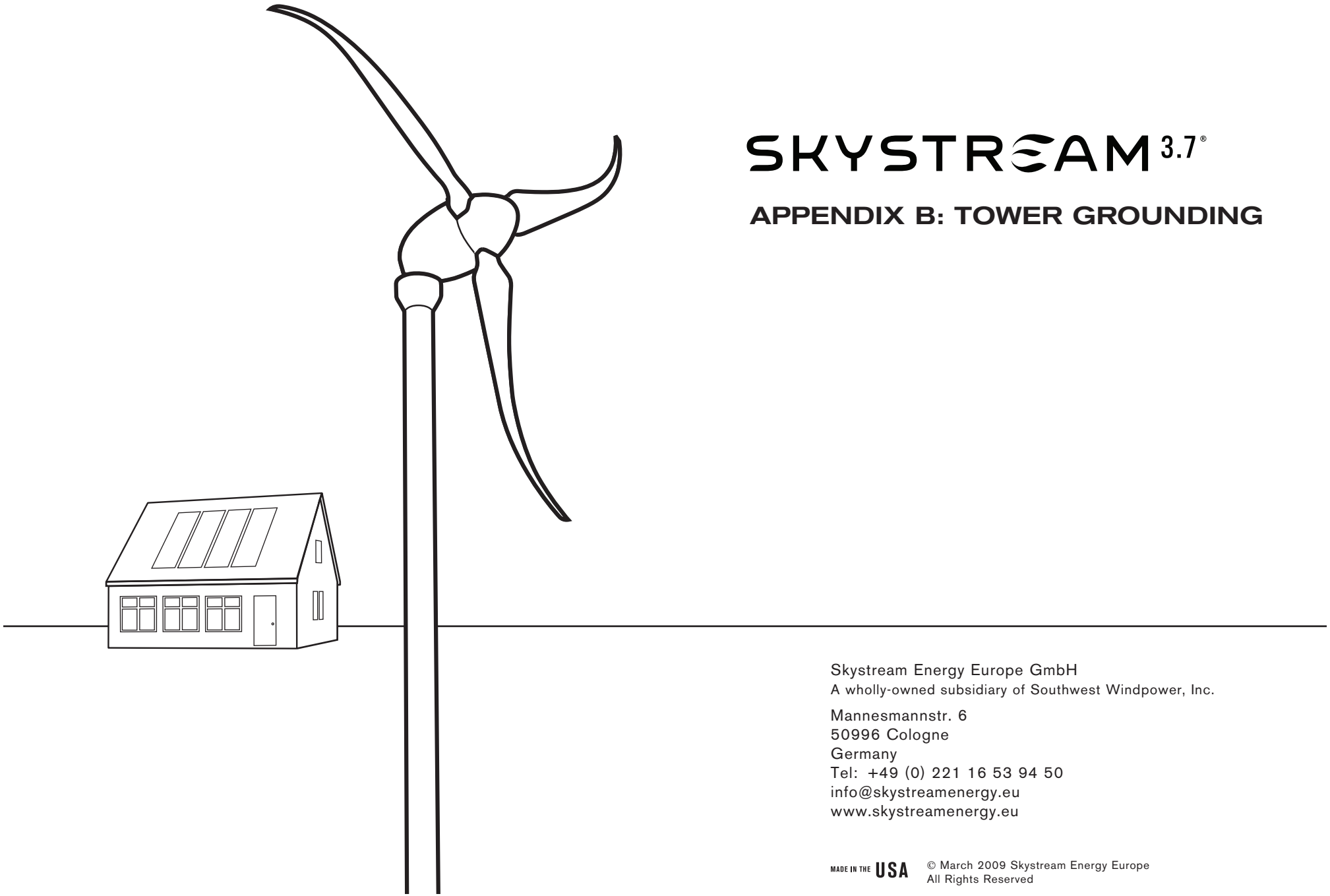

SKYSTREAM 3.7®

APPENDIX B: TOWER GROUNDING

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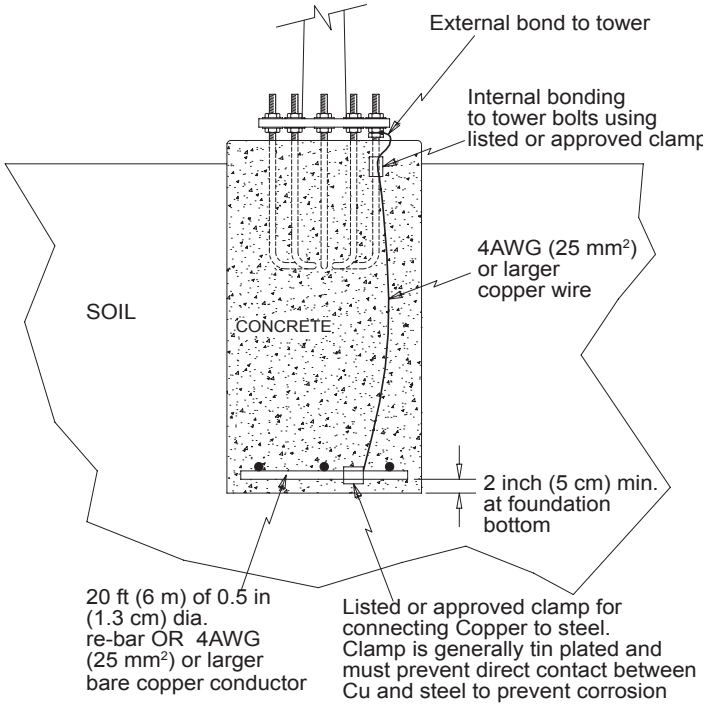
MADE IN THE USA

Skystream 3.7® Owner's Manual

Appendix B: Tower Grounding



IMPORTANT SAFETY INSTRUCTIONS

READ THESE INSTRUCTIONS IN THEIR ENTIRETY BEFORE INSTALLING.

Professional installation
highly recommended

1) SAVE THESE INSTRUCTIONS. This manual contains important instructions for grounding your Skystream tower.

2) Read these instructions in their entirety before beginning.

3) Do not start installation unless all required equipment and tools are on site.

In this guide

TIP: Helpful information to ease the installation

Professional installation
highly recommended

Warning: Risk of injury or death - proceed with extreme caution

One - Introduction

Even though the wind turbine is grounded at the service panel it must also be grounded at the tower base. Grounding the tower at its base may prevent electrical shocks, voltage surges and static charge build up. Proper tower grounding may also limit or minimize damage due to lightning strikes.

This document provides recommendations for grounding small wind turbine systems with rated line currents of less than 200A to achieve compliance with the 2005 USA National Electrical Code (NEC) as well as IEC (International Electrotechnical Commission) standard 60364-5-54 Selection and Erection of Electrical Equipment – Earthing Arrangements, Protective Conductors and Protective Bonding Conductors.

The grounding information contained in this document is provided as a reference. Please refer to the aforementioned NEC and IEC standards for complete detailed information. Local building codes and electrical standards may differ from the information presented here and have precedence over this document.

Two - Grounding Techniques

There are several tower grounding techniques compliant with NEC and IEC standards, this document presents two of the most common approaches:

- **Copper clad electrodes driven into the soil**
- **Electrodes encased in the concrete of the tower foundation**

2-1 Copper Clad Electrodes Driven Into the Soil

The figure 1 depicts a typical tower grounded using an electrode driven into the soil.

The tower may be grounded using a copper-clad electrode(s) of appro priate diameter and length. See the section entitled “Electrode resistance to ground” to determine the dimensions of the rod. The electrode shall be free from non-conductive coatings such as paint or enamel. Rod and pipe electrodes shall not be less than 2.5 m in length and shall consist of the following materials:

