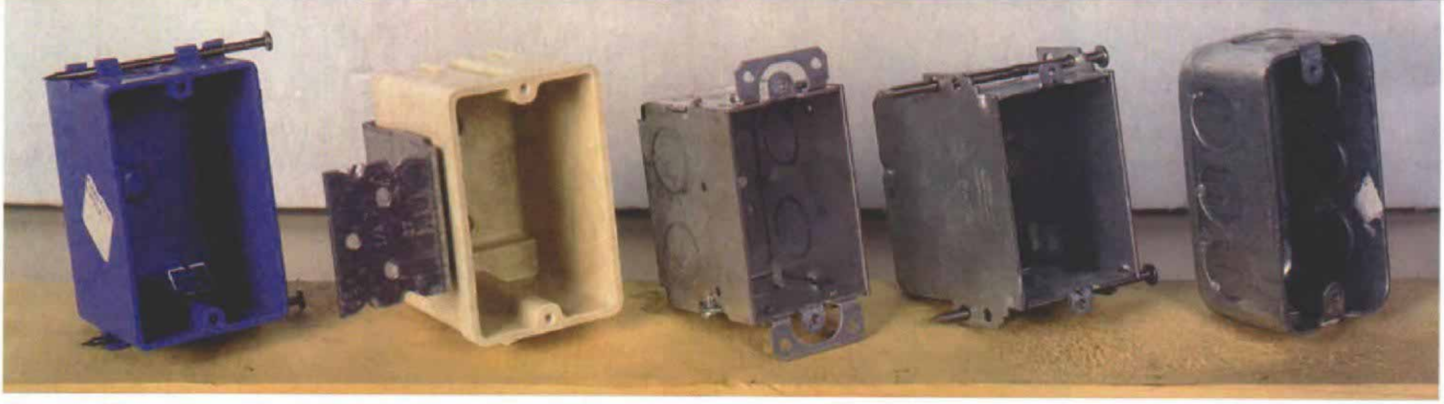


Electrical-box lineup. The plastic electrical boxes on the left mount either with built-in nail holders or a bracket that attaches to a stud. The plastic box with the face-mount bracket is automatically set at the right depth in the wall. Metal boxes are available in a variety of depths, and the utility box (far right) has rounded corners for mounting in exposed inside areas.

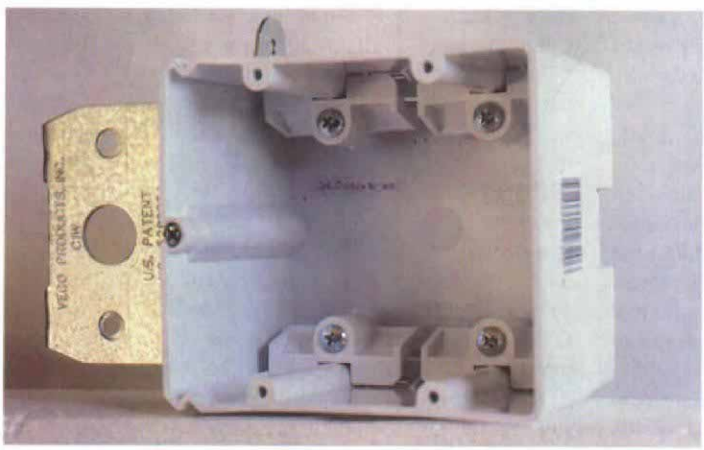
Installing Electrical Boxes and Receptacles

Keep boxes straight and splices tight for safe, trouble-free circuits

by Rex Cauldwell

Becky and Tyler were convinced that their house was haunted. Calling me was their last resort. The demon in residence was causing lights to go on and off mysteriously, and several of those child-protector inserts had actually melted in receptacles. A few hours before the couple called, sparks had flown from an outlet in the nursery; nothing was plugged into it. If I couldn't help them, they were moving out.

When I got there, I could feel heat radiating from a number of outlets. In fact, one kitchen outlet was so hot that it had deformed the plug on a blender. It didn't take long to find the problem. Cheap receptacles had been installed and wired using the push-in connections in the back. These connections were beginning to fail, causing heat in the outlets and the intermittent flow of current. I exorcised the evil spirit by correctly wiring in new outlets in the house, and my head didn't swivel around even once.



Correct box volume is the law. Plastic boxes have their volume clearly stamped on the outside, but a manufacturer's chart is needed to determine the volume of a metal box. Box volume indicates how many wires can safely and legally be run into it.

Receptacle boxes: a question of volume— The first step in correctly installing a receptacle is choosing the right box. The array of electrical boxes can be bewildering even to an electrician: metal vs. plastic, integral nail vs. bracket mount, square vs. rectangular, deep vs. shallow and so forth (photo above). The main factor to consider when buying an electrical box is volume, or cubic inches of space inside the box. The National Electric Code calls this space "cable fill" and specifies the necessary amount of cable fill based on the size of the wires, the number of wires entering the box and the type of device the box will hold. If a box is too small, the wires will be overcrowded, resulting in broken, shorted wires and possible damage to the box's receptacle-holding threads.

