Concrete-Encased Electrodes

Introduction: The 1965 edition of the National Electrical Code, as pictured below, made no reference to a "Made Electrode" called a "Concrete Encased Electrode".

NFPA Volume-70 1965 Edition of the National Electrical Code
Chapter 2. Wiring Design and Protection
Article 250 Grounding
Part H. Grounding Electrodes
Section 250-83 – Subsection (a) through (d)

250-83. Made Electrodes. Where electrodes described in Sections 250-81 and 250-82 are not available, the grounding electrode shall consist of a driven pipe, driven rod, buried plate or other device approved for the purpose and conforming to the following requirements:

(a) Plate Electrodes. Each plate electrode shall present not less than 2 square feet of surface to exterior soil. Electrodes of iron, or steel plates shall be at least ¼ inch in thickness. Electrodes of nonferrous metal shall be at least 0.06 inch in thickness.

(b) Pipe Electrodes. Electrodes of pipe or conduit shall be not smaller than of the ¾-inch trade size and, where of iron or steel, shall have the outer surface galvanized or otherwise metal-coated for corrosion protection.

(c) Rod Electrodes. Electrodes of rods of steel or iron shall be at least 5⁄8 inch in diameter. Approved rods of nonferrous materials or their approved equivalent used for electrodes shall be not less than ½ inch in diameter.

(d) Installation. Electrodes should, as far as practicable, be imbedded below permanent moisture level. Except where rock bottom is encountered, pipes or rods shall be driven to a depth of at least 8 feet regardless of size or number of electrodes used. Pipes or rods when less than standard commercial length shall preferably be of one piece. Such pipes or rods shall have clean metal surfaces and shall not be covered with paint, enamel or other poorly conducting materials. Where rock bottom is encountered at a depth of less than 4 feet, electrodes shall be buried in a horizontal trench, and where pipes or rods are used as the electrode they shall comply with Section 250-83(b and c) and shall not be less than 8 feet in length. Each electrode shall be separated at least 6 feet from any other electrode, including those used for signal circuits, radio, lightning rods, or any other purpose.
Introduction: The 1968 edition of the National Electrical Code, as pictured below, made the first reference to a “Made Electrode” called a “Concrete Encased Electrode”.

NFPA Volume-70 1968 Edition of the National Electrical Code
Chapter 2. Wiring Design and Protection
Article 250 Grounding
Part H. Grounding Electrodes
Section 250-83 – Subsection (a) through (e)

250-83. Made Electrodes. Where electrodes described in Sections 250-81 and 250-82 are not available, the grounding electrode shall consist of a driven pipe, driven rod, buried plate or other device approved for the purpose and conforming to the following requirements:

(a) Concrete Encased Electrodes. Not less than twenty feet of bare copper conductor of a size specified in Table 250-94(a), and in no case smaller than No. 4, encased along the bottom of a concrete foundation footing which is in direct contact with the earth.

(b) Plate Electrodes. Each plate electrode shall present not less than 2 square feet of surface to exterior soil. Electrodes of iron, or steel plates shall be at least ¼ inch in thickness. Electrodes of nonferrous metal shall be at least 0.06 inch in thickness.

(c) Pipe Electrodes. Electrodes of pipe or conduit shall be not smaller than of the ¾-inch trade size and, where of iron or steel, shall have the outer surface galvanized or otherwise metal-coated for corrosion protection.

(d) Rod Electrodes. Electrodes of rods of steel or iron shall be at least 5/8 inch in diameter. Approved rods of nonferrous materials or their approved equivalent used for electrodes shall be not less than ½ inch in diameter.

(e) Installation. - Electrodes should, as far as practicable, be imbedded below permanent moisture level. Except where rock bottom is encountered, pipes or rods shall be driven to a depth of at least 8 feet regardless of size or number of electrodes used. Pipes or rods when less than standard commercial length shall preferably be of one piece. Such pipes or rods shall have clean metal surfaces and shall not be covered with paint, enamel or other poorly conducting materials. Where rock bottom is encountered at a depth of less than 4 feet, electrodes shall be buried in a horizontal trench, and where pipes or rods are used as the electrode they shall comply with Section 250-83(b and c) and shall not be less than 8 feet in length. Each electrode shall be separated at least 6 feet from any other electrode, including those used for signal circuits, radio, lightning rods, or any other purpose.
Introduction: The 2011 edition of the National Electrical Code, as pictured below, show the current, State of Texas adopted, reference to the “Concrete Encased Electrode”.

NFPA Volume-70 2011 Edition of the National Electrical Code
Chapter 2. Wiring Design and Protection
Article 250 Grounding
Part III. Grounding Electrodes and Grounding Electrode Conductor
Section 250.52 Grounding Electrodes. - Subsection (A) Electrodes Permitted for Grounding.
Sub-section (3) Concrete-Encased Electrode.

