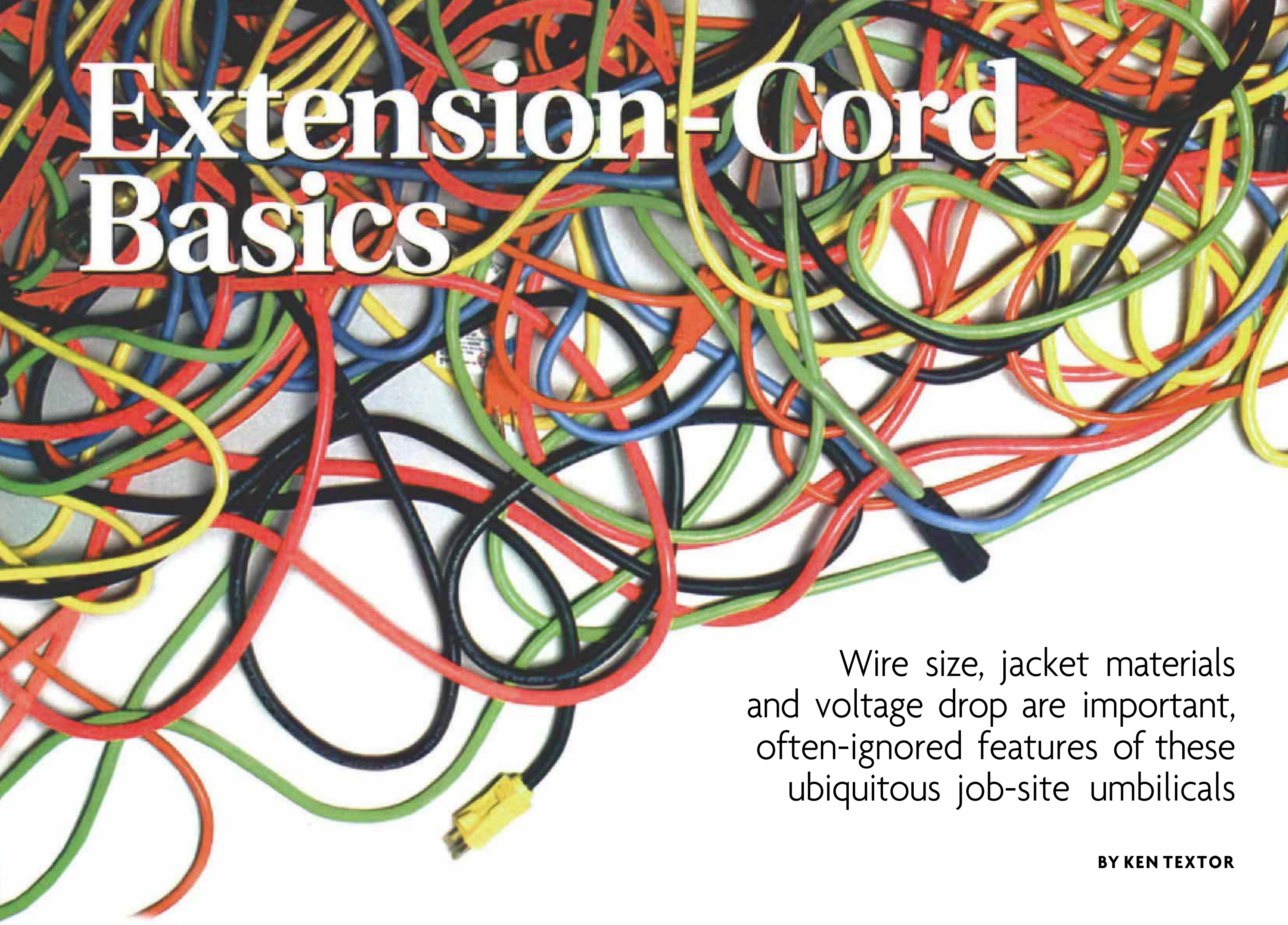


Extension-Cord Basics

Wire size, jacket materials and voltage drop are important, often-ignored features of these ubiquitous job-site umbilicals

BY KEN TEXTOR

Walked on, left out in all kinds of weather, slammed in doors, twisted, yanked, pulled, tied in knots, extension cords are always expected to work. They are as indispensable as hammers or circular saws on a job site.

But if you're like me, you probably don't give much thought to extension cords, except to curse them occasionally when they get underfoot or resist being neatly coiled. I didn't think much about them until the day I eventually killed my best orbital sander by using an extension cord that was too long. After that, I vowed never to make a similar mistake and gave myself a crash course on extension cords and electricity. I talked to electricians, manufacturers and safety officials to find out the facts about extension cords. Here's what I learned.

