

IEEE Standard for Supporting Structures for Overhead Contact Systems for Transit Systems

IEEE Vehicular Technology Society

Sponsored by the
Rail Transit Vehicle Interface Standards Committee

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USA

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IEEE Standard for Supporting Structures for Overhead Contact Systems for Transit Systems

Sponsor

Rail Transit Vehicle Interface Standards Committee
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IEEE Vehicular Technology Society

Approved 19 October 2012

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Abstract: Minimum structural requirements for structural supports used for overhead contact systems for heavy rail, light rail, and trolley bus systems, including loading, safety factors, and deflection are provided by this standard. This standard is developed to govern the design and fabrication of supporting structures for OCS. It is provided to define minimum general design and construction parameters for the following tubular steel pole types: tapered and constant diameter round, tapered and constant diameter multi-sided, sectional and fluted.

Keywords: catenary, design, fabrication, IEEE 1630, OCS, overhead contact systems, pole, steel, structure, support, tubular

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Introduction

This introduction is not part of IEEE Std 1630-2012, IEEE Standard for Supporting Structures for Overhead Contact Systems for Transit Systems.

The vast majority of the presently operating electrified rail transit systems use overhead contact systems (OCS) or third rail to supply direct-current power to the rail vehicles. The OCS Sub-Committee for Rail Transit Systems was formed in 2001 with the purpose of developing standards governing the design and construction of OCS for rail transit. The primary concern of the committee regarding OCS was the lack of uniform practices for the design, fabrication and maintenance of components of the OCS, including but not limited to the structural supports, components and hardware, system parameters and operating procedures, and equipment.

The purpose of this standard is to standardize the design and fabrication of supporting structures for OCS. A variety of structure types, styles, sizes, and strengths are currently in use throughout the industry. By standardizing or limiting the size, material, and strength of supporting structures for OCS, economies of scale and reduction in overall stockpile requirements can be observed. It is the goal of this standard to direct the OCS designer and manufacturer toward economizing the construction of supporting structures for OCS and their corresponding footings through consistency and standardization. This standard is intended for use by the following:

- OCS designers to assist in the selection and specification of structure types and sizes
- Geotechnical engineers to use as a basis for developing footing sizes and anchor bolt configurations
- Owners and maintainers of new or existing OCS
- Contractors that construct new OCS
- Manufacturers

The standard is written to establish the minimum standards and performance requirements to be followed in the design and fabrication of supporting structures for OCS. Its overall goal is to standardize the size and configuration of OCS structures, as much as practical, thereby minimizing the great variety of differing sizes in service and leading to uniformity of design and construction practices throughout the industry.

The current standard only addresses tubular steel OCS poles. Future updates will include other supporting structure types (i.e., steel wide-flange poles, portals, and foundations).

The current standard contains the following main parts:

- A listing of all materials suitable for use in fabrication of all pole elements including the pole shaft, base plate, anchor rods, and miscellaneous appurtenances.
- A detailed description of the process to be utilized by the OCS designer and/or pole manufacturer in the design (strength and serviceability) of OCS poles. Methodology includes methods of loading calculation, loading presentation, strength design, and deflection calculation.
- A tabulated representation of the most commonly produced pole shapes, sizes and properties including pole diameter, wall thickness, loading capacity and deflection characteristics. Tables have been provided for round, 8-sided, 12-sided, 16-sided, sectional, and square tubular poles. Deflection characteristics for both tapered and non-tapered applications are included.
- A tabulated representation of standard base plate and anchor bolt arrangements for use with the commonly produced poles. These tables allow the OCS designer to select individual pole and base plate combinations as required to meet the project specific loading and serviceability requirements.
- Pole testing requirements pertaining to materials, welding, deflection, and protective coatings. An informative annex also includes the description of a commonly used deflection test procedure.
- Acceptable construction and fabrication tolerances.
- Acceptable methods of corrosion protection including galvanizing, metallizing, and painting.

This standard does not include guidance for the installation of the poles or construction of their associated foundations.

