How To
Refurbish Your TVR Speed6 Cylinder Head
With the Engine In-Situ

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Table of Contents

1 Overview

This guide aims to offer some practical advice on how to strip down your Speed6 engine while in situ in the car (a Mk1 2002 Tuscan in my case). Some details will obviously be slightly wrong for Mk2+, Cerb, T350 and Sagaris but the principals should be much the same in all cases. Also note this car didn't have air con so I wont make mention of disassembling this (because I don't know how to).

Right, you're going to need to take a deep breath and really get ready for some skinned knuckles and make sure your swear box is empty when you start.

But it IS possible.

You're going to need tools, lots of tools. I'll try and detail those as I go along.

You're going to need patience.

Don't expect this to be "a couple of days" job either. This job took me several months at a leisurely but constant pace.

This is definitely a "winter lay-up" job, or something to do if you have a second car as a daily driver.

You'll also need a patient partner. But as a TVR owner that's kind of taken as read.

Now a couple of teaser pictures of the finished result.

The keen eyed amongst you will spot the extra oil feed coming off the sender block in the picture above. This supplies decent oil flow to the exhaust follower shaft. I'll talk about that modification.

I took the opportunity to change *all* external fasteners to A2-70 stainless[1]. The tensile strength is not as high as steel but given that almost all of them are threaded into aluminium at pretty modest torques then I took the risk. I also got all those nasty rusted brackets, pulleys and pipes re-zinc'd and colour passivated. Very satisfying. I even had the oil pipes re-plated. They all survived except the high pressure one from pump to cooler…the swivel joints leaked. You live and learn.

The last batch of re-plated parts. About 30 items done in total. Sad?

[1] Except the harmonic damper bolt…that has gorilla grade tension

2 Know What You're Getting Into

Seems obvious, but disassembly is strictly done a step-at-a-time. There are some "high risk" parts to this job and I took the view that I proceed with the highest risk job at hand at that point. The idea being, if any of these high risk jobs went wrong, I could back-out, reassemble and get to a garage.

2.1 The High Risk Items

I'll list the really high risk items here before we start. This way you can look and see if this is for you or not.

2.1.1 Harmonic Damper Removal

Securing bolt is too long to clear the chassis member adjacent without lowering the engine. The damper is a press fit (for a length of about 50mm) onto the crank nose and is probably a bit rusted in to the bargain. The damper weighs 5Kg and can't be easily bullied. You'll need a big strong puller and you'll see there's not much space for it to fit in front of the damper. As the puller draws off the balancer, it gets closer and closer to the chassis and you *could* end up stuck with the damper half way off, no way to remove the puller and no way to push the damper back on. Be careful.

2.1.2 Exhaust Manifold Removal

23 bolts, one nut. 3 bolts are borderline impossible. Small hands are a plus and plenty of Allen keys, and cups of coffee. Leaving the manifolds in situ is possible but not advisable (with the benefit of hindsight)

2.1.3 Timing Cover Removal

It's big, and probably well stuck to the block+sump with 598 RTV; and no, it doesn't just "prise off" (unless you want to crack it of course)

2.1.4 Oil Pipes

Huge spanners and lots of grunting plus limited access (just what you want when huge spanners are involved!)

2.1.5 Head Bolt Removal (Point of no return)

Really, really tight. You'll need a breaker bar and some help.

2.1.6 Head Removal

You'll really want a hoist. Or make sure your BUPA is up to date to treat the bad back you get from manually lifting it out over the wing (yes I did…foolish).

2.1.7 Block Preparation

Not so much difficult as nerve racking to get it really flat.

2.1.8 Head Refitting

Big, heavy and now has manifolds attached. You *need* a hoist.

2.1.9 CAM Timing

Not really difficult, but attention to detail required.

2.1.10 Timing Cover Refitting

Getting it all lined up and engaged with the various shafts and dowels is surprisingly tricky when access is limited. And of course the RTV is curing while you're trying to align it and then get the myriad of bolts torqued up.

2.1.11 Nearside Engine Mount Refitting

Just a pain, there is so little access to the bolts when the manifolds are in the way.

2.2 Have You Got The "Right Stuff" (I don't mean tools)

I rebuilt a Ford Fiesta 1.1L engine once! Taught me a lot. But I don't do engine building per-se. That said, I am a bit of an inventor and for sure I'm an engineer through-and-through (albeit electronics). Resourcefulness has got me out of trouble many-a-time. Take it apart, break it, re-design it, modify it; you know the kind of thing. Guess only you can be the judge of whether you're up to the challenge.

2.3 What Was Wrong With My Engine ?

My engine's always been a bit "ticky" since I bought it and during the 4K miles I'd used it. But on just one journey of around 40 miles it went from "ticky" to "tappy". Odometer was at about 15K miles. It was quite obviously sick. On removing the CAM cover, it became clear that one lobe on inlet #5 was a mess and that the associated follower was seriously worn. There had always been evidence of an oil leak from around the cylinder head just above the coil pack (cyl #5). The scary thing was the valve clearances were OK just 2000 or so miles previously; once the case hardening went it wore down in no time at all.

2.4 Why Did I Choose The DIY Route?

Because I enjoy it and it's a good chunk of the reason I bought a TVR. If you're not sure whether to have a go yourself, you might be better off taking the safer option and entrusting this work to a reputable S6 specialist. That said, the S6 is an engine like any other. All the talk of "don't touch it it's a highly toleranced and magical beast" is, in my opinion, laughable. Tolerances…pah! You'll see what I mean as you start to take it apart ☹ That doesn't mean you can afford to be slapdash and my normal approach is to put it back better than it came off (whatever that means). In fact, that's one of the great things about DIY…you can probably afford to do this where a garage can't.

That said, I did leave the head refurb to a pro. New valves, guides, followers, shims and CAMs. Seats re-cut, reduced pressure springs, and head re-faced. I also took the opportunity to have an extra oil feed put into the back of the head to supply HP oil directly to the exhaust follower shaft.

As a point of note, one of the valves was apparently loose in its guide to the tune of 0.5mm! No wonder it puffed some blue smoke when I started it!

2.5 The Bible

Yes, you are going to need to get a copy of Graham Varley's Sagaris workshop manual. It has many helpful facts and figures.

2.6 Disassembly Limits

There are some things you can't do with the engine block still in-situ.

2.6.1 Dry Sump Cover

It *can't* come off because there is a rear crank seal plate at the gearbox end that bolts to the block *and* the sump cover. Unless the gearbox is off (in which case the engine is most likely out anyway) then the sump cover stays put. Doesn't mean you can't pull the LP oil pump out though ☺

2.6.2 Bottom End

Dry sump cover cant come off, so no access to main bearings, rods, pistons etc. I didn't touch any of this.

2.7 Credits

I have to pay special thanks to Dave Davies of RND Engineering (dpd3047 on PH). Your patience and willingness to help has been invaluable. Oh, and the refurbed head you did for me rocks! I have no special allegiance with Dave but I feel he deserves a special big "thank you". The parts fitted to the head are now much closer to Melling's original design and just as importantly are made of decent material and hardened and finished properly by reputable firms like Kent CAMs.

2.8 Abbreviations

PSP = Power Steering Pump
A/C = Air con
ALT = Alternator
HP = High Pressure
LP = Low Pressure
CAT = Catalytic Converter
CYL = Cylinder (1 is frontmost)
HD = Harmonic Damper (aka “the front pulley” which it isn’t!)
ARB = Anti-roll Bar
RTV = Room Temperature Vulcanizing (i.e. silicone or 598 sealant)
CLA = Centre Line Angle

On pictures

R = Remove
M= Move out of the way

3 Disassembly

3.1 Assumptions

- Bonnet is off
- Scuttle cover is off
- Windscreen wiper assembly is off

Some of the photos in the early section are a little out of sequence or don't quite show the exact state of the disassembly. Please forgive this; I hadn't gotten into the swing of photographing *everything* at this stage. I am also writing with the benefit of hindsight so please go with the text advice in preference to what the pictures show.

NB: I took *everything* off the engine block in the end. I won't describe every item, but it's a great chance to inspect check and renew pretty much everything engine related (the external stuff anyway).

3.2 Basic Prep

Position the car so that you have really good access from the exhaust side. The hoist will push in and out from this side. Inlet side access is not so important but being able to get up into the wheel arch *is* to loosen the PSP and oil unions etc.

- Handbrake hard on!
- Engage 3rd or 4th or 5th gear (which ever one wants to play)
- Loosen front wheel bolts
- Open both doors (the chassis can flex a bit and the doors get tough to open…seriously!) And you're going to take the battery out! You might want to wind the windows down first too
- Jack up the front, both sides. Use axle stands, one under each side of the car on the outrigger front-most chassis members just behind the wheels
- Aim to get the car up off the ground at least 30cm, ideally 35cm. Don't go too high, your back won't thank you leaning in over the wing
- Leave enough room around the stands to remove the battery cover and battery and for access for the engine hoist legs you'll use to put the head back on
- Front wheels off
- Battery Cover off
- Battery out (-ve terminal first in case your spanner hits the chassis when undoing the +ve)
- Remove the battery under tray
- Pull back the various bits of heat proofing between the compartment and the exhaust manifolds (you should be able to see up into the bay to the exhaust headers back to about CYL4/5)
- You should also be able to see the lambda sensors bolted into the manifold collectors, just ahead of the CATs. Don't touch them for now
- Air box out, upper and lower parts and intake pipe. You don't want to damage this while trying to get the HD off AND we are going to lower the engine a bit
- Disconnect oil reservoir breather pipe
- Drain the oil from sump AND header tank

- Remove the large metal tray that covers the entire underside of the engine bay. It's heavy, be careful. Lots of M10 bolts that may well be rusted. 4 of the bolts are longer to hold a pair of strengthening plates over the ARB mounts
- Remove the CAM cover
- Remove the spark plugs and leads

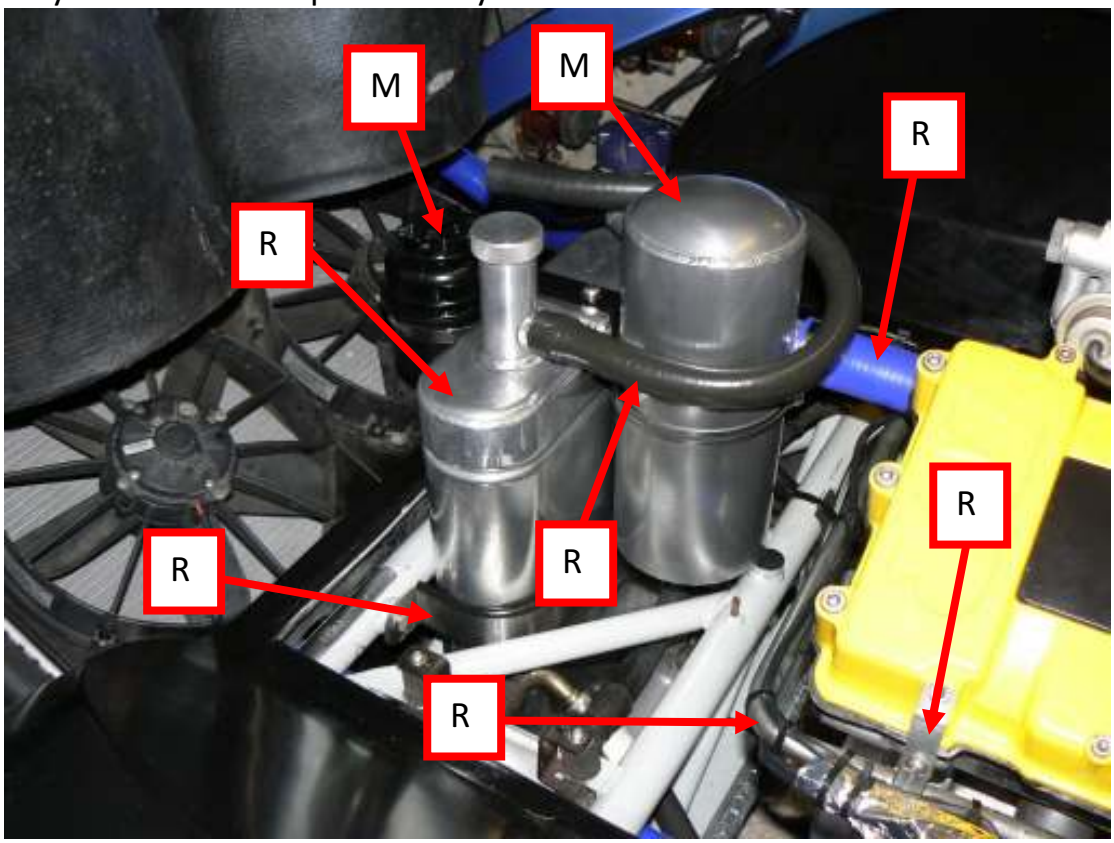
3.3 Harmonic Damper Removal

3.3.1 Prep

- Drain the coolant (discard IMO but your call). Just pull off a low down water pipe and catch it into a pan
- Undo the oil pipe union at the top of the oil header tank (38mm A/F) and the one at the bottom of the tank on the exhaust side (32mm A/F access from below)
- Undo the clamps holding the water tank, the main oil tank, power steeling reservoir etc. Also remove the big band holding the oil tank in place and remove the support bracket from the top of the oil tank
- Undo and pull away the short pipe from the water tank to the thermostat housing. It will need a good heave and twist but it will come free.

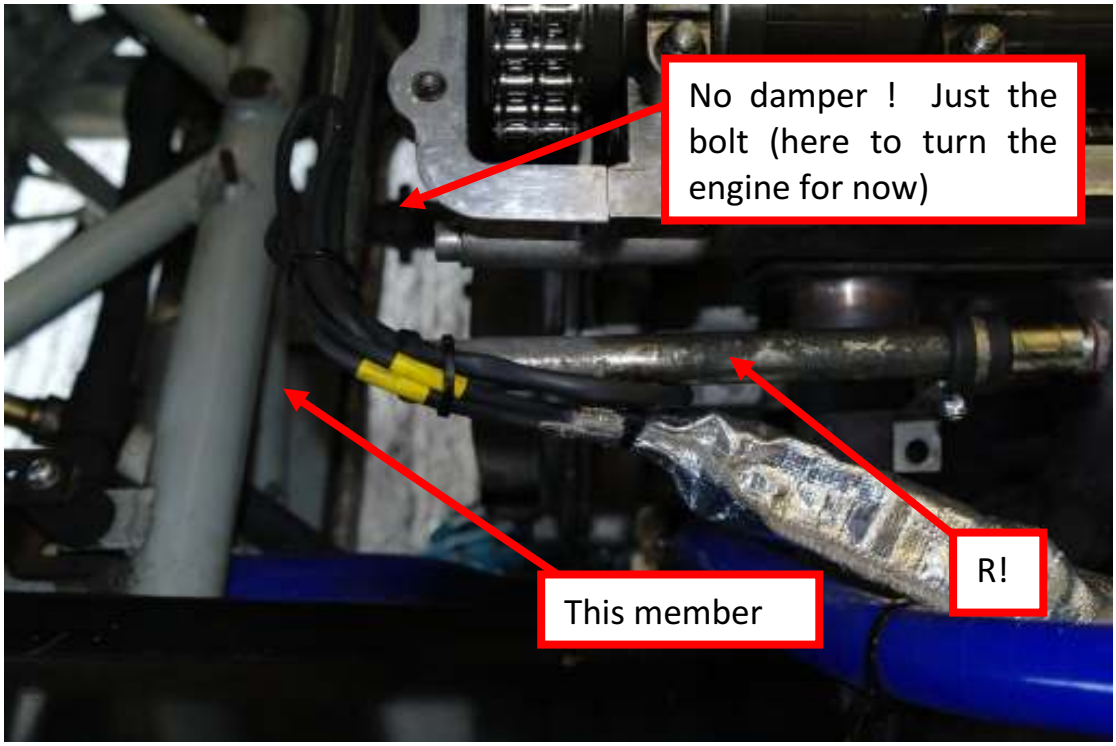
- Now the oil reservoir can come out completely
- The water tank and power steering reservoir can move out of the way over the radiator
- Remove the upper metal water pipe (snip off the wraps holding the lambda cables and just lay the cables up over the engine out of the way

- So you should end up with fairly clear access to the HD



3.3.2 Getting the HD Bolt Out

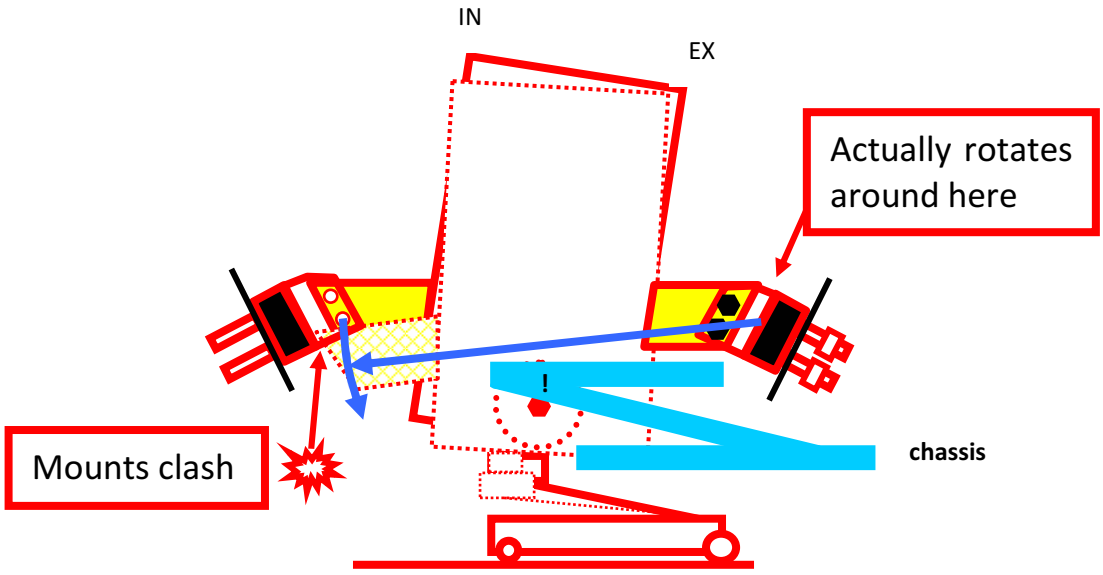
- 22mm AF spanner needed. Probably a ring type won't fit past the chassis due to the crank in the neck near the ring. So it's an open ended type OR, a very stubby 22mm socket and a skinny torque wrench if you're lucky. I ended up with this option later on (I cut down a ½" drive 22mm socket…you are going to be turning the engine a lot during this process)
- Check car is in high gear and handbrake firmly on, the bolt is *tight*
- Undo the crank bolt (regular thread so rotation to undo is counter clockwise viewed from front of car)
- Now you can see the problem. Pull the bolt forward and the head hits the chassis before it comes anywhere close to "out" of the crank nose. Its M14x175 and you can pull it forward perhaps 80mm
- We need to lower the engine enough so the bolt head goes just under the chassis member shown



- This is most easily achieved by disconnecting the inlet side engine mount *while the engine is supported underneath*
- I supported it on a wooden block using a hydraulic jack on the lowest "rib" of the sump cover…its pretty thick and substantial. Don't forget

the jack may sink over time so don't leave the engine in this state on just the jack!