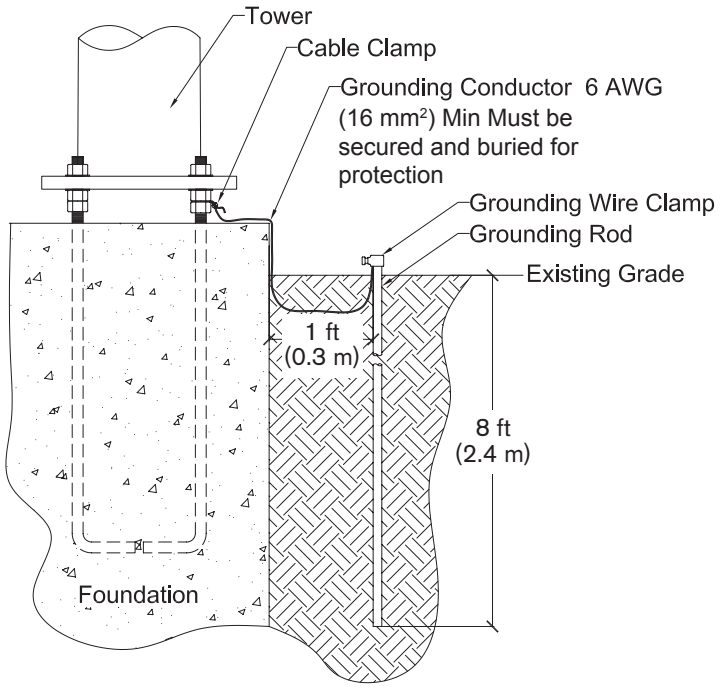


Fig. 1 Electrode driven into ground.

a) Electrodes of pipe or conduit (hollow electrodes) shall not be smaller than metric designator 21 (trade size 3/4) and, where of iron or steel, shall have the outer surface galvanized or otherwise metal-coated for corrosion protection.

b) Electrodes of rods of iron or steel shall be at least 15.87 mm in diameter. Stainless steel rods less than 16 mm in diameter, nonferrous rods, or their equivalent shall be listed* and shall not be less than 13 mm in diameter.

NEC section 250.52 and in accordance with the user's local electrical code authority.

*Be included in a list published by an organization (or marked as such) that is acceptable to the local authority having jurisdiction in the area. For example, UL/CSA listed in USA/Canada.

2-1-1 Grounding Electrode Installation

The following information is excerpted from the 2005 NEC article 250.53 (G). Refer to code for additional detailed information.

The electrode shall be installed such that at least 2.44 m of length is in contact with the soil. It shall be driven into undisturbed soil within 1 ft of the tower foundation. It shall be driven to a depth of not less than 2.44 m except that, where rock bottom is encountered, the electrode shall be driven at an oblique angle not to exceed 45 degrees from the vertical or, where rock bottom is encountered at an angle up to 45 degrees, the electrode shall be permitted to be buried in a trench that is at least 750 mm deep. The upper end of the electrode shall be flush with or below ground level unless the aboveground end and grounding electrode conductor are protected against physical damage as specified below (quoted from 2005 NEC article 250.10):

a) In installations where they are not likely to be damaged.

b) Where enclosed in metal, wood, or equivalent protective covering.

2-1-2 Electrode Resistance to Ground

The resistance to earth of a single ground rod can be calculated using Dwight's equation:

$R = [r/(2\varpi L)]x[\ln(4^{L}/R)-1]$, where r is the soil resistivity, L is the length of the rod buried inside the earth and R = radius of the rod; ln stands for the natural logarithm.

For calculating the resistance of the rod to ground, one must know the value of soil resistivity. This may be found in the local electrical code or building inspector's office/municipal office or by an actual soil resistivity test.

The resistance of a rod electrode to ground may be lowered by increasing the rod diameter, increasing the buried length of the rod or by treatment of the soil to reduce its resistivity.

If the single chosen electrode does not have a resistance to ground of 10 ohm or less, it shall be augmented by additional electrodes as necessary. The overall resistance of multiple rods to ground would roughly equal the resistance of a single rod to ground divided by the number of rods. Where multiple such electrodes are installed to meet the above requirement, they shall not be less than 1.8 m apart. The multiple rods must be bonded together using the grounding electrode conductor.

2-1-3 Grounding Electrode Conductor: Material, Size, Bonding to Electrode and Bonding to Tower

Material (Ref. 2005 NEC articles 250.62, 250.96(A).