A cord's wire gauge and length affect power supply

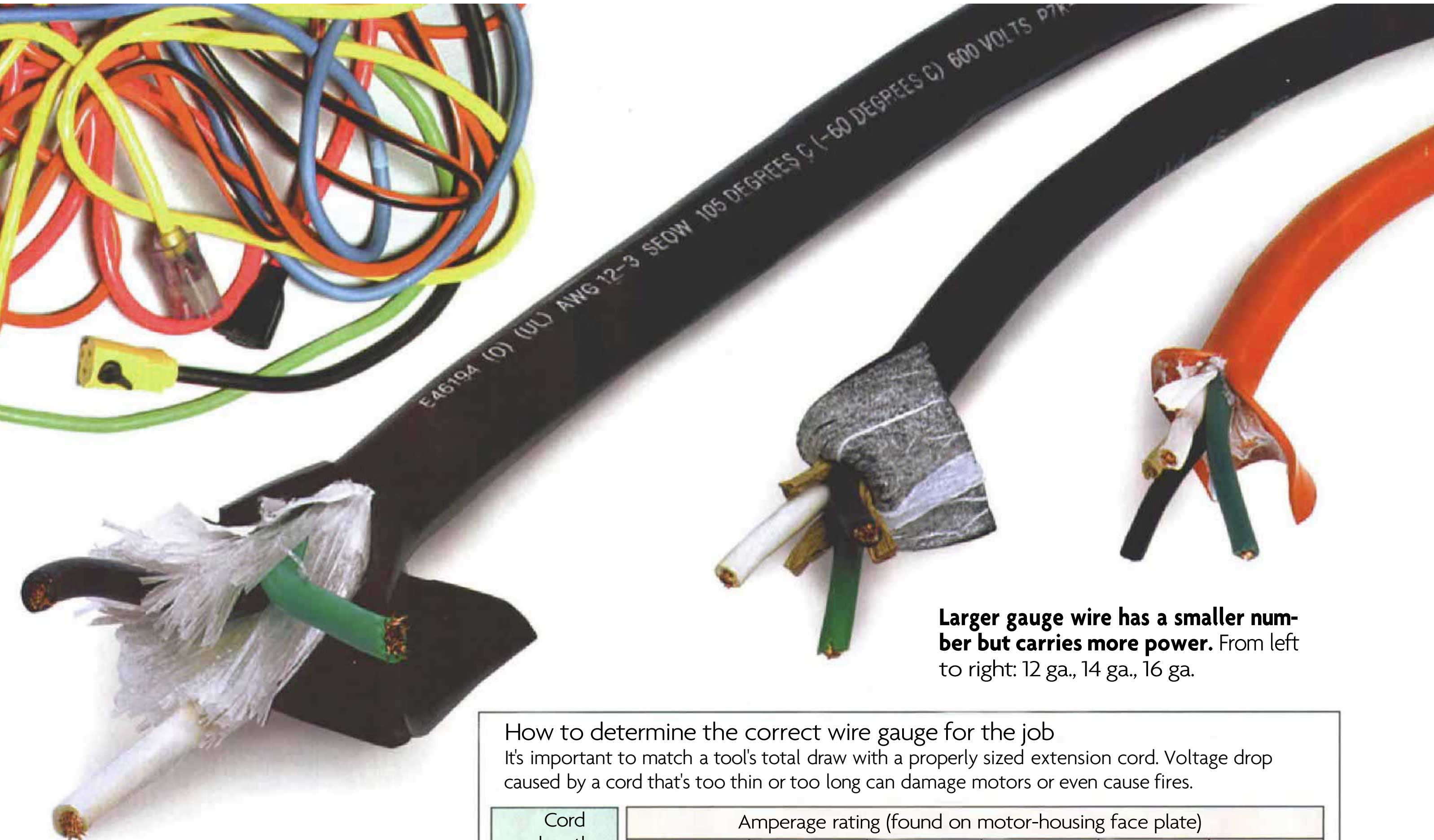
Like a garden hose carrying water, the diameter of any wire determines its ability to carry electricity. A wire with a small diameter can't carry as much power as a wire with a larger diameter; the smaller wire has greater resistance. Wire resistance is also determined by length, composition, generation source and demand on the other end. When it comes to extension cords, wire diameter and length are the most important factors to consider.

First, the diameters of each wire (the hot, neutral and ground) inside an extension cord are classified by American wire gauge (AWG). The largest diameter has the smallest AWG number; most job-site extension cords are made with wire ranging in size from 10 to 18 AWG (top photo, facing page) and are stamped on the cord's insulation jacket (bottom photo, facing page). Each gauge has a recommended amperage capacity. Because all electric tools demand different amounts of power to run properly, it's in your best interest to match the tool's power demand to the cord's capacity (chart facing page).

Second, an extension cord that's too long can also create a type of resistance known as *voltage drop,* which increases as the cord gets longer; as the electricity travels farther from the source, its energy diminishes. Voltage drop can have adverse effects on power tools. As I said earlier, I killed my best orbital sander by repeatedly using a cord that was too long; in this case, it was an 18-ga. extension cord that was 100 ft. long. The voltage drop over the long thin cord made the motor run slower, which in turn created carbon deposits on the brushes, which decreased the motor's efficiency. I started to push the sander harder, which just aggravated the sander's decline. To avoid voltage drop, it's always best to use the shortest possible cord.

