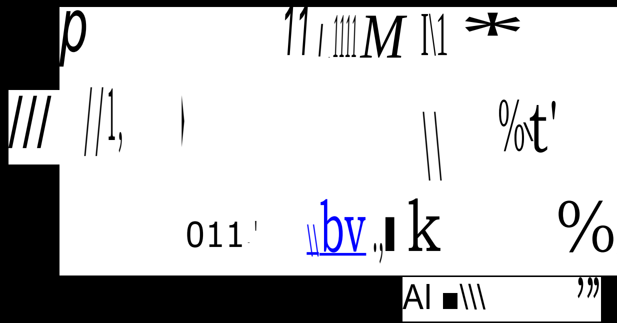

EVALUATING ELECTRICAL WIRING

Compared to water and gas, electricity is the youngest service, and the one that truly makes the modern house possible. In its short hundred years, domestic electric wiring has undergone a technical metamorphosis every two decades or so, and has grown from a temperamental novelty to a highly reliable resource. For owners of houses wired with one of these old systems — and most pre-1940 houses are — the big question is: *Where do I stand?*

The answer is not always simple and has at least two sides: legality and safety. The legality of existing wiring has to be determined case by case. The National Electrical Code (begun in 1897) is a set of model electrical safety requirements published for building and insurance inspectors and electrical contractors, and has no legal power of its own. Most cities and towns adopt the code as their standard, but they are also free to interpret and enforce it according to their needs. The result is that many an obsolete system that would not be permitted in new work is allowed to remain in service if deemed to be in safe condition. A pass or fail depends on the local codes, and the judgment of the inspector.

The safety of old wiring, then, is the most important issue. The best remedy for any questionable circuit is, of course, disconnecting the system and installing new materials, In fact, *electric* wiring of any age has a finite life and might have to be replaced in the future.

While old wiring is in service, its safety can be improved by understanding what the system is and inspecting it with an eve for its known problem areas. Old houses are frequently wired with combinations of systems (for instance, cleats *and* knob and tube *and* BX cable). Understanding the age and specific shortcomings of each type is important in determining whether it is workable, in need of repair, or completely obsolete. In addition, much old wiring falls short of the modern standards for insulation, current-carrying capacity, and grounding. Applying some basic practices, though, can keep these systems operating within their designed limits and help them run safely.

PRE-1940

WIRING SYSTEMS

Electricity had no purpose in houses until it became a means to light them The change came in 1679, when Thomas Edison built upon the experiments of mum others to produce a practical incandescent lightbulb. Tom, also something of a businessman, realized that the market for his bulbs would he soft if no one had access to the energy that made them work. By 1882 he was operating the first plant specifically designed to supply electricity on demand to any consumer: Pearl Street Station in New York City.

Tom's power was DC (Direct Current), a cumbersome first choice for domestic electricity, Direct current is not transmitted easily over long distances, and buildings had to be wired

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fig I

in the "tree" fashion (fig, 1) to feed early power-hungry bulbs, That is, the wire diameter was gauged down from the bottom to the top of the house by load. *Exposed* systems became the popular *choice* for finished buildings. The wires were stretched between cleats or knobs spaced about four feet apart, and run in open view on walls and up staircases to reach the next floor.

CLEATS AND INSULATORS

Wooden cleats (fig, 2) supporting an exposed system, the earliest (and cheapest) wiring method, had disadvantages that were recognized early

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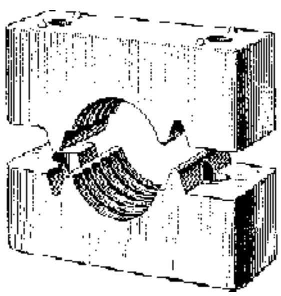
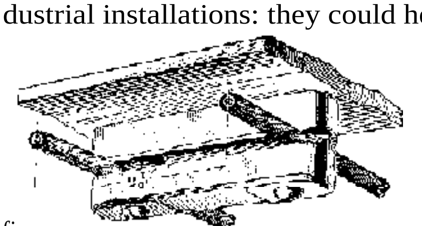
on First, the exposed wires were easily abraded and broken, Second, the wood could *become* an electrical conductor W›en it got damp, and might short-circuit the lines if splinters on the cleats had cut into the primitive insulation.. They were obsolete by 1900,

Porcelain cleats (figs, 3 & 4) were intended to make a safer exposed system than wood and started to appear in the 1880s, Single or tandem wires



could be carried by mating ceramic halves that were superior to wood as insulators and eliminated the threat from splinters. Porcelain cleats *were* well adapted to high-voltage and industrial installations: they could he



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changed readily for repairs and alterations, running them high on walls and ceilings (out of harm's way) improved their safety, and they were inexpensive. Always ugly, they saw less use in houses, and were usually restricted to hidden areas such as basements and attics. In addition, they were considered unfit for wiring in damp places Dr outdoors as earls as 1911.

