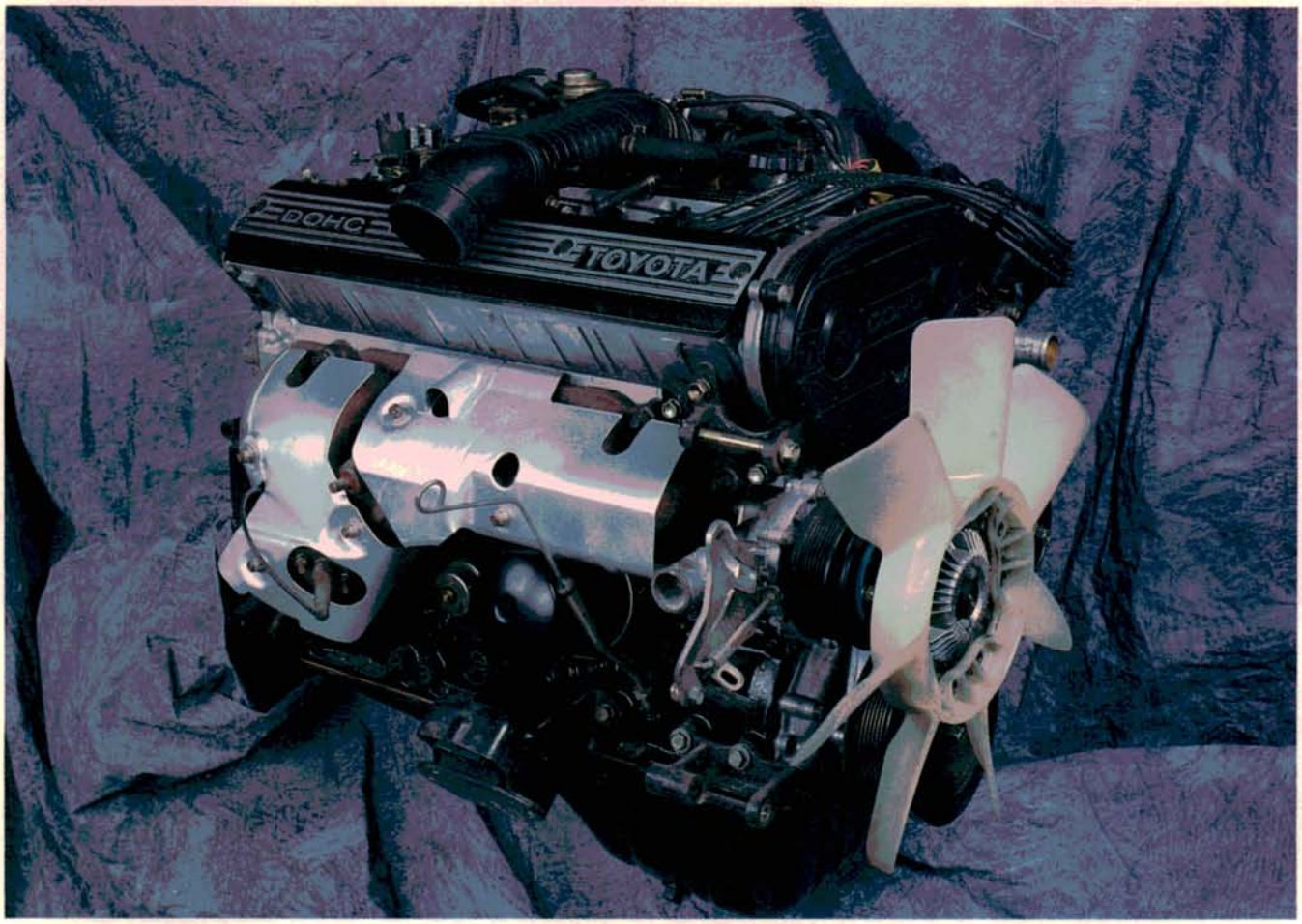
Head First



There are still a few misguided car owners out there who think that regular oil changes are a waste of time and money. After all, why spend money on something you can't see? This hands-off maintenance philosophy served the owners of a certain 1984 Toyota Cressida for almost 100,000 miles. Oil changes and other scheduled maintenance came at very irregular intervals, if at all.