(3) Concrete-Encased Electrode. A concrete-encased electrode shall consist of at least 6.0 m (20 ft) of either (1) or (2):

(1) One or more bare or zinc galvanized or other electrically conductive coated steel reinforcing bars or rods of not less than 13 mm (½ in.) in diameter, installed in one continuous 6.0 m (20 ft) length, or if in multiple pieces connected together by the usual steel tie wires, exothermic welding, welding, or other effective means to create a 6.0 m (20 ft) or greater length; or

(2) Bare copper conductor not smaller than 4 AWG

Metallic components shall be encased by at least 50 mm (2 in.) of concrete and shall be located horizontally within that portion of a concrete foundation or footing that is in direct contact with the earth or within vertical foundations or structural components or members that are in direct contact with the earth. If multiple concrete-encased electrodes are present at a building or structure, it shall be permissible to bond only one into the grounding electrode system.

Informational Note: Concrete installed with insulation, vapor barriers, films or similar items separating the concrete from the earth is not considered to be in “direct contact” with the earth.
**Purpose of this Presentation**

The National Electrical Code has recognized a “Made Electrode” called a “Concrete-Encased Electrode” since the Code year 1968. The description of this electrode is worded in the exhibits pictured above which was produced directly from the National Electrical Code. One of the most important specifications of the Concrete-Encased Electrode is its “direct contact with earth”. The direct contact with earth is the primary reason the installation is effective in providing a qualified ground connection. The National Electrical Code in Article 100 – Definitions, defines “Ground” as earth.

A properly installed Concrete-Encased Electrode provides an excellent grounding point, as required by the National Electrical Code, for Safety in an electrical system. However an improperly installed Concrete-Encased Electrode will provide an electrical hazard. This is why it is imperative that all electrical personal and inspectors understand and properly enforce the National Electrical Code.

The knowledge and information necessary to comply with the rules pertaining to “Concrete-Encased Electrodes” have been grossly misunderstood and misapplied due to the way our homes and other buildings are constructed in our area (Houston) of the State of Texas. Due to the problem of ground moisture entering our structures, products called insulation, vapor barriers, films, and similar items must be installed between the earth and the concrete slab. Building Codes require this type of installation and Builders are required to comply.

This compliance with mandatory Building Codes presents a big problem with electrical grounding when a grounding installation, relying on a Concrete-Encased Electrode, is employed. Simply explained, the insulation, vapor barriers, films, and similar items act as “Electrical Insulators” preventing necessary contact between the concrete slab and the earth. This contact is necessary to ensure a low resistance path to ground (earth) for safety in the electrical system.

The continued improper understanding of Concrete-Encased Electrode installations prompted the NFPA (National Fire Protection Association) to add an “Informational Note:” to the 2011 edition of the National Electrical Code. This informational note is shown on Page 3 of this presentation. The note informs the electrical installer that “direct contact” with the earth is NOT achieved, as required by Code, when insulation, vapor barriers, films, and similar items are installed separating the slab from direct contact with the earth. Therefore the National Electrical Code DOES NOT “Consider” this type of installation as qualified to serve as a “Concrete-Encased Electrode”.

Some jurisdictions, enforcing electrical installations, do not agree with the National Electrical Code on this issue and basic electrical technology knowledge presented by the “Informational Note:” to the 2011 edition of the National Electrical Code. Therefore many improper grounding installations exist in homes built today.

In this presentation, I have endeavored to present the issue of “Concrete-Encased Electrodes” as it exists in the electrical construction industry today.

The purpose of the National Electrical Code is “the practical safeguarding of persons and property from hazards arising from the use of electricity” as quoted from Article 90, Section 90.1(A) of the 2011 National Electrical Code. The use of a concrete slab installation as a “Concrete-Encased Electrode” when insulation, vapor barriers, films, and similar items are installed is a direct violation of the National Electrical Code and should not be allowed.
What Are Some Different Types of Grounding Electrodes?

Ufer Ground or Concrete Encased Electrodes

Originally, Ufer grounds were copper electrodes encased in the concrete surrounding ammunition bunkers. In today’s terminology, Ufer grounds consist of any concrete-encased electrode, such as the rebar in a building foundation, when used for grounding, or a wire or wire mesh in concrete.

Concrete Encased Electrode

The National Electrical Code requires that Concrete Encased Electrodes use a minimum No. 4 AWG copper wire at least 20 feet in length and encased in at least 2 inches of concrete. The advantages of concrete encased electrodes are that they dramatically increase the surface area and degree of contact with the surrounding soil. However, the zone of influence is not increased, therefore the resistance to ground is typically only slightly lower than the wire would be without the concrete.