- ALT needs to come out. Undo all the wires etc and make sure you know how they go back (most are unambiguous)
- With the ALT out you can see the mount clearly
- You may need to move the oil sender and pipe out of the way (I'd already moved the mounting on mine to a bracket on the front of the engine rather than on the wing)
- I advise that you loosen the 2 nuts holding the exhaust side engine mount to the chassis first. Access these from inside the battery compartment. When you lower the engine it means you're putting less twist into the rubber by letting this mount move a bit in its mounting holes
- If your mounts are in good order then just undoing the 2x M10 bolts (take the load with the jack first) between the inlet side mount and the engine bracket *might* not be good enough; as the engine lowers the chassis side mount "blade" will meet the engine side metal bracket because they only miss each other by perhaps 10mm but the edges aren't parallel so they actually crash into each other on lowering



- This means the engine isn't low enough. A good guide is that the lowest part of the sump should just be touching the ARB
- If this is the case then the best bet is to remove the bracket from the engine (the chassis side mount is trapped by the engine bracket so it won't come out! Don't bother, I tried)

- This will need a 10mm AF Allen Key. Access is “tricky” for 2 of the bolts (3x M12 cap head) if you try and use sockets. Better get yourself some of those super long Allen keys
- Once the engine is lowered down, the HD bolt will withdraw out over the steering rack *just* clearing under the chassis member
- Jack the engine back up and refit the mounts (no need to fully tighten as we’re going to do this several times ☹)
- Remove the thick backing washer and put with the bolt. Don’t be surprised to find sealant around it, there’s a path through to the oil system so it and the bolt head need to be sealed on re-fitting

3.3.3 Getting the HD Off

You're going to need a puller. A good one! Forget hammers or a gemmy. The puller from Machine Mart is "ok" but it couldn't touch my HD until it was part way off. For that I used a 1960's vintage British Leyland brick outhouse type as pictured below. I had to modify it to add the correct bolt holes, and I also reduced the centre boss thickness a tad and shortened the centre bolt 15mm-ish to try and get max clearance between the puller, bolt and the chassis. It's a very tight fit; and shortening the bolt means not much withdrawal length.

Note the ball bearing in the bolt tip and the metal disc that sits in the end of the crank to protect it and act as the load bearer. Proper bit of kit this.

The machine mart one show below just bent, so I stopped tightening ☹ I used it later on however so I reckon its worth buying. It also comes with the correct 5/16^{ths} bolts.

Getting the HD off is not rocket science. You need to use the 3x 5/16^{ths} UNF bolt holes in the damper to secure a plate and use this to draw the HD off by pushing onto the crank nose. I've read reports that people have also done this with a "plain" heavy steel plate (I'd guess min 8mm thick), HD bolt screwed fully in, bolt the plate up tight against the HD bolt then undo the HD bolt against the inner face of the plate and push the HD off. Why not? ☺; but access to the HD bolt head is "fun" because of the other 3 bolts. Guess you could trap a 22mm AF ratchet ring spanner in there as long as the ratchet step is fine enough to allow progress.

A very important point here. As the HD draws off, the 3 securing bolts get closer and closer to the chassis. Unless you fancy having to cut them off in-situ, then DON'T forget to keep a weather-eye on the distance left between them and the chassis. If they get trapped you are in BIG trouble. Can't take them out (no room), can't turn the engine (bolts are trapped by the chassis), can't push the HD back on (one way puller or pusher). Think carefully about how you are going to get the last 15 to 20mm of withdrawal done without getting stuck. This is when I used the Machine Mart puller. It's small and easier to manoeuvre than the big one and far less prone to getting stuck.

- Run the 5/16^{ths} bolts into and out of the damper holes with some grease. They are bound to be rusted and you don't want to be fighting the threads
- If you have a crank nose protection disc fit it now. Check it's a nice loose fit and cant bend or get trapped ! That would be a disaster. It might be a good idea to pop a very small hole in the middle (2mm) so you can use a length of wire to hook the disc out later
- Fit the puller with the centre bolt fully withdrawn. Use packing washers under the 3 puller bolts or better still, use bolts that are just the right length (note, try to use all the threads in the damper don't part engage them, the loads here are going to be big)
- The crank should still be locked from when you did the HD bolt
- Start to tighten the centre bolt
- Make sure everything is centralised and even. Off centre wont cut it!
- Don't be shy! It takes an amazing amount of torque to crack the HD off the shaft. It goes with quite a pop. The large puller shown

above has a 29mm AF bolt head and the spanner is probably 40cm long; and it needed all of this length to get enough torque

- Keep drawing it off ***with regard to the clearance issue noted above***! The torque to pull it off is quite high all the way and goes in regular stages from moderate to high to moderate to high etc as it binds then releases
- Eventually you may need to swap to the lightweight puller to get the last few cm done
- Don't expect it to just fall off. Getting it the last mm is still a bit of a struggle. And its heavy (5Kg)
- I had to remove the cable tie holding the main 12V starter feed so I could gain enough clearance to get it right off the crank nose. The power steering braided pipe gets in the way too; careful not to damage it
- You might find the long thin crank key steel pulls away with the HD too. This can be a real pain because it stops the HD coming off the nose. You may need to push the key back up the crank slot with a pair of pliers. It serves the HD and the 3 sprockets inside the timing chest. Nothing can fall off inside but try not to let the key come out and definitely don't let the engine turn until the key is back where it belongs (just in case you decide to abandon this whole job later on)

HD off, pat yourself on the back. Major hurdle out of the way ☺

BTW: There shouldn't be anything that leaks from the crank seal, the timing chest is well drained at the bottom into the LP oil pump so it's pretty "dry" in there.

I de-rusted and smoothrite'd my HD. Much nicer to look at. Also have a look at the shoulder on the HD; you'll see the bright line where the crank nose seal rubs against it. We'll replace that seal later on.

3.4 Exhaust Manifold Removal

I, rightly or wrongly, chose to undo all the bolts on the 2 manifolds whilst the head was in place. I decked (honed) the block with them in place, and only finally removed them when I decided I wanted to add exhaust wrap to try and keep the engine bay temperatures down a bit.

With hindsight, it would have been far better to just remove the head with the manifolds attached.

I'll describe what I did, and then what I should have done.

3.4.1 Leave the Manifolds in the Car (Non preferred)

- You'll need several 6mm AF Allen Keys; suggest some long, some short and some you don't mind re-grinding
- There are 23x M6x20 cap heads and 1x 10mm lock nut
- General advice: unless you can be sure you have full key engagement into the cap head DON'T apply torque. They Cam-out quite easily and you can start to damage the socket making extraction even harder
- Some of the bolts you'll have to reach up behind 123 manifold pipes to access…not easy, hence the extra long Allen key need
- The nut likewise…get a nice long slender 10mm open spanner
- There are 3 bolts in around 5 and 6 that start to seem impossible as you try to get them started. In fact the one in the bottom left of 6 flange you can only really access through between 5 & 6 pipe and the amount of rotation possible is tiny. For this one I ended up making a new 6mm AF using an 8mm AF and re-grinding the end to be "point up". Then using this and a normal key I eventually got it out

- Two or three of the bolts can only withdraw so far before their heads *hit* the pipes as they curve past! So you cant get them all the way out until all the neighbouring bolts are also loose and you can pull the manifold bank away from the head and then undo those bolts a bit more
- Once all the bolts come out the manifolds sit quite happily away from the head without dropping down too far

3.4.2 Leave the Manifolds on the Head (Preferred)

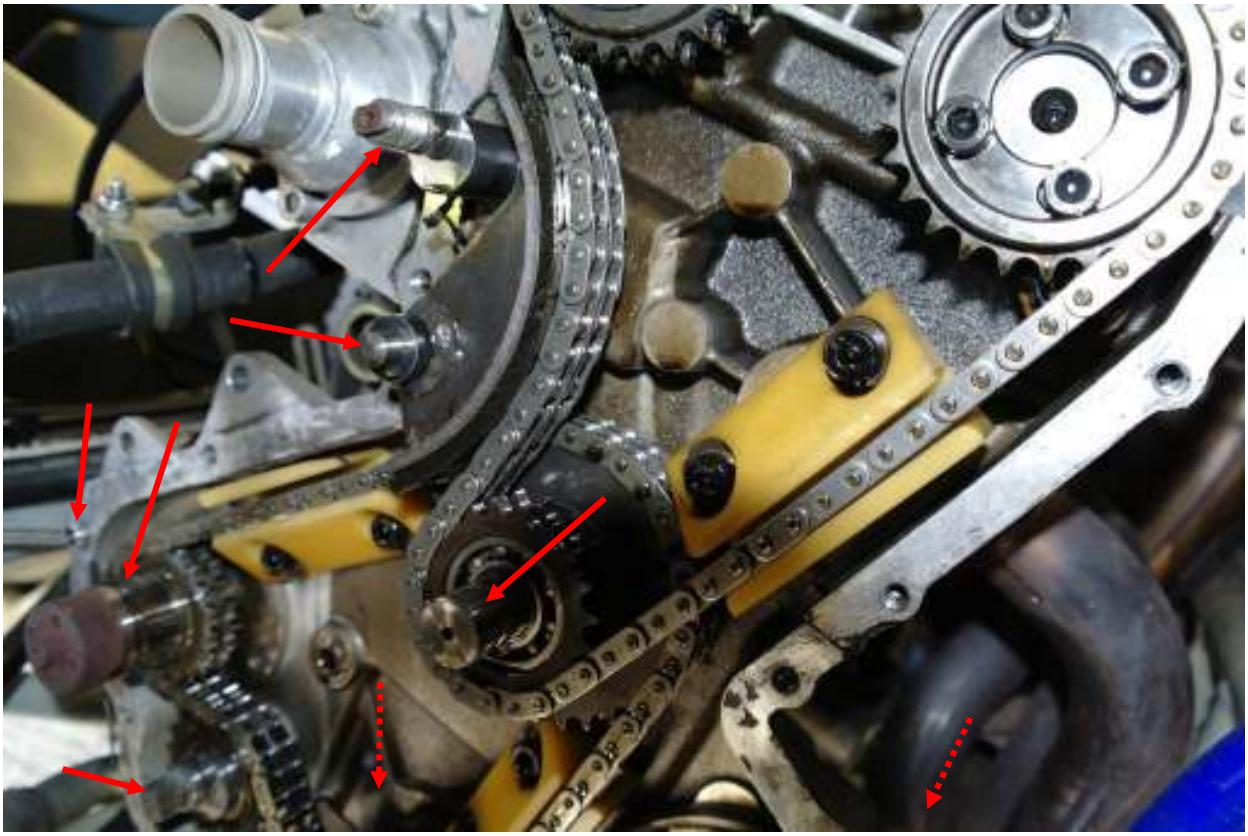
- Undo the 2x Lambda sensors (22mm AF) that are in the exhaust manifold collectors; they can be quite tight so be careful to ensure proper access for full spanner engagement and be careful not to damage the wires
- Once they are out mark which one Came from which bank and then tie them up in a bag to protect them
- Undo and remove the 2 band clamps that hold the exhaust collectors to the cats. You'll need to undo them almost all the way
- Once undone, wriggle them out of the way over the cats. They might need some persuasion to release from the two flanges around which they pinch but the bands are stainless so will eventually release from any rust
- The exhausts will drop down a few inches and then just sit in place by virtue of the rear under tray near the gearbox
- To get the head off with the manifolds attached you're going to have to take the engine mount out as it sits right between the two exhaust banks. I suggest at this stage you loosen the 3x M12 cap head bolts that secure the bracket to the block. A half turn will do, just ready for later. You cant take it out yet because the torque to undo the head bolts will need the mount's strength to hold the engine properly
- Undoing these bolts is a real fiddle again because of access. The top one is "ok", the other two are a pain. You might want to consider making a special short 10mm AF Allen key to access the lower one from underneath. Be ready with various 3/8th socket Allen keys and extension bars that can drive off centre (wobble type). You might have to work up through the battery compartment

3.5 Timing Cover Removal

- There are 18x M8 cap heads to remove but they all come out quite easily
- The lower tensioner needs to be undone. Remove the M6 cap head that secures the tension adjustment plate first

- Then remove the large nut on the end of the shaft (24mm AF). It might twist the tensioner (anti-clock) but you'll soon be hard up against the chain tension so it should come loose. You could consider putting a longer M6 into the lock hole so that its head doesn't foul the nut so you can get the first fraction of a turn to undo the main nut without twisting up the tensioner…its up to you and your circumstance
- Once it's off, the round lock plate will simply slide off. Don't worry too much about marking its position because we'll re-tension on re-assembly anyway and its pretty basic stuff! And nothing will fall off inside btw
- Next the upper tensioner nut needs to come off. Just undo the 14mm AF lock nut

- If you like you can hold the shaft for the first fraction of a turn (anti-clock) of the locknut using an 8mm AF (7mm?) spanner but probably not required
- Behind the lock nut are a washer and a “shim”. Just remove them and then remove the small o-ring that sits against the cover around the shaft. Be ready to replace this seal with a new one on re-assembly. As can be seen the larger shim is against the cover. Again, nothing will fall off inside
- Once those are out, the only thing holding the cover in place is probably RTV and definitely 2x hollow dowels, one each side at the outer-most bolt positions (about half way down on each side)
- DON’T try to lever the cover off by prying against the timing sprockets; this is destined to failure even if the cover is loose! A gentle amount of leverage is OK just to get the very first upper 20mm or so released each side, but the split wont run much further and if you pry too hard you risk bending and cracking the cover. I also would strongly resist the edge to wedge a sharp screw driver into the “gap” and just force it open because in some places there is not a huge amount of sealing face and if you damage it you risk a difficult job getting it to re-seal.
- The best method for release is to use a 4 or 6thou feeler gauge and very carefully work your way around the cover-to-block joint “cutting” the silicone away; push the feeler right through and then push it forwards and rock it back and forth at the same time
- Work around a bit, prise a bit, work a bit and so on. It will start to release. Expect a couple of hours to do this unless you are very lucky
- Eventually it will release all around (you’ll hear a sort of hollowness once its off) and you can work it forwards off the 2x dowels (about 10mm long and tight-ish) and off the crank nose, aux shaft, two timing adjuster shafts and clear of the half time shaft nose and upper tensioner slipper shaft nose



- Again, don't worry about anything falling off, its all well held in place
- Try to recover any bits of silicone from the chains, gears, sump lip etc before doing anything else…we really don't want those getting into the oil system!
- Clean off the timing cover faces ready for reassembly. I chose to fabricate my own cardboard gasket and pre-secure it to the cover using a very thin smear of 598 and clamping it a flat surface while it cured. Used 0.6mm gasket cardboard, nothing exotic

- I also replaced the crank nose seal arrowed above. This is an easy enough job. Just remove the aluminium seal mounting plate (4

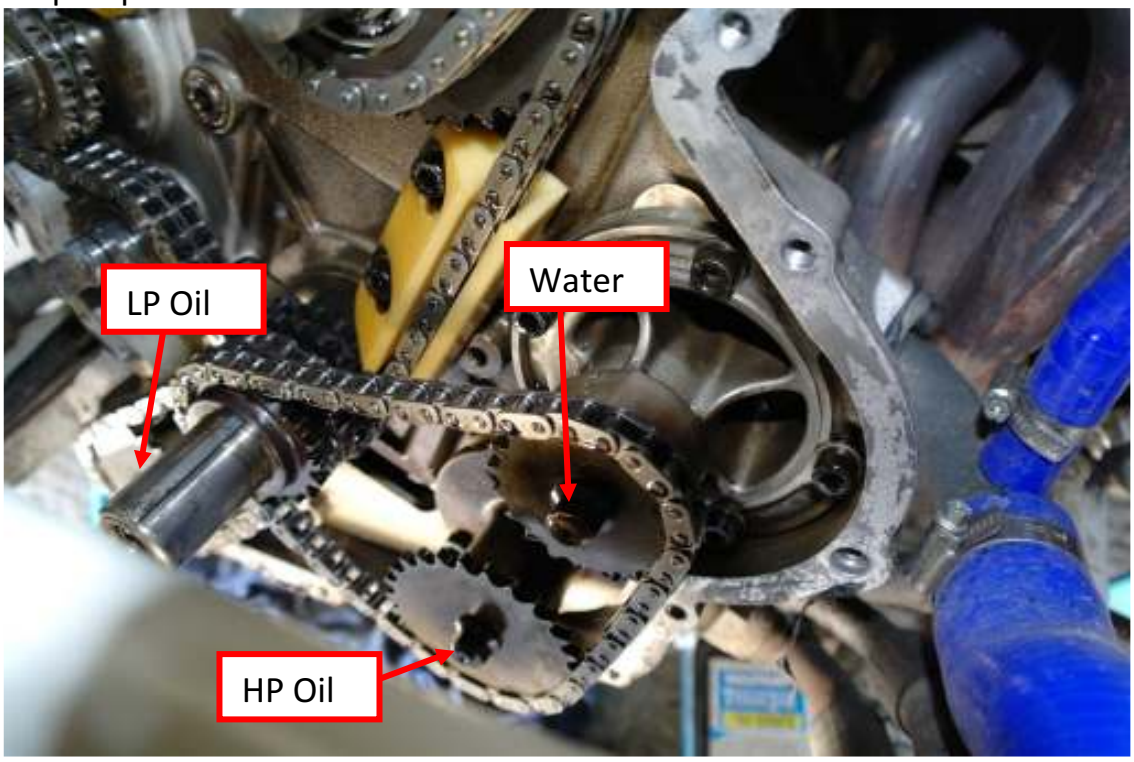
screws) and then prise the old seal out (its metal reinforced so expect it to put up a bit of a fight. Be careful not to damage the holder). Put the new one back in with a drift or parallel squash in a vice with two flat plates of metal or wood. The mounting plate needs to be RTV'd to the timing cover. On mine the plate was a snug fit in the cover hole but oddly the Sagaris manual makes reference to a centring tool which is a bit weird…I could find nothing that needed help centring!