Here are the NEC cable-fill requirements for wiring a standard 120v receptacle. A typical cable for wiring receptacles, such as 12/2 NM (nonmetallic) cable with ground, has three conductors: black, white and ground. Each conductor adds one volume unit (2.25 cu. in. for 12-ga. conductors), except for the grounding conductors. Regardless of the number of cables entering or leaving the box, the grounding conductors together equal one volume unit for the total of the box. Add a volume unit for cable clamps or support fittings in the box. Add two volume units for the receptacle. Add nothing for NM external connectors.

In a typical situation of a 12/2 cable with ground entering and exiting the receptacle box, the two cables add up to 9 cu. in. Add another 2.25 cu. in. for the ground wires and 4.5 cu. in. for the receptacle itself. The total cable-fill requirement for this very basic receptacle installation is 15.75 cu. in. for boxes without hold-down clamps and 18 cu. in. for boxes with hold-down clamps, which add 2.25 cu. in. A third cable entering the box brings the total to a minimum 20.25 cu. in., and a fourth cable puts the minimum volume requirement at 24.75 cu. in. for plastic. The largest single-gang box currently available is around 23 cu. in., so legally there is no single-gang box that accommodates four 12/2 cables with a receptacle without being in violation of cable-fill requirements. In this situation I usually install a larger 4-in. square box with a ½-in. cover plate, also called a mud ring.

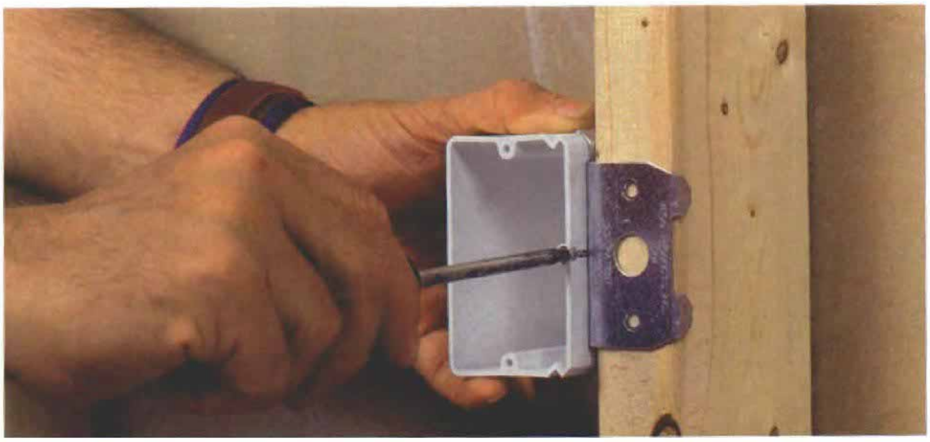
After you've figured out how much volume you'll need, take a look at a manufacturer's chart to figure out which size box matches or exceeds those requirements. If you go with a nonmetallic box, the size is usually stamped directly on the box (bottom photo, facing page).

Nonmetallic boxes are inexpensive and easy to install—Nonmetallic boxes have become the most commonly used boxes for residential applications. They're easy and fast to install and usually cost less than metal boxes. Nonmetallic boxes are also nonconductive, made of PVC plastic, fiberglass and thermoset. Nonmetallic rough-in boxes are more fragile than their metal cousins, so these boxes are to be used inside walls and not in exposed areas where they can be bumped and broken.

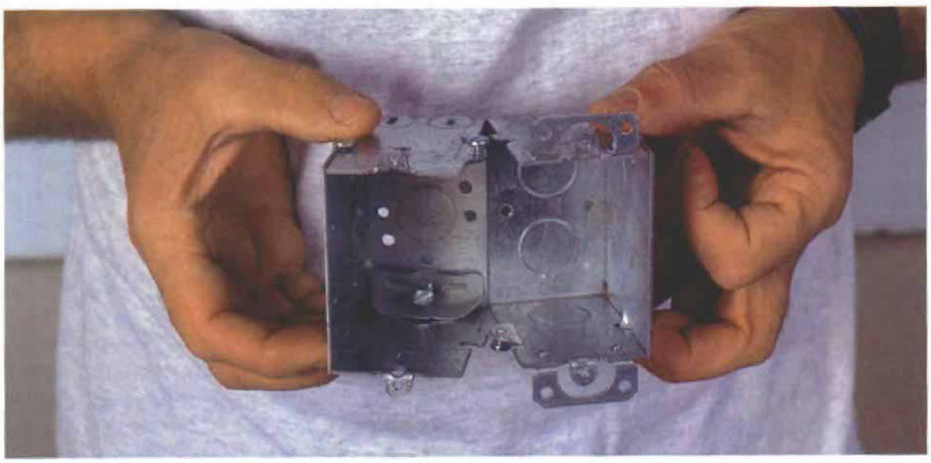
There are many different varieties of nonmetallic boxes, but the most commonly used for receptacles is the single-gang integral-nail box. These boxes have nail holders molded into the top and bottom of each box, and usually come with nails already in the holders. Installation of these boxes seems simple enough—just nail them to the stud. However, other considerations can make installing integral-nail boxes a little tricky.

