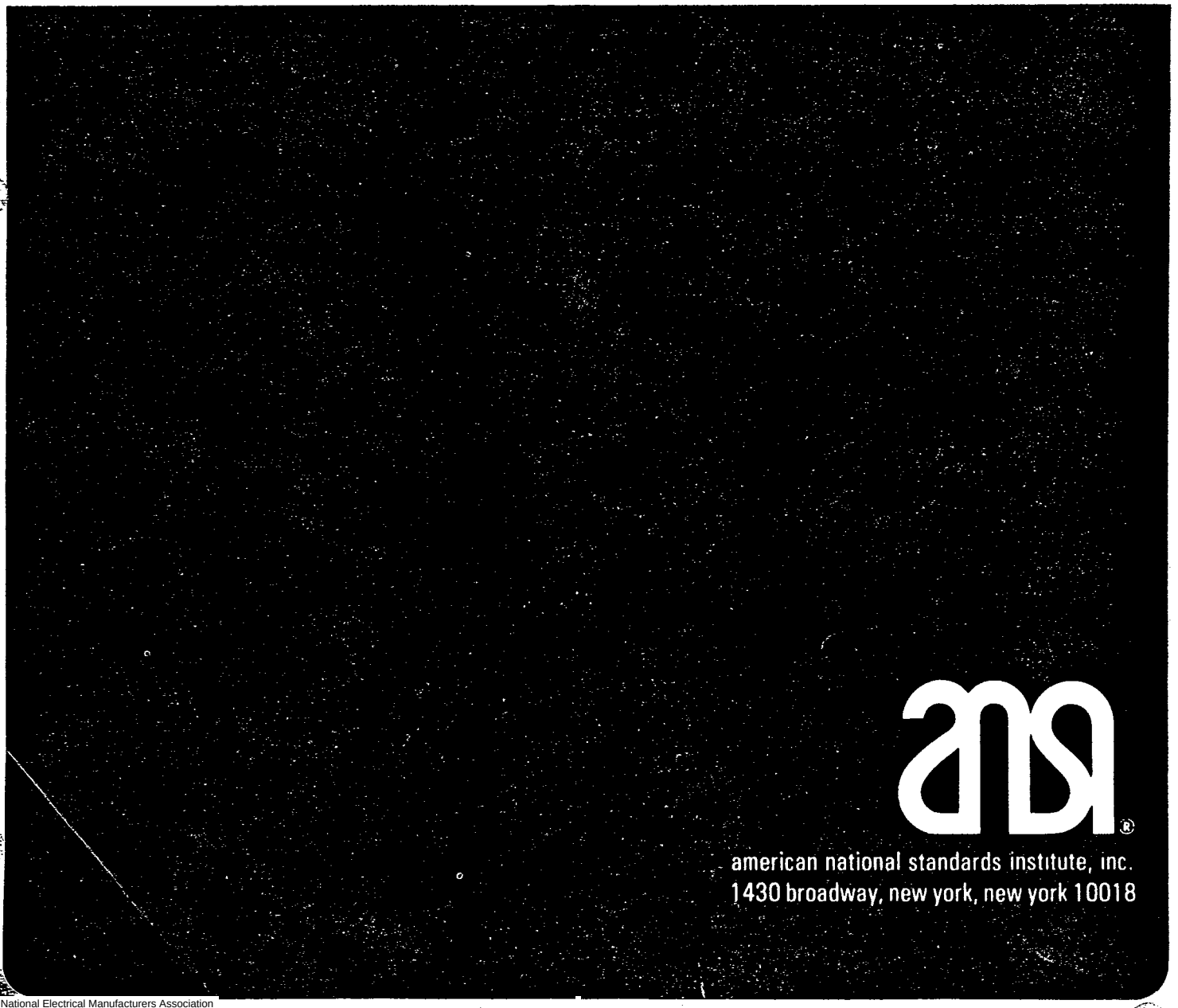
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American National Standard

tapered tubular steel structures



american national standards institute, inc.
1430 broadway, new york, new york 10018

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Foreword

This standards publication covers technical requirements for the design, materials, fabrication, testing, packing, and assembly of tapered tubular steel structures used in electrical transmission and distribution lines. Its purpose is to provide guidance to both users and manufacturers of tapered tubular steel transmission structures concerning design, fabrication, inspection, testing, packing, and assembly. It is intended to be used in conjunction with existing codes, standards, and specifications such as those published by American Welding Society and American Society for Testing and Materials and others, as referred to in this publication.