- Watch out for the aux shaft seal; during removal and a couple of trial-refits I found it very easy to accidentally dislodge the steel spring tensioner band that sits just inside the seal lip. If this goes back together with the band out of place I guess you can expect an oil leak. Unfortunately there is no way to know its on correctly during re-assembly. We'll cover that a bit more later on

3.6 Simplex Chain Removal

To be able to remove the duplex timing chain from the CAM Sprockets, the two simplex chains can be left in place. However, to be able to inspect the various pumps and to replace the simplex chains, the old ones first need to be removed.

- With the engine locked in gear loosen and remove the nuts on the end of the water pump shaft, the HP Oil pump shaft and LP Oil pump shaft



- With a scriber or indelible marker put an identifying mark on each of the 3 simplex sprockets. Their alignment with their chains is not important if you intend to replace them. If you plan to reuse the chains then mark the side that faces out so that they can be reassembled rotating the same way
- The 3 sprockets should pull off fairly easily (do this with the chains still in place so that each pump is prevented from rotating, working each sprocket forward a bit at a time) but for each be careful not to loose the woodruff key that locates it to its shaft (remember it might be on the underside of the shaft and not visible…the keys are quite small “half moons” and can easily be lost). Keep the keys paired with their respective shaft on reassembly (use a marker pen)

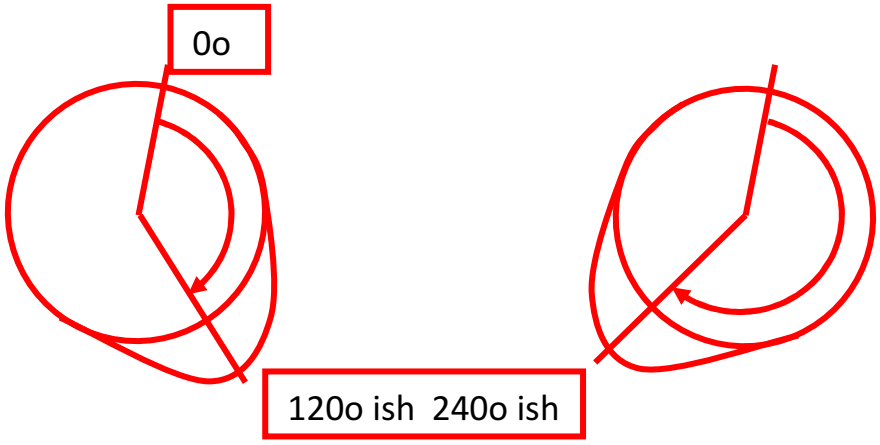
- There is no need to remove the 2 simplex sprockets from the crank nose
- The 3 pumps will be removed and inspected later on

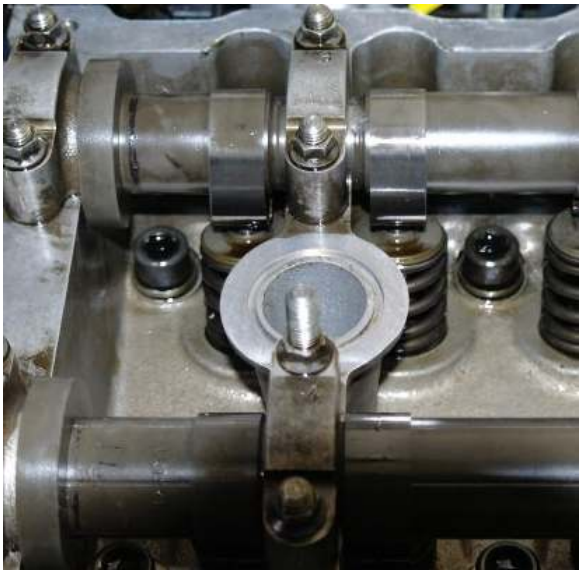
3.7 Upper Timing Chain & Sprocket Removal

3.7.1 Prep

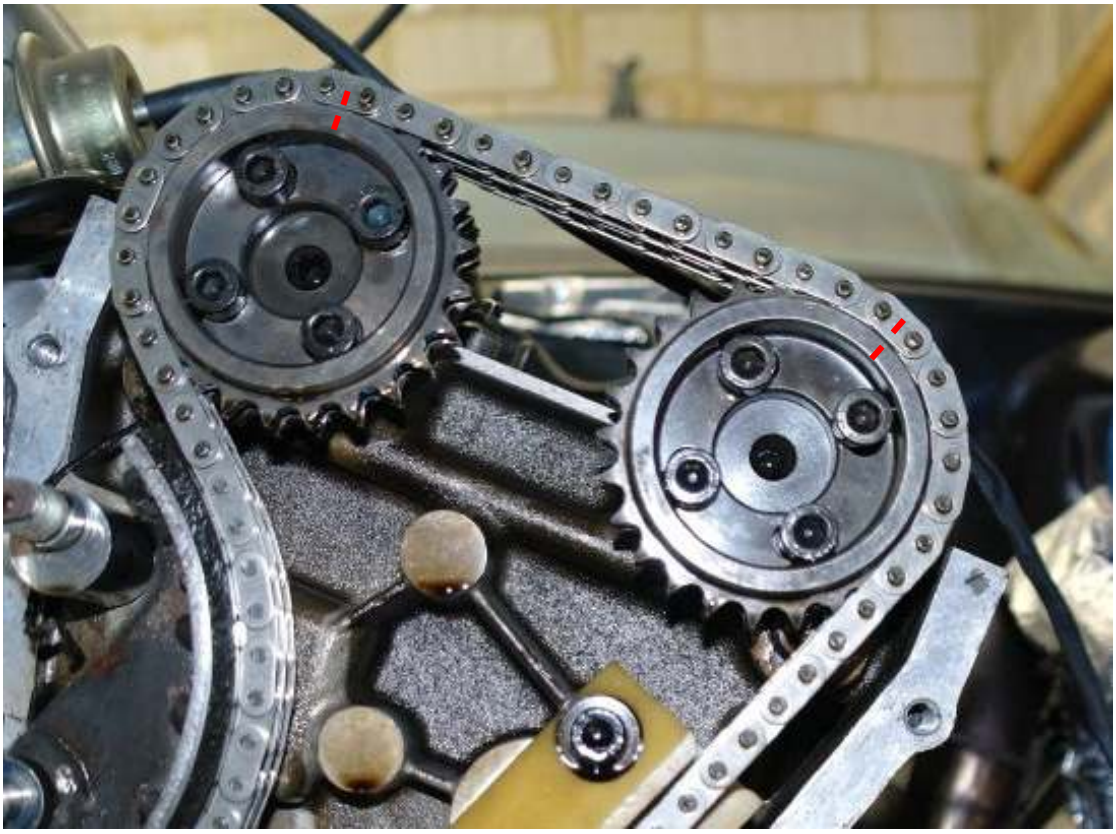
Put the gearbox to neutral and rotate the engine using a bolt in the crank nose (you'll need a spare M14 unless you want to keep bothering to get the existing HD bolt in and out. Interestingly the first few cm of the crank nose has a much coarser thread inside that happened to match the bolt used on my puller…so I elected to put that in and tighten it against the locked engine)

Rotate the engine to #1 TDC on the induction stroke. This is easy…just turn clockwise (as viewed from the front of the engine) until the CAM lobes on #1 are sort of "knock knee-d" i.e. the they point inwards, downwards and at about 120o ish on the inlet and 240o ish on exhaust (0o being up along the line of the piston and increasing clockwise from the front of the engine).





This is close to #1 TDC-power but not exact. There are no markings on *anything* to tell you where you are. The easiest way to get approximate TDC is to pop a wooden dowel or even a slender extension bar down into the #1 spark plug hole…make sure its at least 30cm long. Then turn the engine back and forward noting the rise and fall of the dowel and trying to gauge the approximate mid point where it stops moving (we'll do this *far* more accurately later on). Once you've done this, stop at this zero-motion point (as near as you can with the CAMs roughly as described above) and then apply a small "nick" mark on the upper duplex chain and an adjacent mark on the associated timing sprocket. Do it for both sprockets. This is useful for a sanity check later on but more importantly it does allow you to ***put the chain back on rotating the same way*** (it will have worn onto the sprockets in a directional way and its important to preserve this to avoid more bed-in and a possibly noisy chain)



You can use ink but make sure it will still be there on assembly! I used a scriber. The mark positions are not too important just make the marks are nicely adjacent chain and sprocket where they "touch"

Now make a mark to identify the inlet and exhaust sprockets ("I" and "E" perhaps)

3.7.2 Measuring Existing CAM Timing

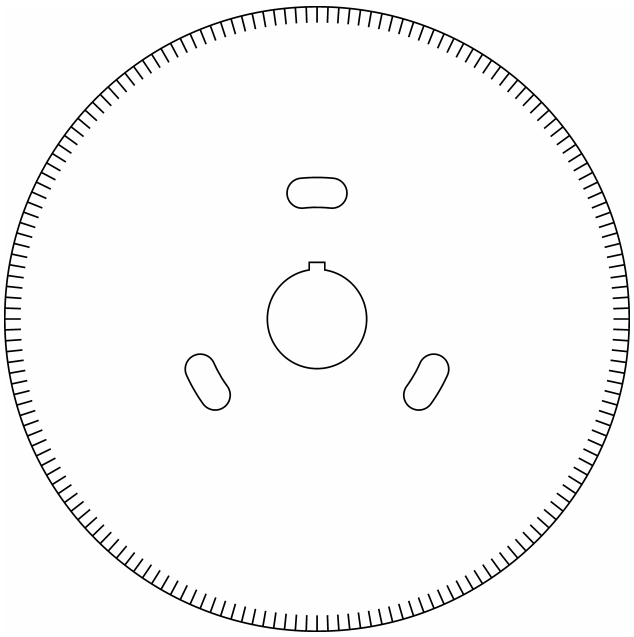
If you plan on setting the exact same CAM timing as you have now, then you'll need to measure what you've got before you go further.

It's not a hard job but you need to take care and pay attention to detail.

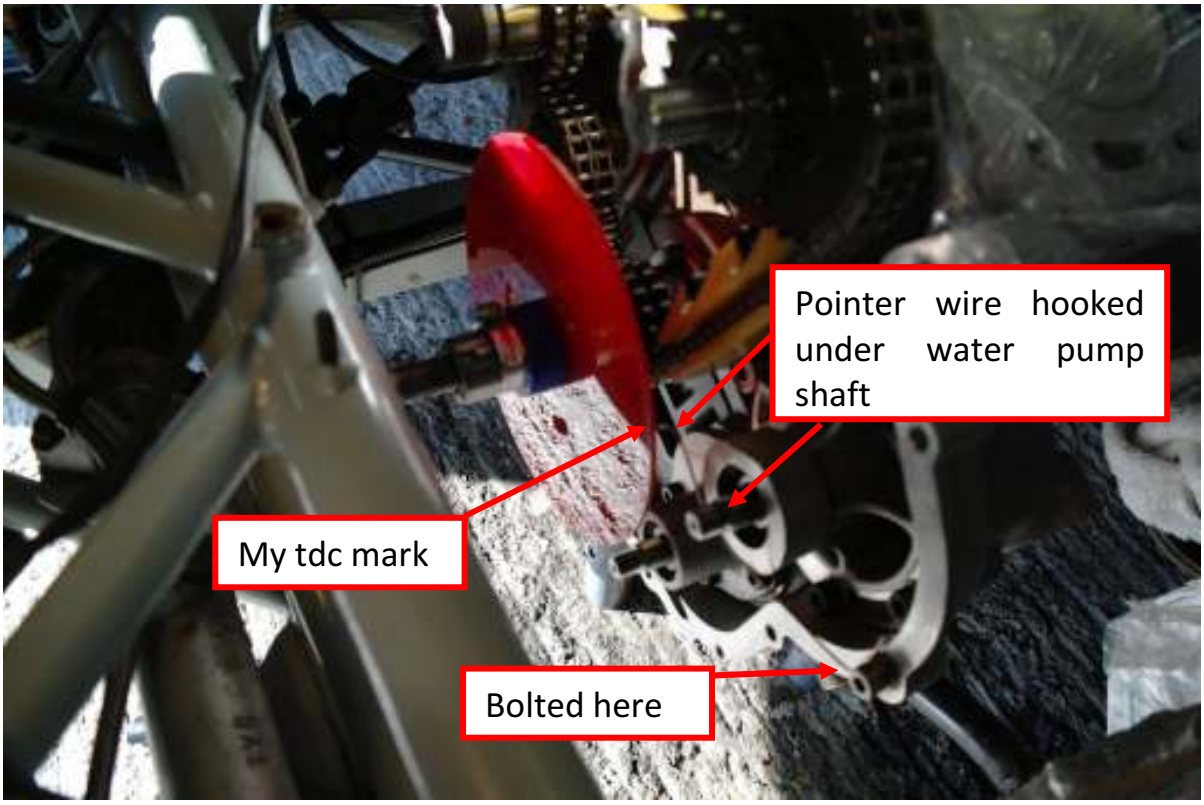
You will need a timing wheel fixed to the crank nose and a fixed pointer to indicate crank position. Also be sure to always approach reference points rotating clockwise so that all the chain to sprocket and CAM backlash are factored into the measurement i.e. everything is tight in the direction of engine rotation.

I made my own timing wheel being lucky enough to have access to a laser cutting tool and some sheets of 5mm thick acrylic.

The wheel shown below is 200mm in diameter and has marks at every 2o. I used the main crank key to position the wheel[2], held it in place with a jubilee clip and thick rubber spacer (piece of old tube). I used a bent wire pointer bolted into one of the timing cover holes to point at the exact TDC position once I'd found it (just bent it to point to the nearest convenient 2o mark and took that as "zero", and marked it with indelible pen on the wheel of course).



[2] rotational slack is not acceptable; remove by some means otherwise you won't achieve consistency



(note: I'd removed the water pump chain already at this stage)

So the basic process is as follows:

1. Find exact #1 TDC induction stroke
2. Measure fully open angle for inlet
3. Measure fully open angle for exhaust

All three of these steps require a dial-test-indicator (Machine Mart or similar). I used one with a plunger and a 0-10mm measurement range.

I added an extra length to the plunger to reach down past the Cam.

Just for completeness, its worth pointing out that the CAMs rotate at 1/2 crank speed so it takes two full crank rotations to achieve the 4-strokes and the single CAM rotation to open and close the valves appropriately. So the term “TDC” is ambiguous because there are two points where the each piston is at the top in a single 4-stroke cycle. There is “TDC compression/power stroke” and “TDC exhaust/induction stroke”. We are only interested in the latter and I’ll call it the Induction stroke.

3.7.2.1 Finding Exact #1 TDC Induction Stroke

- Place a rod into #1 spark plug hole so that it rests on the piston crown and stands clear of the plug recess by a few cm
- Choose a rod that has a diameter just under the hole diameter and don’t use threaded rod…its going to move up and down and we don’t want anything catching. You could use metal, plastic or wood
- Ideally, if you can improvise some kind of “guide” at the top of the plug recess to let the rod move up and down without flopping around then that would be ideal; perhaps a bottle top with a hole or even some scrunched up tin foil at the neck of the tube just to support the bar (photo below is NOT #1 cylinder btw but you get the idea)

- Mount the DTI to the head *very firmly* so that it squarely and truly touches the top of the rod ready to measure its rise and fall. Screw a DTI mounting kit into one of the CAM cover M6 holes (again, Machine Mart do a suitable adjustable stand that with a simple adaptation will bolt to the back of the DTI. Picture below shows the idea albeit measuring the valve top and not the rod for later in the procedure)

- Now rotate the engine backwards a reasonable way past TDC Induction, at least enough to remove all the “reverse slack” and a bit more
- Now rotate forwards just to take up the forward slack
- Set the DTI to approximately the middle of its stroke range and lock tightly so that its body cant move out of position (vital for consistent measurements)
- Rotate the engine forwards and watch the DTI spin round then slow down, stop and then start to turn backwards. Watch it closely. As soon as the pointer starts to go backwards, stop turning the engine, mentally note the max pointer position attained as it slowed to a stop and set the DTI outer band reference dial to align the zero mark to that “max” pointer position (the actual reading is not important and don’t zero to the current pointer because we’ve overshot slightly…we want the max pointer position that we saw[3])
- Now turn the engine backwards past TDC again…enough to remove slack and a bit more
- Rotate engine *slowly* forward. You should “feel” as you are starting to get close to TDC by the DTI pointer speed and position. As you get close rotate until you are say 10 units *before* your zero point i.e. 10 units before TDC. Try to stop exactly on 10 (you could use 20 but be sure to use the same amount for before and after TDC)
- Mark the precise position of the timing wheel relative to your bent wire pointer
- Now rotate *slowly* forward some more, passing through the zero point and out the other side and slowly try to stop when the pointer returns to exactly 10 units again i.e. 10 units after TDC (the DTI pointer is running backwards now don’t forget)

[3] CARE not to move the DTI body…you’ll be amazed how easy it is to magically gain or loose 5 units…find a way to rotate the dial as carefully as you can