First, the box has to project out from the stud so that it's flush with the finished wall. If the box sticks out too far, the receptacle wall plate won't lie flat against the wall. If the box doesn't stick out far enough, spacers have to be added under the drywall ears on the receptacle, or *a* box extension has to be installed to make the box flush with the finished wall.

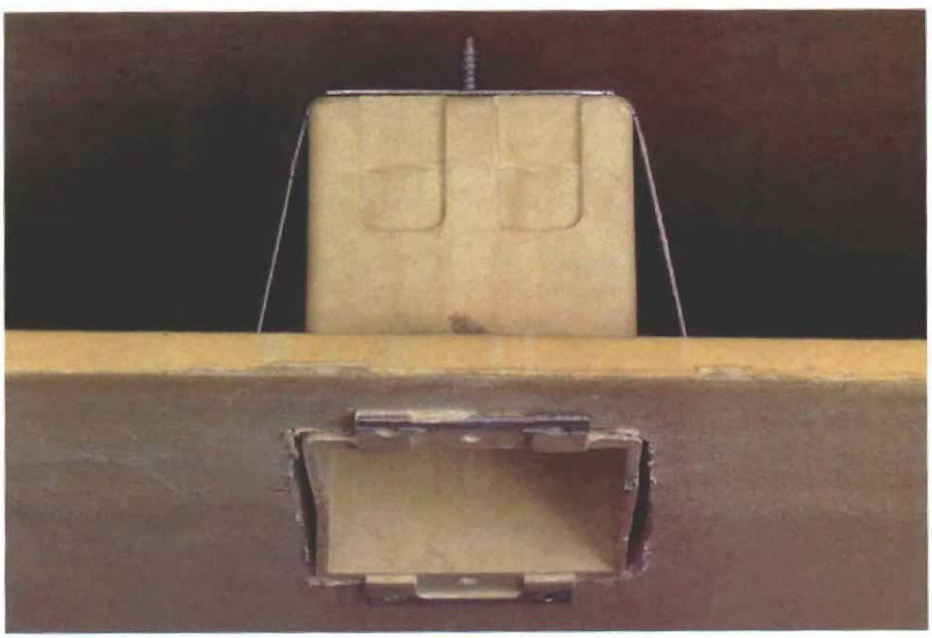
Another problem is keeping the front of the box parallel to the front of the stud while it's be-



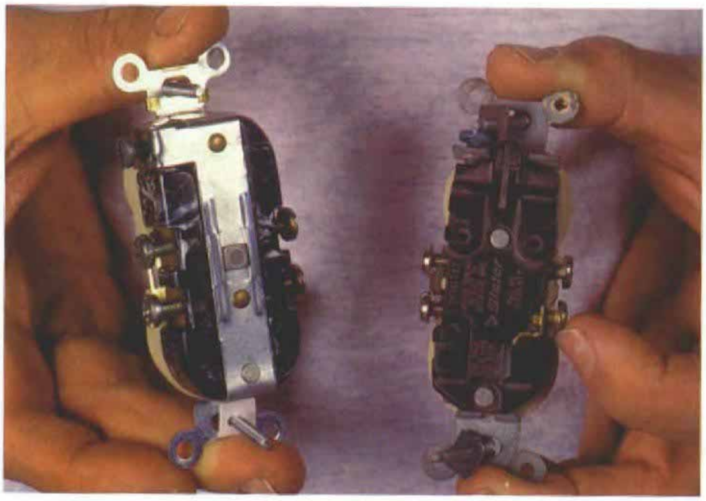
A screw changes the mounting position. Veco's Adjust-A-Box mounts on the face of a stud but can be adjusted in or out to match any wall surface.



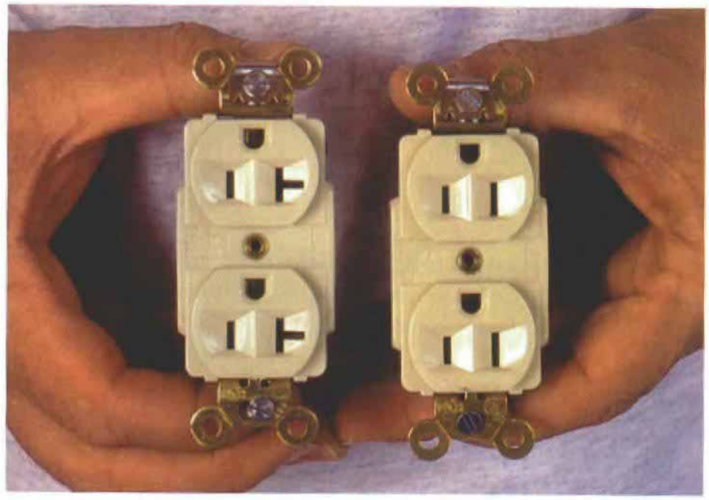
Metal boxes can be ganged together. Interlocking notches and flanges allow metal boxes to be joined to increase the volume of the box or to accommodate multiple receptacles.



