WATER POWER

Photographs by Antony Fraser

One day, the engine in your 911, Boxster or Cayman might need a rebuild. It's a costly business, admits Chris Horton, but for perhaps an additional £1500–£2000 you could also increase the cylinder capacity for a worthwhile increase in power and crucially torque. Suddenly that dark cloud has a silver lining

There is, as we car enthusiasts like to say, no substitute for cubic inches. It's a commonly quoted automotive 'proverb', one of those hoary old aphorisms that we use without considering their real meaning, but like most of its kind it is based upon easily observable fact.

American 'muscle cars' have for many years relied on the sheer size of their usually V8 engines to generate the power and specifically the torque needed to deliver the performance for which they became famous – albeit usually in a straight line only. And here in Europe, where smaller four-cylinder motors are the norm, both after-market and DIY tuners long ago realised that often the most effective way of significantly increasing a given unit's output, its ability to propel the car satisfyingly quickly and easily from 'A' to 'B', is to increase its capacity, or in more scientific terms the swept volume of its cylinders.

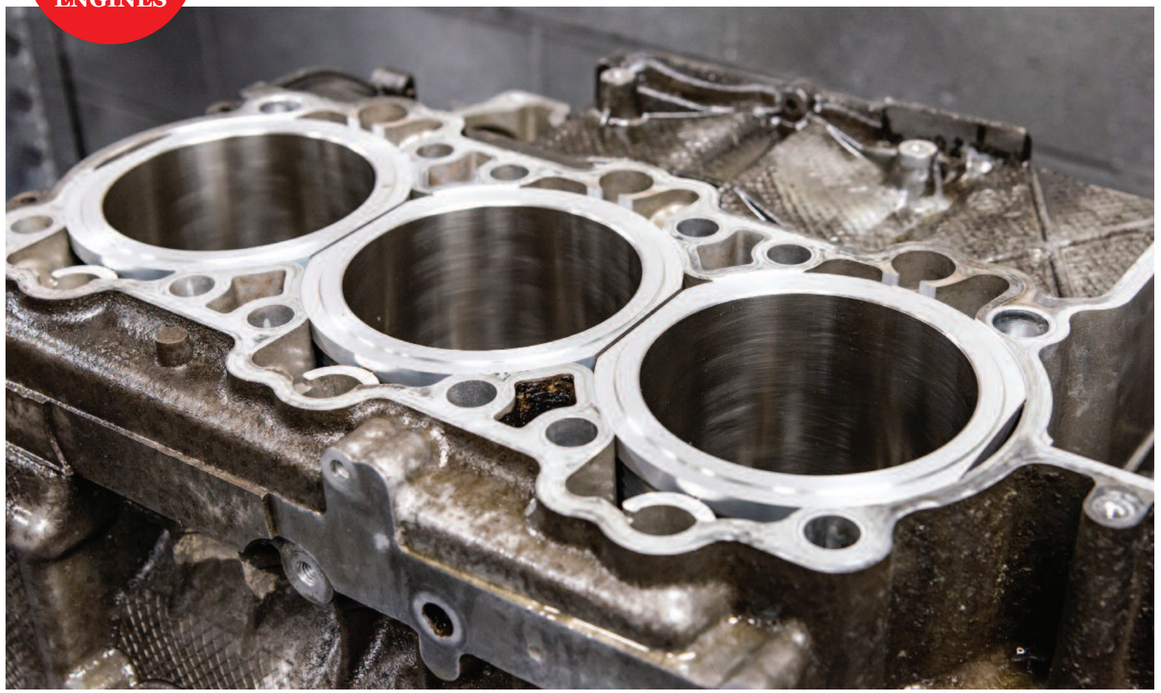
This capacity increase, all things being equal, allows the engine to burn more fuel in the larger quantity of air which – if the induction and exhaust (and ignition) systems are up to the job – it can draw in to and then expel from its larger combustion chambers. That pushes the pistons with greater force, which in turn turns the crankshaft with more of that same energy. It's much the same principle as throwing a stack of hefty logs on a sputtering campfire to create a bonfire, and thus generate more heat.