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1. Overview

This standard is divided into eight clauses. Clause 1 provides the scope of this standard. Clause 2 lists references to other standards that are useful in applying this standard. Clause 3 provides definitions that are either not found in other standards, or have been modified for use with this standard. Clause 4 establishes material properties and design methodologies used in the design and fabrication of tubular steel poles for overhead contact systems (OCS). Clause 5 defines material and construction testing requirements used to verify the quality of the fabricated pole assemblies. Clause 6 establishes tolerances to be utilized in the fabrication of the poles. Clause 7 indicates workmanship and finishing techniques to be adhered to and utilized in the fabrication and delivery of the poles. Clause 8 indicates required inspections and corresponding acceptance and rejection criteria for final owner acceptance of the completed poles.

This standard also contains three annexes. Annex A contains procedures to be used in calculating the theoretical deflection of tubular steel poles. Annex B contains a tabular summary of the most commonly utilized and fabricated tubular pole sizes, including diameter, wall thickness, and maximum yield moment capacity for varying grades of steel. It also provides a tabular summary of the most commonly utilized pole base plate sizes, including overall dimensions, bolt size, anchor bolt diameter, and yield moment capacity. Annex B includes typical data for poles ranging from 228.6 mm (9 in) to 406.4 mm (16 in) in nominal diameter. Base plate arrangements for each of the pole diameters listed are included. Annex C provides a description of typical deflection testing methodologies.

1.1 Scope

This standard determines minimum structural requirements for structural supports used for overhead contact systems for heavy rail, light rail, and trolley bus systems, including loading, safety factors, and deflection.

1.2 Purpose

At the present time there are no suitable standards governing structural requirements for supports used for overhead contact systems. The purpose of this standard is to improve design efficiency for new and existing rail transit projects.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

AASHTO LTS-4-2001, Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals.¹

Accredited Standards Committee C2-2007, National Electrical Safety Code® (NESC®).²

AISC 360, Specification for Structural Steel Buildings.³

ASCE/SEI 48-05, Design of Steel Transmission Pole Structures.⁴

ASTM A36, Structural Steel.⁵

ASTM A53, Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.

ASTM A123, Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products.

ASTM A143, Safeguarding Against Embrittlement of Hot-Dip Galvanized Steel Products and Procedures for Detecting Embrittlement.

ASTM A153, Zinc Coating (Hot Dip) on Iron and Steel Hardware.

ASTM A384, Safeguarding Against Warpage and Distortion during Hot-Dip Galvanizing of Steel Assemblies.

¹ AASHTO publications are available from the American Association of State Highway and Transportation Officials, 444 N Capitol St. NW - Suite 249 - Washington, DC 20001 (<https://bookstore.transportation.org/>).

² The NESC is available from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, Piscataway, NJ 08854, USA (<http://standards.ieee.org/>).

³ AISC publications are available from American Institute of Steel Construction at One East Wacker Drive Suite 700, Chicago, IL 60601-1802 (<http://www.aisc.org/>).

⁴ ASCE publications are available from the American Society of Civil Engineers at 1801 Alexander Bell Drive, Reston, VA 20191 (<http://www.asce.org/>).

⁵ ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (<http://www.astm.org/>).

ASTM A449, Specification for Quenched and Tempered Steel Bolts and Nuts.

ASTM A500, Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.

ASTM A501, Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing.

ASTM A563, Carbon and Alloy Steel Nuts.

ASTM A572, High Strength, Low-Alloy Columbium-Vanadium Steels of Structural Quality.

ASTM A588, Standard Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4-in. [100-mm] Thick.

ASTM A595, Steel Tubes, Low-Carbon, Tapered for Structural Use.

ASTM A847, Cold-Formed Welded and Seamless High-Strength, Low Alloy Structural Tubing with Improved Atmospheric Corrosion Resistance.

ASTM A871, Standard Specification for High-Strength Low-Alloy Structural Steel Plate with Atmospheric Corrosion Resistance.

ASTM A1011, Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability.

ASTM E709, Standard Recommended Practice for Magnetic Particle Examination.

ASTM F436, Hardened Steel Washers.

ASTM F1554, Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength.

