The Weatherization Training Center

Voltage Drop and Test Equipment

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Introduction

Many state, county, municipal, and electrical inspection agencies have utilized voltage drop testing protocols to evaluate the safety of wiring in buildings. There are several weatherization agencies within PA who have utilized diagnostic equipment such as the "SureTest Analyzer" to help them render decisions about the integrity of wiring circuits prior to installing insulation in wall and roof cavities.

The purpose of this article is to explain the principles voltage drop and provide an interpretation of applicable code. Voltage drop testing equipment and its limitations will also be discussed.

Background on Voltage Drop, Resistance, and Heat Generation

Heat is generated in a circuit whenever current flow (amperage) encounters a resistance to the flow. Voltage drop normally occurs when current passes through a wire. The greater the resistance of a circuit, the greater the voltage drop. A small voltage drop of between 1% and 5% is expected in all electrical circuits. Excessive voltage drop can cause excessive heat, which should create a concern for the safety of the circuit.

Excessive voltage drop leads to poor efficiency, wasted energy, higher electric bills and may cause damage to motors and electrical equipment.

Voltage drop is caused by high resistance in a circuit when the following conditions are present:

1. There are long runs of wire
2. The wire size is too small to carry the load.
3. There are point sources of high resistance such as poorly made splices or corroded connections.

Temperature Rise and Voltage Drop

Corroded or loose connections create a voltage drop at a junction, which leads to a temperature increase. This temperature increase will cause a higher resistance at the connection and raise the temperature even further. The amount of load or current flowing through the connection is also a major contributing factor.

Here's an example based on research performed at the University of Illinois that modeled the consequences of "point source resistance". A circuit sees a 4% voltage drop at a loose connection with a load of 2 amps resulting from some table lamps and possibly a television set.

The calculated temperature of the poor connection is around 95^0F and most likely will not be a fire hazard. If the homeowner now plugs in a 1200-watt electric heater into the same wall receptacle as the table lamps and TV, the load is now at 12 amps. This is still well within the limit of the 15-amp fuse protecting the circuit. However, with a 4% voltage drop at the same single point connection the temperature of this same connection now rises in excess of 1022^0F creating a fire hazard.

If the problem area is encapsulated with insulation the heat may now dissipate to a combustible source where a fire now becomes imminent.

Electrical Alterations

As modern electrical needs grew through the decades since the 1920's, alterations were often made by "amateurs ". Most of the time they were not up to standard wiring practices. One of the reasons why alterations put added stress on the existing wiring system was due to the limited number of original receptacles per room. The difficulty of adding new circuits to an existing structure and the limited number of original circuits at the fuse panel encourages modification and underscores why wiring in older housing stock has the greatest potential for abuse.

Point sources of high resistance where substandard alterations were performed should be of the greatest concern to the weatherization program. This relates primarily to the addition of thermal insulation in building cavities where these kinds of potential problems often lurk.

After removing a section of tongue and grove flooring in the attic, a taped splice was found. This splice was made in two pieces of rubber extension cord supplying power to a kitchen fan/light combo

The National Electrical Code (NEC) and Voltage Drop

The 2002 National Electrical Code, "article 210-19 (a) fine print notes" discusses voltage drop, which states: *"where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5 percent, provide reasonable efficiency of operation"*

It should be noted that the NEC's fine print notes (FPN) are for informational purposes only, are not enforceable and therefore **not** mandatory rules. Pertaining to voltage drop the FPN sites "reasonable efficiency" of electrical equipment and not fire safety.

There is no statement or implication within the the NEC that a total voltage drop above 5% is a fire hazard. In fact it is often difficult to measure less than 5% in new houses where long runs of wire and associated voltage drop is typical.