Metric measurements must be converted to English units for use in many of the equations herein. The units incorporated in this publication and their metric equivalents are listed below.

Inch (in)	= 2.540000 E−02 m
Pound-force (lbf)	= 4.448222 E+00 N
Kip	= 4.448222 E+03 N
Kips per square in (ksi)	= 6.894757 E+06 Pa

This publication will be reviewed periodically by the Tapered Tubular Steel Structure Section of NEMA in order to keep it up to date with advancing technology. Comments will be welcomed. They should be sent to:

Manager, Engineering Department
National Electrical Manufacturers Association
2101 L Street, NW
Washington, DC 20037

Scope

This standards publication covers only tapered tubular (pole type) steel transmission structures including free-standing cantilevers, guyed cantilevers, and H-frames.

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TAPERED TUBULAR STEEL STRUCTURES

Section 1
REFERENCED STANDARDS

In this publication, reference is made to the standards listed below. Copies are available from the indicated sources.

Reference Number

1 American Institute of Steel Construction, *Manual of Steel Construction,* 7th edition, New York, 1970.

2 American Institue of Steel Construction, *Specification for the Design, Fabrication and Erection of Structural Steel for Buildings,* New York, 1969.

3 American Iron and Steel Institute, *Specification for the Design of Cold-formed Steel Structural Members,* New York, 1968.

4 Bleich, F., *Buckling Strength of Metal Structures,* McGraw-Hill Book Company, New York, 1952.

5 Clark, J. W. and Hill, H. N., *Lateral Buckling of Beams,* Journal of the Structural Division, American Society of Civil Engineers (ASCE), July 1960.

6 Column Research Council: *Guide to Design Criteria for Metal Compression Members,* Johnston, B. G., ed., John Wiley & Sons, Inc., New York, 1966.

7 Gaylord, E. M. and Gaylord, C. M., *Design of Steel Structures,* 2nd Edition, McGraw-Hill Book Company, New York, 1972.

8 Gore, J. M. and Carter, W. O., *Critical Buckling Loads for Tapered Members,* Journal of the Structural Division of American Society of Civil Engineers (ASCE), February 1962.

9 Lee, G. C., Morrell, M. L. and Ketter, R. L., *Design of Tapered Members,* Welding Research Council Bulletin 173, 1972.

10 Newmark, N. M., *Numerical Procedure for Computing Deflections, Moments, and Buckling Loads,* Transaction of American Society of Civil Engineers (ASCE), Volume 108, 1943.

11 Wilhoite, G. M., *Design of Steel Transmission Pole Structures,* Journal of the Structural Division of American Society of Civil Engineers (ASCE), Volume 100, No. ST 12, Procedure Paper 11009, December 1974, pages 2449-2518.

12 American Concrete Institute, *Building Code Requirements for Reinforced Concrete,* ACI 318-71, June 1971.

13 Industrial Fasteners Institute (IFI), *Fastener Standards,* Fifth Edition, 1970, Cleveland, Ohio.

14 American Welding Society, *D.1.1,* Miami, Florida, 1975.

15 Steel Structures Painting Council, *Surface Preparation Specification,* SSPC-SP6, Pittsburgh, Pennsylvania 1972.

16 Steel Structures Painting Council, *Specification PA 1,* Pittsburgh, Pennsylvania, 1974.

17 American Society for Nondestructive Testing (ASNT) *Recommended Practice* SNT-TC-1A 1963 (With Supplements A, B, C, D), Evansville, Illinois.

18 American Society for Testing and Materials (ASTM), Philadelphia, Pennsylvania:

A 123-78 *Specification for Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed, and Forged Steel Shapes, Plates, Bars and Strip*

A 143-74 (1979) *Recommended Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement*

A 153-78 *Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*

A 370-77 *Methods and Definitions for Mechanical Testing of Steel Products*

A 563-78a *Specification for Carbon Steel Nuts*

A 673-77 *Specification for Sampling Procedure for Impact Testing of Structural Steel*

E 709-80 *Practice for Magnetic Particle Examination*

E 112-80 *Estimating the Average Grain Size of Metals*

E 165-80 *Recommended Practice for Liquid Penetrant Inspection Method*

19 American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code (Section V Recommended Practice for Radiographic Testing* SE 94, 1974), New York.