- Mark the precise position of the timing wheel relative to your bent wire pointer again
- The mid-way point between these two marks is exactly TDC. Find and mark that by whatever means you fancy (ruler, protractor or just good old fashioned judgement from the timing marks on the wheel). Don't remove the wheel to do this btw! You'll have to do all this with the wheel in-situ
- Once you've found the middle, turn the engine backwards for slack and some more, past TDC, then slowly forwards to remove slack and keep going until you exactly stop at this mid point i.e. exactly TDC. Perform a quick sanity check that the pointer is still at zero (give or take a count or two!)
- Repeat the above at least once to make sure you get the same answer. If you don't you're doing it wrong…probably not removing all the chain slack when changing engine direction. You'll never get an exact repeat but it should be possible to get within a degree if you are careful
- Once you've done this and you are happy with the consistency, rotate the engine forward one full turn and slowly edge-up to TDC stopping as close as you can to your mid point on your timing wheel
- Now, re-bend your wire pointer to *any* 2o mark that happens to be nearby its current tip location; be quite fussy to get the pointer tip right up to the wheel edge and right to the middle of the 2o mark so that observation parallax doesn't degrade your measurements later on. This is now your golden TDC mark so clearly and indelibly mark that 2o notch as "0" so that it can easily be identified, and remove or cover over the temporary marks you made to find TDC. Make sure the pointer can't move or jump position especially given that you'll be rotating the engine close by the pointer
- Take some time to write angles onto your timing wheel so you don't end up making mistakes trying to count 2o marks later on. The angles go 0(TDC),2,4,6,8 etc increasing clockwise. As a sanity check your very last mark should be 358 before you are back to the 0o notch at TDC

3.7.2.2 Measuring Inlet Fully Open/Centre Line Angle (CLA)

- Move the DTI probe so that it now rests squarely and truly on the top of one of the inlet valve spring retainers for cylinder #1

- Make sure the DTI probe wont hit the CAM body or lobe as it rotates
- Now, use the exact same method described above for TDC but instead to find the mid-point of where the valve stops moving when its fully down (open)
- You should read off the degree wheel angle for 10 DTI units before the “max” DTI pointer deflection and 10 units after
- Add these two values and divide by 2 to get the average
- A standard 4.0L/3.6L S6 setting is around 107.5o after #1 TDC Induction for the inlet to be fully open[4]. For Red Rose it is around 113.5o.
- Record the value you calculate

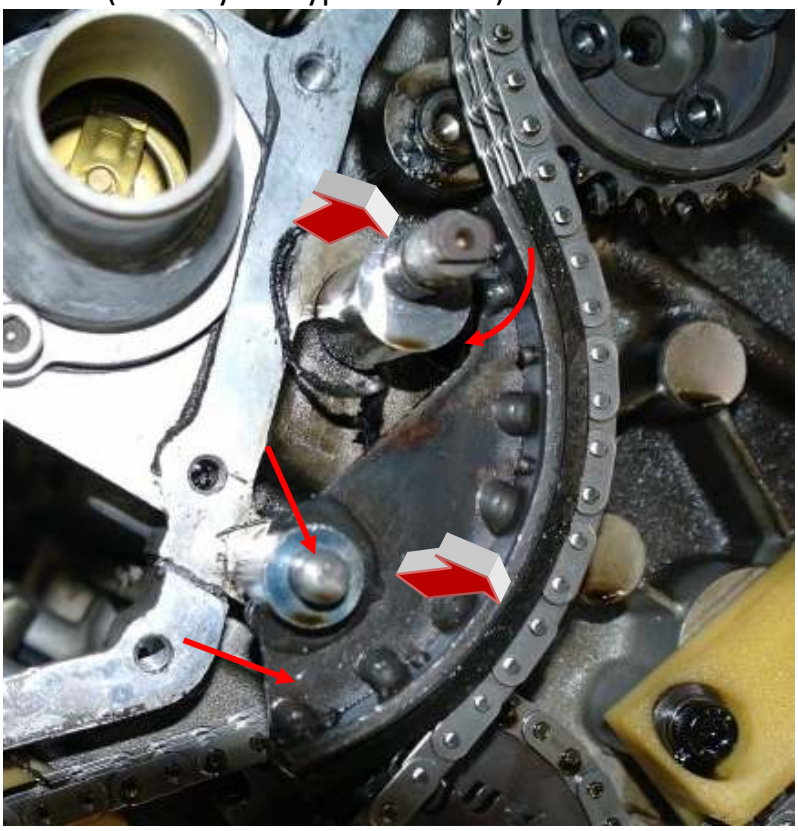
[4] i.e. we’ve had the “bang”, the piston has gone down making power, then back up expelling exhaust, the exhaust valves then start to shut as the inlet valves start to open to charge with new fuel and air and are fully open with the piston just past half way down the bore on the induction stoke. And yes, the exhaust valves *are* still open somewhat while the inlet valves are open; this is the “overlap” and helps to increase power/torque

3.7.2.3 Measuring Exhaust Fully Open/Centre Line Angle (CLA)

- Move the DTI probe so that it now rests squarely and truly on the top of one of the exhaust valve spring retainers for cylinder #1
- Follow the exact same process as for inlet CLA to find the exhaust CLA keeping in mind that the exhaust valves are fully open before top dead centre on the exhaust stroke i.e. the measurements will be on the high degree end of the wheel so you'll have to measure and average the angles as before but then subtract from 360o to get the degrees before TDC
- Typical values will depend on the engine variant etc but a standard 4.0L/3.6L S6 is around 104.5o BTDC and for Red Rose this is around 107.5o
- Record the value you calculate
- Also note that the CAM profile for the exhaust is the mirror of the inlet profile making the exhaust valves open slowly and close very abruptly so the fully open point will be very much more sensitive to engine rotation and correspondingly a little more difficult to gauge exactly

3.7.3 Chain and Sprocket Removal

- Rotate the upper tensioner CAM until it's slack
- Pull the tensioner CAM out
- Now pull the chain slipper off its shaft and remove. The shaft stays put
- Expect to replace the slipper with the upgraded one from Racing Green (solid nylon-type material)



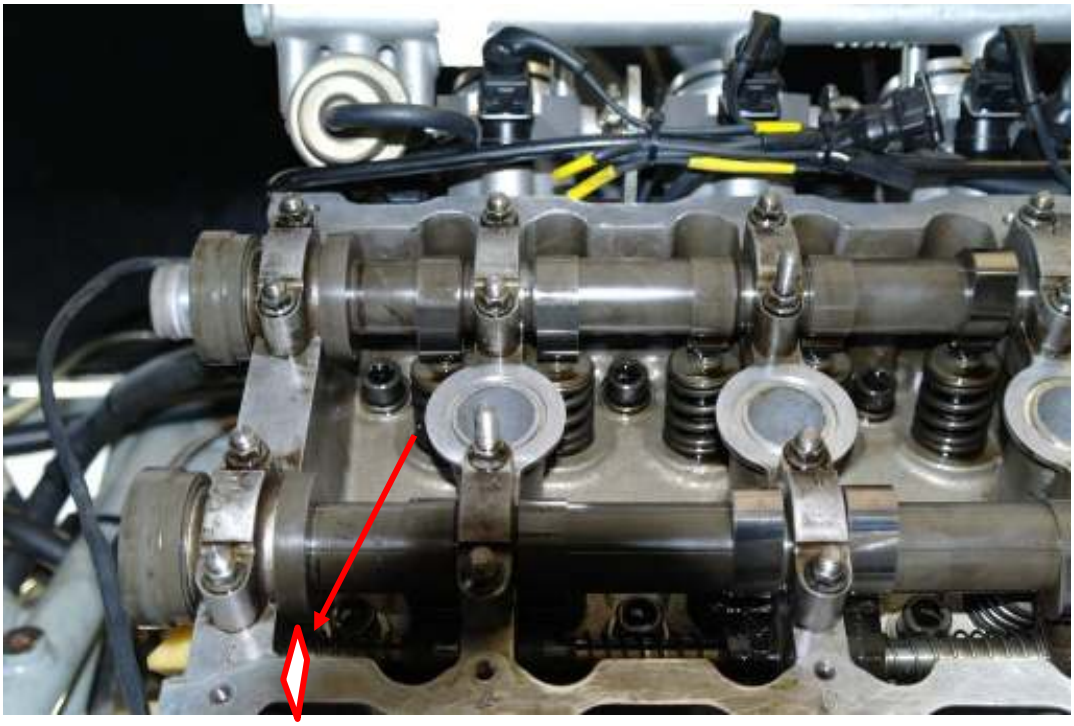
- This is how nasty mine was

- Next, loosen and remove the 4 bolts securing each CAM sprocket
- The sprockets will easily slip off their mounting boss and come free, together with the chain. Work against the locked engine to loosen all the bolts before removing everything
- Note that the sprocket bolt holes are slotted; this is how the CAM timing is fine tuned

- Clean and check the chain and sprockets. Expect the chain to "droop" when held sideways supporting its own weight by around 10mm across a length of 200mm, give or take. Replace the chain if you're unsure or if it's obviously worse than this or damaged. The sprockets will doubtless show signs of wear too but some judgement will be needed as to whether they need replacing or not. If the teeth look really sharp and pointed its probably quite worn

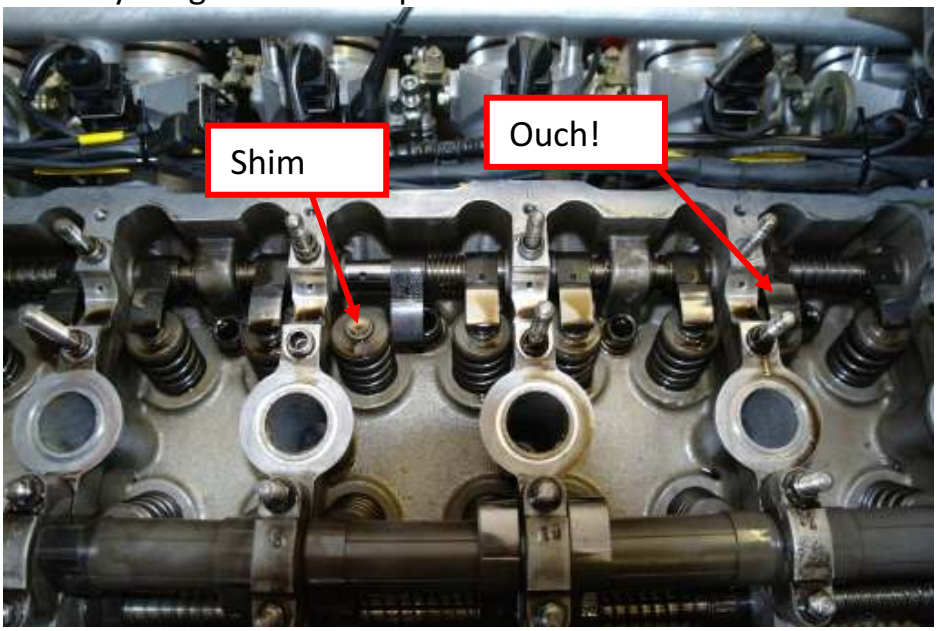
3.8 CAM Shaft Removal

Because of the risk of dropping items down the oil returns, this is a good time to plug them! Use a piece of rag or foam rubber (not too small, don't want to loose that down the oil return either!) to pack them. There is one at each corner of the head on the exhaust side. The photo below shows the approximate position of the #1 end drain. The equivalent drain at #6 end is in a similar position but is even further obscured by the final CAM bearing casting bridge.



- Start with the inlet shaft, loosening each bolt holding the bearing caps in place a bit at a time working back and forward along the shaft
- Don't undo any one bearing cap too far in isolation or you run the risk of damage due to massively uneven load from the valve springs
- Some bolts will come away from the studs, some will rotate with the studs; this is normal so just remove everything progressively
- The bearing caps should all be marked already but double check before final removal
- Lift each bearing cap away and any hollow alignment dowels that choose to come loose too
- Once all the caps are off, the inlet CAM will lift away easily. It should already have a unique marking but just in case mark it "i" with a marker pen

- The bearing caps are all reused unless they are clearly damaged / scored etc in which case talk to a S6 specialist to source them
- Once the CAM is out and before doing anything else, carefully lift each finger follower up and remove and mark the valve shim from the top of each valve shaft. Mark them i1 to i12. It is highly likely that the shims will be reused in a different order (with new CAMs etc) but marking them in case you choose to abandon the project and re-fit everything is not a bad precaution



- Repeat the process for the exhaust CAM and shims marking them e1 to e12 instead
- If there a few studs left in the head at this point, it's a good idea to remove them as the head is heavy and awkward and if a stud happens to catch something during removal it will come off the looser. Lock M8 nuts against each other to undo the stubborn ones (rather than use mole grips!)

So now there should be clear access to all the head bolts

3.9 Throttle Body Removal

- Disconnect the oil and water sender connectors on the inlet side. The senders themselves should ideally be removed too at this stage to avoid damage but access is not so easy

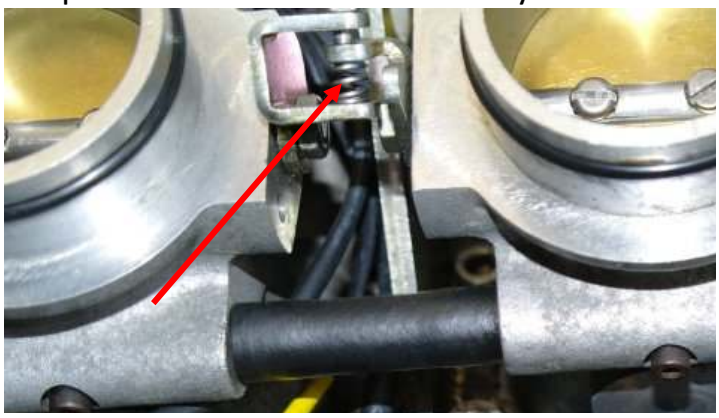
- Next the throttle bodies and related stuff needs to come off
- Disconnect the 6 fuel injector connectors
- Now unbolt the fuel rail (4x M8 cap heads with spacer tubes)

- No need to undo any fuel lines for this
- Prise the fuel rail up so that each injector pops loose from the throttle body…it's only held in with an o-ring per injector
- Once all are loose, lift the rail and tip towards the exhaust side to about 45o. The injectors will *just* clear the throttle body holes enough to then allow the whole rail to move sideways towards the front of the car

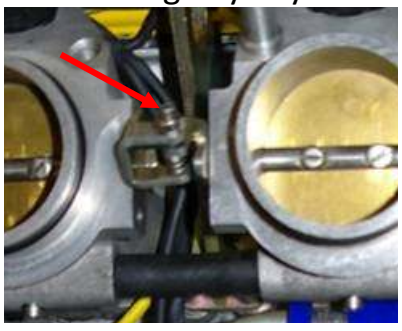
- Align the injectors into the gaps between bodies and now tip the rail back and down towards the inlet side taking advantage of the clearances between the bodies to “loose” the injector length
- The rail will then pass the bulk head and come away (you’ll need to pop off the vacuum pipe from the rail pressure regulator (no fuel in there). Lay it up against the inner wing as far out of the way as possible
- Undo the two throttle position sensor connectors (one on body #1 and one on #6)
- Undo the 2x “Y” vacuum pipes from the bodies #3 and #4…the rubber pipes use factory crimps onto the one-way valves screwed into the bodies; you most likely have to bend these to loosen the crimps and remove…refit with jubilee clips

- Pull the vacuum balance pipes off each end of the #1 and #6 (should just slide off) as shown above (yellow)

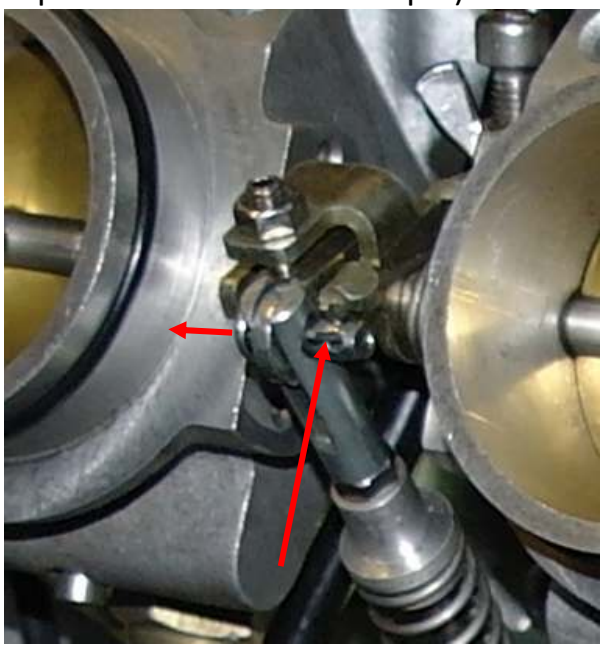
- Now undo the M8 cap heads holding each body (4 per). You'll need a ¼" socket drive and long extension ideally the wobble type because some heads are a little off-line with the access between the bodies. Try not to drop any bolts or shake-proofs
- Note that between #1&#2 and #5&#6 there are engine lift eyes. The M8's are a little longer plus there may well be a packing washer between the face of the eye and the body casting. To remove these eyes you'll have to snip free the wraps holding the injector loom in place
- Don't loosen the bodies yet!
- Next, remove all the throttle body balance springs. Use a very small pair of needle nose pliers and just grab firmly on the middle coil and wriggle the spring out from between the two faces of actuators. They are only held in by small bumps on each face and the fact they are under compression. I strongly suggest you cover around the area with a towel or something so that if one of these little suckers "pings" off then you've got a fighting chance of catching it before it disappears into the engine or onto the floor! Keep them in order for reassembly BTW!



- Now remove all 5 of the balance grub screws and lock nuts and again keep them in the same order for re-assembly. You *could* try to mark/note/record the positions (depths) of each screw but frankly when you reassemble this it will be miles out and will need rebalancing anyway



- Undo the throttle linkage from #3 actuator (just pull out the spring clip and remove the clevis pin)



- Now all of the bodies should be free but may be stuck to the head. Normally these are sealed to the head face with Blue Hylomar and you'll find they come loose alarmingly easily[5]
- Start at #1 end. Grab the body, pull gently away from the head, lifting slightly more towards the #1 end to clear the head casting and the dowel pins that locate the body, carefully pull towards #1 end as the dowels clear to de-mate the short rubber vacuum tube AND de-engage the actuator mechanism from #2. Be careful not to bend either body's actuator mechanism; you may find it helps to turn the butterfly a bit on #2 and also to really loosen body #2 as well. Body #1 should come free and can be put to one side (these bodies are all unique in some way or another, there is no way to muddle them up)
- Now remove #2 body, then #3 etc until all 6 are removed
- You'll need to clean the faces of the bodies so they completely free of sealant etc, ready for re-assembly

[5] After 4 failed attempts to re-seal with Hylomar I gave up and now use a very thin smear of petrol friendly RTV (very thin!). It works every time…BUT…removing the bodies again is much more difficult; I had to resort to a snug fitting extension bar in the injector hole to get some initial leverage.