But what goes around comes around. And it eventually did, in a big way. Several seized piston rings, some scuffed cylinder walls, and other internal engine problems finally brought the Cressida into the shop for some long overdue attention. After the engine was disassembled to total up the damage, the owners were given their choices. They could:

a. rebuild the engine
b. install a remanufactured engine
c. install a used engine from a wrecking yard.

After considering the expense of all three options, they chose:
d. none of the above, and sold the car instead.

That's the end of one story, but the beginning of another. We decided to buy the Toyota and turn it into a long term project. When two guys from Ohio find a rust-free 1984 Cressida from North Carolina, a blown motor that's in pieces in the trunk seems like a minor inconvenience.

Over the next few months, we'll look at the repair, overhaul, and installation of the twin-cam six in four separate articles. We're jumping in head first this month with a complete rebuild of the top end. Next month we'll handle the repair of the bottom end. Then we'll cover timing belt replacement, final adjustments, and installation of the 5M-GE further down the line.

Decisions, Decisions

Many technicians and shop owners approach internal engine repairs with clenched teeth and a decidedly negative attitude. Some will even tell you that you'll lose your shirt doing this kind of work. We're not here to tell you whether you should or shouldn't do internal engine repairs. That decision is up to you.

What we are suggesting is that you consider a more "hands on" approach to engine repair. Maybe you've been entrusting your internal engine repair work to a local machine shop. Your involvement in the job may be limited to removing and installing the engine. Perhaps it's time to reconsider your options.

Rebuilding an engine is really one long string of decisions. The decisions begin when your customer decides that he wants you to rebuild his sick engine. After that, it's up to you to make the right decisions so that you can provide him with a lasting repair at a fair price while assuring that you receive a fair profit for your efforts.

You'll have a better chance of satisfying those two basic requirements if you stay actively involved in every step of the decision-making process. Even if you lack the specialized tools and equipment to perform all of the work shown in these articles, you'll still be better off if you inspect the engine yourself before deciding on the work that needs to be done.

Cylinder Head Warpage

A few simple checks can be used to determine what shape the head is in. Some manufacturers list the normal cylinder head thickness for a new head. Others also give a specification for the minimum allowable head thickness after resurfacing. Either of these measurements can be used to determine whether the head has been resurfaced before — and whether there's enough material left for another cut.

The Toyota service manual we checked didn't list a head thickness specification or a minimum allowable thickness after resurfacing. The only specification listed was for maximum allowable warpage. If the warpage exceeds the limit, the head must be replaced. No resurfacing is allowed.

Let's assume the head is warped, what next? We know we can't resurface our head, but we aren't quite ready to toss that expensive casting on the scrap heap. Straightening the head is one alternative. Using a combination of special holding fixtures and a moderate amount of heat, the head can be "encouraged" to return to its original unwarped condition.

Unlike our Toyota head, a small amount of resurfacing is usually allowed on most aluminum heads. There are several important considerations if you decide to go the resurfacing route:

- Aluminum heads generally arch upwards at the center and become concave. Resurfacing the head removes more material from the *ends* of the head, making the combustion chambers at the ends of the head smaller than the chambers closer to the center of the head.
- Engine performance and emissions may be affected because combustion chamber volume and compression ratios will be slightly different from one cylinder to the next.

Valve Protrusion

You're probably already familiar with a cylinder head measurement called installed spring height. We'll spend the next few paragraphs explaining a related measurement called valve protrusion. These measurements shouldn't be confused with one another, although they are directly related.

When a valve seats, the face of the valve extends into the combustion chambers an exact amount. Meanwhile, at the other end of the valve, the valve stem extends above the cylinder head's valve spring seating surface by a measurement called valve protrusion.

As the valve and valve seat wear, the valve head sinks deeper into the head. As the valve recedes, it also affects our valve protrusion measurement. For proper engine operation, the valve protrusion must be returned to its original measurement. Any of the following factors will change valve protrusion and must be taken into consideration during an overhaul:

- Valve or valve seat wear
- Valve refacing or replacement
- Valve seat reconditioning or replacement
- Valve tip grinding

Unfortunately, valve protrusion specifications can be just as hard to come by as other cylinder head information. A valve protrusion measurement was not listed in any of the manuals or other printed material for our Toyota engine.

