How to Rebuild Your VOLKSWAGEN Air-Cooled Engine

How to troubleshoot, remove, tear down, inspect, assemble & install your Bug, Bus, Karmann Ghia, Thing, Type-3, Type-4 & Porsche 914 engine. Includes parts interchange. All models, 1961 and up.

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Table of Contents

1. Time To Rebuild? .......................... 5
   Accumulated Mileage .................... 5
   Oil Consumption ........................ 5
   Poor Performance ...................... 7
   Diagnostic Tests ....................... 13

2. Engine Removal ......................... 18
   Preparation ............................ 18
   Beetles & Karmann Ghias (Type 1) ..... 19
   Bus & Transporters (Types 2 & 4) ..... 23
   Fastback, Squareback, Notchback (Type 3) 26
   411/412 .................................. 26
   Porsche/VW 914 ........................ 27

3. Parts Identification & Interchange ...... 31
   Identification .......................... 32
   Engine Descriptions .................... 34
   Cases .................................. 35
   Crankshafts ............................ 38
   Flywheels ............................... 43
   Connecting Rods ....................... 44
   Pistons & Cylinders .................... 45
   Cylinder Heads ......................... 46
   Oil Pumps & Camshafts .................. 53
   Oil Coolers & Sheet Metal .............. 55

4. Teardown ................................. 57
   Accessory Removal—Uprights ............ 58
   Accessory Removal—Flat ................ 62
   Basic Engine ............................ 66
   Valve Train ............................. 66
   Cylinder Heads ......................... 68
   Oil Pump ................................ 68
   Splitting Cases ......................... 70
   Crankshaft Teardown ..................... 72

5. Crankcase & Cylinder Reconditioning .... 75
   Clean & Inspect Crankcase Parts ........ 75
   Crankshaft .............................. 82
   Pistons & Connecting Rods ............. 88
   Oil Pump ................................ 94
   Camshaft ............................... 96

6. Cylinder Head Reconditioning ........... 100
   Disassembly ............................. 101
   Valve Guides & Stems .................... 105
   Inspecting & Reconditioning Valves .... 107
   Valve-Seat Reconditioning ............. 110
   Rocker-Arm Service ..................... 111
   Valve-Spring Inspection & Installation 112
   Cylinder Head Assembly ............... 114
   Intake & Exhaust Manifolds ............. 115

7. Engine Assembly .......................... 116
   Crankcase Assembly ..................... 119
   Install Crankshaft ..................... 121
   Install Camshaft ....................... 122
   Prep Cylinders .......................... 132
   Valve Train .............................. 134
   External Accessories ................... 138
   Type 1 & Pre-’72 Bus ................... 138
   Type 3 .................................. 143
   411/412, Post-’72 Bus, 914 ............. 148

8. Engine Installation, Break-in, Tuneup .. 156
   Transaxle Prep .......................... 156
   Engine Installation ..................... 157
   Type 1 .................................. 160
   Type 2 .................................. 161
   Type 3 .................................. 162
   Type 4 .................................. 163
   914 .................................... 166
   First Start! .............................. 169
   Break-in & Tuneup ....................... 170

   Index .................................... 173
Introduction

The Volkswagen Beetle hardly needs an introduction. In any society with private transportation they’re ubiquitous in the extreme; it’s difficult to imagine roads without them.

But in the mid-'30s there were no Volks- wagens, not even in Germany. In fact, there weren’t many cars of any type on German roads, a fact Adolf Hitler said he was going to change. His requirements for an inexpensive, mass-produced, high-cruising-speed car were presented at the 1939 Berlin Motor Show. A factory was built in Wolfsburg for Beetle production and Germany was about to get its car.

Of course, what Germany got was a long way from the people’s dream of motoring down the autobahn. War brought Volkswagen production only in the transmuted Type 82 military form, now known as the Thing. Although 70,000 Type 82s were built for the Wehrmacht, such a basic design was hardly suitable for popular transportation when hostilities ended, or for the chaos in what was left of Germany. Without a government, currency or economy, it seemed the Volkswagen had been stillborn. But from the rubble of 1945 a few cars were built from spare parts. The British officer in charge of the Wolfsburg factory assisted the German workers in building more cars, and the Beetle was on its way.

Eventually the Volkswagen came to the United States. As in other worldwide markets, the Beetle sold on its economy and superior workmanship. Americans came to respect and ultimately adore the round-backed car, buying it in numbers other import builders could only envy. Bus and Squareback versions followed with equal success.

Now, long after the introduction of faster, quieter and roomier economy cars, air-cooled Volkswagens continue to be popular. Other cars may be more modern, but none offer the old-world craftsmanship or personality of a Volkswagen.

And so we reach the point of this book, rebuilding air-cooled Volkswagen engines. This is an engine that needs step-by-step instructions for rebuilding. It’s not that it’s so difficult to rebuild. No, with minimal patience, tools and cash, the air-cooled VW is easily overhauled. It’s just that the engine is so completely different. In fact, you’d have difficulty coming up with a design more out of the ordinary if you tried. Traditional rebuilding techniques and books based on them don’t have much to offer the VW rebuilder.

But just as unfamiliar roads are easily traveled if you have a good map, this book helps make VW engine rebuilding easy. Pitfalls can be avoided if you know about them ahead of time, and like a detailed map, this book points out the hazards.

With the wrong turns clearly marked, rebuilding an air-cooled VW is fun. Just as a Beetle or Bus is fun to own and drive, rebuilding these engines is probably more satisfying than going through other, more common engine styles. Unlike many engines, the VW offers opportunities to measure and adjust basic engine parameters; not just disassemble and assemble engine components.

This book eliminates a lot of legwork for you. I’ve traveled to machine shops, parts suppliers, manufacturers, racers and other VW specialists to gather the information presented here. The knowledge in these words and pictures represents the combined experience of many people, all experts in their field.

For the camera and personal experience, I rebuilt several air-cooled engines, and I think you’ll agree the intricacies of VW engine rebuilding are more thoroughly documented here than anywhere else. Additionally, the “Parts Identification & Interchange” chapter offers considerable money-saving information, not available anywhere else.

A few specific understandings and cautions are appropriate here. First, until you’ve been around VWs for some time, it’s difficult to remember to keep the positions front and back properly oriented. Like left and right, front and back in this book are based on the engine while it is in the chassis. Thus, the flywheel is at the engine’s front, and the crankshaft pulley is at the rear. Cylinders 1 and 2 are on the right, and 3 and 4 are on the left. This goes against common, ingrained automotive knowledge and takes some time to get used to.

Therefore, you have to keep reminding yourself that the flywheel end is the engine’s front. After awhile it becomes natural. Of course, there has to be an exception, and the 914 is it. A mid-engine car, the 914 engine is turned around so its flywheel is at the car’s rear. Unless this is important, as in the removal and installation sequences, 914 engines are treated like any other. So when I speak of the front oil seal I mean the one at the flywheel end, whether you have a Bus or 914.

Also, always take the time to double-check your work. Just remember the saying, “There’s never time to do it right the first time, but there’s always time to do it over.” It’s a lot faster to double-check than it is to rebuild it twice.

Finally, while VWs are a common sight and don’t command high prices, that doesn’t mean they are a cheap, throw-away car. A lot of care and thought went into every VW built, and engines like an appliance won’t pay off. VW engines are full of precision tolerances that respond to cleanliness and careful assembly.

So read ahead, and keep this book on the bench where it will be handy. If this is your first engine rebuild, it may seem like there are too many steps or points to remember. To that I say, get started and handle each point one at a time. Read ahead of your progress in the shop to keep the job in perspective and alert yourself to needed tools or supplies. Soon you’ll be listening to your Volksputtering smoothly in the driveway—a sound of wonderful personal satisfaction.
Simple as it may sound, before beginning an engine rebuild, first decide if a rebuild is necessary. Sometimes this is easy, for instance, when two connecting rods are poking through the top of the case. Other times, some diagnosis is needed.

In this chapter, we'll examine some diagnostic steps to determine engine condition. By following them, you'll get an exact "State of the Engine," which will help you decide if a rebuild is required.

Before beginning your efforts, leaf through this book and any other VW literature available, i.e., the owner's manual. Study the pictures and skim the high points of the text. Get a basic comprehension of how air-cooled VWs are bolted together, so you can understand what's going on when they fall apart.

**ACCUMULATED MILEAGE**

Total mileage isn't a very good yardstick of engine condition. Pay more attention to how the car was operated and maintained during those miles. These are more important than the accumulated miles.

While the air-cooled VW engine, especially Types 1—3, isn't well-known for extreme longevity, it will go more than 100,000 miles between rebuilds. When driven inside its performance limitations, and given proper service, a sedan engine should last this long.

Bus engines and those driven off-road typically last less. Bus engines wear faster because of extra weight, wind resistance and their low gearing. A Bus engine revs higher than a sedan, so the engine "travels farther" than a sedan powerplant for each mile covered. Dirt is the enemy of off-road engines.

Those engines with the shortest lifespan are the poor engines driven hard and given little service. VW engines are susceptible to heat. Driven hard, they can be overheated, especially if the oil isn't changed often. The air-cooled VW just doesn't hold that much oil. It also has no paper oil filter, (except in the late Bus and Type 4), so frequent oil changes are absolutely mandatory for long engine life.

**OIL CONSUMPTION**

Oil consumption is determined by an engine's internal clearances and is an excellent gage of engine condition. When an engine is new, its internal clearances are easily bridged by an oil film. There are tight seals at the piston rings and valves, and high oil pressure at the main, rod and camshaft bearings.

As miles accumulate, these parts wear and dimensions increase. Then, oil cannot bridge the gaps between rings and cylinder walls and is sucked into the combustion chamber and burned. You'll see a wispy trail of blue smoke from the exhaust pipe.

At the crankshaft, excess clearance has less resistance to oil flow, and oil works its way to the ends of the journals where it's flung off. This causes more oil to try and fill the void and...
Oil consumption is an excellent indicator of an engine's internal condition. To check, make sure oil is level with top line. Record odometer reading, and read dipstick regularly. When oil level drops to the first line note mileage and subtract first reading from second. Difference is oil consumption rate.

Filthy engine and missing air filter will shorten this Bus engine's utility. Lack of service and poor operating practices will destroy any engine, but air-cooled VWs in particular require regular oil changes and spot-on ignition timing.

How Much Is Too Much?—Certainly, there's no harm in burning a quart of oil every 1000 miles or more. Between 500—1000 miles per quart indicates a slightly wide clearance somewhere in the engine, but not enough to justify tearing it down. Such oil consumption can result from parts on the loose end of the acceptable-tolerance range, or from partial rebuilds where the cylinders and pistons were not replaced. If a new quart is needed every 500 miles or less, the engine needs attention.

There are two parts that contribute to an engine burning oil: worn rings and valve guides. Both let oil enter the combustion chamber where it is partially burned and sent out the exhaust. A single puff of smoke immediately upon start-up after sitting overnight usually means worn guides and piston rings.

Another good test is to find a long hill to coast down while in top gear. When you reach the bottom, glance in the mirror as you open the throttle. A puff of smoke indicates worn guides or rings. But, if the engine lays down a smoke screen, you can bet the rings are at fault.

Blowby—Just as worn rings and cylinders allow oil to enter the combustion chamber, they also let combustion gases pass in the other direction, into the crankcase. These blowby gases pressurize the crankcase, contaminating the oil. Telltale signs are blowby vapor blowing out the oil-filler and dipstick holes.

Blowby used to be vented to the atmosphere at the oil-filler hole, but it has been routed to the air filter by a hose and metered orifice (valve) since the mid-'60s. From the air filter, the blowby is burned in the combustion chambers, along with the normal air/fuel mixture. This positive crankcase ventilation (PCV) plumbing draws more blowby out of the crankcase than merely venting it to the atmosphere. Oil stays cleaner, and less pollutants are spewed into the atmosphere.

There is no PCV valve on Type I and upright Type 2 engines. Type 3 and 4 engines use a PCV valve in the hose leading from the crankcase to the intake-air distributor. Fresh air from the air filter enters the engine at the rocker covers on these engines. A flame arrestor is placed in both hoses running from the air filter to the rocker covers to stop backfires from reaching the crankcase.

Valve Guides—Some oil passage past the valve stems and piston rings is normal. After all, if the rings and guides were sealed oil-tight, they would wear out in less than 10 miles from metal-to-metal contact.

Excessive oil loss through the guides occurs when guide-to-valve clearance is too large. This lets too much oil between the guide and valve stem. Then, next time the intake valve opens, oil is sucked into the combustion chamber. Exhaust valves can pass oil the same way. But because an exhaust port is a hot, mostly high-pressure area, excessive clearance there results in blowby into the rocker cover. Air-cooled VW engines are hard on guides because of the angle with which the rocker arm contacts the top of the valve stem. So, oil loss through the guides is common.

