Assessing The Integrity Of Electrical Wiring

Dense-pack cellulose insulation is a very useful and cost-effective technique for lowering both conductive and convective heat losses in a variety of housing types. In row homes, for example, GRASP in Philadelphia has found dense-pack cellulose to be very effective in treating attic bypasses that can be reached only by a hose. In areas where the distance between the ceiling and the roof deck is small (12 in or so), insulation is blown so that there is virtually no empty space between the ceiling and the roof deck. These areas tend to be in the rear of row houses, where there may be a master bedroom lit by a fixture hanging from the ceiling.

Half a dozen smoldering fires have been associated with these jobs, and although no serious damage or injury has yet resulted, there is cause for concern. Most people believe that the fires are caused by defective wiring, which is common in Philadelphia's housing stock. It is also possible that the action of the hose installing the insulation, or the movement of the insulation itself, could damage wiring that has been on the grim edge of safety for decades. The fact that thermal insulation allows heat to concentrate, rather than being dissipated by convective air movement, may worsen the situation.

The Philadelphia Housing Development Corporation's (PHDC) first response was to require visual inspections of wiring before installing insulation. Of course, such visual inspection is often difficult or even impossible, shy of radical surgery. And even a close look doesn't always reveal corroded connections, which may have high resistance. Roof insulation was not installed in many of these homes pending a solution to the wiring problem, resulting in lost opportunities for much-needed energy conservation.

Now PHDC has found what appears to be a practical solution to the problem. Their insulation contractors use a clever technique to test for the integrity of wiring quickly, accurately, and safely, without the need for extensive visual inspection. According to Jeff Allegretti, PHDC's director of Home Improvement Programs, there have been no fires in the 2,500 plus houses insulated since the wiring integrity testing technique was instituted two years ago.

Measuring Technique

Fire requires heat, and heating of electric wiring in a circuit can only occur when current is drawn. Accordingly, it is desirable to have a simple procedure to measure the extent of heating likely to result from placing a substantial (and known) load on a circuit.

Imagine a simple circuit like the one shown in Figure 1, where a load can be switched in or out, reading the line voltage in both circumstances. A large percentage difference in the two readings indicates an unsafe condition in the wiring, probably somewhere between the service entry and the point of measurement.

The diagram shows the line voltage at the service entry (V_S) and downstream at the end of a branch circuit (V_L). The sum of the resistance of the wire and sundry connections between the service entry and the point of testing the branch circuit is represented by R_W. As shown in the diagram, when there are no other loads on the circuit and the switch is in the open position, the voltage at the load, V_L, equals the voltage at the service entry, V_S. (Since there is no current flow, there is no voltage drop across R_W.) However, when the switch is closed, the voltage measured is dropped in proportion to current drawn, I, and the amount of the resistance of the wiring, R_W. The difference between the two readings is the voltage drop across R_W. Thus, if one knows the current draw causing this voltage drop, it is possible to calculate R_W from the expression $R_W = (V_S - V_L)/I$.

The power dissipated by R_W is given by I^2R_W watts. This expression times 3.4 is the heat produced (in Btu/h) by the wiring over one hour of operation at a given current draw. Once R_W is determined by this methodology, one can calculate the rate of heat production by the circuit under any condition of load.

The heating of the circuit wiring varies directly with its resistance and the *square* of the current flow. This means that if a marginal circuit that operates satisfactorily when illuminating a 60W bulb and running a radio is suddenly used to power a space heater or an iron, at least one hundred times more heat is dissipated on the line. If the high resistance is at a single bad connection--and the heat cannot dissipate--a fire can result.

