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07.21.2017

REPUBLIC OF THE PHILIPPINES
DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
OFFICE OF THE SECRETARY
MANILA

18 JUL 2017

DEPARTMENT ORDER) **SUBJECT : DPWH Standard Specification on Item 1109 – Grounding Systems**
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No. 88
Series of 2017 07.21.17

In order to provide specifications for grounding systems which are specified in Department Order No. 05, Series of 2017 [*Revised Standardized Pay Items of Works for Civil Works Construction for Infrastructure Projects*], and also, in line with the mandate of the Department in providing effective Standard Specifications in the implementation of various infrastructure projects, the attached **DPWH Standard Specification on Item 1109 - Grounding Systems** is hereby prescribed, for the guidance and compliance of all concerned.

This specification shall form part of the on-going revision of the DPWH Standard Specifications for Public Works Structures - Buildings, Ports and Harbors, Flood Control and Drainage Structure and Water Supply Systems, Volume III, 1995 Edition.

This Order shall take effect immediately.

MARK A. VILLAR
Secretary

14.1.2 FET/RGT

Department of Public Works and Highways
Office of the Secretary
WIN7U01494

DPWH STANDARD SPECIFICATION FOR ITEM 1109 – GROUNDING SYSTEMS

1109.1 Description

This Item shall consist of furnishing all grounding system materials, labor, tools, equipment and others in undertaking the proper installation works required as shown on the Plans and in accordance with this Specification.

1109.2 Materials Requirements

1109.2.1 Grounding System

Grounding system shall conform to the applicable material requirements of NEC 250 – Grounding and Bonding and Philippine Electrical Code (PEC) Part I, Article 2.50 - Grounding and Bonding.

1109.2.2 Exothermic Weld Connector

1109.2.2.1 General Material Requirements for Exothermic Weld Connector

Weld metals shall be manufactured with copper, copper oxides, aluminum, and minor constituents for rate control, wetting and deoxidizing molten metals formed during reaction. Formulations shall not contain caustic, toxic, or explosive substances including but not limited to magnesium, and phosphorus. Weld metals shall easily be cleaned out of the crucible after each shot. Cathodic protection and Rail formulations shall be free of tin.

Starting powder shall contain aluminum, copper oxide, and iron oxide. No phosphorus, magnesium, caustic, toxic or explosive substances shall be present in formulation.

Molds for multiple uses shall be manufactured from graphite formulated for high temperature applications and designed to provide an average of 50 connections satisfactorily.

Remote ignition system products shall be manufactured for use with tubes of weld metal. System shall be designed to allow initiation with battery pack or a flint ignitor without loss of product to change initiation method.

Handle clamps shall be offset design to reduce excavation requirements of installer and to achieve quick application of x-type grid connections.

1109.2.2.2 Quality Control

Products shall have a lot number and/or dated recorded on the product during manufacture to provide traceability for quality assurance purposes.

1109.2.2.3 Marking

Weld metal shall be packaged indicating the date of manufacture or lot number on each box label to assure that the received product are manufactured in accordance with current specifications and to provide maximum shelf life by allowing First In – First Out stock rotation.

a. Weld metal shall have cartridge size, formula, and lot number clearly visible on the container to aid in identifying intended use. UL marking shall be displayed in accordance with the requirements for listed products. General safety instructions shall be provided in each package of weld metal.

b. Molds made with graphite shall have permanent tag attached that clearly identifies mold number, connection type, conductors, weld metal cartridge, and formula of weld metal. One time use ceramic molds shall have mold number, connection type, and conductors clearly marked on the package. UL marking shall be displayed in accordance with the requirements for the listed products. Application instructions shall be provided with each mold detailing the general safety procedures, general preparation and welding practice, and information specific to each weld type to assure a quality connection each time.

1109.2.2.4 Packaging and Shipping

Weld metal shall be packaged in containers designed to maximize shelf life of the product and prevent damage from atmospheric moisture normally encountered during use.

The product's package shall be designed to prevent damage or spilling during conditions normally encountered during shipping from factory to customer point of use.

Product shall be packaged in a manner to prevent mixing of starting powders with weld metal during transportation to assure customer is able to initiate reaction with flint ignitor.

1109.2.3 Air Terminal

Any aluminum alloy or solid copper product shall not come into direct contact with earth and any bimetallic fitting and shall not be installed within 45.7 mm above earth level. Aluminum products shall not be embedded in concrete or masonry, in direct contact with a surface coated with alkaline paint, nor shall be installed in wet locations such as inside of downspouts.

