

About Our Stator...And How It's Affected By The System Load

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In the manual you're given the specs for the “*peak to peak unloaded*” stator voltage measured between two phases. (80VAC @ 5000RPMs) These specs only apply to the stator when it is “*unloaded*”, or *disconnected* from the system, and only useful in testing the AC stator voltage output to see if it's good.

The manual also gives a spec of 340 watts maximum power. This spec gets a bit misunderstood because it isn't really about the amount of electrical power going out to the system. It's about the amount of *heat* the stator should be able to safely dissipate consistently without the high temp coating on its wire self-destructing. Since the stator absorbs heat from the engine, and the charging system “pulses” as it operates, it would be extremely difficult to figure out just how much of a load would cause the stator to be pushed into overheating. Especially since battery health would be a factor. Even if you don't add accessories to the system, as the battery ages it becomes more of a burden to the charging system.

When the stator is disconnected from the system (with the engine running) there is no current flowing in the stator. In order for current to flow in the stator there has to be a complete circuit. When you hook your multimeter between any two phases you are completing a circuit. A multimeter has a very high input impedance. (typically 10 megohms) If you are dropping 80 volts across a load of 10 megohms that would mean the current flowing in the circuit would be .000008 amps. The wattage being dissipated in the circuit would be .00064 watts. Not very big numbers.

Stators are always talked about as generating maximum current. This is *mostly* true...*if* kept in proper context. Think for a moment about the example above testing the *unloaded* stator. If the stator generated its maximum current, say 22 amps, through your multimeter at 80 volts, that would mean the stator would have to dissipate an enormous 1760 watts while you were testing it. (over 5 times its maximum rating!) Your multimeter wouldn't have been too happy about it either.

The Voltage, Current, and Power, a stator can produce is completely dependent on the circuit it's part of.

With the load and voltage the stator is designed to work at it *can* generate maximum current. The maximum current the stator is capable of generating is governed primarily by the strength of the permanent magnets in the rotor.

Suppose we had an adjustable load hooked up to the stator. If we started out with a very light load (like the load of the multimeter...10 Megohms) we've already seen that the current flowing in the stator would be quite low, and the voltage quite high. If we could dial down our adjustable load, what you would see is as the load increases (which means the resistance gets smaller) current would increase and the voltage would decrease.

The stator/rotor combination is designed to work at that point where the load of the bike is great enough to hit the point where maximum current flows in the stator. From this point on increasing the load will only cause the stator voltage to drop. The stator current cannot increase because of the limitation of permanent magnet strength.

How many times have you heard this: “The OEM R/R causes the stator to burn up because it shunts and allows maximum current to flow.”

In use, the stator is always generating maximum current. (a bit off idle) If the stator always generates maximum current whether it's “in circuit” or “shunting”, then why don't they *all* just burn up?

Because it isn't about Current, it's about Power...More Power means more Heat.

Power, (Wattage) is the product of *instantaneous Voltage* times *instantaneous Current*. If the current remains

steady, as you increase voltage you will increase power. Here's a few examples with simple math:

$$10 \text{ amps} \times 5 \text{ volts} = 50 \text{ watts} \quad 10 \text{ amps} \times 10 \text{ volts} = 100 \text{ watts}$$

As you can see, as we increased the voltage we increased the power. Increased power means increased heat. The reverse is also true. Less power would obviously mean less heat. This becomes important as we go on.

You must also realize the stator is not like a battery. With a battery, as you increase the load the battery can compensate by supplying more current to the load, while still keeping the voltage steady. The stator is putting out the maximum current it can generate. This means as the load on it increases, the voltage it's putting out will get loaded down. This is actually how shunting the stator keeps the voltage from rising above the adjusted threshold.

Earlier we said the voltage, current, and power, the stator can generate is completely dependent on the circuit it's part of. This is important because the stator is actually a part of two separate circuits. One circuit is when it is charging/supplying loads, and the other circuit is when it's being shunted. They must be thought of as separate circuits to understand what is happening with the stator in each scenario.

When 'in circuit' charging the battery/supplying the loads, the stator will have a voltage high enough to forward bias the positive rectifier diodes and pull charge from the positive side of the battery. This is the very purpose of the stator-rectifier diodes and how they work together. A higher stator voltage during this time will mean more power and more heat dissipated by the stator.