On some job sites, extension cords may supply three or more tools running simultaneously, so some quick math may be required to determine the right wire size and length for your extension cords. For instance, suppose you're going to use a heavy-duty drill that pulls 6 amps while your partner uses a 4-amp sander. Additionally, you both want to keep the coffee maker going, and it pulls 900w. Will a typical 50-ft, 16-ga. extension cord be able to deliver enough power?

It's easiest to convert everything to amps. In this case, watts (900) divided by standard voltage (125) gives the coffee maker a 7.2-



Larger gauge wire has a smaller number but carries more power. From left to right: 12 ga., 14 ga., 16 ga.

amp draw. Added together, the total possible draw from these three appliances is 17.2 amps. As the chart (right) shows, the 50-ft. long, 16-ga. extension cord is not adequate. You should either use a cord with a larger AWG or, better yet, find another outlet for the coffee maker.

In most cases, the total number of amps drawn through an extension cord should be kept to 15 or less. Typical three-prong outlets are usually built to carry a maximum of 15 amps; it's best to limit the total draw to that amount.

So what happens if you try to pull too many amps through a wire gauge that's too small? As previously discussed, the resulting voltage drop isn't good for motors. In the worst cases, you can cause a fire. Wires heat up when they are forced to draw too much electricity (another property of resistance), the insulation melts, wires short, and depending on what's nearby, a fire may start.

On the subject of heat, most manufacturers recommend against using a cord while it's still coiled up. Although not a common occurrence, if a cord is continually drawing its

How to determine the correct wire gauge for the job

It's important to match a tool's total draw with a properly sized extension cord. Voltage drop caused by a cord that's too thin or too long can damage motors or even cause fires.

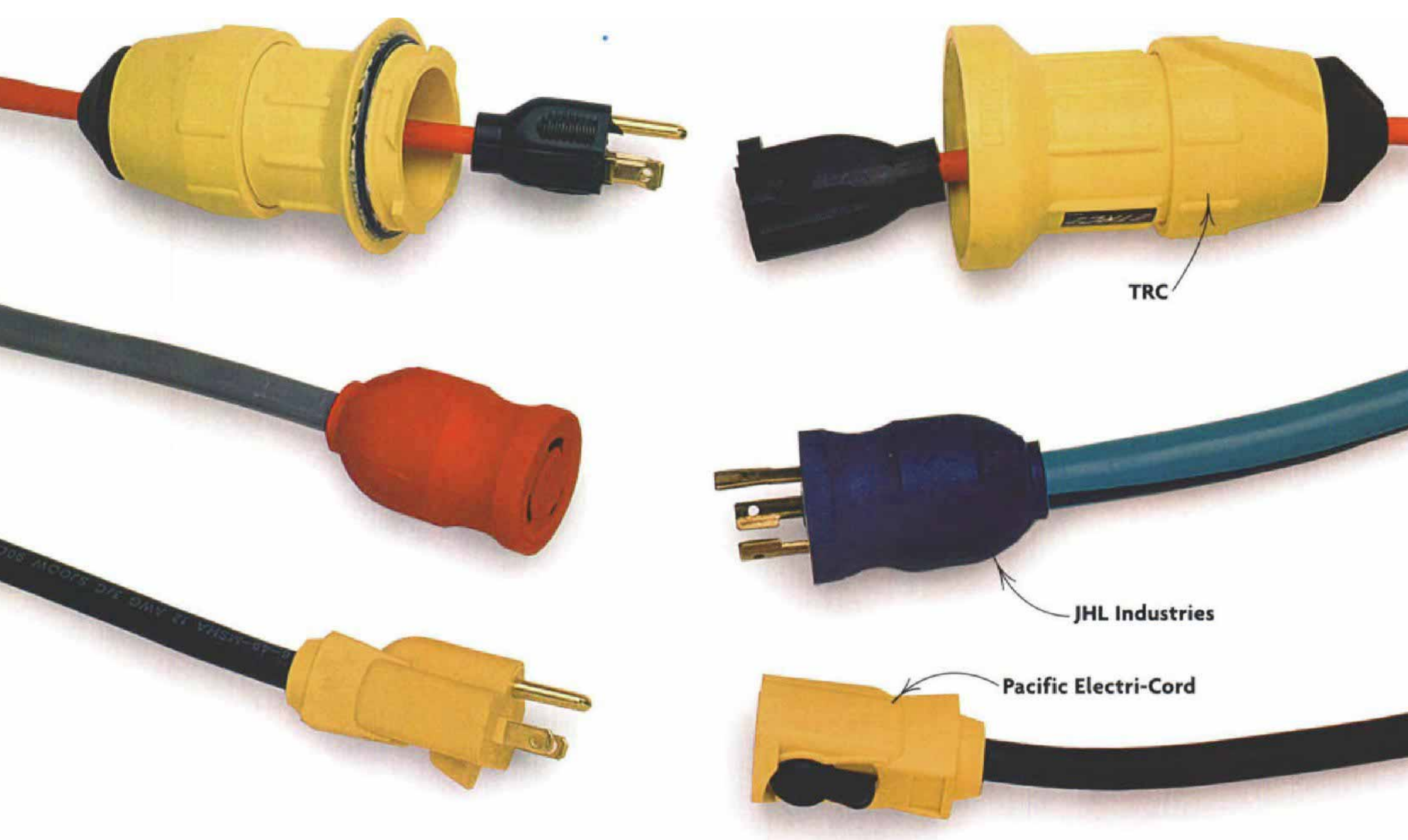
Cord length	Amperage rating (found on motor-housing face plate)					
	0-2	2-5	5-7	7-10	10-12	12-15
25ft	16 ga.	16 ga.	16 ga.	16 ga.	14 ga.	14 ga.
50ft.	16 ga.	16 ga.	16 ga.	14 ga.	14 ga.	12 ga.
100 ft.	16 ga.	16 ga.	14 ga.	12 ga.	12 ga.	
150 ft	16 ga.	14 ga.	12 ga.	12 ga.		
200 ft.	14 ga.	14 ga.	12 ga.	10 ga.		

