Troubleshooting with a Load Tester

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http://www.kennedyelectric.com/SureTest/Suretest-Troubleshooting_with_a_load_test.htm - Link Now Dead

Troubleshooting fixed wiring and receptacles and identifying and isolating problems in 120 volt circuits can sometimes be difficult. Testing with conventional multi-meters and non-load plug-in type testers will identify conditions of Low/high Voltage and incorrect wiring such as no Ground, no Neutral, Hot/Ground reversed, Hot/Neutral reversed. However static tests do not measure the current-carrying capability of the circuit under full load.

The effect of a full load on the circuit can be determined with a multi-meter by measuring the voltage of the circuit under no load, and then placing a 15 ampere resistive load on the circuit, remeasuring the voltage, and then comparing the effect of the load on the voltage. This procedure will reveal deficiencies in circuits and receptacles that static non-load tests do not - such as damaged conductors and other high resistance connections. However, if there is a deficiency in the receptacle or wiring system, the imposition of that load - and the test itself - could create a hazard.

New generation hand-held testers use a patented method to safely impose a full 15-ampere load on the circuit for a fraction of a second. A microprocessor in the tester compares measured voltages at no-load and under a 15 ampere load to effectively measure the circuit's resistance and identify deficiencies in branch circuits and receptacles.

The effect of a poor/loose connection or damaged conductor is to increase the total impedance of the circuit and cause an excess voltage drop under load. This circuit impedance is normally reported as the **% Voltage drop** on the circuit.

% Voltage Drop =

VoltageLine(no load) **–** **V**oltageLine(15 ampere load)

VoltageLine(no load)

A reduced voltage under load may cause damage to equipment, however also important, excess voltage drop generates heat - which in fixed wiring can be a fire hazard if the cause of the excess voltage drop is a point source such as a poor/loose connection or splice that is in contact with a combustible material (ie. Wood). When current flows through these high resistance defects, heat buildup results at the connections, and can be "fire starters" if full loads are placed on the circuit.

How much voltage drop is excessive? The **NEC** guideline is that a maximum total voltage drop on both feeders and branch circuits to the farthest outlet of **5 percent**, will provide reasonable efficiency of operations.

Assume that the total voltage drop on a circuit at the furthest outlet is 9% at a 15 ampere current flow, and that normal wire and connector resistances in the circuit account for 5% of that total voltage drop. Assume further that the voltage drop in excess of that amount is due to a point source (connection, splice, etc). Then the loose or damaged connection has caused an additional voltage drop of 4% or 4.8 volts in a 120 volt circuit. This additional resistance of 0.32 ohms (4.8/15) would generate a point source of heat of 72 watts at a 15 ampere current flow. A 72-watt point source of heat in prolonged contact with combustible material can cause ignition.

LOOSE WIRES START FIRES

NFPA reports during the period 1989-1993 indicate that approximately 10% of the average of more than 600,000 fires/year were caused by electrical distribution systems. The largest portion of these fires were caused by faulty fixed wiring, receptacles and switches. Analysis [1] of of that data and actual field studies show that the overwhelming cause of failure of these components in faulty fixed wiring and receptacles was due to poor or loose splices, damaged connectors, improper installation and ground faults. Estimates total 25,000 fires/year that are caused by loose connections/splices damaged conductors, and improper installation.

TROUBLESHOOTING A CIRCUIT WITH A LOAD TESTER

These new generation hand-held testers take only seconds to test each outlet and circuit under a 15 ampere load and quickly identify hazards due to poor/loose connections, inadequate grounding, bad splices and damaged conductors in addition to also detecting incorrect wiring, high/low voltage conditions, false grounds (the illegal connection of ground-to-neutral at the outlet), and measures the exact trip point of a GFCI (in ma) - independent of line voltage variations. Testing a circuit under load is actually testing the circuit back to the utility's transformer on the pole. Simple-to-use, the testers **isolate hazards** using simple logic as the electrician moves along the branch circuit.

