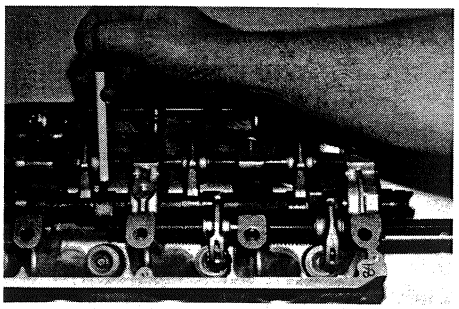
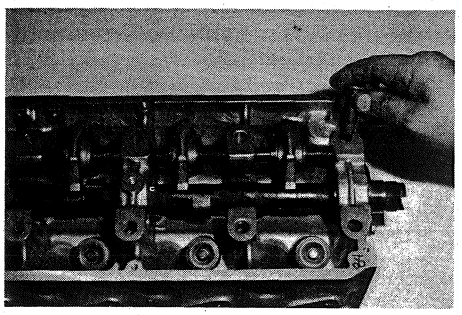


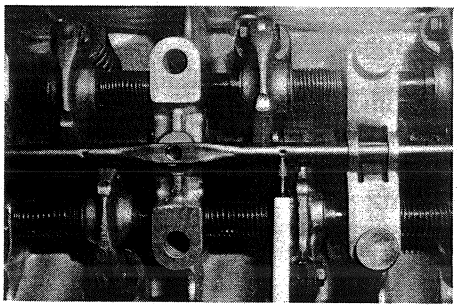
30. Insert proper shaft and install assemblies for sections 1 & 2.
■ Rotate cam until #3 lobe is as shown. ■ Finish assembly of section 3. ■ Assemble both rear shafts and their sections.

ALL CAMSHAFTS

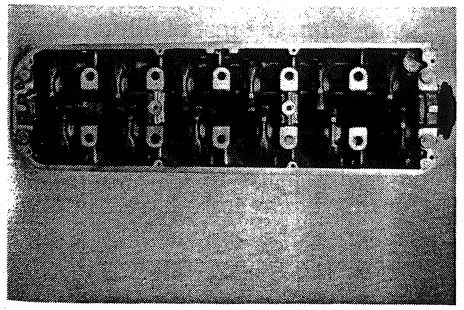
■ Finally, rotate cam to TDC #1, with both lobes 'down'.
■ Remount rear cover plate using new gasket and sealant.



31. When all head bolt slots align with all bolt holes, insert one bolt for each of four shafts to anchor shafts.
■ Bolt cam in position at retaining plate with 6mm bolts. ■ Reinstall sprocket drive flange, lock washer and nut. ■ Then install all "c" clips, rotating camshaft as necessary.



32. Place oil sprayer bar into position, then turn upside down to:
■ Insure that oil holes locate between the intake and exhaust lobes for each cylinder (If the oil sprayer bar is installed incorrectly, only the intake cam lobes will receive oil). ■ Invert bar and bolt to head, noting special "banjo" bolts (with 12mm heads) and sealing washers (aluminum or copper) for above and below the bar.



33. Fully assembled head.

CAUTION: For those of you who are stopping here, important Head to Block assembly info and related procedures will be covered in the JUNE '87 article.

Shade Tree Topics

by Jim Rowe and Jim Blanton

ENGINE BLOCK DISASSEMBLY EVALUATION PREPARATION

Engine Block [Lower End] Disassembly

The strength and endurance of your engine is centered in the lower unit. Accessories and even cylinder heads come and go during 100,000 mile intervals, but the block, if rebuilt and maintained correctly, will persevere.

As you dismantle, its relatively straightforward design might fool you into taking the block's simplicity for granted and thereby overlooking that which is more important than the simple separation of pieces, namely, recognizing the engine's *Assembly Code.* This code is so fundamentally crucial that anything short of strict abidance will result in disaster. It is as follows:

ASSEMBLY CODE

- Main bearing saddles have one and only one correctly fitted bearing cap, each matched pair mating "locks-to-locks" ie. (bearing lock tabs are on the same side).
- Connecting rods likewise have one and only one correctly fitted rod cap, each matched pair mating "locks-away from-locks" ie. (bearing locks tabs are 180° apart.)
- Connecting rods are fitted such that the oil hole in the small end of the rod points toward the front of the block.
- The arrow on the top of the piston points toward the front of the block

Keeping these points in mind, let's begin by positioning the block upside-down. If you are on a flat surface instead of an engine stand, the front of the block will have to hang over the edge to avoid damaging the protruding timing chain guide

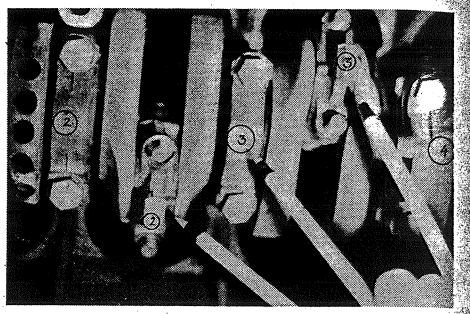
Oil Pan Remove pan bolts. Make sure none are hiding under the usual accumulation of dirt and grease. Note all missing, broken, stripped or otherwise unusable ones.
(6 cyl.) Unbolt power steering pump bracket from crankcase and pan.
(All) Drive something similar to a putty knife through the gasket at each corner of the pan to break what is oftentimes a very firm bond. Some coaxing with the dead blow hammer might be useful.