Reading the jacket code

All extension-cord jackets are marked with a code that indicates (among other information) the American wire gauge (AWG) and the jacket material and its properties, according to standards established by the National Electrical Code.

S: Standard service (synthetic-rubber insulated, rated for 600v)
SJ: Service junior (synthetic-rubber insulated, rated for 300v)
ST: Extra-hard usage, thermoplastic (PVC)
SE: Extra-hard usage, elastomer
O: Oil-resistant, usually synthetic-rubber jacket, more flexible in cold temperatures
OO: Oil-resistant synthetic-rubber jacket and inner-conductor insulation
W: Extra-hard usage, weather-resistant
SJTW: Thermoplastic-jacketed, weather-resistant, rated for 300v
SEOW: Oil-resistant and weather-resistant elastomer jacket, rated for 600v (photo below)
SJOW: Oil-resistant and weather-resistant synthetic rubber, rated for 300v
SJOOW: Oil-resistant and weather-resistant synthetic rubber (jacket and conductor insulation), rated for 300v
SJTOW: Oil-resistant and weather-resistant thermoplastic, rated for 300v

Bottom photo this page: Judi Rutz

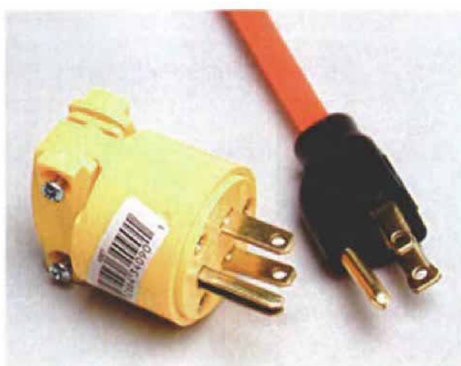


Locking plugs prevent accidental disconnections and possible hazards. A water-resistant locking connector (top) keeps midline connections dry; a locking plug (center) for 20-amp cords stops potential arcing during disconnects; a dedicated locking switch on the female end (bottom) of a 15-amp cord.

limit of 15 amps over a period of time, heat can build up in the conductors. The coiled cord can't dissipate the heat efficiently, and the cord's insulation may eventually melt.

A cord's flexibility and durability depend on its jacket

When the weather here in Maine turns cold, some extension cords get as stiff and brittle as uncooked spaghetti: They're hard to uncoil, and they won't lie flat. The cord's jacket material (and to a lesser extent, the conductor's insulation) determines whether it will be easy or difficult to handle, especially in subfreezing temperatures. Unfortunately, it's hard to tell from the packaging if a cord will be flexible. Cord manufacturers commonly claim that cords will remain flexible between 140°F and -35°F, for example. These temperatures actually indicate the jacket materials' point of failure (cracking or deforming), information required for Underwriter's Laboratories (UL) and Occupational Safety and Health Administration (OSHA) approval, rather than the cord's ability to remain flexible in cold weather. The difference between good and bad lies in the materials used to make the jacket; the best way to find out about an extension cord is to look on the cord's jacket itself. Next to the AWG designation, the cord has a letter code that indicates the jacket materials' properties (photo, chart, p. 85).



Replacement plugs have stronger pins. Heavy-duty replacement plugs have U-shaped ground pins that won't bend or break easily, unlike pins that are round.