We took valve protrusion measurements before the valves and seats were reconditioned to find an average reading. Our engine didn't have any valve protrusion problems before we took it apart, so this became our "known good" specification.

Incorrect valve protrusion can affect the rest of the valve train:

- Hydraulic lash adjusters may not work properly because they are working outside their designed operating range.
- Valve train geometry changes. Valves may not work properly.
- Valve spring installed height changes, as we've already noted.

Correct valve protrusion is the key to avoiding these problems. When valve protrusion is returned to original specifications, or at least to where it was before repairs began, then everything else will fall into line.

• On engines with close operating tolerances, there may also be interference between the pistons and valves in the end cylinders if too much material is removed. The valves will be too close to the pistons because of the removed cylinder head material.
• Valve timing may also be retarded when material is removed from the head. Head shims are available for some aluminum heads to make up for the material that has been removed. This restores the original distance between the crank and camshaft centerlines and corrects the retarded cam timing which can result from resurfacing.
• Some aluminum heads will warp in the opposite direction, becoming convex rather than concave. The ends of the head curve upward, away from the engine block's deck surface. This can cause a different set of problems if the head is resurfaced.
• If the milling machine operator assumes that the head is concave, he will start with with a light cut at one end of the head. As the milling machine reaches the true high point at the center of the head, much more material than necessary will be removed.

For your own piece of mind, it's worth measuring the head carefully and consulting a service manual before you send the head off to the machine shop.

Checklists

There's no sense wasting a lot of time on an engine that's ready for boat anchor duty. The photo captions at the beginning of this article are arranged in a logical sequence that will help separate a live, from a cooked cylinder head as quickly as possible. Using an inspection checklist during each repair can also take some of the complexity out of the job.

It's much easier to run through a checklist than trying to remember everything that needs to be done on every job. A checklist also gives you a written record of what parts are worn, what has been checked, what work is necessary, and what work has been completed.

Use your checklist to prepare cost estimates and show them to your customers. Exact measurements are more understandable and will help convince your customer that you are committed to doing a professional job. We've included a sample checklist for cylinder head rebuilding as a sidebar to this article.

Collecting information about factory updates or modifications that have already been made to the engine you are working on is also a good idea. This may change your parts list as well as the procedures involved when installing these parts.

We found out there had been several important modifications to 5M-GE engines installed in later model Cressidas. These modifications were designed to correct several of the problems we found on our engine and should be retrofitted during an overhaul. We'll note the factory modifications as they come up.

Cylinder Head Checklist

1. Measure Cylinder Head Thickness (compare to specifications if available).
2. Measure Cylinder Head Warpage (compare to allowable limits).
3. Is the cylinder head warpage concave or convex?
4. Check for pits, gouges, or corroded areas which can only be removed by resurfacing.
5. Is resurfacing permitted? If so, how much material can be removed?
6. Other external damage to the head? Visible cracks, stripped threads, or other damage?
7. Pressure test for coolant passage leaks.

Valve and Valve Seat Checklist

1. Check valves for:
   a. straightness
   b. stem diameter
   c. overall length
   d. measure valve face margin
   e. check valve stem tips for irregular wear.
2. Is valve resurfacing permitted?
3. Measure overall valve lengths after valve stem tip resurfacing. Still within specs?
4. Measure valve face margin after resurfacing. Still within specs?
5. Measure valve guide wear. Special replacement procedures? Oven required?
6. Check valve seat condition. Burned or pitted valve seats? Cracks or other damage to the cylinder head which could cause the seats to loosen or move? Are seats replaceable? Special replacement procedures?

Valve Spring Checklist

1. Measure valve spring free height.
2. Measure valve spring tension.
3. Check springs for straightness?
4. Check for cracked, corroded, or damaged valve springs.

