The Ubiquitous Coaxial Connector

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Connectors . . . can't live with 'em, can't live without 'em. Coaxial connectors, especially, are a real bugaboo for many hams faced with the challenge of installing them in a proper, professional manner and trying to keep the weather elements out of them for any length of time.

Fear not! Coaxial connectors are truly easy to install properly—it just takes the right tools and training (like any job). Luckily, the right tools are likely to be in your own toolbox, or at least at the local discount hardware store. Let's start with the most popular connector in amateur use for 1.8 through 220 MHz, the "UHF" type PL-259.

PL-259 "UHF" Connectors

PL-259 "UHF" connectors are so named because way back when they were invented, any frequency above 100 MHz was considered to be Ultra High. These were the frequencies of our earliest radar systems, and little work had ever been done, except by pioneering experimenters, above this frequency range. Since that time, we have redefined our spectrum to divide it up in "decade" (factors of 10) ranges, and UHF is now defined as 300 through 3,000 MHz. ("VHF," the next decade range below, is defined as 30 through 300 MHz; "SHF," the next decade range above, is defined as 3,000 through 30,000 MHz; etc.).

In any case, UHF connectors are badly misnamed because they really don't work at all well in the real UHF spectrum and their use should be confined to the MF (medium frequency), HF (high frequency, or 3-30 MHz) and VHF ranges. The reason PL-259s work so poorly at Ultra High frequencies is that they are not constant-impedance devices and their physical dimensions are such that they can appear as quite an impedance "bump" (or discontinuity) in the UHF range.

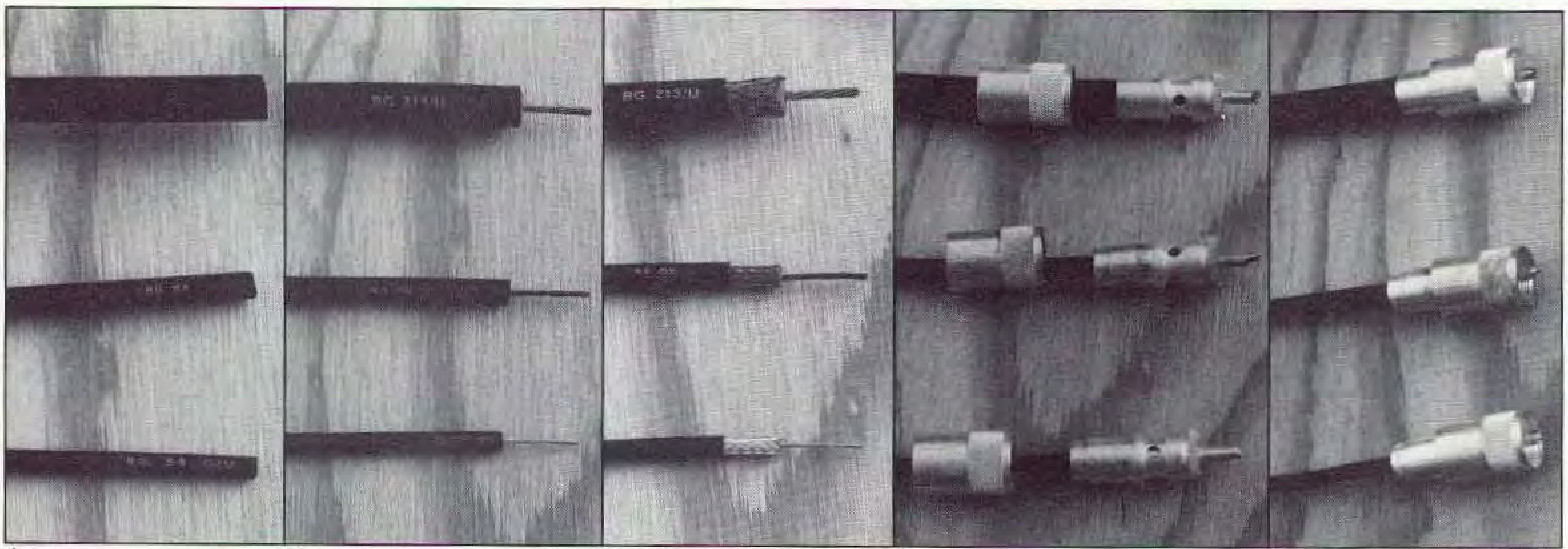
This bump can cause attenuation, which of course is normally undesirable, so PL-259s are best used in the frequency ranges where their impedance discontinuity will be of no consequence. (The bump is created by loose mechanical tolerances in the PL-259 connector design, as well as by variations in the dielectric materials used, construction by different manufacturers, and so forth.)