3.10 Head Removal

- Remove the upper water pipe attached to the back of the thermostat housing

- You'll probably have to bend and destroy the factory crimps that holds the rubber pipe to the tube
- The head *should* now be free of all attachments etc ready to be removed, but a final check is prudent
- The head bolts are very tight, don't scrimp on good tools
- You'll need a ½" 10mm AF socket (forget 3/8ths drive!!!!). Buy a good one. Halford's Professional series worked for me; the body is small enough to *just* clear the casting in the #6 cyl corners!
- You'll need a <u>good</u> quality ½" short extension bar, around 50-100mm is fine; long enough to reach clear of the head casting (plus your knuckles!) with the socket attached but short enough to clear the bulkhead. I started with my trusty old "cheapie" from the £1 tool stall; I twisted it 45^{o} on the tightest bolt and it wouldn't budge. I also recommend NOT using the wobble type…you need all the positive engagement you can get
- You'll need a breaker bar of at least 70cm length. I don't think I'd attempt this with anything less
- You'll really need a mate to help you support the extension bar while you use both hands on the breaker bar
- I started at #1 end and loosened each bolt pair (inlet side and exhaust side) and worked towards #6
- I first undid each bolt just a 1/8th turn for all 14 bolts, then undid them all, all the way loose
- I replaced the bolts with new ones BTW, using the extra long pair from Racing Green for the holes with hollow dowels[6]

[6] Their website gives a good explanation on how to cut them to length

- Remove all 14 bolts and thick washers and keep in order if you plan to reuse the bolts (I replaced them)
- Now, the head *should* be loose
- You've got plenty of leverage if the exhaust manifolds are attached so use that if the head is stuck
- The head aligns with two hollow dowels one at inlet #1 bolt and one at exhaust #6 bolt. They are pretty tough but don't forget they are there if the head puts up a fight to release from the block
- Now, to lift the head off, you might as well refit the 2 lifting eyes into #2/3 and #4/5 throttle body holes (or where they came from in #1/2 and #5/6…guess it doesn't matter really)
- Now, use some good strong rope through those eyes and loop around the exhaust manifolds as shown below (photo is during re-assembly) and lift the head up a little

- You can see the lifting crane I borrowed from a friend. Worked a treat
- Carefully lift the head up, a bit at a time and keep a close watch on the manifolds to help them clear the various bits-n-pieces around the exhaust side. Probably a two person job

Having got the head off, place it down carefully and onto something soft. A cloth on a WorkMate is ideal with the manifolds hanging down. The manifolds need to come off next (assuming you left them on)

Loosen all the manifold bolts. A couple of "gotcha's". The M6 nut won't come off until all the other cap heads are out on that bank so that you can pull the manifold forward as you undo the nut. This is also true for a couple of the cap heads on the rear bank. Take out all those that want to come out easily, loosen those that don't. The ones still there at the end only come out by pulling manifold forward, undo cap heads a bit, pull forward, undo. Nice ☹

3.11 Head Prep for Refurbishment

- Remove the thermostat housing and thermostat
- Leave the coolant pipe adapter in place at the back of the thermostat casting
- Remove the 2 senders (oil and water) if you didn't already
- Leave the upper tensioner shaft in the head (long polished bar that the slipper pivots around)
- Remove the nylon chain guide and cap screws
- Don't worry about cleaning up the head face or exhaust manifold face, this will all be prettied up during the refurb

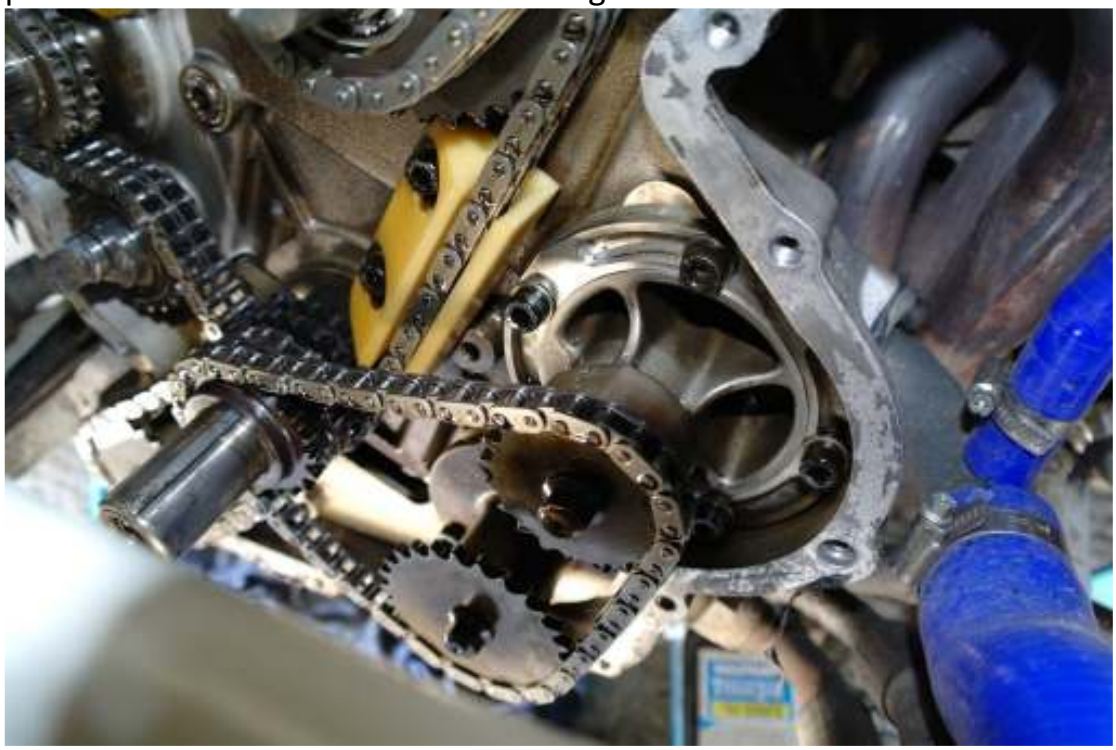
I would package up the CAM bearing caps, cap nuts and studs, shims ready to give to the head refurb company if you plan to get them to shim the new CAMs for you. Otherwise keep these parts safe and don't ship them with the head.

3.12 Pumps

With the engine this far in bits, you are strongly advised to go the rest of the way and check the various pumps for condition.

3.12.1 Water Pump

- Undo the four bolts that secure the pump noting the approximate position of the bolts relative to the long slotted holes



- There is a parallel flat on the pump casting as it necks to the shaft. This is how to rotate the pump to facilitate removal and later to tension the simplex chain. The AF measurement is beyond the range of regular spanners! A stubbly but wide jawed wrench is the best bet; but there is limited space for movement of the wrench shaft ☹

- The pump body is a large round casting pushed up into a machined void in the block. The casting seals to the block with a pair of large o-rings

- Remove the pump by rotating the body a few degrees back and forth and pulling. This is easier said than done! The seals are a very tight fit. I resisted the temptation to prise the pump out because its flange is only made of aluminium and there is limited access. Instead, I elected to pull the pump forward by hand using

a spanner behind the head of the sprocket nut refitted for the purpose. Its hard work

- Once the pump body comes out you can inspect the impeller for damage. Its likely to be fine
- Check for play in the shaft and any signs of water leakage around the shaft. If there are signs of this, a new pump may be needed
- Clean the pump with white spirit and pay particular attention to the groove in the pump and the small hole therein. This is the "escape route" for water *if* the pump shaft seal fails. Look on the inside of the block void an you'll see a small hole that exits to outside. Make sure it is clear as this is the route for the water in the case of trouble[7]
- Fit a *new* pair of o-rings to the pump and apply a smear of grease or silicone lube to them prior to refitting
- Push the pump back into the block and apply pressure to the body as evenly as possible to get the first then second seal into the block (its not easy). I used a hand-pump clamp to squeeze the pump body into place. Again, due to the strength of the flange I decided not to use the mounting bolts to press the pump in but I may have been overly cautious here
- Once the pump is in place, check the shaft turns freely and check you can rotate the pump body easily with a spanner. Rotate the pump so that it is well towards the slack end and hand fit the securing bolts

[7] Contrary to popular belief a failed water pump is more likely to vent water *out* of the engine than into the oil system

3.12.2 HP Oil Pump

- Remove the 4 bolts that secure the HP oil pump (just below the water pump)

- Withdraw the pump taking care not to drop either of the pump rotors as it comes free
- The pump seal is a simple o-ring that gets squeezed between the parallel faces of the pump flange and block; I reused mine
- The rotors should slip out and off very easily. Inspect them for scores and scratches and for any metallic contamination "smeared" across the lobes. These two components are the lifeblood of the oil system; any doubts at all about their condition and you should replace them both. Mine showed very light scoring but some weird aluminium specks on the outer rotor so I replaced them both

- Use STP to pre-lube the two rotors, slip both onto the pump and rotate by hand until they align to allow the outer ring to sit centrally to the body, then slide the whole assembly into the block
- Use thread lock and re-fit the 4 bolts and torque to 15ft lbs

3.12.3 LP Oil (Scavenge) Pump

- Remove the 4 bolts securing the pump

- Find a small thin spanner (10mm ish)
- Pull the body forward as far as you can; the suction into the sump casting is quite remarkable! At times you'll doubt its going to give. I even wondered if it was caught on the filler plug in the sump at one point (its not btw)
- Once you have sufficient distance out, pop the spanner head under the right hand edge of the pump and carefully prise/lever forward and pull too
- You'll find the pump will come forward in stages as each seal "breaks" free. There is *just* enough room to withdraw it past the chassis
- All the pump rotors are simply pushed onto their shaft and the right hand shaft is just a push fit into the body; expect the whole lot to come apart as you withdraw the pump. Try your very best to keep it all assembled to allow you to preserve the order of the rotors and spacers

- Inspect all the rotors and seals for damage. Most likely they will be OK
- Clean and reassemble the components and lube well with STP
- Check the inside of the sump void for any contamination (just in case!)

- Push the pump back into the sump, working against the pressure caused by the quality of the seals. It takes pressure and time to get it fully home
- Use thread lock and re-fit the 4 bolts and torque to 15ft lbs

4 Reassembly

4.1 Refurbished Head

I had the following done to my head:

- Skimmed face
- Recut valve seats
- New 214N Stainless valves with wider 8mm stems and slightly larger diameter
- Colisbro guides
- Reduced pressure valve springs
- Supply of new chilled iron CAMs with standard profiles
- New hard chromed finger followers with revised profiles and lube improvements
- Fully re-shimmed clearances
- Additional oil way drill and tap into back of head to meet exhaust follower oil way (thread to suit RG's oil feed kit banjo bolt that I sent with the head)

Here are some photos. See intro for details of who did the work.

A worthwhile thing to check at this point; the two grub screws that hold the follower shafts in place really need to be thread locked to make them oil tight. In particular on the exhaust side, if you are having the extra oil way drilled, there is now a direct path for HP oil past the thread of this screw from where it *will* leak past the CAM cover securing bolt and onto the hot exhaust.

The grub screws are down in here:

Just unscrew them, coat with thread lock or hydraulic lock and re-tighten. Run a clean M6 screw in and out of the thread above the grub screw afterwards just to clean out any excess thread lock.

4.2 Decking the Block

I would suggest this is a DIY job only if you're brave or crazy. I manually decked it because after removal of the old gasket the deck was very obviously a bit of a mess; not very flat with pronounced low spots between the cylinders.

There are some quite serious risks to doing this in-situ with the pistons in place and doing it by hand:

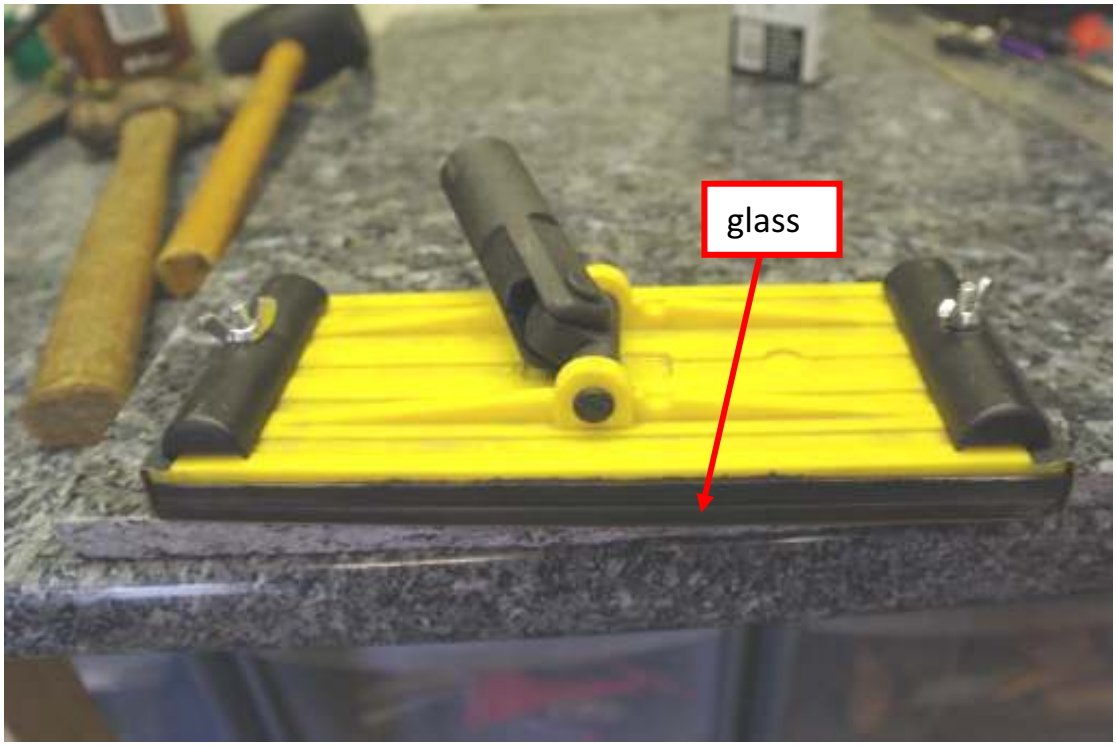
- You're going to use abrasives and some of these could end up washing down the bores and get into the oil system
- You might make the deck worse, less flat etc etc

To mitigate these I did the following:

- Grease packed all cylinders around the piston rings and placed plastic discs into the bores that were also "sealed" with grease
- Filled all the waterway and oil way holes with foam rubber to stop ingress of abrasive
- Used a VERY flat lapping tool
- Removed the two hollow head alignment dowels to give me proper and free access across the whole deck surface
- I flushed the oil from the sump afterwards using fresh oil and an extra drain that I made at the back end of the sump to ensure I got everything out (just in case anything got in there in the first place !). See 4.3
- I cleaned up afterwards *very* thoroughly using white spirit and loads of kitchen roll. Down around the bores is the most important; move the pistons up and back and wipe away any residue. Also raise each piston to the top of its stroke and use a feeler gauge to clean around the gap down to the first piston ring
- After the entire rebuild I also used a full oil charge with new filter and circulated it using the starter for 5 mins or so. Then I dumped the whole lot ready (including filter). For that flush I used fully synthetic oil

If you do feel like having a go, here are a few pointers that may help:

- Removing the dowels is a pig ! Protect the deck face with a large metal washer over the dowel, use good quality grips low down on the dowel (resting on top of the washer) and twist and pull the best you can. They will twist reasonably easily; it's the pulling that's hard. You *will* mash up the surface of the dowel…no question. And they are not a listed spare. I had to re-dress the surface of my dowels using a small lathe. I took the opportunity to skim them so that they fitted "easily" but snugly into both the block and the head to ease re-assembly
- I used a plastic sanding pad (Oakley) from B&Q…but, alone it's not good enough as it flexes when used. So I reinforced with a piece of 5mm thick glass stuck to the foam pad. The wet-n-dry then pulls tight over the glass surface. Glass is *really* flat and very stiff.



- I used 120 grit wet-n-dry to get the basic level right. Follow with 180, 240 and 600. Finally I used auto-sol so that I could search for any blemishes or (god forbid) cracks
- I worked in a mix of directions right out over the edges (the only tough one is the timing chain end…you're restricted there). Use cross-wise, length-wise, figure 8 and circular. This helps to avoid "over-doing it" in any area
- I started by using a water spray to lubricate but gave up with that in the end and just used the 120 grit dry to get the level right

- Periodically I stopped, cleaned the deck off, applied an all-over smear of engineers blue (aka “Stuart’s Micrometer” from ARC Eurotrade in the UK)

- With the uniform blue in place, you can carefully, lightly and evenly abrade the entire surface to look for high/low spots
- For accurate level checking I used a big hunk (6”x3/4”x3/4”) of cobalt tool steel with a lovely ground flat edge; lay it on the deck and probe under it with feeler gauges to measure the depressions
- You can also use a straight edge to achieve the same, and you can use a small LED torch to see if light leaks underneath
- You are shooting for better then 2thou across the deck, 6tho from end to end. It needs to be pretty flat!!!!
- The end-to-end measurement is not easy; you’ll need to apply some judgement. I worked along with my tool steel to check for local lows and then with across the whole length with a good 1m stainless steel ruler (but it tends to bow slightly so its more hit and miss IMO)
- The thin regions between the bores were *very* low on mine
- When I had finished the steel liner top edges had just been abraded all round on all cylinders (might not be true on all engines!)
- Below are some pics of the finished item. This took around 15 man hours and used a lot of wet-n-dry paper and elbow grease!

