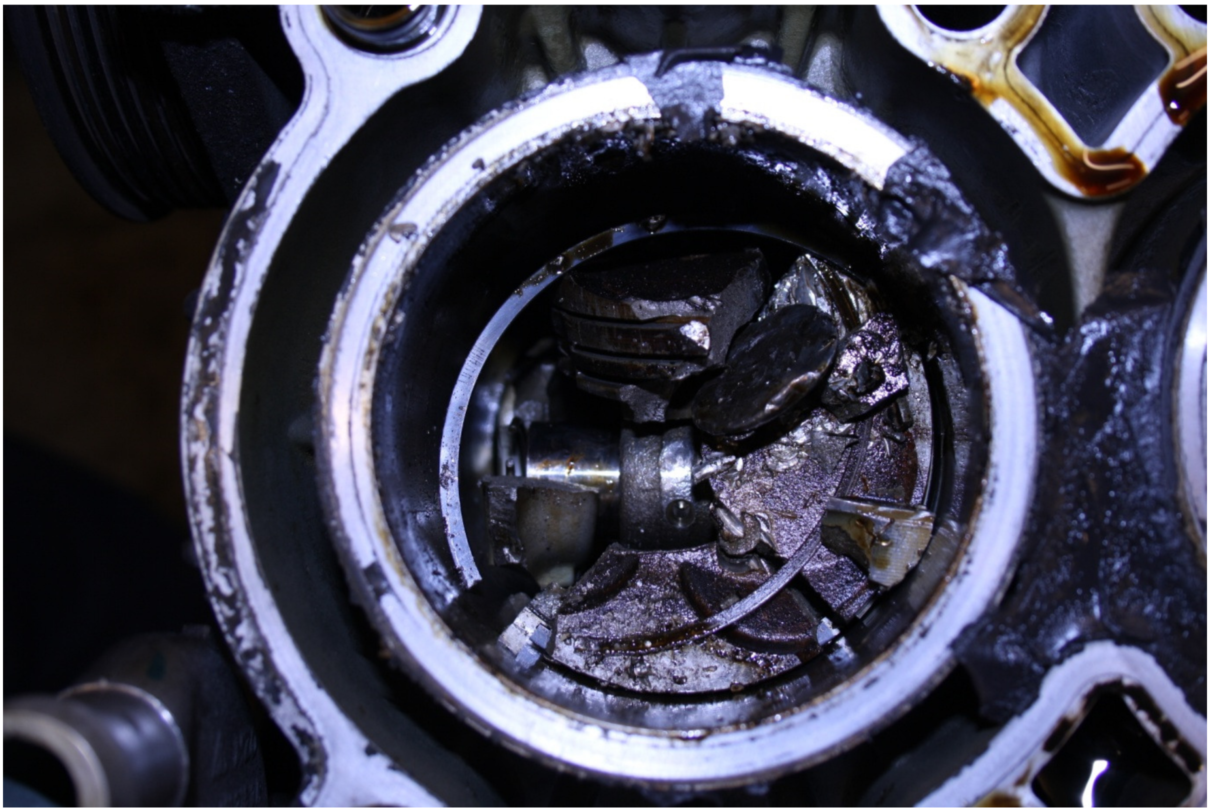
New IMS shaft drive gear and larger bearing

Although the Hartech modified and replaced original IMS bearing and stronger spindle shaft have proven reliable – later engines have a larger bearing fitted that is definitely better.