So, now that we know where we should be using UHF connectors—or at least where their inadequacies can be tolerated—let's install one on a cable.

The PL-259 is designed to accommodate coaxial cables measuring 0.405" outside diameter, like RG8A/U, RG213/U, etc. The rear (cable-entry) end of the connector *body* has internal threads which allow the connector to be literally screwed onto the mating cable's jacket, making a secure mechanical connection prior to any soldering operations. If you have been installing PL-259s *without* screwing the connector body onto the cable jacket, you've been doing it wrong, and the results can be devastating to prolonged performance.

PL-259s can also be modified to accommodate the smaller-diameter cables, like RG58/U (and A/U, C/U, etc.), RG59/U and RG8X (or RG8M) "mini-8" cables. This modification involves using the correct "reducer" size, type UG175/U for RG58 and UG176/U for RG59 or RG8X, which is screwed into the rear end of the connector body as part of the assembly operation, and prior to any soldering. Whether using the larger-size cables (0.405" o.d.) or the smaller-size cables (which are 0.195" or 0.242" respectively), the rear-end internal threads in the connector body are *always* used.

UHF connectors are available in a variety of construction materials and finishes, but the essential dimensions should always be the same. Popular finishes include bright nickel ("Astroplate" from Amphenol, for example), silver plate, and gold flash. Popular dielectric materials include Rexolite, Phenolic and Teflon. Combinations of plating finishes can be found in a single connector. I find the easiest ones to work with are silver-plated (at least the *body* should be silver-plated, if not the connector shell), with Teflon dielectric. The reason for this is that



A B C D E

Photo 1.

the silver-plated body accepts soldering at a lower temperature than nickel-plated connectors will, making the soldering operation a much easier job; and the Teflon dielectric will withstand soldering heat better, and be less hydroscopic (will absorb moisture less easily) than other materials. The silver-plated Teflon-dielectric connectors cost a bit more than other constructions, but I find they're usually worth the small amount extra.

Installation

To do a professional job in the installation of a PL-259, you'll need an X-acto knife or a sharp single-edged razor blade (sold in wallpaper/paint shops for a few cents each in boxes of 24 or so), a sharp pair of scissors, similar to manicuring scissors (available in stainless steel for about $5), and a heavy-duty soldering iron, usually a "gun," rated at 260 watts or more, like the Weller D550 or equivalent. It doesn't pay to try using a smaller soldering gun because the heat transfer to the connector will take too long and can cause damage to the cable. If you can't heat up the connector body to the solder-melting point (about 230 degrees C for standard 60/40 alloy solder) in just a few seconds, you're taking too long and will be frustrated. You'll also need some rosin-core solder, usually 60/40 (tin/lead ratio) or 63/37 alloy, 0.047" or 0.050" diameter. The most expensive item here is the big soldering gun, which could cost as much as $50 or so if you don't already own one.

Prepare to work on a *non-metallic* surface because a metal surface will act as a heat sink and draw heat away from the connector so rapidly that soldering will become a difficult task. I do most of my PL-259 soldering on a slab of ceramic (like a large piece of ceramic tile from a bathroom, kitchen or foyer floor—available for free as "scrap" or "sample" from most flooring shops). Ceramic is an excellent material because it will withstand very high temperatures without burning and is a lousy heat sink.

Prepare the cable end for installation of the PL-259 as follows:

(1) Slide the connector "shell" or "nut" over the end of the cable, with its internal threads facing towards the cable end, and push it far enough down the length of cable so that it's out of the way.