- Once you are finished, **remove any water and oil way blocks you put in place**, ideally I'd use a vacuum cleaner as you pull each piece out to catch any nasties that might be trapped down there. Then remove the piston covers and clean out the bores to within an inch of their lives ! See the note above about using a feeler gauge around the pistons

- Wipe the deck over with white spirit again, and one last time down the bores to make sure you didn't pull any abrasive out of the water/oil ways straight into the bores
- Cover the deck with cling-film to cover the whole area while you work

4.3 Head Bolt Hole Prep

I took an M10 bottoming tap and ground the end flat to make it even more “bottoming”. I then ran the tap into each head-bolt hole in the block to clean out the thread. Be careful to not allow any small bits of swarf or old oil crud to drop down into the bores or back into the bolt holes for the matter. All the bolts are blind so a quick vacuum out afterwards is a good precaution.

Use a wire brush to clean the tap between each operation.

4.4 Extra Oil Drain

As mentioned in 4.2 I took the opportunity to add an extra oil drain into the sump to allow me to get rid of the residual oil (you'll be shocked how much is in there…nearly a litre!)

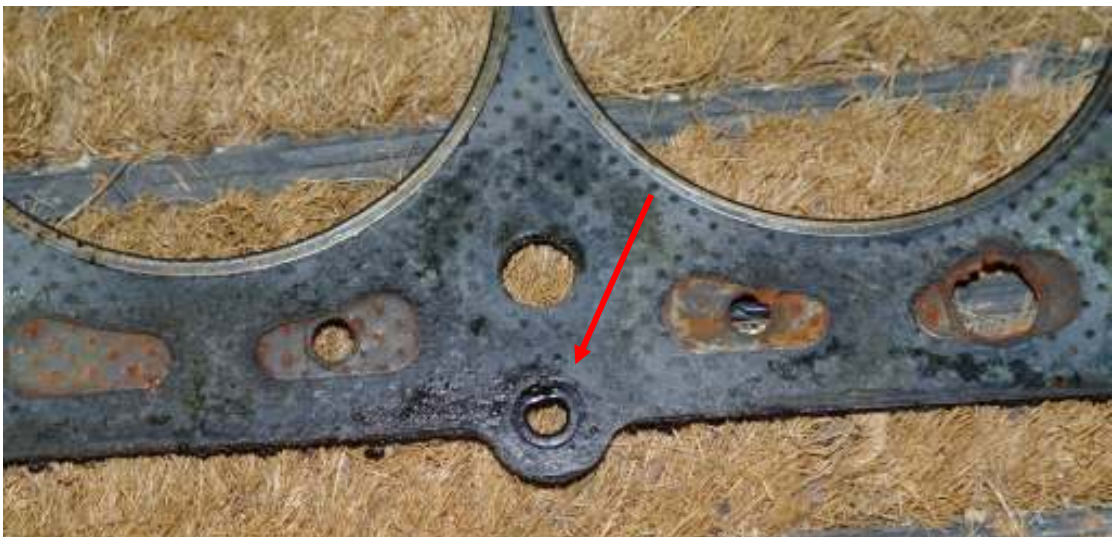
I drilled and tapped an M6 hole just ahead of the core plug that is (unfortunately) obscured by the bell housing. A stainless button head screw with fibre washer makes the seal. When drilling the hole, go really slowly and try to stop just as you break through, then cleanly allow the drill to cut right though and pull the drill out and let the oil flush out any swarf. After M6 tapping, flush several times with ½ litre or so of oil introduced down the oil return way in the block (exhaust #6 corner); again to clear any swarf.

The (nasty) oil that came out !!!!

4.5 Modified Oil Ways

One of the weak points of the S6 design (IMO) is the way the oil gets to the head via the small O-rings resting in the head gasket. Once these perish and/or deform, the oil is poorly constrained to go where expected…the gasket may or may not be enough as it is right out at the far edge of the block/head. Note that the new gasket *is* reinforced around these holes, which is definitely a good thing. But, overall I was not too impressed.

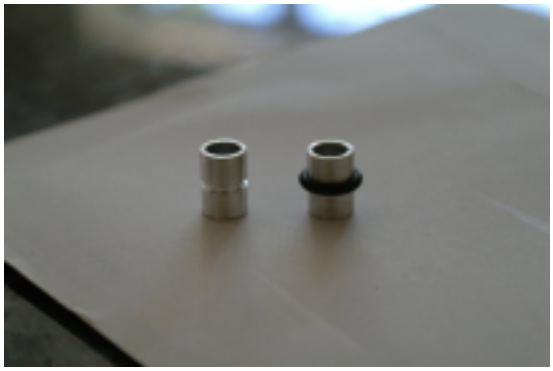
This is what mine looked like after 14K miles ☹ It might well have been a factor in why the inlet side CAM shaft died (lack of oil pressure); who knows. There absolutely *was* an oil leak from around this seal down the back of the block.



So I decided to modify the oil feeds to include some small aluminium "stand pipes", pushed into the block oil ways, supporting the o-rings and then pushed up into the head oil ways. The pipes support the o-rings and also avoid them being the main channel for the oil.

I plugged the oil ways in the block with foam, then counter-drilled the oil ways with an 8mm drill to a depth of about 10mm. The same was done in the head. I used a vacuum to pull any bits of swarf out as I removed the foam plugs from the oil ways. **Don't forget to remove the foam plugs or disaster could result.**

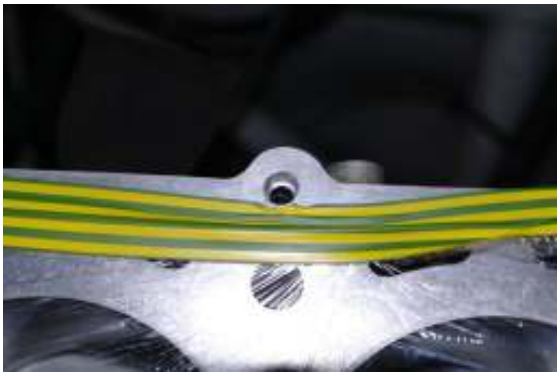
Using a 15mm length of aluminium tube from B&Q (O.D. 8mm, I.D. 6mm) for each oil way, with a small groove formed in the middle to seat the o-ring into. You may need to pick the o-ring to have a slightly smaller section than the “normal” one so that it doesn’t get too fat when put onto the pipe. The first photo below (only) has o-rings that were definitely too fat!



The “stand pipes”

Fitted into the head

The counter-bore in the head…



…and in the block

When I came to perform the actual fit and head mating, I smeared a tiny amount of 598 into the pipes' outer faces before pushing them home. This way they become fully sealed (give or take) and take the pressure off the o-ring to an even greater extent.

4.6 Exhaust Manifolds

I chose to refurbish the manifolds a bit and also to cover them in black exhaust wrap to try and lower the engine bay temp. There are various schools of thought about the wisdom of wrap, but for me, and my non-everyday-drive Tuscan, I was happy with the risks (mainly that it holds water against the stainless and can accelerate its rusting…sounds plausible). Ceramic coating is pretty but expensive so I eliminated that idea.

- I firstly used some Hydrochloric Acid to de-rust the flanges (aka Spirit of Salts at Robert Dyas). Be careful!!! Gloves, goggles and don't breath it in. When the rust is gone, wash off very thoroughly with water and then use a wire brush on a drill to burnish the surface to help prevent re-rusting (it will re- rust in front of your eyes unless you have a way to passivate it; wire brushing works ok as a substitute). I also wire brushed all the down pipes and collector
- Then I gave the whole lot a coat of hi-temp silver paint (having dried them with a blow lamp)
- Then I wrapped them. What a fun job! Great when it's done but oh boy, will it test your patience!
- Here are some photos

- Once they are ready, they can be bolted to the head. Use a small bead of 598 around each port, then bolt to the head. And yes, this *is* easier than it sounds. Those few pesky bolts that foul the pipes will be *even worse* with the wrap in place; you'll have to pop them though the holes then magically "hover" the flange above the head face to get both (or was it 3?) started by hand for a turn-or-so, then progressively tighten down. Once those tricky ones are done the others are easy enough. Torque them up to 15ft lbs
- A word of warning; the wrap makes the re-fitting of the engine mount bracket *a total and utter pig*. You have been warned. In fact I almost couldn't get the mount in and twisted around through the gaps to line up as required. Very nearly a hot-and-cold moment where I had to back-track. But….there is a way. And now with the benefit of hindsight, the answer is to tie the mount onto the manifold in roughly the right position, as you fit the head. That said, getting the bolts in is still nigh-on impossible, especially the lower one. But as I said, it can be done, but be ready for some head scratching and swearing and aching arms!

4.7 Fitting the Head

Preparation is the key. Get everything where you need it, ready to go and keep everything good and clean. I kept cling-film over the block right up to the point where I was ready to lower the head down.

I'm assuming that you have the block well supported from underneath (don't forget the hoist needs to roll underneath) with the exhaust side engine mount bracket removed but the rubber mount in-place on the chassis (btw: you might want to chop 10mm or so off the bolts of this rubber mount so that it doesn't hit the battery quite so badly ☺)

Now is the time to prepare the head bolts. I used new bolts (12 of regular length and 2 over-length). Inspect the threads for "dings" where they have been stored…if you find a small dent in a crest, remove it with a fine file. *Don't* chase the threads with an M10 die…the threads are formed by rolling and you don't want to wreck the surface hardness this generates. Do, however, clean the bolts with white spirit before you start and then wipe the threads with a cloth that is coated with fresh engine oil. Don't go crazy! A very light oiling is all you want[8].

Here are the steps to follow:

- If you are adding the extra oil feed to the back of the head, now is the right time to fit the banjo union and feed pipe. You can still access it later on but it's more tricky. I set mine to point down and towards the inlet side at about 20^{o} below the horizontal
- Get the head onto the hoist, and get it at about the right angle in *both* axes; you want it to "drop" onto the block as parallel as possible. In the photo below, the head, when turned to line up with the block is an almost exact parallel match face-to-face. It's a good precaution to cover the top of the head with cling-film

[8] There are some good articles on the web about the effects of oil on torque readings for head bolts

- Now is a good time to tie the engine mount to the manifold as mentioned in 4.6. The picture/arrow above shows approximately where…you'll need to convince yourself of the precise details!
- Wipe the head face over with alcohol (IPA) or white spirit and let it dry
- Make a visual inspection of the head face checking for no bits of "stuff" stuck to it…last chance!
- With the engine still at approximate #1 TDC Induction, rotate it clockwise on a bit until ALL the pistons are a reasonable distance (20+mm?) down the bores. When you fit the CAM shafts you don't want any of the valves meeting pistons crowns!
- Remove your protective cling film from the top of the block
- Make sure the block-to-head hollow dowels are fitted
- Wipe the surface of the head with alcohol (IPA) or white spirit and let it dry
- One last inspection to make sure there are no bits of anything lying around in the bores or on the deck
- **Make sure one last time that you have removed any bits of foam rubber you used to block the water and oil ways. This is the last chance to avoid a disaster**
- Place the two new oil standpipes with o-rings fitted into the block with a very thin smear of 598 to seal them in (assuming you are doing this mod)

- Place the new head gasket onto the dowels onto the block then cover over with a sheet of cardboard in case any “stuff” drops when moving the head around

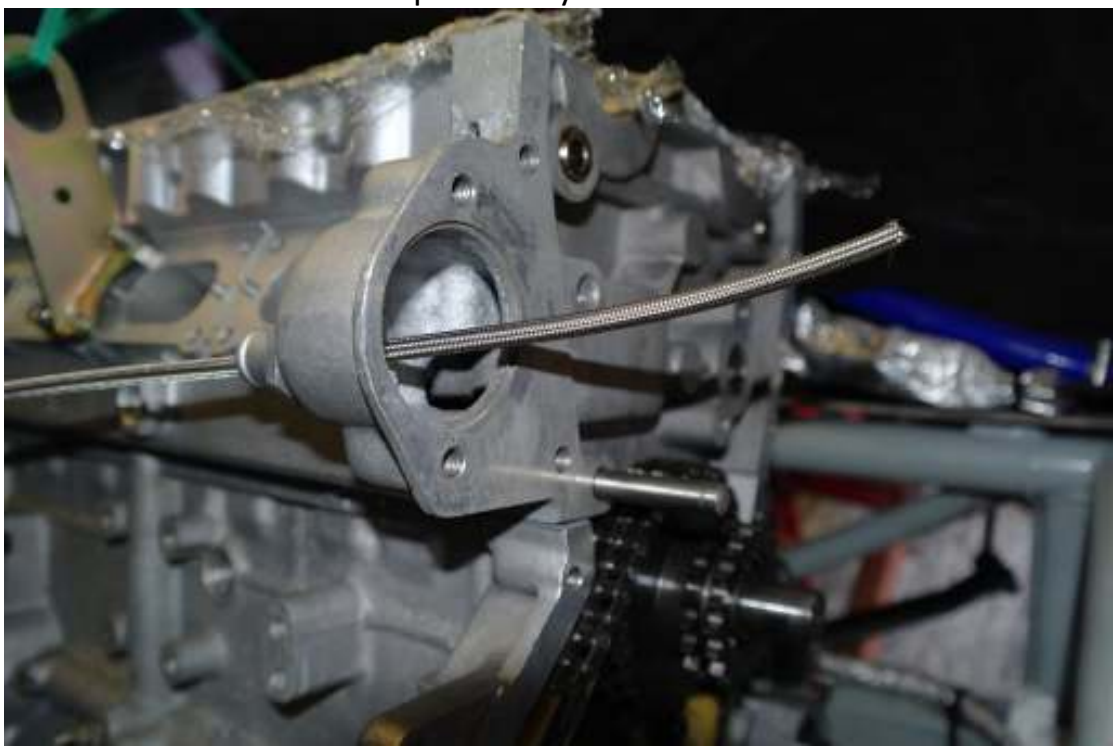
- Move the head on the hoist to approximately the right place above the block

- Once you are happy that its in the right place, remove the protective cardboard sheet, and apply a small smear of 598 to the top edge of the oil standpipes (if applicable)

- Lower the head in small steps until you can “hook” one or other of the dowels into the head to steady it

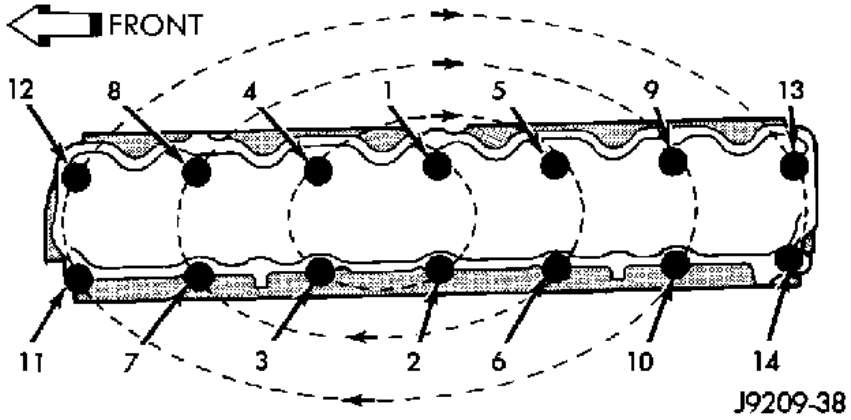
- Now lower and manipulate the head until the dowels are both engaged, then lower the rest of the distance and make sure the oil standpipes are engaged and easily sliding into the head

- The head should sit down quite easily until flush



- Next, place the 12 normal head bolts into place with their respective thrust washer omitting the two longer bolts in the hollow dowel positions
- Hand tighten the 12 head bolts
- Apply a quick “nominal” torque to all the bolts (say 5 lbs/ft) just to get the head into position and seating down

- Now place the two longer bolts *without* their thrust washer into the dowel positions and tighten them down all the way by hand
- Measure the distance from head face to under-side of bolt head on these over-long bolts. Remove them and cut this amount off with a hacksaw and tidy up the edge of the thread where you cut them
- Re-install the long bolts *with* thrust washers and tighten to 5 lbs/ft
- Now, in the order shown, tighten all head bolts to **20 lbs/ft**



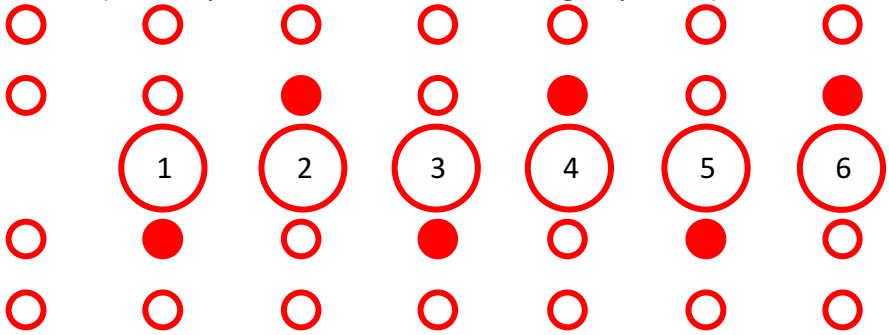
- Leave for ½ hour
- Tighten in the same order to **40 lbs/ft**
- Leave for ½ hour
- Tighten in the same order to **80 lbs/ft**
- Wait for 1 hour
- Loosen in the same order by 1 turn for each bolt
- Re-torque in the same order to **20** then **40** then **80** lbs/ft with no need to wait between each pass. This is the final tightening
- Now is the right time to re-fit the exhaust side engine mount bracket and get the engine weight back onto it. As I said elsewhere, if you have used exhaust wrap I can only wish you luck getting all the bolts in. Don't think that an M12 can't cross thread…oh yes it can. Not far admittedly but if it feels wrong don't tighten it. Yes, I stopped before I did any damage. Getting the bolt to re-start true was a challenge though!)

4.8 Refitting CAM Shafts

You'll want some STP or other re-assembly oil for this job and the next few too.
I'll assume you didn't rotate the engine since re-fitting the head, that way we'll know all the pistons are down the bores and hence as the CAM shafts open some of the valves, we can be sure they won't hit the piston crowns. Once the CAM shafts are fitted but before the chains are re-fitted, you must not freely rotate the engine for the same reason!

Follow these steps:

- Fit all the inlet and exhaust shims into position in their correct order
- Make sure all the finger followers are in the correct position riding on the shims. Some STP on the shims is a good idea
- Fit all the hollow dowels for the bearing caps into the head (use a hollow drift to tap the dowels in square until you can hear they are fully home)
- Hand fit all the bearing cap studs into the head. Make sure they are all the way down (use a pair of locked-together M8 nuts to turn them if they are stiff). Note that the shorter thread goes into the head and there is an extra long upward facing thread on each journal in a staggered pattern that reaches up through the CAM cover (check you have these in the right place!)