There are three basic materials used in the manufacture of jackets: PVC (polyvinyl chloride), TPE (thermoplastic elastomers) and synthetic rubber. Until fairly recently, there was a clear delineation between the three: PVC was the most inexpensive to produce but had poor flexibility and resistance to abrasion; synthetic rubber was about 20% more expensive but was tough and flexible; TPEs were an improved version of PVC that possessed some of synthetic rubber's characteristics. Within the past few years, however, advances in polymer technology have narrowed the gaps in performance between all three. The main difference that remains is that PVC is less flexible in cold weather than synthetic rubber.

The problem with synthetic rubber, according to John Quinn of Electri-Cord Manufacturing Inc. in Westville, Pennsylvania, is that "synthetic rubber won't bond to plug ends that are typically made from PVC. If the jacket and plug aren't bonded, when someone pulls the plug out of the wall from 10 ft. away, the inner conductors are easily exposed, and that's a dangerous situation." Being hybrids, TPEs (designated by an *E* on the jacket code) usually make the best choice for an all-purpose cord; they remain more flexible than PVC in cold temperatures and can possess the resiliency of synthetic rubber. However, Quinn says that the synthetic-rubber cords are fine if used with after-

Bottom photo this page: Charles Bickford market plugs that have mechanical strain reliefs (sidebar p. 89).

Both Leviton Mfg. Company (800-824-3005) and Eagle Electric (800-366-6789) plugs have served me well over the years, but any number of manufacturers make good replacement plugs. Look for commercial or industrial-grade plugs, which have stiffer conductor blades and U-shaped (rather than hollow) ground pins that are nearly unbreakable (bottom photo, facing page). The plug should have a strain-relief clamp at its rear secured by two screws that immobilize the wire. Also, if you can look inside the plug, make sure the wire terminals are well separated by plastic dividers. It's important to remember that most of these after-market plugs are not waterproof; if you're going to use them in the weather, be sure to protect them with a GFCI and/or a watertight cover.

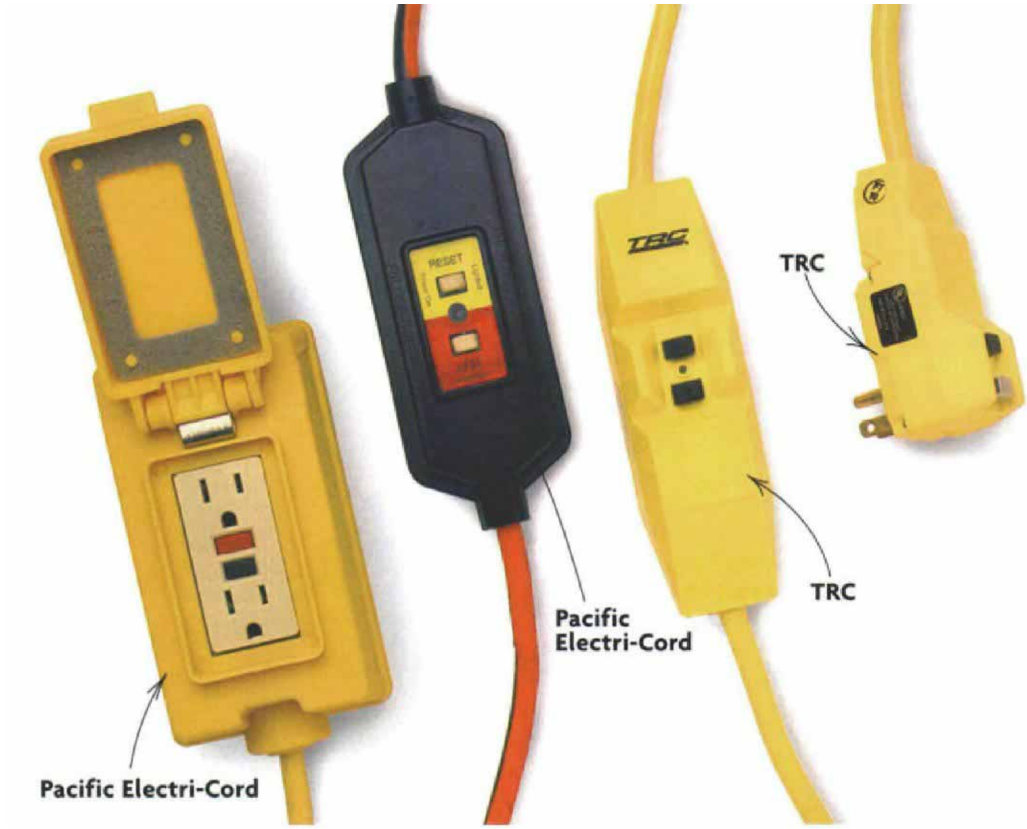
Electrical safety shouldn't be an option

When you work with electricity, you always run the risk of electric shock, burns or fire. A good preventive measure is to buy cords that have the UL and OSHA labels on them. Those labels mean the cords have met rigorous standards and been subjected to spot-testing to ensure their reliability. UL samples random lots of cords and tests jacket retention, amperage ratings, resistance to crushing and weather, and strength of plug ends, among other things.