Porcelain and glass knobs (fig, 5) were also used in exposed wiring, though the latter versions were more breakable and never as popular.

four or four-and-a half feet to make sure that parallel lines didn't sag touch. The National Electrical C now allows exposed wiring on

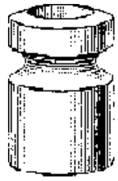


fig. 5

porcelain cleats or knobs only in industrial and agricultural installations, subject to local requirements.

Direct current systems survived into the 20th century in pockets around the country, but the seductive advantages of alternating current (you didn't need a generating station every three blocks or so) made it the preferred power after 1890 Much of the equipment designed For DC could also he used for AC, but as electricity became more popular, there was a demand for better-looking (and, secondarily, safer) wiring.

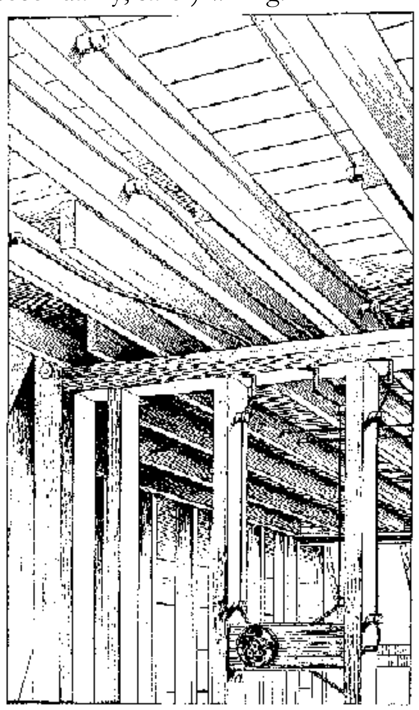


fig 8

KNOB AND TUBE

Knob-and-tube wiring was a *Concealed* (hidden in walls and under floors) version of the exposed knob system. Porcelain knobs (fig. 6) carried individual lines along open runs (such as the length of a floor joist), while tubes of the same material (fig. 7) were inserted through the wood as protectors when making runs perpendicular to framing (fig. 8). Knob spacing was still a maximum of four-and-a-half feet,

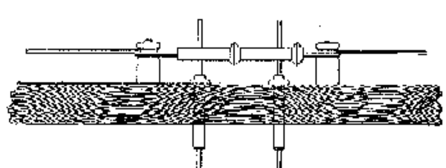
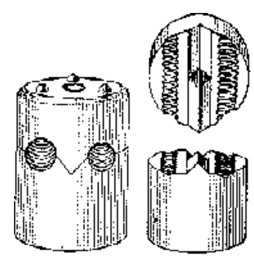


fig. 9

and wires had to be located at least one inch off the carrying surface and five inches from other wires. Where wires had to cross each other in close proximity. tubes were also employed as protective sheathing by taping them in place on the wire (fig. 9). Loom (made of woven fabric) was usually slipped over wire ends where they connected with switches, outlets, fuse boxes, or other terminations.

Knob and tube could be installed cost-effectively in both new and existing construction, and thus was highly popular, despite its flaws, from the 1890s until after 1920. The considera-



fig, 6

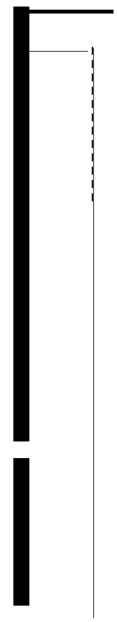


fig. 7

ble in-air isolation of the wires Was the system's biggest attribute, making accidental bridging of the lines (with a misplaced drill bit or nail, for instance) unlikely. The system was plagued by most of the drawbacks of exposed cleat or knob work, though, and kept these problems hidden in an environment of wood and sawdust where fires start easily. Completely unprotected from mechanical injury, the copper conductors were essentially naked except for the electrical insulation, Rubber or other insulating material was easily removed by rodents (or nicked by humans while doing alterations), producing a great potential for disaster (fig. 10). Poorly soldered connections