Porsche, too, has long been an enthusiastic proponent of 'oversizing' its engines for more power and torque; for upscaling, perhaps, to use a modern term. In standard production form the naturally aspirated air-cooled 911 expanded from its original modest 2.0 litres to 2.2, 2.4, 2.7 and 3.0 litres, and then finally to 3.2 and 3.6 litres. The water-cooled M96/M97 grew from 2.5 to 2.7, 3.2, 3.4 and 3.6 litres, and finally to 3.8. (The subsequent 'shrinkage' of the current gen 2 9A1 to 3.0 litres is another matter, prompted by the need to reduce overall exhaust emissions, but is arguably more than offset by turbocharging.)

Oversizing is not necessarily a simple process, though. At the very least it requires the engine to be stripped, and then the cylinder block to be machined to the size necessitated by the chosen larger-diameter pistons. Attention must also be paid to smaller but no less important details such as the resulting compression ratio (which will naturally increase), piston-to-bore tolerances, valve sizes, cylinder-head gasket(s) and, for optimum results, camshaft profiles and timing, ignition settings, and not least the intake and exhaust systems. And obviously you need to make sure that the rest of the engine's structure is strong enough, too.

Arguably by far the simplest engine to modify in this manner is the air-cooled 911, with individual and easily replaceable cylinder barrels suspended from the external faces of a vertically split crankcase by through-bolts, once you have removed the camshafts and the individual cylinder heads. (Likewise the VW Beetle engine and its Porsche variants, of course.) That's the way Porsche generally did it, and the reason why, even today, a good set of crankcases from even a 1965 2.0-litre can with the appropriate barrels and pistons become the basis of a no less than 4.0-litre motor. There can't be many other designs with that kind of versatility.

It is, unsurprisingly, a different story for the water-cooled flat-sixes, designed for the easiest and cheapest possible initial assembly processes, and in effect as sealed-for-life units probably intended, like most mass-produced modern engines, to be discarded when they wear out or go wrong. Few, if any, enthusiasts, then, would in this case routinely embark upon a tuning programme based first and foremost on capacity. A remap and an after-market exhaust system will deliver a



One of Hartech's most significant upgrades to M96 and M97 engines is to fit a supporting collar between the top of each cylinder 'barrel' and the inside of the surrounding coolant jacket, to prevent distortion of the bore and even cracking. Porsche itself eventually adopted this so-called closed-deck construction. Note, too, the subtly cut-back areas where coolant passes between the block and the head

cost-effective improvement quite sufficient for most, and ultimately it is cheaper and easier to fit a larger second-hand unit – or perhaps just to buy another car.

But the times they are a-changing. History has shown many of the water-cooled engines to be disappointingly fragile (although some do manage to notch up impressive mileages; we know of several 2.5s that have happily exceeded 200,000), and a significant sub-industry has sprung up to cater to the needs of enthusiasts who, understandably, don't wish to consign to the scrap-heap a high-value and certainly highly desirable sports car that they justifiably cherish.

Pre-eminent among those specialists here in the UK is Barry Hart, since 1985 the tireless engineering talent behind Bolton, Lancashire-based Hartech, and in terms of the molecular-level metallurgy and thermodynamics of Porsche's water-cooled flat-sixes probably the most knowledgeable – and certainly the most boldly and painstakingly innovative – man outside the factory itself. His long career in the automotive industry began way back in the late 1960s, and includes both the designing and manufacturing from scratch of a number of race-winning motorcycle engines and gearboxes. A beginner he is not.

Barry's first reworking of the then contemporary M96 was as long ago as 2002, when it was becoming painfully apparent that the standard offering wasn't quite as robust as we had all hoped, and since then he has gone on to develop solutions covering just about every aspect of the units. One of his earlier upgrades was to fit a purpose-designed bracing collar between the top of each cylinder and the surrounding coolant jacket, to prevent the former distorting and cracking, and it was surely no coincidence that Porsche itself later adopted this so-called closed-deck construction.