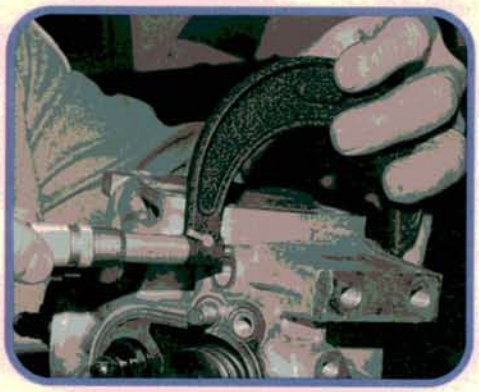
One of the most important parts of a successful engine overhaul is cleanliness. We had a trunk load of oily and dirty engine parts that needed to be cleaned and sorted before we could begin to rebuild the 5M-GE. Our thanks to the Safety-Kleen Corporation for generously loaning us a solvent cleaning tank to make the job easier.

Thanks also to the TRW Automotive Aftermarket Division for supplying the upper engine parts used in our Toyota rebuild.

And a special thanks to Greg Boyd, Technical Training Instructor at TRW's Training Center in Cleveland, Ohio. Greg rebuilt the Cressida's cylinder head in the Training Center machine shop while I watched, listened, took pictures, and got my hands into the action as often as possible. Hopefully, some of Greg's knowledge and experience made it onto the pages of this article.

— By Karl Seyfert

Head First

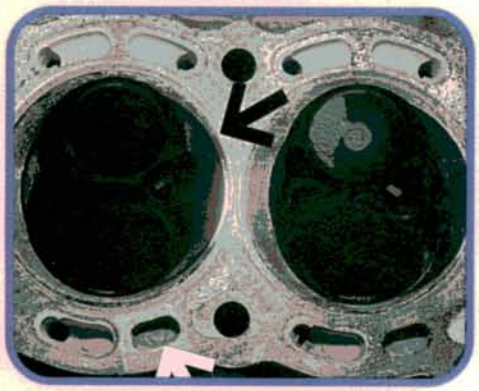


1

Start by measuring the head thickness. This will help you determine whether the head has already been resurfaced. There's no sense wasting time on a head that's already been machined to the limit. Some manuals list new and minimum head thickness dimensions. Build your own library of "known good" specifications.

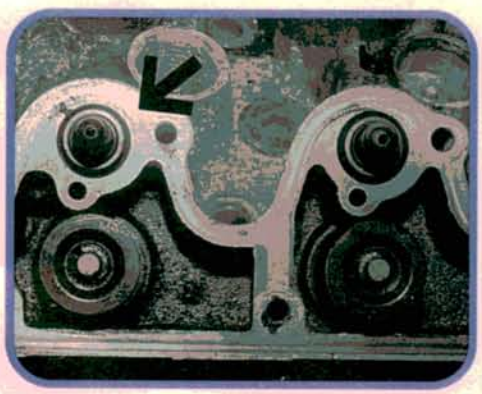
2

Clean the cylinder head sealing surface with a razor blade, then use a straight edge to check for warpage from several different angles. Toyota permits a maximum warpage of 0.10 mm (0.004 in) with no resurfacing allowed. We couldn't fit a 0.025 mm (0.001 in) feeler gauge under the straight edge.



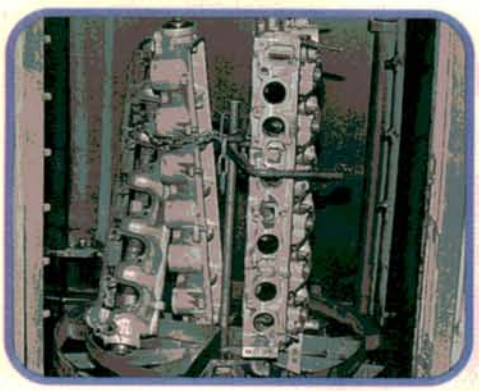
3

There are other problems besides warpage that may require resurfacing. Watch for erosion around the coolant passages caused by coolant leakage at the head gasket. Mild erosion can be corrected by resurfacing, if allowed. Also check for an undamaged head gasket sealing area around the combustion chambers.



4

Two cam housings bolt to the top of the Toyota head. Head or cam housing distortion can cause the cams to bind. Check the mating surfaces on the head as well as the intake and exhaust manifolds and manifold mounting surfaces for warpage or damage. Toyota recommends replacement of any warped parts.



