Rebuilding a VW Bus Engine

By SG Kent 4/12/2017

Synopsis: Rebuilding a VW bus engine is no different than rebuilding a beetle, Ghia, or T3, or T4 engine other than some of the mechanical parts are different. A T3 for example uses bellows to bring air to the fan then the engine, while a Beetle or Bus use either an upright fan mounted in a shroud, or a fan mounted to the crankshaft that pulls air thru vents into the engine compartment. This article will not cover those differences. This article is designed to assist the rebuilder in finding a good course to sail when rebuilding. This article assumes that you, as the engine builder, have the time, patience, tools, and place to work on an engine. This paper is not an emergency repair manual, nor does it go into John Muir type shade-tree workarounds. This white paper is written for someone wanting a high quality rebuild. The rebuilder should also be aware than many VW shops, and machine shops say they do outstanding work, but in practice this is not always true. The author cannot begin to paint a picture for you how when he worked as an automotive machinist in a racing shop, how many times client provided "supposedly" quality parts from well-known sources turned out to be simply "cleaned parts," or "cleaned and repainted" worn out parts." The burden to find a quality shop is totally on the rebuilder, but this author will try to give some tips on how to tell if a shop is thorough in their work.

First step – clean up and claim your work area. You are far better off to start the rebuilding process with a clean established work area that is at least 5' x 5' in area plus storage, than to keep pushing things out of the way to make room. There should be ample clean rags that are lint free, and a metal container to store any used oily ones. If lint free cloth towels are not available, rolls of quality lint free paper towels will do. Oily rags, towels and paper towels are a fire hazard. They heat up as the oil decomposes. They will ignite from spontaneous combustion if left in the open. Linseed oil is especially known for this, sometimes igniting in just two or three hours after use. The work area should have an assortment of plastic bags (ziplocks) and sharpies. There should be adequate storage areas to put parts as the engine is disassembled. Access to a welder to repair cracks in tin, or replacement tin is good too. These air-cooled VW bus engines are often full of broken tin due to their age and mileage. A low mile engine will not have this issue as much, but low mile engines are rare these days. Various ways to clean parts should exist. Some shops will rent out time on a glass bead machine if the home rebuilder does not own a good one. Stoddard solvent ,or mineral spirits do a good job of cleaning things. Although it is flammable, it is not nearly as flammable as gasoline, which should never be used. Brushes and toothbrushes are handy for cleaning small things. An electric carbide engraver will help mark parts. Sometimes bolts in an object vary in length. One can engrave a number on the head of each bolt and a number next to it just to be sure the right length bolts go in the right boltholes. Use paper and pen to make notes and take many photos. Later you can refer to these items if you need to. You would be surprised how much one can forget in a month or two of working on a project when the tasks are not something done frequently.

Second step. Read a manual, or manuals, on the engine so you are familiar with it, and the parts. You do not need to memorize each part, but a good overview of the parts will help.

Third step. Grab the wrenches and start taking things apart. Penetrating oil is used on rusty nuts. Rust swells the iron in the bolt and nut so they bind. Penetrating oil has chemicals in it that help convert the rust to a form that is not as swollen, thus releasing the nut. Penetrating oil is not WD-40 or acetone and ATF even though some people will swear by it. Penetrating oil contains a special acid that causes the oxygen atoms in the steel to rearrange themselves to a less swollen form. (Phosphoric acid). This only applies to RUSTED ON BOLTS AND NUTS. If you are working with simply a tight dirty nut or bolt then something like WD-40 or acetone and vegetable oil will help loosen and lubricate it. As you take the engine apart put the parts in plastic bags, and label them well. Do not forget the photos. Use blue or green masking tape on wires to label where they came off.

Fourth step. Tools. If specialty tools are needed you may have to buy or rent them. Pulling a gear off the crankshaft for example takes a special puller. Before you makeshift a tool, and damage something ask yourself if you can afford to buy

a new part, and are they even still available. Beware that when pressure is released springs and small parts take off. I keep the garage door down to contain any parts that do take off. Learn to listen when that happens. The sound of a spring going clink may tell you it landed next to the kid's trike instead of a thunk which was it bouncing at low speed against the plywood piled by the door. IMPORTANT – if there are multiple parts (like lifters) that come from different spots, they MUST go back in the same places. If you pull multiple parts out like that do not mix them up.