Testing sequence - The reason that circuits should be checked from the panel out to the end of the circuit is that conditions such as reverse polarity may be the result of the circuit being crossed before the receptacle being tested. By testing outward from the panel, the first incorrect condition (ie. reverse polarity) will identify the location of the mistaken wiring.

1. Loose Connections/splices - When testing a circuit under load, it is difficult to set one specific value (% voltage drop) at which a circuit or particular receptacle becomes a hazard, because the % voltage drop normally increases along the circuit as the tester moves outward from the panel. What indicates a hazard is the identification of a high-resistance location (receptacle, junction box) by the amount of the increase that occurs along the circuit. If tests of a receptacle circuit result in gradual increases to acceptable levels of voltage drop at the last receptacle (no more than 5%), this circuit checks out as "ok". If, however, one of the receptacles on the circuit measures a significant voltage drop difference from the previous one (say + 2-3%), the electrician should flag that receptacle as having a potential problem (loose/ poor connection, damaged conductor). If further receptacles on that circuit all read high, the electrician should suspect the wiring or splice (junction box) between the last "normal reading" receptacle and the first "high reading" receptacle.

If all receptacles on a circuit read high, there is a possibility that the high resistance is either in the wiring from the panel to the first receptacle, or at the panel itself, either in the panel connections or a high resistance within the circuit breaker.

If all circuits are reading "high", and panel connections check out "ok", there may be a problem at the meter, in the entrance wiring from the utility pole, or in the wiring at the transformer.

Another cause of the high resistance readings in residential situations is the greater likelihood of use of the "backwire", quick connect, push-in type connections. These are installed more by do-it-yourself installers, than by professionals, since electricians and contractors generally favor the use of the alternative screw terminals. Many municipal inspectors forbid the use of backwire connectors. The reason is that although most of the time these quick connections add reasonable levels of resistance to the circuit, sometimes these connections have a high resistance. This occurs because the clamping mechanism doesn't operate or isn't engaged completely, and the actual contact made is insufficient - resulting in a high resistance connection. Several municipal inspectors have reported high voltage drop readings under load (as high as 12%) when testing receptacles with these type connections. In every case reported, the voltage drop readings fell to acceptable levels when the connection was remade using the alternative screw terminals.

Testing wiring circuits under full load is taught in safety classes at the OSHA Technical Institute in Des Plains, IL.

The **National Assoc. of Home Builders** Research Center states ***"Because the load test is able to quickly and safely apply a full load test to the circuit, we can test all circuits in a house for hidden, sometimes deadly flaws within minutes"***.

2. Ground Impedance - The measurement of ground impedance under load will also identify poor/loose connections in the ground circuit. Although a standard "outlet tester" may indicate that a receptacle is "grounded", it cannot indicate the quality of the ground. By testing under a 15 ampere load, the new circuit analyzers calculate and display the ground impedance in ohms (IEEE recommends no more than 0.25 ohms). Loose connections or other causes of inadequate grounding not only are hazards because of inadequate fault current paths, but they often render useless the protection of computers and other expensive equipment by devices that rely on good quality grounding.

3. False Grounds When 3-wire receptacles were added to many older homes often an illegal tie was made between the Ground and Neutral at the receptacle. If there were no grounding system available, this practice didn't worsen the situation - except that it created an illusion of the presence of grounding safety. One inspector found 13 of these false ground connections within one older home. The owner thought he was improving the safety of the circuit. This practice also creates a misimpression of the state of the wiring condition to a potential buyer.

4. Undersized wires/Overlong circuits A circuit with proper connections and splices should exhibit no more than a 5% voltage drop at the farthest outlet. Excess voltage drop at the farthest outlet may be an indication of an overlong circuit (underwized wire for the length of run). Overlong circuits are frequently found in commercial installations that have undergone several expansions and modifications. Adding a receptacle or two to an existing circuit is an easy alternative to installing a new circuit.