(2) Use the razor blade to cut all the way through the cable jacket, braid, and dielectric materials, stopping at the copper center conductor (you can feel it when you hit this obstacle), using vigorous pressure at first to cut through the braid, then lighter pressure as you slice through the dielectric. Don't use so much force that you cut into the center conductor with the blade. If, after you're done, inspection reveals that you *have* cut into the center conductor a bit, cut off and discard this piece of cable and chalk it up to experience, then try again. With a bit of practice it is easy to know how much pressure to use and to stop applying pressure as soon as the blade touches the center conductor. Perform this operation at 5/8" (0.625") from the end of the cable. Once you've successfully sliced through in one spot, hold the razor blade in a fixed position with one hand and rotate the cable 360 degrees so that it cuts in a similar manner all the way around the cable.

(3) When you're done, pull off the piece you've just sliced through, exposing 5/8" of undamaged center conductor (Photo 1B).

(4) Now use the razor blade to slice through *only* the cable jacket, which will not offer much resistance to penetration at all. Do *not* use enough force to cut into the braid material. Make this cut another 5/8" down the cable, or 1-1/4" from the end of the copper center conductor. Rotate the cable 360 degrees again, this time slicing through only the outer jacket material. When you're done, pull off the jacket material you've just sliced through, exposing 5/8" of nice, undamaged braid material (Photo 1C).

(5) Inspect the exposed cable end to be sure no braid "hairs" protrude beyond the freshly-cut dielectric material, risking short-circuiting to the center conductor. With practice, you'll find there won't be any hairs, especially if you use a new, sharp razor blade. If any braid hairs protrude beyond the dielectric and look like they might short circuit to the center conductor, use the small, sharp scissors to cut them off, one by one.

(6) Now, line up the connector body with the end of the prepared cable so that the center conductor will center itself with the 0.150" diameter center pin of the plug. If your coax has a stranded center conductor, inspect the strands to make sure they are tightly wound together, with no "rogues" sticking out. If any strands *are* sticking out, gently twist them back together by spiraling *in the same direction* as they already were in the fresh coax, making a neat, tight bundle for the center pin.

(7) Next, begin inserting the connector body onto the prepared cable end, twisting the body clockwise as you push gently on it. You'll find that within a very short distance the internal threads in the rear end of the connector body will "grab" the jacket material and bite into it quite well, resisting the rotation. Continue to gently push on the connector, while rotating it clockwise, until the cable is firmly "seated" inside the connector and no further progress can be made. At this point the center conductor should protrude slightly (about 1/8") from the end of the center pin hole (Photo 1D).

(8) Now you're ready to solder! The cable braid should be showing through all four PL-259 body "holes," which are there precisely for soldering. Place the connector down on your soldering surface with one body hole straight up, and place a gentle weight on the cable a few inches away from the connector to hold it in place. A heavy book is a good weight. Don't clamp the cable in a vise or anything that can crimp it too hard. Coax is fragile stuff. Pull the trigger on your soldering gun, and wait a few seconds for the tip to heat up to soldering temperature, which will usually be indicated by a bit of smoke coming from the tip. Holding the solder in the other hand, apply the gun's tip to the connector body, right over the soldering hole, and hold it firmly in place for a few seconds to allow the connector to heat up. Now apply a small amount of solder to the joint between the iron's tip and the connector body, and wait a few seconds for it to flow. Once the solder has flowed, move the iron's tip just a small distance (maybe 1/16") out of the way so the connector hole and braid are exposed, and feed the solder right into the hole. Wait another few seconds for the solder to flow into the hole and completely cover the braid and the hole. When the solder has flowed properly it will look bright and shiny, even after you pull the iron away.