Thus far Hartech has in one way or another reclaimed at least 2000 of these power units for owners right around the world (there is at least one Hartech engine in Iran), and even now, with the potentially affected models rapidly ageing, and being replaced by more modern and almost certainly more reliable versions, there is no sign of the steady flow through the company's busy machine shop diminishing. Like any genuine enthusiast, however, Barry couldn't help thinking that for all its flaws – entirely fixable, thanks to those repair techniques and modifications – this was a design that had still more to give.

With time on his hands, then, now that the day-to-day running of the business is ably handled by his stepson, Grant Pritchard, and with a team of long-serving technicians and machinists behind him, Barry has spent the last three years devising a programme of capacity increases applicable to pretty much the entire range of M96 and M97 engines (but not the MA1/9A1 from the gen 2 997 and the gen 1 991). All are designed around the holy grail of the easily accessible and enjoyable performance that comes not just from their headline-grabbing power output, but primarily from the increased torque available. (See pages 84–87 for an explanation of the crucial differences between power and torque.)

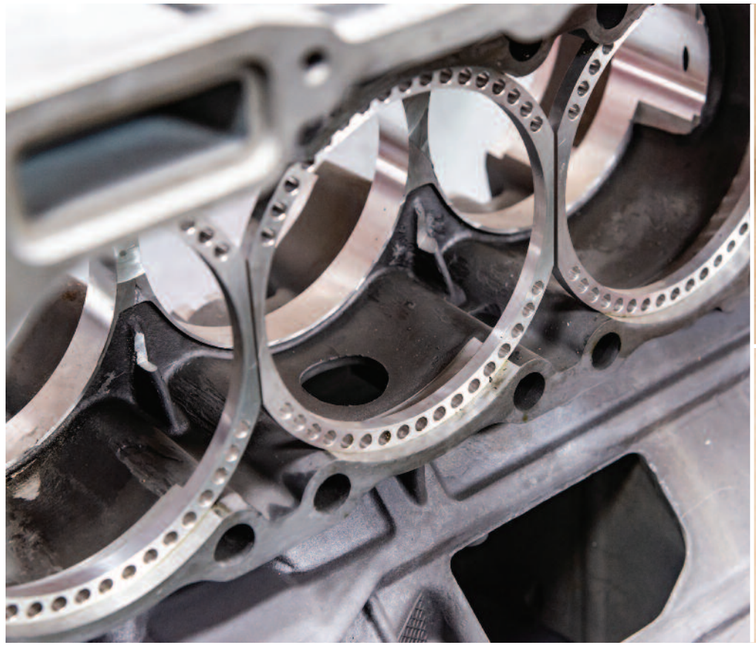
Not for a moment is Barry suggesting that anyone in their right mind will spend the best part of £10,000 on an engine rebuild purely for the sake of a capacity increase somewhere between 200cc and 500cc, and increases in power and torque of around 15 per cent at the very most. His programme is based on the perfectly reasonable assumption that any engine receiving such an upgrade requires reconditioning anyway, either because of a failure, or because its owner wishes to avoid one. In which case, for the sake of perhaps just £1500–£2000 plus VAT out of that £10K bill, why would you *not* go the extra mile? Or in this case, perhaps, the extra cubic centimetre?

Central to each oversize conversion is a set of six Nikasil cylinder inserts and matching pistons, designed by Barry himself and manufactured under licence by Capricorn in Hampshire, and in principle no different to

From left to right: Hartech director and service manager Tobias Higgins; company founder Barry Hart; and Grant Pritchard – Barry's stepson, and now MD. Barry began his career designing and manufacturing race-winning motorcycle engines and gearboxes, including one for the late Barry Sheene, although sadly he never competed with it. Barry (Hart) also designed the innovative square-four motor for the Phoenix 4 bike that featured in the 1980 British movie *Silver Dream Racer*, starring David Essex