Cut-in boxes go into existing walls. Old-work, or cut-in, boxes let you add a receptacle without tearing out the wall. The wallboard is sandwiched between plaster ears on the front of the box and a bracket on the back.



Better receptacles have wraparound yokes. The heavy-duty receptacle (left) has a metal yoke for support. The inexpensive receptacle (right) has no metal yoke, and the plastic housing has broken.



15-amp vs. 20-amp receptacles. The 20-amp receptacle on the left has a horizontal slot for the neutral side of the outlet to accommodate the special plugs on appliances that draw a lot of power.

ing nailed and at the same time making sure the nail doesn't bend or deflect, which can break or distort the box. All of these problems are solved by choosing a box with a side-mount bracket that nails or snaps onto the front of the stud, automatically positioning the box parallel to the stud at the proper depth.

Nonmetallic boxes don't vary much between manufacturers. However, Veco (Veco Products Inc., P. O. Box 692, Lyle, Wash. 98635; 800-688-0890) makes the Adjust-A-Box, which attaches to the stud with a bracket and can be adjusted easily to any finished wall depth (top photo, p. 59). If the homeowner decides to change a wall from panelboard to tile, a turn of a screw moves the box in or out flush to the new finished wall. Positioning prongs on the bracket grab onto the stud to hold it temporarily, and then a screw or nail into the side or front of the stud anchors the bracket permanently. In addition, the box can be removed from the bracket, allowing you to change quickly from a single-gang box to a multiple-gang box or to gain access to the inside of the wall by removing the box altogether. The single-gang Adjust-A-Box has around 21 cu. in. and costs about the same as a metal box of the same size.

Metal boxes need to be grounded—Once the standard of the industry, metal boxes have now taken a backseat to nonmetallic boxes, although they have some distinct advantages. Metal boxes are stronger and come in a wider variety of designs. The biggest advantage of metal boxes is that they can be stacked or ganged together using interlocking notches and flanges to go from a single to a double or a triple, etc. (center photo, p. 59). Some metal boxes come with rounded edges for surface-mounting in places such as garages and basements.

Because the metal yoke on a receptacle is attached to the box, metal boxes need to be grounded. The best way to ground the box is by adding a pigtail or a short length of ground wire to the ground-wire splice inside the box. The other end of the pigtail is attached to the box with a green grounding machine screw in the back of the box. These green screws cannot be used for any purpose other than grounding. A common but illegal trick is wrapping the ground wire around the screw that attaches the box to the wall. Another option for metal boxes is a grounding clip that retains the grounding wire and slides onto the edge of the metal box, but grounding clips don't stay put unless a mud ring is installed to keep the clip from sliding off.

The most misused of all electrical boxes is the common round-edge metal utility box, or handy box (top photo, p. 58). At 1½ in. deep these boxes have only 10 cu. in. of cable-fill space, which is not even enough room for a single 12/2 cable with ground and a receptacle. In other words every time this box is used for a receptacle, it is in violation of code requirements for cable-fill space. Yet every electrician I know, including me, has used these boxes for receptacles in a pinch. Handy boxes also come in 1⅞-in. and 2⅛-in. depths. Square-edged handy boxes have around 3 cu. in. more space than the same size round-edged metal boxes.

Cut-in boxes are for receptacles in existing walls—If I'm installing a receptacle box in an existing hollow wall, I use a special box called an old-work or a cut-in box (bottom photo, p. 59). This type of box is not mounted to a stud but is attached directly to the finished wall. Plaster ears hold the front of the box to the drywall surface, and wings or brackets on the sides sandwich the drywall to hold the box in place. In addition, adapters are available to make boxes with drywall ears work like cut-in boxes. But take care if installing a cut-in box in a wall with a receptacle directly on the other side of the wall cavity. The new box needs to be offset a bit because the boxes won't fit back to back.

The problem with all cut-in single-gang boxes is again volume. The common sizes are usually no larger than 18 cu. in., which severely limits the number of cables the box can hold. However, if you have a single cable running to a box in a narrow wall cavity, the 10-cu. in. and 12-cu. in. boxes are ideal because they are shallow.

Better receptacles are worth the extra money—One of the biggest mistakes made in residential construction today is the use of low-cost, light-duty receptacles, especially in heavy-use areas. These receptacles sometimes fall apart in my hands as I install them and won't hold up under heavy or even medium-duty use.

For 50¢ to a dollar more, you can get a receptacle with a hard-to-break nylon face, a wraparound yoke for receptacle support, a heavy-duty body and heavier metal on the inside (photo left). For high-abuse areas, the garage or even the kitchen, you might consider commercial or industrial-grade receptacles, which cost a few dollars more but are almost indestructible.