On job sites, cords suffer routine wear and tear that can compromise their safe operation. For instance, although many extension cords are rated water resistant, they should not be left underwater for extended periods of time; minor nicks and abrasions on the insulation can allow water to seep into the cord's interior and cause shorts.

Another job-related problem concerns plug ends: It's all too tempting to yank a cord out of an outlet from a distance of 10 ft. or 15 ft. rather than walk across the room and lay hands on the plug itself. Turning the cord into a whip will eventually make the jacket separate from the molded plug and possibly break the wire connection inside the plug. At the least, you'll have to buy a new plug; you also could end up with a hidden short that gives someone a nasty surprise.

Obviously, extension cords should be kept away from high-heat sources and high-traffic areas, for their own good as well as yours; cords seem to wrap themselves around feet at the worst times. Left on the floor of a high-traffic area, kinked over windowsills, slammed in door jambs, the outer insulation can be cut or torn, exposing the inner con-



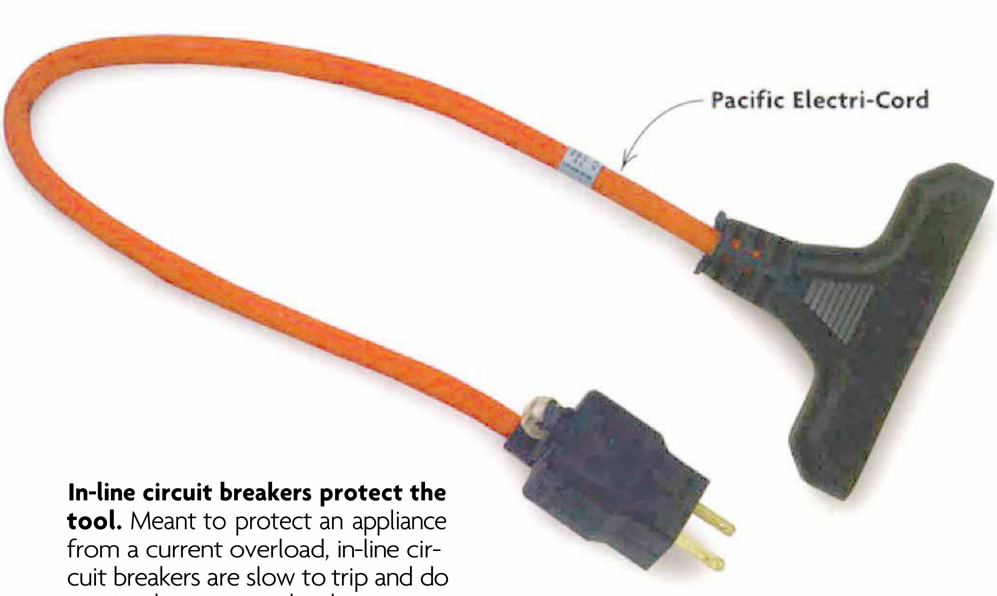
In-line GFCIs required by OSHA on all job sites. Like household GFCIs, these portable units are designed to prevent electrical shocks caused by ground faults in a circuit. Variations available include (left to right] all-weather outlet boxes, and in-line and plug-end models.

Wrapping cords: Looser is better

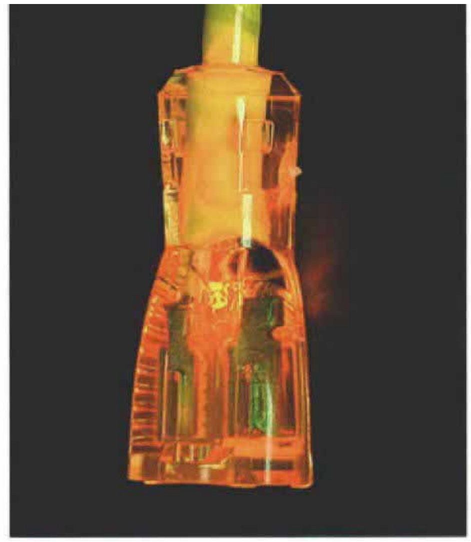
Although many people wrap extension cords tightly for storage, it's probably not good for the cord. Paul Hedrick, technical director of BICCGeneral (maker of Carol cords), recommends that cords be coiled like garden hoses, gathered loosely with even loops in one hand. "The worst thing anyone can do is wrap cords tight around their elbow and thumb, which milks the jacket away from the plug and exposes the conductors," Hedrick says. Reels often encourage this condition. If a cord is coiled loosely, it's less likely to retain its shape in cold weather. Once coiled, cords can be secured with a short length of nylon line (photos below), Velcro strips or commercially available plastic hangers and stored out of the way.

—K.T.

