

Rebuilding An Air Cooled VW Engine - Machine work

By SG Kent 4/12/2017

About the author: The author worked as an automotive machinist in a racing machine shop during the late 1970's, and early 1980's under the apprenticeship of Bill and Wally Kaiser of Burns Engine. Bill and Wally were well known in the automotive racing circuits for outstanding Formula Ford motors, Indy engines, Cosworth race engine rebuilding, and full racecar design and prep. Clients included Al Unser Jr, Goodyear, and Popeyes, among many others including some NASCAR teams. Bill was also crew chief on a trophy Super Vee team before opening his machine shop. The author also supported (built engines and chassis design work for) two winning production (F Prod and G Prod) SCCA racing cars driven by H. Leland Lowe and Charles Budenz of Riverside California. Both cars were consistent trophy winners. The G Prod (1438 cc) was faster than the F Prod (1608 cc) due to outstanding head, and intake porting work by the author under the mentorship of Bill Kaiser. During this period, the author used a 1971 VW bus for transportation, as a mobile automotive shop, and for sleeping when on the road racing. It was used for approximately 400,000 miles until sold, at which time it was still like new. Currently the author owns a 1977 VW FI bus that was completely restored in 2009 by the author.

Synopsis: This white paper describes the machine work that should be completed on any VW air-cooled engine when it is being rebuilt if the owner wishes a like new experience. While work may not be required in each category, each category should be checked by a competent machine shop. Whenever possible the author will make suggestions on how to determine whether a machine shop is competent.

The Machine Shop - All machine shops used should show some level of organization. If the shop builds engines, a clean work area should be present. If the shop also builds high-end racing motors, a full clean room should be present. A clean room needs to keep all metal and dust out of the assembly area. If headwork is done on high-end heads, then a professional flow bench should also be present. Tooling should include:

- A rod honing machine
- Presses for installing bearings and bushes
- A cylinder boring and honing machine should be present
- Gauges for measuring should be stored in a professional manner, in a stable room temperature environment
- The general machine area should be uncluttered

- A mill for milling heads and decking blocks should be present
- The shop may have a collection of torque plates for high-end cylinder resizing jobs
- A high-end drill press with many speeds. It should include an air table with 360 degree rotation ability
- An align boring hone for water cooled engines
- An align boring tool for air-cooled engines. This should be stored in a most professional manner to prevent damage to the device.
- Some form of belt sanding machine for flattening manifolds and shaping parts
- A professional glass-beading machine with a broken bead separator
- Professional parts washers. Typically one will wash engine blocks etc, and the other for small parts
- A storage area for completed engine work
- A workbench set up with professional head rebuilding equipment including reams, cutters etc.
- Professional scale(s) to weigh pistons and rods. A professional balancing service should be available thru the machine shop
- A professional crankshaft grinder who does racing crankshafts should be available to the machine shop.
- The machine shop should have a strong knowledge of bearing types, as well as cam grinds and grinders
- Magnetic flux and aluminum dyes to test for cracks in blocks and heads

Below are this author's opinion of the items on a VW air-cooled engine that need checking. Simple ways to tell if the machinist has done his/her work are included whenever possible.

Case – The case must be thoroughly cleaned including all oil passages. Most quality machine shops will offer a service to clean a dirty case. In support of my current local machine shop, I once found their owner cleaning my type 4 case with a toothbrush to get rid of the last traces of dirt that had accumulated. The case looked almost new when I picked it up. The main bearings on a type 1 case are always a concern on a high mileage motor. To test a main saddle, one can run a fingernail across the main saddles. If the saddles have an indent at the sides of the bearing that a fingernail can feel, or if the saddle or bearing has shiny spots from working in the case, then the case should be replaced, or at least align bored if that option is available thru the machine shop. When assembled after an align bore, plasti-gauge should be used on the split bearing to test clearances, and an oiled crankshaft should freely spin in the main bearings. If the crankshaft is hard to spin by hand it will grab the bearing at RPM. Studs should be checked to make sure they are not pulling free from the case. If the case requires case savers, the work should be done before the case is thoroughly cleaned. A plate can be tig-welded behind #3 cylinder to strengthen the case. This upgrade can only be performed by shops that are familiar with the work. If the shop doing a case is not familiar with any of these jobs, including replacing oil gallery plugs then it may be time to consider another shop.