Most household receptacles are rated for 15 amps of current, even if they are wired into a 20-amp circuit. Fifteen-amp receptacles typically have two vertical slots with a hole for the ground prong on the plug. Twenty-amp receptacles have a vertical slot for the power-supply side of the receptacle and a horizontal slot on the receptacle's neutral side (photo right). Twenty-amp receptacles are for appliances that draw a large amount of current, such as some air conditioners or refrigerators. These appliances are usually fitted with special 20-amp plugs that will not fit into a 15-amp receptacle. A 20-amp receptacle should not be installed on a circuit protected by a 15-amp circuit breaker or fuse, and a circuit with 20-amp protection should always be wired with 12-ga. cable.

When running wire, always leave plenty of slack—After you've chosen and installed electrical boxes and picked the appropriate receptacles, it's time to get down to the nitty gritty of wiring. I usually run the supply cable about a foot past the box and cut it there (photo top left). Any cables coming out of the box are left about a foot long as well. This practice might seem wasteful, but be assured that the 6 in. or so of wire that gets recycled or used for pigtails saves hours of frustration and countless gray hairs from dealing with wires that are too short. All wires to and from each box should be stapled within approximately 6 in. of the box.

Many electrical inspectors around the country like to see ground wires twisted and wire-nutted together at the rough-inspection stage. So after feeding the cables into the box, I strip off the sheathing. Sheathing slitters made out of lightweight sheet metal are available, but I find that a utility knife with a sharp blade works better. I reach into the box with my knife, and starting about ¼ in. from where the cable enters the box, I slit the sheathing down the middle of the flat side of the cable (photo top right). Because the ground wire is in the middle, it's possible to do this without damaging the insulated conductors, but you have to be careful.

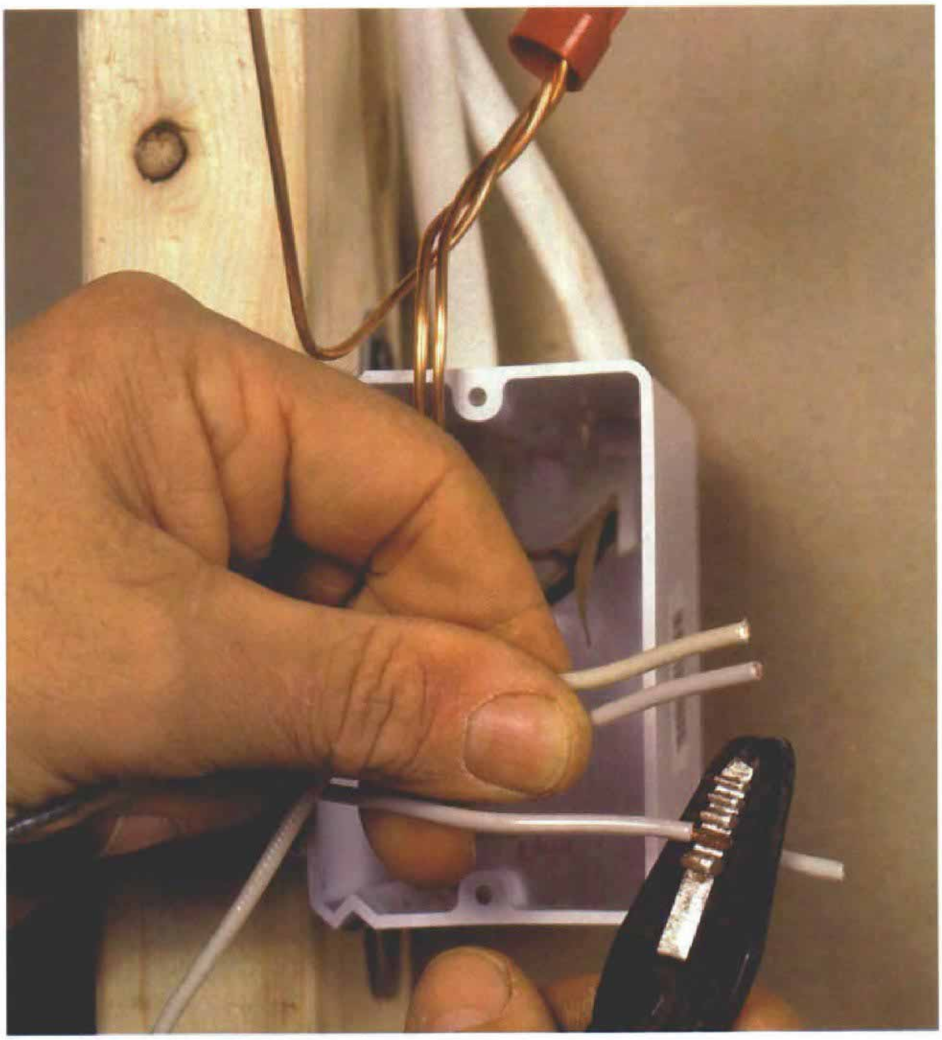
Next I peel back the sheathing and the heavy paper or cardboard in the cable and slice it off with my utility knife as close to where I started my slit as possible. After peeling back the sheathing on the cables in the box, I group together all of the grounds and like conductors, pulling each group toward a different corner of the box.