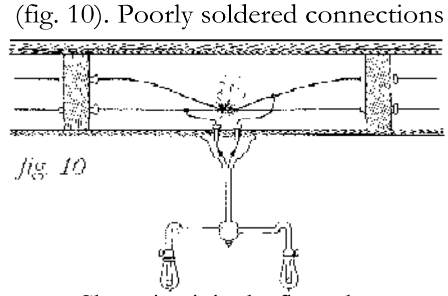


fig. 10

Short circuit in the floor above chandelier.

on tap lines could hear up to the combustion point, a threat recognized before the turn of the century, Dampness, too, was still an enemy, particularly when parallel knob runs were laid out -- contrary to most regulations on the same rafter or floor joist. Although it saw later use in rural areas, there was a strong call for the outlawing of knob and tube by 1921,

fig. 11

MOULDING

Wood and metal surface mouldings were a solution to the aesthetic problems of exposed wiring systems. Retrofitting existing houses with the new power was a big chunk of the early electrical business, but a concealed system was prohibitively expensive for some customers. Mouldings, however, made it possible to wire a building with a non-concealed system that didn't look like railroad tracks, and at about of the cost of concealed.

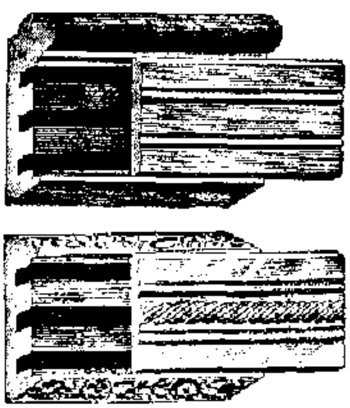
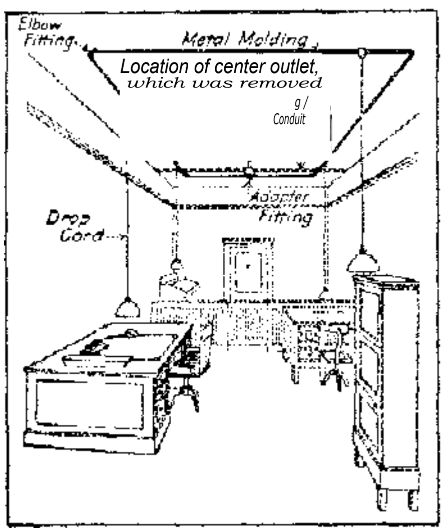


fig. 1 la

Wood mouldings (fig_ 11) were decorative, inexpensive, easy to use, and a big hit early on. They were assembled from two weatherproof-painted pieces: a base strip channeled to accept either two or three wires, and a cap that was usually beaded with some ornamental design. Layouts could be planned so that they harmonized with a room by following its lines (much like interior trim) and still service lights and other electrical apparatus.

Convenient as this system was, it had safety drawbacks. Wood moulding offered the wiring it carried little protection from impact, and could even attract trouble by being mistaken for solid wood and having nails driven into it. The wood was so close to the wiring, it ignited readily if there were overload problems, and like wooden cleats, could short the lines if it became wet. Money-saving installation shortcuts often made this system even more dangerous. Mouldings were intended to be made of hardwoods, but softwoods could be substituted at half the price and with even more vulnerability to water. Another economy was eliminating the base strip and just using a grooved version of the cap. 'Ibis practice didn't guard the wiring, it just hid the problems. By 1911, use of wooden moulding in damp locations was not permitted, and it was not *recommended* for any application in most communities by the '30s.



Metal moulding installed in a panel effect

Metal mouldings (fig. 12) appeared shortly after 1900, and were outselling wood by the 1920s. Also a base-and-cap design, they were made from galvanized sheet metal and were usually large enough to hold four #14 wires. Metal moulding was slim and took paint well, and thus was relatively inconspicuous_ As a safety measure, all mouldings had to be grounded at at least two points.