AWS D1.1, Structural Welding Code, Steel, Latest Revision.⁶

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁷

anchor rod (bolt): A round steel bar, partially or fully threaded, inserted into a concrete foundation and used to transmit loads from an attachment or pole into concrete supports or foundations by means of tension, bearing, or shear.

base plate: A welded attachment at the bottom of a pole structure used to transmit applied axial loads, shear loads, and overturning moments from the pole to the foundation.

blind half couplings: A short threaded pipe fitting welded into the pole shaft for the purpose of providing protective wire ingress or egress.

⁶ AWS publications are available from the American Welding Society at 8669 Doral Boulevard, Suite 130, Doral, Florida 33166 (<http://www.aws.org>).

⁷ *IEEE Standards Dictionary Online* subscription is available at:
http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

butt section: The lowest section of a sectional steel pole, typically outfitted with an end plate for direct embedment in earth or concrete, or a base plate for attachment to a structural footing.

c-hook (j-hook): A formed rod welded to the inside of pole members for the purpose of providing support of conductor weight.

dynamic deflection: Horizontal displacement of the pole due to live loadings including wind, ice, and changing wire loads due to temperature differentials.

feeder spout: A short pipe installed through the wall of a tubular pole through which a cable exits the pole.

flute: A decorative pole section composed of alternating crests and valleys.

full base cover: An aesthetic or protective treatment at the bottom of the pole used to protect anchor bolts from damage and pedestrians from injury.

ground collar (ground sleeve): A protective jacket that encapsulates a portion of a buried pole immediately above and below the groundline. It protects the pole from the potentially harsh environment.

grounding stud: A threaded bolt or plain rod attached to the structure of the pole and used to facilitate electrical grounding.

hand hole: An access opening in a pole for cable installation or inspection.

hold down nut (upper nut): The hardware installed on an anchor rod on top of the base plate after installation of the pole.

jam nut (half nut): The hardware installed on an anchor rod above the hold down nut to prevent the hold down nut from loosening.

j-hook (c-hook): A formed rod welded to the inside of pole members for the purpose of providing support of conductor weight.

leveling nut: The hardware installed on an anchor rod below the base plate and used for the purpose of plumbing or raking the pole.

middle section: The intermediate portion of a sectional steel pole.

multi-sided pole: A pole cross-section that is polygonal in shape, typically constructed using a break press process.

permanent set: Sustained deformation of a pole upon removal of stress after being stressed beyond its elastic limit.

ply construction: Tubular pole manufacturer composed of two or more steel shells compressed together along the length of the pole acting as a single unit.

pole: An independent slender vertical structure, with or without a guy, used to support the OCS.

pole shaft: The long, slender, hollow tube that is the main part of a completed pole assembly.

pole cap: An attachment over the top of the pole used to prevent intrusion of rainwater. Decorative designs are known as “finials”.

round pole: A pole with a circular cross-section along its entire length.

sectional pole: A steel tubular pole constructed of two or more shafts of different diameter.

static deflection (dead load deflection): Horizontal displacement of the pole due to weight and tension of the supported components at normal atmospheric conditions.

swage: A method of joining two sections of pipe whereby the smaller section is inserted within a heated larger section that is then mechanically worked to conform to the shape of the smaller section.

taper: The rate of change of pole diameter per unit of pole length.

top section: The uppermost portion of a sectional steel pole.

4. Pole assembly

4.1 Materials

Pole shafts, hand hole reinforcements, and other structural items shall be fabricated from a structural steel material type conforming to the following ASTM specifications.

4.1.1 Pole shafts

For plain or alloy steel construction, the pole shafts shall be constructed of one of the following types of steel:

- a) Carbon Steel
 - 1) A53 Grade B
 - 2) A500
 - 3) A501
 - 4) A572 Grades 50, 55, 60, or 65
 - 5) A595 Grades A or B
 - 6) A1011 Grades A, B or C
- b) Weathering steel construction, the pole shafts shall be constructed of the following types of steel:
 - 1) A871 Grades 50, 60, or 65
 - 2) A595 Grade C
 - 3) A847

4.1.2 Base plates

Base plates shall be fabricated from structural steel conforming to ASTM A36 or ASTM A572, Grades 42 or 50 for plain or alloy steel construction, and ASTM A588 for weathering steel applications.

4.1.3 Anchor rods

Anchor rods (bolts) shall be fabricated from ASTM F1554, Grades 36 thru 105, or ASTM A449. Nuts shall comply with ASTM A563, hot dip galvanized, over tapped threads in accordance with AISC requirements for UNC series. Washers shall be hardened washers complying with ASTM F436.

