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Frequently Asked Questions - Voltage Drop

By Harold P. Kopp

What is voltage drop? A voltage drop in an electrical circuit normally occurs when current is passed through the wire. The greater the resistance of the circuit, the higher the voltage drop.

How much voltage drop is acceptable? A footnote (NEC 210-19 FPN No. 4) in the National Electrical Code states that a voltage drop of 5% at the furthest receptacle in a branch wiring circuit is acceptable for normal efficiency. In a 120 volt 15 ampere circuit, this means that there should be no more than a 6 volt drop (114 volts) at the furthest outlet when the circuit is fully loaded. It also means that the circuit has a resistance that does not exceed 0.4 ohms.

What causes "excess voltage drop" in a branch circuit? The cause is usually:

1. High resistance connections at wiring junctions or outlet terminals, usually caused by:

- poor splices anywhere in the circuit
- loose or intermittent connections anywhere in the circuit
- corroded connections anywhere in the circuit
    - inadequate seating of wire in the slot connection on backwired "push-in type" receptacles and switches.

2. The wire does not meet code standards (not heavy enough gauge for the length of the run).

What are the consequences of "excess" voltage drop in a circuit? Excess voltage drop can cause the following conditions:

1. Low voltage to the equipment being powered, causing improper, erratic, or no operation - and damage to the equipment.

2. Poor efficiency and wasted energy.

3. Heating at a high resistance connection/splice may result in a fire at high ampere loads.

At what % voltage drop does a circuit become hazardous? It is difficult to say at what point excess voltage drop will cause a fire, because it depends on how much current is flowing through the high resistance connection, what is the resistance of that connection and because many factors must be considered regarding at what point ignition will occur, e.g.:

1. Is the high resistance connection in contact with a combustible material?

2. Is there air flow to dissipate the heat?

3. Is the area around the connection insulated, so that heat cannot escape.

The NFPA reports [1] that from 1988-1992, there was an average annual total of 446,300 fires in homes, resulting in 3,860 Deaths and $4.4 Billion property damage. 42,300 (9%) of these fires were caused each year by **Electrical Distribution Systems**. The largest portion of fires caused by electrical distribution systems (48%) were caused by **faulty fixed wiring, receptacles and switches**.

Electrical Distribution Equipment Fires in U.S. Homes2

1988-1992 Average

Cause of Fire	**No. Of Fires**
Total Electrical Distribution System	**42,300 (100%)**
Faulty Fixed Wiring	15,400 (36%)
Switches, Receptacles, Outlets	4,800 (11%)

The results of an in-depth investigation of 149 residential fires caused by electrical distribution systems was summarized in an article by Smith & McCoskrie [2] . Of the fires occurring as a result of:

1. faulty fixed wiring - poor/loose splices, damaged connectors, improper installation and ground faults accounted for **94%** of these fires.

2. receptacles and switches - loose/poor connections accounted for **59%** of these fires.

3. Lighting fixtures - loose or poor connections accounted for **37%** of these fires.

Most of these faulty circuits and receptacles could have been previously identified as hazards with a 15-ampere load test, and many of these fires could have been easily prevented.

The **Philadelphia Housing Development Corporation** requires contractors to perform the 15-ampere-load test prior to insulating existing homes with insulation blown into attic crawl spaces in older row homes. [3] Prior to instituting the test, smoldering fires were associated with half a dozen

installations. The PHDC found that 70% of the homes flunked the 5% maximum voltage drop test with “a cluster around 6%”. The PHDC arbitrarily established **10%** as an unacceptable voltage drop, beyond which the contractor must repair/replace the circuit prior to proceeding with the insulation project. PHDC has been using this criteria successfully for 2 years (no fires in 2,500 installations).

RECOMMENDATIONS

For power efficiency, the NEC standard of 5% maximum voltage drop is recommended.

From a safety perspective, because wiring connections in some homes deteriorate with time (particularly in homes that use aluminum wiring for power circuits), and do-it-yourself modifications may be less than professional, excess voltage drop is a concern because of the potential fire hazard at high resistance connections, particularly on circuits that power electric motors while occupants of the dwelling are asleep, e.g. air conditioners, refrigerators, furnace fans, exhaust fans, etc.

Some agencies arbitrarily set a maximum voltage drop criteria of 10% to be considered unacceptable and a hazard. The author believes that any voltage drop difference of >1% from an adjacent receptacle should be investigated, that any voltage drop difference of >2% from an adjacent receptacle should be considered a hazard, and that using a maximum voltage drop criteria of more than 8% (3% above the “efficiency” recommendation) is courting disaster. A 3% voltage drop (3.6 volts in a 120 volt circuit) at one connection with a 15 ampere flow develops 54 watts of heat - which can cause ignition under certain conditions.

Footnotes

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

[2] Smith, Linda & Dennis McCoskrie, “What Causes Wiring Fires in Residences” *Fire Journal* Jan/Feb 1990: 19-24, 69

[3] Kinney, Larry “Assessing the Integrity of Electrical Wiring” *Home Energy* Sept/Oct 1995: 5,6