When the voltage rises high enough for the regulator to kick in the SCR's and "shunt" the stator voltage drops dramatically. When "shunting" the circuit only consists of the stator, the negative rectifier diodes, and the SCR's. The diodes/SCR's present a *very* small resistance. Earlier we said if the current is at it's maximum, as the resistance decreased, voltage decreased also. When "shunting" the stator voltage drops way below the point it could forward bias the positive rectifier diodes. This is the very purpose of "shunting" the stator.

If stator current is always at it's maximum, the higher voltage the stator has when it is "in circuit" charging/supplying loads *has to mean* more power being dissipated by the stator then when the stator is "shunting" and the stator voltage is lower!

So the question now becomes:

"If the stator always generates maximum current, and the regulator always kicks in at it's adjusted threshold to keep the voltage from rising beyond a certain point, how could you possibly generate enough electrical power to fry the stator?"

Because as we said earlier...the spec of 340 watts maximum wasn't about the amount of electrical power going out to the system. It's about the amount of heat the stator can safely dissipate. The stator doesn't just produce its own heat. It also absorbs heat from the engine.

The charging system pulses. This means it alternates between charging/supplying loads and shunting. In other words it goes from "high" to "low". This "high" and "low" action helps to control the amount of heat the stator produces. The ratio of the amount of time it spends on "high" (charging/supplying loads) to what it spends on "low" (shunting) can be called its Duty Cycle. (the *period* of the duty cycle in this case is *aperiodic*, as it would be the time the bike spends running) More time on "high" means a higher Duty Cycle.

(I grant you this is a pretty liberal interpretation of Duty Cycle...but I think you get the idea)

Let's use a lamp with a 60 watt bulb as an example. If you turned on the lamp with your hand on the bulb, in a very short amount of time you wouldn't be able to keep your hand on it. It would be way too hot. But if you

turned the lamp switch on and off quickly you would be able to hold your hand on it for a much longer period of time. (it still gives off heat when it's off) More “off/low” time means it would generate less heat overall. It would have a shorter Duty Cycle.

The more electrical load your bike has means it's using more power. In order for the charging system to recycle more power to the load it has to increase its Duty Cycle to keep up with it. A higher Duty Cycle means the stator spends more time on “high” with a higher voltage. Higher voltage with a consistent amount of current means more power. More power over more time means more heat dissipated by the stator.

This is why increasing the electrical load on your bike puts more stress on the stator.

How *Much* Load...?

How much load can the system handle? Honestly, I couldn't tell you. There are way too many variables. No two stators will be exactly the same. The high-temperature coating on the wire will always have a certain amount of imperfections. How those imperfections line up with each other when the stator is wound is a crapshoot. The wire itself is made of copper...and copper expands greatly as it heats up. As the copper expands the coils they are wrapped in become a bit looser and are more prone to vibration and rubbing against each other. (I *personally* believe this is the biggest contributing factor in *most* stator failures) The heating, expanding, cooling, and shrinking, the copper is doing over time isn't doing the high temp coating any good. Oil *could* get splashed on the coils and *could* possibly contribute to a failure also. How hot the engine gets would be a big factor. Bikes run in dessert climates will certainly get hotter than bikes run in the northern climates. City driving generates more heat than highway driving...and what about parade riding? This means the stators in the hotter bikes are already at a disadvantage.

...and some will fail strictly because they are defective to begin with.

Less load will mean less heat stress for your stator. If you can find ways to lessen the electrical load on your bike your stator will be happier for it.

...a possible clue you have too much load?

Your voltmeter may be giving you a possible clue that you have too much load on your system. The OEM R/R's are most likely regulated by a zener diode. As soon as its threshold (breakdown voltage) is reached it “turns on” and the circuitry tells the SCR's to shunt the stator.

Let's say when cruising your voltmeter 99% of the time reads 14.1 volts. As you start turning accessories on at some point the voltage will start to drop a bit. That could very well be a sign you have reached the point where the stator-R/R is now working full time charging/supplying loads and not getting the tiny break it gets when shunting. (to be honest, I cannot come up with a scenario that would disprove this) If this is indeed true, then the stators are much more robust than they're being given credit for.