The grounding electrode conductor shall be of copper, aluminum, or copper-clad aluminum. The material selected shall be resistant to any corrosive condition existing at the installation or shall be suitably protected against corrosion. The conductor shall be solid or stranded, insulated, covered or bare. Any non-conductive paint, enamel, or similar coating shall be removed at threads, contact points, and contact surfaces or be connected by means of fittings designed so as to make such removal unnecessary.

Note: Many local electrical standards do not permit the use of aluminum or copper-clad aluminum conductor and strictly require the use of copper conductors.

2-1-4 Conductor Size

(Ref. 2005 NEC article 250.66(A)):

Where the grounding electrode conductor is connected to rod, pipe or plate electrodes, that portion of the conductor that is the sole connection to the grounding electrode shall be a minimum of 6AWG copper wire or 4AWG aluminum wire.

2-1-5 Bonding the Grounding Electrode Conductor to the Earth Electrode

(Ref. 2005 NEC article 250.70):

The grounding or bonding conductor shall be connected to the grounding electrode by exothermic welding, listed lugs, listed pressure connectors, listed clamps, or other listed means. Connections depending on solder shall not be used. Ground clamps shall be listed (approved) for the materials of the grounding electrode and the grounding electrode conductor and, where used on pipe, rod or other buried electrodes, shall also be listed for direct soil burial.

2-1-6 Bonding the Grounding Electrode Conductor to the Tower

The grounding conductor may be connected to the tower by any one the following means:

2-1-6-1 Using a Tower Bolt/Nut Assembly

a) Pre-assemble the extra nut (supplied in the tower bolt kit) on one of the tower bolts containing nuts “A” or “B” as shown in fig. 2C of Skystream Foundation and Tower Installation Manual. Move the extra nut towards the bottom of the bolt so that it does not interfere with the nut to go on top of it.

b) Assemble the nut and washer on top as explained in the Installation Manual. Generously apply a listed “joint compound” to the sandwiching surfaces of the two nuts as well as to the tower bolt in question. The joint compound must be of the type to prevent corrosion between copper and galvanized steel.

c) Take one end of the grounding conductor and loop it once around the tower bolt containing the extra nut, between the upper and lower nut. Generously apply joint compound to the grounding conductor and cable clamp in the area of attachment. Secure the conductor with a cable clamp around the loop so that it just clears the tower nuts and keeps the loop snug around the tower bolt (see fig. 3). The cable clamp is required so that the ground wire does not slip out from between the nuts when the lower nut is tightened.

d) Ensure that surfaces of the lower and upper nuts facing each other are free of dirt and have very clean surfaces. If necessary, wash and clean these surfaces. This is essential for a good electrical connection between the ground conductor and the tower. Tighten the lower nut towards the upper nut applying sufficient torque (68 N-m minimum) to securely clamp the grounding wire (see **Fig. 3**).

e) Erect the tower and level it as required by adjusted any or all of the tower nuts. You may have to loosen the ground wire nut during this adjustment. After finished adjusting the tower level, re-tighten the lower nut to the suggested torque to make sure the ground wire is securely sandwiched and bound between the two nuts.