Oil Leaks—Many air-cooled VW engines leak oil. Much of the time, the leaks are minor, and won't affect oil-consumption calculations. But, if the engine has more than one leak or one bad leak, it will affect these figures.

So you won't be fooled by an oil leak when trying to figure how much oil is being burned, let's review some of the common oil leaks. Because some oil leaks result from worn engine internals, this review should be an integral part of the engine diagnosis.

Oil Pressure Sender—Oil-pressure senders often dribble from their plastic centers, causing a puddle right under the sender. Wiggle the plastic center. If it is loose, replace the sender. Original-equipment (Bosch) senders are best.

Oil Pump—Leaks from around the oil pump are most common in recently rebuilt engines. They result from prying the crankcase halves apart with screwdrivers, ice picks and other barbaric instruments. Tighten the oil-pump cover plate first. If that doesn't stop the leak, remove the pump and try repairing the mating area of the crankcase. RTV silicone sealer makes a good temporary fix here, but the per-
A permanent cure is disassembling the engine and adding material by welding.

**Engine/Transaxle Mating Surface**—Most engines leak some oil at the front, the result of an overworked crankshaft oil seal. This results in a mess on the engine's bottom, but shouldn’t cause any alarm.

On the other hand, if the area is washed clean by oil flowing from the bellhousing area, the oil leak is serious. If the seal was recently replaced, it may have been installed incorrectly. Removing the engine and installing another one is the only cure.

If the engine has a lot of miles on it, and the seal has not been changed recently, then the rear main bearing may be pounded out—the case is actually deformed—from excessive end play. This is a serious problem and should be investigated right away.

The cause originates from the #1 main bearing, the one closest to the flywheel, wearing out. The wear is in two directions, one parallel to the crankshaft, called end play, and the other perpendicular to the crankshaft. The perpendicular force wears the main-bearing bore eggshaped, so the crankshaft is free to wobble.

Of course, excessive end play and wobble distort the neoprene oil seal at the bearing bore, and oil pours past it. If this problem is detected soon enough, the main-bearing bore can be machined and the case saved. If the problem is allowed to continue, machining probably won’t do any good, and the case will have to be replaced—an expensive fix.

There isn’t any method for detecting crankshaft wobble while the engine is in the chassis. But you can measure end play, at least in Beetles and early Buses. Mount a dial indicator to read directly off the crankshaft pulley and measure end play. It can take lots of muscle to move the crank when the engine is together, so depress the clutch and then monitor the pulley. Use the detailed directions for measuring end play on page 126, if necessary. If there is a large oil leak at the bellhousing, and the end play is or even seems to be excessive, pull the engine and rebuild it. Putting this problem off can be very expensive.

There’s a chance, too, that the transaxle seal is leaking, and it also drips out the bellhousing. Get a dab of the dripping liquid on a finger tip, then smell or taste it. If you’re unfamiliar with the smell and taste of gear oil used in the transaxle, open the transaxle filler hole and take a sample. Compare it to the bellhousing leak. If the transaxle is leaking, pull the engine or transaxle and replace the transaxle seal right away. This problem won’t go away, and the longer it leaks the greater the chance of ruining the clutch disc.

**Oil Cooler**—Oil coolers leak for two reasons. Either the cooler has split apart anywhere along the tubes, or it is loose on its mountings. Both leaks are real gushers because of the large volume of oil passing through the cooler. Remove the cooler to inspect the mountings and have it pressure-checked.

**Case Leaks**—These can be anywhere along the case parting line. Usually these are little weeping leaks and pose no danger. When oil pours from between the case halves, however, someone has used a screwdriver to pry the case apart there; a definite mistake. The machining on VW case halves is of the highest quality, and their precision, gasketless joint is a marvel of German production technique. To stab a screwdriver into this joint is criminal, and will cause a leak. Unfortunately, there is no cheap, sure, cure. You can try RTV sealer, Devcon or some other material to fill the gap, but the only enduring cure is to weld or replace the case.

A case can also leak through a crack. The magnesium case of Type 1—3 engines will crack sooner or later from fatigue. Chapter 5 has more information on case cracking. See page 76.

**POOR PERFORMANCE**

Performance is best defined for our purposes as efficiency. This is because when an engine yields poor fuel economy and power, it is inefficient. Diagnosis should determine if the engine is using the right amount of fuel to produce the expected amount of power. Remember, performance refers to both engine power and fuel consumption. If power or fuel economy drops, engine internals may or may not be the cause. The diagnostic tests later in this chapter are designed to systematically uncover the specific problem.

To locate the source of poor performance, start with a tuneup. This means a valve adjustment, points, plugs, dwell, timing and carburetor or injection tuning. Complete the tuneup yourself before performing any diagnostic tests or have it done by a professional tuneup shop. Get a complete analysis of the engine’s condition from the shop. They see many, many cars and have learned to quickly and accurately diagnose their problems.
Basic Fuel-Injection Troubleshooting—

Later engines have lots of vacuum and fuel hoses that are part of the fuel-injection system. All hoses must be in perfect shape and tightly sealed, or the engine will not run right or respond to tuning. The idle may be erratic, stumbling and searching (increasing and decreasing); this is called hunting.

Other fuel-injection problems can convince you the engine is at fault, but can be solved with minimal work, if not expense. If an injected engine won’t run, first make sure all fuel-system parts are correctly installed. Every part must be in place, including the air filter.

Check all hoses for connection and condition. A stuck airflow sensor, the flap in the box next to the air filter, can cause driveability problems. If the flap won’t move freely after a little fiddling, buy a new one. Finicky idle problems and weird throttle response on fuel-injected Buses and 914s are often caused by a bad throttle switch mounted right next to the throttle, move the cover and note the wiper contacts that signal throttle position. Bending the arms so they wipe a new area often helps. Fuel-injected engines have few adjustments and are great at-home tuneup projects.

If a tuneup doesn’t restore lost performance, do the following diagnostic tests. Tuning the engine will have helped in two ways. One, by showing there is something internally wrong and two, eliminating external variables from the diagnostic tests. Don’t skip the tuneup, or some of the diagnostic tests will be inaccurate. For example, a cylinder won’t have full compression if the valves are incorrectly adjusted. Vacuum test results will also be affected.


CAUSES OF POOR ENGINE PERFORMANCE

A quick look at the most likely internal engine problems will help put them in perspective before you start testing for them individually. Keep in mind that internal-combustion engines are nothing but air pumps. They perform work by inhaling air, compressing it and expanding it, harnessing the expansion and exhaling the byproducts. Burning fuel only makes the air expand. So, anything that hinders an engine’s breathing reduces its efficiency—both power and fuel economy.

The key to an engine’s pumping efficiency is the tightness of the combustion chamber: the area formed by the piston top, rings, cylinder wall, head, valves and sparkplug. If any of these parts allow air to escape from the combustion chamber, engine performance will drop. Additionally, engine breathing will suffer if the valves and valve train are in poor shape.

A worn-out engine will generally perform poorly and use a lot of oil. This is most likely caused by worn rings and cylinders. But it is also possible for engine performance to be low and oil consumption to be normal. In this case, the valves, camshaft, or valve springs could be at fault.

Burned Exhaust Valve—When a mechanic says a valve is burned, this means that some of the valve’s face (sealing surface) has been eroded away or cracked by the blast of hot combustion gases. Think of combustion gases as an inefficient cutting torch and you’ll understand why valves burn.

A burned exhaust-valve face can’t make a gas-tight seal against its seat, which causes a large drop in power and compression. As this condition worsens, a chunk may be burned from the valve head, allowing all compression to escape out the exhaust port. The engine then runs on only three cylinders. When a chunk is missing, it’s indicated immediately during a compression test. If a valve won’t stay closed, the valve guides or stem may be worn.

Exhaust Valve—Another clue. If the engine responds to the tuneup with renewed performance, you’ve probably cured any problems and a rebuild isn’t necessary. But, go ahead and do diagnostic tests as a double-check.
compression test because engine cranking speed doesn’t change on that cylinder's compression stroke and the gage reads very little or no compression.

Even worse than a burned exhaust valve is a dropped exhaust valve. A valve drops when the head breaks off from the stem. Because many Type 1-3 exhaust valves are made with heads and stems joined together, they sometimes separate at the joint. When this happens, the valve head destroys the piston crown, cylinder wall and cylinder head as it gets slammed around by the piston.

The valve stem, spring, retainer and keepers usually separate also, causing all sorts of havoc in the rocker cover. Metal particles circulate with the oil and score the crankshaft, camshaft lifters and oil pump. Luckily, the exhaust valve will burn badly before it drops, so this is some warning before it destroys the entire engine.

It’s painfully obvious when an engine drops a valve. It will immediately begin running on three cylinders accompanied by a lot of horrible (and expensive) rattling. Instantly shut off the engine to help minimize damage.

One primary cause of burned valves is incorrect valve adjustment. This isn’t a factor on ‘78 and later Buses because they have hydraulic valve lifters. Hydraulic valve lifters adjust the valves automatically and eliminate the need for periodic valve adjustments. All other VW air-cooled engines use solid valve lifters and need periodical valve adjustments. Skipping this service or maintaining insufficient valve clearance can easily lead to burned valves.

A valve cools best only when it is fully seated. Some cooling takes place through the guide, and some at the seat when the valve is closed. If a valve stays open longer due to tight clearances or whatever, it has less time to cool and absorbs even more combustion heat.

The burning process has begun.

Even well-maintained valves can burn if a piece of carbon gets caught between the valve head and seat as the valve closes. This holds the valve partially open and can start the gaseous process. Once it starts, the valve becomes open and the valve becomes uncontrolled. Usually a valve will be noticeably burned in 2,000 miles or less.

The exhaust valves used in 914 engines are less prone to burning than other Type 4 engines because they are sodium-filled. This type of valve has a hollow stem, partially filled with sodium. Sodium melts well below the operating temperature of the valve, so it is a liquid when the engine is running. Reciprocating valve motion throws the sodium back and forth with piston motion. The problem is the threads in the case, not the studs. The studs are steel, and their threads are strong. The threads in the case are magnesium, which is a match for steel when it comes to mating threads. Under normal conditions, the studs won’t pull. But after 100,000 miles, the magnesium can fatigue and the threads weaken. Then the weak threads are ripped right out of the case by cylinder-head torque and combustion pressure.

Excessive cylinder-head torque will also destroy these threads in short order. Some people may look at the low torque specifications given for these cylinder heads and figure they aren’t enough. So, when they assemble the engine, they add ten pounds torque to the cylinder-head nuts. Or, perhaps they are having cylinder-head sealing problems. So they whip out the breaker bar and crank the head nuts down another turn.

What they don’t understand, is the torque applied to the cylinder-head nuts is not the same amount of torque that seals the heads. When the engine is cold, there is only 18 or 23 ft-lb of torque on the studs. But when the engine warms up and expands like a balloon, the aluminum cylinder heads and cast-iron barrels grow a lot longer than the steel studs. The studs are strained and being pulled from the case. Now the effective torque on the studs is nearer 55 ft-lb. If the at-rest torque is missapplied, for example, to 40 ft-lb, then it will reach over 70 ft-lb at operating temperature. No wonder the studs pull out of the case!

Overheating the engine has the same effect as overtorquing the cylinder-head nuts. The engine expands oversize when it is overheated, putting more strain on the cylinder studs. The first point to give is the cylinder stud threads in the case.

When the studs do pull, it leaves the cylinder free to hammer the crankcase and cylinder heads. If the problem is caught soon enough, the heads and case can be machined back to service, but don’t count on this remedy all the time. The hammering ruins the engine and it’s not even a worthwhile core. Because once the cylinder heads, barrels and case halves are replaced, you’ve just about bought a new engine.

Pulled studs are a very common problem up through the ’70 Type 1—3 engines. Type 1—3s from ’71 have steel thread inserts installed in the case at the factory. The steel thread inserts are commonly called case savers. They can be added when rebuilding to earlier cases that don’t have them.

With case savers installed, pulled threads are no longer a common problem. If an engine with case savers is overheated, however, the cylinder heads can warp, letting combustion pressure escape between the cylinders and cylinder heads. Hammering of the case and heads by the cylinders is not a problem with warped heads.

**Carbon Deposits**—Although carbon deposits don’t fall under the category of engine damage, and a rebuild is not necessary to remove them, a few words about carbon will help you with engine diagnosis.

Carbon is the solid byproduct of incomplete combustion, some of which sticks to the combustion-chamber surfaces. Both gasoline and motor oil are hydrocarbons, so burning them in the combustion chamber in the wrong amounts causes excess carbon deposits.

The most common source of harmful carbon deposits is excessive oil consumption, although a rich air/fuel mixture can be just as bad. Prolonged idling and slow driving can also cause carbon buildup. So, carbon deposits are a symptom of a problem, not the source. Merely ridging the engine of carbon won’t cure the problem, only delay the symptoms. Therefore, while there may be ways to get rid of carbon buildup without overhauling an engine, curing
excessive oil consumption may mean an engine overhaul.