Rear Seal
Flange Remove both 6mm and 8mm bolts and tap on inside edge to slip it off the two alignment pins. Note relative position of the seal with respect to the flange lip.
Front Pulley Before removing, note any adjusting/mounting bracket(s) that will have to be in place *before* the pulley is reinstalled. Remove nut and warpy washer. This nut may take up to 200 ft. lbs. of torque on a 4 cylinder & up to 300 ft. lbs. on a 6 cylinder to break loose. Then wiggle the pulley back and forth to test for any looseness in the machined fit. It should require the use of a puller or at least some tapping with your composite hammer. Six cylinder engines use a harmonic balancer and need to be removed by using a special puller that uses two 8 mm bolts (approx. 80-100 mm long) that screw into the holes just off center of the harmonic balancer. (A harmonic balancer is an inner and outer pulley bonded together by rubber and is built this way to dampen out engine vibration from the crankshaft.) *Caution: do not use any removal method which might distort the pulley.*

Water Pump
(4 cyl) These bolts are the most likely to be corroded and are therefore the weakest. Work them back and forth and/or apply some heat from the torch while removing gingerly. We suggest replacing the 6mm ones and wire brushing the rest. Keep track of especially long 8mm bolts used to mount wrap-around a/c bracket.
(6 cyl) First remove engine "lift" bracket [6mm bolt is the longest of its size on the engine]. Again, the pump bolts will probably be corroded and should be replaced [except for the two studs].

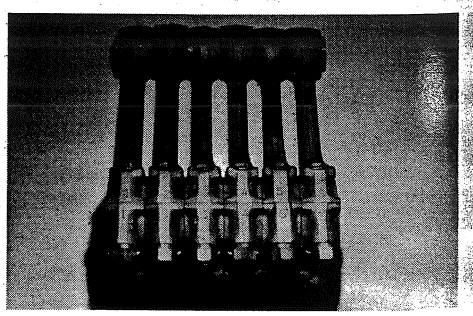
Front Cover Remove all 6mm and 8mm bolts then pry from the back until you've worked it off its alignment pins. Before it comes completely off, notice that the little arm at the top of the chain tensioner guide rail sits in the small oil cavity formed by the front cover casting and the block. Again, note relative position of the pulley seal [either flush with the front lip or against the seal stop on the back side of the cover.]

Timing Chain.
Tensioner & Guide Rails Remove and discard old chain [money well spent). Pry off "E" clips [3 — two of one size, one larger] and save in a safe place. Guide rail can be reused but replace tensioner rail if rubber is cracked, separating or badly grooved [more than .5mm].
Oil Pump Sprocket & Chain Loosen three 6mm bolts and slide sprocket off the shaft. Discard the pump chain as well and inspect crank sprocket for chipped or otherwise misshapen teeth.
Oil Pump
(4 cyl) Remove two 6mm bolts at rear pump support from the main bearing cap and safely store lock tab [pre-'77]. Unbolt front 8mm bolts and pry pump off of alignment pins. Don't misplace "O" ring for external oil return line or any shims underneath the pump.
(6 cyl) Remove two 6mm bolts at rear pump support from the main bearing cap and safely store lock tab [if any]. Unbolt remaining three 8mm bolts and pry pump off of alignment pins. Look for shims underneath the front bolts [long one] and matching shim [short one] under third bolt.



1. Before continuing, look for stamped numbers on the centers of the main bearing caps. Although difficult to read, all but the center [thrust] and "last" [rear] caps are numbered. The rod caps are numbered on one or the other of the sides where the bearing splits [through '74 only]. Later model rods have U distinguishing marks. *CAUTION:* IT IS IMPERATIVE THAT THE MAIN AND ROD CAPS ARE NUMBERED. IF THEY ARE NOT, OR IT IS UNCLEAR, YOU MUST NUMBER THEM WITH A NUMBER PUNCH SET OR CENTERPUNCH, [AS SHOWN].

Piston/Connecting Rod Remove all the nuts on all of the connecting rods. Now position the block on its side and rotate the crankshaft until one pair of pistons is at the bottom of its stroke. Use the dead blow hammer to tap alternately on the ends of one piston's rod bolts. When the rod and cap have separated, slip the cap off the bolts carefully noting on which side of the cap the bearing lock appears. Now look at the rod and locate its bearing lock. THE ROD BEARING LOCKS SHOULD BE 180 DEGREES APART. Before removing the rod and piston, note the relative position of the rod. THE VISIBLE OILING HOLE IN THE SMALL END OF THE ROD POINTS TOWARD THE FRONT OF THE ENGINE. Now tap the rod and piston completely out of the cylinder, pry the bearing shells from both halves and mate the cap back to the rod — LOCKS AWAY FROM LOCKS.



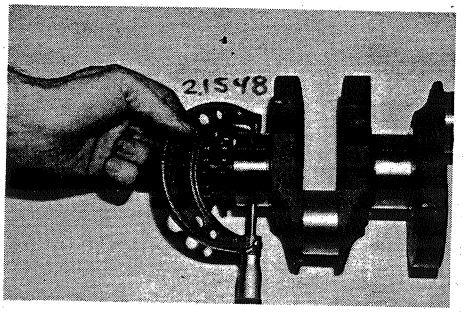
2. Before removing any other pistons, use your number punch to mark one side of the big end of the rod. Stamp both the rod and its cap with the number of the cylinder [numbered from the front of the engine]. Repeat this procedure for all the rods of the engine.

Main Bearing Caps/Crankshaft Now remove all the bolts securing the main bearing caps. Assured that they are legibly numbered, use a large pair of adjustable pliers and wiggle the caps back and forth until they dislodge. *Note that the main bearing locks of the cap and saddle are facing each other [locks to locks].* The final step in disassembly involves simply lifting the crankshaft out of the block.