4.1.4 Miscellaneous fabrications

Feeder spouts (outlets), where specified, shall be constructed of standard steel pipe conforming to ASTM A53, Grade B, Type E or S.

Pole caps shall be fabricated from cast aluminum, cast zinc, cast iron plastic, stainless steel or forged steel and fitted with a minimum of three stainless steel set screws for round or multi-sided poles and a minimum of two set screws for square or rectangular poles.

4.2 Design

4.2.1 Design methodology

Strength design of supporting structures shall be as described in ASCE/SEI 48-05, Section 5.0. This design is based on elastic properties and analysis. Generally speaking, rigorous fatigue stress analyses of steel OCS pole structures have proven unnecessary. If this mode of failure is suspected to be a factor in the design, refer to the methods used in the AISC "Specification for Structural Steel Buildings" for fatigue.

4.2.2 Loading determinations

The OCS designer shall determine the maximum loading for use in design of the support structures. Loading determinations shall be made in accordance with the provisions contained in the National Electric Safety Code (NESC) and include as applicable the following:

- a) Gravity loads
- b) Termination loads
- c) Radial loads
- d) Wind loads
- e) Extreme wind case
- f) Ice, where it applies
- g) Construction, stringing, and maintenance loads
- h) Broken wire conditions
- i) Any special loading conditions that exist due to local field conditions or unusual installations must be considered as well

Individual loadings shall be combined into specific load cases as documented in the NESC. NESC overload factors shall be utilized for strength design. Additional loading cases may be required to be investigated as dictated by specific project design criteria.

4.2.3 Loading presentation

Deflection calculations shall be prepared to verify the performance of the poles against predetermined standards. Where performance specifications are developed, the OCS designer shall provide information to the pole manufacturer in sufficient detail to enable deflection calculations to be undertaken. Loading trees for each class of pole shall be developed along with required deflection acceptance criteria for the class in question. Loading trees shall include at a minimum the magnitude, direction, and point of application of the loadings. The deflection of the supporting structures shall be investigated for static and dynamic loading combinations. Static loading shall include all dead loads and attached facilities. The dynamic loads shall include wind, ice, where applicable; seismic, non-operating and operating loads. The overload factor for all loads shall be 1.0, when deflection is being investigated.

The format for the load trees as shown in ASCE/SEI 48-05, Section C4.2.3 and C4-1 is preferred. See Figure 1 for a typical load tree associated with OCS construction.

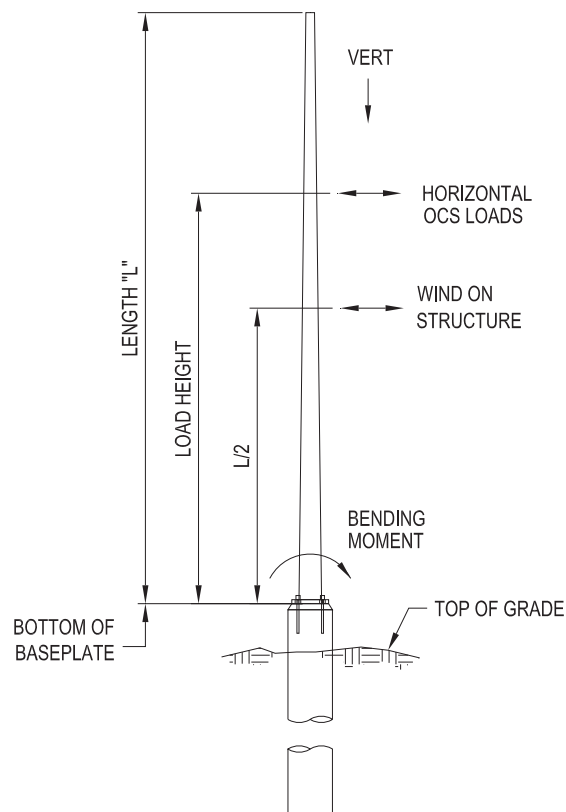


Figure 1—Typical OCS loading tree

4.2.4 Deflection

Dynamic deflections under operating conditions shall be limited to the magnitude allowed by the project criteria for the type of system used. This value is based upon limiting pole movement during train operations to maintain acceptable current collection. These deflection limitations are typically given at the height of the contact wire or the wire attachment point. In addition, under total non-operating load (combined static and dynamic) conditions the deflection at the top of the poles shall be limited to 2.5% of the pole length. Deflections shall be computed using the maximum unfactored loads (overload factor of 1.0).