Carbon deposits cause trouble in two ways. First, they may shroud the valves. Carbon deposits build up on the backside of a valve and restrict air/fuel mixture flow into the cylinder. Carbon deposits in the combustion chambers can also cause damage. Carbon easily heats to incandescence, causing preignition and detonation. These types of abnormal combustion can damage an engine by placing a heavy load on engine internals.

Imagine red-hot carbon in the combustion chamber. When a fresh intake charge is compressed on the compression stroke, the hot carbon preignites the mixture. A moment later, the sparkplug fires and the mixture also starts burning near the plug. The two flame fronts collide, sometimes producing an explosion—detonation—rather than even burning. The resulting sudden pressure and temperature rise is more than the engine was designed for. Piston, valve and ring damage can result if preignition or detonation is prolonged. Although as severe as preignition without detonation causes excess combustion-chamber pressure and temperature, but without any accompanying pinging or knocking.

Detonation is very similar to preignition, but the second ignition source, the glowing carbon, lights the mixture after the sparkplug has fired. Again, combustion-chamber temperature and pressure exceeds engine design limits and damage occurs. Audible signs of detonation are pinging or knocking, sounds akin to colliding billiard balls.

Admittedly, substantial engine damage from preignition or detonation isn't prevalent, but severe cases can burn or blast holes in pistons, break rings, and deform the main-bearing bores in the crankcase. Also, long-term light detonation will wear the rings, pistons and cylinders more quickly. So, prompt attention to the causes of abnormal combustion is wise. They are usually associated with low-octane gasoline or over-advanced timing.

Recent research indicates a small amount of knocking or pinging is not harmful to an engine, but does reduce fuel economy and power. This is sometimes called light pinging. Nevertheless, be concerned if the engine is knocking heavily. Besides carbon buildup, detonation can be caused by stale or low-octane gasoline, over-advanced ignition timing and engine overheating. Check for these problems if the engine detonates.

Pay special attention to the ignition timing of a VW engine. As an air-cooled engine, it is very susceptible to overheating and preignition caused by too-advanced timing. If the engine pings at the slightest load, retard the timing a degree at a time until it doesn’t ping. This timing setting may be retarded from the specified stock setting, but with today’s fuel it might be necessary.

Ignition timing is also commonly over-advanced by owners looking for more power. It’s no secret that advancing the spark in air-cooled VW engines increases their power. throttle response and improves engine acceleration. But the penalty for too much total advance is severe detonation. If you advance the ignition past specification, you may pay for it with an engine overhaul.

Need another warning: These engines self-destruct rather quickly when the cooling system fails. If the cooling flaps remain shut from a broken or missing spring, stuck thermostat, or foreign objects in the fan housing, cylinder temperatures will quickly go sky-high. The excess heat will cause severe detonation, hole a piston and spew metal throughout the lubrication system. This devastation can happen in less than one minute if the engine has been running for 10 minutes and is fully warmed.

Loose carbon deposits can also lodge between the electrodes of a sparkplug, or get between a valve head and its seat, as mentioned earlier. If a piece of carbon sticks between the plug electrodes, the sparkplug will short out and the cylinder will misfire or go totally dead. Plug replacement or cleaning usually cures these problems.

A carbon-aggravated problem most people are familiar with is dieseling—the engine runs on after the key is turned off. A hot piece of carbon acts like a diesel-engine glow plug by supplying an ignition source other than the sparkplug. Ridding the engine of carbon, slowing the idle and reducing spark advance a few degrees will help eliminate dieseling.

As a final note on carbon, consider vehicle operation. If you drive a delivery route, or do a lot of in-town, slow-speed, short-trip driving, carbon will build up because of low cylinder temperatures. You can easily burn-out excess carbon accumulated this way by taking the car for a long trip. Drive it a half hour or more at freeway speeds. This will heat the combustion chamber and burn away excess carbon. If that doesn’t help, the engine may need a professional tuneup or carburetor overhaul. Worn rings and valve guides will also cause excessive carbon buildup from incomplete oil burning. They contribute excess oil to the combustion chamber and it can’t be completely burned.

Fuel Shut-Off Solenoid—Type 1 and 2 carbureted engines since ’70 have an electric fuel shut-off solenoid attached to the idle circuit of the carburetor. When the ignition is turned off, the solenoid is deactivated and a spring-loaded plunger closes the idle circuit. This should stop the dieseling mentioned above. So, if there is a problem with it, the fuel shut-off solenoid may be faulty.

To test the solenoid, remove its electrical lead. Look for the small can on the side of the carburetor with the wire leading to it. The solenoid is on the left side on ’71 and later carburetors (34mm) and on the right side on earlier carburetors. Turn on the ignition without starting the engine. Now touch the lead to the solenoid connection. Each time you touch the lead, the solenoid should click (the plunger is moving inside). The continuous clicking indicates the wire is good. If the wire is bad, check for a "dead spot" in the wire. Sometimes, solenoids with a carbon problem will stall the engine. The solenoid may have shorts, but switch the speed and it may stop detonating.

On older models, the solenoid may be a plug-in type. The only problem with this type is that if you push it in, it作风

FITNESS FOR THE JOB

Now that you've seen the problem with the solenoid, you may want to replace it. It is sometimes a good idea if it is in doubt, but don't wait for the problem to occur.

Stethoscope is preferred tool for pin-pointing internal engine noises because it amplifies sound coming through probe and reduces surrounding noise with earplugs.
inside. If you don’t hear a click, check if the wire is supplying electricity with a test light. If the wire is “hot” (has voltage), the solenoid is bad and needs to be replaced. If the wire is “dead” (no voltage), trace and repair the wiring fault, and then recheck the solenoid operation.

Someone may have replaced the solenoid with a standard idle screw. If so, there’s no problem, unless the engine diesels. Then reinstall the fuel shut-off solenoid. Carburetors not originally equipped with the solenoid can’t have it added. Consequently, timing and idle-speed adjustments are required in these cases to stop dieseling.

On pre-'71 carburetors, the fuel shut-off solenoid’s end doubles as the idle metering jet. The orifice is very small and even the tiniest dirt particle can clog it. A shot of compressed air usually clears the orifice.

On Type 3s with dual carburetors (and two solenoids), determine which one is defective by disconnecting first one solenoid and then the other. The engine will die when you unplug the solenoid that’s working and show little change when you unplug the one that’s not.

Fuel-injection systems stop fuel delivery when the engine is shut-off, so dieseling shouldn’t be a problem with them.

**DIAGNOSIS**

Now that we’ve examined some engine problems, let’s start in on how to find them—without taking the engine apart. The engine may or may not be exhibiting problems, but do the tests anyway. If it has a problem, you’ll find it. If not, you’ll have established a baseline of the engine’s condition. From there, you can decide whether to rebuild now or later.

**NOISE DIAGNOSIS**

**Internal Noises**—Diagnosing engine noises is a difficult and imprecise art. Many factors influence the way sounds are perceived, not least being the human factor. When investigating an automotive sound, try different spots. Open the hood, close the hood, sit inside the engine compartment will help mask the exhaust, so close your eyes to help focus attention on the sounds. Cupping your hands around your ears may look funny, but it helps mask sounds from the sides and amplifies those in front. It’s a great way to pinpoint a noise.

Finally, learn to mentally dissect what you are hearing. Upon first hearing a running engine, the initial impression is a big jumble of sounds. By critically identifying each sound, you can more easily block out the unimportant sounds while concentrating on those you want to hear. Aids for locating noises are a stethoscope, length of heater hose or a wooden dowel. Unlike the stethoscope a doctor uses, an automotive stethoscope has a solid metal probe at the business end. It works best when held against a solid part—head, case, manifold, bolt head or the like. If you suspect a noise from beneath a cover, place the stethoscope against a nearby bolt head or solid rail. For example, a noisy valve can best be heard by listening at the edge of the rocker cover or cylinder head, not at the middle of the rocker cover.

As a second choice, a length of hose or dowel can be used instead of a stethoscope. With a hose, hold one end firmly against the engine and the other end to your ear. When using a dowel, position the receiving end of the dowel against your skull, just forward of your ear, so engine vibrations don’t bounce the dowel into your ear.

Engine noises can be lumped into three categories: intermittent ones, those occurring at every crankshaft revolution, and those occurring at every other crank revolution. First, the intermittent sounds—the oddballs. These are external sounds coming from loose brackets, rubbing hoses, items stuck in the fan and so forth. By poking around the engine compartment, you can single out and stop these noises.

Noises that occur at every other turn of the crank—at camshaft speed—are most likely coming from the valve train: valves, rocker arms and lifters. There is one bottom-end noise that can happen at every other revolution—piston slap. Piston slap is the sound produced by the piston slamming against the cylinder as that cylinder fires at the top of the power stroke.

Piston slap is audible when piston-to-bore clearance is excessive. And, because there’s only one power stroke for every two crank revolutions, it occurs on every other crank revolution. Piston slap is easiest to detect on a cold engine, before the pistons have expanded, reducing piston-to-bore clearance.

Noises occurring at every turn of the crankshaft come from the bottom end: worn piston pins, broken rings, worn rod bearings and main bearings.

If you have trouble telling whether a noise is at one-half or at crankshaft speed, hook up a timing light and see if the noise coincides with flashes of the light. If it does, the noise is at one-half crankshaft speed—a top-end problem or piston slap. If the noise occurs twice for every flash, it’s at crankshaft speed—a bottom-end problem.

**Isolating Normal Noises**—Now for the hard part: What do these problems sound like? Let’s start with normal engine sounds. As you listen to an air-cooled VW, the dominant sound will be the exhaust. Leaning forward into the engine compartment will help mask the exhaust, so you can more easily hear internal engine noises.

Once past the exhaust, the main noise of an idling engine should be the soft ticking of the valve train. Raise the rpm past idle and the ticking should turn into a whirr. If you hear one valve over the rest, or if all the valves are making more of a harsh clacking sound, adjust the valves.

A proper valve adjustment can only be done while the engine is cold. But, if you are checking for one loose valve, you can locate it on a warm engine. Just remember to properly adjust the valves after the engine cools. All air-cooled VWs use 0.006-in. valve clearance, unless it is a Type 4 engine with hydraulic lifters. There have been other clearances specified by VW in the past, but all have been superseded by the 0.006-in. measurement. Valve adjusting procedures are on page 136—138.

If valve adjustment doesn’t cure a valve-train noise, it’s possible there is a worn camshaft lobe or lifter. Then all the valve-adjustment tightening in the world won’t quiet the engine; it will only burn the valve. Never close a valve adjustment tighter than 0.006 in., or the valve will burn. If the valve noise remains after adjustment, look elsewhere for the source. Try the rocker arms, lifters or camshaft.

Rocker arms can be checked by moving each by hand with the valve completely closed. If there is any appreciable movement other than 90° to the shaft, the rocker-arm bushing or shaft is worn. This, in effect, increases the valve clearance, which increases noise. Cam and lifter inspection require engine disassembly.

The other major noise in a air-cooled VW engine compartment comes from the fan. It can make several different sounds, ranging from the low-pitch noise associated with a house fan, to a high-pitch whistle. Type 3s and flat-engine Type 2s project more fan noise than Type 1s, early Type 2s and 914s because the fan is right in front of you when looking into the engine compartment.

**Abnormal Fan Noises**—A lot of abnormal noises come from outside the engine. For example, a whining or screaming from the fan area usually means something is caught in the fan. Stop the engine, and probe the fan area with your fingers. If the fan noise is whining or screaming, try loosening the fan belt or drive belt.

Another test is to unplug the fan motor, and probe the motor. If the noise disappears, you’ve got a cracked fan or bad generator or alternator bearings.

This test will isolate only the generator or alternator on Type 3 and 4 engines because their fans are driven directly off the crankshaft. Therefore, if you still have the noise with their fan belts removed, the problem is in the fan.

A sharp, intermittent rattling noise from the sheet-metal fan shroud of Type 1 and 2 engines may be a loose or broken fan. Check the tightness of the large fan retaining nut, and try to wiggle the fan on its hub. It may be necessary to remove the fan and generator assembly to investigate this noise.
Rhythmic scraping sounds are likely to be a bent crankshaft pulley or the cooling fan rubbing the fan shroud. Pushing or pulling on the top of the fan shroud will probably eliminate the fan noise. Bent crank pulleys are easily seen by sighting across them while the engine idles. A few well-placed wooden block and hammer blows can straighten out a bent pulley. The short-metal shrouding can be bent out of the way with a wooden dowel, screwdriver or the like.

**Distributor Chirping**—Dry distributor-cam surfaces can cause the points to give a high-pitched chirping. Make sure the distributor cam and points rubbing block are well-lubricated and then recheck.