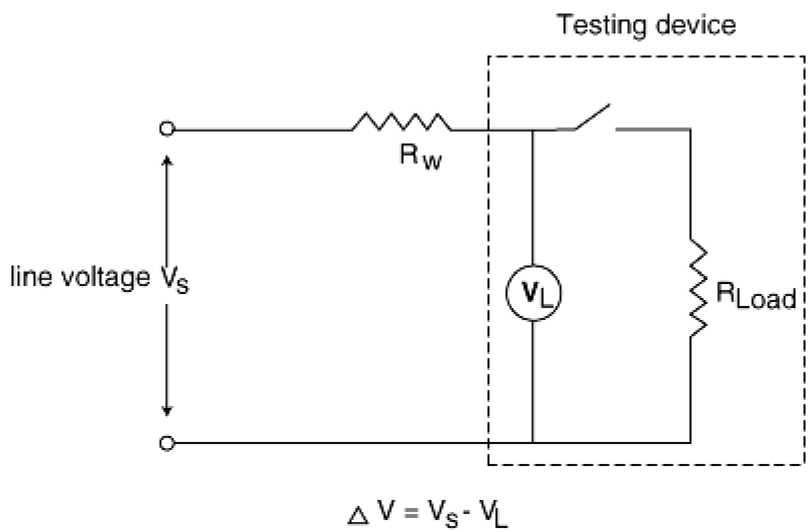

Figure 1. Schematic of a branch circuit wiring analyzer.

A Practical Tool

To test for the integrity of a circuit, it's simple to build a device that uses an electric resistance heater, a digital voltmeter, and a switch. Fortunately, a much more elegant device is available that runs this test and others, yet fits in the palm of the hand. Called the Ideal SureTest® Circuit Analyzer, this device has a built-in microprocessor, which switches in a 15-amp load on the circuit being tested for a small fraction of a second. This is enough to measure the voltage of the circuit with and without the load. The digital display alternates between showing the voltage measured under no load and the percentage by which the voltage drops under a 15-ampere load. According to the National Electrical Code, if the drop in voltage is greater than 5%, the branch circuit may be defective.

For example, if under no load a branch circuit measures 120 V, then drops 5% under a 15-amp load, the resistance of the wiring is 0.4 ohms. If a 1,200W heater is hooked up to the circuit, 37 W (130 Btu/h) will be dissipated along the wire. If most of the resistance is at a single bad connection, this amount of heat could cause a large temperature rise.

Field Use

The SureTest (or a similar device) offers a way to check the integrity of a circuit in only a few seconds. However, since the procedure merely measures the potential for heating of the line between the point of measurement and the service entry, one cannot determine precisely where the problem may lie between those two points. But with multiple tests on a circuit and a little common sense, one can narrow it down considerably.

Since the test is simple and quick--and the problems it can identify are potentially quite serious--it's wise to employ it both before and after installing insulation. The pretest can verify the integrity of the wiring before work is begun, and the post test can confirm that no harm was done during the installation.

All of the insulation contractors working on retrofit projects for the City of Philadelphia are now required to use this technique to test circuits associated with wiring in the attic before and after insulating. They use a 10% voltage drop threshold for the test, and Jeff Allegretti reports that approximately 25% of the jobs flunk at the initial audit. (They initially used a 5% threshold, but more than 70% flunked, with a cluster around 6%. PHDC adopted the 10% threshold in the interest of practicality, and this seems to leave an ample safety margin.) PHDC's solution for circuits that flunk is to have an electrician replace the entire circuit by running new wiring from the offending light or plug directly back to the fuse box at the service entry. Other weatherization programs may choose less extensive repairs, since many wiring problems can be solved by merely checking and tightening accessible connections.

Of course, the usefulness of the circuit-testing tool goes beyond row houses. It's clearly helpful when wall insulation is to be blown, where there's evidence of aluminum wiring (which can corrode in contact with copper and has a greater tendency to develop bad connections over time), and whenever a visual inspection raises doubts about the safety of the wiring in a dwelling.

The Ideal SureTest® Circuit Analyzers Model 61-154 appears to be the most appropriate meter for weatherization operations. It is manufactured by Ideal Industries, see web http://www.idealindustries.com/tm/SureTest.nsf

--Larry Kinney

Reprinted March 2004 (with updated vendor info) from Home Energy, Sept/Oct 1995

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