APPENDIX G: GROUNDING PV MODULES

Grounding PV modules to reduce or eliminate shock and fire hazards is necessary but difficult. Copper conductors are typically used for electrical connections, and the module frames are generally aluminum. It is well known that copper and aluminum do not mix as was discovered from numerous fires in houses wired with aluminum wiring in the 1970's. PV modules generally have aluminum frames. Many have mill finishes, some are clear coated, and some are anodized for color. The mill finish aluminum and any aluminum surface that is scratched quickly oxidizes. This oxidation and any clear coat or anodizing form an insulating surface that makes for difficult long-lasting, low-resistance electrical connections (e.g. frame grounding). The oxidation/anodizing is not a good enough insulator to prevent electrical shocks, but it is good enough to make good electrical connections difficult.

Underwriters Laboratories (UL), which tests and lists all PV modules sold in the US, requires very stringent mechanical connections between the various pieces of the module frame to ensure that these frame pieces remain mechanically and electrically connected over the life of the module. These low-resistance connections are required because a failure of the insulating materials in the module could allow the frame to become energized at up to 600 volts (depending on the system design). The *National Electrical Code* (*NEC)* requires that any exposed metal surface be grounded if it could be energized. The installer of a PV system is required to ground each module frame. The Code (110.3(B)) and UL Standard 1703 require that the module frame be grounded at the point where a designated grounding provision has been made. The connection must be made with the hardware provided using the instructions supplied by the module manufacturer.

The designated point marked on the module must be used since this is the only point tested and evaluated by UL for use as a long-term grounding point. UL has established that using other points such as the module structural mounting holes, coupled with typical field installation "techniques," *do not* result in low-resistance, durable connections to aluminum module frames. If each and every possible combination of nut, bolt, lock washer, and star washer could be evaluated for electrical properties and installation torque requirements, *and* if the installers would all use these components and install them according to the torque requirements, it might be possible to use the structural mounting holes for grounding.

New grounding devices are coming to market that will eventually ease the problems of module grounding, but until the module instructions address these devices, they do not meet the requirements of *NEC* Section 110.3(B).

Some US PV module manufacturers are providing acceptable grounding hardware and instructions. Japanese module manufacturers are frequently providing less-than-adequate hardware and unclear instructions. Future revisions of UL 1703 should address these issues. In every case, the module manufacturer's hardware and instructions should be used (where possible) to ground the module at the points marked on the frame. Starting in August 2007, UL Standard 1703 will require that the module manufacturer specify the specific grounding methods

that are to be used and either provide or specify the hardware to be used. These methods and the hardware will be evaluated during the listing of the module. It is likely that thread-cutting or thread-forming screws will no longer be used.

In the meantime, installers have to struggle with the existing hardware and instructions, even when they are poor. SWTDI has identified suitable grounding hardware and provides that information when installers ask about grounding—a frequent topic.

For those modules that have been supplied with inadequate or unusable hardware or no hardware at all, here is a way to meet the intent of the Code and UL Standard 1703.

For those situations requiring an equipment-grounding conductor larger than 10 AWG, a stainless-steel #10 screw, nut, flat washers, Belleville spring and lock washers can be used to attach an ILSCO GBL4 DBT, Burndy CL50-DB-T, or equivalent lug to the module frame at the point marked for grounding. See Figure G-1. Before attaching the lug to the module, a stainless-steel brush should be used to remove any anodization or oxidation from the aluminum module frame, and a thin coat of anti-oxidant film should be placed on the clean aluminum surface. Burndy Penetrox A-13 or equivalent should be used. The flat washers are required to prevent the lock washers from digging into the soft copper or aluminum. The Belleville washer provides uniform tension, and a torque screwdriver should be used for all electrical connections. See Figure G-2. Some new grounding lugs have been listed for use without the anti-oxidant compound since the design of the lug penetrates the oxidation. It is not acceptable to use the hex-head, green grounding screws (even when they a have 10-32 threads) because they are not suitable for outdoor exposure and will eventually corrode. The same can be said for other screws, lugs, and terminals that are not suitable for outdoor applications.