20 American Welding Society, D1.4-79 *Recommended Practices for the Welding of Reinforcing Steel.*

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Section 2
DEFINITIONS

2.1 ELASTIC ANALYSIS
Structural analysis in which stress and strain are considered to be directly proportional.
NEMA Standard 10-21-1976.

2.2 ALLOWABLE STRESS
A theoretical stress limit when using elastic analysis; it does not include concentrated or residual stress.
NEMA Standard 10-21-1976.

2.3 MEMBERS
Constituent parts of a structure (components).
NEMA Standard 10-21-1976.

2.4 SEGMENT
A portion of a member.
NEMA Standard 10-21-1976.

2.5 SECTION
A part of a member set off by, or as if by, cutting.
NEMA Standard 10-21-1976.

2.6 COMPLETE PENETRATION WELD
A weld in which there is complete penetration and fusion of the weld metal and base metal throughout the depth of the joint.
NEMA Standard 10-21-1976.

2.7 PARTIAL PENETRATION WELD
A weld in which penetration of the weld metal in the joint is less than complete.
NEMA Standard 7-12-1983.

2.8 GROUND LINE REACTIONS
The reaction of a structure or component at its base or at the earth's surface, caused by external forces and by its own weight.
NEMA Standard 10-21-1976.

2.9 NORMALIZED PLATES
Steel plates which are treated by heating to a predetermined temperature above the critical range, after which they are cooled slowly to below that range in still air.
NEMA Standard 10-21-1976.

2.10 CRACK
A linear rupture of metal under stress that can be determined by the required inspection procedures.
NEMA Standard 10-21-1976.

2.11 CHEMICAL CONDITIONING
Surface preparation by chemical reaction.
NEMA Standard 10-21-1976.

2.12 DELAYED CRACKING
A crack which occurs after the weld has cooled to room temperature without any external loading.
NEMA Standard 10-21-1976.

2.13 LOCAL BUCKLING
Localized failure of a structural member due to compression.
NEMA Standard 10-21-1976.

2.14 MILL SCALE
An oxide on metal surfaces caused by heating or by the metal-making process.
NEMA Standard 10-21-1976.

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Section 3
INFORMATION REQUIRED FOR DESIGN

3.1 INFORMATION TO BE SUPPLIED BY THE PURCHASER

It is recommended that the prospective purchaser provide the following information:

3.1.1 Configuration Requirements

1. Structure dimensions.
2. Conductor support locations.
3. Shield wire support locations and shield angle.
4. Insulation assembly length, swing angles, and electrical clearances.
5. Grounding attachment description and locations.

