ELECTRICAL TROUBLESHOOTING – VOLTAGE DROP TESTING

REVIEW OF ELECTRICAL CHARACTERISTICS AND MEASUREMENTS

The following paragraphs summarize briefly the various characteristics of electricity that are measured during troubleshooting. More detailed review can be pursued by reviewing the chapters on electrical theory and batteries.

Electricity and Electrons

Electricity is simply the flow of electrons through a conductive path or load device. A conductive path can be a wire that feeds current from a power source to a load component. A conductive path for electrons can also constitute a ground return back to the power source.

The ground return can be a ground wire, the motorcycle frame, the engine or transmission. Spark plugs for example are grounded in the engine, which is bolted to the frame. The battery negative terminal ground wire is also bolted to the frame. This wire, connected to the frame and the negative battery terminal, constitutes the final ground return path for the entire electrical system.

Amperage – Electrical Current

Amperage is measured with an ammeter that is connected in series, with power turned on and flowing in the circuit.

Amperage is the quantity of electricity that flows through a conductor or circuit. The measurement of amperage is a measurement of the volume of electrical current - the rate of current flow – that flows through a conductor or load device, (circuit).

At the atomic level, amperage represents the measurement of the volume or amount of **electrons** flowing through a conductor or circuit. The measure of the flow rate of electrons is commonly referred to as “current”.

Amperage is measured in units called amperes or amps for short. Amps are measured with an instrument called an ammeter. **An ammeter must be connected in series in a circuit.** In other words, the ammeter is connected into the circuit and becomes part of the circuit. The ammeter then measures the current that flows through the circuit, because the current flows straight through the ammeter. The ammeter is basically “spliced into the circuit”.

For example, an inductive ammeter has a clamp that fits around a wire and measures amperage flow without being “spliced into the circuit.” It is commonly used to measure amperage flowing from the battery to the starter.

The smallest unit of measurement of amperes is the **milliampere or “milliamp”** for short.

Voltage - Electrical Pressure

Voltage is measured with a voltmeter that is connected in parallel, with power turned on and flowing in the circuit.

Voltage is a measure of the force that pushes electrons along – voltage is not the electrical current itself. Voltage is a measure of electrical pressure.

Voltage is the energy required to push electric current along a path between two points. In other words, voltage is equal to the work which needs to be done to move an electrical charge between two points.

Voltage is the power, the force, or the energy **available** to push electrical current from the positive battery terminal, through the electrical conductor (wire), and through the load device (i.e. light bulb or starter). Voltage is the power that pushes current through the circuit.

Note that for purposes of motorcycle and auto mechanics, current moves from positive to negative, even though it actually moves from negative to positive at the atomic level.

Chemical reactions inside the battery, supply the 12 volts of electrical pressure needed to push electrical current through a circuit. The battery does not store voltage – it only stores the “chemical potential” to produce 12 volts of voltage when needed.

A voltmeter is used to measure the units of potential energy – for example: the volts that reside between the negative and positive battery terminals. A voltmeter measures the difference in voltage between the red and the black leads of the voltmeter. The voltmeter is connected in parallel into a circuit.

For example, if the red lead of a voltmeter is touched to the positive battery terminal, and the black lead is placed on the negative terminal, the voltmeter will take the difference between the voltage sensed by the two leads and this will be the measurement of voltage. If the battery is fully charged, the red lead will measure about 12.8 volts and the black lead will measure zero volts. The difference between the positive and negative terminals is therefore 12.8 volts.

Resistance – Restriction of Electrical Flow

Resistance is measured with an ohmmeter that is connected in parallel, with the power turned off and not flowing in the circuit.

The electrical term called “resistance” represents “opposition” to the free flow of current. Resistance impedes the flow of electrons, and resists the flow of current. A kink in a garden water hose is a good visual example of resistance - an impediment to flow.

Resistance is a measure of how much a conductor or load device opposes the free flow of electrons.

For example, the flow of electrons is slowed down by resistance in electrical wires, resistance in starters, resistance in light bulbs, or other electrical loads. The amount of resistance to current flow is measured with an ohmmeter.

An ohmmeter is connected in parallel to a component or wire that is being tested.

An ohmmeter measures the resistance present in an electrical circuit by injecting a very small amount of voltage into a circuit or load device through one of the multimeter probes. The ohmmeter then uses the other multimeter probe to measure the amount of voltage that managed to travel all the way through the circuit.

Microcircuits inside the ohmmeter then calculate the resistance of the circuit based on the return voltage. The resistance that opposes the electrical flow in a circuit is measured in ohms.