- Now, smear STP onto all the CAM bearing journals
- Take the new inlet CAM shaft and wipe STP onto all the lobes and the bearing faces
- Sit the CAM shaft into place with #1 lobe pointing down and inwards approximately as shown in 3.7 so that its in about the right place for #1 TDC Induction

- Smear STP onto the face of all the inlet bearing caps and sit them into position in the correct order and orientation over the studs
- Hand fit the lock nut onto each stud and give it a half turn with a spanner
- Now, work up and down all the nuts giving each about a turn and then moving on. It is imperative NOT to blindly tighten any one nut because the uneven loading you can create on the CAM shaft from the valve spring pressure can snap the shaft (or distort it)
- Once all the nuts are fully down, torque them to 15ft lbs
- Repeat the same process for the exhaust CAM shaft, noting #1 lobe's correct approximate assembly position from 3.7

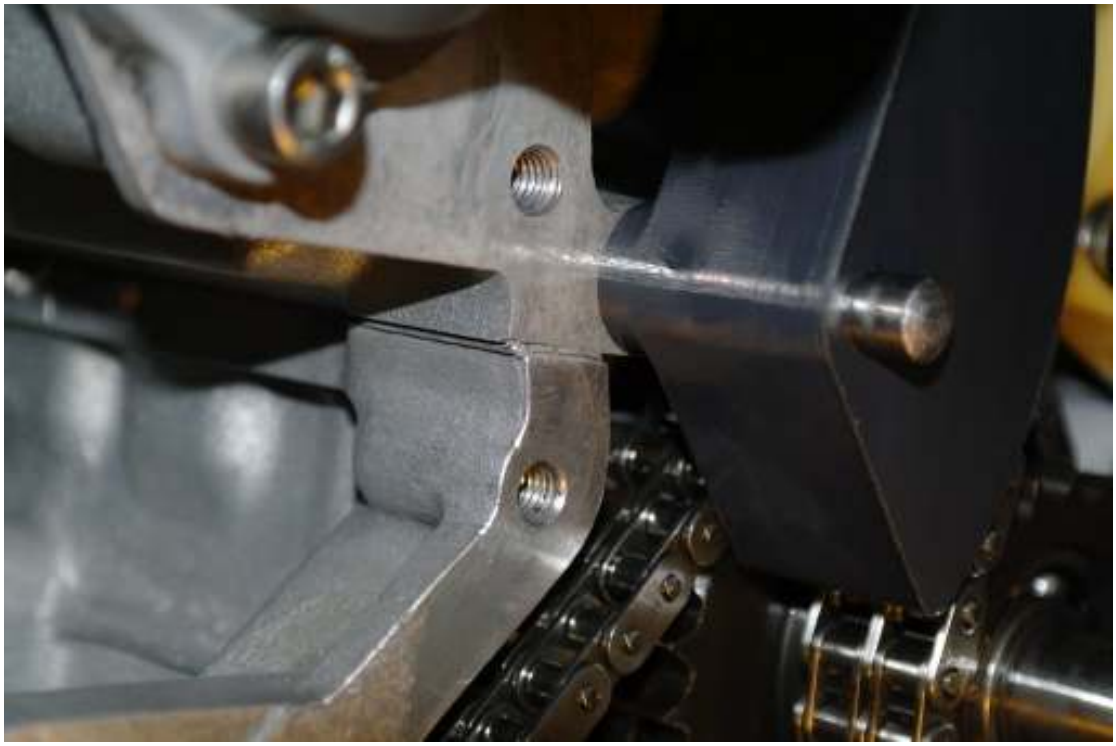
4.9 Chain and Sprocket Refitting

4.9.1 CAM Chain and Sprockets

Before you begin, rotate the engine *very carefully* anticlockwise back towards #1 TDC Induction (you moved it clockwise a bit to lower all the pistons). Use the timing wheel to get TDC as close as possible.

Now follow these steps:

- Refit the nylon chain guide to the head and torque to 15ft lbs with thread lock
- Oil the duplex chain with STP and hook it over the drive sprocket on the half-time shaft
- Find the marks that you made on the chain and move the chain around until they are up in roughly the correct place near the CAM shafts
- Next take the inlet CAM sprocket and hook it into the chain so that the marks align and pull the sprocket up until you can slide it onto the CAM shaft drive boss
- Take the exhaust CAM sprocket and do the same
- If the positioning cannot be achieved move the chain on the half-time drive sprocket by a tooth and try again
- Once the chain and sprockets are all in place, fit the M8 cap heads into the drive bosses and loosely tighten
- Now, slide the new tensioner slipper onto its shaft up behind the duplex chain, then STP and fit the tensioner adjuster and rotate a bit to take up the slack in the chain (wiggle the CAM sprockets on their slotted holes a bit to help spread the tension)



- Recheck that your alignment marks are correct and if they are tighten the sprocket bolts. If the marks are wrong, start over to correct them

4.9.1.1 CAM Timing

- At this point, the timing should be close to correct but because of the slotted sprocket holes, the timing could be in error to a significant amount and needs to be adjusted
- Adjust the upper chain tensioner to get the tension in the chain span between the CAM sprockets such that when all the slack is taken up with the engine having turned clockwise, a strong push with a thumb causes no more than about 1mm movement. Its quite tight but don't go crazy or the half time bearing can suffer
- Refer to 3.7.2. This same method is used to check the timing on each of the inlet and exhaust CAMs
- Measure the timing on the inlet CAM first, using the CLA method previously described. Assuming the timing is in error, loosen the 4 sprocket bolts and turn the CAM shaft (only) using a large spanner on the hex section in the casting mid way along. You'll need to make an educated guess for the amount to turn (1^{o} on the degree wheel is $½^{o}$ on the CAM, but the direction of turn can be figured out with a little thought. Lock off the sprocket bolts.

- Re-measure the timing. Repeat 11 and 12 until the desired timing is achieved. Aim to get to within 1^{o} of desired CLA averaged over 3 measurement runs
- If you can't achieve the right timing you may well be one tooth out on the half time sprocket. Remove the 8 CAM sprocket bolts, turn the engine carefully so that the sprockets turn but the CAMs don't. Rotate until the next sprocket bolt holes are aligned. Refit the bolts and try the whole process again. The slotted holes *just* span one tooth's worth of rotation so that all timing settings are possible
- Repeat the process for the exhaust CAM
- Once you are happy with the timing setup, remove each sprocket bolt in turn and apply thread-lock and re-fit and torque it to 25ft lbs (don't undo more than one bolt at once or you risk disturbing the timing!)
- If you are paranoid like me, repeat the inlet and exhaust measurements one last time
- You are now finished with the timing wheel so it can come off

An important point to keep in mind is to always know the relative rotation of the engine with respect to #1 TDC inducion when the CAM shafts are being adjusted. If you get the CAM phase too far out, the valves could meet piston crowns. If you feel resistance when turning the engine over, tread very carefully!

4.9.2 Simplex Chains and Sprockets

The simplex chains and sprockets should now be refitted. It is strongly recommended to fit new simplex chains because they are relatively cheap yet drive such essential pumps in the engine and are hence a false economy to re-use.

Also look critically at the woodruff keys; they transmit all the torque to the pumps after all. If they look damaged replace them.

Please refer to 3.12.1 because it is important to renew the water pump seal to ensure that rotating the pump to achieve the desired tension doesn't cause it to leak! Better to be safe than sorry.

First for the LP oil (scavenge) pump chain:

- Rotate the shaft on the LP pump so that the woodruff key slot is facing up
- Slide both crank nose simplex sprockets forward on the crank about 20mm
- Insert the right key into the slot on the pump shaft, being quite meticulous about getting it in deep and parallel with the shaft
- Hook the chain over the inner simplex crank sprocket
- Then hook the LP pump sprocket facing the right way out into the chain so that it will coincide with the pump shaft and its keyway
- Work the sprocket onto the shaft and be ready for disappointment as the woodruff key "catches" and dislodges ☹ forcing you to have to try again
- Once everything is engaged slide the sprocket fully home including the crank nose one. A gentle tap with a soft hammer is ok but if they wont go, *don't* force it or you'll damage the key
- Check to be 100% sure the woodruff key is properly in (and actually still there; I had this one fall out without a sound and I only found out when I came to try and tighten the pump shaft lock nuts after having fitted the second chain and sprockets so trapping the inner chain preventing refitting of the key; damn!)
- Fit the lock nut to the pump and torque as to 35ft lbs
- There is no tension adjustment on this chain; it is what it is
- Wipe some STP over the chain and sprockets

Now the chain for the water pump and HP oil pump.

- Rotate the shafts on both pumps so that the woodruff key slot is facing up
- Slide the outer crank nose simplex sprocket forward on the crank about 20mm
- Insert the right key into the slots on each shaft, being quite meticulous about getting them in deep and parallel with the shaft
- Hook the chain over the outer simplex crank sprocket
- Then hook the water pump sprocket facing the right way out into the chain so that it will coincide with the pump shaft and its keyway when most of the chain tension on the upper run is taken up
- Now the fun part; hook the HP oil pump sprocket facing the right way out, into the chain too and again such that it aligns with the keyway and shaft on the oil pump. You need several hands!
- Work the sprockets onto the shafts and be ready for disappointment as the woodruff keys “catch” and dislodge ☹ forcing you to have to try again
- Once everything is engaged slide the sprockets fully home including the crank nose one. A gentle tap with a soft hammer is ok but if they wont go, *don’t* force them or you’ll damage the keys
- Check to be 100% sure the woodruff keys are properly in
- Fit the lock nuts to the two pumps and torque to 35ft lbs
- Push the upper run of the chain down hard to get all the slack onto the upper run (the pumps will turn easily). With a ruler measure the top to bottom slack from chain “pulled up” gently to “pushed down” gently in the middle of the upper run. You need 10mm total using only moderate pressure on the chain. Turn the water pump body to achieve the correct slack. Then remove the 4 pump securing bolts, apply thread lock and torque to 15ft lbs
- Wipe some STP over the chain and sprockets

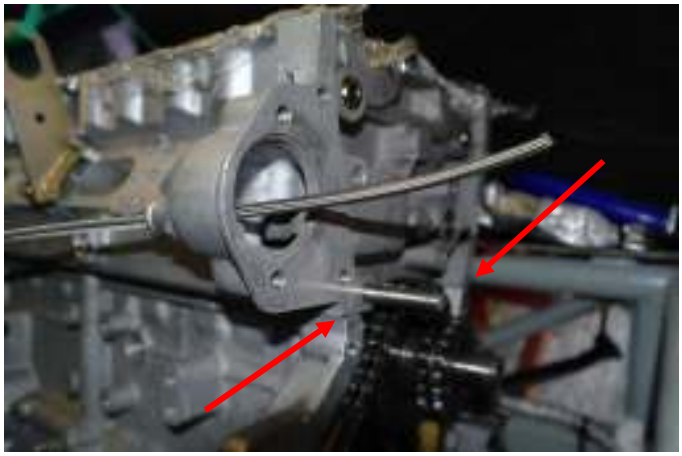
4.10 Timing Cover

Aligning the timing cover over all the various shafts and dowels is quite tricky with the engine in-situ. Have a practice first!

I found a couple of problems getting it to fit easily

- The end of the upper tensioner shaft would snag on the machined hole in the casting and stop it moving the final 10mm or so. Remedy: I opened up the drilling in the cover by 1mm (it only server as a clearance not a support)
- The upper tensioner that protrudes through the cover was a very tight fit and getting it started through the cover hole was tricky. Remedy: I put a small chamfer on the inner edge of the drilling in the cover to help the shaft through
- Getting the half time shaft into its drilling was very fussy. Remedy: Just persevere
- Keeping the oil seal spring in place around the auxiliary shaft needed care on assembly (it would tend to pop out when starting to stretch over the shaft if there was any significant movement of the cover back off the shaft). Remedy: I made an insertion guide around the shaft by taping a thin piece of stiff plastic sheet around the shaft to form a shallow tapered cone making it much easier to slide the oil seal over than the rough end of the shaft

Something to watch out for prior to refitting is the two points where the head gasket pokes out at the interface between head and block.



I used a very sharp knife to remove the gasket to get it flush with the faces (don't let any bits fall into the timing chest! The gasket has metal layers in it)

I also chose to fabricate a proper gasket for the timing cover. That said I still used a very small amount of 598 to seal it and I pre-fixed it with 598 to the cover clamped to a nice flat surface.

Make sure the sealing o-ring is present on the lower duplex chain tensioner (lube it a bit with STP). You may want to replace this seal but overall its fairly non-critical as there is no oil pressure in the timing chest.

Don't forget the two dowels on re-fitting and be ready to work fast to get all those bolts in a torqued up before the sealant cures. Tighten the bolts progressively and if you're using a gasket too I suggest a re-tighten after a couple of hours to compensate the compression of the material. Torque to 15ft lbs.

4.11 Oil System

Refit the various oil pipes, oil cooler and the header tank. If you have opted for the additional oil feed to the back of the head, the pictures below show how I spurred it off the oil pressure sender block using a pair of 90° banjo oil connections and a double banjo bolt. I used the Goodridge style called Series 600-3 available from folks like Merlin Motorsports in the UK.

The upper pipe runs to the back of the head and the lower one provides the oil flow from the supply on the engine block just below the alternator (the normal one that runs to the sender block).

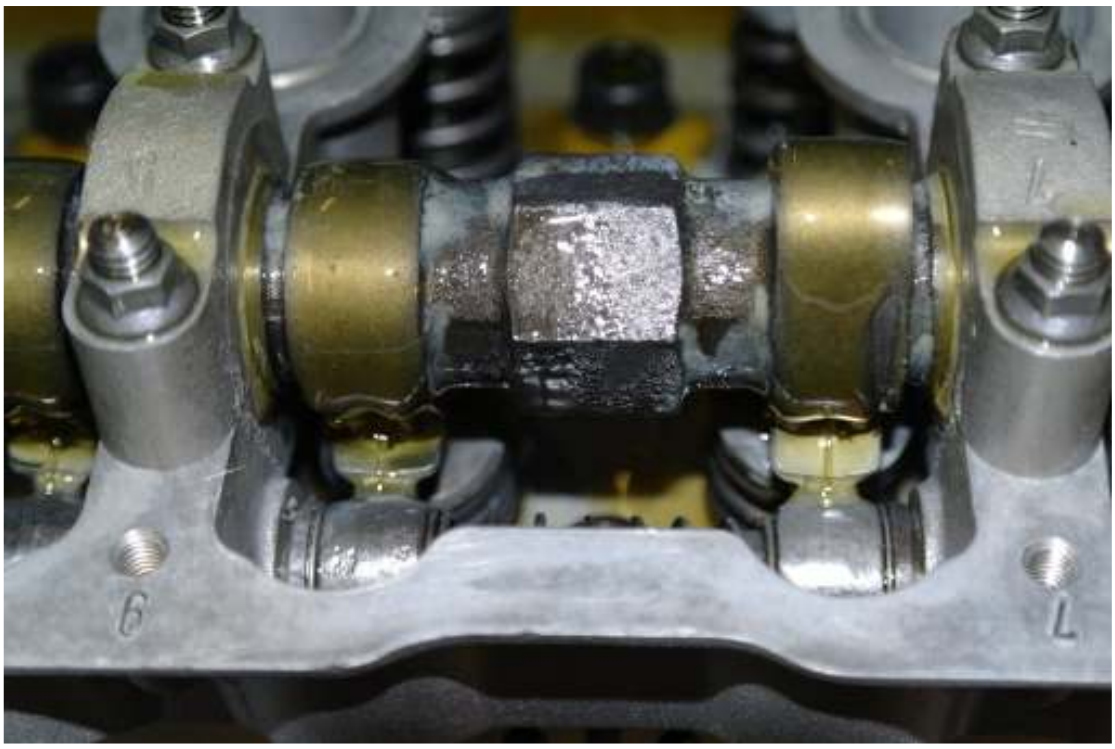
4.12 Testing

Before going any further I chose to run the engine using the starter motor with a full charge of new fully synthetic oil, a new filter and with the CAM cover off so I could watch the proceedings.

To do this I used jump leads directly to the starter motor (the leads from the loom are *not* connected to the starter at all). You'll need to enable the starter by connecting 12V to the small 3rd terminal to pull the solenoid in.

The jump leads and croc clips will *get very hot*. You have been warned.
Also make sure you haven't left the engine rotation spanner in place!

It's also a good chance to see the new finger followers squirting jets of oil onto the CAM lobes (despite the meagre 100 to 200 rpm crank speed…a good sign!).



I let the engine run for several minutes to circulate the oil fully. After this I drained the oil completely and discarded it, together with the filter.

4.13 Valve Clearances

Before the final stages of reassembly, the valve clearances need to be checked. I would suggest you do this even if they were done as part of the head refurb.

Start with the inlet CAM.

- Turn the engine until the #1 inlet lobes point up so that the #1 valves are fully closed
- Push a feeler gauge between the cam lobe and the follower's face
- Measurement is the thickness of gauge that "scuffs" significantly on insertion
- Record the measurement
- Repeat for all 6 inlet cylinder lobe pairs
- Target is 6 to 8 thou

Do the same for the exhaust CAM. Target is 10 to 12 thou.

I aimed for the middle-bottom of the range (a "tight" 7 and 11) with the assumption that during bedding-in there would probably be a ½ thou-or-so increase.

If any of the shims need changing, they can be removed by compressing the valve using a very large screw driver as a lever between the follower shaft and the valve spring pressure disc. With the valve pressed down, *carefully* remove the shim with a magnetic pick up. You might want to plug the oil returns first as shown in 3.8.

If you can swap shims around to solve any issue then great. If some of the shims are too thick (gap too small) then remove the required thickness using 180 grit wet-n-dry, being careful to rotate the shim regularly as you press down and rub with the paper on a hard flat surface. Use water to lube. Clean thoroughly afterwards! When re-inserting the shim, be sure it's squarely seated in the cup (you don't want it popping out later).

4.14 Harmonic Damper Refitting

You'll need to drop the engine again. Refer to 3.3.