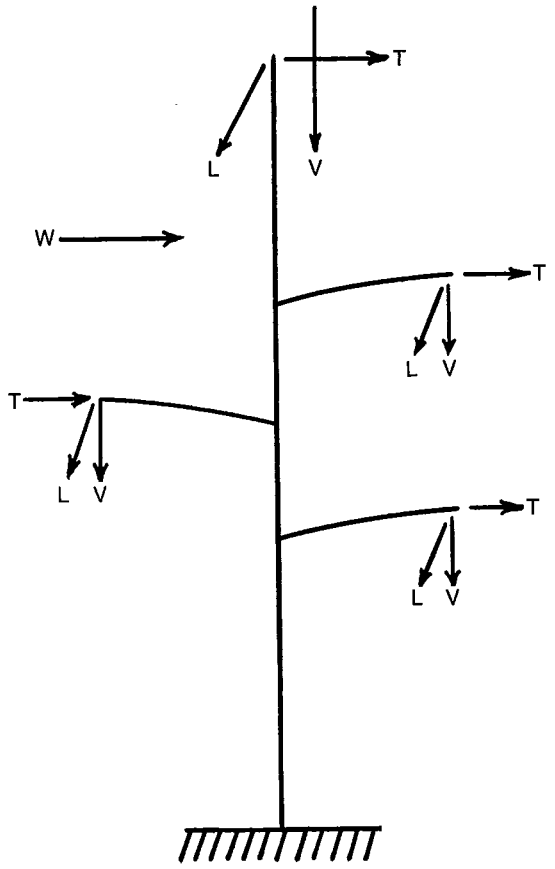
3.1.2 Structural Requirements

1. Loads, including overload factors, shown in the form of a loading tree (see Figure 3-1). Each loading condition should be shown separately, either in tabular form referencing a single, general loading tree or in individual loading trees.
2. If deflection limitations are required, the loading condition(s) and limitation(s).
3. Desired method of anchoring structures to the foundation, such as anchor bolts or embedment.
   a. If anchor bolts are to be used—minimum compressive strength of foundation concrete, any restrictions on anchor bolt dimensions, and whether individual anchor bolts or preclustered assemblies will be used.
   b. If embedment is to be used—embedment length and whether bearing plate is required.

3.1.3 Other Features

1. Diameter limitations (point to point or flat to flat for other than round cross sections).
2. Camber and/or rake of structure.
3. Location, orientation, size, length, material, and rated strength of guys.
4. Attachment requirements. (The effects of wear and corrosion should be considered and, if necessary, minimum thicknesses specified.)
5. Corrosion protection.
6. Climbing devices and working location supports for construction and maintenance.
7. Provisions for hot line maintenance.
8. Component weight and/or length restrictions.
9. Special tolerance requirements if different than those given in 8.7.

Authorized Engineering Information 7-12-1983.



T = transverse loads
L = longitudinal loads
V = vertical loads
W = wind loading on structure

Figure 3-1
SAMPLE LOADING TREE

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Section 4
NOMENCLATURE (SEE SECTION 5)

		Paragraph
A_o	Cross-sectional area of small end of tapered beam-column, in^2	5.3
A	Cross-sectional area, in^2	5.2.1
A	Stress area of a bolt across the threaded part, in^2	5.2.3
A_g	Gross cross-sectional area; in^2	5.2.1
A_n	Net cross-sectional area, in^2	5.2.1
C_c	Column slenderness ratio dividing elastic and inelastic buckling = $\sqrt{\frac{2\pi^2 E}{F_y}}$	5.3
C_m, C_{mx}, C_{my}	Coefficients applied to bending term in interaction formula and dependent upon column curvature caused by applied moments	5.4
C_w	Warping constant, in^6	5.4
c	Distance from neutral axis to the outer surface, inches	5.7
CRT	Cathode ray tube	10.2
D	Outside diameter of cylindrical cross-section, inches	5.8
D	Nominal bolt diameter, inches	5.2.3
E	Young's modulus of elasticity, 29 000 ksi	5.3
f_a	Computed compression stress P/A, ksi	5.7 5.8
f_b, f_{bx}, f_{by}	Computed bending stress Mc/I, ksi	5.7 5.8
f	Computed stress, P/A + Mc/l, ksi	5.7 5.8
f_t	Computed tensile stress, ksi	5.7
f_v	Computed shear stress, ksi	5.5 5.7
F_a	Maximum axial stress permitted in the absence of bending moment, ksi	5.3 5.7
F_b, F_{bx}, F_{by}	Maximum bending stress permitted in the absence of axial force, ksi	5.4 5.7
F'_a	Maximum compressive stress permitted considering local buckling	5.8
F'_b	Maximum bending stress permitted considering local buckling	5.8
F_E, F_{Ex}, F_{Ey}	Maximum Euler stress, $\frac{\pi^2 E}{(KL/r)^2}$, ksi.	5.7
F_p	Maximum allowable bearing stress, ksi	5.6
F_u	Specified minimum ultimate tensile stress, ksi, as defined by ASTM A 370 (see Reference #18†)	5.2.3 5.5 5.6
F_t	Maximum allowable tensile stress, ksi	5.2.1 5.5 5.7
F_v	Maximum allowable shear stress, ksi	5.5 5.7
F_y	Specified minimum yield stress of the type of steel being used, ksi, as defined by ASTM A 370 (see Reference #18†)	5.2 5.2.3 5.3 5.4 5.5 5.6 5.7 5.8

† See Section 1.