Despite its many advantages, metal moulding had limitations. It could not

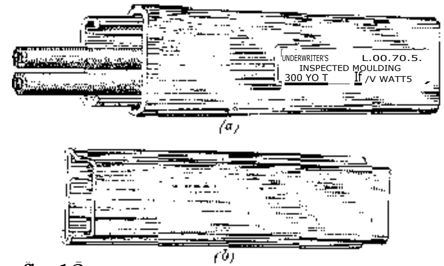
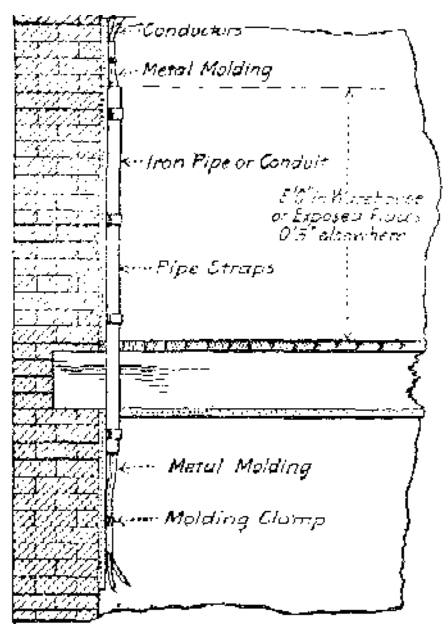


fig 12

be used where dampness was a threat, and the National Electrical Code restricted its use to surface wiring. Each types had no galvanizing along the cut edges of the metal, which opened the possibility of either sharp edges or rust compromising the wiring insulation and causing shorts, Improved versions of metal mouldings are still on the market today, and are approved for most dry, surface installations,



Metal moulding through floor protected by iron pipe.

PLASTER

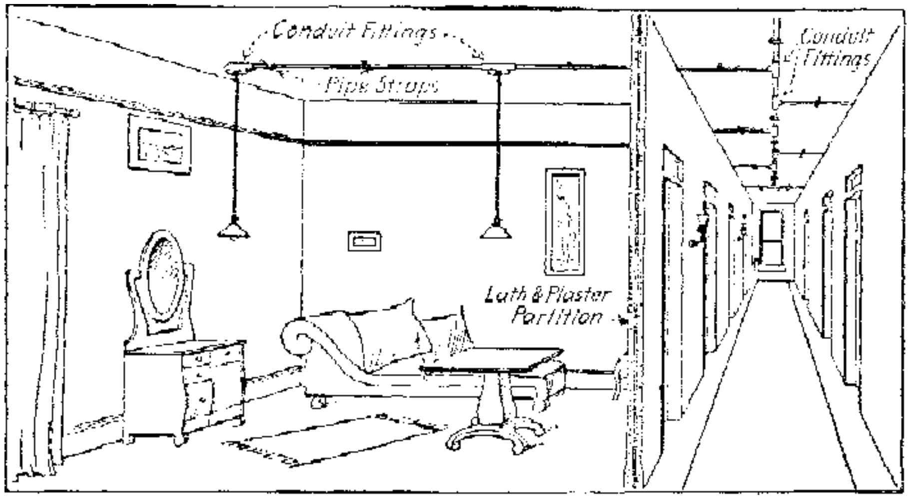
Embedding wiring in plaster or masonry was, both figuratively and literally, a short-lived technique. Even in 1897, the Edison Illuminating Company noted it was "peculiar to modern fireproof building construction, and is rather more popular than its merits deserve "

Wiring in plaster was supposed to produce a high-quality concealed job. The method was straightforward: insulated wires were simply mortared over while running cornices. repairing or finishing walls, or laying brickwork. Besides making faults nearly impossible to locate and messy to repair, this kind of wiring was doomed technically. The lime in either plaster or brick mortar decomposed the insulation, rendering the system highly dangerous, The National Electrical Code stopped recommending wiring in plaster by 1901,

CONDUIT

Conduit and pipe, always considered the hest wiring methods money could buy, had a limited appeal for houses because they took, roughly, twice the money to buy.

Rigid conduit (fig. 13), made from nonmetallic fiber for brief early period, was primarily iron or steel piping. The plumbing of gaslight systems undoubtedly spawned the idea of protecting electric wiring with pipe and, indeed, wires were snaked through defunct gas pipes in countless retrofits, In time, the same gauge pipe and fittings, galvanized or enameled on their interiors, were also used for new work.



