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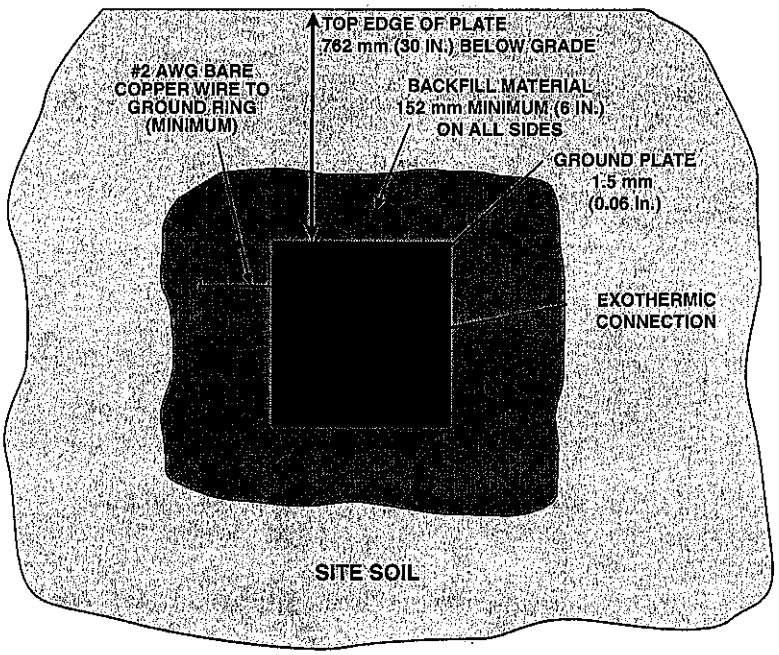

FIGURE 4-16 TYPICAL GROUND PLATE INSTALLATION

- A grounding electrode encasement material should be used to backfill around the ground plate to help insure effective contact with the earth (BS 7430:1998, clause 10). See "Grounding (Earthing) Electrode Encasement Materials" on page 4-27.

4.4.1.5 CONCRETE-ENCASED ELECTRODES

Though concrete-encased electrodes (also known as Ufer electrodes, named after Herbert G. Ufer, or foundation earth electrodes) are not required by this standard, they should be used in new construction as a method of supplementing the grounding (earthing) electrode system (IEC 61024-1-2, section 3.3.5). Concrete-encased electrodes (Figure 4-17) enhance the effectiveness of the grounding electrode system in two ways: the concrete absorbs and retains moisture from the surrounding soil, and the concrete provides a much larger surface area in direct contact with the surrounding soil. This is especially helpful at sites with high soil resistivity and/or limited area for installing a grounding electrode system. See IEEE STD 142-1991 section 4.2.3, and the International Association of Electrical Inspectors publication, *Soares Book on Grounding and Bonding*, 9th Edition, Appendix A for additional information. Requirements for a concrete-encased electrode, if used, are listed below (IEC 61024-1-2; NFPA 70-2005, Article 250.52; and NFPA 780-2004, section 4.13.3).

- Concrete-encased electrodes **shall** be encased by at least 51 mm (2 in.) of concrete, located within and near the bottom of a concrete foundation or footing that is in direct contact with the earth.
- Concrete-encased electrodes **shall** be at least 6.1 m (20 ft.) of bare copper conductor not smaller than 25 mm^2 csa (#4 AWG) or at least 6.1 m (20 ft.) of one or more bare or zinc galvanized or other conductive coated steel reinforcing bars or rods at least 12.7 mm (0.5 in.) in diameter.
- Concrete-encased electrodes **shall** be bonded to any other grounding electrode system at the site. See "Common Grounding (Earthing)" on page 4-5.