LARGER THAN LIFE

In which editor Steve Bennett gets behind the steering wheels of a trio of Hartech's large-capacity engine conversions, and finds their improved pulling power very much to his liking. Stand by for Project Oversize... Photographs by Antony Fraser



Belt and braces: it's not just the middle and the top of each cylinder that is firmly braced against the crankcase. Latest Hartech innovation is to add these drilled rings at the base of each tube – holes are partly for lightness, but primarily to aid oil drainage. Pistons and cylinders (top) designed by Barry, and manufactured under licence here in the UK by Capricorn. Both first- and second-generation intermediate shafts, with small-diameter bearing, can be modified for the larger-diameter third-generation job (above, left of pic), and which has proved itself virtually unbreakable. Chart below gives a good overview of various capacity options

those used in all of the company's engine reclamation jobs. Thoroughly tried and tested, in other words – and things of undeniable beauty if you should be lucky enough to hold them in your own hands. Significantly, all have a nominal working diameter of 100.0mm, finished capacities (see chart below right) determined by the stroke of the crankshaft.

The original Porsche cylinders are machined out and the new ones pressed in, and crucially with a supporting ring not just at the top of each bore, but now also at the bottom. These are themselves drilled (see photo above), partly for lightness, but primarily in order to facilitate oil drainage back into the sump. There is an additional supporting interference fit between the block and roughly the mid-section of each cylinder; and the upper area of the tube, inside the coolant jacket, is ribbed to give additional surface area and thus more efficient heat transfer.

> "Increases in both power and torque depend on a number of factors"

Cooling is further assisted by the opening up of the coolant pathways between the top of each block and the cylinder head – another proven Hartech modification to aid cylinder-bore longevity. That said, Nikasil cylinders are inherently resistant to scoring, because the cylinder surface does not consist of hard silicon particles trapped in an aluminium matrix that gradually comes loose and scratches at the piston surface, but instead a homogeneous electroplated surface that remains permanently fully bonded, like a complete thin tube within the aluminium.

It would for similar reasons be the brave owner of an earlier engine who turned down the option of an intermediate shaft modified to take the later larger-diameter IMS bearing. This can be installed in either the earliest sprocket- or the slightly later gear-type shaft – and that first shaft is itself 'updateable' to the subsequent gear-style item if required, although naturally that requires the matching chain, and various other parts. Famously, that final iteration of the IMS bearing cannot later be replaced without splitting the crankcases again, but such appears to be its dramatically improved reliability and longevity that this should hardly be an issue.

It would be understandable if at this point you are imagining all sorts of exciting possibilities – turning your Boxster 2.5 into a 3.9, for instance; and remarkably every single one of these Porsche engines has the same overall external measurements – but not surprisingly there is a practical limit to what is possible, and Barry has no less sensibly set out just five options. (And, based upon the simple but often overlooked fact that today the 2.5 and 2.7 rarely, if ever fail, neither of those units is considered to be a viable basis for conversion.)

In order of original size, then, the range commences with the 3.2-litre Boxster 'S', which with those 100.0mm pistons in place of the original 93.0mm items gives a nominal 3.7 litres. The 3.4-litre 996 (96.0mm bore, again raised to 100.0mm) becomes a 3.7, and with the additional fitment of the appropriate longer-stroke crankshaft the 3.4-litre Cayman 'S' can be stretched to 3.9. The 3.6-litre engine (96.0mm) is another good candidate for the 3.9-litre upgrade, not least because it already has the same free-breathing cylinder heads as the 3.8, and likewise the 3.8 itself can easily be given those extra 100ccs, although obviously by this stage any benefits are beginning to be outweighed by the costs.

Precise increases in both power and torque depend on a number of factors, but generally, as we've said, amount to some 15 per cent, and with a no less useful lowering of the revs at which they are achieved. Both the 3.6 to 3.9 and the 3.4 to 3.7 will run with the original engine management system, we understand, although perhaps unsurprisingly the 3.4 to 3.9 will benefit from a remap – as, of course, will those smaller versions. There should also be an improvement in the engine's overall efficiency and thus its fuel consumption, although since you would have to be as abstemious as a Franciscan friar not to use the additional performance at every available opportunity, that is unlikely to figure in any calculations. It is certainly not something that Barry Hart is championing.