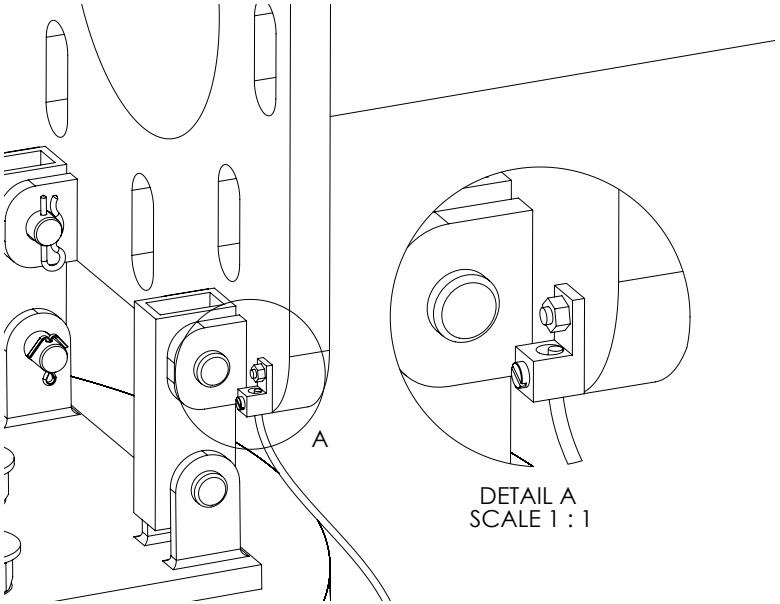


Fig. 2 Attaching the grounding wire to the tower base.

2-1-6-2 Using a Grounding Lug at Tower Base

Bond the grounding conductor to the tower base flange through a ground terminal lug attached to the tower base as shown in figure 2. Use a 1/4-20 x 1.75 in long stainless steel bolt through a hole in the tower base and a Nyloc stainless steel nut to fasten the ground lug to the underside of the tower base. The ground lug must be UL listed and must be type to that accommodates up to 1/0 AWG wire minimum.

2-1-6-3 Using Exothermic Welding

Bond the grounding conductor to the tower base flange by exother welding of the conductor to the base flange. Make exothermic welds strictly in accordance with the weld manufacturer's written recommendations.

Electrode conductor routing and placement / installation:
Ensure that the grounding conductor has no sharp bends in it. This is important to keep its inductance low. The grounding conductor may be buried or contained in a conduit as explained in 2005 NEC article 250.64.

2-2 Electrodes encased in the concrete of the tower foundation

(reference 2005 NEC article 250.52(A)(3))

A grounding electrode may also be encased in the concrete of the tower foundation. The electrode is located at the bottom of the foundation and connects to the tower mounting "J" bolts and to the tower base by means of a grounding conductor.

Because the grounding electrode will be encased in concrete it should be inspected and approved prior to pouring the foundation to avoid conflicts with local construction inspectors.

Two types of electrodes, their locations and their connection to the electrode grounding conductor are described below:

a) The Electrode must be at least 6.0 m of one or more (electrically connected by steel tie wires) bare or zinc galvanized steel or other electrically conductive coated steel reinforcing bars or rods of not less than 13 mm in diameter, located near the bottom of the concrete foundation that is in direct contact with the earth. The electrode must be encased by at least 50 mm of concrete as shown in figure 4. The reinforcing bars, if bare, must not be rusted at the time of installation to prevent bad electrical connection between bars and with the grounding electrode conductor. The reinforcing bars must be electrically connected to the anchor bolts either using the steel tie wires or using the grounding electrode conductor. The grounding electrode conductor must not be smaller than 4AWG copper and must be electrically bonded to the bottom reinforcing bars using listed/approved means that is suitable for concrete encasement. Sufficient extra length of the conductor must be available to bring it out of the foundation top and at least 46cm above the foundation top. It should then be bonded to the tower as described in section 2-1-6 of this document.

b) The Electrode must be least 20 ft (6.0 m) of bare copper conductor not smaller than 4AWG. The copper conductor, which may be in the form of a coil, must lie at the bottom of the foundation with either a 2-in thick (maximum) tamped fill of earth covering the grounding coil or covered in concrete a maximum of 2 in above the soil at the bottom of the foundation. Sufficient extra length must be present in the copper conductor to bring it at least 18 inch above the foundation top where it should be bonded to the tower as described in section 1.5 of this document. On its way up, the copper conductor must also be bonded to the tower anchor bolts using a clamp listed or approved means that is suitable for concrete encasement and also suitable for connecting copper to steel. This listed clamp is generally tin plated and must be of the type to prevent direct contact between copper and steel to prevent corrosion.

