Whenever we have had a technical problem to solve we don't latch onto the first explanation or what everyone else thinks – but adopt a forensic approach – collecting evidence, testing causes, and seeing if an explanation fits – and even with the most difficult and convoluting problems – when the answer eventually emerges it is ALWAYS extremely simple – making us wonder why we didn't see that in the first place - as I this case of BORE SCORING because unlike claims to the contrary – **THERE IS ONE SIMPLE CAUSE!** (but difficult to condense into a short article)

But there are so many other explanations doing the circuits, well intentioned people trying to help, businesses trying to enhance reputations, others with vested interests and something to sell – it is not surprising if there are still different explanations – and because the real cause cannot be eliminated – greedy unethical businesses exploit owners fears (who are instinctively clutching at straws). So - if you want to know the truth – read on.

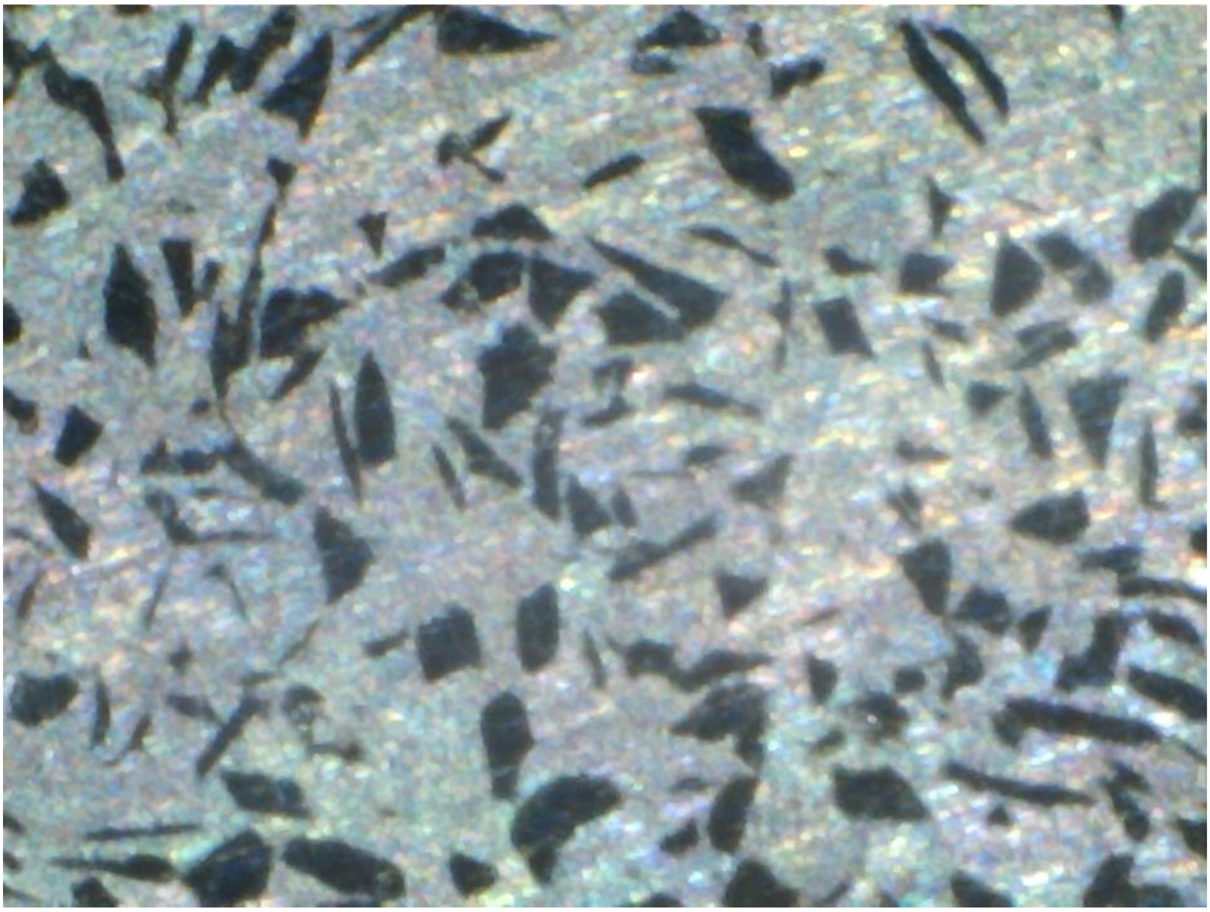
But before I get to that – let's just point out some of the evidence that a lot of explanations don't fit to and correct some of the misinformation that is circulating.