I then cut all of the grounds to the same length, about 6 in., and twist them together clockwise along with a 6-in. pigtail that will connect to the ground terminal on the receptacle. Next I trim off the end of the splice evenly and screw on a red wire nut. (The color of a wire nut indicates its size, and red is the most commonly used color for wiring receptacles. Yellow wire nuts are usually too small, and blue wire nuts are much too big.) For ground wires, a brass sleeve can also be used to hold the splice together. Now I push the stiff ground splice back in against the back of the box so that only the pigtail remains sticking out.

The neutrals (white wires) can be spliced next. Again, I cut them all at about 6 in. and add a 6-in. neutral pigtail. I strip off about ½ in. of insulation from each of the neutral wires using a wire stripper-cutter (photo right). This type of

Leave plenty of slack. Run the cable about a foot past the box to give yourself plenty of wire to make splices and connections.

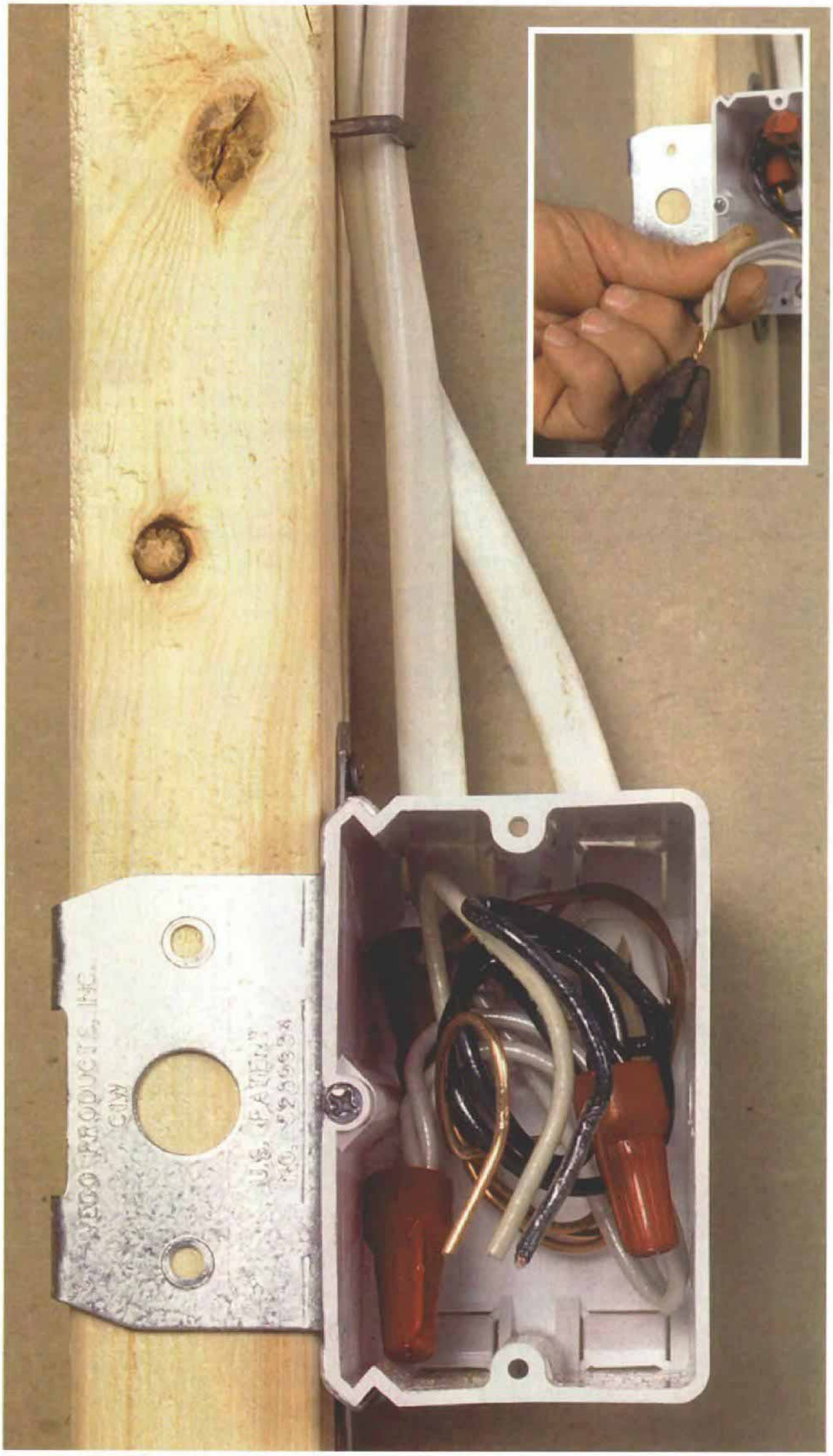
A utility knife slits the sheathing. Leaving about ¼ in. of sheathing coming into the box, slit the sheathing carefully along the flat side of the cable to avoid damaging the wires inside. Then peel the sheathing back and slice it off carefully inside the box.