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g	Spacing (transversely) between successive holes normal to line of stress, inches	5.2.1
HAZ	Heat affected zone	10.5
I	Moment of inertia, in^4	5.5
I_x	Moment of inertia with respect to the X axis, in^4	5.7
I_y	Moment of inertia with respect to the Y axis, in^4	5.7
I_y	Moment of inertia for axis perpendicular to axis for bending, in^4	5.4
J	Torsional constant, in^4	5.4
K	Effective length factor	5.3 5.4
Kip	1 000 pounds	. . .
ksi	Kips per square inch	. . .
L	Member, length, inches	5.3 5.4
M	Applied bending moment, in-kips	. . .
M_1	Smaller moment at end of unbraced length of beam column, in-kips	5.4 5.7
M_2	Larger moment at end of unbraced length of beam column, in-kips	5.4 5.7
M_x	Moment about the X axis, in-kips	5.7
M_y	Moment about the Y axis, in-kips	5.7
n	Number of threads per inch	5.2.3
P	Applied load, kips	5.3 5.7
P*	Coefficient accounting for effect of taper	5.3
Q	Moment about the neutral axis of either of the two parts into which the cross section is divided, in^3	5.5
r	Governing radius of gyration, inches	5.3
r_{eq}	Equivalent radius of gyration, inches	5.3 5.4
r_o	Radius of gyration at the small end of a tapered column, inches	5.3
s	Spacing (pitch) between successive holes in line of stress, inches	5.2.1
S_x	Section modulus for axis of bending, in^3	5.4
t	Thickness, inches	5.5 5.8
V	Shear force in bending, kip	5.5
w	Flat width of section element exclusive of fillets, inches	5.8
y	Bending deformation of the beam-column, inches	5.7

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Section 5
STRUCTURAL ANALYSIS AND DESIGN (SEE SECTION 3)

5.1 GENERAL

5.1.1 Analysis

Elastic analysis shall be used.

5.1.2 Deflected Structure

The vertical loads shall be considered as acting on the horizontally deflected structure, which could impose additional stresses until a steady state is reached. Deflections and stresses shall be the result of design loads including overload factors.

5.1.3 Allowable Stress

The allowable stresses and guy forces specified in the following sections shall not be exceeded when considering design loads which include overload factors.

NEMA Standard 7-12-1983.

5.2 TENSION STRESS

5.2.1 Members

The allowable stress F_t on the net section A_n shall be taken equal to F_y. The net section A_n is the gross cross-sectional area A_g minus the loss in area because of holes or other openings. Where there is a chain of holes in a diagonal or zigzag line, the net width for determining the net area shall be obtained by deducting from the gross width the sum of the diameters of all of the holes in the chain and adding, for each gage space in the chain, the quantity $s^2/4g$, where s = longitudinal spacing (pitch) and g = transverse spacing (gage) of two consecutive holes.

5.2.2 Guys

The allowable tension force in stranded guys shall be 65 percent of the minimum rated breaking strength.

5.2.3 Bolts

For bolts of material having a specified proof-load stress, the allowable stress F_t on the stress area A shall be the ASTM proof-load stress.

$$A = \frac{\pi}{4}\left(D - \frac{0.974}{n}\right)^2 \qquad \text{(Equation 4-1)}$$

where D = nominal diameter of bolt and n = number of threads per inch.

† See Section 1.

If a proof-load stress is not specified, the allowable stress shall be $F_t = 0.6\ F_u$ except that $F_t = F_y$ for the anchor bolts, reinforcing bar bolts and other threaded parts having a specified yield stress.

5.2.4 Nuts Other Than Anchor Bolt Nuts

Nuts shall conform to the ASTM requirements for the bolts on which they are to be used. Threaded parts for which there is no ASTM specified nut and which are designed to carry tension or are to be installed to a specified pretension shall have a proof-load, determined in accordance with ASTM A 370 (see Reference #18†) capable of developing the tensile strength of the bolt.

5.2.5 Through-thickness Stress

The tensile stress in the through-thickness direction of a steel plate (as a result of a force imposed by a member welded to the plate) shall not exceed 36 ksi regardless of the yield strength of the material.

NEMA Standard 7-12-1983.

