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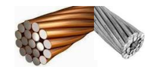
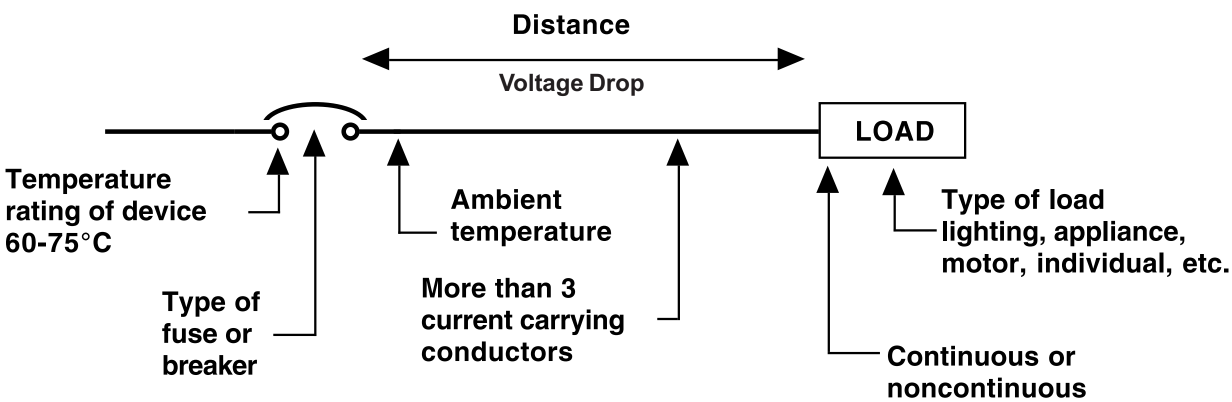


Remember, conductors are not intelligent. They don't know where they are going to be installed (in the basement, attic, soil, free air). They don't know the environment where they have been placed (wet, dry, hot, cold). They do not know how crowded it will be in the conduit or how many conductors beside them will be carrying current. They do not know how far they will be run or how long and hard they will have to work. They do not know if they will be properly protected and insulated from heat and moisture. Conductors aren't very smart.

The Variables



The flow of electrons through a conductor creates an electrical current. By definition, two essential factors facilitate an electric current.

First, you'll need a flow of electrons, which is done by a potential difference. The next is a **conductor** which is a material that enables electrons to flow.

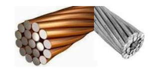
A conductor is a material which electricity, heat or sound can flow through. An electrical conductor conducts electricity. The ability to conduct electricity is called electrical conductivity. Most metals, like iron and copper, are electrical conductors.

It must be understood that not all conductive materials have the same level of conductivity, and not all insulators are equally resistant to electron motion.

Conductors and Insulators. In a conductor, electric current can flow freely, in an insulator it cannot. Conductors conduct electrical current very easily because of their free electrons. Insulators oppose electrical current and make poor conductors. Some common conductors are copper, aluminum, gold, and silver. Some common insulators are glass, air, plastic, rubber, and wood.

An electrical conductor allows the electric charges to easily flow through them. The property of conductors to "conduct" electricity is called conductivity.

One must learn the meaning of resistivity, resistance, the temperature coefficient of resistance.



Some of these scientific adventurers won fame, some fortunes; others only the pleasure of discovery. Many obscure men, whose names we have never heard, discovered and are still finding scientific nuggets by experimenting in electricity's goldfields. Others, and from a long list we might mention Volta, Franklin, Faraday, Ampere, Morse, Bell, Edison, Kelvin, and Tesla, were electrical adventurers whose experiments made them world famous.

What is electricity?

A most amazing fact is that not one of these men, not even Faraday or Edison, ever saw or felt or heard the wonderful force which helped them master. *Not one of them ever knew what it was*.

Neither can we hope to see or feel or hear electricity itself. It is invisible. It is somewhat like the wind. It is a force - a form of energy. We can only see the effects of the wind - those things the wind does. We can hear leaves rustle, feel pressure against our faces, see trees sway, smoke swirl and waves and ripples sweep over the water, yet we will be only hearing, feeling and seeing the effects of the wind and not hearing, feeling, or seeing the wind itself.

Materials for wiring interior electrical systems in buildings vary depending on:

- Intended use and amount of power demand on the circuit
- Type of occupancy and size of the building
- National and local regulations
- Environment in which the wiring must operate.

Wiring systems in a single family home or duplex, for example, are simple, with relatively low power requirements, infrequent changes to the building structure and layout, usually with dry, moderate temperature and non-corrosive environmental conditions. In a light commercial environment, more frequent wiring changes can be expected, large apparatus may be installed and special conditions of heat or moisture may apply. Heavy industries have more demanding wiring requirements, such as very large currents and higher voltages, frequent changes of equipment layout, corrosive, or wet or explosive atmospheres. In facilities that handle flammable gases or liquids, special rules may govern the installation and wiring of electrical equipment in *hazardous areas*.