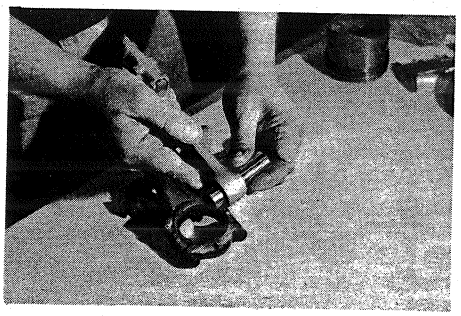
EVALUATION OF PARTS

Next we need to evaluate all these assorted pieces to determine what machining needs to be done. Whether you are going to perform the work yourself or rely on the local machine shop, the end result will depend on your judgement as to which of your "as is" *and* machined parts meet factory specifications. You are going to need the factory specs for your engine [from the BMW or Haynes manuals] and the following tools:

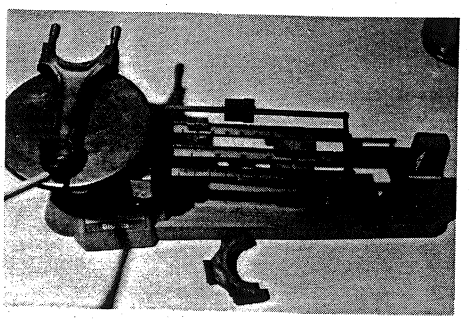
■ Set of micrometers ■ Set of snap gauges ■ Scale-accurate to one tenth of a gram ■ Feeler gauges ■ Precision Hone ■ Ball Hone ■ Die grinder



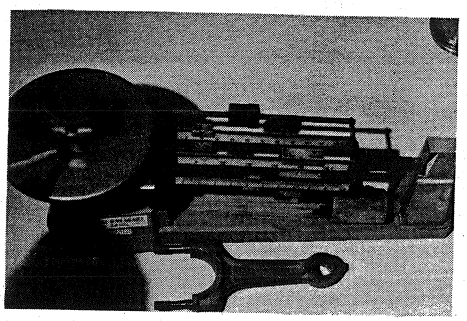
3. Measure the size of one of the main bearing journals, then lock the micrometer on this reading and rotate the micrometer 90 degrees and measure it again. The two readings should be identical (the micrometer should "drag" the same). If they are not you need not measure the remaining ones, for the journal is out of round and will have to be ground. However if they are alike compare the measurement you have obtained with your specs (wear tolerances ar provided). *The example shown is that of a crankshaft ground to .010 undersize.* Repeat this procedure for all the main and rod journals. If any one of the two groups is not within specs, or there are journal surface imperfections the crank had better go into the machine shop pile. If all is well to this point, there is one more measurement to check. Place both halves of the new center main bearing — the one with the thrust surfaces on both sides — around the center main journal. Slide them both to one side of the journal and slip a feeler gauge between the bearing and the other side. Find the blade that will just fit with the slightest amount of drag and compare this measurement with the specs. As a rule if there is more than a .006″ gap, your machinist will have to repair this as well. Everything still within specs? Just for fun, suspend the crank in the air and tap it with a metal hammer. There should be a sustained "ring" with lots of overtones like a triangle. If you hear an abrupt "clank" or "thump", you could have fractures.



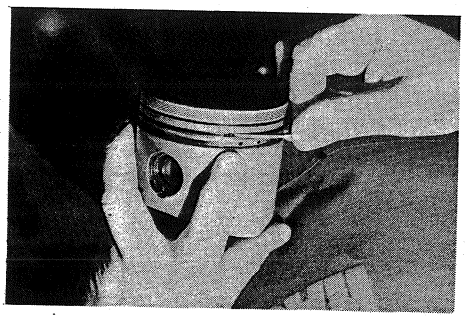
4. If you haven't already, separate the pistons from the connecting rods by removing the circlip on one end of the pin and tapping the wrist pin completely out of the piston. Use some solvent to clean and dry the small end bushing of all the rods and one wrist pin. One by one slip the pin into each rod and wiggle the pin from side to side to feel for any movement at all. A clearance of .0004″ (yes that's ten-thousandths) is easily felt and usually .0003″ can be as well although it is very slight. Ideally the fit should be .0002″, which can't be felt by wiggling, should your wrist pin bushings feel sloppy. BMW will not have these bushings but VW Bug ones are close enough for your machinist.



5. Separate the caps from the rods — if and only if they have been properly numbered — and record the weight of each. Weigh the *lightest* rod again and remove it but leave the scale set to its weight. Now grind on the "nub" of each of the remaining rods [where the pen is pointing] until all weigh within one gram of the lightest. Usually the Factory has them within 5 to 10 grams of the lightest, so it shouldn't require a great deal of grinding.

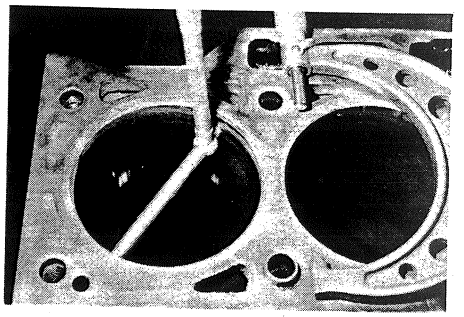


6. Repeat the above procedure for the rod caps and if necessary grind on its bottom "nub".

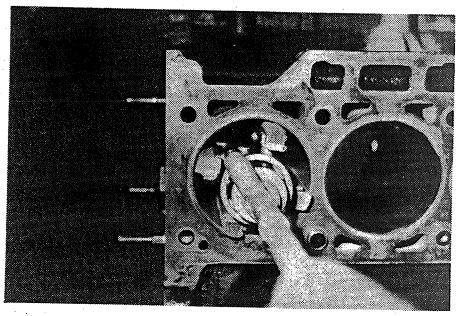


7. Remove the old rings from your pistons and use them to scrape the carbon buildup out of the ring lands. Avoid removing any aluminum in the process. Most of the wear occurs at the top ring land so install a *new* top ring and use your feeler gauges to determine the clearance left between the top of the ring and top of the ring land. If your measurements are greater than the factory tolerances plus .001″, you would be wise to replace the pistons.