Fifth step. This is really the whole purpose of this article. The engine is apart, what do I do next? What parts can I reuse? If I cannot reuse it, why not? What should I look for? Let us face it – you are spending some hard-earned cash here and the last thing you want to hear is that 7.000 miles later a small part you neglected broke and cost you the whole job. What you do want is five to ten years of trouble free driving other than normal maintenance.

Engine Parts:

TIN – Inspect it. Clean it first. Glass beading tin after pressure washing works well. If you live near a stream, this may not be feasible but the quarter car wash is feasible. A used old dishwasher works well too on parts like that. Cracks in tin will grow with time. Is the found crack material? If so, it needs to be welded or the tin replaced. If you are not a welder, get all your tin to someone who is a proficient welder so they can repair the cracks. You can use a Dremel tool to grind down any high spots after the welding, and you will not even see where the weld is. Welding is often less costly than new tin. However, beware when buying used tin – some sellers will hide cracks under new powder coating. Powder coating only hides it until you use it then it flexes and the crack shows again.

CARB – FI ETC – not much here I can suggest. Each part, carb or FI, needs to be inspected. If you are not familiar with the parts, it is best to find someone who can look them over with you. If the engine was running fine when it was disassembled, other than being worn, you may not have that much to worry about with the carb or FI so leave them carb and FI for now in a safe place. The carb can contain gasoline so do not park it next to the water heater or spill the gas onto the garage floor by tilting the carb. There is a FI manual on the Samba that gives a test for each FI part. You can make a note to yourself to test each item as part of the project before you put it back. The Bentley manual has a great section on rebuilding and tuning stock carburetor such as the 34-pict-3. Finding a good used one is the hard part because these cars are over 40 years old, some buses are approaching 50.

ROCKER ARMS, ROCKER SHAFTS, PUSH RODS ETC. When loosening these loosen a little on each bolt at a time or the rocker shaft may bend and break from the valve spring tension. You can roll all the pushrods on a used piece of glass or an old flat glass window to see if they roll smoothly (or are bent). Trust me; you will feel the thump-thump-thump as they roll if they are bent. I like to pull the rocker arms off the shafts and inspect each one. Some folks will just set those aside as a unit. Pushrods and lifters should be labeled to go back where they came from if they are reused. If the cam and lifters are changed it usually does not matter which cylinder the pushrods go back in. Otherwise, they need to go back exactly where they came from.

HEADS – pull them off and set them aside for now. If they are "high miles" just replace them. If they are heavily cracked, replace them. If they have sunken valves, replace them. Can you have them rebuilt if they are high miles and worn out? – yes but you are better off just replacing them. Once a head is beat into the ground by pushing a bus around it has done its job. But – if you can find an identical head that came off a low miles engine – or perhaps say a Beetle or Ghia, then that head might go to a machine shop for an inspection and rework. If it goes to a machine shop you want a 3-angle valve job, springs tested for tension or lined up and eye-balled to see if any are different in height, and new valve guides. If you do this for a living feel free to do your own head. If you think "I'll just drive the guides out, drive new ones in and clean the valves off" you are sadly mistaken about what you will accomplish. When done you will have accomplished nothing but throw each valves geometry off. No two valve guides are concentric to where the valve will seat properly in the same valve seat once the guides are replaced. Check the combustion chambers and port runner roofs for cracks. With air-cooled engines they are often there. Small ones on a T1 engine might not be an issue but a deep one on a T4 engine may dive under a valve seat, or guide and cause it to come loose.

PISTONS AND CYLINDERS. Do not mix and match. If you replace one, replace all. When the pistons are pulled out of the worn cylinders, you need new rings. You cannot put them back in the same exact spot they were run for 40,000 miles. 100 miles yes, 1500 miles maybe, 5,000 miles no. Get new rings.