The two (2) classes of air terminals and its material requirements are the following:

Class I Material Requirements

Type of Conductor		Copper	Aluminum
Air Terminal, Solid	Min. Diameter	9.5 mm	12.7 mm
Air Terminal, Tubular	Min. Diameter	15.9 mm	15.9 mm
	Min. Wall Thickness	0.8 mm	1.6 mm
Main Conductor, Cable	Min. Size ea. Strand	1.1 mm dia.	1.6 mm dia.
	Wt. per Length	278 g/m	141 g/m
	Cross Sectional Area	29 mm^2	50 mm^2
Main Conductor, Solid Strip	Thickness	1.2 mm dia.	1.6 mm dia.
	Width	25.4 mm	25.4 mm
Secondary Conductor, Cable	Wire Size	0.9 mm^2	2.0 mm^2
	Number of Wires	14	10
Secondary Conductor, Solid Strip	Thickness	1.2 mm dia.	1.6 mm dia.
	Width	12.7 mm	12.7 mm

Class I shall be used on structures up to 23 m tall.

Class II Material Requirements

Type of Conductor		Copper	Aluminum
Air Terminal, Solid	Min. Diameter	12.7 mm	15.9 mm
Main Conductor, Cable	Min. Size ea. Strand	1.2 mm dia.	1.8 mm dia.
	Wt. per Length	558 g/m	283 g/m
	Cross Section Area	58 mm^2	97 mm^2
Secondary Conductor, Cable	Wire Size	0.9 mm^2	2.0 mm^2
	Number of Wires	14	10
Secondary Conductor, Solid Strip	Thickness	1.2 mm dia.	1.6 mm dia.
	Width	12.7 mm	12.7 mm

Class II shall be used on structures greater than 23 m tall.

Other Specifications related to air terminal shall conform to the applicable requirements of PEC Part 1.

1109.2.3.1 Base Supports

The air terminal bases are permitted to be stamped or cast construction. If stamped, the thickness shall be 2.5 mm for aluminum and 1.5 mm for copper material. If casted, either copper or aluminum shall be at least 2.3 mm thick. A base support must incorporate a connector fitting for connection of the lightning conductor. The conductor contact area must be at least 38 mm on all sides of the cable, and at least two mounting holes that will accept a No. 10-24 or larger bolt or screw shall be provided in the support so that it can be permanently and rigidly fastened. Bases shall not be limited to horizontal or vertical bases since there are variety of air terminal bases types such as Universal Bases, Parapet Bases, Saddle Bases, and others, whichever is best applicable as long as technical notes are properly followed.

1109.2.3.2 Air Terminal Braces

Air terminals exceeding 600 mm in height shall be braced or supported at least one-half of the terminal height. The brace shall be at least 6.35 mm rod, constructed from aluminum, copper/copper alloy, stainless steel, or hot dipped galvanized if made of steel and shall be flattened on the end for attachment to the structure with at least a 10-24 bolt or screw.

1109.2.3.3 Conductors

Specifications related to grounding conductors shall conform to the applicable requirements of PEC Part 1.

1109.2.3.4 Grounding Electrodes

Air Terminals, main and secondary conductors plus all other ancillary parts are for the sole purpose of conducting a lightning stroke to earth and dissipating it through the use of various grounding electrode methods.

The grounding electrode shall be made of a rod of not less than 12.5 mm in diameter, and 203 mm in length and be of copper-clad steel, solid copper, or stainless steel. It shall not be resistant to any corrosive condition existing at the installation or be suitably protected against corrosion. The rod shall extend vertically not less than 254 mm into the earth and below the frost line where possible.

Concrete encased shall only be used in new construction. It shall be of the same diameter as with the main-size conductor. It shall be 6.1 m in length and be encased in at least 50 mm of concrete. Steel rebar shall also be permitted as a grounding electrode. At least 6.1 m of (#4 or 12.7 mm dia.) steel reinforcing bar shall be used for main-size conductor. Overlapping at least 20-rod diameters shall be maintained if more than one piece is spliced in the footing, using tie wire or welding.

A main-sized conductor can also be buried from each down conductor in the form of a radial. A radial conductor must be at least 3.6 m in length and buried at least 750 mm depth.

A ground ring shall be permitted if at least 450 mm under the earth and equal in size to the main-size conductor.

Ground plate(s) shall be permitted if 0.186 sq. m or more in size and 0.81 mm thick or more and buried not less than 450 mm under the soil.

Where there is shallow topsoil, a combination of the methods above shall be permitted to provide an effective means for dissipating a lightning stroke.

1109.3 Construction Requirements

1109.3.1 Grounding System

1109.3.1.1 Earth or Ground Electrode

Earth electrode shall consist of one or more earth rods (also earth plate or earth matt), interconnected by buried earthing tape or cable, which is to have a total combined resistance value, during any season of the year and before interconnection to other earthed systems or earthing means, not exceeding one (1) ohm. Distance between 2 rods shall not be less than twice the length of one rod driven depth, or less than 1.83 m.