For him – and, as you will see elsewhere in this story, for us, too – it is all about the torque, and the resulting improvements in not just the cars' 0–62mph times, but also in real-world, mid-range acceleration. The ability not just to maintain a relaxed motorway cruising speed, but also to overtake swiftly and safely when needed. Sounds ideal to us. **PW**

	Bore (mm)	Stroke (mm)	Capacity (cc)
Boxster 2.5	85.5	72.0	2481
Boxster 2.7	85.5	78.0	2687
Boxster 'S' 3.2	93.0	78.0	3179
Hartech Boxster 'S' 3.2 to 3.7	100.0	78.0	3676
996 Carrera 3.4	96.0	78.0	3388
Hartech 996 3.4 to 3.7	100.0	78.0	3676
Cayman 'S' 3.4	96.0	78.0	3388
Hartech Cayman 'S' 3.4 to 3.9	100.0	82.8	3902
996/7 3.6	96.0	82.8	3596
Hartech 996/997 3.6 to 3.9	100.0	82.8	3902
997 3.8	99.0	82.8	3825
Hartech 997 3.8 to 3.9	100.0	82.8	3902

Bennett at the wheel of Hartech's capacity-enhanced, 352bhp Cayman 'S'. Both power and torque have been increased by 48 per cent, with torque at 320lb ft at 4500rpm

When it comes to torque versus revs I am definitely in the former camp. High-revving engines do have a certain appeal, particularly the small-capacity screamers – like Honda's VTEC units – where all the power happens at once, in a narrow power band. But crucially they rarely seem that fast out in the real world, where a linear power delivery feels just that. Or, to put it another way, they are rather flat as you wait for a discernible peak in the power curve somewhere near the redline. Such engines work best in small, lightweight sports cars, but largely they have disappeared, killed off by emissions and the rise of turbocharging in both diesel and petrol engines, plus emissions-friendly 'tall' gearing.

Not that Porsche engines have been lacking in torque in recent years. The most popular sizes at 3.4, 3.6, 3.8 and 4.0 litres have sufficient capacity to produce that 'big' engine feel, which is what you notice in road driving. They can be improved upon, too, but not significantly, unless you start to play around with camshafts, throttle bodies, engine management systems, and so on. Indeed, take that route and you might see some similar gains to Hartech's big-capacity engines, as tested here. The difference is, though, that you will have spent a great deal more money, and you will have something that feels raw, noisy and decidedly non-factory, which isn't what most people want. No, the beauty of Hartech's conversions, is that they feel and drive like standard Porsches, which is surely the ultimate accolade for any modified car.

> "As a 3.4 owner myself, I was intrigued to try the 3.7 conversion first"

Here at *911 & Porsche World* we know this because a few weeks ago we paid a visit, mob-handed, as it were, to Hartech's labyrinthine but well-equipped premises in Bolton, Lancashire. While technical guru, Chris Horton, was getting the lowdown from Barry Hart, I was getting the seat-of-the-pants driving experience with the help of a number of modified-by-Hartech machines: a 996 Carrera 2 3.7, up from its original 3.4 litres; a 996 Carrera 2 3.9, increased from 3.6 litres; and a Cayman 'S' 3.9, up from its original 3.4 litres. Corresponding standard cars were on hand, too, with their owners, who also drove the Hartech cars. It was, as you can imagine, a fascinating exercise. Just a shame about the suddenly very autumnal weather…

As a 3.4 996 Carrera 2 owner myself, I was intrigued to try the 3.7 conversion first, against the standard 3.4-litre 996 Cabriolet belonging to Alex Yates. As expected,

Hartech's 3.7-litre conversion as fitted to a lovely, early 996 makes 325bhp, and 283lb ft of torque, which is an increase of 20 per cent

Alex's car felt more than familiar, with the 3.4's typically wide power band. For all its issues, it's a lovely, smooth, flexible unit. It's not lacking in torque, either, but more of this valuable commodity is never a bad thing, particularly if – as here – it is produced lower down the rev range.