Bottom photos this page: Charles Bickford



In-line circuit breakers protect the tool. Meant to protect an appliance from a current overload, in-line circuit breakers are slow to trip and do not insulate against shock.



Lighted plug ends indicate a live circuit. Cords that have lighted plug ends eliminate troubleshooting steps when power outages occur. If you have light, you know that there's power.

ductors. Exposed individual conductors can then short out, causing a severe shock or even fire.

Extension-cord accessories

OSHA regulations require the use of ground fault circuit interrupters (GFCIs) on any nonpermanent power (i.e., extension) cord used on a construction site. Like household GFCIs, these portable units (top photo, p. 87) compare the incoming to the outgoing current and will shut off power within one-fortieth of a second if there is a difference, preventing possible electrocution. (Incidentally, household GFCIs do not meet code for temporary job-site power; for more information, see FHB #108, pp. 126-128.) Although some carpenters I talked to don't like to use them because they trip too easily (GFCIs will trip if dropped or kicked, for instance), GFCIs are meant to protect.

These same carpenters preferred circuit breakers built into the extension cords (photo top left) because the breakers were less sensitive. However, these in-line breakers are light-duty devices meant to protect an appliance from a current overload and should not be used in place of a GFCI. By the time a breaker has kicked in, someone depending on a circuit breaker could be electrocuted.

Locking cords and lighted cords also have become popular options. Locking cords (top photo, p. 86) simply have male and female ends that will not separate easily when kicked or yanked. This design eliminates the old-fashioned method of securing plugs with a loose knot, a practice that tends to pull the conductors out of the molded plug ends. Lighted-plug cords (photo top right) contain a tiny light bulb to make it easier to pinpoint power problems; the female plug end lights up when electricity is being drawn through the cord. The light feature usually adds about $5 to the price of a cord.

Although handy and available in molded-PVC blocks, multiple outlets such as surge-protected power strips shouldn't be used at all in higher-amperage situations. Portable GFCI outlets, although expensive, are the safest to use.

Sources of supply

Extension cords are a stock item in every hardware store and lumberyard, but if you can't find the exact cord you're looking for, here's a partial list of extension-cord manufacturers. Many have online catalogs and informative Web sites as well.

Coleman Cable, 1586 S. Lakeside Drive,
Waukegan, IL 60085
(800) 323-9355
www.colemancable.com

Woods Industries, 510 Third Ave. SW,
Carmel, IN 46032
(800) 447-4364
www.woodsind.com

JHL Industries, 10012 Nevada Ave.,
Chatsworth, CA 91311
(800) 255-6636
www.justcords.com

Pacific Electri-Cord, 747 Redondo Beach
Blvd., P. O. Box 10, Gardena, CA 90247
(310) 532-6600
www.leviton.com

TRC, 5250 140th Ave., North Clearwater,
FL 33760
(727) 530-9580
www.shockshield.com

BICCGeneral Inc., 4 Tesseneer Drive,
Highland Heights, KY 41076
(606) 572-8000
www.biccgeneral.com

What's the cost?

Extension cords are a staple in every hardware store, but until recently, you'd be hard pressed to find anything that wasn't clad in orange PVC. Lately, manufacturers have started to introduce a wide variety of cords that have heavier, more flexible jackets in colors not seen before in nature, good for safety and for keeping cords separate. There's even a place called Just Cords (sources of supply, left) that sells cords made in custom colors and patterns, although you do have to order 10,000 ft. at a time.

Six bucks will buy a 50-ft. AWG-16 PVC-clad cord, but the price goes up as the wire diameter gets bigger and as the jacket materials get tougher. For example, a 50-ft. AWG-12 synthetic-rubber cord with locking plugs made by Electri-Cord costs about $30 at my local home center. Portable GFCIs can range in cost from about $10 for a short molded power block to about $80 for a heavy-duty all-weather outlet box. ☐

Ken Textor is a carpenter and free-lance writer living in Arrowsic, Maine. Photos by Scott Phillips, except where noted.

Making and repairing extension cords

Because molded plugs can't be repaired, it's often more economical to replace the plug with an after-market model rather than buy a new cord. These plugs offer the additional benefit of stronger pins and more effective strain-relief clamps that do a better job of securing the jacket to the plug. Here are some techniques for repairing old cords or building new ones.

STRIPPING THE RIGHT AMOUNT OF INSULATION

With a pair of cutting pliers, cut off the end of the cord square, then cut the outer jacket lengthwise (top photo); be sure to leave enough jacket to engage the strain relief. (Don't use a knife: You're more likely to cut the conductor insulation that's below.) Peel the jacket back, trim away excess, and splay the conductors. Clip the filler between each wire, and then inspect for nicks or cuts in the insulation.

On most after-market plugs, the proper strip length is molded in relief near the pins (center photo). Using a wire stripper, strip the wires back to the prescribed length, usually about ½ in. Twist each stranded wire clockwise until the strands are tight. Notice that each of the three screws is a different color; each conductor must be attached to the proper terminal (bottom photo): green for the ground, dark or bronze for the hot wire (usually black or red), and white or silver for the neutral (usually white or light gray).