**Intake-Air Hissing**—A loud hissing accompanied by poor idling usually indicates an intake air leak, commonly called a vacuum leak. Check the tightness of the carburetor-to-intake manifold connections, plus the intake manifold-to-cylinder head hardware. On dual-port and fuel-injected engines, examine the rubber hose sections of the intake manifold, plus the air intake and metering area in general. Cold-start enrichment devices normally make some sucking or hissing sound while they are operating, so don’t be confused by them.

**Exhaust Leaks**—These are often confused with other, more serious problems, so it’s a good idea to check the exhaust system before jumping to any conclusions. If the exhaust system is tight, sealing the ends of the pipes will stop the engine.

So, with the engine idling, cover the exhaust outlets with palms that are swathed in wet rags or block the pipes with your shoes, if that’s easier. You’ll have to apply considerable pressure to exhaust openings as a well-sealed system has a lot of pressure. If there are leaks, you’ll hear a phut, phut, phut sound coming from the leak. Don’t leave your hands or shoes over the exhaust pipes very long, or they’ll get burned. Exhaust systems are very hot.

Exhaust systems can leak from anywhere, but mating flanges at the cylinders, muffler and tailpipe extensions are the usual spots.

Another typical exhaust sound is a whistle as the engine is accelerated. It is caused by loose or cheap replacement tailpipe baffles on Beetle and early Buses.

**Piston Slap**—Piston slap has already been mentioned because of its timing. It occurs at power stroke, so it sounds off in time with the valve train. Piston slap is a dull, hollow sound. It’s difficult to hear over the normally loud VW engine mechanicals and not easy to isolate. In fact, there’s a better chance of hearing it while driving than listening for it with the hood open.

If you think you hear piston slap, remove and replace the sparkplug wire to each cylinder one at a time. When you get to the affected cylinder, the noise will greatly diminish. Disabling the cylinder will reduce piston slap because combustion loads no longer exist. Reconnecting the plug lead will restore the noise. Be sure to ground the plug lead when disabling a cylinder. See the sidebar for more information on disabling the ignition.

**Piston-Pin Noise**—All air-cooled VWs use full-floating piston pins. When these pins wear, or their bushings get loose, they don’t make any noise. Even when a clip is broken and the pin is free to score the cylinder, it won’t raise any racket. You have to take the engine apart to detect bad piston pins. They are very rarely a problem, so don’t lose any sleep over them.

**Intake-Air Leak**—If there is one internal engine leak, commonly called a vacuum leak. There should be no more than a 1/4-in. gap between the free end of the lead and ground, or ignition system damage may occur. This gives the high-voltage electricity somewhere to go, instead of continuing to build voltage and try to arc to ground inside the coil. This can destroy an expensive electronic-ignition module. Once the test is done, simply reinsert the lead into the distributor cap.

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**DISTRIBUTING THE IGNITION**

Many diagnostic tests call for the ignition system to be disabled. With conventional ignition systems, there are several ways to short-circuit the electrical supply to the plugs: some are better than others. The best way is to remove the high-tension lead from the center of the distributor cap and ground it.

The high-tension lead is the large, heavily insulated wire running from the coil to the center of the distributor cap. To remove it, grasp the boot around the distributor-cap terminal, twist the lead slightly, and pull out the lead. The twist helps break any corrosion that resists wire removal. Now, ground the lead to the head or engine block.

On engines with electronic ignition, there should be no more than a 1/4-in. gap between the free end of the lead and ground, or ignition-system damage may occur. This gives the high-voltage electricity somewhere to go, instead of continuing to build voltage and trying to arc to ground inside the coil. This can destroy an expensive electronic-ignition module. Once the test is done, simply reinsert the lead into the distributor cap.

**Round can at right is throttle dashpot. It slows throttle closing via rod resting against throttle linkage, which is being disconnected. For quicker throttle response when testing for rod knock, disconnect and plug vacuum line leading to dashpot. This is a 1411 engine, but dashpots are found on all air-cooled VWs.**

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**Piston Knock**—If there is one internal engine problem, so don’t lose any sleep over them. Usually metal particles from the rod have been pumped through the engine with the oil, and all other precision clearances have been destroyed by the passing metal. When you hear a rod knock, STOP! Rebuild the engine while there is still enough to rebuild.

Rods also wear with accumulated mileage. Then they wear in sets, so you’ll hear a castanet-like rattling with old, tired bearings. This sound is often heard during a cold start before oil pressure builds.

To test for rod knock, thoroughly warm the engine to operating temperature. With the transaxle in neutral, lightly rev the engine, say from 1000–2000 rpm, and abruptly lift off the accelerator. Engine rpm must drop sharply. As rpm drops, the rods should rattle, knock or pound, for an instant, depending on how you hear it. This is because the rods float on their bearings. When a bearing is bad, you'll hear a steady knocking noise. When the bearing is good, it will rapidly overheats.

**Main Bearing Knock**—Sounding similar to rod knock, but deeper than, worn rod bearings are bad main bearings. Main bearings knock for the same reasons as rods—excessive oil clearance—but under different conditions. To test for main-bearing knock, put the thoroughly warmed engine under load.

On a test stand, or by setting the idle high enough until the engine stalls, place the engine on the brake pedal. Use lowest speed at which you don’t hear a throttle sticking, and main bearing knock. Oil pressure must be lower than normal for this test. For main bearings, there are more problems than just the engine itself, while giving the bearings periodic lubrication. With the engine idling, place the low sound. It’s difficult to hear over the normal pressure. If there are leaks, you’ll hear a phut, phut, phut sound coming from the leak. Don’t leave your hands or shoes over the exhaust pipes very long, or they’ll get burned. Exhaust systems are very hot.

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On a manual-transaxle car, load the engine by selecting first gear and letting out the clutch until the engine begins to labor. Then load the engine further by putting half of your right foot on the brake and the other half on the accelerator. Use the parking brake, too. Keep engine speed at about 1000 rpm during the test and don’t let the car creep forward. With a little throttle and clutch juggling, the knocking main bearings will sound off with a heavy, low-frequency pounding. You can practically feel this better than hear it. Be careful! Don’t do this for more than three seconds or you’ll burn out the clutch. You can also hear bad main bearings while going uphill, accelerating or during other periods of high engine load.

With an Auto-Stick or full automatic transaxle, the test for bad main bearings is easier. Place the transaxle in gear, hold the brake firmly with your left foot and depress the accelerator slowly with your right. Don’t overtread it; just load the engine so the car tries to creep. If the main bearings are going to knock, they’ll do so right away. There is no need to keep the engine and transaxle straining—this is very tough on the transaxle. A few seconds (5–10) and the test is over.

VW main bearings are quite large and strong for the horsepower of the engines. Therefore, they rarely fail, wear out, or make noise. This is especially true of Type 4 engines. The rod bearings are much more suspect. If you hear knocking or pounding from the engine, chances are a rod is about to fail.

**DIAGNOSTIC TESTS**

**Cranking Vacuum**—The next diagnostic step is an engine-cranking vacuum test. This checks the pumping ability of the engine. By measuring the vacuum an engine produces while cranking, you are really testing how well-scaled the cylinders are. If all internal parts are in good shape, the engine will produce a lot of vacuum—if not, vacuum will be proportionately lower.

Begin by warming the engine to operating temperature—ten minutes idling or a five minute drive. Check for heat out of the heater, too. There’s no need to overheat the engine, just warm it up.

Once the engine is warm, shut it off, disable the ignition so the engine can’t start, and connect your vacuum gage to a full manifold vacuum source. Any vacuum nipple on the intake manifold will do. Just make sure the vacuum source isn’t ported vacuum—from one of the small diameter nipples on later carburetors or fuel-injection systems.

Ported vacuum exists in the carburetor primary venturi, just above the throttle plates. It creates a vacuum signal used for operating various emission-control switches. But, it’s a vacuum signal that reads low on part-throttle applications—opposite of the high manifold vacuum readings under the same conditions.

A note about altitude and how it affects vacuum readings. Because atmospheric pressure drops as altitude increases, cranking vacuum will drop about 1 inch of mercury for each 1000–ft increase in altitude. So, at 5000 ft, for example in Denver, Colorado, cranking vacuum values will be 5 in.Hg below a reading taken at sea level. The vacuum values given below are for measurements at sea level.

Prop the vacuum gage so you can see it through the rear window, or have a friend crank the engine. An engine in good condition will pull a steady vacuum of about 10 in.Hg. (This same engine in Denver is registering 5 in.Hg.) A worn engine with no major problems will have a steady, but lower reading. Don’t be alarmed if the needle swings about 2 in.Hg—it’s normal on a four-cylinder engine, especially slow-cranking ones with 6-volt starting systems.

If the needle regularly drops to near 0 in.Hg, then there is a problem. Such a vacuum drop can have numerous causes: poorly adjusted valves, burned valves, worn cam lobes, pulled head studs, warped cylinder heads and worn cylinders, pistons or rings. To pinpoint the cylinder at fault, you’ll have to perform more tests.

**Power-Balance Test**—This test shows how much each cylinder contributes to the power output of an engine. Thus, it also isolates which cylinders contribute little to manifold vacuum. You can perform a power-balance test at home on any air-cooled VW except for ‘79 and later Buses. They are equipped with electronic ignition that can’t be open-fired.

To do a power-balance test on them, the lead has to be grounded without open-firing it first. A professional oscilloscope/diagnostic tester easily does this. You can do the same by inserting a metal spring between the sparkplug and lead. Then to ground the lead, touch a grounded wire to the spring. This is easier said than done in the confines of a Bus engine compartment, so a professional test is the best method.

To perform a power-balance test on other engines, pull all sparkplug leads off the sparkplugs, then set the leads lightly back on the plug tops. You’re going to lift a lead off its plug without a lot of tugging. The idea is to pull the lead away from the plug and ground it against the head and stop that plug from firing—this is called open-firing. The engine will then be running on three cylinders. By comparing the resulting rpm drop for each disabled cylinder, you can determine which cylinder is at fault.

If you suspect a burned valve or other major problem, a quick, ear-calibrated power-balance test will tell what you want to know—which cylinder is it? Because VWs have only four cylinders, a bad one shows right away. If you are looking for a more subtle problem, however, use a dwell/tachometer to measure rpm drop for each cylinder. The car’s tach is not
Cylinder layout, distributor position at TDC (Top Dead Center) and firing order. All distributor rotors, crank pulleys and fans rotate clockwise. Note vacuum advance can position and rotor tip points at #1 when installed.

Distributor driveshaft slot position at TDC, cylinder #1. Note offset of slot: thicker arc faces different position depending on engine.

**Accurate Enough for This Test.**

With the tachometer connected, ground the first plug lead and wait for engine rpm to stabilize. Now, write down the reading and reconnect the plug lead. Go to the next plug and do the same until you’ve done all four. It doesn’t matter how far rpm drops as how close the readings are to each other. Don’t expect the readings to be any closer than 20 rpm. But when these readings start varying by more than 40 or 50 rpm, take notice. Remember, the cylinders with the least drop are the bad ones. Therefore, a really bad cylinder may not drop in rpm at all. Of course, if all cylinders are bad, none will drop very much. Good VW cylinders usually register a drop of about 200 rpm.

**Reading Sparkplugs**—Think of a sparkplug as a removable portion of the combustion chamber, and you’ll see it has useful diagnostic potential. Because the compression test follows, which requires sparkplug removal, let’s discuss sparkplug reading now. Normally, a plug should be dry, with an even tan coating and slight rounding of the electrodes. If the fuel mixture is too rich, the plug will be coated with dry, flat-black carbon. Rub the carbon onto the palm of your hand. The black deposits should wipe off easily. If the mixture is too lean, the plug will be powdered with a white coating, and the porcelain insulator will appear burned. The insulator can also turn a pastel green or yellow in normal operation, depending on the individual fuel blend being used. Oil in the combustion chamber will leave the plug wet and shiny black. Rub that into your palm and you get an oily mess that won’t rub off easily.

When reading plugs, pay more attention to the porcelain insulator around the center electrode than the metal shell. It’s most sensitive to coloring and more likely to show symptoms of unusual combustion. Also be aware that spark
Plugs from a street-driven engine can only show the most basic combustion conditions because of the many operating conditions a street-driven engine is subjected to.

You may have heard about the ace mechanic who read the plugs, then made a one-eighth turn adjustment to the carburetor and won the race. That's on a race engine; plugs in a street engine can't be read that way. Check for the oily plug on a street engine. It reveals a problem with the rings or valve guides.