Deflections shall be computed by usual methods or equations for elastic deformations. Annex A contains common deflection formulae that are used for standard types of tubular sections.

4.2.5 Standard pole sizes and types

Although a variety of different pole designs are possible, economies of scale and standardization can be obtained by utilizing more commonly fabricated pole sizes and material grades. Annex B contains a listing of the most commonly fabricated pole sizes and types. The list is not considered to be all-inclusive and pole configurations other than those specified are allowed as required. Information contained in Annex B includes the yield base moments and deflection characteristics for steel poles of varying shapes including round, square, sectional, and multi-sided configurations. For each pole type included in the tables, separate allowable base moments are provided for anchor base poles constructed with base plates of both 248.2 MPa (36 ksi) and 344.7 MPa (50 ksi) steel. Deflection characteristics per applied unit load at a specified height are also included to aid the OCS designer in initial pole size selection based on both strength and deflection.

4.2.6 Anchor rod and base plate configurations

A steel base plate, of sufficient cross-section to fully develop the yield strength of the pole, shall be secured to the base of each pole by means of a socket type joint with two fillet welds. For this joint, the base shall telescope the pole, and one weld shall be made inside the base at the end of the pole, with the other on the outside of the pole at the top of the base. Another acceptable procedure for base plate connection is the full penetration butt weld. All welding shall be in accordance with AWS D.1. See Figure 2 for typical pole base fabrication details.