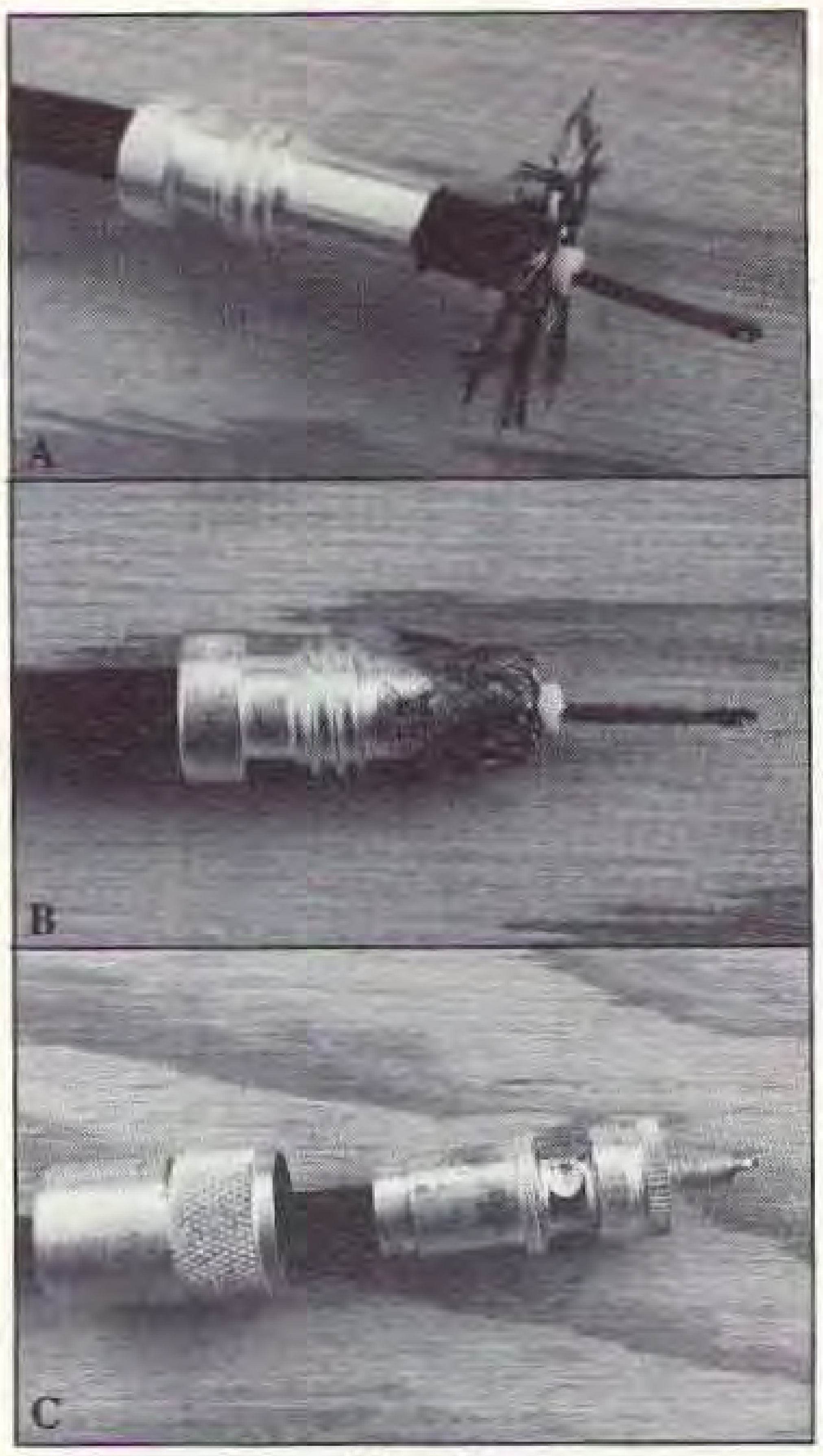


Photo 2.

(9) Now, rotate the connector 90 degrees and do the same thing in the next solder hole. This one will go much faster because the connector is already very hot. So hot, in fact, that you could burn yourself on it if you're not careful. (Some might want to use heat-insulating gloves for this whole operation to help prevent minor burns.)

The second solder hole should fill up in just two to three seconds. Now, rotate the connector body 90 degrees again and do the same thing in the third solder hole. Again, this should happen very fast because the connector is already at soldering temperature. Then, rotate 90 degrees again, and fill up the last solder hole with solder.