Apply a smear of STP to the crank shaft and to the oil seal lip that rubs on the damper's skirt.

Fitting it should be easy, but the distance I could get the damper onto the crank shaft was not enough to allow the crank bolt to start to push the damper on.

I resorted to honing the inside of the damper with a small flap wheel on a dremel. Probably only removed ½ a thou but it worked just enough to get the bolt started. Then tighten away until the damper is about 8 to 10 mm ish away from the timing cover as a guide as shown below. The bolt will fully press the damper so that it holds all the crank sprockets in compression so there's no danger of pushing it on too far.

Before you commit the final tightening of the crank bolt, you'll need to take it right out, with its thrust washer and apply a thin bead of 598 to the back face of the washer (the face that presses to the damper front face) and to the inside of the bolt head. This is to ensure no oil seeps past from the hollow crank shaft. Re-insert the bolt and washer and fully tighten to 125ft lbs. I used a cut down 22mm AF socket to allow use of a torque wrench with ½" drive.

4.15 Chain Tensioning

There are two tensioners to adjust.

The upper one should be done before the CAM cover goes on so that you can feel the slack in the top duplex chain between the CAM sprockets. The upper tensioner has a small o-ring to fit over the shaft, then a large thrust washer, and small thrust washer and a lock nut.

- Rotate the engine by hand to get the chain "slack" distributed evenly (probably already is)
- Turn the upper adjuster with an 8mm AF spanner to tighten it to "moderate" torque
- Rock the engine forward a back and feel the slack in the upper run under firm thumb pressure
- Aim for about 1mm downward deflection in the middle. Don't over tighten
- Test several times after engine rotation to make sure this is consistent Lock the adjuster once you are happy

The lower adjuster is subtly different.

- Slip the round lock plate onto the shaft
- Turn with a spanner until it is "reasonably tight" against the chain inside
- Note the holes in the plate relative to the threaded M6 hole in the cover. Flip the plate over to get closer by ½ hole if needed. Try to get one of the plate hole close to lined up with this cover hole
- Now loosen the shaft by one full hole on the plate (as close as possible erring somewhat to the tighter side)
- Thread on the large lock nut and tighten against the plate with the shaft held in place with the spanner. Make sure a flat on this nut in central to the lock plate hole chosen
- Screw in the cap head M6 with some thread lock

I found that if I tightened the large lock nut onto the plate, it became a fantastic way to transmit all the timing chain noise into the timing cover and boy, was it noisy. I elected to NOT tighten the lock nut but instead

used thread lock and simply run the nut up finger tight until flush with the plate in the correct alignment, then fitted the M6 lock screw.

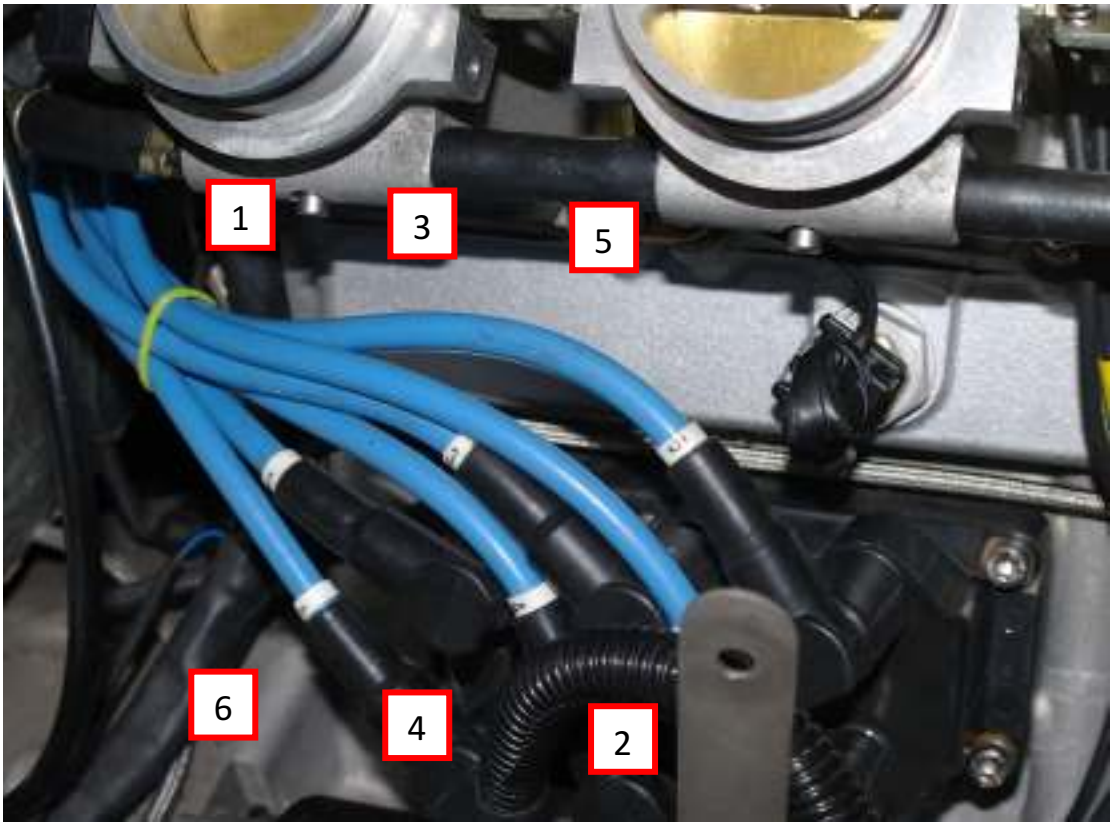
4.16 CAM Cover

I really struggled to get the CAM cover to seal as it got up to temperature. After 2 or 3 attempts I realised I was missing something; the grub screws holding the follower shafts had NOT been thread locked (strictly not needed because they live with an M6 bolt above them in the same hole…but good practice). However, the new oil feed passes HP oil directly into the exhaust follower shaft just 20mm away from this grub screw that has a direct path into the shaft. No wonder it leaked when the oil got thin.

So I thread locked the grub screws and for “belt and braces” I converted the back two M6 cover bolts to studs instead and thread clocked those into the head too. I made a cardboard gasket too: totally sealed without the use of 598!

4.17 Refitting Everything Else

This is where I go slightly "Haines" and say refitting is the reverse of disassembly; for all the other ancillaries that is ☺
Don't forget the plug leads have a quirky order:



Hopefully you are familiar with the process of refitting the throttle bodies and balancing them. Fitting them is easy enough but my advice is *don't* use Blue Hylomar. It's rubbish for this task. I find it vanishes within a few miles and starts to allow air in around the throttle flanges. Use automotive petrol tolerant RTV (the red stuff normally, despite most saying not suitable for permanent immersion in petrol these seem to be OK for gaskets where the fuel is a vapour). Let it cure 24 hours before use.

BTW: I didn't clean off the "dress up" silver paint that was used during the head refurb, but it seems to have sealed just fine nonetheless.

Right at this point with a rebuild, there is a slight moment of dilemma; to run the engine safely you really want to balance the throttles. But to balance the throttles you need to run the engine and let it idle. This is

NOT a good idea with a new set of CAM shafts and followers. See 5. My advice is to follow the process below down to the point where you start and reset the adaptives and pots for the first time. Assuming the engine is running reasonably OK and not coughing, popping and spluttering then a short run-in drive prior to proper throttle balancing seems the lesser of all evils. The biggest risk is over-lean mix damaging the cats. If the engine is popping and spitting through the throttles, DON'T drive it. Try to reduce the airflow (close down the butterflies further).

The quick version of how to balance the throttles goes like this:

- Seal the bodies to the head with RTV and allow to cure
- Reassemble all the throttle linkages, balance springs, adjuster screws, vacuum pipes, sensor pots etc etc etc. Don't connect the throttle cable (no point yet)
- Check for smooth operation of all butterflies; no stickiness allowed
- Undo all the balance screws and main idle adjuster so that ALL butterflies are totally shut
- Tighten each balance screw until it *just* contacts its neighbour's linkage arm with the butterfly still fully shut
- Check for adjuster screw "slop" by actuation of the main throttle arm and look critically for initial movement of *all* butterflies at the same exact point for a minute input movement. If any are "lazy" tighten their adjuster screw a bit
- From here, tighten the main idle screw by say a $1/8^{th}$ turn. This will open all the butterflies a small amount
- Start the engine with a laptop and the diagnostics running
- Immediately reset the throttle pots and adaptive maps (quick as you can in case its idling way too fast)
- Get it to the point where its idling reasonably OK by adjusting the main throttle position adjuster on #3 to raise the speed a little if needed and reset the pots again
- Now, start at #3. Measure the air flow in #3 body at idle with a synchrometer. Note the reading (hopefully between 5 and 8 ft^3/min)
- Now measure #2. Turn its adjuster screw to try to match #3
- Reset the pots and adaptives again
- Now measure #1. Turn its adjuster screw to try and match #3
- Reset the pots and adaptives again

- Now measure #4. Turn the adjuster screw on #3's arm to try and match #3
- Repeat for #5 and #6
- The fun part is that of course all these bodies are slaved off their neighbour so you can only adjust from centre outwards. If at any point one of the bodies flows can't be reduced enough, you'll have to go back to #3 and reduce that one to affect a reduction in all the bodies and start all over again
- Once you have balanced all the bodies to about the same value (within 1 ft^3/min) you can then set the overall correct flow with the main adjuster on #3 (aka the idle speed adjuster, which it isn't really). Aim for a flow of around 6 to 7 ft^3/min at an idle speed of 800 to 900 rpm
- Make sure the adjuster screws are locked off
- Once the engine is fully warmed up, reset the throttles and adaptives again and recheck all the flows again. Readjust as required

5 Testing and Running In

New CAM shafts don't like running at constant speed for any length of time while they run in. But of course, you have to fire the car up and make a basic check for fluid leaks *and* to purge the water system of air. For this, you need to run up to temperature and so a few minutes of idling and manual revving is needed. Be very careful with the temperature BTW. When charging the system with water, there will be large air pockets until the thermostat opens. You might want to consider introducing water into the upper pipes beyond the thermostat before running up. Alternatively, as soon as you feel the short pipe to the header tank get hot, switch off the engine and repeatedly squish the large lower pipe to the radiator on the air box side to force the water up through the radiator and allow the air to escape via the header tank. Keep topping up the header as you do this. It took me several goes to get all the water in.

The advice from CAM shaft manufactures seems to be pretty consistent; drive the car briskly and normally with plenty of varying revs but don't rev too high (max of 4 to 5K). Do this several times to build heat cycles into the CAM shafts and allow them to bed-in over a range of operating conditions.

Avoid labouring low revs too.

I've chosen to run my engine now on Semi-synthetic 15W50. It seems like a good compromise for this engine.

After the first run, check for leaks of course. I had some issues with the main oil pipes not quite sealing and as previously mentioned the CAM cover had a sting in its tail. But once all that was overcome, I had no coolant leaks or oil leaks whatsoever.

It's running fine at the time of writing (like a different engine in fact!) with about 1K miles covered so far. A quick spot check of a couple of valve clearances has shown minimal change and nice signs of polished CAM lobes where the parkerizing has worn off.

Oh, and if you fitted exhaust wrap get ready for some SERIOUS smoke for 10 to 15 mins after starting (its horrible acrid grey smoke)

6 Other Stuff

6.1 Honing the Cylinder Bores

My bores were fairly glazed. There was no evidence of a ridge at the top of the cylinder which was encouraging. So I chose to re-hone the bores using a special device called a Flex-hone. I used the 105mm size with 180 grit SC.

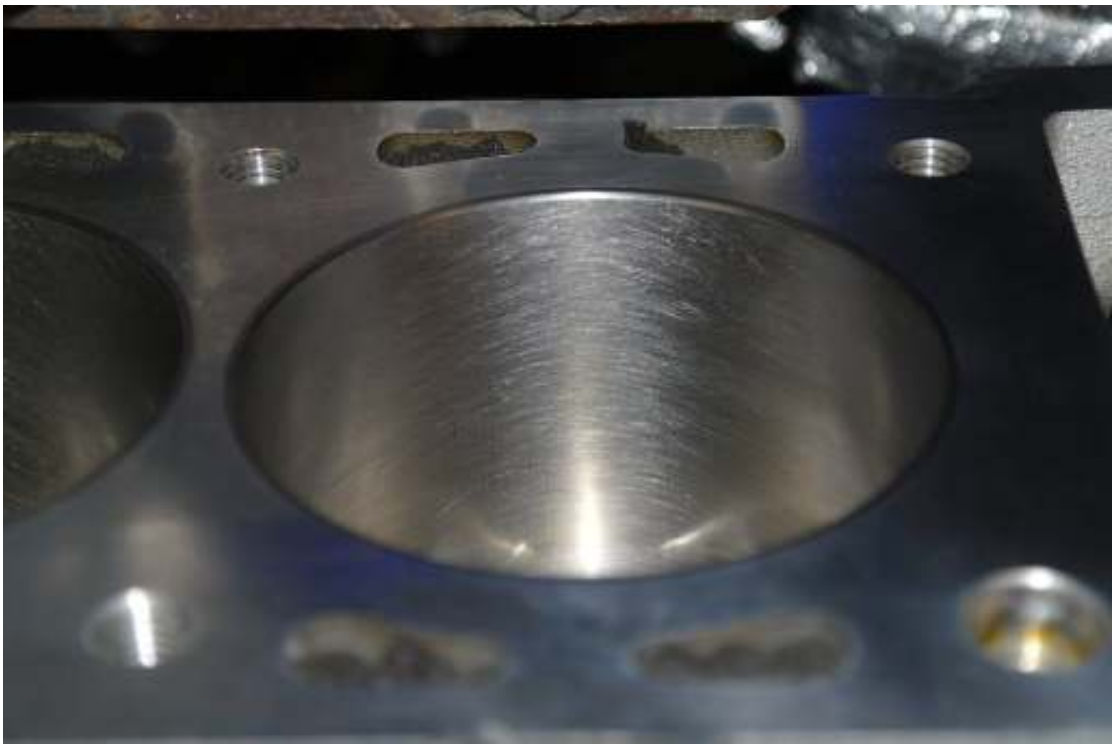
Just after I decked the block, having cleaned everything up meticulously, I then made it all messy again.

Pushing each piston to the bottom of its stroke and with everything sealed, covered and plugged as before, and with the piston crown covers and grease packing in place, I attacked each bore. A slow electric drill (really very slow!) and a fast up down stroke (really very fast!) for 40 strokes did the job beautifully. I used a small amount of 3-in-1 oil to aid the cut.

After each bore was done, I cleaned it, cleaned it and then cleaned it some more. The silicon carbide from the tool gets *everywhere* ! Kitchen roll and white spirit until the bore left absolutely zero residue when wiped with a clean white cloth. The grease packing caught all the stuff that would otherwise get down the sides of the piston. This could be scooped out before moving the piston.

The fact that only the top 2-3 inches gets a thorough honing is fine, as this is the bit that does all the work during the power stroke.

Some before and after photos:

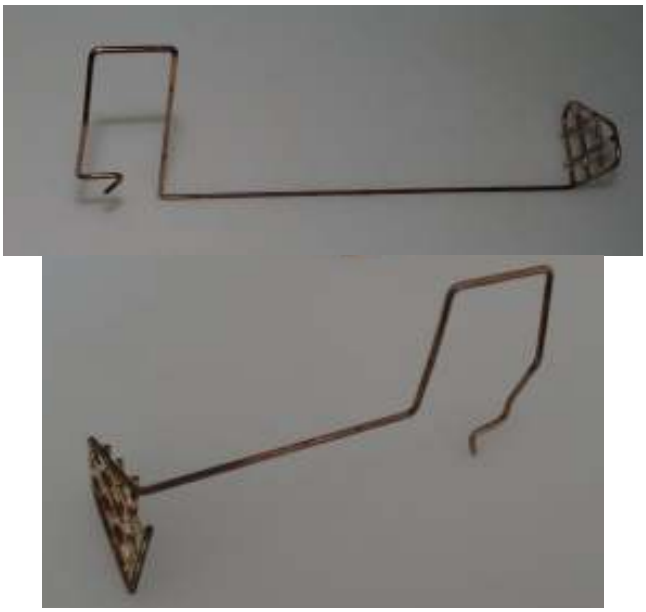


Running in re-honed bores needs a slightly different approach to the CAMs btw: Don't "nanny" the engine during run-in and include 4 or 5 *full* load applications immediately when first warm on first outing revving from 2K to 4 to 5K each time (i.e. 4th gear at 25 ish mph, floor it up to 60 to 70ish); country road required close to your home ☺ or a *very* quite motorway)

6.2 Shim Catchers

There are various S6 owners who've had the nightmare of a shim popping out and finding its way down to the LP oil pump. Once jammed in there, untold damage can occur.

The solution seems simple; catch them in the head. To this end I fabricated a pair of shim catchers that push and clip into place to put a mesh in front of each oil return. Sorry, no drawings ☹ These were one-offs made to suit from weld wire with the cross pieces brazed into place.



Appendix A: Bill of Materials

Item	Qty	Supplier
Refurbed head	1	Rnd engineering
Head gasket (TVR E6026 RGL)	1	Racing Green
Oil feed kit	1	Racing Green
Oil pipe parts for sender & feed	various	Merlin Motorsports
Oil pump rotor inner	1	Racing Green
Oil pump rotor outer	1	Racing Green
Water pump seals	2	Racing Green
Crank front seal	1	Racing Green
Tensioner seals	2	Racing Green
Tensioner	1	Racing Green
Belts (alt and psp)	2	eriks
HP Oil pipe pump to cooler	1	Racing Green
Simplex chain for HP oil pump	1	Racing Green
Simplex chain for LP oil pump	1	Racing Green
Head bolts	12+2	Racing Green
Gasket paper	1	ebay
Oil tank boss gasket	1	Racing Green
Heat shield	1	ebay
Exhaust wrap	2x10m	ebay
Various ss bolts	1	Boltmeup/ebay
Re-plating parts	various	Calmac gosport
Oil 5L	3	local motor factors
Oil filter	2	local motor factors
Flexhone	1	ebay

For those wanting to make up their own oil pipes, I used 600-3 series brake hose (s/s braided with white nylon inner). The threads to use are 1/8th BSP (but check first), might be different of other models.