(1) EVIDENTIALLY bank 2 scores in generally @ half the mileage as bank 1 – therefore any claim of a cause that must involve BOTH BANKS equally - has to be suspect. Fuels, Injectors and spray patterns, Cast or Forged pistons, Rod stroke ratios, oil types and viscosities etc all apply equally to both banks and simply cannot therefore be the main CAUSE!
(2) SIMILARLY WITH PISTON PIN OFFSETS - Ironically it was actually the early engines that don't score (that have the different piston pin offset in bank 1 and 2) and later engines (3.6, 3.8 and Cayman S) that HAVE THE CORRECT OFFSETS that do score – it is therefore both impossible and misleading to claim this to be the cause (and Porsche went back to unequal offsets for the Gen 2's).
(3) **Ferrostan** is not the "vulnerable coating" in fact it is the only coating that **does not result in scored bores** (as used in 944's, 968's Chevrolet Vega's 1975 and early Boxster and 3.4 996 engines up until the piston coating changed). The only piston coating that **does result in scored bores is Ferroprint** as fitted to all the later engines that suffer bore scoring – see the link there? but it still doesn't explain the frequency difference between

bank 1 and 2 – but that follows (incidentally Ferrotech is the later coating for Gen 2 Alusil bore - pistons – it is better than Ferroprint but still not as good as Ferrostan).

(4) Wikipedia "Chevrolet 2300 engine" explains more about the casting process and states "plating the piston skirts was necessary to put a hard iron skirt surface opposite the silicon block to prevent scuffing" (another word for scoring) with pictures that apply equally to the Porsche engine.

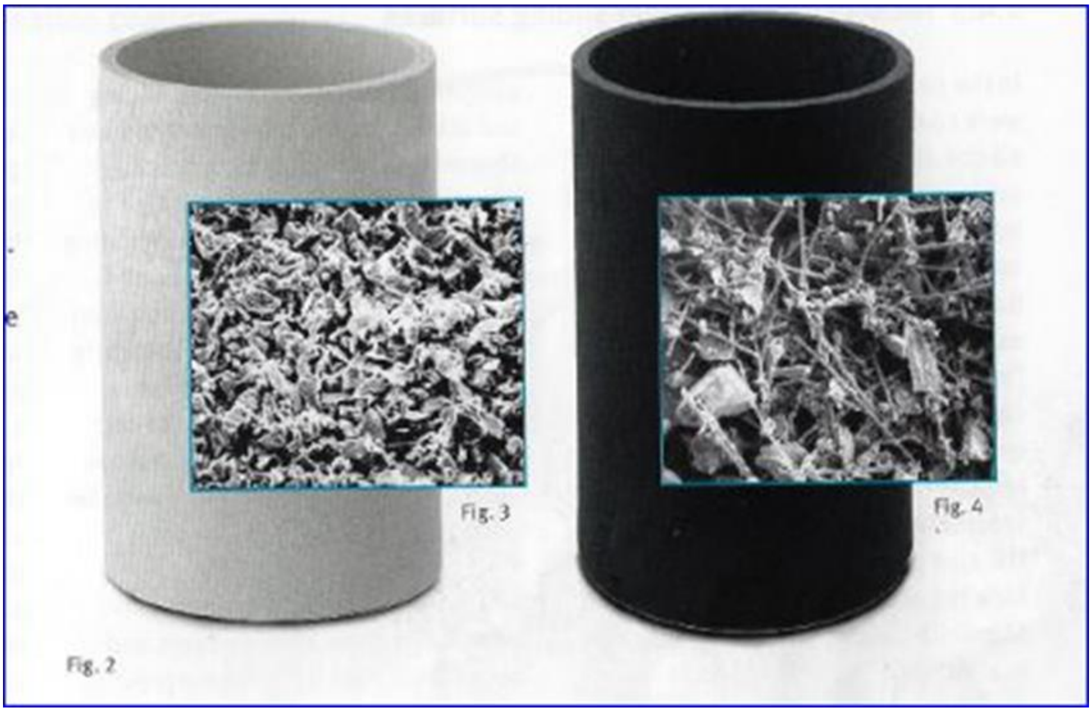
(5) Hypereutectic bores have small (about 0.001") hard sharp particles of silicon embedded in them held in place by the aluminium substrate and honed to a smooth surface finish.