The OEM R/R shunts the stator when the voltage reaches the zener diode threshold. Let's say that is 14.1 volts. (according to your voltmeter) We know that the stator is putting out maximum current, so as the load increases the voltage will get loaded down. (because current cannot increase to compensate) If the load is great enough you could load the voltage down below the point where the zener diode never gets triggered. This would mean the stator is always “in circuit” doing its best to try and keep up with demand. Since it isn't getting shunted the heat being produced is steadier and not intermittent. Remember the example trying to keep your hand on the light bulb when it was on steadily?

As the voltage goes down you are also lessening the charge you're putting on the battery. The higher the voltage difference is between the at rest battery voltage and the charging voltage means more electrons getting deposited in the negative side of the battery. More electrons on the negative side of the battery means more

muscle to start the bike.

A Few Issues/Misunderstandings To Address...

I've heard it stated that, "Stators burn out in part because the wire gauge they are wrapped with is too small."

This is not the case, but I do understand where this idea comes from. Without getting too complicated, it has to do with the difference between *steady consistent power*, and the way three-phase AC power is actually generated. The current, voltage, and power, in each *separate* phase of the stator isn't steady. It constantly increases and decreases. The *overall total power output* from the stator remains fairly constant, but the *consistent total output power* isn't *constantly* dissipated by any one single phase all the time. This is why the stators can be wound with wire that *appears* undersized. If those separate phases had to carry the *total power output constantly* as would be the case with steady DC then yes...it could be argued that the wire might be undersized.

When a stator dies it is usually due to the high temp insulation the wire is coated with breaking down. When this happens it shorts the phases together, or phase to ground, and reduces the output of the stator far below anything useful. As we discussed earlier this can be caused by many things.

If you look at a burnt stator the damage is *usually* localized. When you see this it is a direct result of a breakdown of the insulation in that particular area and could have been caused by any of the things we discussed earlier. It is unlikely that an R/R failure had anything to do with this.

Occasionally you'll see a stator that is burnt on the majority of its coils. There's only a few ways this might happen. One would be the result of a multiple diode failure. It would take at least two of the 6 rectifier diodes and 3 SCR's to fail in such a way that they allow the battery to be shorted by the stator. (not really very likely, but never say never) The second way would be if you had so much electrical load on the charging system that it was working close to its limit. This could be because your battery may have decided that it was time to slack off, or you got carried away and put too many accessories on your bike, or a combination of both. If you see this you should probably replace the R/R. Your battery would/could also be toast as well. Even if it can be recharged initially it most likely won't be able to do its job effectively anymore. It should probably be replaced. It's a judgment call.

Testing an R/R appears to be a simple straight-forward test...but things are not always what they seem. It *is* simple in that using a meter to check for obviously bad diodes is easy enough...*if* they are shorted or will not pass current. The trouble with this is diodes are semiconductors. They can test perfectly fine when the unit is cold but fail when they are heated up trying to do their work. So, how can you be sure yours is functioning properly? I'm afraid you have to take it on faith. If the only test you can do says it works then what else have you got? If you are among the unlucky ones who have burned more than one stator in a short period of time that to me suggests your R/R may not be functioning correctly under load. It's a lousy way to find out...but it is what it is.

When you test a stator you should do three checks. Continuity to ground, the continuity between phases, and also the AC output test. You can pass both the continuity to ground and between the phases check, and still fail the AC output test.

If there is a short in the windings between phases it won't necessarily be a short to ground, but it will show up in the AC stator output test. The AC output will be lower than you would see if the phases weren't shorted out. Do all three tests.

The wiring used in the wire harness is sized to carry the current. The trouble spots for the charging system are the Stator-R/R plug, and the connection in the starter relay. It's the connections, and *not* the wiring that cause the problems.

The connection in the relay must either be undersized, or just doesn't make good contact after a period of time. If it loosens up it can begin to oxidize/corrode and that would introduce resistance in the circuit. Either way the cure is simple. Bypass the connection with a fuse pigtail. There is plenty of info on doing this in the Helpfiles on the forum start page.

The connections in the Stator-R/R plug are in a bad spot. They can get water and road grime in them. They can also get oil in them if it seeps from the stator wire grommet. The protective braiding on those wires helps to wick oil through the grommet, down the wires, and into the plug connections. Once the connections get contaminated they lose clean mating surface area and that causes resistance and heat. Basically the connections become a load because they drop a small amount of voltage across them due to the resistance. More resistance means more heat which in turn means more resistance, etc. The heat that gets generated melts the plug and allows the wires to short together. If the connections in the plug remained tight, clean, and dry, they wouldn't present a problem. If it happens to you just cut the plug out and solder the connections together. This is also covered in the Helpfiles.