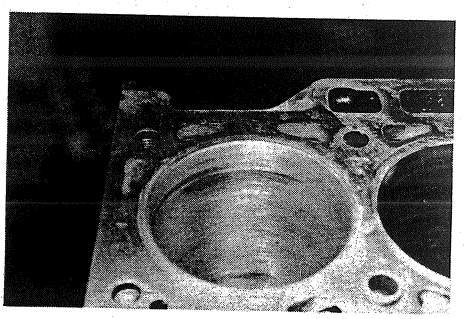
8. If the ring lands are acceptable, weigh each of the pistons to locate the lightest one. Set the scale on this weight and use the die grinder to remove sufficient metal to match the weight of the lightest piston to the nearest tenth of a gram. Grind on the lip along the inside circumference of the piston (where pen is pointing).



9. Clean the oil and carbon from the cylinders and the top edge of the bore for a ridge. As a rule German castings don't wear so much as to leave a ridge, but if your finger nail catches on one you should consider boring to fit oversized pistons (especially if your pistons are borderline or not reusable anyway). With the appropriate size micrometer, measure the diameter of each piston from one side of the skirt to the other at a point about halfway between the bottom of the wrist pin hole and the bottom edge of the skirt. Then, using a snap gauge, measure each of the cylinders at approximately the same point you measured the piston diameter if the piston was at the top of its stroke. The difference in these two measurements represents the piston-to-cylinder clearance and should not exceed .003″. If it does have the block bored for oversized pistons.

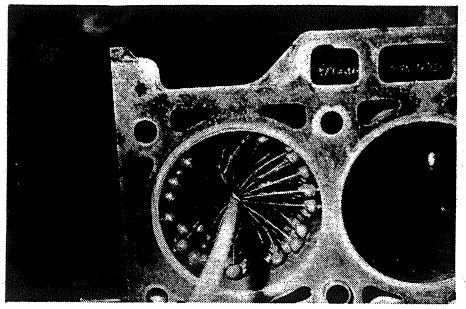


10. The maximum acceptable piston/cylinder clearance is .004″. Admittedly this is precious little to work with since new engine clearance is .0015″ and honing usually removes an additional .001″. However quite frequently high mileage, well maintained engines can fall within these tolerances after they have been rehoned. If yours is one of these, use the precision hone to initially resurface the cylinder walls.



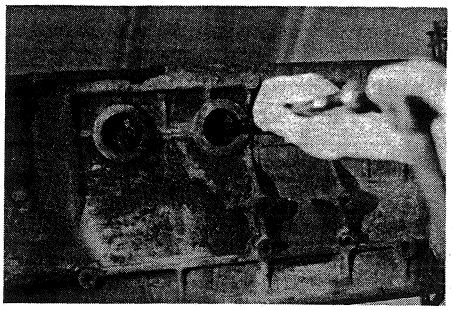
11. The first few passes will dress most of the cylinder wall with exception of the typical low spots at the top and (frequently) the bottom of the piston rings' travel. It is not necessary to completely remove thes low spots, but only to prevent them from totally encircling the cylinder (as shown). Also ideal cross-hatching at between 45 and 60 degrees from horizontal.

Continued

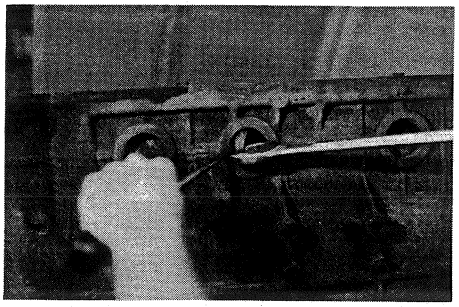


12. Next use the ball hone briefly just to "soften" the rougher texture left by the precision hone. When finished, once again measure the cylinder wall bore and verify that it is no more than .004" larger than the diameter of the piston.

ADDITIONAL PREPARATION

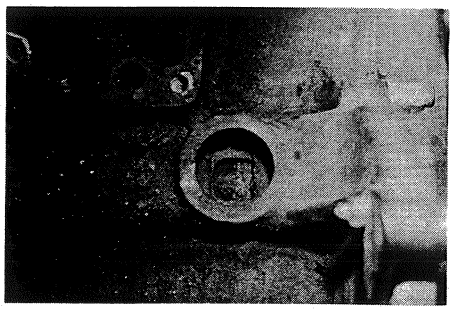


13. Since the following procedures require removal of some of the freeze plugs, it might be a good idea to remove them all. If nothing else it will facilitate the cleaning of the block at the machine shop. Use a large screwdriver or rod and hammer to force the plug *into* the block.

