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Rebuild a Cylinder Head

by Stephen Chastain

Photos by Author

Rebuilding cylinder heads is not particularly difficult and may be done in the home shop with a lathe, mill, a tool post grinder and a few "shop-made tools."

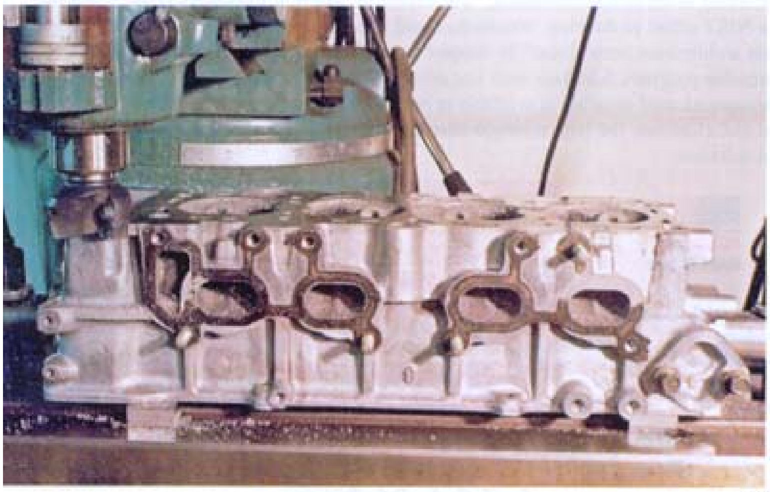
I have brought several engines back to life for little cost by doing the work here at the house. In this case, it was a 1990 Nissan Sentra with a 1600cc overhead cam engine.

On our evening walks around the neighborhood, I noticed a car had been sitting in a neighbor's yard for several months... maybe a year or more. One day, I happened to see him outside and asked about it. He said that the car had overheated and, despite replacing the waterpump, radiator and hoses, it still blows all the water out after running only a few minutes. I suggested that the head may be warped and that car may be fixed. He said that he had already bought a new car and only wanted to get the Sentra out of his yard. I told him I needed a 4-door car; I could probably fix it and asked what he wanted for the car. He replied $50 to $100. I offered him $75. He said, "sold!"I brought a portable air tank over, filled up the flat tires and with a few friends, pushed it home.

PREPARING THE HEAD FOR MACHINING

Before removing the head, all the connections are labeled. It's also a good idea to photograph all the hoses and wires if you have a camera.All the accessories, cables and the valve cover are then removed. A spot on the timing chain and sprocket are cleaned and marked with a "Sharpie" pen. The cam sprocket is removed and the chain secured. The "tightening – removing" sequence of the head bolts is found in a *Haynes* service manual available at auto parts stores. The head bolts are loosened in steps... about a quarter turn at a time. When all the bolts are removed, rap the head with a rubber mallet (shot filled dead blow hammer) to loosen it. The head can then be lifted off the engine and set on the bench.

Before any judgments are made as to the condition of the head, it must be thoroughly cleaned. The best cleaner for this job is *"Purple Stuff"*, or an equivalent



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water-based product, sold at auto parts stores. It *really works well*... much better than the solvent-based products I have used. After the head is cleaned, dry it with compressed air and give it a light coat of WD-40 to prevent oxidation. Carefully scrape any remaining gasket with a gasket scraper being careful not to nick or scratch the head. Wipe or rinse the head clean again.

Carefully, I looked for cracks, especially in between the valve seats. The head looked good so far. Then, I checked for warp with a straightedge and a feeler gage. The head had .010" warp around and between cylinders #2 and #3. Other than that, it looked pretty good.

The maximum total height that may be machined off the head and block combined is .008", however the specification allows .002" warp. On this motor, any machining brings the cam closer to the crank, changing the valve timing among other things. There are a number of options here. I can machine off .008" and live with a little bit of warp or I can completely clean up the head and get a copper shim to restore the original height. Being cheap (remember it was a $75 car), I chose to live with .002" warp in the head.