5.3 COMPRESSION STRESS

For axially loaded compression members having a uniform cross-section and meeting the requirements of 5.8, the allowable compression stress F_a shall be equal to:

$$F_a = F_y\left[1 - \frac{1}{2}\left(\frac{KL/r}{C_c}\right)^2\right]$$

when $0 \le \frac{KL}{r} \le C_c$

and (Equation 4-2a)

$$Fa\ \frac{\pi^2 E}{(KL/r)^2}$$

when $\frac{KL}{r} > C_c$ (Equation 4-2b)

where

$\frac{KL}{r}$ = the largest slenderness of any unbraced segment

r = the corresponding radius of gyration

and $$C_c = \pi\sqrt{\frac{2E}{F_y}} \qquad \text{(Equation 4-2c)}$$

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Unless a more exact nonlinear analysis is used, members with a nonuniform cross-section shall be evaluated in accordance with Equations 4-2 if an equivalent slenderness ratio is used. The allowable load P for a uniformly tapered member may be found by multiplying the cross-sectional area A_o of the small end by the value F_a computed for the equivalent slenderness ratios given by

$$\left(\frac{KL}{r_{eq}}\right) = \frac{1}{\sqrt{P^*}} \frac{KL}{r_o} \qquad \text{(Equation 4-3)}$$

Where r_o is the radius of gyration at the small end and P* is a coefficient which accounts for the effect of the taper. Values of P* shall be as given in Reference #8†. Equation 4-3 does not apply if significant abrupt changes occur in cross-sectional properties. In such cases F_a shall be determined by the numerical methods given in Reference #10†.

NEMA Standard 10-21-1976.

5.4 BENDING STRESS

For members which are supported against buckling out of the plane of the applied moment (lateral-torsional buckling) and which have cross-sections meeting the requirements of 5.8, the allowable bending stress F_b in tension or compression shall be equal to F_y.

For members which are not supported against lateral torsional buckling but which have a uniform cross-section and meet the requirements of 5.8, the allowable bending stress in compression shall be determined from Equation 4-2 by using the equivalent radius of gyration r_{eq} from Equation 4-4.

$$r_{eq}^2 = \frac{\sqrt{I_y [\, C_w + 0.04J\,(KL)^2\,]}}{C_m\, S_x} \qquad \text{(Equation 4-4)}$$

The coefficient C_m shall be taken equal to unity, except that for members acted upon by end moments M_1 and M_2, and with no intermediate loads, the less restrictive value given by

$$C_m = 0.6 + 0.4\frac{M_1}{M_2} \geq 0.4 \qquad \text{(Equation 4-5)}$$

shall be used, where $M_1 \leq M_2$ and M_1/M_2 is positive if the member is bent in single curvature. Values of C_m for other loadings are given in References #5, #6 and #8†.

Members with open cross section (e.g., I's, wide-flange shapes, channels, etc.) shall be analyzed for lateral torsional buckling when bent about the strong (x) axis of symmetry. Values of C_w and J are given in References #1, #4, #6 and #7†.

NEMA Standard 10-21-1976.

† See Section 1.

5.5 SHEAR STRESS

5.5.1 Members

The allowable shear stress for members other than fasteners shall be $F_v = 0.6\,F_y$. The shear V for rectangular box and I sections in bending shall be considered to be distributed uniformly over the web (or webs) of the section. In members of circular, elliptical, or polygonal cross-section, it shall be computed by the formula $f_N = VQ/2\,It$.

5.5.2 Bolts

The allowable shear for bolts shall be as follows:

$$F_v = 0.6F_y \qquad \text{(Equation 4-6a)}$$

or

$$F_v = 0.45F_u \qquad \text{(Equation 4-6b)}$$

Equation 4-6a shall be used if F_y is known; equation 4-6b, if only F_u is known. The allowable shear F_v shall be multiplied by the nominal area of the bolt if the shear plane is in the shank and by the area at the root of the threads if the shear plane is in the threads.

NEMA Standard 7-12-1983.

5.6 BEARING STRESS

5.6.1 Surfaces

For milled surfaces and other surfaces fitted for direct contact, such as drilled holes for pins, the allowable bearing stress F_p on the contact area shall be:

$$F_p = 1.50F_y \leq F_u \qquad \text{(Equation 4-7a)}$$

where F_y is the yield stress of the connected parts and provided that edge distances of Reference #1† are maintained.