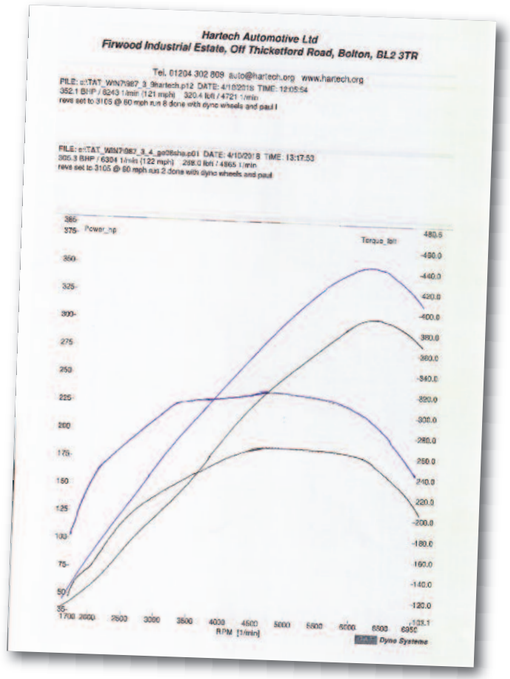
Hartech's demo 996 3.7 is a 1998 car, but it has weathered well, given that it's now 20 years old. Predictably it feels more like a gen 2, 3.6-litre 996, and compared to the standard 3.4, the power builds earlier, becoming meaningful from 2500rpm and making progress all the more effortlessly swift, without needing to run the engine into the higher rev range – unless you want to, of course. And if you do, then it's just as smooth as the standard 3.4-litre, with peak power arriving at much the same point. The difference is, as with the torque, there's more of it. Indeed, if you look at the graphs, the power and torque curves are remarkably similar in terms of shape, which is very much what you feel on the road. And for the record, the 3.7 conversion is making a maximum of 325bhp between 1500rpm and 7500rpm, an increase of nine per cent. But what you're really feeling is the torque, which goes from 237lb ft between 1500rpm to 7500rpm to 283lb ft, an increase of fully 20 per cent.

> “Using the Tiptronic in manual highlights the engine's power curve”

Time to try the 3.9-litre 996 now. Again it's a C2, but a 3.6 gen 2, which this time belongs to Hartech director and service manager Tobias Higgins. It's a Tiptronic, and we have a 996 C4S Tip on hand for the standard comparison, which from the seat of my pants feels, well, standard. That is to say that over the gen 1 3.4-litre 996, there is appreciably more torque, which is what you would expect from another 200cc. And the 3.9 Hartech engine? Well, the basic facts are these: power is up from 320bhp to 347bhp, while torque increases from 273lb ft to 313lb ft between 1500rpm and 7000rpm. Put into a different perspective, and perhaps a more real-world one, for both power and torque that's a 14 per cent increase between 3000rpm and 6000rpm.

And how does it feel? Muscular! Using the Tiptronic in manual mode in third and fourth gears highlights the engine's power curve,

Using a gen 2 3.6-litre 996 as a starting point, capacity increases to 3.9 litres and power to 347bhp, with torque increasing from 273lb ft to 313lb ft



Rolling-road graph for the Cayman 3.9 conversion clearly demonstrates a 48 per cent increase in both power and torque. Note how the curves have essentially the same profile for both standard and modified engines

and again the experience is mirrored by the numbers. After all, you're not going to mistake an extra 14 per cent of power in that real-world sweet spot. It's there, you can feel it and you can exploit it, but without having to work the engine's upper rev range. Again, that's power from capacity and torque, rather than power from revs.