I removed the valves with a *Craftsman* valve spring compressor. Because many valve springs are wound with a variable pitch, I made a note of the coil spacing. I put each valve and all the components for that valve in a labeled *Zip-lock* bag. The valves were cleaned up later, after I saw how well the head would machine. I lightly sand-blasted the carbon from the combustion chambers and the ports being careful not to get sand down in the valve guides where it may become embedded in the bearing surface. It's also a good idea to try to blast away as much of the deposits in the water jacket as you can. This head was warped because it overheated. Try to eliminate as many of the possible reasons for the overheating as you can. Clean water passages can't hurt. I blew all the sand out with compressed air and took the head to the mill.

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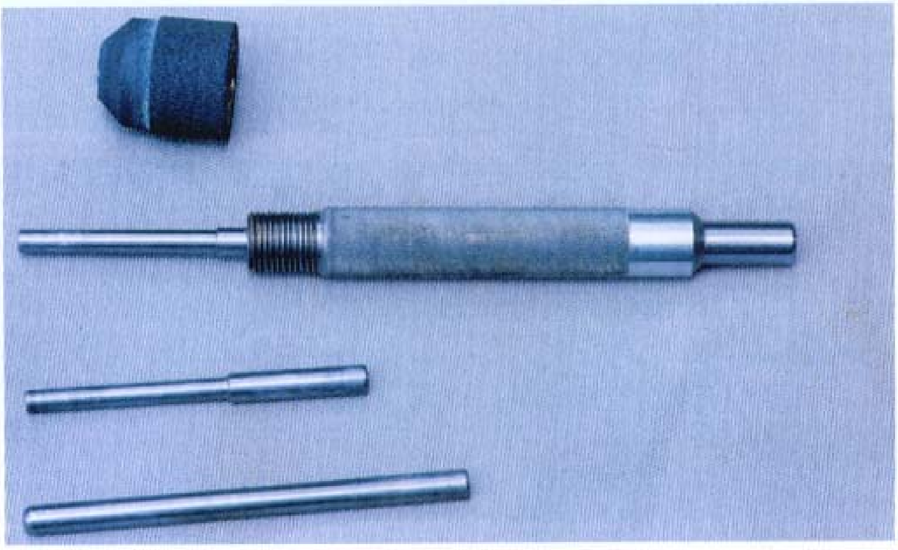

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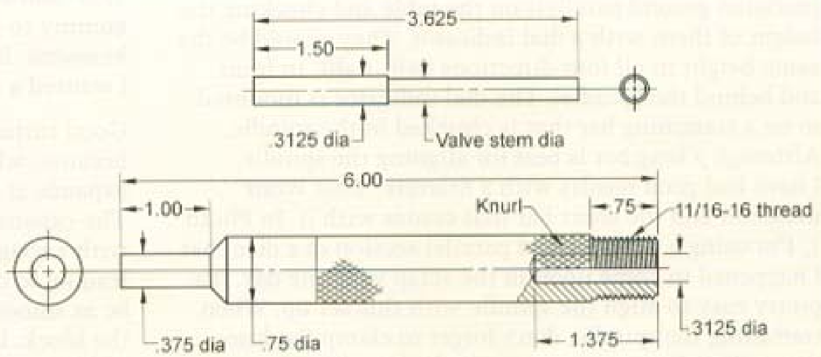

VALVE SEAT TOOL AND INSERT

SETTING UP THE MILL

Clean the mill tabletop with kerosene. Any burrs, if found, can be smoothed with a fine whetstone. Again, wipe the mill table clean and then run your bare hand over it to detect any remaining foreign material. The spindle is then "trammed", or set, so that it is perfectly perpendicular to the tabletop so that successive surfacing cuts across the cylinder head will not have a burr between them.