An *exposed conduit*

Flexible steel conduit (fig. 14), also known as **Greenfield** after the inventor of one model, was manufactured from galvanized steel strips assembled in a manner that allowed the finished "pipe" to be readily articulated in almost any direction. In use, it was first run through walls and voids, secured at bends, and then snaked with wiring to complete the installation.

Flexible conduit appeared at the turn of the century, and seemed to be provide an unbroken electrical path (as a continuous wire or pipe might), and rust or poor connections along the way could become high-resistance "hot spots" that might heat to the point of combustion. Modern versions of flexible conduit are extensively used, subject to local code requirements.

ARMORED CABLE

Similar in concept to flexible conduit, armored cable (fig. 15) came prefab-

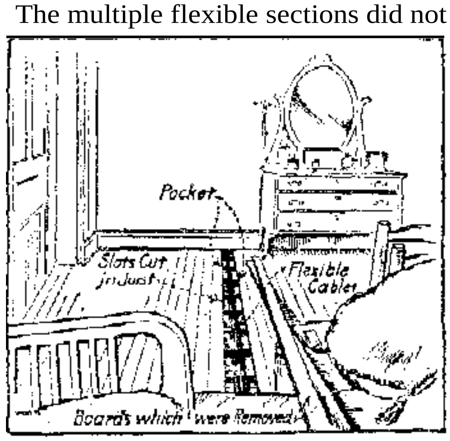
jig 73

.fig- 14

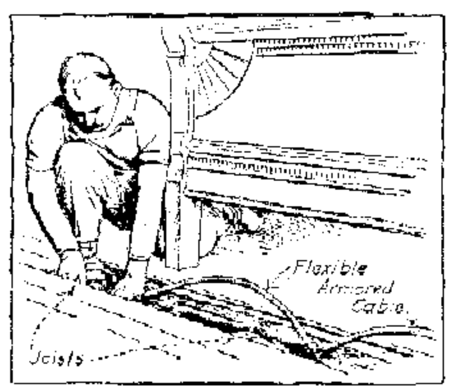
fig. 15

Rigid conduit provided excellent mechanical protection for the wiring, but it could develop electrical faiths. Plumbing that once served as gas lines might retain moisture that would rust the interior of the pipe. This in turn would deteriorate the electrical insulation of the wiring (rubber with a double fabric braid), and the bare copper conductor would come in contact with the metal pipe. If the pipe was resting on damp wood, a short was likely and fire possible. For this reason, all conduit systems were required to be grounded at two locations. Coating the interior of pipes to inhibit rust was a -rep toward improving this safety problem, but highly reliable conduit wiring _ad to wait for the introduction of vinyl i-sulation after 1940. The acceptability - early rigid conduit systems for use - Jay is dependent upon local codes.

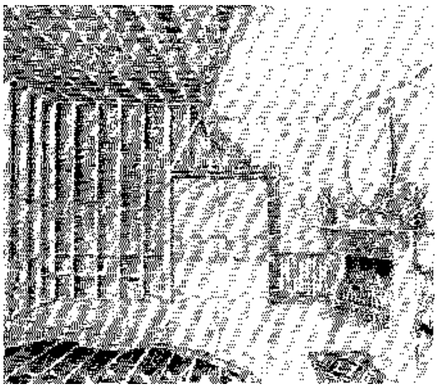
an ideal means to wire a finished building. It provided good mechanical protection for the wiring, it was well adapted to retrofit installations and it was easy to work with. Like rigid conduit, though, there was a potential for problems if the wiring insulation failed and sought a ground through the steel. The multiple flexible sections did not



ricated with the wiring in place and protected by a continuous spiral galvanized-metal strip. Cable was made practical by (and relied upon) improved insulation compounds that staved intact when bent in tight turns, The popular versions were known as BX and BXL (which had an interior lead sheath for damp applications).



Rust, again, is early armored cables worst enemy. The sheet-metal armor was ungalvanized along its edges after cutting ("much like metal moulding), and rusted over time. Like flexible conduit, hot spots and sparks were found to develop along the spiral if it should accidentally become a ground path. Years later, the problem was compounded in many installations by hooking up the armor as a working, "third



never intended to perform. The dangers of this practice led to code restrictions for 13X in the past. Today, armored cable is manufactured with continuous ground conductors and rust-inhibiting armor, and is approved by the National Electrical Code for dry residential applications (fig. 16).