The ohmmeter injects only 0.6 to 0.75 volts through the circuit. This is only 6/10'ths to 7.5/10'ths of one volt. No amps are put through the circuit.

The circuit or load device that is being tested for resistance must be disconnected from power and must not have any current running through it. Zero current or voltage should be running through a circuit or load device that is being tested for resistance with an ohmmeter. To be certain that a circuit is dead, it is a good idea to disconnect the battery before using the ohmmeter. Never apply the test probes to a live circuit. It will likely damage the ohmmeter if not completely destroy it.

A load device that is being tested must be disconnected from the circuit in order to secure an accurate resistance reading. A wrong reading will occur if the ohmmeter is measuring the resistance on the entire circuit – especially a circuit with many branches.

If a measurement of resistance is desired for one branch of a circuit, the branch must be disconnected from the circuit and tested separately.

Polarity is not important when doing resistance testing unless there is a diode that is being tested. If the current is sent through the diode in the wrong direction, the diode will block the current.

As resistance increases, current flow decreases. As resistance decreases, current flow increases. A large conductor diameter – such as the thick wire going from the positive battery terminal to the starter - will offer less resistance than a smaller diameter wire.

The longer the conductor, such as a wire, the greater will be the resistance of that wire conductor. If two wires have the same diameter and are made of the same material, the longer wire will have more resistance than the shorter wire.

The condition of a conductor may also affect resistance. A loose wire connector, a loose ground wire, a corroded connection, a partially cut wire, or a bad splice where the wire was crimped and not soldered – all of these conditions may increase the resistance in the conductor.

Ordinary load devices that put up “normal” electrical resistance are wires, starter motors, lights, relays, solenoids, coils, spark plugs, computer electronic control modules, radios, heated seats, and so on.

Unwanted Resistance

There may be other forms of resistance in a circuit that may be abnormal and unwanted resistance - “abnormal loads”. Unwanted resistance will consume and waste voltage.

Unwanted resistance causes low performance in an ordinary load device, or complete non-operation of the load device. The additional resistance restricts the free-flow of electrons, or in some cases can completely block the free-flow of electrons.

Unwanted resistance – unwanted loads - does not show up on wiring diagrams! Unwanted resistance is what a technician looks for when troubleshooting an electrical circuit. Unwanted resistance causes low performance in electrical parts.

If a headlight starts going dim, or a starter is turning over too slowly - these are signs that there are simply not enough electrons available to power the headlight or the starter. These are examples of low performance.

Other unwanted resistance can come from a shorted wire, a loose wire connection, corroded connections, dirty contacts in switches, a ground wire that is corroded or loose and not grounding properly, a bad relay (switch), a fouled spark plug, a blown fuse, or a broken filament in a light bulb.

Extremely low resistance is the opposite of high resistance and can be more damaging. No resistance can occur in a circuit if a wire feeding current to an electrical load becomes frayed and touches the frame of the motorcycle. In other words, the wire grounds out on the frame – it shorts out.

What will happen if a wire grounds out on the frame? First of all, the current will by-pass the intended load such as the headlight and it will create its' own new circuit by taking a short-cut path back to the battery.

Secondly, the wire that touches ground – the short circuit – can cause the battery to release an enormous amount of amperage. This high amperage will now flow through the grounded wire and through the wiring circuit, unless there is a fuse along the path that melts and stops the flow of current.

Most electrical circuit wires are not thick enough to carry the high amperage released from the battery during a short circuit. The thinner wires will heat up from all the amps, and the plastic wire casing will likely melt and possibly catch fire.

Where do all these amps come from when a wire shorts out? Why are there so many amps released? As an example, the battery for the engine of a large displacement motorcycle may hold the potential to release as many as 250 cold cranking amps (CCA).

This huge number of amps is required to turn over big engines during starting – and the starter wire is thick so as to be able to carry this amount of current. However, the release of this quantity of amperage, through an electrical circuit with thin wires that put up high resistance, will cause electrical overload in the wires. Think of it as an electron traffic jam that creates a lot of heat.

What can be done to prevent the serious consequences of a short circuit? The solution is to insert the proper size fuse into the wire that feeds current to a load, or multiple load devices. If a short circuit occurs in the “hot” wire, the fuse will melt from the high amperage that begins to flow, and disconnect the circuit so that the electrons no longer flow. The blown fuse stops the huge flow of electrons. Note that the fuse is not inserted into a ground return wire, but only into the positive side of a circuit – the “hot” wire and not the ground wire.