Concrete encased electrodes also have some significant disadvantages. When an electrical fault occurs, the electric current must flow through the concrete into the earth. Concrete, by nature retains a lot of water, which rises in temperature as the electricity flows through the concrete. If the extent of the electrode is not sufficiently great for the total current flowing, the boiling point of the water may be reached, resulting in an explosive conversion of water into steam. Many concrete encased electrodes have been destroyed after receiving relatively small electrical faults. Once the concrete cracks apart and falls away from the conductor, the concrete pieces act as a shield preventing the copper wire from contacting the surrounding soil, resulting in a dramatic increase in the resistance-to-ground of the electrode.
There are many new products available on the market designed to improve concrete encased electrodes. The most common are modified concrete products that incorporate conductive materials into the cement mix, usually carbon. The advantage of these products is that they are fairly effective in reducing the resistivity of the concrete, thus lowering the resistance-to-ground of the electrode encased. The most significant improvement of these new products is in reducing heat buildup in the concrete during fault conditions, which can lower the chances that steam will destroy the concrete encased electrode. However some disadvantages are still evident. Again, these products do not increase the zone-of-influence and as such the resistance-to-ground of the concrete encased electrode is only slightly better than what a bare copper wire or driven rod would be in the ground. Also a primary concern regarding enhanced grounding concretes is the use of carbon in the mix. Carbon and copper are of different nobilities and will sacrificially corrode each other over time. Many of these products claim to have buffer materials designed to reduce the accelerated corrosion of the copper caused by the addition of carbon into the mix. However, few independent long-term studies are being conducted to test these claims.

**Ufer Ground or Building Foundations**

Ufer Grounds or building foundations may be used provided that the concrete is in direct contact with the earth (no plastic moisture barriers), that rebar is at least 0.500 inches in diameter and that there is a direct metallic connection from the service ground to the rebar buried inside the concrete. This concept is based on the conductivity of the concrete and the large surface area, which will usually provide a grounding system that, can handle very high current loads. The primary drawback occurs during fault conditions, if the fault current is too great compared with the area of the rebar system, when moisture in the concrete superheats and rapidly expands, cracking the surrounding concrete and the threatening the integrity of the building foundation. Another drawback to the Ufer ground is they are not testable under normal circumstances as isolating the concrete slab in order to properly perform resistance-to-ground testing is nearly impossible.
The metal frame of a building may also be used as a grounding point, provided that the building foundation meets the above requirements, and is commonly used in high-rise buildings. It should be noted that many owners of these high-rise buildings are banning this practice and insisting that tenants run ground wires all the way back to the secondary service locations on each floor. The owners will have already run ground wires from the secondary services back to the primary service locations and installed dedicated grounding systems at these service locations. The goal is to avoid the flow of stray currents, which can interfere with the operation of sensitive electronic equipment.

**How To Do Grounding System Testing**

The measurement of ground resistance for an earth electrode system is very important. It should be done when the electrode is first installed, and then at periodic intervals thereafter. This ensures that the resistance-to-ground does not increase over time. There are two (2) methods for testing an existing earth-electrode system. The first is the 3-point or Fall-of-Potential method and the second is the Induced Frequency test or clamp-on method. The 3-point test requires complete isolation from the power utility. Not just power isolation, but also removal of any neutral or other such ground connections extending outside the grounding system. This test is the most suitable test for large grounding systems and is also suitable for small electrodes. The induced frequency test can be performed while power is on and actually requires the utility to be connected to the grounding system under test. This test is accurate only for small electrodes, as it uses frequencies in the kilo Hertz range, which see long conductors as inductive chokes and therefore do not reflect the 60 Hz resistance of the entire grounding system.

**Fall-of-Potential Method or 3-Point Test**

The 3-point or fall-of-potential method is used to measure the resistance-to-ground of existing grounding systems. The two primary requirements to successfully complete this test are the ability to isolate the grounding system from the utility neutral and knowledge of the diagonal length of the grounding system (i.e. a 10’ x 10’ grounding ring would have a 14’ diagonal length). In this test, a short probe, referred to as probe Z, is driven into the earth at a distance of ten times (10X) the diagonal length of the grounding system (rod X). A second probe (Y) is placed in-line at a distance from rod X equal to the diagonal length of the grounding system.
At this point, a known current is applied across X & Z, while the resulting voltage is measured across X & Y. Ohm’s Law can then be applied (R=V/I) to calculate the measured resistance. Probe Y is then moved out to a distance of 2X the diagonal length of the grounding system, in-line with X & Z, to repeat the resistance measurement at the new interval. This will continue, moving probe Y out to 3X, 4X, ... 9X the diagonal length to complete the 3-point test with a total of nine (9) resistance measurements.

Graphing & Evaluation

The 3-point test is evaluated by plotting the results as data points with the distance from rod X along the X-axis and the resistance measurements along the Y-axis to develop a curve. Roughly midway between the center of the electrode under test and the probe Z, a plateau or “flat spot” should be found, as shown in the graph. The resistance of this plateau (actually, the resistance measured at the location 62% from the center of the electrode under test, if the soil is perfectly homogeneous) is the resistance-to-ground of the tested grounding system.

Invalid Tests

If no semblance of a plateau is found and the graph is observed to rise steadily the test is considered invalid. This can be due to the fact that probe Z was not placed far enough away from rod X, and can usually indicate that the diagonal length of the grounding system was not determined correctly. If the graph is observed to have a low plateau that extends the entire length and only rises at the last test point, then this also may be also considered invalid. This is because the utility or telecom neutral connection remains on the grounding system.

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