Generator Rehab

Part 2 – Testing, Repair, and Re-assembly by Bruce Smith

Disassembling an old generator involves some challenges, but the repair and re-assembly steps are where things get interesting. As addressed in the first part of this article (in Vol. 43-4), basic generator maintenance might give some improved performance, but it will usually fail to address any underlying electrical or mechanical issues. That generator you found that was supposed to be professionally rebuilt may simply have new brushes, greased bearings, and a fresh coat of aluminum paint. Doing a proper job requires several other important steps. Even when some of these steps may require outside help, it's still a project that you can manage yourself.

Last time, we dismantled a 6V Bosch generator into its basic parts. The main components included the housing, armature, field coils, pole shoes, brushes, bearings, and fan and commutator end caps. If you've got a 12V generator, it isn't much different, but the armature, field coils, and brushes will be unique. This time, we'll restore, repair, or replace these parts and put the generator back together.

Armature Rehab

The heart of a generator is its armature, which interacts with the magnetic field generated by the coil windings to produce, together with the commutator, electrical direct current (DC) flow. Each brush makes contact with the commutator with the help of spring pressure, which will lead to wear of the brushes and, eventually, the commutator. Brushes are serviceable items and are replaced as needed throughout the life of the generator. Service of the armature's commutator is not such an ordinary task. It may suffer significant wear before getting any attention.

Reconditioning the armature requires two basic operations. The first is electrical testing to determine whether there are any problems with the windings or wiring. The second is machining and physical repair to the commutator, if not too far gone, to correct for wear.

Sources of Armature Problems

Bad armature windings can be caused by internal short circuits, open circuits, or grounds. A once-good armature can develop these problems over time, eventually leading to failure. Internal shorts can develop, which may start off relatively small but gradually increase with the armature's high circulating currents. As localized heat builds up, the insulation will degrade, and a catastrophic short circuit can result. Failures are also possible at the ends of coil windings, where local currents are the highest. Weak wiring can lead to increasingly higher local currents and an eventual open circuit. Common ground failures develop from insulation loss between the wiring and a ground, particularly to the generator housing. One can test for all of these potential problems to determine whether an armature can be used, or instead needs to be replaced.

Armature Testing

The basic electrical tests described in the previous article involve the resistance measurement of the field coil windings and a functional powering of the generator. If results are good, electrical issues may be minimal. But there are other tests that can be carried out to ensure that there are no problems with the armature's internal workings. Such testing is done using a specialized piece of equipment called a *growler*.

A growler is used to check for armature shorts, open circuits, and grounds. Though not overly sophisticated, this is not a very common tool among home mechanics. But if you encounter or suspect problems with your generator's armature, plenty of shops can provide basic testing and machining services. Because armatures are used in electrical motors, generators, and alternators, finding a shop that can help isn't too difficult. Though you can no longer walk your fingers through the yellow pages, a quick search on the internet should lead to some nearby shops.

I have an old Sears and Roebuck growler, the same sort used in most auto repair shops back in the day. These are pretty easy to find at swap meets or internet markets. Seen in **Figure 1** below, a growler is essentially an electrical transformer with a V-block frame.

Figure 1: Armature testing for shorts, opens, and grounds is done using a growler.

Though the structural configuration of a growler is quite basic, the testing it enables is quite elegant. If you look closely at an armature, you see that it's comprised of individual segments separated by slots. Internally, there as many windings in one direction as in the other. If each is subjected to an alternating magnetic field, electric fields of opposite phase will be created, which will cancel out around the entire circumference of the armature. In the case of a short, this symmetry is destroyed, electric fields no longer cancel, and circulating currents are set up in the defective windings. These circulating currents produce a magnetic field, which can be easily detected at the surface of the armature.

For testing, the armature is placed in the V-block and the growler is turned on. A thin metal blade (like a hacksaw blade) is held in contact with each segment as the armature is rotated. Any shorts within the coils will result in a magnetic field that will attract the blade. If no magnetic field is created throughout an entire rotation, there are no short-circuited coils. The test is then repeated the same way over the commutator. An ammeter can also be used to test for coil shorts, where the current between each pair of adjacent bars in the commutator is measured as the armature is rotated. If a short exists in the corresponding coils, the current reading will drop to zero. Grounds can be tested by measuring the resistance between the core of the armature and each commutator segment. A drop in resistance at any of the bars indicates a ground in the corresponding circuit. Open circuits are tested by measuring the resistance between the risers of individual commutator bars, as shown in **Figure 2**. By walking two test probes around to test each adjacent pair of bars, an open coil circuit can be found.