So, you are now holding a piston in front of you. Look around the sides. How much wear is on it? How much scuffing is on the crown? Slide a feeler gauge between a ring and its land. Is it still in spec or has the land worn too loose? Have a machinist measure the pistons near the wrist pin holes, and again at the skirt. Have the skirts collapsed? If it just a little collapse – maybe .0015", that can be corrected with a light whack from a rawhide mallet on each skirt tang. If it is too much collapsed, please replace the cylinders and pistons together as a set. "OMG," – you say to yourself – this is getting expensive - I need new heads, and new pistons and cylinders. I was going to change the cam too, which means new lifters. This engine is getting expensive!! Yes it is, and it has been going on with VW bus engines for 50 years or more. That is life with a VW bus. Take up a part time job if you need more money. It is life with a VW bus. Let us say the pistons are Ok. How about the cylinders? How much of a ledge is there at the top? How even is the glazing on the inside of the cylinders? Does it look good enough to maybe use? Hand them to the machinist to clean, measure, put a cross hatch in with hopefully a Sunnen boring hone, and BALANCE. MAKE SURE YOU HAVE THE PISTONS BALANCED. This is whether you get new ones or use the old ones. Balanced pistons extend the life of the engine a lot and minimize wear.

CONNECTING RODS. The stock VW connecting rod is sufficient for most applications. When extra large pistons/bores are used, along with say turbo charging then they may need to be upgraded. This article deals with stock rods only. A connecting rod has several components. They are the rod itself, the rod cap, the rod bolts, the rod nuts, the big end bore, and the small end bore and bushing. Each of these areas must be dealt with separately. To refurbish, rods are normally cleaned, then glass beaded and inspected for cracks and/or flaws. Bolts are removed and inspected. The nuts are replaced. The small end bushing is tested with THE ACTUAL piston pin that will be used. These pins float inside the small end, unlike some cars where the pins are captured by heating the rod, inserting the pin, and then cooling the rod. The way to test the pin fit is to lay the rod flat on a sturdy table, put the pin in flush with the table and wiggle the part of the pin sticking out. The pin should feel solid and not wiggle around. The pin is then slipped thru the bore with a little oil on it and the action should be smooth without binding. The big end is measured with a specialty tool that is part of the hone machine for the big end. It is normally done before the bolts are driven out. The matching numbers cap is torqued in a special vise so the cap and rod are parallel, then the inner diameter of the big bore is measured against factory specs. The most important part is the measuring scribe tool must go 360 degrees around. It takes some skill as a machinist to do this because our wrists do not swivel 360 degrees. As a result, many machinists only measure about 3/4 of the way around. This is no good because although the size of the rod may be correct say between 10 - 4 and 8 – 2 (like on a clock), the bore may be pinched near the part line. I have seen it, and the results are a failed engine where many machinists will never understand why. The way to determine if a machinist is good in part is to look at the inside of the big bore. The tool that measures leaves a small scribe line. The scribe line should be continuous 360 degrees with no breaks. Each side of the rod should have one on the bearing surface – quite faint. This is because the machinist will flip the rod over and measure both sides – not just one side. The rods can be accidentally bell shaped when honed, and measuring both sides is the only way to assure the rod is properly honed. The refurbishing process is that the bolt and cap are removed. The cap and rod are clipped a tiny bit with a surfacing tool. Then the rod is put back together, and torqued. It is honed until it is the correct size. Then it is placed on a belt sander, just a kiss so not to remove metal, and that makes both sides parallel. The part line will be almost invisible. If new small end bushings are needed on the set, the old bushing are pressed out by the new ones, then the new ones MUST be honed and tested with each pin it will be used with. There is no one size fits all. Each pin must be fitted to the rod. This is why you will want to have your connecting rods refurbished rather than buying ones that are premade exchanges. Exchanges are not custom fitted to your wrist pins. At this point, the rods are balanced and small amounts are taken off until they balance. The rod is not overheated while doing this or it will need to be re-machined. If any additional work is done – polishing, shot beading to reduce the risk of cracks etc., this is all done before the rods are sized. New nuts are used for your final engine assembly. If the bolt feels funny like it is stretching then it is replaced. I personally like to clean the rods, glass bead them, polish away excess forging marks, press out the small end bushing, do a rough check of balancing, drive the bolts out, inspect the bolts, clip them, hone the big end measuring 360 degrees, and polish the sides, press in new small end bushings, drill

the oil holes if needed, polish the sides of the small ends so they are flush, hone the small end to fit the pin (marking each so they are a matched set), and then balance.