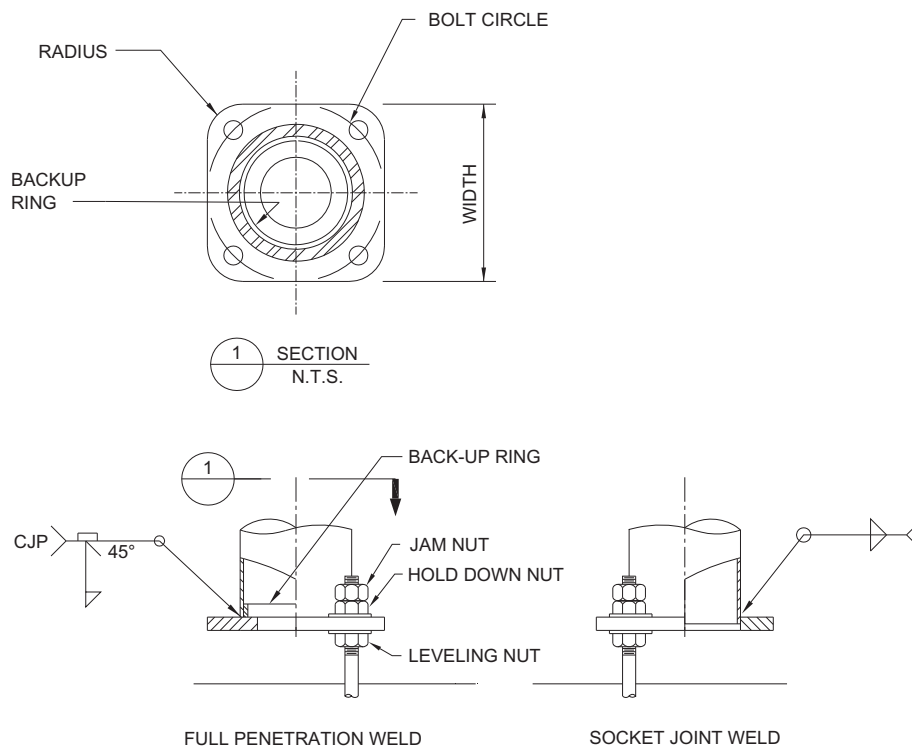


Figure 2—Typical base fabrication details

Anchor rods of sufficient quantity, diameter, and length to fully develop the yield strength of the pole shall also be designed and allocated with each pole. Each anchor rod shall be supplied with a leveling nut, a top nut, and a jam nut, if specified. During installation after the poles have been erected to their final rake and alignment, the leveling nuts shall be in full contact with the base-plate washers, and their top nuts and jam nuts shall be tightened according to the “turn-of-nut” method, as defined by the Research Council of Structural Connections (see AISC). In order to permit air flow through the pole and eliminate inside condensation or sweating, the area between the bottom of the base plate and the top of the concrete footing shall either remain free from grout or the grout shall be constructed with a minimum of two weep holes. Under no circumstances shall weathering steel poles be assembled with grouted base plates.

The tables in Annex B provide typical base plate/anchor rod/pole combinations that are routinely used in practice. Use of alternate combinations that are not included within the tables are acceptable; however, each combination shall be in accordance with the previous requirements. In establishing these standard base plate dimensions, there is no intention to preclude other types of base plate arrangements. However, through use of these standard dimensions, reduced lead times and economies of scale can be expected.

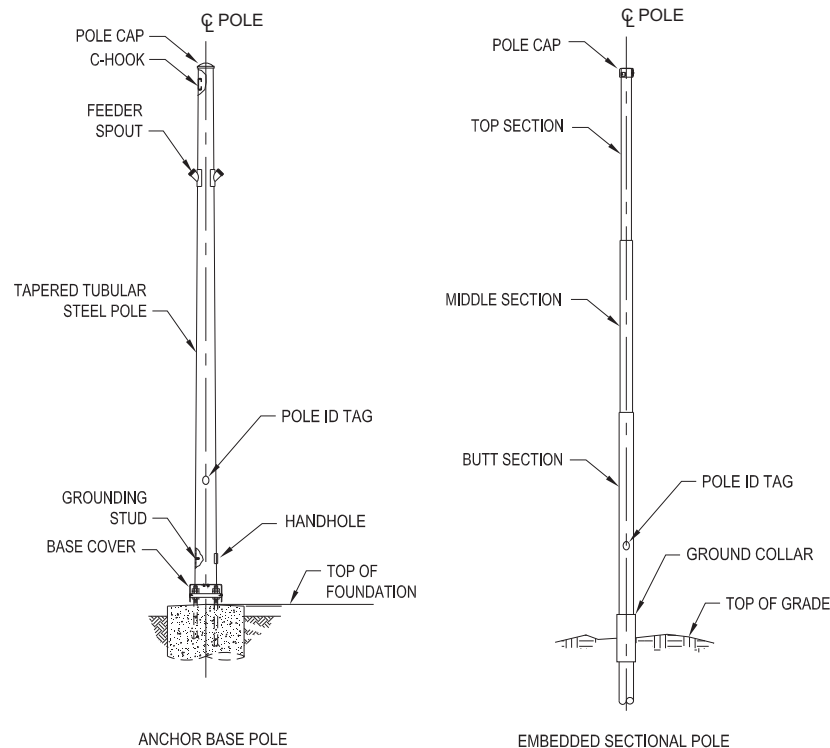


Figure 3—Typical pole assembly details

4.3 Construction details

The following subclauses indicate some of the construction details associated with standard tubular pole construction. To aid in the explanation of various details, Figure 3 has been included to illustrate the major elements of both standard tubular (constant diameter or tapered) and sectional poles. Although several of the construction details are common to both of the pole types, features included on each pole type depiction have been varied in order to show the range of construction features possible.

4.3.1 Pole taper

For tapered poles, uniform taper shall be between 6.25 mm and 12.08 mm change in diameter per meter (0.075 inch and 0.145 inch change in diameter per foot) of length and be uniform for the entire length of the pole. Unless dictated by specific project requirements, standard taper shall be 11.67 mm change in diameter per meter (0.14 inch change in diameter per foot) of length. Nominal dimensions for tapered poles are typically noted at the base plate.

4.3.2 Grounding assembly

Poles shall be fabricated with a suitable means of providing grounding. This shall be provided by either fabricating a grounding assembly welded directly to the pole base plate or secured inside the pole shaft. When installed within the pole shaft, a suitable hand hole shall be provided to facilitate grounding conductor installation and inspection. See Figure 4 for typical details of each type of connection. The grounding lugs and nuts shall be heavy square M14x2 (½"-13-UNC-2B). Ground connectors shall be stainless steel or bronze.