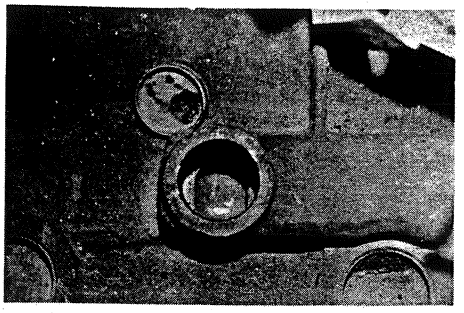


14. Now simultaneously twist the plug with the screwdriver and pry it out with a large open end wrench. Sometimes they are stubborn, be tough.

SIX CYLINDER



15. When all the plugs have been removed, compare the two plug hole that are located in the coolant galley directly behind the water pump mounting flange. Coolant from the pump travels through this gallery and is diverted into these two smaller, more restrictive ports into the cylinder sleeve chamber. As a rule 6 cylinder engines run hottest in the middle of the block, which is evidenced by the frequency of center combustion chamber cracks in 6 cylinder heads. For this reason we suggest you do the following.



16. Enlarge the inner port of the plug hole at the back of the coolant galley with your die grinder. Increase the size of this hole by about 50% to 75% to force more water circulation to the center and back of the engine block.

17. At the front of this same coolant galley where it meets the water pump flange is another restriction caused by some of the residual casting material. Just where the spiraling water passage feeds the galley there is a raised lip and an abruptly sharp bend. Once again, use the die grinder to remove the lip and smooth the bend into a more gradual curve to promote maximum coolant flow.

A final word:

We must emphasize the importance, make that the absolute necessity, of not compromising the bottom end. It is the focal point of any notion of longevity and dependability in an engine. For this reason you, the rebuilder, have the added responsibility of double-checking the machinist as well as yourself. Check the crank journal size, wrist pin bushing and piston/cylinder clearances when the machining is completed. Furthermore, if you're using new oversized pistons, verify that they conform to factory specs, for cylinder wall clearance and balance. Sure, everyone will stand behind their part and/or workmanship, but you will be the one doing the work when it has to be redone. Remember — *assume nothing!* (Next month we'll put the "som-beech" together!

Captain Says

Usually when we think of learning, we think of that stiff/dry text book type education that we used to get in school. Gateway Tech uses a relaxed format for technical exchange. It's a fun way to learn about what makes your BMW tick.

In addition to hearing a great slate of speakers, you'll have a chance to visit with the Area Tech Representatives and National Officers. You'll hear talks on everything from turbos to suspension and from radar to the nuts and bolts of car repair.

I've had an ear on the inside planning of this year's Gateway Tech and I'll just say that Paul Johnson (event Chairman) and the St. Louis Chapter have one hot event planned. So aim yourself in the direction of the Gateway Arch in St. Louis and on March 21 we hope to visit-meet-see you there.

Jim Rowe and Jim Blanton

Shade Tree Topics

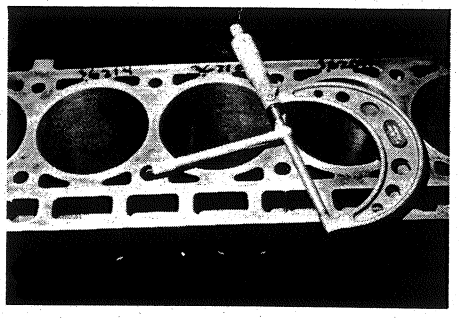
ENGINE REBUILDING
Part V
Engine Assembly

by Jim Rowe and Jim Blanton

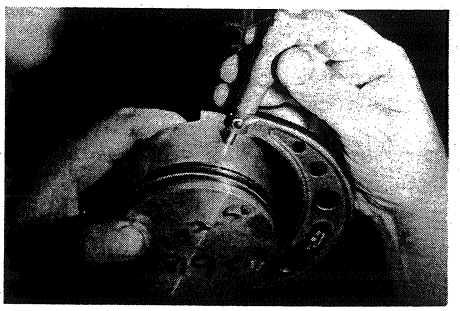
This is it! We are now ready to assemble the lower unit — the foundation of our engine. At this time, more than any other, it is imperative that we check and double-check everything we use and every step we take. A small mistake here could be devastating, so let's get it right the first time.

Note — In the following procedures we use a micrometer and snap gauge set to figure clearances. If you are uncomfortable using either one, we suggest you use Plasti-gauge for measuring bearing clearances and feeler gauges for measuring piston-to-cylinder wall clearance, crankshaft end play and ring gap.

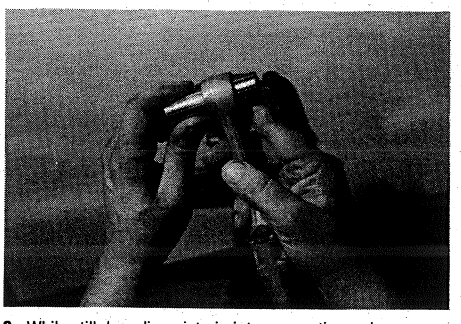
Preassembly Procedures — verifying parts dimensions and proper clearances



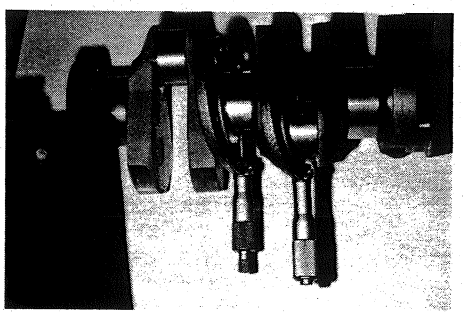
1. Remeasure cylinder bores with snap-gauge and 3″-4″ micrometer.
Write respective measurements next to cylinders.