(6) In Alusil (944, 968, Gen 2 etc) the whole block is cast with a mixture of silicon particles that emerge evenly out of solution as the casting cools forming securely entrapped evenly distributed surfaces – but it is therefore very hard to machine all over the block - and therefore expensive to manufacture.

(7) With Porsche trying to emerge from possible bankruptcy in the early '90's (caused by years of out-dated manufacturing systems) the idea emerged to only place the silicon where it is needed – at the cylinder surface (hence the name change to **LOK**al a**SIL**icon) a brilliant idea enabling the rest of the block to be machined much more quickly with less tool wear and changes.

(8) They did this by suspending the silicon particles in a tube (displaced by a bonding agent).



(9) The tubes (called pre-forms) were then held in the casting mould but the molten aluminium could only permeate the preform and burn off the bonding agent at extremely high pressure (15,000 psi) and this needed metal moulds to withstand the pressure (and in turn resulted in the "open deck Gen 1 cylinder block design - which is another long subject). Our investigations reveal this method to result in less even silicon particle distribution and bonding strength than Alusil.

(10) This leads to a rather obvious question – "**what actually causes the scoring – is it (a) the rough cylinder bore surface or (b) the softer piston coating – or (c) something else –** and once again **– why bank 2 first?**

(11) To answer this we need to think about what oil lubrication does. Its purpose is to "**keep the surface of moving parts apart".** It achieves this in a cylinder bore because it is splashed up into the bore at TDC and as the piston descends the rings trap that oil and create hydrodynamic pressure

between the piston and the cylinder wall keeping the two apart. The piston is oval so the pressure (and close clearance) is only in the centre of the thrust face both sides (the power stroke side taking the highest loads). As long as the oil film strength and thickness will not all squeeze out by resisting the thrust loads for long enough to cover one revolution – the piston and bore will not come into contact and should not wear.