5

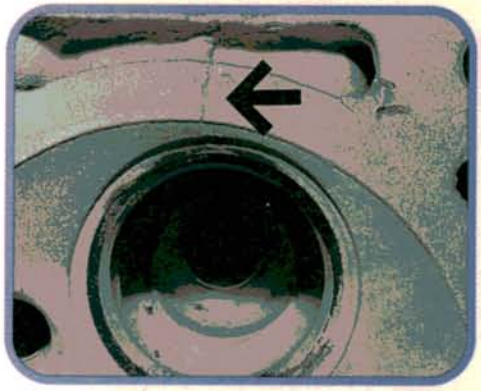
A jet washer and caustic soda removed most of the dirt. Later we glass beaded the head to remove deposits from the areas the jet washer couldn't reach. Make sure all left over beads are removed before reassembly. Thermal cleaning methods used for cast iron parts aren't recommended for aluminum castings.

6

Continue your visual inspection of the head. Check for visible cracks, broken studs, stripped holes, or anything else that will make the job take longer or make it difficult to properly repair the head. You'll want to include the cost of correcting these problems in your estimate.

7

These special fixtures seal the head's external cooling passages so the head can be pressure tested. All core plugs must be tight when using this testing method. Slowly bring the pressure up to 50 PSI, then listen for leaks. Cover the head with soap suds. Small leaks will show up as soap bubbles.

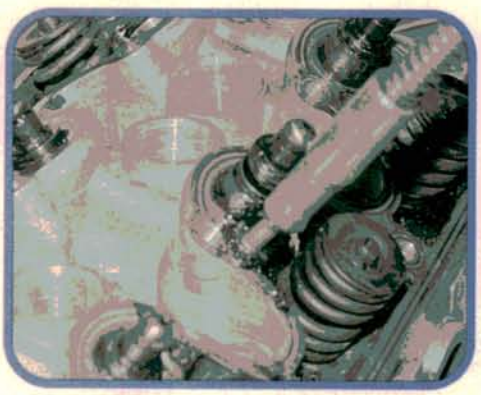


8

Dye checking will locate cracks that haven't reached the water jacket. Cracks show up as dark lines against the light background of the dye checking spray, almost like dusting for finger prints. Dye checking shows this demonstration head is clearly cracked near the combustion chamber.

9

The Toyota's lash adjusters were wasted. Heavy sludge had clogged the adjuster oil drain passages, and the adjusters were stuck solid in their bores. We tried grabbing the adjusters with locking pliers, but they wouldn't budge. We drilled the drain passages to remove the sludge.

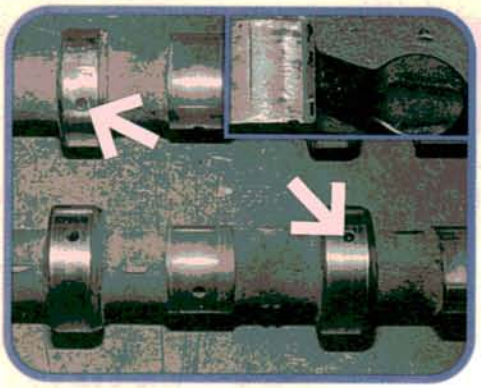


10

After removing the sludge, we threaded the drain passages to install a grease fitting. Pumping grease into the passages pushed the adjusters out until the adjuster oil supply passages were exposed. Working carefully with penetrant and locking pliers, we removed all adjusters without damaging the bores.

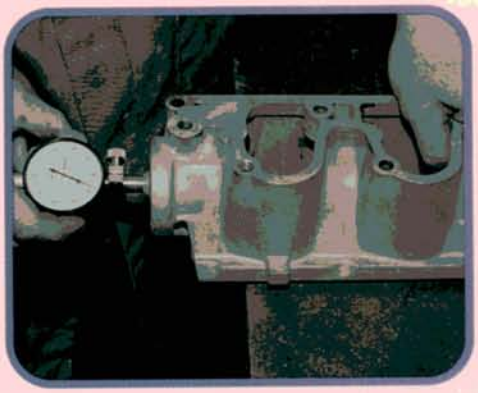
11

Next we removed the valve springs, keepers, retainers, seals, and spring seat inserts (left photo). Use a vernier caliper to measure valve stem protrusion (valve stem height above the cylinder head's machined spring seat. Compare your measurements to specifications if available.