Wire strippers cut through just the insulation. Although you can strip insulation with a knife or with a pair of diagonal-cutting pliers, you risk damaging the wire itself. Wire stripper-cutters have a hole in the blade the same size as the wire. Closing the cutters and pulling back severs the insulation and removes it.

wire stripper works like a pair of pliers with a hole in the blade the same diameter as the wire being stripped. Closing the pliers around the wire will cut through just the insulation, leaving the wire core untouched. Pull on the pliers to slide severed insulation off the end of the wire.

When all of the neutral wires have been stripped, twist them together clockwise using broad-nose pliers (inset photo left). As you twist the splice, keep an eye on it to make sure the wires are twisting together evenly without one being pulled more than the others. Trim the ends of the bare wires evenly and screw on a wire nut clockwise. Repeat the procedure for the hot (black) wires, and carefully push the splices for the neutral and hot wires into the back of the box, leaving just the two pigtails sticking out. Coil these neatly into the outer part of the box, and the box is ready either for the rough inspection or for the receptacle to be hooked up (photo left).



A good electrical connection starts with a good mechanical connection. Each group of wires is cut to about 6 in. and twisted together along with a pigtail to connect the splice to the receptacle, in the inset photo, the neutral wires are twisted together and wire-nutted to ensure a lasting connection. When all of the splices are completed, just the three pigtails are sticking out of the box. They can be coiled in the box for the rough inspection, or they can be stripped and hooked up to a receptacle.

Parallel circuits are more dependable than series circuits—A client once called me because her goldfish had died. The electricity to her tank warmer had stopped suddenly, but no circuit breaker had tripped. I couldn't revive the fish, but I quickly discovered that the receptacles in this lady's house had been wired in series like a string of cheap Christmas-tree lights. When the first one goes, the whole string goes. In this case a receptacle in another room had broken, cutting power to all other receptacles on the circuit, including the fish tank.

Unfortunately, wiring receptacles in series is the method most commonly used, and it's also pretty easy to spot once the receptacle wall cover has been removed. Instead of being spliced together in the back of the box, both the wire coming in and the wire leading to the next receptacle are attached to the screws on the receptacle (photo right, facing page). Current flows from one wire across a metal tab between the screws and back out the other wire to supply the next receptacle. If the screw loosens, or if the tab between the screws breaks, all of the receptacles to the end of the string lose power.

A better way of wiring receptacles is in a parallel string. With the method I described earlier, the wires entering and leaving the box are spliced together so that the current is passed to the next receptacle at the splices, rather than depending on connections at the receptacle itself. Parallel wiring takes more labor and a couple of extra wire nuts. But each receptacle on the circuit is independent, and the circuit ends up being more reliable.

Ground to green, black to brass, white to silver—The inspector has just okayed your rough wiring, and now you're ready to install the receptacles. Pull the three pigtails out of the box and twist the end of the ground wire into a clockwise loop with needle-nose pliers. Slip the wire over the green grounding screw on the receptacle and tighten the screw.

Next, strip about ½ in. from the end of the neutral wire and form a small clockwise loop in the end. Back out one of the silver screws on the receptacle, and slip the loop around the shaft of the screw (photo left). Be sure most of the looped wire is under the screw. As the screw tightens in a clockwise direction, it will grab the wire and pull it a little farther around the screw.

Tighten the screw securely, but take care not to strip the terminal's threads. If the threads do become stripped, throw the receptacle away. Once the terminal's threads are stripped, the most you can hope for is a loose connection, which can cause the receptacle to overheat and start a fire.

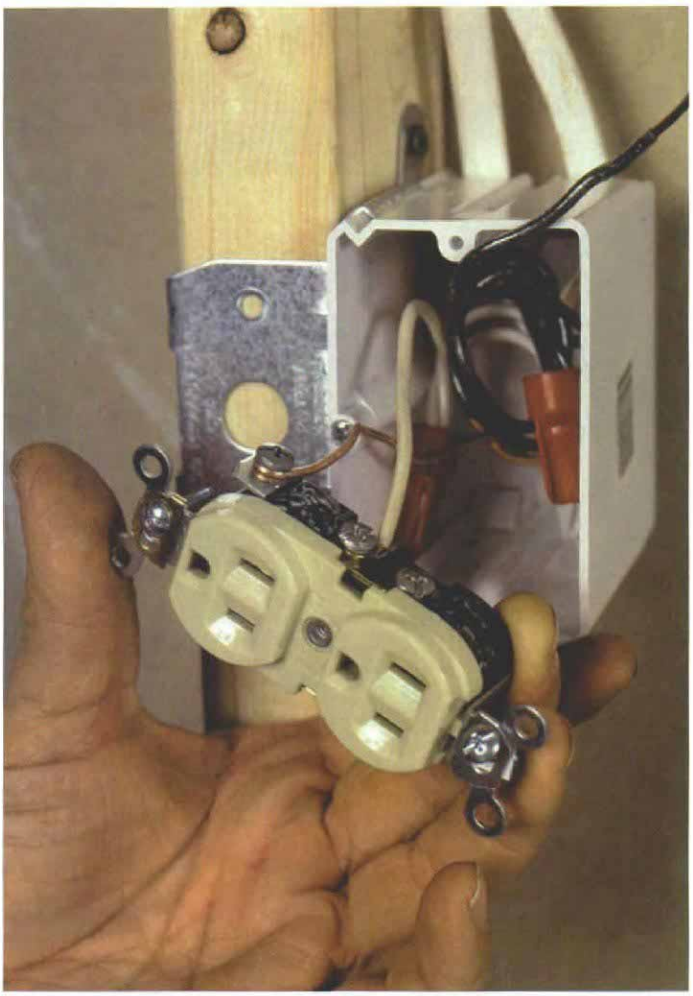
Finally, connect the hot wire to the corresponding brass screw on the opposite side of the receptacle using the same method. Before you push the receptacle into the box, make sure the screws are tight even if they aren't being used. Screws left sticking out can make it difficult to push the receptacle into the box and can short out if they touch the side of a metal box.