Rods – Asking a machine shop to take a look at some connecting rods, or looking at some they have done, is a good way to size up the quality of work coming out of a shop. When the rod big end is honed out it must be measured on both sides. There should be a scribe mark 360 degrees around the inside of the big end. If the measurement has gaps in the scribe marks at, or near the part lines, then the machinist is either lazy or has not developed the skills needed to measure 360 degrees. This is in part because the human wrist does not rotate 360 degrees, so to measure 360 degrees, a slight amount of arm and shoulder contortion is needed. Someone who has done this for years, and who understands the importance will ALWAYS turn the rod 360 degrees on both sides to be sure it is not wide or pinched across the part line. If those scribe marks are lacking 360 degrees on both sides I personally would reconsider the shop. The small ends require a press to replace the bushings, and they should be custom fitted to each wrist pin. A properly fitted pin will slide thru slowly of its own weight in a few seconds of time minimum, and not bind or wiggle. General balance should be within a gram of one another. Any balancing should be done before the final sizing on the rods. Bolts can be reused for final assembly. Nuts should be new on final assembly. When in doubt use a name brand that carries a warranty. If a bolt feels like it is stretching it should be replaced. A good machine shop will recognize this when they prepare the rod for sizing. A special vise that keeps the cap and rod in line should be used to tighten the rod nuts before re-sizing the rod.

Pistons – Should be cleaned with either chemicals and washed, or cleaned lightly with glass beads. They should never be wire brushed. The pistons then must be inspected for:

- Galling, heavy scuffing or extreme wear near the crown. On a VW air cooled motor this is where pistons are most common to fail from heat.

- Measured just below the wrist pin holes, then again near the bottom of the skirts. If they are collapsed at the bottom of the skirts it is best to replace them. If the remainder of the piston is excellent, the skirts can be lightly tapped outwards with a rawhide mallet to expand the skirts. This is not the preferred solution but on a frugal rebuild, the builder may choose to do this.
- Check for cracks
- Check ring lands with old rings, then the new ones to make sure they are within spec. Beware that worn rings cut like razor blades.
- Wrist pin fit. The pins should slide in with no wobble or heavy resistance.
- Within 1 gram of each other as to balance
- Cylinder should not have a lip at the top, and a new light crosshatch should be put on the cylinder.
- When in doubt just replace the cylinders and pistons as a set. Mahle, Cofap, and Kolbenschmidt are considered good quality consumer grade sets.

Heads - Headwork is an art form. The machinist must have many skills to successfully rework heads. Things that make it harder to find a good machinist and rebuild an air-cooled VW head, VW air-cooled heads are made of aluminum, and when they get excessively hot they warp, crack, and soften. VW air-cooled technology came from the aircraft industry in a country known for being cooler than many places VW buses are used. An aircraft engine running a constant speed at 10,000 feet ASL runs in a lot cooler air when compared to a VW bus shifting up - down, and climbing long grades near sea level in the Southwestern USA where it is 110F+ in summer. Because of the head temperatures encountered by a VW bus head, most VW bus engine builders in the 1970's preferred just to replace the heads with new ones, or used bug ones rather than rework them. At best, the heads were given one light valve job, driven another 40,000 to 60,000 miles then discarded for a new set. That said, those days of inexpensive quality replacements are long gone, and many report come back that the quality of newer replacement heads does not come close to the quality of the older heads. As a result, many people choose to send their air-cooled bus heads off to be rebuilt. While I unfortunately cannot tell you how to instantly size up a machinist whether they are any good at rebuilding VW bus heads, I can suggest you talk with the machinist, look over their air-cooled work, and especially their attention to detail. As a rule, if a shop is willing to let any head out the door with less than near perfection, they are probably not to be dealt with on an air-cooled head, because there are way too many pitfalls that can be encountered. Below are some suggestions of the things to consider when having headwork done.