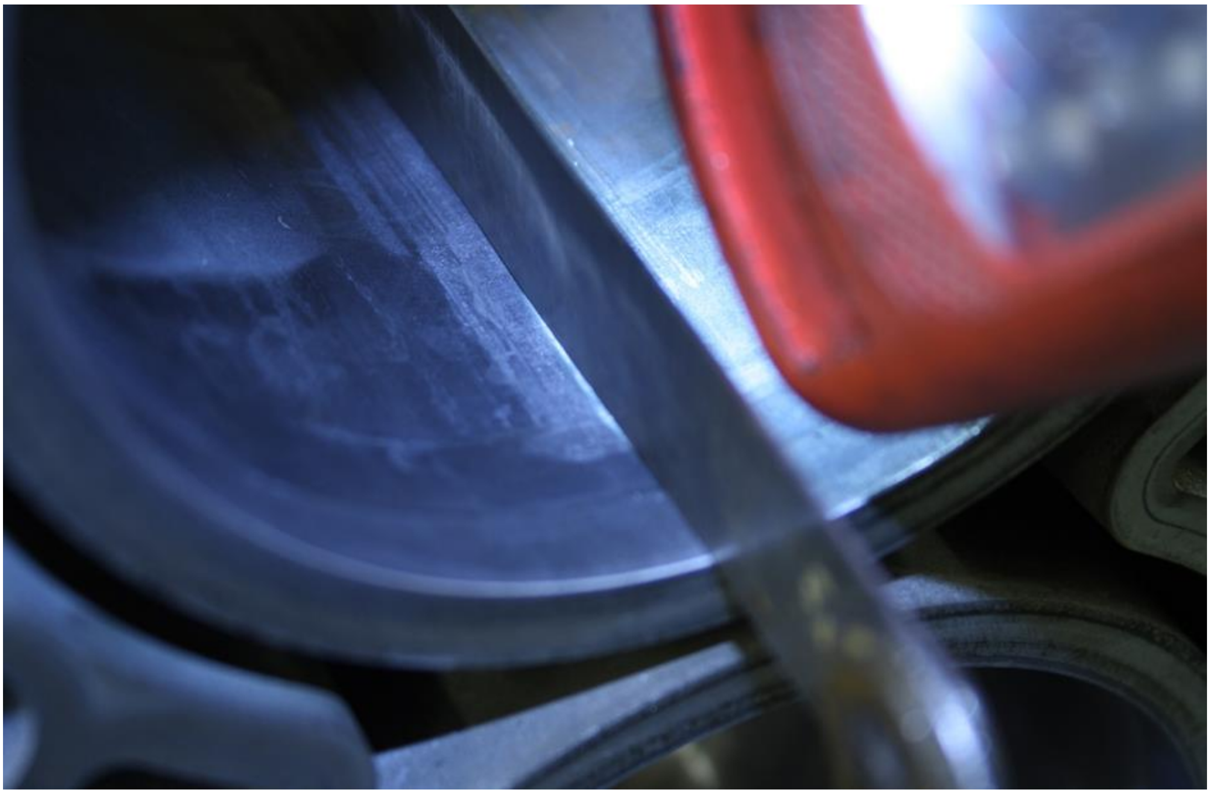
(12) This provides a clue to one of the anomalies – why bank 2 first. If we can establish that the thrust face on bank 2 is hotter than on bank 1 then the oil would be thinner and would squeeze out quicker resulting in possible contact.

(13) But there could be another explanation if we consider that as the oil is squeezed between the gap it also slowly erodes the aluminium surface that is holding the silicon particles in place because if one such particle became free of the bond it will temporarily sit between the piston and the cylinder being squeezed between them.

(14) Now load/unit area is the load divided by the area (and explains why a stiletto will damage lino when a large heel will not). One piece of silicon 0.001" in size taking all the piston thrust load amounts to over 1,000 times the load/unit area of the whole piston face normally and easily will penetrate the oil film and possibly a soft piston coating before either being washed away with the oil or sticking to the piston to rub up and down the cylinder, knocking out more pieces of less well bonded silicon (exactly like the rapid deterioration of a pot hole in the road).

(15) So is it (a) the rougher silicon exposed by hydraulic erosion or (b) released particles – that initiate bore scoring?

(16) During our research we found evidence of erosion.



(17) We also tested different piston coatings in the same engines.

(18) The piston we had coated in "**Diamond Like Coating"** revealed the answer because the very thin coating on most of the thrust face was still

shiny (untouched by the bore) while in several other places very thin vertical lines had been scored into it – the result (we believe) that could only be caused by lose silicon particle release.

(19) We were aware that later engines do not exhibit as much stretch ovality as earlier ones and then discovered that there were two versions of Lokasil (1 & 2) the latter of which could have silicon particles 0.0008” to 0.0028” in size (0.02 to 0.07mm) which would make the bores stiffer but with particles that actually exceed the bore clearance. It seemed likely that initially securely bonded sharp silicon particles gradually become lose and some simply wash way while others stick to the piston to score bores depends upon their random distribution, size and shape the piston coating and one other explanation that resolves the “why bank 2 first” question..