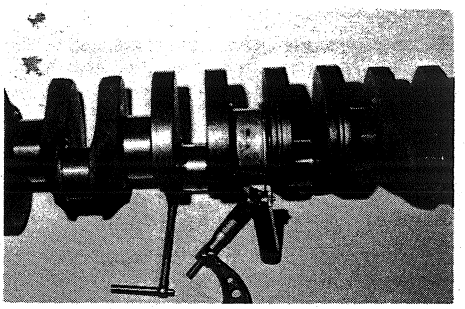
2. Use mic to measure piston diameter (perpendicular to wrist pin).
Match pistons and cylinders to get the tightest fit for all.
Ideal clearance is 0015″-.002″, but not more than .004″.



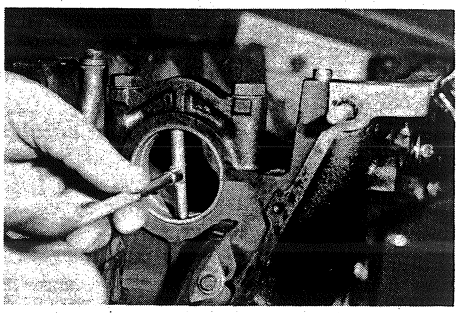
3. While still dry, slip wrist pin into connecting rod.
Try to wiggle the pin 90 degrees to its axis.
If there is *any movement at all*, it will have to be rebushed (even if you are measuring a new bushing, machinists make mistakes too).
Pin clearance needs to be .0002″, any wider and you will feel side-to-side movement.



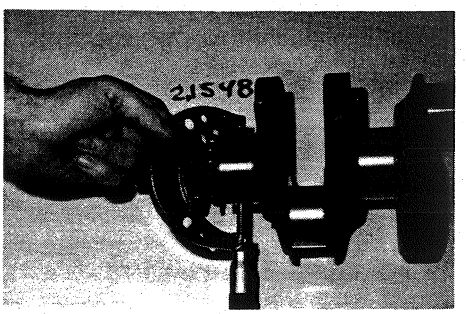
4. Use your 2″-3″ mic to measure all of the main bearing journals, and the 1″-2″ one for measuring the rod journals. Whether standard or ground undersized, compare measurements with factory specs to verify all are within tolerances (some machine shops purposely grind for extra clearance to "cover" themselves).



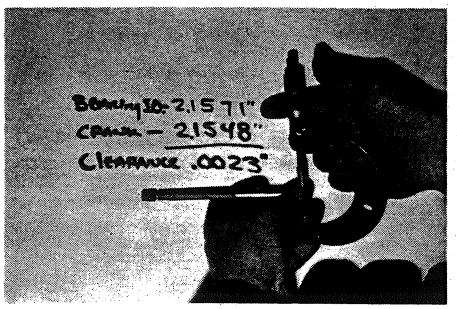
5. Place the middle (thrust) main bearing on the center main journal and use a feeler gauge to measure the distance between the side of the bearing and the crank.
This distance needs to measure between .003″ and .006″.



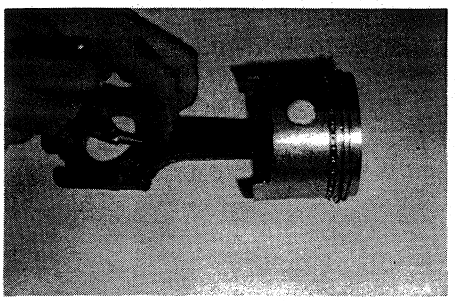
6. Find #1 main bearing cap and install a bearing shell into the cap and #1 saddle (make sure all pieces are clean and dry).
Position cap over saddle with bearing locks-to-locks, start both bolts and washers in by hand, tighten alternately until snug, then torque.
Use snap-gauge to measure opening diameter.



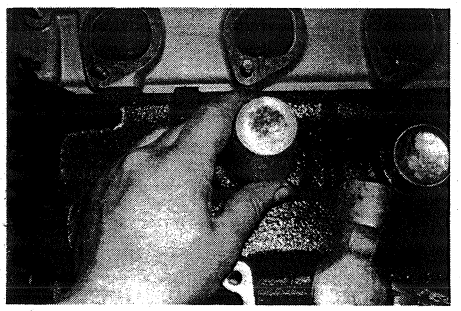
7. Once again, mic #1 main journal (example shown is a .010″ under crank).



8. The difference in the two measurements will represent the bearing clearance and it should meet factory specs (the general rule of thumb is .001″ clearance for every 1″ of journal diameter).

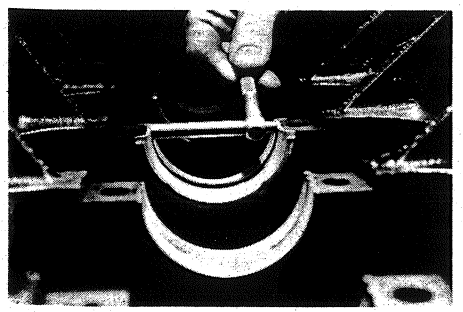


9. Likewise assemble a connecting rod (dry), complete with bearing shells and measure the shell inner diameter, the rod journal size and take their difference to find the clearance. Again, verify that these clearances conform to specs.

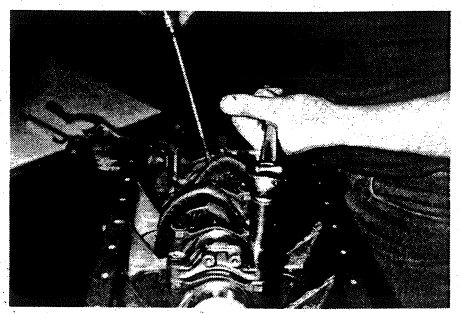


10. If you removed your freeze plugs earlier, now would be a good time to install the new ones.
Find a drift (e.g. large socket, aluminum dowel) that is large enough to align with the outer edge of the plug and with firm blows push it in until the lip edge is flush with the boss.