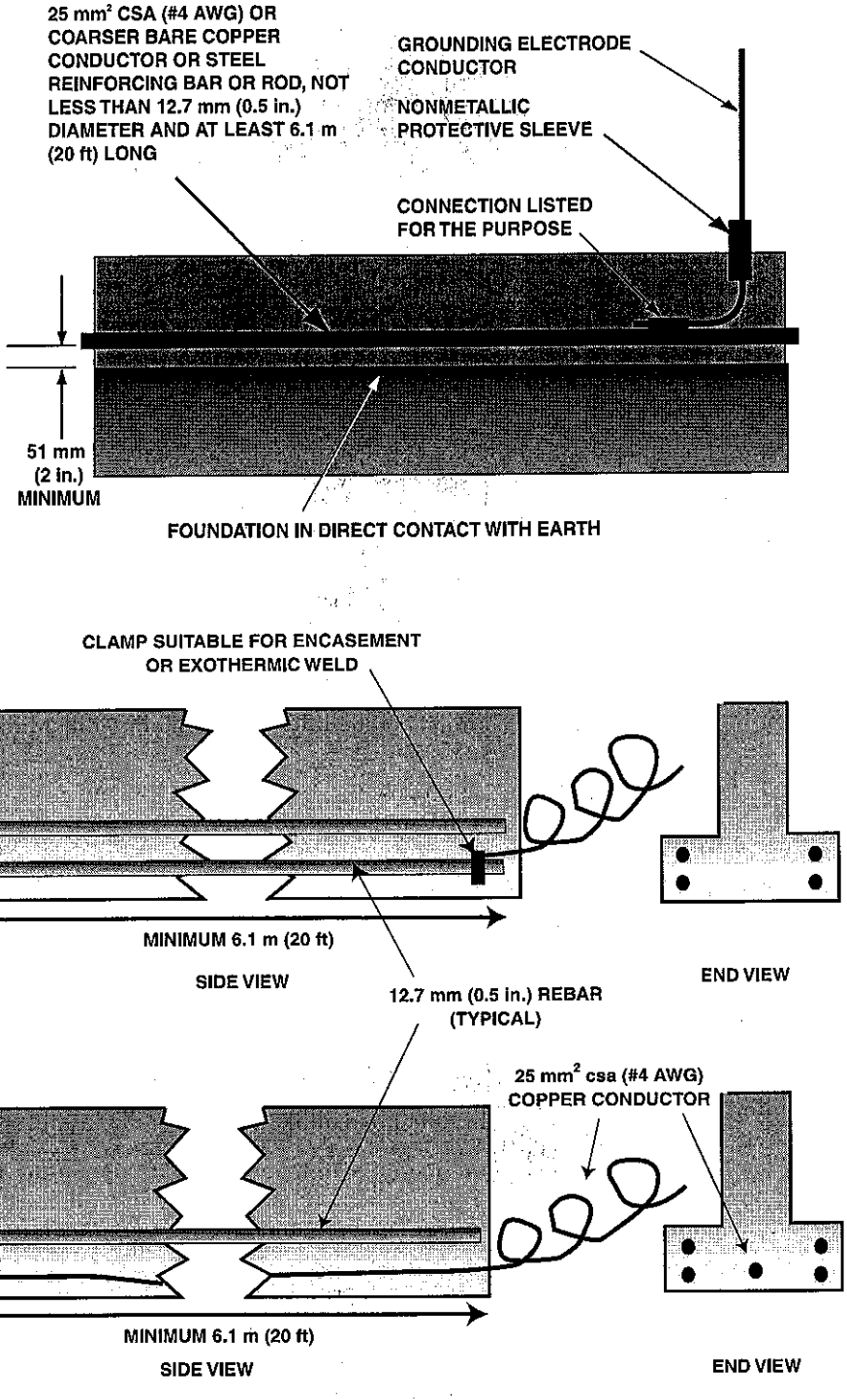

FIGURE 4-17 TYPICAL CONCRETE-ENCASED ELECTRODES

4.4.1.6 EXTERNAL BUILDING AND TOWER GROUND RING

The buried external ground rings (building and tower) provide a means of bonding ground rods together and bonding other grounding (earthing) electrode system components together, improving the overall grounding electrode system. The ground rings also help to equalize potential in the earth surrounding the tower and building structures, regardless of earth resistivity, by insuring that a low impedance current path exists throughout the area (ANSI T1.334-2002, section 5.3).

Requirement for external ground rings are listed below (see Figure 4-18):