Steer clear of push-in connections—If you're installing low-cost receptacles, they're probably equipped with push-in connections for the wires. Although it's tempting just to push the stripped wires into these holes and be done with it, use the screws on the side instead.

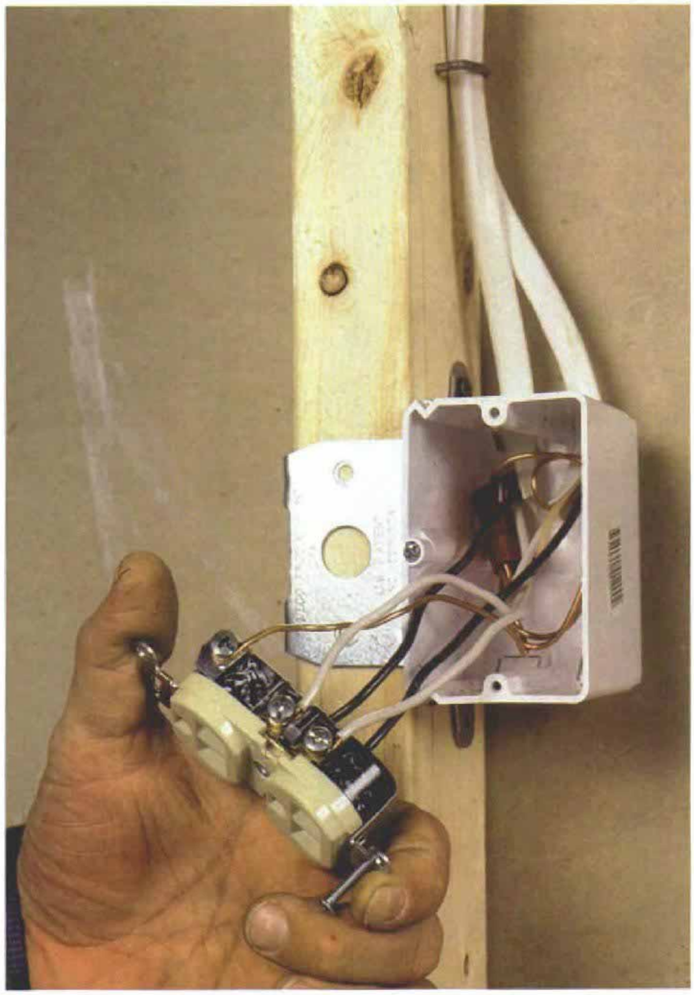
Push-in connections use the spring tension of a metal "check" (similar to a clamp) inside the receptacle to hold the wire after it is pushed into a hole in the receptacle back. Such a system is custom-designed for lazy electricians or do-it-yourselfers. The metal in the check often fatigues, causing a loose connection and eventually allowing the wire to pull back out. In the interest of safety, never use push-in terminals. Since January 1995, Underwriters Laboratories has not approved 20-amp circuits with push-in terminals. New receptacles prevent insertion of 12-ga. wire into push-in terminals but are able to take 12-ga. wire under the screw terminals.

After all of the connections to the receptacle have been made properly, it can be inserted into the box. If you've installed a large enough box and if the splices have been pushed neatly into the back of the box, the receptacle should slide in easily. It helps to prebend the three pigtail wires into a "Z" pattern so that they accordion neatly into the box instead of crumpling haphazardly behind the receptacle. After all of the receptacles in the circuit are securely fastened in their boxes, the power can be turned on and the receptacles tested. The last step is attaching the wall cover plates. □

Rex Cauldwell is a master electrician and plumber in Copper Hill, Virginia. His book Wiring a House *will be published by The Taunton Press in September 1996. Photos by Roe A. Osborn.*



Slip a clockwise loop around the screw. Form a clockwise loop with needle-nose pliers in the end of the neutral (white) wire and slip the loop under a silver screw. Tightening the screw will draw the wire a little farther around the screw.



Series wiring is less dependable. When receptacles are wired in series, both incoming and outgoing wires are attached to the receptacle screws, and the flow of current to receptacles downstream depends on the tiny metal tab between the screws.