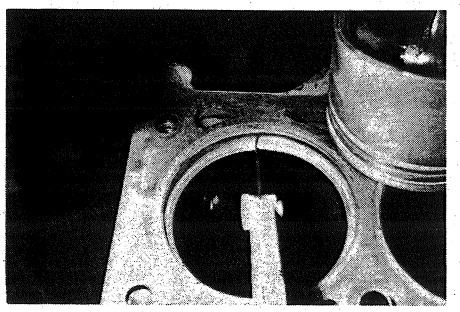
Assembly Procedures



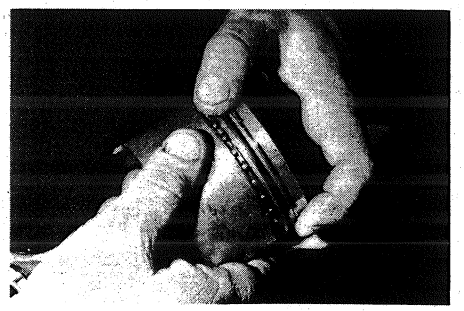
11. With the engine block upside down, install the remaining bearing shells in all the main bearing caps and saddles, making sure everything is clean and dry.
The thrust bearing must go into the center saddle and corresponding cap. Perform one last measurement, from tip to tip, of all shells to insure that all are of the same size (i.e., standard, .010″ under, .020″ under).



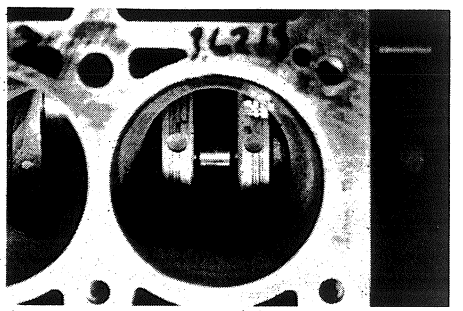
12. Spread a generous amount of white grease, or similar, on the shells in the block and lower the crank into position. Lube the bearings of the caps and place them correctly in position over their respective saddles.
Hand-start the cap bolts and washers (don't forget the additional oil pump support bracket where applicable) and alternately tighten until bolts are *nearly* snug.
Now lever the crankshaft, either forward or backward, to set the two halves of the thrust bearing exactly in line with each other (as shown). Once all bolts are snug, check that the crankshaft rotates freely then torque bolts to spec and once again verify easy rotation.
Install rear seal into rear seal flange, align with pins and bolt to the block.



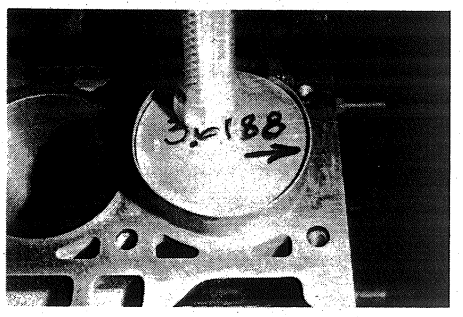
13. Rotate block to upright position, place the top piston ring into the largest of the cylinders and measure the ring gap with a feeler gauge.
To be correct the gap should be about .014″ (this measurement is not that critical). The general formula is .003″ per 1″ of cylinder bore.



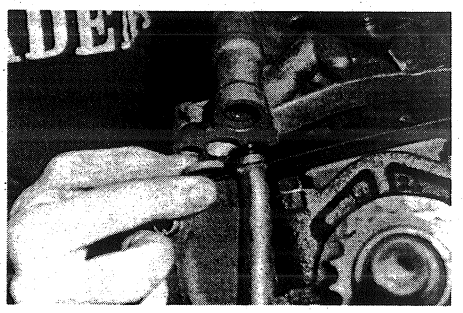
14. Install piston rings.
Locate the gaps of the four rings — two thin oil rings, two compression rings-over the wrist pin holes alternately 180 degrees apart.
If you haven't already, apply some grease to the wrist pins and rod bushings and assemble so that small oil hole in small end of rod and arrow on top of piston are on same side (don't forget both pin circlips).



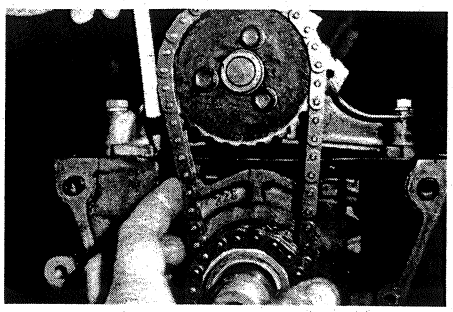
15. In preparation for installing pistons, rotate crank so that two rod journals are at bottom of their strokes.
Apply a generous amount of oil to the cylinder wall, piston rings and skirt as well as light grease to the rod bearings.