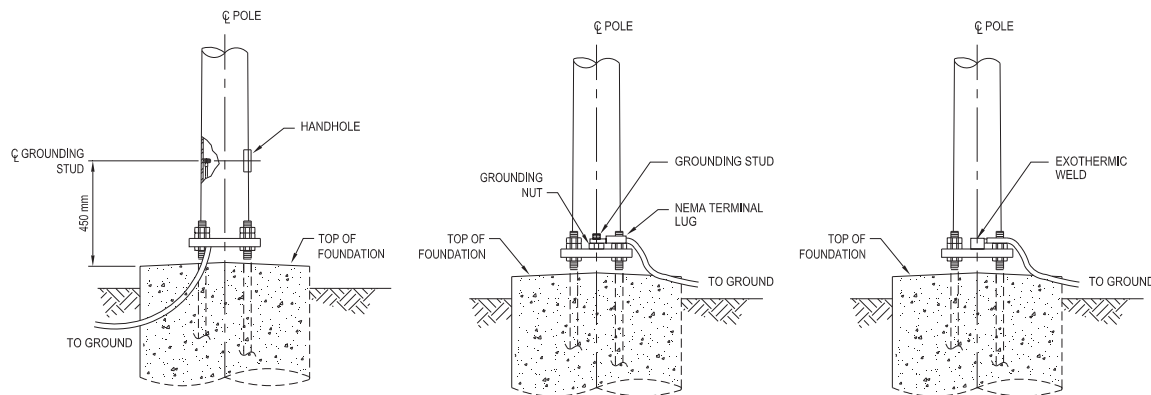


Figure 4—Typical pole grounding details

4.3.3 Hand holes

Where specified, access hand holes shall be provided along the shaft of the pole. The design of the hand hole shall be such that the strength and stiffness of the pole shaft are not compromised at the hand hole location. Hand hole reinforcement frames and covers shall be fabricated from steel material that is compatible with the pole shafts. Hand hole cover screws shall be stainless steel. Edges of hand holes shall be free from rough edges and burrs. Hand hole size, location, and orientation shall be specified. The designer shall ensure that hand holes do not conflict with pole brackets and other appurtenances.

4.3.4 Ground collars or ground sleeves

For all embedded poles, a ground collar of a compatible grade of steel shall be attached to each pole. Unless otherwise indicated, the collar shall be 600 mm (2 ft) long. Minimum thickness of ground collar shall be 9.5 mm (0.375 in). The collar shall be slid over the pole from the butt end to a specified location and swaged or shrunk sufficient to secure a watertight fit between the collar and the pole. The upper end of the collar shall be secured to the pole shaft with a full throat fillet weld to shed water away from the joint. The collar shall be located such that it extends 400 mm (16 in) above the ground line and 200 mm (8 in) below when the pole is installed.

4.3.5 Base covers

For purposes of aesthetics, poles may be specified to be supplied with ornamental base covers. Base cover fasteners, if used, shall be stainless steel.

4.3.6 Pole caps

In order to provide a more finished appearance of the pole and to prevent water from accumulating inside the pole, thereby minimizing corrosion, each pole shall be fitted with a cap. See 4.1.4 for additional requirements.

4.3.7 Pole identification tag

A metal tag shall be welded to the shaft of the pole 1.8 m (6 ft) above the base plate (above ground level for embedded type poles). The tag shall be deeply engraved and state the section modulus of the pole, strength of steel at yield, and year of manufacture of the pole.

4.3.8 Feeder spouts

Feeder spouts shall be provided where cable egress is required from inside a tubular pole. Portions of the feeder spout that contact the conductors shall be made smooth and free of sharp edges that may cause damage to the conductors during installation or chafing due to gravity loads. Pole shafts shall be of sufficient diameter to accommodate the total number of spouts required at any elevation. See Figure 5 for suggested feeder spout installation details. Feeder spout size, location, and orientation shall be specified. The designer shall ensure that feeder spout locations do not conflict with pole brackets and other pole appurtenances. Cables shall be installed with watertight bushings. Cables shall be supported from a c-hook or j-hook, as required.