INSULATION, CURRENT-CARRYING CAPACITY, AND GROUNDING

INSULATION

Electrical insulation, always the Achilles heel of early wiring, is no less of a problem as these systems age. Mr. Edison resorted to cloth strips soaked in linseed oil, asphalt, and wax after laying bare wires in wood tracks (underground) failed miserably, Prepared papers and varnished cloths in the 1800s had a fair tolerance to heat (about 150 degrees), but succumbed to moisture. Natural rubber compounds stood up to water, but melted in heat and oxidized (dried out and cracked) in air. Care and caution can improve the safety of old insulation still in use.

■ No old insulation can withstand the effects of moisture. Old wiring in damp locations should be replaced.

■ Rubber insulation (the standard before 1930) seems to have a life of about 25 years, so any such system still in use is operating beyond its expectancy. In this light, disturbing old wiring is very risky, as it can crack or break off insulation that is no longer supple, exposing bare copper wire. Extreme care should be taken when altering or even inspecting old lines.

■ Rubber insulation deteriorates more rapidly in open air than when confined in a conduit, say, or armored cable assembly. Therefore, most of the insulation on open wiring systems (like knob and tube) is frequently very brittle and a potential hazard. Confined wiring, on the other hand, may only be cracking where it leaves its enclosure to make connections at switches and outlets. These leads can be improved by wrapping with vinyl electrical tape or covering with heat-shrink tubing, In the case of armored cable, it is often possible to cut back to fresher insulation if there is enough slack in the cable, (Power must be disconnected before performing either of these operations.)

CURRENT CARRYING CAPACITY

Old wiring has limited current (amperage) carrying capacity, Most pre-1940 systems were only intended to power lights and the odd radio, refrigerator, Waffle or curling iron. Their branch lines are commonly #14 wire, which is rated to carry no more than 15 amperes of load. (In contrast, the general service wiring of contemporary houses is frequently #12 — a size larger.) To avoid a fire hazard, it is important to make sure that old wiring isn't overloaded by today's complement of air conditioners and microwave ovens.

■ The combined wattage of all the lights and appliances on a branch circuit should not exceed the wattage rating of the fuse (or circuit breaker) protecting that circuit. For example: watts = amperes X volts; therefore, a 15-ampere fuse (multiplied by 115 volts, the usual figure) should not have to handle more than 1,725 watts.

■ The fuse protecting any circuit should be appropriate for the gauge or the wiring. Oversize fuses (installed in an attempt to get more capacity from the circuit) allow a line to carry more current than it is designed for, with overheating and fire as a potential result, To determine the correct fuse size for old wiring, first disconnect the power, then measure the diameter of the copper conductor with a wire gauge (fig. in and apply this table:

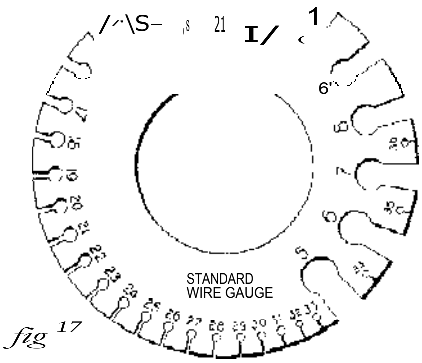


fig 17

Wire Size	Maximum Fuse Size
#14	15 Amperes
#12	20 Amperes
#10	30 Amperes

■ The current-carrying capacity of concealed knob-and-tube systems depends on the circulation of free air around the wiring; it should not be surrounded with weatherproofing materials. When wall and attic spaces containing knob and tube are packed with rolled or blown-in insulation, the wiring is forced to conduct at a higher temperature that can break down old electrical insulation and start tires,

GROUNDING

A ground-continuity test is valuable for determining if the safety leg on three-pin outlets actually is connected to ground. Since the 1950s, the National Electric Code has required that new domestic wiring be three-wire/grounded, but many three-pin outlets have also been retrofitted to old BX and conduit systems using armor or pipe as the ground conductor. To make sure the electrical path is not interrupted by breaks or loose connections, the ground can be checked either by an electrician, or by using simple test devices like those on page 70.