And so to the Cayman 'S', which Barry Hart reckons to be the most interesting and appealing conversion here, because unlike the other two it has jumped an extra 500cc (as opposed to 300cc for the two 996s), which has resulted in a massive improvement in breathing at low revs, compared to the 3.7-litre engine, with which it shares the same stroke. Digging into this further and at 2000rpm both torque and bhp are some 48 per cent higher. Yes, that's worth a double take! This tails off to 20 per cent at 5000rpm and 16 per cent at 7000rpm, but who's complaining? In terms of power the 3.4-litre to 3.9-litre conversion goes from 303bhp to nearly 352bhp, between 1500rpm to 7000rpm, while torque – as you would expect from the above figures – jumps from 250lb ft at 4500rpm to 320lb ft at roughly the same rpm.

Study the graph for the full lowdown, but those differences between the standard and modified power and torque curves are replicated on the road. Between the standard Cayman 'S' on hand and the modified 3.9, the difference was all too clear, aided by the fact that each car was a manual, giving maximum control over the two engines. The 3.9 has power everywhere, starting with that massive surge from low rpm, which feels like an electric motor has joined the party or, as Barry describes it, rather like combining a low-pressure and a high-pressure turbo.

Certainly the Cayman hits the sweet spot, thanks to that capacity-versus-stroke combination. Yes, it's fast, but it's the way that it produces the power that makes it so suitable as a road-car engine. The same applies to all the conversions, but more so with the Cayman. Its broad spread of power and its incredible flexibility give you options. Overriding memory? A long, straight, uphill drag and, even in sixth gear, the Cayman simply demolishing it.

An absolutely fascinating experience, then. And a potential cherry on the cake for anybody pondering an engine rebuild. I mean, why wouldn't you? Right now, I just can't get out of mind the prospect of that 3.9-litre engine sitting in the back of my gen 1, 3.4-litre 996. How about it, Barry? **PW**

THE REAL-WORLD VIEW

THREE OWNERS OFFER THEIR OPINIONS ON THE BIGGER-EQUALS-BETTER DEBATE

Alex Yates: 996 Cabriolet 3.4

We used Alex's 996 as one of the comparison cars. He has owned it for nearly five years and has covered 45,000 miles, using it as a daily driver. It's now on 130,000 miles and significantly still has its original M96 engine, which says a lot for regular use. Is it on borrowed time? Who knows, but Alex's engine is a prime candidate for a Hartech capacity upgrade when the time comes. And after a drive in the 996 3.7? 'In third and fourth gear at 3500rpm–4000rpm it's much more flexible,' reckons Alex. 'More mid-range, too!' And of the 3.9 Cayman 'S'? 'That seemed as fast from 3000rpm to 5000rpm, and it goes like stink from any revs!

Mike Hibbins: 996 3.4 Tiptronic

Another encouragingly high-mileage 996, this time with 155,000 on the odometer, although owner Mike Hibbins concedes that it received a Hartech rebuild at 92,000 miles. It's another daily driver, too, which is equally encouraging for a 20-year-old car. Mike was impressed with the 3.7 and 3.9 996 conversions – 'A definite difference from 2000rpm' – and reckons that had the option been available when his engine was rebuilt he would definitely have gone for it. But he reckons that there's no reason why he couldn't apply the mods to his current engine, and was last seen having a quiet word with Barry Hart...

Eric Munro: 996 Carrera 4S GT3 RS replica

Serial Porsche owner, Eric Munro, bought this 991 GT3 RS lookalike as it stands. The body conversion was carried out in Germany, and the interior has been retrimmed in leather and Alcantara. He's no stranger to modded Porsches, and once owned footballer Rio Ferdinand's ex-TechArt Cayenne Magnum. Underneath, Eric's GT3 RS lookalike is a standard 996 C4S, and he's not going to be shy about modifying the engine. All that show deserves an equal amount of go. Predictably, Eric was impressed with the 3.9 Cayman 'S'. 'It pulls very well in sixth,' which we can vouch for, too. Again, last seen in the queue to have a quiet word with Barry...