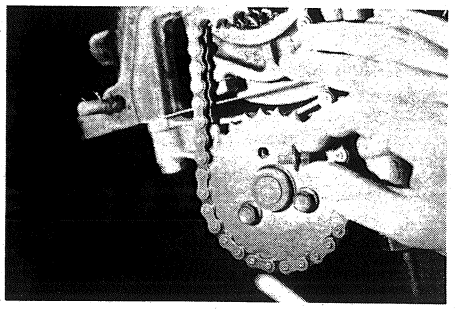
16. Using the appropriate sized ring compressor, tap the piston/rod into the cylinder taking care to point the arrow on the top of the piston towards the front of the engine.
Once the top of the piston is totally into the cylinder, reach around to the big end of the rod and guide it onto the rod journal while you continue tapping on the piston.
When the rod is seated, install the rod cap and nuts tightening alternately a little at a time until the nuts are snug.
Repeat for the other cylinder with its rod journal in position and then rotate the crank to both check that the crank moves freely and position another pair of rod journals at bottom-dead-center.
Continue until all piston/rods are installed and rod nuts snug. Finally, torque each pair of rod nuts to spec and after each one also move the crank to check freedom of movement.



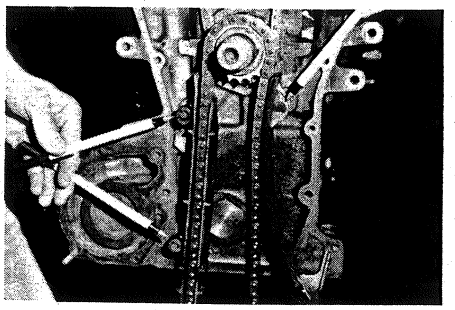
17. When the oil pump is placed in position, there should be a slight gap where the pump shims are, due to the "o" ring on the oil supply tube. You should feel the "o" ring compress slightly when you push the pump down against the block. This engine required an additional "o" ring for a proper seal.



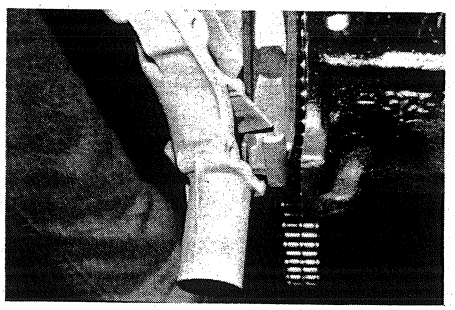
18. Mount the oil pump to the block making sure that the thin shims that were removed are back in place.
Next place your *new* oil pump chain on the crank sprocket, slip the pump sprocket into the chain and onto the pump shaft.
Attach the pump sprocket to the flange with the three 6mm bolts and measure the deflection in the oil pump chain. There should be a slight amount of chain movement without being taut or too sloppy (add or remove shims as necessary).



19. Once the right shims are chosen, remove the pump sprocket bolts and apply "Loctite" or something similar to retain the bolts.



20. Replace the timing chain guide and tension rails as shown.
Note that the largest of the "e" clips retains the tension rail and the two smaller clips are for the guide rail.
Next position the *new* timing chain on the crank sprocket as shown.



21. Install the front cover.
Note that (1) the cover must locate on the alignment pins and (2) the tab on the top of the tension rail must go inside the oil reservoir formed by the cover's casting.

OIL PAN Apply a thin coat of gasket sealant to block and oil pan. Position the gasket on the block and then the pan. Attach and tighten (choke-up on your ratchet) all pan bolts as evenly as possible.

CYLINDER HEAD Reposition the block upright, disregarding the timing chain for now. Check that the block surface is clean and dry, that the two head alignment pins are in place and that the head bolt holes are clean. Rotate the crank until the first and last pistons are at TDC, while making sure that the timing chain does not catch.
Apply some gasket sealant to the top edge of the front cover only and position the head gasket on the alignment pins.

IMPORTANT — DOUBLE CHECK THE POSITION OF THE CAM.

It must be on TDC #1 cylinder, where both valves are closed and the cam lobes are pointing down toward the cylinder head.

- **4 CYL The cam alignment groove on the edge of the sprocket flange aligns with a 'boss' on the head, just under the sprayer bar.**
- **6 CYL One of the bolt holes aligns with a 'boss' on the head.**

Carefully place the cylinder head onto the block so as not to dislodge or damage the head gasket. When properly located on the pins, it will sit squarely and evenly without rocking. Slip the head bolts into the head and snug them all evenly. Now follow the torquing sequence and tighten to specs.

CAM SPROCKET Slip the sprocket into the chain and pull it up to align it with the flange. The sprocket can only attach one way due to an alignment pin pressed into it.
Once mated to the flange, use the special lock tabs and bolts to fasten it.
When the bolts are tight, bend a corner of each tab up against its respective bolt head.

CAM SPROCKET COVER Apply gasket sealant to the exposed head gasket and the front edges of the cylinder head.
6 CYL. ONLY Insert distributor drive with "o" ring into the front of the cam.
Position the cover and bolt it to the front cover and head.

TIMING CHAIN TENSIONER Move engine so that it is approximately in its normal tilted position with the bottom of the oil pan horizontal.
Insert *new* tensioner piston into hole so that the tab on the tension rail sits in the slot on the end of the tensioner.
Next insert the spring, washer and threaded plug, then tighten.
Pour oil down the inside edge of the cam sprocket cover to fill the tensioner oil reservoir.
Now with a long screwdriver pry on the tensioner rail against the force of the tensioner spring, then release the rail. Repeat until the air is nearly bled from the tensioner and the rail quits moving.
Then push the tensioner rail the opposite direction, against the chain, until the tensioner will hold it tight against the timing chain (it might be necessary to refill the oil reservoir to completely bleed the tensioner).

SET VALVE CLEARANCE Since the engine is still at TDC, adjust the valves of #1 cylinder.
Now rotate the engine clockwise until the next set of cam lobes are pointing directly down and adjust these valves. Continue until all valves are adjusted.
Now you have felt the engine turn over one final time to insure there is no binding and you are back to TDC #1 for setting the distributor timing.