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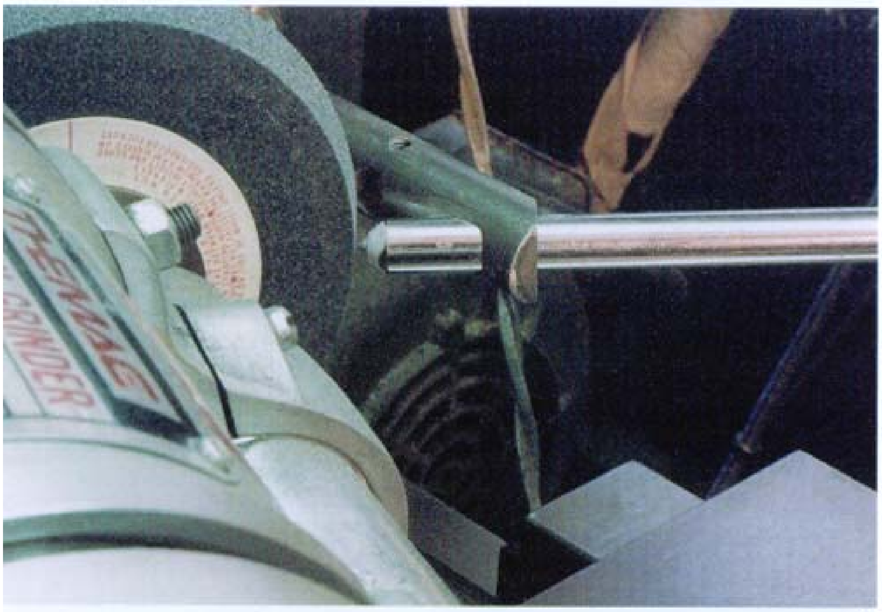

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CLAMPING THE HEAD
No matter what kind of head you are surfacing, the real trick is to clamp it to the table without distorting it. This particular head was machined parallel on the top and bottom. I often clamp through the sparkplug holes when surfacing "flatheads." The sparkplug holes are at an angle in this head, however, so that was not an option. The cam bearing journals are all machined flat on top and they are level with the top surface of the head. I chose to insert a 1-1/2" diameter bar through the cam journals and clamp it as seen in Photo 2. Before clamping, I drilled two holes in the bar, carefully cleaned it and removed any burrs. I wanted to be sure that no dirt was present on the bar that might become embedded in the cam bearings.Because the head had a little warp and because I wanted a direct clamping load (not transmitted through the head to another surface on the head), I inserted parallels under the journals. The clamping nuts and bolts were lubricated and torqued, in steps, to 20 foot/pounds. The trick here is to securely clamp the head, but not to apply enough force to distort the head.

SURFACING THE HEAD:
I used a 2" carbide cutter to surface the head. It was a little slow because I had to make several passes to cut the whole width of the head. I started the operation by setting the cutter to height using a sheet of paper (Photo 3). The paper was .003" thick so I raised the table until the paper was just caught. From there I removed the paper, lowered the table .003" and set the dial on zero. Aluminum may be a little gummy to machine so I'll use a cutting fluid... often kerosene. In this project, I used *"Tap-magic"* because I wanted a really smooth finish (Photo 4).

Good surface finish is important on aluminum heads because, when at operating temperature, aluminum expands at about 1.7 times the rate of cast iron. The expansion and contraction of the head combined with a rough surface can saw into the gasket material leading to early failure. Cast iron heads do not need to be as smooth because they expand at the same rate as the block. I made cuts .002" deep, using a spindle speed of 1340 rpm and a slow table feed to cut the surface. My final passes were .001" deep. The head cleaned up well... only two small places were left un-machined. I could barely get a .001" feeler between a straightedge and the low spots. I was happy with the work so I loosened the clamping bolts, in steps, and removed the head.

Tramming the spindle is done by placing a set of precision ground parallels on the table and checking the height of them with a dial indicator. They should be the same height in all four directions (left, right, in front and behind the spindle). The dial indicator is mounted in on a tramming bar that is chucked in the spindle. Although a long bar is best for aligning the spindle, I have had good results with a Starrett *"Last Word"* indicator and the short bar that comes with it. In Photo 1, I'm using a very flat and parallel section of a disc that I happened to come upon in the scrap yard one day. It's pretty easy to align the spindle with this set up. When tramming the spindle, don't forget to clamp the knee down. This is sometimes overlooked producing inaccurate results. The set-up can be a time consuming job but it's well worth all the effort you put into it. Your cuts will be much smoother afterwards.