(20) It now made sense why a manufacturers (KS) technical engineer made the statement that “Lokasil will only work with a hard piston coating” and interesting that when that hard coating was outlawed in

Europe – they stopped making them to be replaced by Mahle with a plastic piston coating (and nothing to do with being cast or forged).

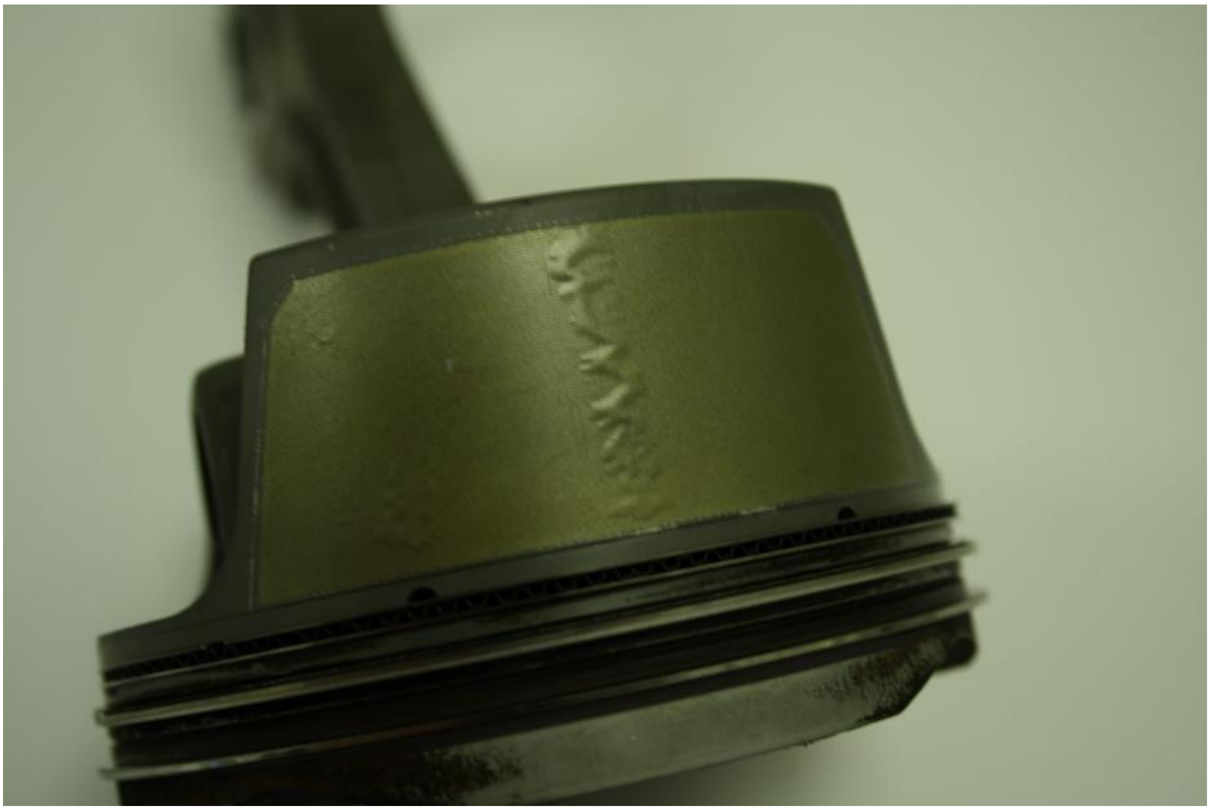
(21) So how good is that coating? Some pictures showing evidence the first 2 typical of a particle plucking out some coating.

If it was silicon still bonded to the bore that plucked out the coating then the loss would extend up and down the piston at this stage while these pictures demonstrate the temporary nature of the particle release.

The next picture shows poor coating bonding.