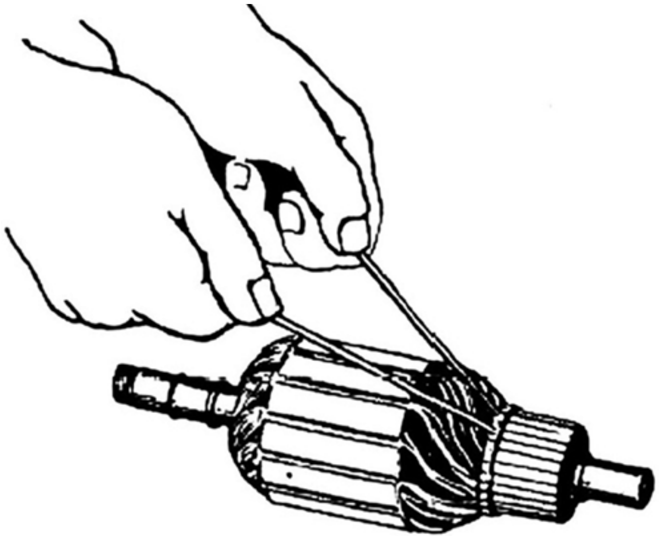

Figure 2: Open circuits are probe tested at the commutator risers.

The repair of most alternator faults is difficult, and certainly not cost effective if a replacement can be found. Although new replacements are no longer made, the equivalency between Bosch armatures for Porches and VWs means that good used ones aren't too hard to find. **Figure 3** shows a comparison of three 6V Bosch armatures. Although there are visible differences between the windings over the twenty-year span that these were made, the three are dimensionally and electrically equivalent.

Figure 3: Three tested, cleaned, and machined Bosch 6V armatures made in Germany and Brazil from 1961 to 1984.

The armatures pictured in Figure 3 have not only been tested for electrical integrity, they have also been cleaned and the commutators have been machined. The commutator bears the brunt of mechanical wear, with constant contact from the brushes and their spring pressure. If the commutator wear or pitting is minor, a polishing of the bar surfaces and cleaning of the recesses between them may suffice. But it's more likely that years of wear will result in out-of-roundness that exceeds Bosch's spec of about 0.015 inch. Wear to the commutator will also lessen the depth to the insulating mica that is recessed between the segments, which should be greater than about 0.012 inch. As the copper surfaces of the segments wear, recesses that are too shallow will cause brush wear and arcing. If the worn ridge near the brush contact areas exceeds about 1/32 inch, the commutator is likely also outside of the roundness spec. If wear or prior resurfacing is minor, skimming of the commutator can be done on a lathe, appropriately set up for armatures. The recesses between segments should also be re-cut and de-burred. Again, you can probably find a shop near you that has the skill and tools to do this. The center armature shown in **Figure 3** had very heavy wear. Although the commutators of each of the three were skimmed to meet roundness spec, and the recesses were properly re-cut, the large loss of material for this particular armature may lead to eventual brush contact problems if spring pressure is weak.

Field Coils and Insulators

Field coils should be tested for both open and shorted circuits with an ohmmeter. A very high resistance through the coil indicates an open circuit. But a good coil will not show zero resistance because of the full path resistance through the entirety of the field coil wiring. As described before, a resistance through both coils of about 1.5 to 2 ohms is normal. Below that would indicate a probable short. Coil shorts or opens are difficult to repair, and a defective field coil is best replaced. A field coil can also be tested for grounding before removal from the generator housing. Missing insulation is a likely culprit for ground problems, which are usually correctible. The field coil pictured in the last article tested fine, but the insulation was falling apart and the wire connections had been weakened. Damage to wires also occurs when a terminal post is turned in the attempt to tighten its retaining nut. When an entire post turns in the generator housing, the corresponding lead wires get twisted. It's a good idea to closely inspect terminal sections of wire, and to replace all of the old insulation around the coils themselves. Glass cloth tape, like 3M Scotch Type 27 tape, is specifically made for high-temperature electrical applications. Replacing the old paper insulation with new is pretty easy. With the old material carefully removed, leads can be re-soldered and the glass tape can be wrapped by overlapping layers by about 1/4 inch around the coils. **Figure 4** shows original coils before repair, and **Figure 5** shows the same coils re-wrapped with glass cloth tape. Wires have also been insulated with high temperature polyolefin shrink tubing (not ordinary PVC tubing) and wire ends and connections have been re-soldered. During assembly, additional glass cloth tape will be added to the wiring as needed. If the original terminal screws are damaged, they can be replaced with new M5x25 screws and terminal wires soldered into their slots.