Some recent reports from field testing:

A FIRE WAITING TO HAPPEN

A municipal inspector in Michigan who was evaluating a circuit load tester on the circuits in his home found a high voltage drop on the receptacle powering his refrigerator. On dissassembly, he found a loose connection that caused the high resistance. An induction motor has very low impedance on start-up, and draws 6-8 times its full-load ampere rating until the motor starts turning. As the motor gains speed it develops a back-emf and higher impedance. If a circuit has a high resistance, the motor doesn't get enough current to quickly reach operating speed and develop its operational back-emf. It will maintain a low impedance for a much longer time period as it slowly comes up to operating speed, and can cause extended periods of higher-than-usual amperage draws through the circuit. This can cause overheating of, and damage to the motor. A point resistance in the circuit - such as a poor/loose connection or damaged conductor - can become a definite fire hazard in this condition. The larger the motor in the circuit, - the worse the potential hazard. Consider air conditioners, attic fans, furnace fans, microwave ovens, exhaust fans, vacuums, etc.

FORSOOTH - YOUR TOOTH'S TOO LONG !

Convinced that a contractor was doing damage to wiring circuits with his wallboard hole cutter, a city inspector in Elko, Nevada tested the circuits in a new building. The contractor had set his cutting blade well beyond the thickness of the wallboard, and the inspector suspected that he was nicking wires with the hole cutter. He performed a load test on the branch circuits at each receptacle, and like a “divining rod” the readings of the load tester pointed to the locations of the nicked wires. Under load, back-to-back receptacles in the same circuit showed 3.5% and 9.5% voltage drops, respectively. Further investigation revealed a nicked wire to the receptacle with the high voltage drop reading. There were several other isolated receptacles that were identified with this same problem. If current to all “downstream” receptacles had flowed through the damaged conductor, they too would have exhibited high voltage drop readings under load. The closest receptacle to the panel exhibiting a high voltage drop would be the starting point for investigation.

SAM, YOU MADE THE PANTS TOO LONG - AND THE CIRCUIT TOO

On a new hospital construction site in Roanoke, Virginia, a county inspector reported high voltage drop readings at the end of circuits on the upper floors of the building. Further investigation revealed that the actual circuit run length exceeded the maximum allowed in the code for the wire size used. The contractor was required to replace the undersized wire with larger diameter wire - two extra weeks of work! This condition would probably have gone undetected without the load test.

FINDING A NEEDLE IN A RECTORY

A troublesome GFCI circuit in a Rectory in Saranac Lake, New York was tripping intermittently at the panel for no apparent reason. Several hours of investigation proved fruitless. Subsequently the receptacles in the circuit were tested with a load test circuit analyzer, and one of the receptacles registered an “FG” False Ground reading. Removing the cover plate from the receptacle revealed that a sewing needle had fallen behind the cover plate and was shorting the neutral to the box, which was grounded - causing the problem. Time to test the entire circuit with the tester was less than 5 minutes.

IF YOU WANT THE JOB DONE RIGHT - DO IT YOURSELF

Proud of his handiwork at wiring his own home, the electrician who had just purchased a new generation load tester went through his house testing all the branch circuits. One receptacle showed a false ground (illegal joining of ground and neutral at the receptacle). Investigation revealed that the receptacle was wired properly, but when the wiring was pushed into the box the bare ground wire bent back and touched the neutral, causing the false ground.

The load testing of branch circuits has been proven to be the most effective method of troubleshooting problems and identifying deficiencies in branch wiring and receptacles. The **isolation of hazards** such as **inadequate grounding, loose connections, Improper wiring** can also prevent thousands of fires if used routinely by electricians, contractors, and inspection personnel.

The author is chief engineer and executive vice president of Industrial Commercial Electronics, Inc. manufacturer of SureTest circuit analyzers at 590 Young Street, Tonaawanda, NY 14150 ***(800) 442-3462; (716) 692-3061.fax***

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Footnotes

[1] Miller, Alison NFPA *U.S. Home Product Report 1988-1992 (Appliances & Equipment)* Aug. 1994