The last is by far the best showing how despite still being in tact with adjacent coating it has bubbled away from the piston – but still running OK against the bore. If it was the rough surface of the bore causing scoring them that would have picked off this area of bubbles but instead the thrust loads have squeezed the piston against the bore and the bubbles have been squashed to move up and down with the piston. However – if a small piece of silicon became free and dug into the bubble – it is easy to imagine it plucking that portion free of the piston.

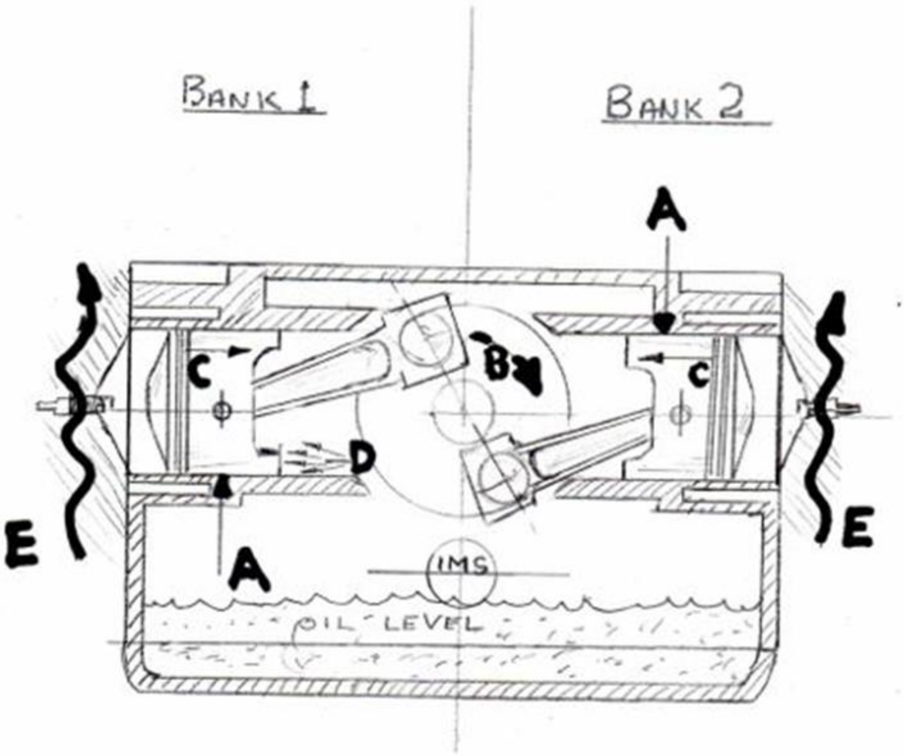
This proves to us that the bore surface is smooth enough to run without scoring the lining as long as it is intact and the oil film is present - but equally makes it obvious what would happen if a small piece flowed free and penetrated to one of those bubbles!



One other observation needed exploring – we were getting more Tiptronics with scored bores than manuals (despite less sold) but if we were right that it was particles penetrating oil film thickness causing scoring – that fits because the slower the revs the more time there is to squeeze out the oil film in one cycle and the higher the thrust loads the quicker they will reduce the film thickness – and Tiptronics naturally pull away in 2nd and under higher torque – so that fitted perfectly.

Hydro erosion leading to Particle release also explained why there was a delay of several years and thousands of miles before the problem emerged and a random influence (depending upon the differences in castings and distribution) partly explained why some engines outlasted others - and we now felt there was no other explanation that proved the primary cause was **particle release** and that is why the previous hard iron coating survived (because it didn't get penetrated and the particle washed away) and why plastic piston coatings were not quite hard enough for long life in all circumstances.

Just one major piece of evidence needed explaining – **why bank 2 first?**



(22) **IF** the resistance to scoring related to the oil film thickness then anything that made the oil on the top of bank 2 thinner than on the bottom of bank 1 would explain its inability to keep the piston and bore far enough apart to allow the released particles to float away in the gap the oil film creates for longer and that would be caused if the temperature was higher there on bank 2.