Crankshaft. It should be measured and polished or ground by a reputable grinder. The edges of the journals have new radiuses also. Each rod is laid into a journal and the side clearance checked. It cannot be excessive or tight. I personally do not used crankshafts beyond the second grind - .020" removed. I prefer standard crankshafts that have never been ground. All oil holes should be cleaned with small bottle brushes and solvent when done, and then again before assembly. The surface of the journals are more fragile than an egg shell. Do not let anything bump up against them. The pilot bearing needs to be replaced if it is a built in bearing like the T4 motors. The crank can be fluxed at the machine shop to look for cracks. It should ring like a bell when struck lightly (do not hit a journal). Before polishing, I tape the journals heavily with blue or green masking tape, lightly glass bead the crank except the journal areas to clear debris off it, clean it in solvent then very hot soapy water, blow it dry, then have it fluxed and measured. Then clean it again – every nook and cranny before assembly. IF THE CRANKSHAFT HAS ANY RUNOUT IN IT REPLACE IT.

Timing Gears etc. Remove, glass bead, clean in hot soapy water and inspect. Replace if heavily worn or damaged.

CASE– Clean in parts washer and by hand. Get all the grease and debris off. Some folks paint them. Black is an awful color as one cannot see where oil is coming from on black. It should be inspected for cracks, the cylinder areas should be inspected, some cases may need case savers for the cylinder/head studs. I usually bolt it together and check it with a flashlight for warping. If any studs are loose now is the time to repair them. The main and cam bearing bores should be checked with a straight edge. If the main bores are shiny from the bearings working, or the bearings have pounded in the case may need to be replaced or an align bore. Find someone who does them for high-end motors, and not a shop who has an old boring kit lying around that hasn't been used in years – or they bought off Ebay. Replace gallery plugs with threaded plugs if possible. Clean all passages with bottlebrushes, solvent, hot water and soap, pressurized air and/or pressure washer and air. They need to be spotless.

OIL COOLER - Replace or clean thoroughly. If the cooler is from an engine that had a catastrophic bearing failure and was full of debris – just replace it. Be sure to clean the new cooler too.

FLYWHEEL– professionally surface if needed and check for cracks. Replace if any cracks are found. T4 2L flywheels are cast iron. Double check them as cast flywheels are more prone to failure than forged ones. Make sure the shop that does them is used to doing VW flywheels. BE VERY PROTECTIVE of the surface on the backside that the end play shims ride against. Do not lay it on concrete, other parts where that area can get bumped, dinged, or rusty.

FLYWHEEL SHIMS - Have a plethora of sizes available to you. Lay each on a piece of glass with 1500 – 2000 grit wet and dry. Run it around a little to remove burrs. If any are cupped, bent or wavy they are not to be used except in an emergency, as they will give false readings.

BALANCE - Pay to have all the reciprocating mass balanced professionally - rods, crank, flywheel, pressure plate, fan etc. Do not disassemble T4 fans. Clean and make sure all blades are there and smooth. Check upright fans and blades for cracks. Check Alternator or Generator bearings for smoothness.