Main ring earthing resistance shall not exceed one (1) ohm or otherwise, it shall be indicated on the Plans with the approval of the Engineer.

Ring type earth electrode shall consist of earthing conductors, in a closed loop, buried in exterior wall foundations underneath the water-proofing, or alternatively at 0.6 m around the perimeter of the building foundations, as shown on the Plans. It can also be buried outside the structure at a depth of at least 0.7 m and at a distance of 1 m around the external wall, unless otherwise shown on the drawings. Connect all earthing conductors to this ring. Insulated connection flags into the building, of same material as earthing conductors, shall be located at positions of service entrance and main switchboard rooms, terminating in bolt-type earth points (studs) or test links for connection of main earth bar(s). Additional earth rods connecting with the earth ring shall be provided, as necessary, to bring down the earth electrode resistance to an acceptable value.

Functional earth electrode shall be provided separately from, but interconnected to the other earth electrode(s) through suitably rated (470 V) spark gap. Functional earth electrodes shall be used for earthing electronic equipment (communication equipment, digital processors, computers etc.) as required/ recommended by the Manufacturer.

Alternative Earth Electrode: Other types of earth electrode may be used, after approval of the Engineer or as indicated in the Plans, including:

a) Copper plate(s)
b) Tape mats (strips)

1109.3.1.2 Main Earthing Terminal or Bar

Main earthing bar shall be provided at the point of service entrance or main distribution room, and as directed by the Engineer or as shown on the Plans. Connect all earthing conductors, protective conductors and bonding conductors to the main earthing bar. Two (2) insulated main earthing conductors shall be provided, one (1) at each end of the bar, connected via testing joints to the earth electrode at two (2) separate earth pits. Conductor shall be sized to carry maximum earth fault current of system at point of application with final conductor temperature not exceeding 160° C for at least five (5) seconds. Main earthing conductors shall be at minimum of 120 mm^2 or as otherwise required by the Engineer or specified in the Plans. Main earthing bar shall be positioned at an accessible location within the electrical room and clearly labeled.

The main earth bar shall be in the form of a ring or rings of bare conductors surrounding or within an area in which items to be earthed are located. Where 2 or more rings are installed, they shall be interconnected by at least two conductors, which shall be widely separated.

Testing joints (test links) shall be provided, in an accessible position, on each main earthing conductor, between earthing terminal or bar and earth electrode.

1109.3.1.3 Earthing or Grounding Conductors

Protective conductors shall be separate for each circuit. Selection of sizes shall be indicated in the Plans with the approval of the Engineer or in accordance with the Philippine Electrical Code (PEC) requirements.

Protective conductors shall not be formed by conduit, trunking, ducting or the like.

Continuity of Protective Conductors: Series connection of protective conductor from one piece of equipment to another shall not be permitted. Extraneous and exposed conductive parts of the equipment shall not be used as protective conductors, but shall be connected by bolted clamp type connectors and/or brazing to continuous protective conductors which shall be insulated by molded materials. Conductor sheaths shall be of yellow-green colored PVC with a minimum thickness of 1.5 mm.

Bare strip conductors only shall be used for earth electrodes or voltage control meshes.

Conductors buried in the ground shall normally be laid at a depth of 1000 mm below the underground power cables in an excavated trench. The backfill in the vicinity of the conductor shall be free of stones and the whole backfill shall be well consolidated. All conductors not buried in the ground shall be straightened immediately prior to installation and supported clear of the adjacent surface.

Earth Fault Loop Impedance: For final circuits supplying socket outlets, earth fault impedance at every socket outlet shall be such that disconnection of protective device on over-current occurs within 0.4 seconds. For final circuits supplying only fixed equipment, earth fault loop impedance at every point of utilization shall be such that disconnection occurs within five (5) seconds.

1109.3.1.4 Equipotential Bonding

Supplementary Equipotential Bonding: Connect all extraneous conductive parts of the building such as metallic water pipes, drain pipes, other service pipes and dueling, metallic conduit and raceways, cable trays and cable armor to nearest earthing terminals by equipotential bonding conductors. Cross-section of protective bonding conductor shall not be less than 1/2 of the protective conductor connected to respective earthing terminal with a minimum of four (4) mm^2.

a) Individual components of metallic structures of plant shall be bonded to adjacent components to form an electrically continuous metallic path to the bonding conductor.

b) Small electrically isolated metallic components mounted on non-conducting building fabric need not be bonded to the main earth bar.

c) Bolted joints in metallic structures including pipework, which do not provide direct metallic contact shall be bridged by a bonding conductor or both sides of the joint shall be separately bonded to earth unless the joint is intended to be an insulated joint for cathodic protection or other purposes.