MAKING A VALVE SEAT TOOL

Valve seats are cut with a grinding stone available from autoparts suppliers. I used a 1-1/2" diameter general-purpose gray stone made by *"Goodson."* It was made around a brass center, threaded 11/16-16 so that it could screw onto a small motor.Using a lathe, I made up an arbor to hold the stone (see drawing). When cutting the seats, I can turn the stone by hand or use a small drill to drive it. The arbor was cut from a 6-inch length of 3/4" steel rod. The shaft was knurled to make it easier to turn by hand.

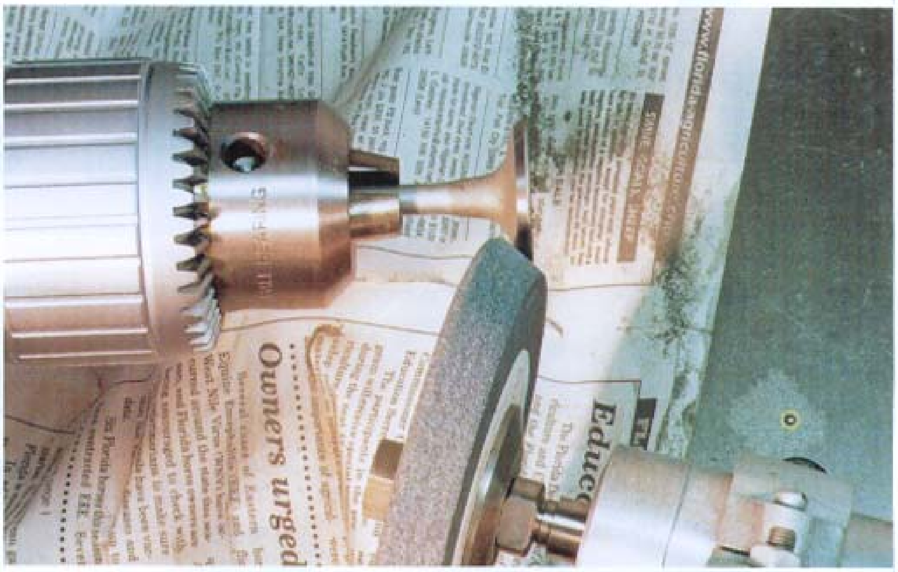
The really critical part of the arbor is the insert that centers the tool over the valveseat. The inserts are machined to the same diameter as the valve stems on one end and the other is machined to a good fit in the arbor. When inserting the tip in the tool, air pressure gives some resistance and, when removing it, makes a popping sound somewhat like a cork.I got that fit by drilling and reaming the arbor to final size (5/16-inch) that gave a smooth finish. I then turned the inserts in the lathe and polished them at high speed with sandpaper until they had a smooth fit with minimal clearance. Many heads have different diameter intake and exhaust valve stems. I had to make two inserts for this head (Photo 5).

SETTING UP THE LATHE TO CUT VALVES AND SEATS

The valves are ground in the lathe by chucking them in a dedicated chuck and cutting the face with a tool post grinder.I have a set of collets that I use to chuck the non-metric valves. I use a chuck setup for all my other non-standard valves. For this project, I used a 3/4" capacity ball-bearing chuck available from *ENCO*. The chuck was mounted on a 5MT taper adapter that fits the lathe spindle. I chose this large combination because I wanted to drill out the center of the taper adapter so that the valves will fit down into the spindle. My taper adapter is drilled out 3/4" diameter and about 4" deep. This is easy to do... just put the adapter in the lathe spindle (without the chuck) and drill it using a drill bit clamped in the tailstock chuck. The large chuck and adapter were fairly inexpensive. Realistically, you can get by with a smaller chuck and drill your taper adapter out to 3/8" diameter because most valve stems are 5/16" diameter or smaller.

Valves usually are ground to 45°. I have had some valves that are ground to 30°. You will find them on old flathead *Continental* engines that are used in old *Jeeps* and forklifts. To improve the flow, some valve seats have three angles, 30, 45 and 60°. If you want to cut all three angles, you will have to have three stones. Set the compound rest to whatever angle that you need to cut. Both the valve and the seat cutting stone should be ground without changing the setting of the compound rest of the lathe so that the seats and the valves have the identical angle.