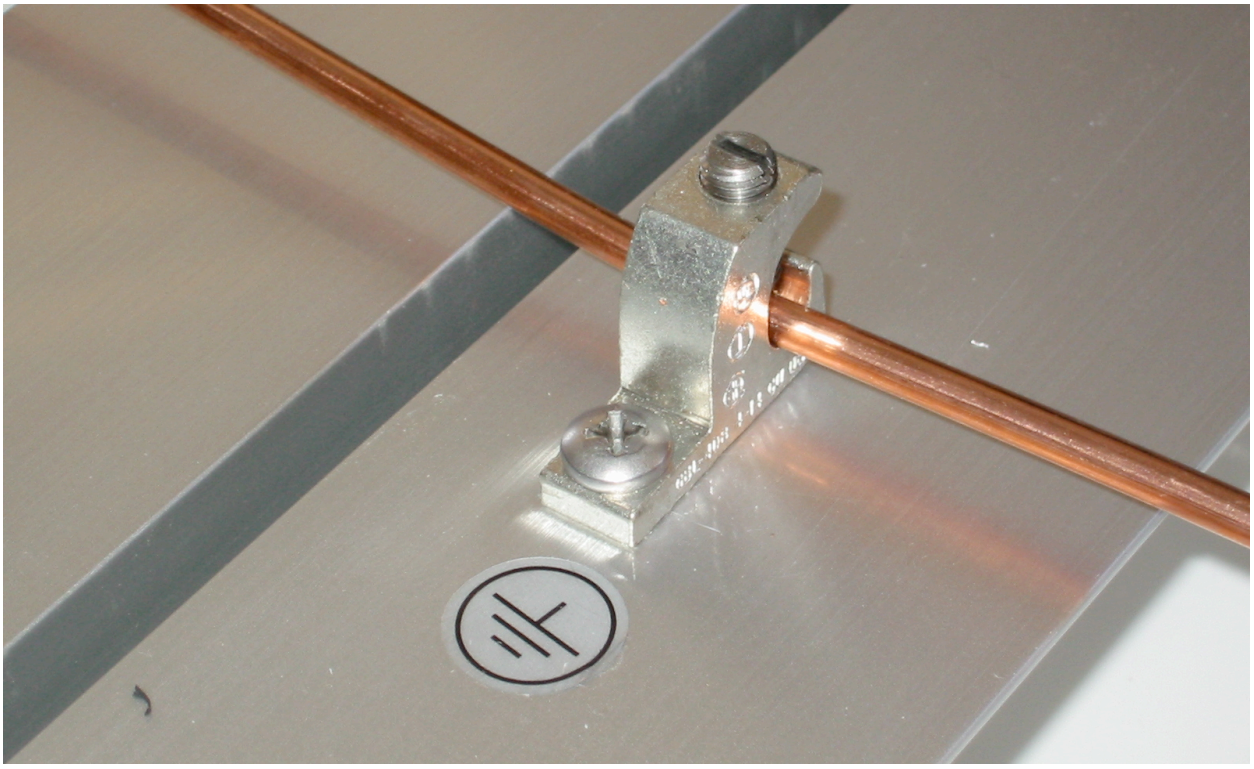

Figure G-1. ILSCO GBL4-DBT Lug

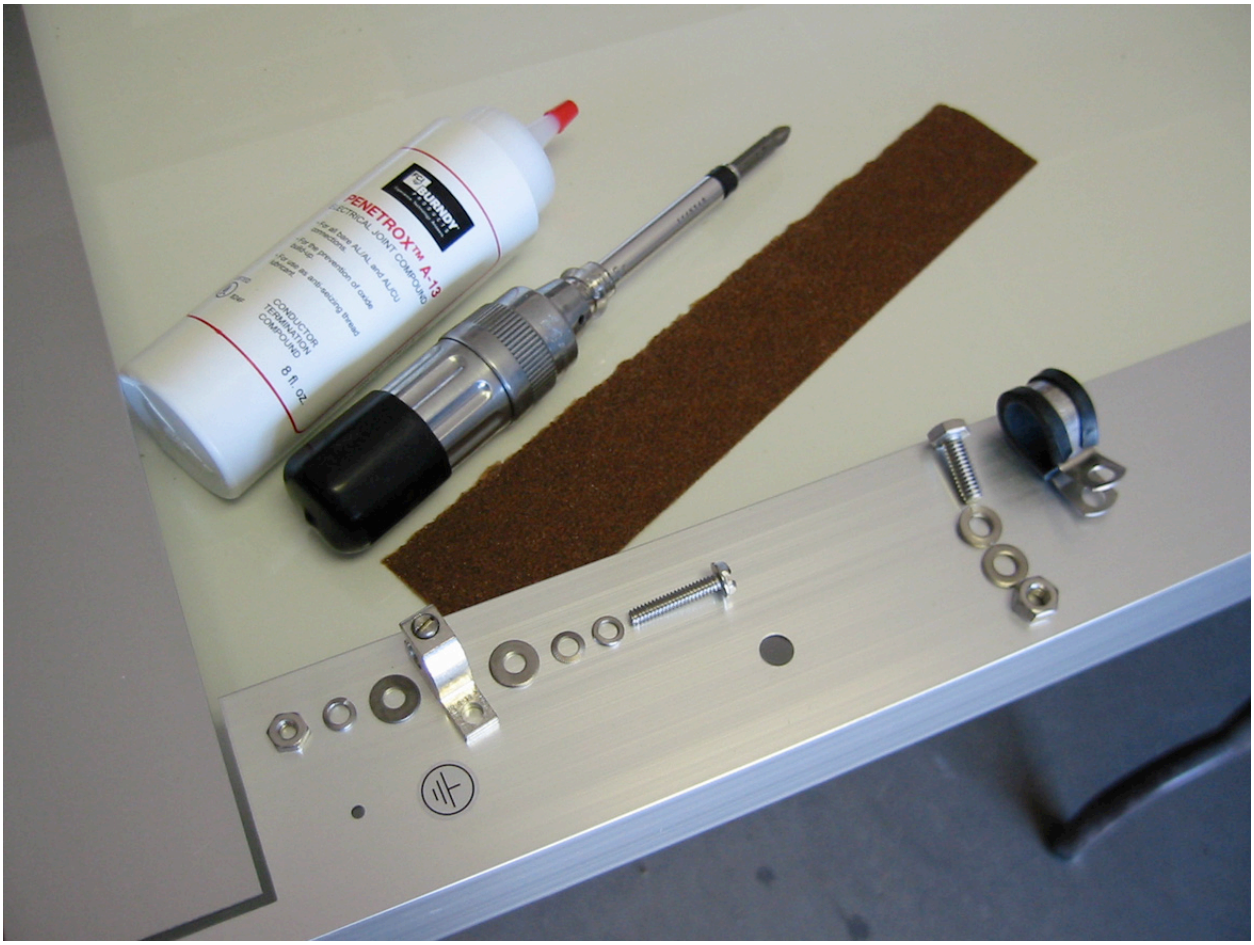

Figure G-2. Connecting Tin-plated Copper Lug to Aluminum

The ILSCO GBL4 DBT, the Burndy CL50-DB-T, and equivalent lugs are tin-plated, lay-in lugs made of solid copper with a stainless-steel screw. They accept a 4 AWG to 14 AWG copper conductor. They are listed for direct burial use (DB) and outdoor use and can be attached to aluminum structures (the tin plate allows this). The much cheaper ILSCO GBL4 lug and the Burndy equivalent look identical but are tin-plated aluminum, have a plated screw, and are not listed for outdoor use. If the module grounding is to be done with a 14 AWG to 10 AWG conductor, then the ILSCO lug may not be needed.

What size conductor should be used? The minimum Code requirement is for the equipment grounding conductor for PV source and output circuits to be sized to carry 1.25 times the short-circuit currents at that point. While this may allow a 14 AWG conductor between modules, a conductor this small would require physical protection between the grounding points. Some inspectors will allow a 10 AWG bare conductor to be routed behind the modules from grounding point to grounding point if the conductors are well protected from damage, as they would be in a roof-mounted array. If needed, an 8 AWG or 6 AWG sized conductor may be required (to meet the Code or to satisfy the inspector) and then the ILSCO lugs should be used.

It is desirable to use the module mounting structure for grounding. Rack manufacturers have been urged to get their products listed as field-installable grounding devices, and some progress is being made in this area. However, the module manufacturers will have to modify the instruction manuals to allow alternate grounding methods.

The Code allows metal structures to be used for grounding and even allows the paint or other covering to be scraped away to ensure a good electrical contact. Numerous types of electrical equipment are grounded with sheet metal screws and star washers. This works on common metals like steel, but not on aluminum due to the rapid oxidation.

Module manufacturers are being encouraged to make that aluminum connection in the factory and to provide a copper-compatible terminal in the j-box or on the frame as is done with the 300-watt Schott modules.

Unfortunately, many PV systems are being grounded improperly even when the proper hardware has been supplied. Figure G-3, a photo taken in March 2004, illustrates that even the proper hardware can be misused. Here, the stainless-steel isolation washer has been installed in the wrong sequence and the copper grounding wire is being pushed against the aluminum frame; this is a condition sure to cause corrosion and loss of electrical contact in the future.

Figure G-3. Improper Module Grounding