CAMSHAFT AND LIFTERS - This is a big area. Different strokes for different people. While I personally prefer Webcam Camshafts for T4 VW buses, I've used Engle on my 1971 T1. We used PBS and Isky on the Fiat Racer. If Isky made a series of T4 cams I might use them. There are some standards that one must watch for. Reground cams are bargain basement stuff. They don't last as well as a new cam because the metal is softer. Same for reground lifters. Would I use them on a T1 engine that is a daily driver – you bet. The engine will wear out before they will. On a T4 that is supposed to go 100,000 miles? No way. The cam will go bad before the engine. When a cam is replaced one needs lifters from the same source as they need to be matched in hardness. I do not approve of hydraulic lifters and camshaft in a VW air-cooled motor. They get air into them and make a racket – pounding the valve seats each time they need to pump back up. After-market cams require that the cam gear be surfaced to fit the aftermarket cam. Special thin headed bolts are used with red Loctite to hold the gear on. Aluminum (marked C on a T4 engine) are preferred to the older magnesium gears

(marked B). The mag gears are old and brittle. They will sometimes fail when new valve springs are used. In general the following holds true:

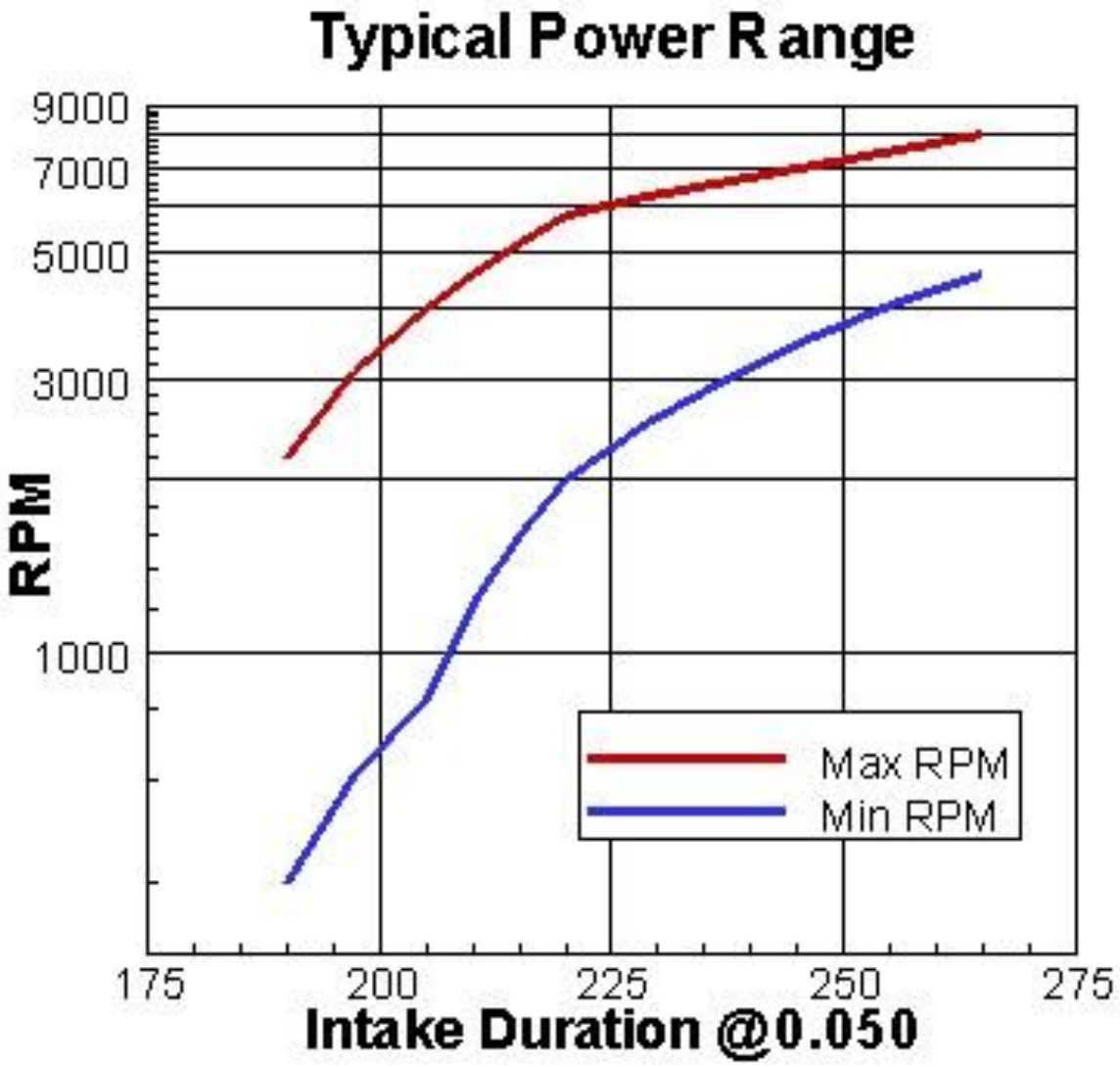
- Choose what RPM range you will spend most of your time driving the bus. Choose a cam that fits that RPM range and you will get best performance. Let us define performance – you can choose a cam and carb combination that works great at 7,000 RPM but lacks power and torque at 2,500 RPM. With that semi-racing cam your bus will require earlier down shifting when you hit that hill or run in to a headwind. Probably this semi-racing cam bus won't be much fun on trips because as soon as the RPM falls off the power will go with it, but it will go like a bat out of hell when you wind it out to 6,000 RPM in 2nd gear all the time. Put two buses side by side you'll beat the other guy once you gear down to 2nd – but your engine won't last as long and you will be gearing down a lot. The other guy with the milder street or RV cam will get there long before you on a trip because he won't be gearing down on every small grade, and he certainly won't suffer the breakdowns you will. His next rebuild will be inexpensive, and yours will require many new parts from all those extra RPM your engine has been running. If you have a T1 engine you may get 30,000 miles on your semi-racing rebuild and he/she will get 80,000 miles on his/her stock rebuild. Below are some general recommendations on cams. Duration on a cam (time the valves are open) is determined in degrees. Duration is measured typically in total just as the valve moves, and again at .050" valve lift - which is more consistent but is also a smaller number of degrees. Do not mix the two measurement types when comparing.