Carefully clean the lathe spindle and adapter to be sure there are no particles on either one. Any dirt here will destroy the accuracy of the valve-grinding operation. Mount the tool post grinder on the compound rest and true up the stone with a diamond wheel dresser. Be sure to cover the ways of the lathe with cloth or paper to protect them from the grinder dust. I made a simple dresser holder from a section of 3/4" diameter steel rod (Photo 6). It's drilled at 90° and 45° and also has a setscrew on each side to hold the dresser in place. The dresser may be chucked in the head or tailstock for cutting the wheel. In this situation, it happens to be in the headstock (Photo 7). I set the spindle in a low gear so that it does not rotate when I cut the wheel.For the best accuracy, the bearings in the tool post grinder have to warm up, so I turn it on and let it run for 10 to 15 minutes before making any cuts.



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Chuck up an old valve as close to the head as you can as shown in Photo 8. Set the lathe to run about 300 rpm in the reverse direction. Make a practice or "test" cut using the compound rest to feed the grinder across the valve. I have a good supply of old valves and springs I got from the scrap yard. I took my spring compressor down there and stripped several heads. Steel was selling for 5 cents a pound so I may have a dollar or two in all of them.

When you are satisfied with your grinding set up, start working on your valves. All of my valves cleaned up with .0015"- .003" in-feed. The whole process may take 15 minutes for all twelve valves.

The valve seats in this head are hardened. They were dirty and only slightly pitted so I cleaned them up by hand (Photo 9). Although it may take me 45 minutes to an hour to clean up all 12 seats, I feel like I have more control over light cuts when I do not use the drill to

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lathe and cut the diameter down .100" using the diamond dresser in the tool post as seen in Photo 11.

Then, I cleaned out the sparkplug hole threads by running a M14 – 1.25 tap through them (Photo12). Cleaning out all the trash helps keep the new plugs from cross threading and thus tearing up the head. Because aluminum (head) and steel (sparkplugs) are dissimilar metals, I always use *"Never Seize"* on the sparkplug threads to minimize any corrosion problems. The plugs come out easily when it is time to change them.

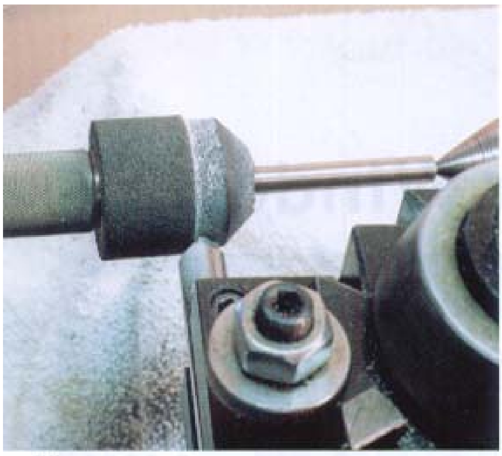
When all the machining was done, I scraped any remaining gasket material from around the ports and thoroughly cleaned the head again. The valve stem seals were given a coat of oil and pushed into place. The valve stems are also given a coat of oil and pushed into the guides. The springs were compressed and the valve keepers were given a coat of grease and put into position. The grease keeps them in place until the springs are released. Be sure to pay attention to the springs. Some springs are wound with a variable pitch. The coils that are wound closer together close up and come together when compressed in use. This raises the natural frequency of the spring to

drive the stone.The intake valve seats (Photo 10) cleaned up nicely as may be seen when comparing them to the intake seats in the photo of the sparkplug tap.

The intake and exhaust valve seats are different diameters. In order to clear the combustion chamber walls, I had to cut the diameter of the stone down before cutting the exhaust valve seats. I returned the tool to the

prevent surging and resonance. The springs on the Nissan engine were wound with the tight coils at the bottom of the spring.

