PURDUE EXTENSION
INDIANA 4-H

Electric (All Levels)

Wire and Cable Basics

What's it all About?

This is to help you learn some of the basics of wires and cables. The construction, sizes, ampacity, the significance of the types of insulation, the variety, and some common uses. This is by no means an all-inclusive list and description of every wire and cable manufactured. From this, you should come to the realization you need to know more about what you are doing when working with electricity. Do your research, as one size does not fit all.

Keys to Remember

- Forms of wire, solid wire and stranded wire. Solid wire, also called solid core or single strand wire, consists of one piece of metal wire. Solid wire is cheaper to manufacture than stranded wire and is used where there is little need for flexibility in the wire. Solid wire also provides mechanical ruggedness and because it has relatively less surface area, which is vulnerable to attack by corrosives, protects against the environment.
- Stranded wire is composed of several small wires bundled or wrapped together to form a larger conductor. Stranded wire is more flexible than solid wire of the same cross-sectional area. Stranded wire is used when higher resistance to metal fatigue (the bending back and forth) is required. Examples of metal fatigue include: connections between circuit boards in multi-printed-circuit-board devices where the rigidity of a solid wire would produce too much stress as a result of movement and servicing, A.C. (alternating current) line cords for appliances, musical instruments cables, computer mouse cables, welding electrode cables, control cables connecting moving machine parts, mining machine cables, trailering machine cables, and numerous others.
- The more individual wire strands in a bundle, the more flexible, kink-resistant, break-resistant, and stronger the wire becomes. However, more strands increase manufacturing complexity and cost. For geometrical reasons, the lowest number of strands usually seen is 7; one in the middle, with 6 surrounding it in close contact. The next level up is 19; which is another layer of 12 strands on the top of the 7. After that, the number varies, but 37 and 49 are common, then in the 70 to 100 range, (the number is no longer exact). Even larger numbers than that are typically found only in very large cables.
- For applications where the wire moves, 19 is the lowest that should be used (7 should only be used in applications where the wire is placed and then does not move), and 49 is much better. For application with constant repeated movement, such as assembly robot and headphone wire, 70 to 100 is mandatory. For applications that need even more flexibility, even more strands are used (welding cables are the usual example, but also any application that need to move wire in tight areas).
- The most commonly used metals for wire are copper and aluminum. Due to its efficiency as a conductor copper is more common for smaller wires. Aluminum is less costly and lighter in weight, but not as efficient in conducting current. Before using either of these alternatives, check with an expert and local building codes.
- Understanding the proper wire size is critical to any electrical wire installation. Wire sizing indicates the diameter of the metal conductor of the wire and is based on the American Wire Gauge (AWG) system. The gauge of a wire relates to the wire's current-carrying capacity, or how much amperage the wire can safely handle. Ampacity is the maximum current that a conductor can carry continuously under the conditions of use without exceeding its temperature rating. You must use the correct size wire with the proper insulation for the load/current requirement of the circuit to prevent the wire from overheating.

- The number and type of electrical devices connected to a circuit determine the ampacity requirement of the conductor. To calculate the load requirement for a circuit, first add up the wattage of all the electrical devices that will be on that circuit. Then, divide the total wattage by the voltage of the system, typically 120 or 240, and that will give you the required current or amps.

	Copper-Ampacity			Aluminum-Ampacity	
Wire Guage Size AWG or kcmil	60℃ (140℉) NM-B, UF-B	75℃ (167℉) THW, THWN, SE, USE, XHHW	90℃ (194℉) THWN-2, THHN, XHHW-2, USE-2	75℃ (167℉) THW, THWN, SE, USE, XHHW	90℃ (194℉) XHHW-2 THHN, THWN-2
14	15	20	25	---	---
12	20	25	30	20	25
10	30	35	40	30	35
8	40	50	55	40	45
6	55	65	75	50	55
4	70	85	95	65	75
3	85	100	115	75	85
2	95	115	130	90	100
1	---	130	145	100	115
1/0	---	150	170	120	135
2/0	---	175	195	135	150
3/0	---	200	225	155	175
4/0	---	230	260	180	205
250	---	255	290	205	230
300	---	285	320	230	260
350	---	310	350	250	280

Ampacities are based on the 2017 NEC and do not reflect any temperature correction or ampacity adjustments that may be required. Please consult a qualified electrician or professional engineer to determine the appropriate values for your specific application.

The lettering on the wires and cables are very important and pertain to the insulation around the conductors. This dictates where and how the wire should be used. The only difference between 60℃, 75℃, and 90℃ wire is the heat tolerance of the insulation around the conductor. That is important due to the environment where a conductor is installed. Other elements may also be detrimental to the wiring. See the other lettering designations below.

- T: Thermoplastic insulation, a fire-resistant material.
- H: Heat-resistant; able to withstand temperatures up to 167℉
- HH: Highly heat-resistant; able to withstand temperatures up to 194℉.
- W: “Wet” or approved for damp and wet locations; also suitable for dry locations.
- X: Insulation made of a synthetic polymer that is flame-retardant.
- N: Nylon-coated for resistance to oil and gasoline.
- MN: Non-Metallic sheathed cable (multi-conductors); rated for interior/dry applications.
- UF: Underground Feeder cable (multi-conductors); rated for direct burial and outdoor use.
- SE: Service Entrance (single or multi-conductors); rated for aboveground services.
- USE: Underground Service Entrance; rated for underground services.

The numbering on the wires and cables are equally important. They tell you the size (AWG) and the number of conductors in the cable assembly. Depending on the ampacity and voltage of the branch-circuit or feeder you must choose an adequately sized wire. Anytime you are uncertain, do not be afraid to ask for help. See some examples below (listing on cables vary slightly).

- 14-2 w/grd; has two 14-guage current carrying conductors and one grounding conductor.
- 14-3 w/grd; has three 14-guage current carrying conductors and one grounding conductor.
- 12-2 w/grd; has two 12-guage current carrying conductors and one grounding conductor.
- 12-3 w/grd; has three 12-guage current carrying conductors and one grounding conductor.

One more thing that also helps in the proper use and identification of conductors is the color. The color identifies wires as “hot, neutral, or ground”. With this standard, it is easy for one electrician to follow-up behind another electrician because they are schooled for the proper use of wire colors. On cable assemblies, the outer jacket color allows one to quickly identify the gauge and possibly the type of cable assembly. Therefore, using the proper color is a standard and very important, especially for the person that comes along behind you. There are more colors of wire than there are in the rainbow, but below are a few examples.

Individual conductors:

- Black wire; designated hot wire.
- Red wire; designated hot wire.
- White wire; when marked with black or red tape designated hot.
- White wire; designated neutral wire.
- Gray wire; designated neutral wire.
- Green wire; designated grounding wire (non-current carrying).
- Bare copper wire; designated grounding wire (non-current carrying).

Outer cable sheathing:

- White sheathing; designates 14-guage wire.
- Yellow sheathing; designates 12-guage wire.
- Orange sheathing; designates 10-guage wire.
- Gray sheathing; designates underground cable.

(information courtesy, Wikipedia, Cerrowire, The Spruce, & Hometips)

Project Note

This information should be useful in most of your projects or could become its own project. Doing further research, say the history of wire, just FYI it was not for electricity, you could do a written report, display board, or video explanation. This would make for another informative and low-cost project.

For the Project

- Record Sheet
- 4-H Exhibit Skills & Knowledge Sheet