**Compression Testing**—The familiar compression test is a good way to measure the condition of the rings, cylinders and valves. There are two types of compression testers: a tapered rubber-cone type that is inserted into and held against the open sparkplug hole, and the screw-in type. The rubber-cone version is difficult to use on VVs because the cone and its mount are usually too short to reach through the cooling shrouding. They are also awkward to hold against cylinder pressure while you are bent into a VW engine compartment. Use a screw-in tester, if possible. If using the cone type, you'll need a remote starter switch or a helper to crank the engine. A helper is best in any case because it leaves you free to watch the compression gauge during the test.

The engine must be warmed up, ignition disabled and all sparkplugs removed. Watch out for hot parts whenever working on a warm engine. The throttle and choke plate must be fully open for an accurate test—part-throttle openings result in low readings. So, if you're using a remote starter switch, prop the throttle linkage open with a screwdriver. If a friend helps, have him fully depress the accelerator and crank the engine. A helper is best in any case because it leaves you free to watch the compression gauge during the test.

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**Double-check your findings with the 75% rule:** All cylinders must read within 75% of the highest cylinder. So, if the highest reading is 125 psi, multiply 125 by 0.75 to get 94. Therefore, if all cylinders read above 94 psi, they are acceptable. Below that, consider them faulty. Notice I said acceptable, not desirable. It is hard to set a wear limit and say anything above is good and all below are bad. In the example given, if a cylinder yielded only 97 psi and the rest were 120 or 125 psi, I would be wary of the low cylinder.

To help determine the cause of low compression, do a wet test by squirting a teaspoon of oil into each cylinder. SAE 30W is fine. To determine how many squirts it takes to make a teaspoon get a teaspoon and fill it while counting the squirts. Then squirt the same amount of oil into the cylinder. Just make sure the oil can spread the oil. Retest the low cylinder. If compression comes up markedly, 40 psi or more, the problem is poor ring-to-bore sealing. A rebuild is needed to restore the lost clearances. If compression doesn't increase much, about 5 psi, then the problem is probably with the valves. It could also be pulled head studs or a warped cylinder head.

You may notice a cylinder that takes a long time to pump up. Usually, a cylinder will produce 40 psi on the first piston stroke, another 35 psi on the next and so on. Problem cylinders may have trouble reaching 40 psi and, instead, increase by 10 psi at a time. If you crank them enough, they'll come close to the other cylinders. Wet test such a cylinder, because this condition is usually caused by poor rings.

On the other hand, a cylinder suffering from excessive oiling—from bad rings even—can yield high compression-test readings because excess oil in the cylinder seals the rings. Again, if you crank this type of cylinder enough, relatively high readings can result.

There are variables that affect the readings obtained from compression testing. One is cranking speed; higher speed gives higher pressure readings and vice versa. With a small, four-cylinder engine, it isn't likely that the battery will run down during a compression tests. But if it does, jump the battery to another one to maintain cranking speed.

Altitude will affect compression readings even as it influences manifold-vacuum readings. They will register lower values the higher the altitude. Worn camshaft lobes can also cause lower-than-normal readings. High-performance camshafts, with their long-duration profiles, also give lower compression readings. This is because such cam sacrifice low-rpm breathing for improved high-rpm breathing. Compression testing takes place at cranking speed—well below idle speed.

**Higher Altitude & Lower Compression**

Compression readings are influenced by altitude and temperature. Specifications for compression values are usually based on standard day conditions: 14.7 psi atmospheric pressure and 69F at sea level. Atmospheric pressure and temperature decrease as altitude increases above sea level, so compensate for this when interpreting compression-test results.

The chart supplies correction factors (accounting for decreased pressure and temperature) for different altitudes. Just multiply the specification value for compression (in psi) by the factor for the engine's operating conditions.

<table>
<thead>
<tr>
<th>Altitude (ft)</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>1.000</td>
</tr>
<tr>
<td>2000</td>
<td>0.9711</td>
</tr>
<tr>
<td>3000</td>
<td>0.9429</td>
</tr>
<tr>
<td>4000</td>
<td>0.9151</td>
</tr>
<tr>
<td>5000</td>
<td>0.8881</td>
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<tr>
<td>6000</td>
<td>0.8617</td>
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<tr>
<td>7000</td>
<td>0.8359</td>
</tr>
<tr>
<td>8000</td>
<td>0.8106</td>
</tr>
<tr>
<td>9000</td>
<td>0.7860</td>
</tr>
</tbody>
</table>

An acceptable compression reading of 125 psi at sea level would register less in Denver, for example. There, at about 5000 ft, the equivalent compression reading would be 125 psi X 0.8617 = 108 psi. The cylinders could be reading low compared with sea-level measurements, but just fine for the actual operating altitude.
Leak-Down Testing—Although it’s also a measure of combustion-chamber sealing, a leak-down test is more accurate than compression testing. Accuracy is improved because variables affecting compression-test readings—that is, those that have no bearing on the sealing capability of an engine—are eliminated.

A leak-down tester uses an external air-pressure source. Testing is done with the engine stationary. Therefore, the test is not influenced by cranking speed, valve duration, altitude or excessive oiling. If you are diagnosing a car before buying it, a leak-down test is an excellent idea.

Leak-down test equipment is expensive. So, unless you do a lot of engine diagnosis, this is one test to farm out. Many tuneup shops can do the test for you. The cost should be minimal. It is also a test that can be skipped most of the time. A compression test gives an accurate enough picture of an engine’s condition 90% of the time. This is especially true if there is a burned valve, holed piston or other catastrophic cylinder damage. If the compression readings are baffling, however, a leak-down tester will definitely help you make a decision. Of course, if you have access to a leak-down tester, skip the compression test and test the cylinders with the more accurate leak-down tester.

You’ll need an air compressor (a 1-1/2-HP model will do) and the leak-down tester if performing the test yourself. Start by reading the instructions that came with the tester. Bring the #1 cylinder to top dead center (TDC) of the its compression stroke. Check the engine timing mark to make sure it’s exactly on TDC. If it’s slightly off, the engine will kick off without warning the instant the cylinder is pressurized.

A good way to check for TDC is to insert a long, thin screwdriver into the combustion chamber through the sparkplug hole. With the screwdriver contacting the piston top, you can feel when the piston is at the top of its stroke.

During the test, have a helper hold the crank with a socket on the crank-pulley nut, generator, alternator, or fan. This will keep the engine for turning over.

Next, install the hose adapter in the sparkplug hole, then connect the tester to the adapter and the air compressor. Compressed air is pumped to the cylinder while the tester monitors how much air it takes to make up for cylinder leakage. The readout is in percent leakage.

Remember, the piston must be at TDC of its compression stroke so both valves are closed. Otherwise, leakage will approach 100% as all the compressed air blows by an open valve, or the engine will turn over. Once finished with the first cylinder, disconnect the tester, rotate the engine 180° to cylinder #4 and test it. Then test cylinders #3 and #2, by again rotating the crank 180° each time.

Leakage for an engine in good condition is 10% or less. The higher the leakage rate, the worse the problem. A 20% leakage can indicate a high-mileage engine, but does’t normally warrant a rebuild. A 30% leakage is serious enough for an engine overhaul or valve job. And, a 90% leakage indicates serious damage, such as a badly burned valve, holed piston or the like.

You can usually tell what’s leaking by listening to the engine with the tester attached. If the exhaust valve is leaking, you can hear the hiss of escaping air in the tailpipe. Leakage past intake valves can be heard at the carburetor or intake-air sensor. Bad-sealing rings and cylinders can be detected at the oil-breather or dipstick holes. Pulled head studs may cause hissing leaks between the cylinder heads and cylinders. A length of hose can aid listening in these areas.

Leak-down testing can indicate more about engine condition than any other test. This unit is part of professional diagnostic testing; others are available as separate tools. Need for air compressor, cost and more involved test procedures usually prohibit home-mechanic use. Farm this test out to get accurate evaluation of engine condition.

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adjusted for the worn section, actual valve clearance is zero and the lobe is holding the valve open all the time. When the engine is started, compression can’t build and the engine runs on three cylinders.

If you recheck the valve clearance, you’ll find it tight on that cylinder, which was just adjusted correctly. So, a bit puzzled, you loosen the adjustment to specifications and the engine runs fine. Then five minutes later it starts clacking away as the dished lifter rotates its low spot over the lobe again. No puzzle now, the engine’s cam and lifters are worn out and need replacing.

If the engine has 50,000 or more miles and needs a valve adjustment every 500 miles, the cam and lifters are worn out and need to be replaced. Complete engine disassembly is required to service the cam and lifters, so it’s timely to rebuild the rest of the engine, as well. Chances are the valves and cylinders are worn anyway, so endless valve adjustments are usually another clue that the engine needs an overhaul.

**Measuring Valve Lift**—Some VW specialists, like drag racers, use a dial indicator to measure valve lift at the valve-spring retainer. They can then determine if the cam lobe is wearing down. Racer’s can’t hear noisy valves over open exhaust, and don’t have time to split the case to look at the camshaft between races. Measuring valve lift lets them determine there is no camshaft wear; consequently, they don’t have to split the cases to determine the cam’s condition.

If measuring valve lift, you’ll need a dial indicator, some way to mount it near the valve springs and enough room to fit the instrument. On some chassis, like 914s, this measurement is out of the question unless the engine is out of the car. Note the space available for a dial indicator before considering measuring valve lift. Indicator magnetic bases won’t attach to aluminum cylinder heads, but might mount on the cooling shroud or exhaust.

Bring the indicator’s plunger to bear on the valve-spring retainer. Rotate the engine until that valve is completely closed. Zero the dial indicator, then rotate the crank pulley until the valve is completely open. Read valve lift directly on the dial.

Remember, because you are measuring valve lift, allow for the rocker-arm ratio and valve clearance. Rocker-arm ratio will add to lift measured at the cam lobe, valve clearance will subtract. For a test of this kind, though, don’t be concerned about the absolute valve lift, but valve lift relative to the other valves. In other words, look for a valve that is lifting considerably less than its neighbors. If a valve is lifting less than the others, the cam is worn and will need to be replaced or reground.
Engine Removal

Power train on 914 is somewhat heavy, but imagine pulling equivalent package (engine with all accessories, clutch, transmission, differential and cooling system) out of a Camaro with only a floor jack!

Engine removal and installation are important steps in any overhaul. Haphazardly removing an engine guarantees headaches during installation. It’s also dangerous. A little preparation and caution before and during engine removal will reward you when installing your rebuilt engine.

PREPARATION

Air-cooled Volkswagen engines are found in many different types of chassis, but the same special tools are needed for all cars: a floor jack, jack stands, and a piece of plywood. Additionally, clean the engine before working on it and decide where to pull it. Containers for hardware must also be readied.

Engine Cleaning—A dirty engine is miserable to work on. Wrenches slip, fasteners hide under the goo and grime gets under your fingernails. Avoid these problems by cleaning the engine before removing it. Three methods are generally available: steam cleaning, solvent blasting and spray degreasing.

Steam cleaning is for truly filthy engines—such as an oil leaker driven on dirt roads. The cost is reasonable and the job takes about a half hour. Most service stations have the equipment. If not, check with a tractor or heavy equipment shop.

Consider having only the bottom of the engine steam cleaned. Steam cleaning the top is too messy as the hot solution is reflected back at the mechanic and is trapped atop the engine by the sheet metal.

Solvent blasting uses compressed air and solvent to blow off the dirt. It works well 90% of the time. Cost is comparable to steam cleaning and practically any shop can do it. A thorough solvent blasting takes about as long as steam cleaning.

Spray degreaser can be used at home if you have a garden hose. Typically, you warm the engine, spray it with degreaser, let it set so the degreaser can penetrate, then hose off the crud. Problem is, the stinky mess ends up on your driveway. Solve that by doing the job at a car wash. Use the high-pressure water/detergent spray and leave the mess there.

Remember to cover the distributor, coil and carburetor with plastic bags or aluminum foil shaped to fit. These parts must be kept dry or you’ll have a hard time restarting the engine. With patience, this method works as well as steam cleaning or solvent blasting. Don’t forget to remove this waterproofing before driving. (Yes, it happens!)

Lifting & Lowering Tools—To raise and support the car during engine removal and installation, use a floor jack and jack stands. The floor jack is a hydraulic jack in a wheeled frame. For VWs a 1-ton version is adequate, but a 1-1/2-ton jack is sturdier and usually will lift higher. Besides, if you’re planning to buy a floor jack, you’ll need a 1-1/2-ton version for lifting most other cars.

Once the car is up, you must support it with jack stands. Never use any jack (bumper, scissors, screw or otherwise) as a stand. Jacks are for raising and lowering, not for supporting a car while you are underneath.

A jack can fail, and if you are under the car when it does, it could be fatal. Use two jack stands to hold up the rear of the car. Both the floor jack and jack stands can be rented. Look in the phone book under RENTALS.

A VW air-cooled engine is lowered from its raised chassis with a floor jack. A balanced jacking point for lowering the engine is right under the oil strainer. You’ll need a sizeable piece of 1-1/2-in. or thicker plywood to place between the engine and floor jack.