If you're doing it right, the whole soldering operation should take maybe 30 seconds or so. If it's taking longer than this, it's taking too long and one of the following might be occurring:

a.) Your working surface is drawing heat away from the connector—remember, don't do this on a metal surface!

b.) Your soldering gun isn't powerful enough. Try a bigger one—although the 260 watt model should be sufficient.

c.) Your connector body is not silver-plated, but it is plated with other metals that do not "wet" as well as silver. Or, maybe the connector is oxidized, in which case it should be thoroughly cleaned prior to use.

d.) Your solder is weird, and either lacks a rosin core (which is essential to dissolve oxides that form in the soldering process), or is some higher-temperature alloy. Check it out.

e.) You're not applying enough pressure between the soldering iron's tip and the connector body to get good heat transfer.

10) Take a short break to let the connector and cable cool off a bit. To accelerate this process, I often use a brief squirt of "circuit cooler" (available in any electronic parts store). These "coolers in a can" are made of chlorofluorocarbons (if you don't care about the environment) or chlorodifluoromethane (if you do) and release an *extremely* cold spray (so cold, in fact, that it can damage your skin if exposed directly), so if you choose to use it, be careful. A brief (two-second) squirt of this stuff will bring down the connector temperature very well, and it helps accelerate the process. If you don't want to use the cooling spray, wait a minute or so for the connector to cool down before proceeding. This is mostly to prevent damage to the cable dielectric, which will also be very hot and could deform if the cable and connector are handled prior to a cooldown period.

(11) Now you're ready to solder the center pin. Use the gun again, applying the tip to the junction of the wire conductor protruding from the pin and the pin itself. Apply a small amount of solder, and when it starts to flow, move the iron's tip slightly down the *side* of the pin to draw the solder down into the connector pin. Add just a bit more solder at the tip, and cover the exposed wire conductor and the opening in the end of the connector pin so there are no holes or gaps here. This operation only takes a few seconds to complete because the center pin is a much smaller heat sink than the connector body.

Wait several seconds for the pin to cool off. Use a sharp diagonal cutter to cut off any extra wire conductor protruding beyond the end of the connector pin. Then wipe the whole pin down with solvent (alcohol, trichlor, flux remover or whatever) and a soft cloth to remove any residual soldering flux. Inspect the pin for any excess solder that might have flowed down the outside of the pin. If there is any (with practice, there *won't* be), use a nail file or fine-grit emery cloth to remove the excess solder. (*Don't* use a large file or rasp, or large-grit cloth, or you risk removing all the silver plating from the pin, which will cause it to oxidize much more rapidly, leading to potentially disastrous results in the field.)

At this point, you're finished, and, if you have used the spray cooler in step #10, the entire installation should have taken less than 90 seconds from beginning to end. If you waited for a "room temperature cooldown" it probably took more like 120 to 150 seconds. Under no circumstances should this operation consume more than 2-1/2 minutes, and with practice it will go faster and you'll still get professional results.

(12) Slide the PL-259 "shell" up the cable to the connector body, and screw it on to the connector body by twisting the shell clockwise onto the body. After a few twists, the shell should fall loose of the threaded area, enabling you to pull it all the way down the connector so the leading edge of the shell is about 0.150" back from being lined up with the end of the connector center pin (Photo 1E). That's it!

Modification for Smaller Cable

All the instructions thus far were for a standard PL259 assembly on to RG213/U or other 0.405" o.d. cables (RG8/U, etc.). A few modifications are required to the instructions if you intend to use the smaller cables which require reducers. Here are the modifications, in order (see Photos 2A, B and C).

Steps (1) through (5) remain the same. The changes for using UG175/U (for RG58-sized cables) or UG176/U (for RG8X cables) reducers begin with step (6).