Main Equipotential Bonding: Main incoming and outgoing water pipes and any other metallic service pipes shall be connected by main equipotential bonding conductors to main earth terminal or bar. Bonding connections shall be as short as practicable between point of entry/exit of services and main earthing bar. Where meters are installed, bonding shall be made on the premise side of the meter. Cross-sections of conductors shall not be less than 1/2 that of the earthing conductor connected thereto, and minimum of six (6) mm^2.

1109.3.1.5 Identification and Protection of Earthing Components

Connection of every earthing conductor to earthing electrode and every bonding conductor to extraneous conducting parts shall be labeled as follows, SAFETY ELECTRICAL CONNECTION - DO NOT REMOVE.

Protective and earthing conductors shall be identified by combination of green-and-yellow colors of insulation or by painting bar conductors with these colors, as approved by the Engineer.

Source earthing conductor (or neutral earthing conductor) shall be identified along its entire length by continuous black insulation labeled 'neutral earthing'. The neutral earthing ground rod pit shall be also clearly identified.

Exposed external earthing or grounding conductor connection joints shall be protected from corrosion with grease caps or bituminous tape or approved equal tape.

The earthing and lightning protection system for any new extension shall be suitably connected to the existing system.

In general earthing conductor connections to structures, connections within the lightning protection system conductors, shall be exothermic copper-weld type unless otherwise stated in the Plans or as directed by the Engineer.

1109.3.2 Exothermic Weld Connector

Standard welding instructions shall be followed as indicated in the Plans.

1109.3.3 Air Terminal

1109.3.3.1 Air Terminal Placement Using the Standard Grid Placement Scheme

When establishing a zone of protection, the air terminal tip shall be located at not less than 250.0 mm above the protected object if the interval spacing shall not be more than six (6) m between air terminals. If a 610 mm air terminal is used, the air terminal spacing shall be increased to 7.6 m.

When the roof exceeds 15.24 m in length or width or both directions, the spacing shall be increased up to 15.24 m between terminals on flat or gently sloping roofs. Pending roof design, air terminals shall be permitted to be in a pattern not exceeding 15.24 m apart in the center part of the roof plan. The perimeter edge spacing shall be up to 7.62 m between terminals when 600 mm air terminals are used.

When the roof is pitched with eaves height of 15.24 m or less above the grade and having no structural projections such as roof dormers or other projections, it requires protection only to be mounted to the ridge of the projection roofline. Air terminals shall be mounted on the ridge at spacing not greater than 7.62 m. If other projections are present such as a dormer, irregular roof lines or lower or higher elevations that area may need air terminal placement based on its physical size and shape. Air terminals 250 mm in height and spaced not greater than 610 mm apart are permitted, interval spacing shall be increased to 7.62 m when 600 mm terminals are installed.

The air terminal spacing shall be either 6.0 or 7.62 m pending on terminal height. Perimeter and down conductors, with connections to ground rods shall also be indicated in the Plans.

1109.3.4 Testing (Basis for Acceptance)

The electrical grounding system shall be subjected to the 3-point or Fall-of- Potential method prior to acceptance.

1109.4 Method of Measurements

All the units installed shall be measured and determined by the number of units approved and ready for service as provided in the Bill of Materials and Quantities accepted to the satisfaction of the Engineer.

1109.5 Basis of Payment

The accepted quantity, measured as prescribed in Section 1109.4 - Method of Measurements, shall be paid for at the contract unit price for Grounding Systems, which price and payment shall be the full compensation for furnishing all materials, handling, storing, installation, labor, equipment, tools and incidentals necessary to complete this Specification.

Payment shall be made under:

Pay Item Number	Description	Unit of Measure
1109 (1)	Grounding System	Lump Sum
1109 (2)	Exothermic Weld Connector	Piece
1109 (3)	Air Terminal	Set

References:

1. https://filipinoengineer.com/wiki/Philippine_Electrical_Code_Part_1/Chapter_2._Wiring_and_Protection/Article_2.50_-_Grounding_And_Bonding - March, 2017
2. https://www.mikeholt.com/mojonewsarchive/GB-HTML/HTML/NECArticle250Sections250.20-250.34~20020124.htm - March, 2017
3. https://www.lopol.org/article/general-requirements-for-electrical-earthing-or-grounding-system-in-building-construction - March, 2017
4. NEC 250
5. thermoweld® Grounding Specification for Exothermic Welding System
6. Philippine Electrical Code – Art 2.90 – Protection Against Lightning