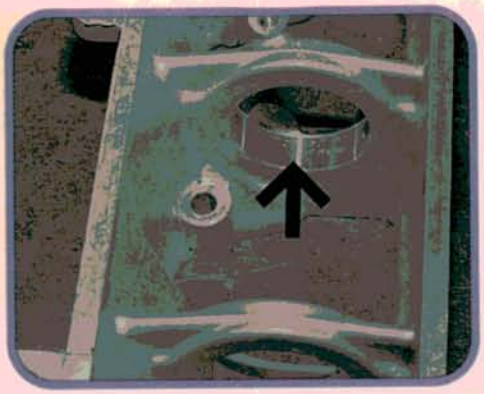
12

The cams and followers were also a write-off. The cams are hollow and lube the cam housing bearings and cam lobes through holes in the cam. Several cam journal holes were plugged with sludge. Updated camshafts include larger oiling passages to prevent clogging and improve valve train lubrication.



13

The seven cam bearings in each housing decrease in diameter as you go further into the housing. The last bearing is about 7.5 mm smaller than the first bearing at the sprocket end of the housing. Measure the O.D. of each cam journal and subtract it from its corresponding cam bearing I.D. to check the oil clearance.

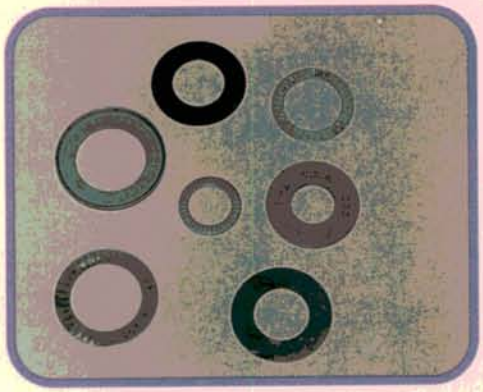


14

The shiny bearing surfaces didn't look like they would be oversized, but they were. The plugged cam journal oil holes did a number on the aluminum bearings. Several bearings in both housings were oversized. A loose cam bearing fit will affect oil pressure and lubrication to the cams and other engine parts.

15

If you're planning to reuse the valve springs, measure their free height, straightness, and spring tension. Weak, twisted, or corroded springs should always be replaced. Our springs were slightly compressed and weak. At 100,000 miles, we decided to replace all of them.



16

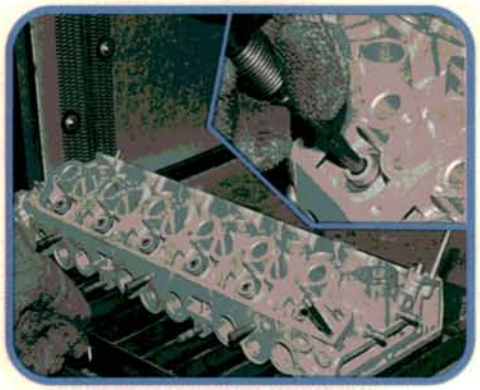
Some engine rebuilders use valve spring spacers to restore proper valve spring installed height after a valve grind. These shims should not be used to compensate for weak valve springs, however. Valve springs that measure more than 10 percent below spring tension specifications should be replaced.

17

Measure the valve stem and check it for wear in the guide area. Compare the valve's overall height to specifications. Operating conditions can cause the valves to stretch over time. Wear in the keeper area is harder to measure. To assure a lasting rebuild, we replaced the valves and keepers.

18

The Toyota head requires a special guide replacement procedure. We broke off the tops of the guides flush with the head first. There's a built-in weak spot at this groove for the guide retaining ring (arrow), so the guides broke easily when we hit them with a hammer and chisel.



19

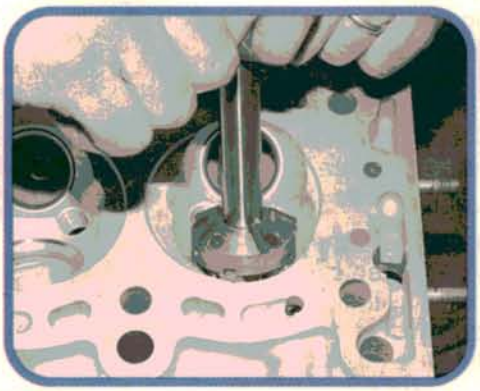
Next we heated the head to 200 degrees in an oven. The aluminum head expands about twice as fast as the guides. We used an 8 mm driver and air chisel to drive the guides out of the head. This removed the guides quickly and easily without doing any damage to the valve guide bores.