5.6.2 Bolts

The allowable bearing stress on the projected area of the bolts shall be:

$$F_p = 2.25\,F_y \qquad \text{(Equation 4-7b)}$$

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5.7 COMBINED STRESSES

5.7.1 Beam Columns

Except as provided in 5.7.2, members which are closed sections, or which are subjected to axial compressions and bending and which are bent about the weak axis, or which are supported against lateral torsional buckling if they are bent about the strong axis, shall meet the following requirements:

$$f_a + f_b \leq F_y \qquad \text{(Equation 4-8a)}$$

and

$$\frac{f_a}{F_a} + \frac{f_b}{F_y} \frac{C_m}{1 - f_a/F_E} \leq 1 \qquad \text{(Equation 4-8b)}$$

Equation 4-8a shall be applied at the points of support in the plane of bending (usually the ends of the member) while Equation 4-8b shall be used to check for maximum stress at points between supports.

In Equation 4-8a, f_b is the stress at the point under consideration. In Equation 4-8b, f_b for members acted upon by end moments M_1 and M_2 but without transverse loads is computed for M_2, which is the larger of the two, and C_m is given by Equation 4-5. If the member carries transverse loads, f_b in Equation 4-8b shall be calculated at the point of maximum moment between supports. Beam columns, except for closed sections, which are bent about the strong axis and not supported against lateral torsional buckling shall be checked for compliance with Equation 4-8a and, instead of Equation 4-8b, with the following:

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \frac{1}{1 - f_a/F_E} \leq 1 \qquad \text{(Equation 4-9)}$$

The meaning of the terms in Equation 4-9 is the same as in Equation 4-8b except that:

1. F_a shall be based on buckling about the weak axis since the member is free to bend laterally.
2. F_b shall be based on Equations 4-2 using the equivalent radius of gyration from Equation 4-4.
3. F_E shall be based on buckling about the strong axis.

Beam columns subjected to bending about both principal axes shall be checked for compliance with

$$f_a + f_{bx} + f_{by} \leq F_y \qquad \text{(Equation 4-10a)}$$

at points of support, and

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} \frac{1}{1 - f_a/F_{EX}} + \frac{f_{by}}{F_y} \frac{C_{my}}{1 - f_a/F_{EY}} \leq 1 \qquad \text{(Equation 4-10b)}$$

† See Section 1.

for intermediate points. The x and y axes are the strong axis and weak axis of the cross-section, respectively, while $f_{bx} = M_x c/I_x$ and $f_{by} = M_y c/I_y$. F_a and F_{bx} shall be determined in accordance with Equation 4-9, except that for closed sections F_{bx} shall be taken as equal to F_y/C_{mx}. For beam columns meeting the requirements of Equations 4-8, Equation 4-8a may be used instead of Equation 4-8b to check for maximum stress at intermediate points, provided the bending moment for the calculation of f_b includes the secondary moment of the product of P and y, where y is the deflection of the member at any point.

5.7.2 Members

The combined shear stress and normal stress due to axial force and/or bending in members other than bolts shall not exceed:

$$f^2 + 3f_v^2 \leq F_y^2 \qquad \text{(Equation 4-11)}$$

5.7.3 Bolts

The shear stress f_v acting in conjunction with tensile stress f_t shall not exceed F_v where:

$$F_v = 0.65 \sqrt{F_t^2 - f_t^2} \qquad \text{(Equation 4-12)}$$

NEMA Standard 10-21-1976.

5.8 LOCAL BUCKLING

5.8.1 Members of Polygonal Cross Section

Formed members of regular polygonal cross-section with twelve or fewer sides for which the compressive stress f can equal F_y shall be proportioned so that

$$\frac{w}{t} \leq \frac{240}{\sqrt{F_y}} \qquad \text{(Equation 4-13)}$$

In determining w, the actual inside bend radius shall be used unless it exceeds 4t, in which case it shall be taken as being equal to 4t. For sections with two or more plies, each ply shall meet the requirements of Equation 4-13. Flatplate elements not covered by Equation 4-13 shall be proportioned to satisfy Reference #3 or Reference #2†. The values of w/t determined in accordance with Equation 4-13 may be exceeded if the compressive stress f does not exceed the value of F'_a given by:

$$F'_a = 1.45 F_y \left(1 - 0.00129 \sqrt{F_y} \frac{w}{t} \right)$$

when

$$\frac{240}{\sqrt{F_y}} \leq \frac{w}{t} \leq \frac{385}{\sqrt{F_y}} \qquad \text{(Equation 4-14a)}$$