The camshaft was cleaned up with the *"Purple Stuff"* cleaner and it was blown dry with compressed air. I chucked the cam in the lathe with a live center in the tailstock. The cam was spun at about 300 rpm and a



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fine (approximately 400 grit) sandpaper strip coated with oil was used to polish it up (Photo 13). After I had gone over all the lobes, I reversed the direction of the lathe rotation and polished them again. That cleaned both sides of the lobes. The cam was thoroughly rinsed and given a light coat of oil to prevent rust. The journals in the head were oiled up and the clean cam was inserted.

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The head was ready to install. Now, here are a few notes about bolts and tightening the newly machined head.

TIGHTENING THE HEAD BOLTS

The head bolts, the head and the engine block are in effect stiff springs. They deflect when loaded and relax when the load is removed. They store potential energy and create a clamping force when they maintain a certain amount of energy. Typically, about 90% of the energy put into tightening a bolt is converted to heat. About 50% is lost due to the friction at the head of the bolt and 40% is lost due to the friction in the threads. This leaves only 10% of the input work as preload or bolt tension. If there is a 10% increase of friction because of dry threads or trash in the threads, then the input work is reduced an extra 4%. This leaves only 6% of the total input torque as preload in the bolted joint. A 10% increase in friction results in a 40% loss in bolt preload. It is very important to clean the threads on the bolts (or use new ones) and to clean the threads in the block by running a tap through them. Some engines, usually very high compression engines, have rounded tips on the threads to reduce the tendency to crack at the threads. These threads require a special tap. After the threads are clean, you should use a thread lubricant such as *Never-Seize* or a *Fel-Pro* product.

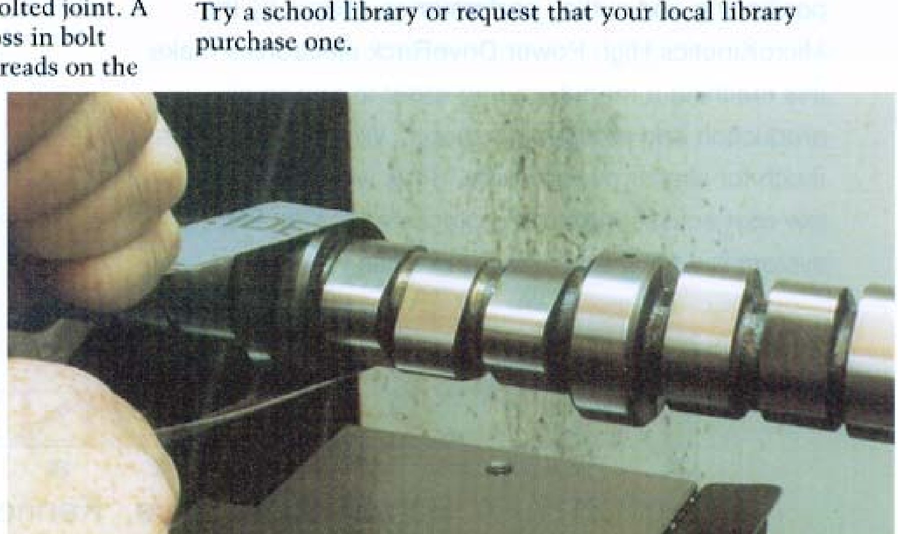
Make a final inspection of the cooling system before starting up your new head. I traced the original failure in this engine back to a weak radiator cap. The cap let the coolant boil out and when it was low enough, the head ran hot and warped.

A $3.65 part caused the original failure.

This engine starts right up and runs very well. I thought it would run, but I am surprised how well it runs. With a little troubleshooting, the air conditioner was brought back to life and blows ice cold (very important in Florida). It is time for a paint job and new tires. I make a 320-mile round trip drive to Orlando several times per week and the car is running great! I was very lucky to find such a car for $75 and I am very happy with the end result.

If you want to try cutting a head or two, go get one from the scrap yard and practice on it before you tackle your wife's car. You can probably get an aluminum one for $.50 a pound. Once you have done it, some of those other restoration or repair jobs are not so intimidating. Good luck!

If you are interested in more information on the statistics of bolted joints, see *"An Introduction to the Design and Behavior of Bolted Joints"* by John Bickford. Try a school library or request that your local library purchase one.



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