Testing Diodes Connected to the Rectifier

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When testing diodes which are still connected to the rectifier, a good visual inspection is the first step. Look for solder joints that have a dull, crystallized appearance or seem to have been re-melted. Look for burned stator phases or coils, broken connection welds, any signs of heat discoloration, melted plastic, loose diodes or other parts, and excessive corrosion. Clean away foreign material that might cause false leakage readings. If you see any of these, you will have to separate the stator and rectifier anyway.

Testing diodes for leakage

The simplest way to test diodes for leakage is to use an inexpensive ohmmeter with a X10K scale which uses a 9-volt battery to power it. Radio Shack used to make a tester like this. I think Triplett or Simpson do too. The 9-volt source gives you a better test than the typical 3-volt (two AA's) which most meters use.

The diode should show low resistance on the X1 scale in one direction, but the needle *should not move* on the X10K scale with the leads reversed. To test diodes for leakage while they are still connected to the stator, you would simply connect your ohmmeter from any stator-diode connection to either the positive heatsink or after reversing the leads, to the negative heatsink. This would give you the combined leakage of all the diodes on that heatsink. The needle should still not move.

In my opinion, most diodes that have been stressed will have increased leakage. If the stator lamination stack is touching the negative heatsink during this test (like the Ford 3G), be sure you are not condemning the diodes when the stator is the one with the leakage.

A more sophisticated leakage test would be to apply 16 volts and measure the leakage current with a microammeter. I choose 16 volts because some diodes will 'zener' (avalanche) at as low as 18 volts (more on zener diodes later). Again, you can measure leakage current with the diodes still connected to the stator. The combined leakage will be three times as high, assuming a three diode heatsink. Everyone wants to know what an acceptable leakage amount is, but the fact is that the fussier you are, the fewer failures you will encounter. Why not compare it to a new diode?

Bosch has a new diode out, the ZR1480, rated at 80A. Its max reverse current rating is 100 microamps max at 16 volts.

The stator itself can be checked in the normal way for current capacity and balance because (non-shorted) diodes will isolate the phases electrically. When checking the stator for insulation leakage, you would have to ensure that the stator lamination stack is not touching the negative heatsink (like Ford 3G).

Either style of diode leakage test, along with a good visual inspection, will eliminate most of the rectifier-stator combinations that will need to be desoldered/disconnected before going any further.

Testing the forward voltage drop

You need to run a substantial current through a diode (not too long) while applying a voltmeter (separately connected; remember Kelvin) across each diode. This will give you a forward voltage drop reading. You can use a 12-volt car battery and a 20A fixed load (0.6 ohm 250W) in series with it. To test diodes while still connected to the stator, connect the load side to the negative heatsink and the battery ground side to the positive heatsink. The 20A load will limit the current, and you are now turning all the diodes on at once.

Measure each diode with the voltmeter. If a diode was open, you would read at its terminal the voltage of the nearest diode plus the drop across coils of the stator. So although the diode wouldn't read open, its forward voltage would be substantially higher.

To check the trio diodes while still connected to the stator, you have to be more precise in reading the voltage. This is because the current should be limited to 3A (1A diode X 3). If one of the trio diodes was open, the low current would not generate much of a voltage drop across that phase of the stator, and so you would have to be more accurate in order to catch it.

Please note that the forward voltage reading varies somewhat from one diode to another. If they have different amperage ratings, are tested at different amperages, and reach different temperatures, you could expect even more variation. This is because of the manufacturing process. This last factor becomes significant when pairing diodes to increase load carrying capacity, because the diode with the slightly lower forward voltage drop will take most of the load, possibly overstressing it. Also, in aircraft applications, diodes that are not exactly matched can cause beat frequencies which may interfere with nav/com equipment.

Please note that the diodes with the higher voltage drop will get hotter than the others, and that is a question of reliability.

For our ZR1480 80A Bosch diode, the forward bias voltage is 1.17 volts, tested at 200A. The maximum surge current rating is an amazing 600A!

Testing the avalanche voltage

An avalanche diode's rating has to be well in excess of the normal operating voltage of the vehicle system, otherwise it will create, in effect, a partial short. The function of this characteristic is to clip off spike voltages that go too high for the system electronics, thus providing protection. Spikes occur when there is a 'load dump,' or a heavy draw is switched off. The regulator tries to quickly turn the rotor off so that the alternator voltage will stay level, but it takes time for the rotor to respond, and thus you have a spike.

If you do not have a means of checking avalanche voltage, you can 'cheat' by using your regulator tester. I am using the VRC101 by Transpo. Connect positive to the cathode (stem on a 'N' diode, and case on a 'P' diode) and the negative on the other side of the diode. Your tester's current limiting will protect your tester and the diode. The diode will avalanche when you set the tester to its 32-volt regulator setting, and function as a regulator, giving a reading of the avalanche voltage on your tester's display.

You can see the avalanche behavior on an oscilloscope. (Use an isolation transformer to protect yourself). Connect a 25W 110V bulb to limit the current through the diode, and connect your diode to it in series with your 110VAC source. Apply your scope probes across the diode. You will observe the switching action as the voltage sits at about 1 volt for half of the AC cycle (forward voltage drop), and then goes to about negative 20 volts (avalanche voltage) for the other half. This will also enable you to see how cleanly the diode switches.

There are several very good avalanche testers out there you can purchase. Dick Vensel at Vensel Enterprises could get you set up.

Three common avalanche voltage ranges are: 19 to 25 volts, 24 to 32 volts, and 34 to 40 volts (used on 24-volt systems). Notice that avalanche specs are in ranges. It is not an exact spec. Fortunately, in automotive applications it is not necessary to match avalanche voltages. The two diodes that are connected to a particular stator phase are the only two out of the six that will even be seeing the 'load dump spike' of that phase, and one of those will be forward biased at the time.

If you do want to match the avalanche voltages so that all the phases are the same you would have to look through a lot of diodes to find six the same. That's why the diodes are each designed to handle it individually. I don't believe it is practical to measure the exact avalanche voltage of each diode while connected to the stator because of the wide acceptability range. However, you could determine whether they are avalanche diodes or not in the same way as above. Our ZR1480 80A diode has a peak avalanche current rating of 125A at an avalanche voltage range of 19 to 25 volts.

Testing the thermal conductivity

I read a fascinating article by former GM engineer Bill Bowman on the ability of a diode to dissipate heat. If a diode is damaged, or has poorly reflowed internal solder joints, it could test good according to our first four tests, and yet reach higher temperatures in normal operation and thus fail sooner. Rust around a press-fit diode, poor heatsinking, or even undersized/overrated diode chips could all cause heat related failures. Here are some additional points made in the article:

- Obviously the bigger the chip inside the diode housing, the better it could dissipate that heat.
- Generated heat, heat flow, and thermal conductivity have a relationship that is expressed by a formula similar to Ohm's Law, so the math is not that complicated.
- This test cannot be done while the diodes are connected to the stator. It has to happen in microseconds and at high amperages, and the inductance of the stator windings would skew the readings.

A diode's voltage drop decreases with temperature, and so change in voltage over time can help indicate how quickly heat can dissipate from a chip after it has been pulsed with high current. (D&V Electronics makes a good tester for this.)

Our 80A Bosch diode has 0.45K/W of thermal resistance as compared to their 35A diode which has almost twice that at .80K/W. Thus you can see it gets rid of heat more quickly.

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