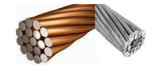
Electrical wiring is an electrical installation of cabling and associated devices such as switches, distribution boards, sockets and light fittings in a structure.

Wiring is subject to safety standards for design and installation. Allowable wire and cable types and sizes are specified according to the circuit operating voltage and electric current capability, with further restrictions on the environmental conditions, such as ambient temperature range, moisture levels, and exposure to sunlight and chemicals.

Except for mechanical abuse, the greatest hazard that conductors must endure is **heat**. Conductor insulation can be damaged by excessive heat in various ways, depending on the type of insulation and the degree of overheating. Continued exposure to excessive heat causes insulation to become soft, perhaps to melt, and in extreme cases to burn.

Designing motor circuits are rather complicated so first we need to understand how a motor functions. A motor doesn't have any intelligence, it will actually work itself to death if we don't protect it. A properly protected motor will last for many years.

Introduction



In our own electrical experiments - adventures in which we become acquainted with electricity and make it do as we ask - we will never see or feel or hear electricity itself. We will be aware only of its effects, of the things that electricity does.

No one knows the answer to the question, *what is electricity?* We know where and how to get it and what to do with it - that is all.

When we speak of generating or producing electricity, we do not mean *creating* it. It is like the rabbit the magician pulls out of his hat. The magician does not create the rabbit. It was hidden in the hat. It is merely *revealed or released* by the magician at the proper time.

Electricity is not created. Electricity itself is a creator. All matter, all substances, are composed of electricity. It is built up as part of every little bit of matter, solid, liquid, or gas, in the universe. Electricity is, in the end, responsible for all varied kinds of light we know, the light of a flame as much as that of an electric light. At least that is what scientists have good reason to believe. It is the only way in which they can logically explain the behavior of electricity.

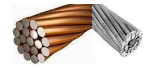
Such an explanation is a *theory*. A theory is sort of a mental tool or implement useful to scientists. It is a plan or scheme which subsists in the mind only, but is based on observation and experiment.

Did Edison invent the light bulb, Marconi the radio, Bell the telephone, Morse the telegraph? The answers are no. They didn't invent the wheel. They were instrumental in making it better and in some cases obtaining the patent.

Electrical history goes back before Christ and brings us to the computer age. Along this journey you will discover it took several people along the way to make the light bulb glow.

The world works and lives at the end of a wire. And we will pay tribute to the many people that made it possible.

The journey won't end with this book, as we are constantly discovering new inventions that will someday even take us to the stars.



I receive calls from people even in new homes that are concerned about the wiring as the lights are diming when an appliance is turned on in the bedroom or bathroom in the far end of the house. Really, the lights should dim!

NEC 90.1 Purpose.
(B) Adequacy. This Code contains provisions that are considered for safety. Compliance therewith and proper maintenance result in an installation that is essentially free from hazard ***but not necessarily efficient,*** convenient, or adequate for good service or future expansion of electrical use.

Are you living in a house that was the "low bid?"

Think for a moment, why would you want the "low bidder?" I would guess because it cost less.

But, I have learned over the years you didn't save any money, plus you may be living in an unsafe house.

With the higher wattage appliances today, a #14 wire should NOT be allowed!