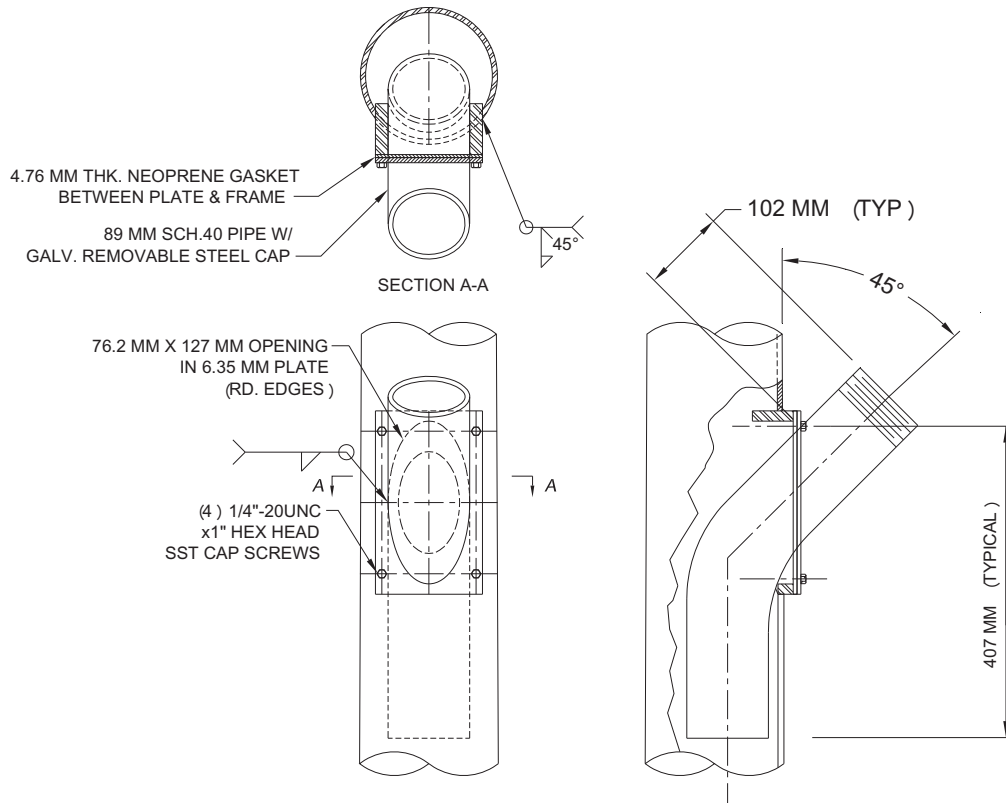


Figure 5—Suggested feeder spout installation details

4.4 Welding requirements

Welding procedures, welders, welding operations, and tackers shall conform to the provisions of AWS D1.1, or equivalent applicable national welding standard.

4.5 Additional requirements for sectional poles

Sectional OCS support poles shall be made of two or more pipe sections connected and attached to form an assembled pole. For a three-section pole, these sections are named “butt,” “middle,” and “top.” Each section shall be inserted into the adjoining section by one of two methods: swaging or welding. The following describes two potential methods of construction. It is not the intent of this standard to preclude the use of other alternate construction methodologies that meet all other requirements of this standard.

For swaged construction, the sections shall be inserted onto the adjoining section a minimum of 457.2 mm (18 in). The larger section heated and the smaller section inserted into it while cold. The larger section shall then be swaged tightly over the smaller section. There shall be no irregularities in the shape of the joint after swaging or lack of contact between the two pipe sections. The thickness of the larger section shall not be reduced by these operations. No mechanical device that would tend to weaken the joint in any way shall be used. The top of the outer pipe shall be fillet welded to shed water away from the joint. The weld thickness shall correspond to the thickness of the pipe.

For welded type construction, the sections shall be inserted into the adjoining section a minimum of 200 mm (7.87 in). The larger diameter pipe shall have three (3) steel tapered wedges welded to it at a distance of 200 mm (7.87 in) from the end of the pipe and shall be spaced equally one hundred and twenty (120)