Besides protecting the engine from gouges, the soft plywood gives the hard engine and jack surfaces something to dig into. This makes the engine less likely to slip off the jack’s pad, making engine removal safer and a lot easier. It’s frustrating to pull on the engine, hoping to roll the engine/jack combination toward you, only to have the jack stop and the engine slip off.

For the same reason, try not to remove a VW engine on a dirt surface. The floor jack resists rolling; it will sink into the dirt instead. Even on very hard packed dirt, little pebbles can chock...
Support car with jackstands any time it is raised. Place stands forward of rear wheels on sturdy chassis component; set them on concrete for best foundation. On soft asphalt or dirt, place plywood between stand and ground to prevent settling and tipping.

the jack wheels, making engine movement a jerking series of barely controlled, backbreaking grunts. If a dirt floor is all you have, lay a full sheet of plywood down to roll the floor jack on. It will also keep you cleaner as you work under the car.

Consider what you’ll do with the chassis when you remove the engine. Once it’s out, moving the chassis means pushing or towing. The chassis will be immobile for awhile, depending on how far you work. Three weeks is about average. Stationary cars attract vandals, angry landlords, even the authorities in some cities.

If you don’t have a dedicated working room, try renting space at a service station. Look in the phone book for a do-it-yourself auto shop or hobby shop. If you are stationed at a military base, they often have auto hobby shops available, complete with some of the larger tools. Get Organized—It’s a trying task to install an engine someone else removed. Who knows where all those nuts and bolts so? Well, pulling an engine and throwing all the hardware in one big box amounts to the same effort. When you do get around to installing the engine, you’ll find your memory can’t make any order from the chaos.

With the earlier Beetle, there aren’t many disconnections to remember, but later engines and different chassis can definitely tax the best memory. Save yourself considerable trouble and frustration by getting several coffee cans and boxes and labeling them. Use one for bellhousing hardware, another for heater tubing and so on. Have the containers ready before dropping the engine, or you won’t use them.

Get a roll of masking or other stout tape and a permanent, waterproof marking pen. Or use a plastic label maker. Use these for labeling the vacuum and electrical disconnections you’ll make. Labeling disconnections is a critical step, so don’t skip it!

There isn’t enough room in this book to list all the hose and wire diagrams for the various chassis. Draw your own schematics of the various connections to help at reassembly. It’s up to you to label and keep track of the electrical, vacuum, mechanical and fuel lines, hoses and cables. You’ll thank yourself at installation.

ENGINE REMOVAL

We’ll examine engine removal chassis by chassis because of the different chassis air-cooled VWs are mounted in. Yet, the first few disconnections of components about the engine are similar in all models.

Battery—On all chassis, disconnect the battery negative cable first, then remove the positive one. The battery is under the rear seat in the Beetle, Squareback and Fastback. On the 411 and 412 look under the driver’s seat. On the Bus, Karmann Ghia and 914, the battery is on the right side of the engine compartment.

It’s not essential, but now is a good time to completely remove the battery for cleaning and charging. It’s aggravating to try and start your engine only to find the battery dead.

Drain Oil—Now drain the oil. On Type 1—3 engines, the drain plug is the large bolt in the center of the oil stainer. On the Type 4, the drain plug is separate from the strainer. Let the oil drain while you make the various electrical and mechanical disconnections. The longer the oil drains, the less mess you’ll have later when you open the engine.

Fuel-Injection Air Filter—Undo the four...
Tipping air filter any more than this will slosh oil inside against upper section; it will also drain from under lid. Clean filter canister and change oil before filter is installed on rebuilt engine.

Needle-nose pliers hold throttle cable and linkage while cable is disconnected. Don't loosen cinch bolt against cable tension, or you'll kink cable. Always hold linkage stationary instead.

After throttle cable is removed from linkage, pull cable guide from fan housing. Sometimes a hose clamp is placed on guide in front of fan housing as a retainer. If so, just leave guide in place.

Generator disconnections are normally three wires right on top of the generator. However, slip-on connectors are used on generator-mounted voltage regulators and alternators.

Also remove the fuel line and throttle cable. The throttle cable is removed by unscrewing or unbolting the clamping bolt and pushing the cable toward the fan housing. Pull the cable guide out of the fan housing and set it aside. Later, when the engine is partially out of the chassis, you can pull the cable out of the fan housing the rest of the way.

A lot of throttle cable guides have been clamped behind the fan housing to hold a homemade grommet. In this case, you can push the throttle cable into the guide now, and pull it completely out when lowering the engine.

Electrical Connections—Look under the distributor for the oil-pressure sending unit. Disconnect and mark its single wire. Disconnect the positive coil wire. Look on the coil, near the terminals for a + sign if you don't know which is the positive wire. The negative wire also runs to the distributor, but it's not the right one.

Generator/Alternator—Mark and remove the three wires on the generator. The voltage regulator is mounted on the generator on '66 Beetles. In that case, remove the three slip-on connections.

If the car has an alternator, remove the multiple-wire connector. The voltage regulator is mounted separately on '73 and early '74 alternators. After that, the regulator is integrally mounted on top of the alternator.

Fuel Injection—Unfortunately, VW's Bosch fuel injection adds a lot of little steps to engine R&R (Removal and Replacement). You have extra marking and removing of necessary wires and hoses for all various connections in fuel system.

The push-on connectors on the other distributors that have not been removed out of the engine typically do not have any grommets connected. Sometimes a hose clamp is placed on guide in front of fan housing. In this case, you can push the throttle cable into the guide now, and pull it completely out when lowering the engine.

Lateral connections from the distributor to the sparking plugs are made by an adapter grommet, which is crimped or otherwise covered over the end of the fuel-injection hose. You can wrap a few turns of wire around the hose to hold it in place.

The other ends of these connections attach to the spark plugs with screws. Sometimes the screw is removed later until it is removed.
and hoses. Take your time when labeling these connections. You'll be reconnecting these extra fuel system wires and hoses during engine installation.

The electrical disconnections are pull-off, push-on plugs. Most plugs separate easily, but others don't. This is especially true of those brownish, rectangular connectors. You usually have no choice but to grasp the wires leading out of this type of connector and pull. Practically every time you succeed and the spade connection inside the connector separates. Sometimes the wire pulls out of its terminal end. Of course, repair the wire in that case.

The fuel-injection wiring is in a harness. Follow it around the engine, disconnecting and labeling wires at the coil, injectors, crankcase and temperature sensors. Then the harness can be pushed aside.

Make sure you follow the harness. Some wires lead from one side of the engine to the other, and there's no reason to disconnect them. Only remove a wire if it leaves the engine and attaches to the chassis.

Also remove the two fuel lines: one supply, one return. Be sure to correctly mark their flow. Get them reversed and the engine will not start. Only remove a wire if it leaves the engine and attaches to the chassis.

If the engine has a throttle positioner, you'll see an aluminum diaphragm-and-cylinder unit sticking out from under the carburetor. Most manuals say the positioner must come off for engine removal, but it isn't so. Just leave it alone. Later, when lowering the engine, you'll have to tilt the fan housing forward. This raises the positioner so it will clear the rear bodywork.

Rear Engine Cover Plate—Between the rear of the engine and the rear of the engine compartment is the rear engine cover plate. This piece of sheet metal is part of the cooling system, which works by sealing the top of the engine from air passing under it.

Because the engine must be slid to the rear to disengage it from the transaxle input shaft, the rear engine-cover plate must be removed. On early 40-HP engines, merely remove the four screws and lift out the plate.

Later engines have two large hoses leading from the fan housing to the heat exchangers. Completely remove these hoses and their rubber gaskets at the cover plate end. Then unscrew and remove the small separate shroud over the crankshaft pulley. (Unless you have a fuel-injected engine. They don't have this small plate.) Finally, remove the two covers around the heat-riser tubes leading to the intake manifold.

The heat-riser tube covers are at the outboard ends of the rear engine cover plate. Four screws attach each one. With those parts gone, you can unscrew the rear engine cover-plate attaching screws and pull the plate out of the car.

Raise Car—Use the floor jack to raise the car until the engine is about a yard in the air. The rear bodywork must be high enough to clear the top of the fan housing. Put the jack under the engine just forward of the transaxle, never under the engine or transaxle. You can crack the case by jacking under the engine.

Immediately place the jack stands to support the chassis, and slowly lower the car onto them. Check the stability of the car on the stands by gently shaking it from side to side. VWs have to be raised a lot to get the engine out, which means most jack stands are raised to their highest, and least stable, position. Be sure your stands are stout and stable before getting under the car.

Heater Cables—At the front and sides of the engine you'll find the two heater-control valves. Remove the heater-control cables from their levers on the control valves. A bolt passes through the lever and cable end and is nutted on the other side.

Use two wrenches to remove the bolt and nut, then the cable will pull free. There is also a small cylinder in the lever which the cable passes through. When you remove the cable, the cylinder should fall free, so be ready for it. Alternately, you have extra steps if the heater controls have rusted shut and then been peened over by rocks. Freeing the cable end requires rust penetrant, pliers to grip the lever, the usual two wrenches and inventive language.

Remove rear sheet-metal tray so the engine can easily slide rearward. Follow tray's leading edge to find its attachment screws.
Once you have the cables free, pull the large flexible hoses off the heater-control valves. Push the hoses away from the engine so they won’t get torn as the engine is lowered.

**Fuel Line**—Above the left heater-control valve is the fuel line connection from the fuel tank. Slip off the flexible line and use a pencil or bolt to plug it. If you use a bolt, make sure it has an unthreaded shoulder. A fully threaded bolt can let gasoline leak past through the threads. Some mechanics pinch the line shut with locking pliers, then pull it off. It’s fast and clean, but I don’t like squeezing fuel hose that hard.

**Bellhousing Nuts**—Remove the two 17mm hex nuts and washers at the lower corners of the bellhousing. These nuts are threaded onto a pair of studs that fit into the transaxle. Don’t worry about the engine falling. There are two more bolts still attached on top of the engine.

**WARNING:** If the lower bellhousing fasteners are nuts and bolts, remove them only after checking that the upper bolts are still in place and the floor jack is set up to support the engine. The engine can fall on you if the upper bolts aren’t in place.

The lower bellhousing nuts may be very tight on their studs because of rust or impact damage. If so, the stud may unthread from the transaxle, not the nut from the stud. There’s no problem with this, so don’t worry about it. You can separate the stud and nut later and reinstall the stud.

**Automatic Stick Shift (Auto-Stick)**—A few extra disconnections are necessary on cars with the Auto-Stick. Two ATF (Automatic Transmission Fluid) lines need disconnecting. One line runs to the ATF tank, the other to the oil pump.

The lines are steel braided and use high pressure hydraulic fittings, like on brake lines. Use two tubing wrenches, also called flare-nut wrenches, on the fittings. If you don’t have tubing wrenches, a regular open end will do, but take extra care to not round off the hex. Be ready for ATF to pour out of the line from the tank. Have a pan underneath and work fast.

Plug the disconnected fittings so they won’t leak, and so dirt can’t enter the transmission system. The best plug is a pipe fitting that has been soldered, brazed or welded shut, but you probably don’t have one laying around. Those small plastic caps new brake master cylinders are shipped with work well, if you have the right size. Aluminum foil wrapped several times around the fitting and secured with a hose clamp works, too.

Because Auto-Stick transaxles have a torque converter between the engine and clutch, there are four driveplate bolts to remove. The driveplate is bolted at its center to the crankshaft, like a flywheel. At its outer edge it is bolted to the torque converter. These bolts are accessible through a hole in the bottom backside of the bellhousing. Fuel-injected engines have a rubber plug in the access hole; carbureted engines have an open hole.

Some of these bolts are 8mm, 6- or 12-point. Make sure your socket is clean, not rounded off and lined up straight with the bolts. These bolts are small and will break or round off if not treated with care. Have a helper rotate the engine with the crankshaft pulley while you watch the access hole. Stop rotation when the bolt is squarely centered in the hole. Remove the bolt, then have your helper rotate the engine 90° where another bolt will appear in the hole. Continue until you have removed all four bolts.

If you don’t remove the driveplate bolts, the torque converter will slide out of the transaxle with the engine. That’s fine if the engine is seized and you can’t rotate it to gain access to the bolts. But the transaxle oil seal will be ruined if it’s necessary to pull the torque converter with the engine. Replace the oil seal if that’s the case.

More Auto-Stick disconnections are necessary inside the engine compartment. Look on the firewall, to the left of the ignition coil, to find the control valve. Mark and disconnect the electrical leads. Investigate the vacuum hoses to see which ones must come off. Those that don’t go to the engine can be left alone. The rest need to be labeled and disconnected.

**Support Engine**—Get the piece of plywood and set it on the jack saddle. Then roll the jack under the engine and raise the saddle until it is just carrying the engine weight. Don’t lift it too much or you’ll bind the engine on the bellhousing studs and have trouble sliding it off.