There are technically two types of electrical resistance – direct current (DC) resistance, and alternating current (AC) resistance. Because AC current flows back and forth in a zigzag motion as it moves forward, there is about twice the amount of resistance than in DC current, which basically flows straight, and not in a zigzag motion.

VOLTAGE DROP

What Is Voltage Drop?

Voltage drop is a disorder in an electrical system. You might call it a sickness in an electrical circuit.

Voltage pushes current (amperage) through the wires of electrical circuits. Along the way, the current is used to power a load device such as a starter. A starter may require about 200 amps in order to have enough power to get the engine to turn over fast enough to start.

In order to get those 200 amps to the starter, the battery must use its voltage to push those amps to the starter. If on the way to the starter, the voltage decides to take a side trip and "waste some voltage energy", there may not be enough voltage remaining "after the side trip" to push enough amps into the starter for the starter to work properly.

In other words, the voltage pressure is now a lot less, after it wasted some precious voltage pressure on the way to the starter. The remaining voltage can no longer push enough electrons (amperage) to the starter. Instead of pushing the whole 200 amps the starter requires, the voltage might only have the strength to push 100 amps. This will not be enough amperage to get the starter to work properly.

The voltage that was wasted along the way is called voltage drop. So, how much voltage was wasted while pushing amperage to the starter? This question can be answered by voltage drop testing.

The phenomenon of voltage drop can be understood and illustrated by quantifying how much voltage can be lost from a battery before it cannot effectively energize a starter.

For example, a sealed battery is 100% charged at approximately 12.8 volts. However, a battery that is only 25% to 50% "charged up" contains 11.5 to 12.0 volts. *(A 25% charge equals 11.5 volts. A 50% charge equals 12 volts.)*

If voltage drops only 1.3 volts - from 12.8 volts to 11.5 volts – this represents a 75% drop in voltage pressure!

This massive reduction of roughly 75% of voltage pressure may result in the voltage only being able to push perhaps 100 "cold cranking amps" into the starter. If the starter only receives half the amperage it needs, how will it then react? It will likely turn the engine over very slowly – too slowly to start the engine. This was the result of a loss of voltage pressure of only 1.3 volts.

Symptoms of Voltage Drop

Voltage drop may be suspected when a load device performs in a weak or sluggish manner. In other cases the load device may perform in an erratic or intermittent manner. More serious symptoms of voltage drop may result in load devices that do not function at all.

Basically, voltage drop can be suspected if the load device is not receiving enough amperage to operate properly. Some kind of resistance in the circuit is preventing the correct amount of current from travelling to the load device.

For example, a starter may not work at all, or it may turn the engine over slowly in a weak and sluggish manner. A headlight may burn dimly. A taillight may not work at all. Or, the taillight may flicker on-and-off in an erratic and intermittent manner. The horn may not work. The battery may keep running down and may even go completely dead. The engine may start and die. Or, the engine may run fine for 20 minutes on the road and then die.

If nothing is mechanically wrong with the electrical parts listed above, then there is a high probability of electrical resistance and voltage drop in the electrical circuits that serve these components.

Causes of Voltage Drop

As discussed, the causes of voltage drop result in either a complete blockage of voltage flow, a reduction in voltage flow, or an erratic and intermittent flow of voltage.

The most common causes of voltage drop are corrosion inside any wire connection – especially a ground connection. Electrical current does not travel easily through rust or other types of corrosion.

Another common cause of voltage drop is a loose wire connection – especially a ground connection. A loose wire connection makes it hard for electrons to get to where they are going.

If a wire is damaged and frayed, and many of the woven strands of the wire have been broken, **the few strands that are left may put up excessive resistance to the flow of voltage.**

A bad connection - such as a cold solder joint or a bad crimp where two wires are connected - can cause voltage drop.

If a wrong wire size – for example a wire that is too thin – is used to transport current, the wire may put up excessive resistance. This will result in voltage drop. In other words, voltage will be restricted along the way and not enough voltage and current will reach the load device.

If a wire has to travel a long distance, the longer distance will cause more resistance. A bigger wire gauge may be needed to provide less resistance for the longer distance the current must travel.

Heat can also cause unwanted resistance to the flow of voltage and current. If load components and circuits receive too much heat, the electrons passing through become sluggish and disoriented. They do not flow properly in the direction they are supposed to go.

Dirty contacts in switches can cause voltage drop. Electrical current does not travel well through dirt.