If the terminal requires you to wrap the wire around the screw, make sure that you wrap it in a clockwise direction so that the screw will draw the wire around itself securely as it is being tightened.

MIDLINE SPLICES MUST BE SOLDERED

Repairs between the two plugs (splices) are trickier. OSHA regulations do allow minor abrasions to be repaired with electrician's tape, but only if bare wires aren't exposed. If the conductors need to be spliced, the afflicted wires must be soldered together and then reinsulated "so that the splice retains the insulation, outer sheath properties and usage characteristics of the cord being spliced." This standard is meant to apply only to cords of AWG 12 or larger.

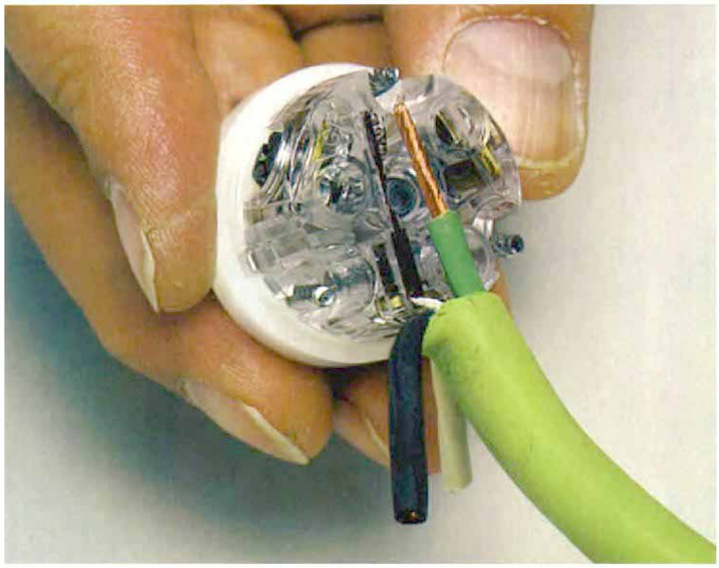
They aren't talking about yards of electrician's tape, which will unwrap or leak when submerged in a puddle. Only heavy-duty shrink-tubing will do the trick, and that's not an item that most of us carry around. In the case of an exposed conductor, probably the safest remedy is to cut the cord completely and make two new cords by attaching the appropriate plugs.

DON'T USE HOUSEHOLD WIRING

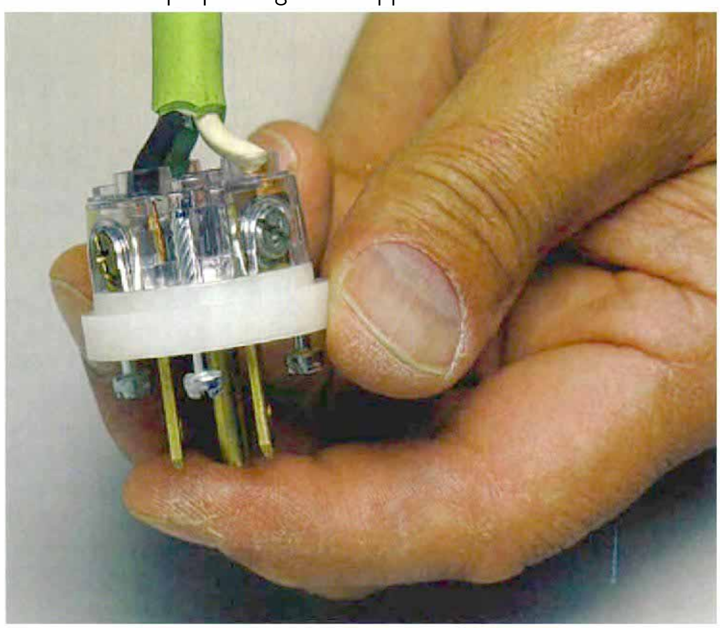
You shouldn't make extension cords out of common wiring material, also called NMB or by the trade name Romex. Residential wiring is meant to be used in one place: stapled to the inside of a wall, not dragged around on a job site. Although common, these hardwire setups are potentially dangerous because the wire is easily broken and the jacket is not made for hard service. These cords are a nuisance, too; they are not flexible.

—K.T.

Use cutters when repairing a cord end. Unlike a utility knife, diagonal cutting pliers won't accidentally nick the conductor insulation when slicing through the jacket.



Use the wire-stripping gauge on the plug end. Most replacement plugs have a gauge molded onto the inner face of the plug that shows the proper length of stripped wire to use.



Conductors must be attached to the proper terminals. Plug terminals are color-coded—green for ground, bronze for hot (black) and silver for neutral (white)—and must always match their respective conductors.

Photos this page: Judi Rutz