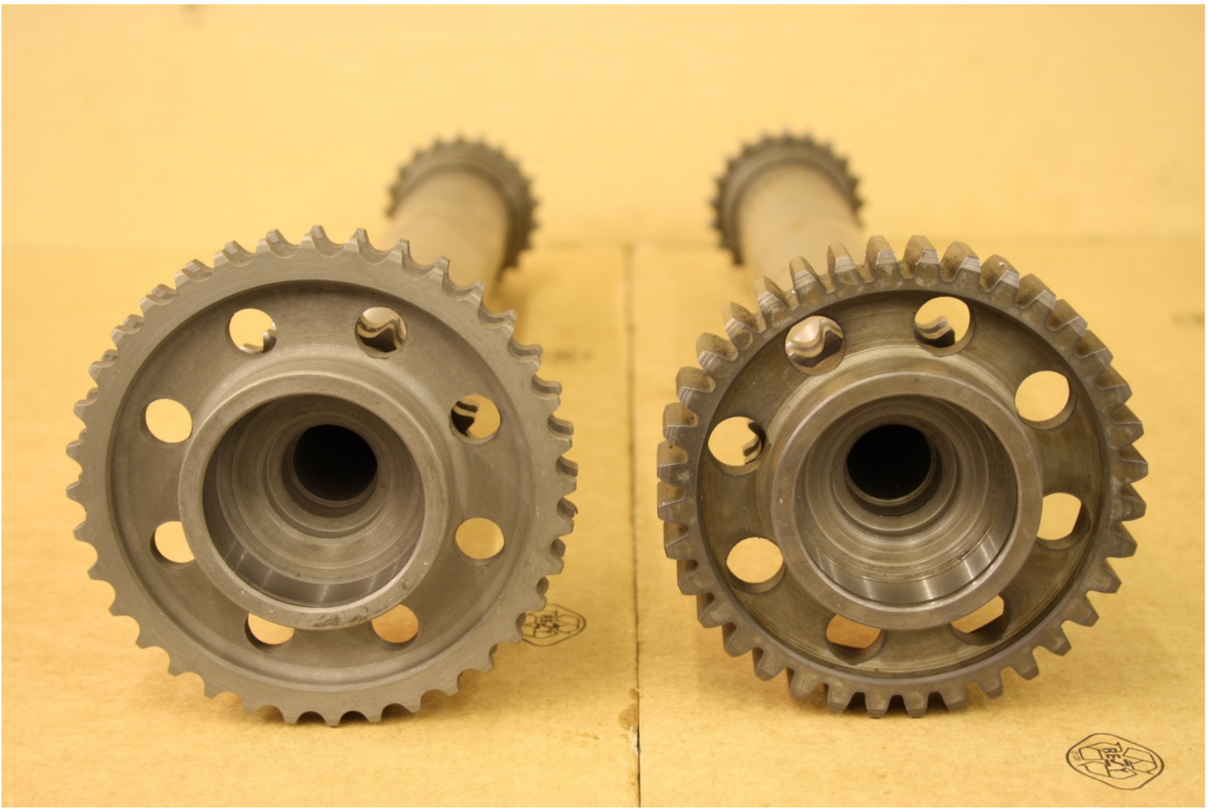
The majority of engines with IMS bearing failure have also damaged the end gear (that supports the bearing) beyond repair. Furthermore older engines with roller chain crankshaft/camshaft drives cannot be fitted with the later IMS shaft with the larger bearing because it would need a new crankshaft to mate with it – so replacing IMS failures is becoming more expensive.

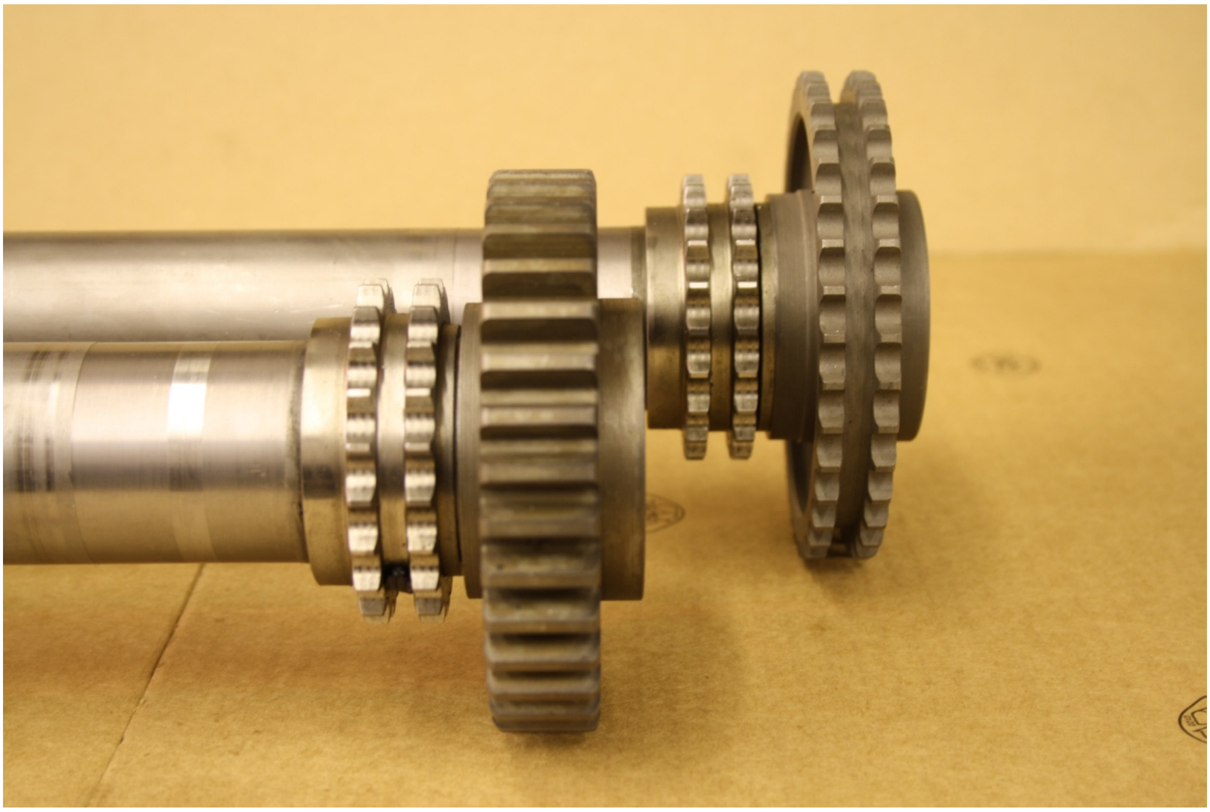


As a result - some specialists are trying replace damaged bearings in situ (to save costs) but the problem is knowing for sure if any damage has resulted elsewhere inside the engine that will come back and bite the owner and involve even more expense in the long run (as it did with the following photo of the end result of someone else's attempt to replace a damaged bearing) – wrecking the engine beyond economical repair..