There are several other insulators in a Bosch generator, as also seen in **Figure 5**. These include square phenolic blocks located at the base of the terminal screws inside the housing, and round phenolic washers located around the screws outside of the housing. Additional sheet insulators prevent grounding between the wiring and the housing. These should all be replaced or otherwise cleaned up as best as possible. Although there aren't any Bosch replacements for these parts, the raw materials to make them are available. Phenolic insulators can be cut from 0.093-inch linen phenolic sheets, available from plastic companies like Professional Plastics in Buffalo, New York. The insulating paper that isolates the field coils from the housing is known as *fish paper*, which is a vulcanized fiber insulator paper used to isolate electrical and electronic parts. Cut to size, this provides a durable replacement for the original insulators.

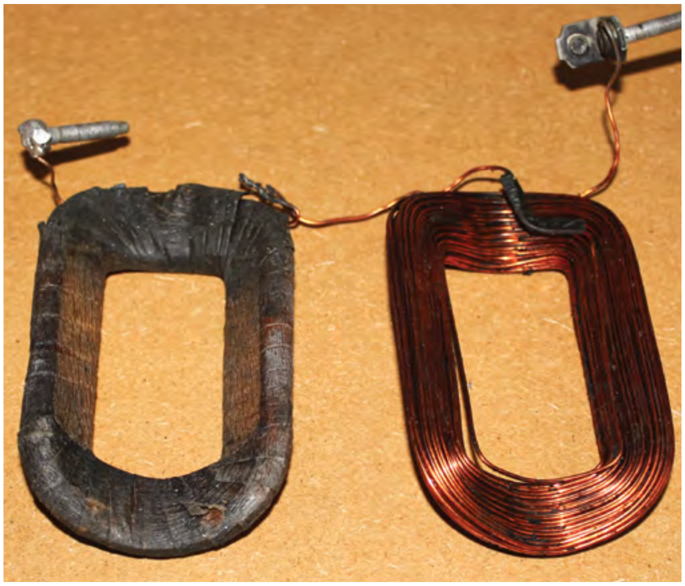

Figure 4: Original field coils showing one side with the old paper insulation and the other side with the insulation removed.

Figure 5: Re-soldered and re-wrapped field coils with high-temperature shrink tubing, together with new phenolic and fish paper insulators.

Housing, Hardware, and End Caps

Rebuilt generators are usually sprayed with a silver or aluminum paint. This is fine, and a fresh coat of paint will make them look good for a while. In addition to zinc plating for the hardware, I've also plated a nice new layer of zinc to the housing using the setup described in an article a few issues back (see Vol. 38-5). The array of cleaned and plated parts, together with new hardware, is shown in **Figure 6**. The pole shoe screws, as well as common nuts, screws, and washers, are new. Both end caps are also shown, which have been cleaned and painted black.

The end caps require special attention, beyond just a simple respray. The springs and spring assembly in the brush end should be inspected carefully and worn parts should be replaced. New springs can be sourced through some VW vendors, but I've had more success getting the right parts with good used replacements. The end caps themselves are also wear items, and the extent of wear around the bearing retaining bores and spacer collars should be checked and measured with calipers or a small dial bore gauge. Over time the forces exerted by the generator belt on the pulley and shaft can cause wear to the end cap bores, resulting in a loose-fit bearing and excessive radial play. While I haven't found a specific Bosch spec for radial play, a tolerance of 0.004 inch (0.10 mm) is common for a generator shaft. Because shaft wear at an end cap isn't symmetrical, out-of-roundness nearing this would indicate excessive wear sufficient to consider replacing an end cap.