1875 watts

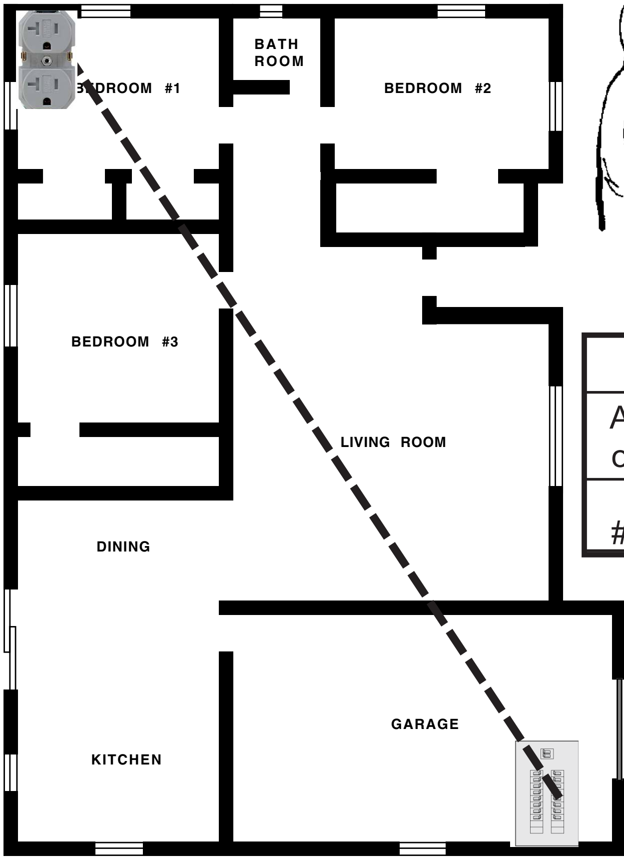
1875 watts ÷ 120 volts
= **15.6 amps**

1800 watts

1800 watts ÷ 120 volts
= **15amps**

12 amps

#14 wire, 15 amp circuit



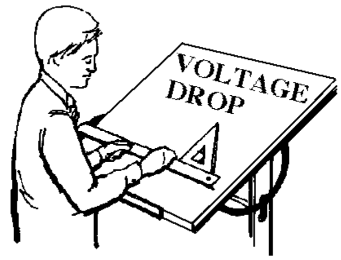


TABLE at 75°C - 167°F	
AWG size of Conductor	Uncoated Copper Ohms per 1000 ft
#14 NM cable	3.07 Ω

$$VD = I \times R$$

Generally, from the panelboard in the garage to the farthest receptacle in the back bedroom, the cable is 75 to 95 feet in length. Let's assume in the sketch it's 85 feet of cable which the #14 wire in the circuit would be 85' x 2 (black & white wires) = 170 feet of #14 wire. The resistance in the wire only (does not include device resistance) is 3.07Ω x .170' = **.5219Ω**. Voltage Drop = 15 amps x .5219Ω = 7.8285 volts dropped in the wire alone.

1875 watts

Let's start with the hair dryer @ 1875 watts ÷ 120 volts = **15.6 amps** on a 15 amp circuit breaker. Plus, any other loads that are turned on on this same circuit which would have 5 or 6 more receptacles generally. So the load on the circuit could easily reach 16 to 18 amps.

Now the voltage drop could reach 18 amps x .5219Ω = 9.39 volts which is around 8% VD. With the added connection resistance in the receptacles in the circuit, the voltage drop on a similar circuit is around 10-12%. At 10% the voltage instead of the 120 volts, is now 108 volts, that's why the lights DIM!

1800 watts

My cousin in Ohio called and said when she unplugs her steam iron a "blue arc" appears at the bedroom receptacle.

I suggested that she should first turn the iron switch to the "off" position before unplugging it. The receptacle blades become pitted from the arcing and make a loose connection.

The steam iron is rated @ 1800 watts ÷ 120 volts = **15amps** on a 15 amp circuit breaker. This is why you see a "blue arc." Plus, any other loads that are turned on on this same circuit which would have 5 or 6 more receptacles generally. So the load on the circuit could easily reach 16 to 18 amps.

Now the voltage drop could reach 18 amps x .5219Ω = 9.39 volts which is around 8% VD. With the added connection resistance in the receptacles in the circuit the voltage drop on a similar circuit is around 10-12%. At 10% the voltage instead of the 120 volts, is now 108 volts, that's why the lights DIM!

12 amps

A contractor called me asking for help, he said a lady living in a new home he had wired was complaining that when she turns on the vacuum cleaner on the 2nd floor of the home the lights in the hallway dim. After several attemps to find the problem he gave up and called me saying now the lady is out by the highway holding up a sign that he does shabby electrical work which is hurting his business reputation.

My first question to him was, #14 wire on a 15 amp circuit? His reply was "yes." Next question what is the branch circuit length? His reply was, possibly 125 feet or so.

The vacuum cleaner is rated 12 amps @ 120 volts. It also has 27 feet of #18 small gauge cord.

Let's assume the circuit is 125 feet of cable which the #14 wire in the circuit would be 125' x 2 (black & white wires) = 250 feet of #14 wire. The resistance in the wire only (does not include device resistance) is 3.07Ω x .250' = **.7675Ω**. Voltage Drop = 12 amps x .7675 Ω = 9.21 volts dropped in the #14 wire.

The #18 gauge cord is 27 feet in length x 2 = 54 feet. The resistance is 7.95 Ω per k/ft. So 7.95 Ω x .054 feet = .4293Ω resistance in the cord plus .7675Ω in the #14 wire = **1.196 Ω** (not counting the other receptacle connections in the circuit).
Voltage drop = 12 amps x 1.196 Ω = **14.36 volts dropped or 11.96%**. 120v - 11.96v = 108v.The hallway lights are suppose to dim at 108 volts or less. Add in the receptacle connections resistance and in reality the voltage drop will be even greater.

With the higher wattage appliances today, a #14 wire should NOT be allowed!

Now you should have a better understanding of voltage drop.

The property owner is **not** knowledgeable in the electrical practices **and depends on the electrician to install a safe and efficient electrical system. But, did they?**