**Upper Bellhousing Bolts**—Slide out from under the car and turn your attention to removing the upper engine-to-transaxle fasteners. All manual transaxle cars through ‘70 have bolts and nuts at the upper bellhousing. In ’71, all cars use two bolts but only one nut. At the right side is the usual nut and bolt assembly, but the left side uses only a bolt. It threads into a special round nut pressed into the engine case.

This is necessary because the offset oil cooler used from ‘71 on doesn’t leave enough room to get at a nut from the engine side. Auto-Stick cars in ’70 use nuts on studs, so their bellhousings have four studs: two at bottom, two at top. In ’71 the Auto-Sticks went with the two bolt, one nut fastening.

Whatever the attachment method, you need
At first, engine must come back and down in small, quickly alternating steps. Once you get this far, a slow, smooth lowering is all that's needed. Keep an eye on hoses, wires and engine compartment seal.

To remove the upper bellhousing fasteners. Remember, the nuts are in the engine compartment and the bolt heads are on the transmission side, accessible only from under the car. With luck, both nuts will come off without anyone holding the bolts from under the car. More typically though, the bolts will turn.

Have your helper get under the car to hold the bolts. If no helper is handy, try pulling the engine away from the transaxle. That might bind the bolts so they won't turn. If that doesn't work, you'll have to attach a box end wrench or Vise-Grip pliers to the bolt heads, then let the wrench turn against the body.

Lower Engine—Once the upper fasteners are out, the engine is ready to lower. It's best to have two people for this job: one to manage the floor jack and another to eyeball the engine compartment to watch for hangups.

Start by pulling back on the floor jack until the input shaft clears the clutch. If you are working on an Auto-Stick, the driveplate will clear the torque converter right away. All that's left to do is clear the bellhousing studs.

Once the engine is disengaged, lower the jack. Continue to pull the engine and jack rearward while slowly lowering the jack. Constantly monitor the engine so it won't snag a wire or cable on the way down. If the engine catches on something, stop the jack, clear the snag and continue down.

Watch for the throttle cable as it pulls from the fan shroud. Steady the engine with one hand on the fan shroud and the other on the muffler. This is another good reason to have a helper move the jack, you'll have your hands full with the engine.

On '70 and later engines with a throttle positioner, you must tip the engine to clear the body. The top of the fan housing needs to be tipped toward the firewall so the throttle positioner can get past the rear body panel. Alternatively, you could remove the carburetor and throttle positioner. Removal requires a very thin, specially bent box-end wrench if you do this with the engine in the car.

With Auto-Stick transaxles, once the engine is out, run a brace across the bellhousing to hold the torque converter. A simple piece of flat metal with a hole in it will do. Use one of the transaxle studs and nuts to secure the brace. Without this brace, the torque converter can slip out of the transaxle, be damaged and its oil seal ruined.

**BUS & TRANSPORTER (TYPE 2 & 4)**

Two sections are necessary to examine removing Bus engines because '71 and earlier Buses use the upright-fan Beetle engine and '72 and later Buses use the Type 4 engine. Early style Bus engines are one of the easiest VW powerplants to drop: a couple of disconnections and it practically falls out of the chassis. The later engine is more difficult, but not overly so.

**Early Bus (Pre-'72)**—Start with the air filter. Up to '68, simply remove the crankcase breather, hot-air hoses and unlamp the filter housing at the carburetor. On '68—'70 models, disconnect the hot-air flap cable, but the '71 version has no cable. Don't tip the oil-bath air filters when removing them.

**Disconnect Wires, Cables, Hoses**—Disconnect the distributor, coil, generator, oil-pressure sender and carburetor wires. Read the Type 1 section if you need more help with these. Label the disconnections. Undo the throttle cable at the carburetor and push it forward through the fan housing as far as it will go. On '70—'71 Buses, disconnect the vacuum hoses at the throttle positioner.

**Engine-Plate Screws**—Unscrew the 10 rear engine-plate screws and lift out the plate. Six are in the left- and right-forward corners of the plate. The other four are in the rear corners, mounted vertically on the plate's rear face.

An optional method is to continue rearward and remove the rear bumper and body panel. With those out of the way the engine can be slid straight back out of the chassis.

**Bellhousing Bolts**—Now reach way to the front of the engine compartment and remove the two upper bellhousing bolts. You'll be looking at the nutted end of the bolts from inside the engine compartment. On a '71 Bus, only the right upper bolt is accessible from the top. The other upper bolt must be removed from underneath.

**Heater-Control Cables**—It's time to go underneath anyway, so get under the engine and disconnect the heater-control cables and hoses. You shouldn't have to raise the chassis very high, as Buses stand pretty tall. In fact, you might not want to raise the chassis now, but wait until the engine is ready to come out. Then the chassis has to go up so the fan housing will slide under the rear bodywork.

**More Cables & Fuel Hose**—Pull the throttle cable all the way free of the fan housing, then loop it out of the way. Slip off the starter solenoid connections and remove and plug the flexible fuel hose. The fuel line is on the left, and it is not clamped. It's just a slip joint.

**Transaxle**—Support the transaxle with a second floor jack or prop it up with wood blocks. The Bus chassis is so tall, you might have to add a wood block to the supporting jack. With the transaxle supported, remove the two lower bellhousing nuts. On '71 Buses, now remove the left upper bellhousing bolt, which doubles as a bolt for the starter mounting.

**Lower Engine**—Place the floor jack and plywood under the engine. Just barely take up some engine weight with the jack, then disconnect the rear crossmember. There is one vertical bolt at each end of the crossmember. Remove them and the engine is ready to come out.

Pull the engine and floor jack rearward until the clutch is clear of the transaxle input shaft and the bellhousing studs are clear of the engine. Then lower the engine while guiding it by the generator and exhaust. Have your helper watch for wire and hose snags on the way down.
Late Bus (Post-'72) — Removing this engine is basically the same as dropping the early Bus engine, but there are more disconnections to make on the Type 4 engine.

Air Filter — Remove the air filter. On dual-carbureted engines, flip open the clips at the carburetors and at the filter's center section. Lift off the top half of the filter and set it aside. Keep it upright. If not stored upright, residual oil will drain into the upper half of the filter and contaminate it. Unclamp and remove the fresh and hot air hoses from the filter bottom half. Then unclip it at its bottom edge and lift it out.

A paper-element filter is used on '73—'74 carbureted engines, and it is removed like the oil-bath type.

Fuel-injected engines have a different paper element filter. It is best removed as a unit with its intake air sensor. Start by disconnecting all hoses, then unclipping the cover. Remove the cover and paper element.

Locate the intake air sensor at the left. It is the aluminum box with the cast-in grid work. Locate the electric connector plug, slip off its protective boot, and carefully pull out the connector. Unclamp the large S-shaped rubber hose from the air sensor and remove the air filter body and intake sensor together.

Electrical Connections — With labeling materials in hand, disconnect the electrical leads from the distributor, alternator regulator, oil-pressure sender, and fuel injectors or carburetors, as the case may be. Follow the wiring harnesses over the engine to find all the disconnections. At the distributor, remove the lead to the fuel-injection triggering contacts. It is attached near the bottom of the distributor.

Throttle Cable & Vacuum Hoses — Undo the throttle cable from the crossbar or at the throttle body. Get the cable started through its guide in the front engine plate. Later, you can completely pull it through from underneath. If the car is an automatic transmission model, remove the vacuum hose from the intake manifold. On carbureted models, the hose is attached to the balance tube. Fuel-injected models have the hoses attached to the intake air distributor. The intake air distributor is the black, sheet-metal section in the center of the intake system.

Coil & More Hoses — Look near the coil for an inline fuse holder. Disconnect this wire (it's for the backup lights) at the fuse holder. The engine may also have a temperature sensor mounted in the upper right engine compartment. If so, disconnect its wire.

Take out the ignition coil and remove the hose leading to the charcoal filter. The charcoal filter is the can suspended from the upper rear ceiling of the engine bay. On carbureted engines there is a hose mounted to the top of the left carburetor; remove it.

All '72—'73 engines, plus '74s with automatic transmissions have a vacuum advance cutoff valve mounted near the blower motor. Disconnect the electrical and vacuum leads from it. On all chassis, remove the two large diameter blower hose leads.

Oil Filler — As on Type 3s, remove the oil filler bellows and dipstick. Then set about removing the rear engine plate, which is in two pieces on the late Bus. Take off the right rear plate first, then the left rear. The left plate wraps around the engine side and runs forward a little, so it isn't a mirror image of the right rear plate.

Automatic Transmission — This causes some extra work. First, remove the ATF filler pipe nuts, rotate the pipe counterclockwise and pull it out. Then remove the driveplate-to-converter bolts. On this chassis, these bolts are accessible through a hole in the bellhousing from inside the engine compartment. Look under the plastic plug in the upper left mounting flange area of the case.

Gravel Guard — Before getting all the way under the engine, remove the gravel guard from under the rear bumper. Take out four bolts and this thin bent strip will come off.

More Cables & Fuel Hoses — Now slide up to the front of the engine and disconnect the heater cables and hoses at the heater-control valves. Pull the accelerator cable all the way through the engine compartment and put it out of the way. Disconnect and plug the fuel lines from the fuel pump on carbureted engines, or pressure regulator on injected engines. Look on the front right of the engine for the fuel lines.

Transaxle — Support the transaxle with a jack or wood blocks. Now raise the jack slightly to remove the two lower bellhousing nuts. Then go to the rear and remove the crossmember. Remove the three bolts at the each end of the crossmember which thread directly into the frame. When those bolts are out, the engine is ready to come out.

Lower Engine — Pull the jack back until the engine clears the transaxle, then lower it out of the engine compartment. Watch for hangups and guide the engine so it won't fall off the jack. You definitely need a helper with a heavy Type 4 engine.

Fit a brace across the torque converter on automatic transmission transaxes immediately after removing the engine. See page 22 in the previous Type 1 section for the reasons for this.

Once the engine is out, check the rubber transaxle mounts on Buses without rear crossmembers. Weak, mushy mounts are cited as a prime reason the cases cracked on these early Bus crossmembers. Weak mounts are a frequent cause of problems, such as oil leaks.

FASTBACK NOTCHBACK

Air Filter — In the air filter area is the canister, a hot-air canister, mounted in the upper right engine compartment, under the intake air distributor. There is a hose leading to the charcoal filter. The charcoal canister, if so equipped, is mounted in the upper right engine compartment. Look under the play in the case sensor area for this hose.

Fuel Filler — As in Type 3s, remove the fuel filler bellows and dipstick. Then set about removing the rear engine plate, which is in two pieces on the late Bus. Take off the right rear plate first, then the left rear. The left plate wraps around the engine side and runs forward a little, so it isn't a mirror image of the right rear plate.

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early Buses. If the transaxle sags almost to the ground, you know the mounts are useless. Replace worn transaxle mounts.

FASTBACK, SQUAREBACK & NOTCHBACK (TYPE 3)

Air Filter—With the battery disconnected and oil draining, remove the air cleaner. All Type 3 air filters are oil-bath units, so don’t tip them during removal. On single-carbureted engines, unscrew the wing nut in the center of the filter canister, plus the air intake bellows from the hot-air control box. Disconnect the intake elbow between the filter and carburetor at the carburetor. Mark and disconnect the crankcase breather hose.

Filters on dual-carbureted engines have wing nuts over each carburetor, plus one at front-center. Unclamp the hot-air hose from the hot-air control box and remove the box with the filter. Snap the throttle linkage off the carburetors and the center-mounted bellcrank before removing the air filters. Don’t fiddle with the locknuts and rod ends of the linkage, you’ll only get the carburetors out of synchronization. Just pop the rod ends off the ball sockets with a screwdriver.

Air filters on fuel-injected engines require only the intake elbow and several hoses be removed. The elbow is clamped and the remaining hoses are slip ons, but remember to label them during removal. With all hoses removed, unscrew the center wing nut and remove the unit. Store in a level position.

Electrical Connections—Label and remove the electrical leads at the carburetors, oil-pressure sender, generator and coil. On fuel-injected engines, remove the wiring harness at the various connections on the engine.

The fuel injection ECU mounts inside the left-rear inner fender, and the wiring harness comes from that side. Follow the harness to the connections at the distributor, injectors, crankcase sensors and grounds, cylinder-head temperature sensors, and intake air distributor. Also remove the vacuum hose from the fuel pressure sensor on the left engine compartment wall. Label each hose and wire before removing them so you’ll be able to reconnect them correctly.

Check the fuel shut-off solenoids on engines with dual carburetors. These are small cylinders with a wire mounted on the outboard side of the carburetor. They usually catch on and foul the bodywork when the engine is lowered, so unscrew them from the carburetors.