- Unless otherwise stated, ground ring conductors **shall** be 35 mm^2 csa (#2 AWG) or coarser, bare, solid, tinned or un-tinned, copper (ANSI T1.313-2003 and ANSI T1.334-2002, section 5.3.1). See "Grounding (Earthing) Conductors" on page 4-28 for grounding conductor specifications.
- Solid, bare, tinned, copper conductor should be used to minimize galvanic corrosion between tower legs and other parts of the grounding electrode system (ANSI T1.313-2003, section 10.7).
- For areas highly prone to lightning, and/or military installations, larger conductors, such as 50 mm^2 csa (#1/0 AWG) or coarser, should be considered (MIL-HDBK-419A and MIL-STD-188-124B); stranded conductors may be used in this application.
- Building ground rings **shall** encircle the building or shelter whenever possible (ANSI T1.313-2003, ANSI T1.334-2002, MIL-HDBK-419A, and MIL-STD-188-124B).
- Tower ground rings **shall** encircle the tower structure whenever possible (ANSI T1.334-2002, section 5.3 and MIL-HDBK-419A).
- The ends of the conductor **shall** be joined together to form a ring using an exothermic weld or listed irreversible high-compression connector (ANSI T1.334-2002, section 5.3.1 and MIL-STD-188-124B). This may be easily completed at a ground rod.
- Building ground rings and tower ground rings **shall** be bonded together in at least two points using a 35 mm^2 csa (#2 AWG) or coarser, bare, solid, tinned or un-tinned, copper conductor (ANSI-J-STD-607-A-2002, section C.4.7, ANSI T1.334-2002, figure 1, and MIL-STD-188-124B). The conductors should be physically separated as much as practical. See "Common Grounding (Earthing)" on page 4-5.

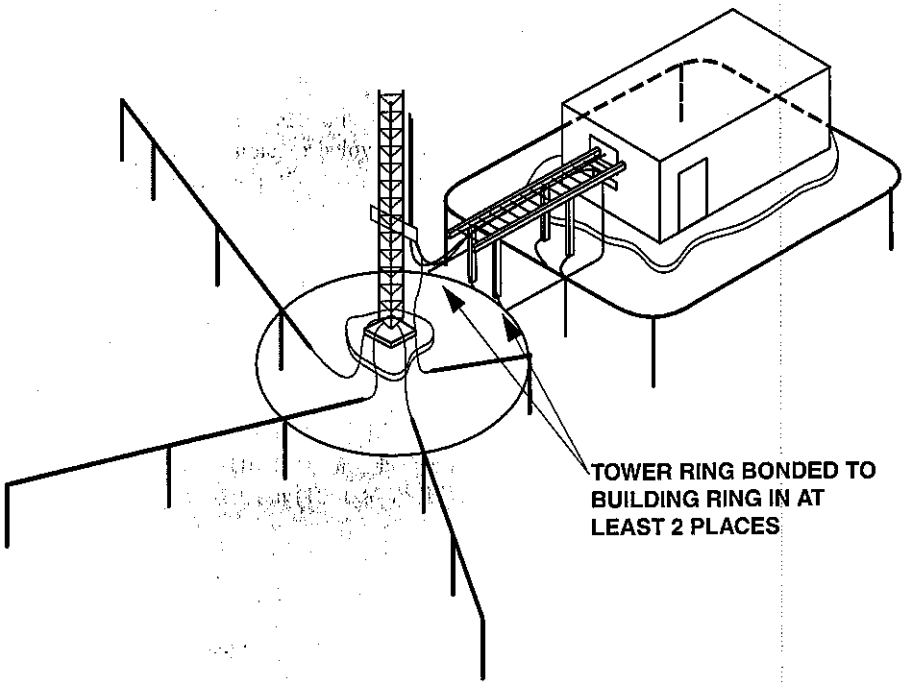

FIGURE 4-18 BONDING BUILDING AND TOWER GROUND RING SYSTEMS

- Ground rings **shall** be installed in direct contact with the earth at a depth of 762 mm (30 in.) below the earth's surface whenever possible, or below the frost line, whichever is deeper (ANSI T1.334-2002, section 5.3.1 and NFPA 70-2005, Article 250.53).
- Building ground rings **shall** be installed at least 914 mm (3 ft.) from the building foundation and should be installed beyond the drip line of the roof. It is recommended that the building ground ring and ground rods be positioned 610 mm to 1.8 m (2 ft. to 6 ft.) outside the drip line of the building or structure to ensure that precipitation wets the earth around the ground ring and rods (MIL-HDBK-419A and MIL-STD-188-124B).
- Tower ground rings **shall** be installed at least 610 mm (2 ft.) from the tower foundation (ANSI T1.334-2002, section 5.3.1).
- If 2.4 m (8 ft.) ground rods are installed along the ground rings, they **shall** be connected to the ground ring conductor at 3 m to 4.6 m (10 ft. to 15 ft.) intervals (ANSI T1.334-2002), unless otherwise specified.
  - If longer ground rods are used, a larger separation proportional to the increase in rod length may be used.
  - Ground rods **shall** be placed a minimum of one rod length apart from one another along the ground rings (ANSI T1.313-2003, figure 3(a)).
  - Ground rods **shall not** be separated from an adjacent ground rod along the ground ring by more than the sum of their respective lengths. (MIL-HDBK-419A).