- Ask to see work that the machinist has already done if you are not familiar with their work. If they have been in business a while they will be happy to show you the quality of work they do, and show you their shop.
- Many shops have one or two people dedicated to doing headwork. If those people leave, they take their skills with them and it takes time to retrain new staff for headwork.
- Small cracks can be tig (Heli-Arc) welded. They usually come back in time however.
- Valve seats should have 3 angles
- Valve seats that need to be replaced because they have sunk usually are an indication that the aluminum has gotten soft. Putting in oversize seats is a work around but replacing the head is best.

- Heads should be matched with similar chamber size and shape whenever possible
- Excess flashing should be knocked out to allow cooling air between the fins
- Poorly installed spark plug repair thread inserts will fail again
- Valve guides that allow any valve rock need to be replaced, and the valve seats reground. If the shop lacks the proper reamers then the guide bosses may split when the new guides are inserted
- Valves can be back cut to allow more air and fuel into the cylinders
- Intake and exhaust ports can be cleaned up but never left too smooth or laminar separations in flow will occur. A flow bench is needed if a head is being built for a racing engine
- Solvent (Stoddard or Mineral Spirits) can be used to fill the intake and exhaust ports. If it leaks past the valves then the valves are not seating right. A well-built head will hold solvent overnight with just a touch of seepage if any. This test can be used on used, rebuilt or new heads.
- Valve springs can be individually tested or lined up to see if any are short (weak).
- Valve stems should not be over tipped or the rocker arms will hit the keepers / retainer.
- Generally, exhaust valves are replaced EACH time a head is rebuilt. A high quality valve should be used as the replacement. Exhaust valves are not the place to cheap out
- If the head is flycut, the barrels should be hand lapped into it to be sure they are seating properly
- Mount the cylinder directly to the head without a gasket
- Only hot water and soap will free up glass bead residue. Be sure to chase all threads and blow out with compressed air

Crankshaft – Many times a crankshaft can be lightly polished, cleaned and reused. Most machine shops send out their crankshafts to a specialty shop. Grinding crankshafts takes a special grinder. If you are considering having the crankshaft ground, go with the best quality available. Usually there is someone who does racing crankshafts – they come back with more precise and polished grinds. In fact, the shops who used to do ours had an almost mirror finish on the journals. They did crankshafts for many Indy, NASCAR, and well-known drag racing cars.

- All journals should have a proper radius
- Check side clearance on rods
- Look for any damage to ends or nose before sending a crank out
- Handle a crankshaft like it is a fragile vase.
- To check for cracks one can set it on end and tap a non-journal area. It should ring like a bell
- Be sure to generously clean all oil passages

Camshaft – Please see a quality cam grinder for a replacement. Figure what RPM range you will be running the engine and buy a cam for that RPM range. Buying a cam that performs well at 6,500 RPM does nothing for you if you will be driving the between 2,000 and 4,500 RPM. I prefer Webcam for VW buses. Type one engines I have used Engle for many years.

Balancing – I balance every engine I build. Finding a successful race shop and asking whom they use for balancing is one of the easiest ways to find a balancer. Items to balance:

- Crankshaft
- Flywheel and clutch pressure plate
- Fan. Check it for cracks or broken blades first

- Rods
- Pistons

Final Thoughts: I wish you the best in your quest to rebuild your air-cooled bus engine. Machine shops come and go. The old-timers are retiring out so it is getting harder to find quality shops. I have found that the best way to locate a good shop is see who is winning at the drag races, at the NASCAR track, at SCCA meets, and ask the drivers and car owners whom they recommend. Then call those shops, and ask if they know someone near you who does machine work on air-cooled VW engines. Most likely, you will find out quickly if there is anyone near you. You can also attend VW drag races and see who has a reputation for winning. Ask if they recommend a machine shop. Last – be ready to wait and pay \$\$\$. If you go with the first shop that can get it done cheaply, you will get what you pay for - a cheap job. In addition, FWIW, good shops will make right their mistakes, cheap shops rarely do. If you are impatient, in a hurry, then that impatience will show up in the quality of your build, or come back and bite you later. Good Luck and Happy Driving.