Duration in degrees **<u>at .050"</u>** lift

- 195 - 210 stock
- 210 - 230 street performance
- 240 – 250 – mild race, 3,500 to 7,000 RPM range
- 260 and above racing up to 10,000 RPM

Lift – go with close to stock lift in a bus. The more lift the more the guides and cam lobe will wear.

Below is a chart snagged off the Internet where someone has plotted minimum and maximum RPM for different durations. As an example, a cam measured @ .050" with a duration of 210 - 212 degrees works best between roughly 1000 RPM and 4500 RPM. This cam will pull from idle to about 4500 RPM where the power will begin to get weaker. Top end on this cam under load with ideal carbs or FI would be about 5000 – 5200 RPM. Likewise, someone with a cam of 220 degrees duration @ .050" will get power at 2000 RPM and have it until about 6000 RPM. This engine will idle poorly and be flat in acceleration until the RPM increases close to 1800 - 2000 RPM. It will pull strongly on the top end range for a VW bus but give some drivers fits in stop and go traffic. I use the Webcam 142, which at 210 degrees @ .050" gives me power from idle to 4500. The engine will pull thru to redline at 5400 but reduce in power the closer it gets to the red line once it goes above about 4500 – 4600 RPM. The stock bus cam gave max power about 4100 - 4200 RPM. The Webcam 73 which is 224 degrees @ .050". It pulls from about 2200 RPM to 6000 RPM. Mind you – these numbers are estimates only as carb/FI and exhaust play a part too. The Webcam 73 may not smog well or work FI well because of the low vacuum signal at idle.



Oil Pump. T1 pumps are readily available at this time. T4 motors not so. The best solution on a T4 motor is to start looking for a NOS T4 pump now -that or find a machinist who can blueprint your old one. If the lash between teeth is reasonable on your old pump, and the teeth are not scored by debris, the machinist should shoot for a .0015" clearance between the pump body and gears in and out. That means if you push the gears in and out they should only move about .0015". Less is too tight and it will bind some, more will cost lost oil pressure. This measurement will open up as the pump wears.

ASSEMBLY OILS AND GREASES - There are many that people use. Some folks like engine oil, others prefer some kind of assembly lube with the oil. The one thing that is important is that the builder keep a good approved assembly grease or fluid on the cam lobes to help break it in. Most cam builders will provide the proper grease or fluid.

Good Luck with your engine build.