(23) So - to find out we fitted temperature sensor inside the engines which revealed just that and it explained why because the coolant enters

the bottom of both blocks and rises to exit at the top (see picture above **E**). As it does so its temperature rises and the top of bank 2 (**A**) is the thrust face which is at the bottom of bank 1 (so the oil will always be thicker on bank 1 thrust face than bank 2 and the oil film at the same torque will always be squeezed thinner in bank 2 allowing any released particles to penetrate the piston coating on bank 2 sooner (which will also be hotter and unlike iron – will be softer with temperature rises).

(24) Also when the engine is switched off oil does fall under gravity to the bottom of both cylinders which means that on the next start-up the thrust face on top of bank 2 will be dry while the thrust face on the bottom of bank 1 will still be sitting in oil – and this could also influence the time before contact knocks free another loosened silicon particle on every cold start.

(25) This also meant that a thicker viscosity of oil would also help (especially as cars age).

(26) As a result of these finding we advised all to use thicker oils and avoid high power take off in second in Tiptronics (to try and delay scoring) and made a 184 page report (explaining all the above in far more detail) freely available but nothing that we understand will ever eliminate it.

(27) Having rebuilt thousands of engines with Alloy closed deck Nikasil cylinders with the same injectors (without a single failure) we can only conclude that the emphasis on that being a contributory factor is totally misplaced.

(28) Furthermore the addition of a 3rd radiator (without some device to only allow it to operate when the other two can no longer hold back the coolant to thermostat temperatures) actually allows the hot area of the top of bank 2 (that we are trying to resist) to run hotter and we also advised against that without our suggestion of a control thermostat housing (which we supply although the routing has to be done by the owner) so fitting a third radiator could make things worse.

IN CONCLUSION

Another analogy that might help is if you picture a cylinder bore like a rolled sheet of fine wet and dry stuck round the bore then as long as there is an oil film between the piston it will not wear away the piston coating –

but if one piece of the grit became free – you might be able to imagine what damage it could then do as it rolled up and down the bore and piston between them.

The difference in silicon sizes, distribution and bonding strength combined with different oils, temperatures and transmissions fitted as well together even with the reason Nikasil works so well (and doesn't even need a piston coating) – because the silicon sizes are 1/10th those of Lokasil or Alusil.

In the early days we tried boring and honing scored bores larger (and had matching pistons made) – but despite taking the advice of KS over honing (and them confirming our honing was spot on) they didn't last as long as Ferroprint (and certainly not long enough to base a repair option on – possibly influenced by less dense distribution of silicon further away from the central area that the high pressure casting method might have pushed the particles towards) so we reverted to supplying our already proven solution for cracked and "D chunked" failures (our Aerospace alloy Nikasil plated closed deck cylinders).

Our report on the topic satisfied every single piece of forensic evidence we had uncovered and also offered a full explanation for it all (which no other alternative got even close to doing).

That full report entitled "the 4 main problems with these engines" (that was subject to an NDA) is now freely available from admin@hartech.org without it and includes IMS failures and Gen 2 cylinder seizing..

I doubt any other business took this problem so seriously or spent as much as we did on trying to understand it.

None of this helped us sell a product or service since in our opinion there is little that can be done to eliminate bore scoring and we don't think preventative measures will extend life without it for long. We tried to find something to help avoid it but when we couldn't we put all our efforts into continuing to provide the best rebuild options (that now include exciting capacity increases).

It took us a very long time, a huge amount of investment and a lot of analysis to work this out and we make no criticism of anyone trying their best to come to terms with it and reaching different conclusions. Doubters should always remember that every engine fitted with a hard iron coated piston does not score bores and every engine fitted with plastic coated pistons has already or probably will eventually and always apply the test to explain why bank 2 scores first (as we have) to every alternative explanation.

Barry Hart, Technical Director, Hartech Automotive

On Facebook The Porsche Gurus also www.hartech.org, technical - baz@hartech.org, - sales auto@hartech.org