A long time ago we designed, manufactured and tested both roller chain and the later Hivo chain new Hartech end gears (designed and manufactured “IN HOUSE”) with satisfaction – in readiness to replace the damaged ends (in preference to buying a new shaft) but at the time new IMS shafts were reasonably priced and we had quite a good stock of good used ones to work through so we didn’t go into volume manufacture or make them generally available. See following photos.





However the price of a new IMS shaft has more than doubled to almost £1000 (including Vat) and meanwhile the larger IMS bearing fitted to the newest cars has proven more reliable. So we have now re-designed these same replacement end gears to accept the later and larger bearing and these will be available later this year to enable any IMS shaft of any year to be fitted with a new replacement end gear of either roller or Hivo chain design and fitted with the larger and later IMS bearing throughout.

This is just a further example of the thought and care that we invest in improving the quality of the engines and the cost effectiveness of our rebuilds.

Just a brief word about that “guarantee” situation.

Hartech will always stand by the cost of any repair that is demonstrably the consequence of anything they have done wrong or the failure of parts or modifications that they offer for sale. We have a superb record of customer satisfaction that we jealously guard and want to keep. We repair so many cars and engines (and a very large proportion for many of the top Independent dealers) that the cost of rectifying a problem would be far less to us than the consequences of any resulting bad publicity (of which the Internet would soon be full if it ever occurred).

However – in all fairness to us – a problem may occur one day that was actually not our fault but the result of either a business assembling the auxiliaries or fitting the engine incorrectly, the owner not looking after it afterwards properly or some other parts contributing to a failure that had nothing to do with the original repair (like say a radiator leaking and overheating the engine). Furthermore – if it is serviced elsewhere and/or the customer does it himself or it isn’t done properly or frequently enough – it is possible that some contributory factors may have influenced the existence of a problem. So to be fair to everyone - we will only consider claims under our engine guarantee if we are contacted before any investigation/work is carried out.

This rule came about when the only engines we have ever had any problems with turned out to be caused by the work done elsewhere in putting the rest of the car together or other parts needed to run the engine but not connected to it and not sent to us for testing or repair. We found that people are quick to blame someone else by assuming the engine has a problem during the rebuild – but so far this has not happened and it has always been someone else’s fault.

It would be impossible to establish this unless we had the whole car at our premises to investigate and even though that adds cost to us (as we may not have even been paid to assemble the engine in the car) for these reasons - we may then require the whole car complete with engine fitted to be returned to us at the cost of the owner/garage until the cause of the fault is identified by us (even if someone else fitted the engine). When it is here - the customer or his representatives are free to inspect the results and this work will be fully carried out without charge by us if it was our responsibility, but if not a charge to rectify the fault not caused by us will be charged at a fair & reasonable rate. In cases where it is difficult to attribute cause or blame but there is clearly some external contributory factors we will always offer to compromise.

Fortunately we have very few problems and the vast majority of engines (some of which were in a terrible condition and condemned elsewhere) continue to perform reliably and to the owners complete satisfaction.

The engines do require running in for 1500-2000 miles during which drivers should avoid aggressive driving & “labouring” the engine too much, such as driving up a steep hill in too high a gear. They should “feed” the throttle rather than just pressing your foot to the floor. They need to regularly check the coolant and oil levels. We recommend an oil & filter change after the running in period.

We presently use Castrol Magnatec 10w40 oil which has proven exceptionally good. We do however operate a policy to test different oils and expect that this may change to something superior in relation to the exact problem of cylinder scoring in some models – as a result of our work with Millers Oils (even if we also have to increase the resulting costs).

The new parts & all our labour are guaranteed for 2 years/24000 miles (whichever first) against failure for normal road use subject to proper maintenance & care. Faults caused by track & competition use, incorrect fitting & abuse are excluded.

Remember - we will only consider claims under our engine guarantee if we are contacted before any investigation/work is carried out

THE BEST THING ANYONE CAN DO WHO IS CONCERNED THAT THEY MIGHT HAVE AN ENGINE PROBLEM – IS TO CONTACT HARTECH TO DISCUSS THE SITUATION BEFORE GOING ELSEWHERE – IN CASE YOU INCUR UNRECOVERABLE EXTRA COSTS, OR ARE MISLEAD ABOUT THE NEED FOR EXPENSIVE INVESTIGATION WORK AND IN SO DOING - MINIMISE YOUR OPTIONS.

For further information please contact Baz or Grant on 01204 302809.

UPDATE February 2012