Oil Dipstick—Remove the dipstick, then unclamp and remove the oil filler rubber boot. This is the accordion piece between the dipstick tube and body. Also unclamp and remove the cooling air bellows. This is the big rubber connector between the engine and rear bodywork.

Throttle Cable—Disconnect the throttle cable. With a single carburetor this is done at the carburetor. On dual-carburetor engines, disconnect the cable at the throttle linkage crossbar. Fuel injection throttle linkage is undone at the throttle body, which is part of the intake air distributor. That’s the sheet-metal center section of the intake manifold.

Fuel Line—Remove and plug the fuel line. On fuel-injected engines, the disconnection should be made on the left and right fuel manifolds. The fuel manifolds are the metal sections of the fuel line right above the injectors.

The rubber fuel line coming from the left front of the engine compartment and running to the left fuel manifold is the fuel inlet line. The fuel lines then connect to the injectors via the manifold. Another line leads off the back of the left manifold and runs to the other side of the engine. It joins the right fuel manifold, and finally runs forward, out of the engine compartment through the rear sheet metal. This last line is the fuel return line. It returns excess fuel to the fuel tank. The entire circuit of U of fuel lines is called the fuel ring.

Bellhousing Bolts—Finish the topside chores by removing the two upper bellhousing bolts. You may need a helper under the car to hold the bolt heads. On ‘71 and later engines, the left bolt threads into a special nut permanently attached to the case. Remove this bolt from underneath.

Another way of doing this is to wait until the engine is on its way down. Then you can get at both sides of the upper bellhousing bolts from the top. Be careful not to lower the engine too far or you’ll damage the transaxle mounts.

There is supposed to be an engine mount attached to the fan housing on cars without a crossmember. It doesn’t provide much support, so a lot of owners leave them off. Two bolts and it’s in hand. If nothing else, it must be off to remove the engine.

Raise Car—Raise the rear of the car 3 ft and support it with jack stands. Undo the heater control-box cable connections and stow the large diameter air hoses out of the way. Pull the throttle cable through the front engine cover plate and gently loop it out of the way. Don’t kink the cable or the throttle will be sticky. Disconnect and plug the fuel return line on the right side of the engine if you didn’t get it from the top. On ‘72 Type 3s, disconnect the exhaust gas recirculation (EGR) wire from its transmission switch.

On cars with an automatic transmission, un-bolt the driveplate from the torque converter. Unlike the Auto-Stick transmission, the full automatic transmission has only three driveplate-to-converter bolts. They are accessible through a hole in the front-bottom of the bellhousing. Also on the automatic transmission, slip off the vacuum hose at the balance pipe and disconnect the kickdown-switch wire.

Because the crankshaft pulley nut is inaccessible on Type 3s, use a stout screwdriver against the ring gear teeth to rotate the engine. Reach the ring gear teeth through the bolt access hole.

Support Engine—Disconnect the lower bellhousing nuts, then place the floor jack under the engine. Don’t forget the plywood cushion. On double-jointed-axle cars, support the transaxle with another jack or wood blocks. Then slide rearward and unbolt the engine crossmember. Undo the two horizontal bolts at each end of the crossmember which connect the crossmember to its rubber mounts.

Don’t unbolt the vertical rubber cushion-to-body bolts or the crossmember-to-engine bolts. The rubber mounts are centered by their mounting bolts. If you undo these bolts, you’ll have to recenter the engine during installation.

Lower Engine—Now you are ready to pull the engine back and lower it. Watch for hangups on
If heater ducts won’t pull off, they are held by clamps. Oil and dirt can combine to camouflage these connections.

Bellhousing and driveplate hardware are accessible through windows in automatic transmission bellhousing.

Automatic transmissions have a vacuum disconnection under left axle flange. It’s probably just as easy to pull off this hose at transmission as at engine.

Bellhousing and driveplate hardware are accessible through windows in automatic transmission bellhousing.

411/412 (TYPE 4)

Engine removal in the Type 4 is roughly similar to dropping the '72 and later Bus engine because they share the same engine, but there are several notable differences.

Air Filter—With the battery disconnected and oil draining, begin the engine bay disconnections. Start with the air filter. Remove the fresh air and crankcase breather hoses. On carbureted engines, unclip the upper filter half at the carburetors and center section, then lift off the upper half. Now unclip the bottom half and remove it. Fuel-injection air filters need the center wing nut undone and the filter removed. Before '72 all 411/412 filters were oil-bath type; post-'72s have paper elements.

Ducts, Wires & Cables—Remove the dipstick and oil filler bellows. Unclamp and remove the cooling air intake bellows. Take off any ducting for the heater blower motor. Disconnect and remove the ignition coil, then the oil-pressure sender lead and throttle cable. Push the throttle cable through the front engine panel.

Voltage Regulator—Pull the plug connector from under the voltage regulator. It is mounted on the right front side of the engine compartment and the connector comes up to the regulator from the bottom. Use a mirror to see this connection.

Fuel-Injection Connections—Label and disconnect the fuel-injection leads at the engine. Follow the wiring harness over the engine to find the connections. They are at the intake air distributor, ignition distributor, injectors, case ground, plus the temperature sensors at the case and heads. Be sure you label all disconnections. Reassembly will be so much easier, and the engine will operate correctly, too.

Automatic Transmission—Remove the three driveplate bolts from inside the engine compartment. Look on the left engine-case vertical flange for a round plastic plug. Pry out the plug with a screwdriver to expose the driveplate underneath. Rotate the engine to expose the driveplate bolts one at a time. Rotate the engine with a wrench on the cooling fan mounting bolts or by simply grasping the fan in your hand. This task is much easier with the sparkplugs removed.

Manual Transmission—An unusual design feature of the Type 4 manual transaxle requires an extra step in engine removal. Because the differential is between the engine and transmission, a driveshaft runs forward from the clutch to the transmission. The front of the driveshaft looks and functions the same as an input shaft on other transmissions, except it is longer than a normal input shaft. To remove the engine the driveshaft must be unlocked and moved forward in the car 4 in. (100mm).

Moving Driveshaft—To reach the driveshaft, remove the rear seat cushion. Under the cushion is an access panel; remove it to expose the front of the transaxle. Find the round, screw-in plug, about 2-1/2-in. in diameter. Unscrew the plug. Inside the transaxle will be the end of the driveshaft with a nut threaded onto it. Unthread the way down, and steady the engine so it doesn’t fall off the jack. Brace the torque converter so it can’t fall out of the transaxle and be damaged. A metal tab nutted to one of the bellhousing studs works fine. Wire up the transaxle on double-jointed-axle cars so you can move the chassis.

Disconnect Type 3 crossmembers where crossmember meets engine mount, not where mount meets body. If mounts are disconnected at chassis, they will have to be aligned at engine installation to keep engine straight in compartment.
Disconnect fuel-injection wiring on Bus and Type 4 engines. Set wiring loom aside once disconnections (label them!) are made. Hand cleaner gel is great hose and wire cleaner to detail wiring.

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Because of the mid-engine mounting, the engine can only be removed with the transaxle or after the transaxle has been removed separately. If using a small floor jack, or working on dirt, it's best to remove the transaxle first, then the engine. If using a larger floor jack with a wide saddle, though, remove the engine and transaxle as a unit.

Install removing the engine/transaxle as a unit here. If you remove the transaxle first, the steps are the same, except you must also remove the four bellhousing fasteners to free the transaxle.

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Pass 914 throttle cables through sheet metal so they completely clear engine. Otherwise, they will kink when lowering engine.

Air Filter & Throttle Cable—Remove the formed sheet-metal air filter support from the center of the engine. Use a long screwdriver to reach down to the case where the two front support legs attach. The other rear attachment is bolted to the case using one of the case flange bolts. With the support removed, the throttle cable can be removed. Unthread the locking nuts on the cable housing, disconnect the cable from the throttle arm and push the cable through the hole in the right side engine plate.

Some engines mount the air filter to one side. On these, leave the air filter support alone. You can remove the throttle cable without detaching the support.

Vacuum & Vapor Hoses—Label and disconnect the remaining vacuum and vapor hoses. Some common hoses go to the charcoal canister and pressure sensor. Drape all the disconnected hoses over the center of the engine so they won’t be in the way when removing it.

Lift Car—Raise the car and support it on tall jack stands. Don’t put them under the suspension or front engine crossmember. Instead, place them at the two small round protrusions in the body, outboard and forward of the engine compartment. Remove the rear wheels and tires. This will give a lot more room and light under the car.

Removing Cables & Exhaust—It helps to remove the work panel below the rear bumper, but if the chassis is lifted fairly high, the engine can be removed with it in place. Remove the muffler from the exhaust pipes and the muffler brace from the rear of the transaxle.

Unplug the reverse-light leads from the left side of the transaxle. Unwind the sardine can clamp over the rear shifter boot and disconnect the shifter. Use a small Allen wrench to remove the set screw. Another set-screw arrangement secures the front end of the shift rod. Look under the rubber boot where the shifter enters the bodywork at the front of the engine compartment. With the forward connection removed, the shift rod can be extracted from the car.

Unbolt the ground strap above the rear transaxle, unscrew the speedometer cable and remove the clutch cable. The clutch cable is undone by removing the self-locking nut in the center of the cable pivot: the round plastic wheel. Under the wheel are two nuts. Remove them, and the metal pivot bracket and cable come free. Loop the cable and bracket aside.

Return to the exhaust system. Remove each exhaust pipe/heat exchanger. Undo the flat sheet-metal shields under the heat exchangers, and disconnect the heater control valves and associated plumbing. Once the exhaust pipes are out of the way, you’ll actually be able to see the engine.

Axes & CV Joints—I’ve left the axles until now because they are such a gooey mess. And the less time you spend pushing the disconnected axles out of the way, the better. Now’s the time, so rotate the axle to get straight...
Speedometer cable is at right rear of transaxle. Unscrew large nut and pull cable out.

Clutch cable pivot uses a self-locking nut for retention. Remove nut and pulley to loosen cable and easily remove it at clutch release-bearing arm.

After ducting from engine is removed, push heater valves out of the way. There's no need to disconnect heater-control cables or flexible ducting.

After clutch pulley is removed, unthread the two bracket nuts. This frees bracket from transaxle, leaving clutch cable-to-bracket connection undisturbed.

Clean dirt from tiny splines in CV-joint bolts. These bolts are heavily torqued to prevent loosening; splines will strip if not completely clean. Short Allen head tool and wrench duo shown here is cheapest method, but special 3/8-drive socket, 12-point 6mm Allen head tool is easier to use.

Support Engine—Place the floor jack and plywood under the bellhousing. The larger the plywood, the better. Extra length will help balance the awkward engine/transaxle unit on the jack.

Go forward and remove the two nuts from the center of the solid metal crossmember. These are the front engine mount nuts. Then remove the two large bolts from the crossmember ends. The crossmember will drop free (it's heavy) complete with the cables that pass through it. Gently set it aside without kinking.
As soon as CV joints come free, wrap them and transaxle flanges with plastic bags. This will save a lot of aggravation when you drag your hair over them.

Front crossmember attaches to engine mounts using small nuts found in recessed wells. Remove these, then large bolts at each end of crossmember.

Crossmember will drop after both sets of bolts are out. This iron piece is heavy, so be careful. Don’t let it lay unsupported over clutch and speedometer cables; prop one end up with a block of wood. Once the engine is out, it can be stored by its mounts on chassis.

CLEAN-UP (ALL MODELS)

Once the engine is clear of the chassis, get a helper and lift it off the jack. Grasp it by the ends of the cylinder heads, not the fan housing, pushrod tubes, flywheel or the like. Set the engine on the floor. If lifting a Type 4 engine be prepared for a heavy load; it weighs about twice as much as a Type 1. That’s about 300 lb for a Type 4. Two strong people are needed when moving it.

Use the floor jack to get the chassis back on the ground and pushed to its storage location. Pick up all tools, rags, hardware and parts before they get scattered. Store all hardware and parts in clearly marked boxes and cans. Do this now while they’re still fresh in your memory. You’ll thank yourself at reassembly. Use the trunk or Bus interior for storage if garage space is tight.

Rear engine mounts must come completely off transaxle to clear bodywork. Start with small mount-to-chassis hardware, then remove larger bolts at center.

or smashing the cables.

Go to the rear and remove the transaxle mounts at the body. Then the entire bolt, rubber cushion and washers will come out with the unit.

Lower Engine—Gently start lowering the engine and transaxle while a helper checks the engine compartment. It’s easy to bang the injectors against the bodywork or have their fuel lines hangup, so pay extra attention to them. It will take a minute or two to jockey the engine free of the chassis, so take your time.

Remove the unit and support it on the floor with wood blocks. Be careful to get the blocks bearing against the cylinder heads, not the sheet-metal pushrod tubes or another vulnerable part. Disconnect the starter motor leads, remove the four bellhousing fasteners and separate the transaxle from the engine.