Why Does The C90 Burn Out More Stators Than The LC?

This isn't as easy a question to answer as you might think. The two bikes obviously have a great deal in common, but being fuel-injected means the C90 is still a different animal. I guess the best way to attempt to answer this is to talk about what is different, and what is the same.

Being fuel-injected means a stock C90 requires a bit more power to operate than a stock LC does.

The Stator and the R/R are the same in both bikes, even though the wiring harnesses are different.

The LC specs say it requires a 14 amp hour battery. The C90 says it requires an 18 amp hour battery.

Right off the bat we can see the C90 uses more power. This is obviously going to put more demand on the charging system. More power, equals more heat, equals more stress on the stator. How much more power it actually uses though I can't say. I don't have access to a C90. I am not aware of any comparisons anyone has made between the two bikes.

The C90 using the 18 amp hour battery means the battery requires more charging current than the battery in the LC does, so that puts more demand on the charging system as well. (you don't get something for nothing...bigger is not always better) I'm not exactly sure why they would have chosen to put a higher demand battery in a C90. Once the bike starts the C90 without question would have absolutely no problem running with a 14 amp hour battery. That leads me to believe they wanted slightly more oomph to start the bike...but is it *actually* needed?

As far as I can tell mechanically the bikes appear the same. The starter is also the same in both bikes. This means from a mechanical standpoint the battery and the starter are doing the same amount of work in each bike.

Is the C90 using so much more power when you turn the key that it robs the battery of that much starting power? No doubt the C90 uses a few more amps than the LC does, but a good battery can supply hundreds of cold cranking amps for 30 seconds.

You could be losing a tremendous amount of power in the starting circuit from connections that aren't clean. (see **Why Isn't There Enough Power To Start My Bike!?!** in the Helpfiles for more on this subject) Much more than you are probably aware of. You may not be getting the maximum amount of charge on your battery either, also through bad connections. It's easy to put the blame on a battery, but if the support system for that battery isn't in top shape than the battery isn't really to blame.

So why did they put the larger battery in the C90? My guess is it was a misguided way to deal with the C90 using more power. To me it makes no sense. If you have a bike that needs more power why put in a bigger battery without beefing up the charging system to meet its need? It only puts more stress on a charging system that is merely adequate to begin with.

We know they made a few bad decisions in other areas. Take that ridiculous loop in the C90 that goes from the stator-R/R to up under the seat and comes back down. I can't even begin to imagine what that was about? It adds connections that can only become problems for the charging system. It serves no useful purpose whatsoever...but it's there. Go figure.

So What Should We Take Away From All This?

Basically the C90 has the same charging system the LC does, but the C90 puts more of a burden on it. *Exactly* how much more I don't know. It doesn't have to be a great deal. It only has to be just enough. That's it in a nutshell. Both bikes are still subject to all the other stresses that can help a stator to fail.

Since there will always be imperfections in the high temp coating, stators that are working harder will also stress those imperfections more. A chain is only as strong as its weakest link.

Will The CE-602 Series Regulator Really Help The Stator Last Longer?

In my opinion...a very wary yes. Let me explain...

On the face of it, the 602 causes the stator to produce less heat overall than an OEM R/R does to do the same amount of work. If you are within the limits of the charging system then yes, the 602 is a more efficient choice. Less heat will have less stress on the stator.

However...

If you're pushing the limits of the charging system by adding/running multiple accessories it will not matter which R/R you are using. Remember what we said earlier. The heat the stator is subject to isn't just from the power it alone dissipates. It absorbs heat from the engine. We really have no idea how much extra load will stress *your* stator on *your* bike?

Also, remember that no two stators will be exactly alike. Some will just flat out be better made than others through nothing more than the luck of the draw. If you replace your stator and install a 602 it doesn't mean your stator won't be a victim of mechanical vibration. They don't all die from just heat alone.

If you have the cash and want to install a 602 by all means go for it. It can only help. Just remember...

It is in no way a guarantee against a stator failure.

Ride Safe!