20

If the guides are removed without heating the head first, they will tear the aluminum head as they are driven out. This galled guide from a different engine shows the results. If new guides are also installed cold, the guide bores will be further damaged, causing a loose guide fit.

21

We reheated the head in the oven. Then we transferred the retaining rings to the new valve guides and used the driver and air chisel to install the new guides. Don't get carried away with the air chisel. The retaining rings located the guides at the proper installed depth.



22

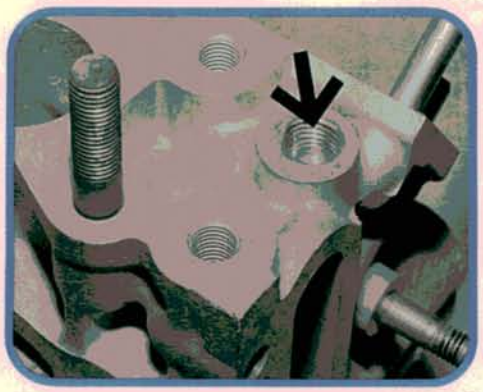
We used Neway valve seat cutters to reface the valve seats. The 45 degree seat cutting tool covers a wide area and cuts fairly slowly. Stop often to check your progress before removing more material. The 30 degree seat narrowing cutters work much faster because they are cutting a narrower area of the seat.

23

A Sioux vacuum tester was used to check for a good valve-to-seat seal before installing the valve springs. Each valve held at least 20 inches of vacuum. Proper sealing is important, a gap the thickness of a human hair between the valve and seat can cause leakage and loss of compression.

24

All oil passage plugs should be removed to clean the rifle drilled oiling passages. We found lots of junk behind the plugs that we hadn't touched while cleaning the outside of the head. Use a bore brush and compressed air to clean the oil passages. Remove any left over glass beads too.



25

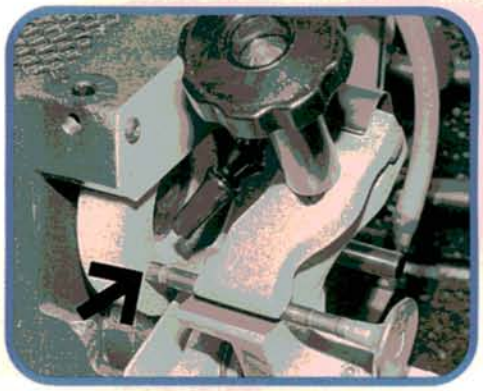
We drilled and tapped the oil passage openings to accept standard pipe plugs. Use a shop vacuum to suck the chips away from the head. Compressed air can blow chips back inside. All oil passage plugs were coated with sealer, installed, then ground flush with the head to prevent interference with other parts.

26

Clean the head in a solvent tank to remove any left over dirt or shavings. Since the head wasn't resurfaced, we polished its sealing surface with a flat stone, using the solvent as a lubricant. This removes small imperfections and also provides a smooth finish to assure a good head gasket seal.

27

Measure the new valve stem protrusion. The combination of new valves and a mild valve seat refacing gave us a valve stem protrusion measurement that was close to the original measurement before seat refacing. The new valve's thicker faces made up for the metal we removed while cutting the valve seats.



28

If the new valve stem protrusion is too great, it can be corrected by grinding a small amount of material off the valve stem tip using a valve grinding machine. Be careful here, we don't want to remove the valve tip hardening or cause interference between the valve spring retainers and the cam followers.

29

If the new valve protrusion is close to the original measurement, installed height should also be correct. Installed height is hard to measure on this head, so we ground a notch in a spare spring retainer of the same type. The vernier caliper fits next to the notch for an accurate measurement.

30

Apply assembly lube to the valve stems and guides, then install the new valves and valve seals. Install the springs, keepers, and retainers. Hit the valves and retainers with a plastic mallet to make sure the keepers are properly installed. We'll be back next month to tackle the block.