2-3 Bolting Grounding Lug to Tower Base

An alternate method of attaching the electrode grounding conductor to the tower is to drill a hole thorough the base and utilize a commercially available lug as depicted in figure 2. To connect the grounding conductor to the tower base using this approach drill a 0.25 in (6 mm) hole through the tower base. After joining the grounding conductor to the listed lug according to the lug manufacturer's instructions, bolt the lug to the tower base with a stainless steel bolt and self locking nut. The listed lug is generally tin plated and prevents corrosion between the galvanized steel tower and the copper conductor.

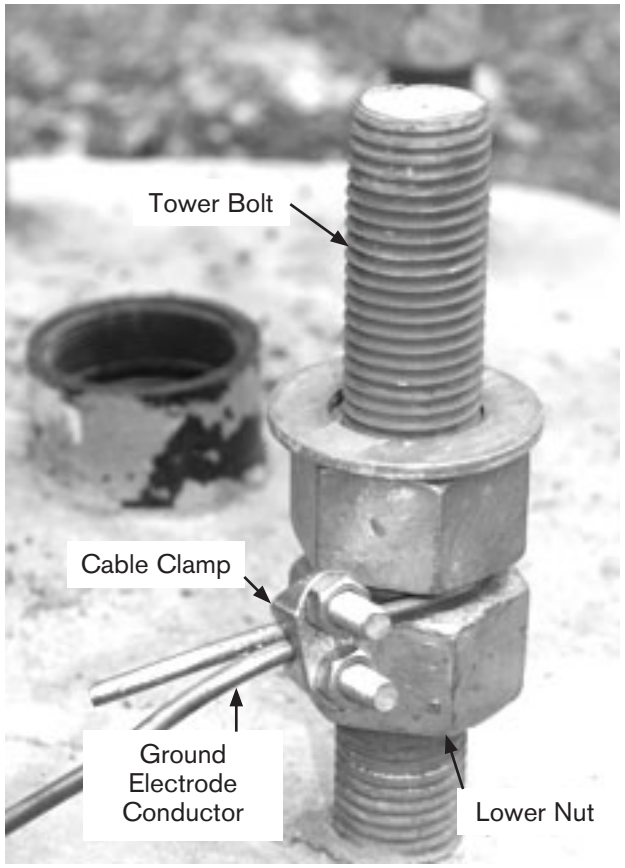


Fig. 3 Tower foundation bolt.

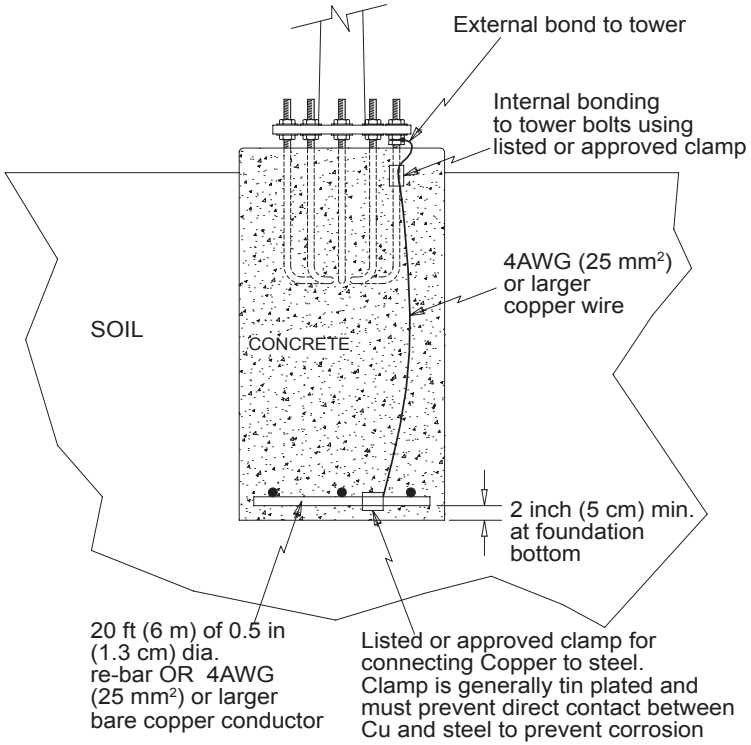


Fig. 4 Concrete encased electrode.