So what's all the fuss about the 5% voltage drop? Perhaps we can trace its roots to some municipalities or boroughs, who have elected to apply Article 90-4 of the NEC in their jurisdictions. Article 90-4 states: *"The authority having jurisdiction for enforcement of the Code will have the responsibility for making interpretations of the rules, for deciding on the approval of equipment and materials, and for granting the special permission contemplated in a number of rules."*

This essentially means that governing jurisdictions have the flexibility to interpret the NEC and apply a requirement that is more stringent. Following this precedent certain jurisdictions and weatherization agencies have required a maximum allowable voltage drop to reduce the potential for electrical fires where thermal insulation is planned. In the process they have decreased their liability.

Test Equipment

Ideal Corporation manufactures a series of testers known as the "SureTest Circuit Analyzer". This device reads the percentage of voltage drop on a circuit. The unit reads the voltage and then applies a 12,15,or 20-amp load on the circuit for a fraction of a second. The processor then displays a percentage of voltage drop. A large difference (above 5%) may or may not indicate an unsafe condition.

SureTest Circuit Analyzer showing a voltage drop of 3.8% (receptacle model 61-151 / ST-1P plus)

Where is the Voltage Drop?

A voltage drop tester cannot measure where the point or points of high resistance are located in the circuit. This tester will simply indicate the total resistance of the circuit and that there is a potential for heat being generated. The point(s) of high resistance may be anywhere between the location of the tested light fixture or wall receptacle and the service entrance equipment. This would include the fuse or breaker panel, the meter base, weatherhead, all the way out to the electric utility transformer.

The highest percentage of voltage drop is often not associated with the internal wiring of the house. It is not uncommon to find high resistance connections in meter bases, fuse panels, and on connections at the weatherhead. Many problems in meter bases and weatherheads are created due to years of stress caused by rain, wind, snow, sun as well through deteriorated connections between dissimilar metals such as an aluminum entrance cable connected to copper meter base terminal.

Reliability of Voltage Drop Data as a Function of Equipment Model and Type

In May of 2002 a field survey of 4 row houses was conducted by the WTC and Energy Coordinating Agency (ECA) of Philadelphia. The purpose of the survey was to compare data generated by various models of voltage drop test equipment. Tests were performed at the top floor ceiling light fixtures and bedroom receptacles of each building.

The four models used were the SureTest ST-1P, ST-1D, 1892, and 1890. Significant variations in readings between these models were recorded when testing at the same time and location. For example, one model displayed a 5% drop the other read 7% in the same location. Also noted were up to 9% differences in line voltage readings.

Concluding Advice

More research should be done on existing and newer models of the voltage drop testers before the weatherization network utilizes this technology to draw meaningful conclusions about the safety of house wiring.

Sources of voltage drop may be attributable to any of a number of locations, some of which may be outside of the house. Testing equipment may offer a quick way to evaluate an entire wiring system. Since the equipment can only measure the resistance of the entire circuit, one will not necessarily be able to determine precisely where the problem or problems are located by simply looking at the test data.

Multiple tests done in separate locations may help isolate a potential problem but a decision on remedial action, should not be based entirely on the information gathered by this test equipment. Only qualified electricians who are knowledgeable about electrical systems in older houses and who understand the limited use of this data, should make these decisions.

Voltage drops in excess of 5% may be of concern only if all 5% is in one location or in relation to a significant load. The NEC does not mandate a 5% voltage drop maximum and is only referenced within the "fine print notes" of the Code. The use of reliable voltage drop test equipment coupled with a thorough visual inspection by a qualified inspector may help municipalities or weatherization agencies make more informed decisions about wiring safety prior to insulating.

Resources:

National Electrical Code Handbook 2002

"Retrofitting Insulation in Cavities with Knob-and-Tube Wiring, An Investigation into Codes, Safety, and Current Practices", by Jeffrey R. Gordon University of Illinois School of Architecture

"*Retrofitting Knob-and-Tube Wiring, An Investigation into Codes, Assessment, Wiring Practices and Cost",* by Larry Armanda of the Weatherization Training Center at Pennsylvania College of Technology.