However, new end caps aren't available. So if yours is out, you're left to replace one old end cap with another, hopefully better, old cap. An alternative is to machine the bore in the cap and insert what's known as a *spring steel tolerance ring* to tight-fit the bearing. But before getting too far along, realize that it may be a long while before the effect of a little extra radial play leads to problems like premature bearing wear. Specs like these are designed to ensure the performance of a constantly spinning shaft over a long period of time, whereas we 356 owners may operate the generators in our cars for less than 100 hours over an entire year.

Putting it Back Together

The field coil windings, pole shoes, wires, and terminal screws are inserted into the generator housing and held in place to receive the pole screws. If the original pole screws are too damaged to re-use, replacements as seen in **Figure 6** are available from some VW suppliers. You'll need to orient the coils, shoes, and wiring the same as when removed with the stack of original terminal hardware and insulators on the inside and outside of the housing. Before inserting the armature, the pole shoe screws should be tightened.

To ensure field grounding, there should be no gap between the pole shoes and the generator housing. To achieve this, the pole shoe screws need to be very tight. I've found torque specs for generator pole screws as high 40 to 60 ft-lbs, which is both tough to achieve and tough to measure when tightening a slotted screw. There are pole screw presses made to do this, which consist basically of a shop press to hold the housing in place while tightening the screw using a breaker bar and a drag-link socket. It's easy enough to fashion such a setup, which is shown in **Figure 7**. With screws inserted into the shoes in the housing, I tighten them with as much force as I can muster with a breaker bar without breaking anything. Together with some blue Loctite, this is as tight as they're going to get. The fish paper insulator is then inserted behind the field coil wiring to prevent contact with the housing.

Figure 6: The zinc-plated generator housing, painted end caps, new pole shoe screws, new brushes, pole shoes, springs, and hardware.

Figure 7: A shop press with a breaker bar and a 1/2-inch drag socket is used to get the torque needed to tighten the two pole screws.

Once the coils, shoes, and terminals are installed into the housing, the armature can be reassembled. It's easiest to start with the commutator side of the armature, with the bearing shield plate fitted first, followed by one of the 6202-ZZ shielded bearings (part number 900.052.002.00 if ordered from a Porsche parts supplier), and a dished washer. A deep 17mm socket can be used to drive the bearing onto the lightly greased shaft. The bearing for the fan side goes next, which is held inside the end cap with the retainer plate. With a little grease in the cap housing, a second dished washer, a 6202-ZZ bearing, and a shield plate are inserted and the retainer is secured to the cap with new screws, blue Loctite, and lock washers. The cap and the bearing are then driven onto the greased end of the armature using a 20mm socket. A spacer collar is then driven onto the shaft end with the 17mm socket. The assembled armature is pictured in **Figure 8**.

The final assembly basically involves the reverse process of disassembly. Brush springs are installed in the commutator cap, which is then fit onto the housing with the detent in the cap matched up to the tab in the housing. The 4mm screw to the D+ terminal bracket is then inserted and tightened. The assembled armature with end cap and bearing is then installed, centered between the field coils, and rotated as the bearing is seated with the end cap mating to the housing. The two long body screws are then inserted in the commutator end, finding their holes in the opposite cap. While tightening the screws, the shaft is aligned to ensure it turns freely with no resistance or interference. The brushes are then inserted into the brush holders, with their terminal wires screwed into place.

Figure 8: The fully assembled armature with the end cap, ready to insert into the housing.

Figure 9: The completed generator, ready to install.

Complete and ready for polarizing, the finished generator is shown in **Figure 9**. The process described earlier to test the generator as a motor is the same one that is used to polarize it. A jumper is first connected from the DF terminal to D– on the housing. The leads from a battery of appropriate voltage are then briefly connected to the D+ and D– terminals. If all goes according to plan, the generator will spin, giving cause to celebrate. The next steps are to reinstall the pulley hub and the fan assembly with the Woodruff key. Then go put that good looking, freshly rebuilt generator back into your car.

Dr. Bruce Smith is a Distinguished Professor of Engineering at the Rochester Institute of Technology and owner of CFI - Carbs, Fuel, Ignition, www.cfi-auto.com