4.4.1.7 RADIAL (COUNTERPOISE) GROUNDING CONDUCTORS

For high lightning prone geographical areas, sites normally occupied (such as 911 dispatch centers), sites with high soil resistivity, or when bedrock prohibits the driving of ground rods, radial (counterpoise) grounding (earthing) conductors should be employed to improve equalization of the grounding electrode system (ANSI T1.334-2002, section 5.4), and to help meet the site's grounding electrode system resistance requirements (see "Grounding (Earthing) Electrode System Resistance Requirements" on page 4-46). Radial grounding conductors are conductors installed horizontally in the ground and radiating away from the tower and building.

In typical soil resistivity conditions of 10, 000 ohm-cm, the addition of five radial conductors 7.6 m (25 ft) in length may reduce the tower grounding electrode system resistance by a factor of two or three. More importantly, adding radial conductors divides lightning strike current into segments that allow for more effective dissipation of energy into the earth, and away from the equipment building.

When used, radial conductors **shall** meet the following specifications:

- The conductors **shall** radiate away from the building and tower (ANSI T1.334-2002, section 5.4).
- The conductors **shall** be installed at the tower or tower ground ring whenever possible. If the conductors cannot be installed at the tower, installation at the building is acceptable, but should be installed near the RF transmission line entry point.

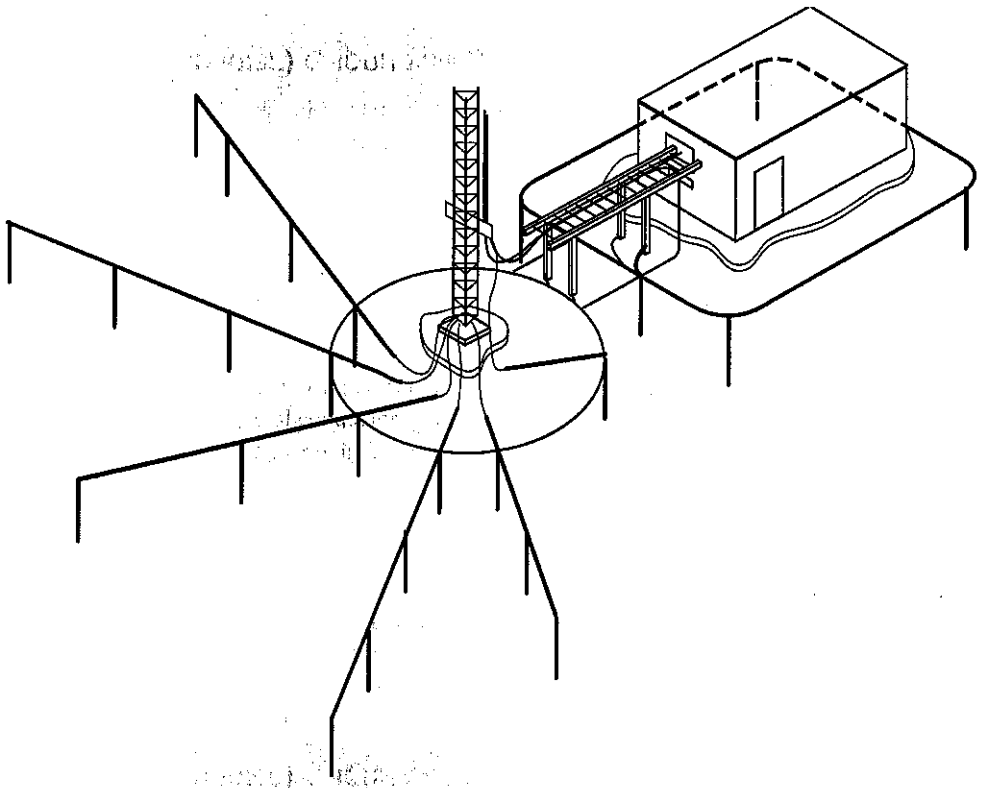

FIGURE 4-19 INSTALLATION OF RADIAL CONDUCTORS

- When radial conductors are used, a minimum of three to five conductors should be used.
- The conductors **shall** be installed equally spaced from one another, as much as practical.