(6) Slide on the appropriate reducer over the cable, with the large-diameter (big) end towards the balance of the cable and the smaller-diameter end facing towards the cable end you just stripped. The reducer should have a slightly snug fit over the cable jacket to work properly. If it slides on *too* easily (no force required at all), it will be difficult to make the connector assembly weatherproof. A too-loose fit indicates a non-standard reducer (check to be sure it's a real UG175 or UG176 type) or a non-standard (too small) cable diameter. This should *not* happen with mil-spec cables, but can occur with commercial types.

(7) Line up the small end of the reducer with the cut end of the coax jacket material so the reducer is flush with the cable jacket, where the exposed braid begins. Holding the reducer in this position with one hand, fold the braid back gently using your other hand. It will fold back easily. Gently pull it down, little by little, until it's all neatly folded back along the surface of the reducer. If you stripped the cable properly according to step (4), the braid strands should end exactly at the beginning of the threads on the reducer. If the braid strands end much *before* the threaded area of the reducer you didn't strip away enough jacket material in step (4) and you must start again. If the braid strands are so long that they overlap the threaded area of the reducer, they are too long and will interfere with the connector assembly. Trim the braid strands back neatly using the small, sharp scissors until they all end right about where the reducer threads begin. The objective here is to avoid having the braid strands pinched between the reducer and the connector body.

(8) You will now find that a lot of dielectric material is exposed between the folded-back braid and the beginning of the center conductor. This is normal. The dielectric must be further stripped off the cable, 1/16" maximum from where the reducer starts, leaving at most 1/16" of dielectric material showing when you're finished. This will leave the stripped (exposed) center conductor quite long, but there is no harm in this because the excess will be cut off.

Now, skip to the *original* step (7), as printed earlier in this article, and follow those directions, *except* that instead of screwing the connector body onto the coax jacket, you'll be screwing it onto the reducer. These threads will mate perfectly if the reducer and the connector body are properly aligned and "squared up" with each other. When the reducer is fully threaded into the connector body, it should push tight up against the connector body, leaving no space between the reducer "nut" (large-diameter part of the reducer) and the connector body itself. If there's any space at all here, the reducer is not properly seated in the connector and this will present a problem with regard to completing the assembly, making it work, and making it weatherproof.

Continue with the assembly procedures detailed in the original steps number (8) through (12). If you have followed these directions precisely up to this point, the cable braid should be exposed through all four connector body soldering holes and the soldering and final assembly operations will be the same as for installing a PL259 onto RG213/U.

Final Notes

My directions differ slightly from those shown in the *ARRL Handbook* and other texts written on this subject in that I instruct you to cut braid and dielectric off flush, so they are both the same length (for the RG213/U assembly), rather than leaving some dielectric exposed between the end of the braid and the start of the exposed center conductor. From my 27 or so years of experience installing probably ten thousand of these connectors, my way works better and will result in a more rugged, reliable assembly. There is *no* risk of producing a short circuit in the cable using my method, if it's done properly, so there's no reason at all to leave any dielectric exposed at the end of the braid.

The photographs accompanying this article show how things look as they're going together, and how they should look when you're done. A properly-installed PL259 is so strong that it cannot be pulled off the cable even with a few hundred pounds of tension. When performing the "pull test" on my cable/connector assemblies (that is, pull on the connector until something breaks!), I can always stretch and break the cable itself before the connector comes off the cable.

When performing step (2) of these instructions, where you use the razor to cut all the way through the jacket, braid and dielectric, but stop short of cutting into the center conductor, you will probably find it takes some practice to determine where to stop cutting and avoid damaging the center conductor. That's fine! Use a scrap piece of cable and make several cuts until you know just how much pressure to apply to get this right. In time, you'll get the "feel" of this, and then in the future it will be a breeze! Razor blades and knives are very sharp and even a small nick can cut a very deep gash in your flesh. You might want to use workman's gloves to help prevent cuts, or at least keep some Peroxide solution and Band-Aids handy to patch yourself up quickly in the event of a mishap (I've only cut myself about a million times doing this.)

So much for PL259s. My next article will detail the installation of higher-frequency connectors, the popular Type "N" and "BNC," which are usable into the SHF spectrum. These are easier, not more difficult, to install than PL259s, because no soldering of the braid is required. 73