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or

$$F'_a = \frac{108\,000}{(w/t)^2}$$

when $$\frac{385}{\sqrt{F_y}} \leq \frac{w}{t}$$ (Equation 4-14b)

The value of w/t determined in accordance with Equation 4-13 may be exceeded without requiring the reduction in stress determined by Equations 4-14 or a postbuckling analysis if resistance to local buckling is demonstrated by tests. The test results shall be adjusted for the yield value of the material determined in accordance with ASTM A 370 (see Reference #18†) and for differences between the design dimensions of the member and the cross-sectional dimensions of the test specimens. The yield stress of the test specimens shall be determined by tests on coupons taken in accordance with Reference #3†. If the member is subjected primarily to axial compression, one coupon shall be cut from each flat side and the weighted average determined. If the member is subjected to bending, or to bending and axial compression with the bending predominant, the coupons shall be taken from the compression face(s). The method of averaging the coupon results and other details of the test procedures are given in Reference #3†.

NEMA Standard 10-21-1976.

5.8.2 Members of Circular Cross-Section

Members of circular, smooth, eliptical, or regular polygon cross-section of more than twelve sides shall be proportioned for the following allowable stresses F'_a and F'_b:

5.8.2.1 Members Subjected to Uniform Compression

$$F'_a = F_y$$

when $$\frac{D}{t} \leq \frac{3800}{F_y}$$ (Equation 4-15a)

$$F'_a = 0.75\,F_y + \frac{950}{D/t}$$

when $$\frac{3800}{F_y} \leq \frac{D}{t} \leq \frac{12\,000}{F_y}$$

when (Equation 4-15b)

† See Section 1.

5.8.2.2 Members Subjected to Pure Bending

$$F'_b = F_y$$

when $$\frac{D}{t} \leq \frac{6000}{F_y}$$ (Equation 4-16a)

$$F'_b = 0.70\,F_y + \frac{1800}{D/t}$$

when $$\frac{6000}{F_y} \leq \frac{D}{t} \leq \frac{12\,000}{F_y}$$ (Equation 4-16b)

5.8.2.3 Members Subjected to Axial Compression and Bending

$$\frac{f}{F'_a} + \frac{f_b}{F'_b} \leq 1$$ (Equation 4-17)

The value of D/t determined in accordance with Equations 4-15a and 4-16a may be exceeded without requiring the reduction in stress determined by Equations 4-15b or 4-16b or a postbuckling analysis if resistance to local buckling is demonstrated by tests. The results shall be adjusted for the yield value of the material determined in accordance with ASTM A 370 (see Reference #18†) and for differences between the design dimensions of the member and the cross-sectional dimensions of the test specimens. The yield stress of the test specimen shall be determined by tests on coupons taken in accordance with Reference #3†. If the member is subjected primarily to axial compression, one coupon shall be cut from each quarter and the weighted average determined. If the member is subjected to bending, or to bending and axial compression with the bending predominant, the coupons shall be taken on the neutral axis. The method of averaging the coupon results and other details of the test procedures are given in Reference #3†.

5.9 WELDS

5.9.1 Complete Penetration

Complete penetration groove welds shall be designed for the same stresses as defined for the base metal in 5.9.4.

5.9.2 Partial Penetration

Partial penetration groove welds in compression normal to the throat shall be designed for the same stresses

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as the base metal. Partial penetration groove welds in shear or in tension normal to the throat shall be designed for the same stresses specified in 5.9.3 for fillet welds.

5.9.3 Fillet

The allowable shear stress on the throat of a fillet weld shall be taken as being equal to the corresponding stress for the base metal.

5.9.4 Dissimilar Properties

In the case of welding elements where the base metal is of different properties and strengths, the lowest grade of base metal shall be used as a reference for the weld design.

NEMA Standard 10-21-1976.

5.10 COLD WORKING

The allowable design stress shall not include any increase in strength in the bend area due to cold working when cold forming bends in steel plate.

NEMA Standard 10-21-1976.

5.11 JOINTS AND CONNECTIONS

5.11.1 Shaft to Foundation

5.11.1.1 Base Plate/Anchor Bolt Type

1. *Anchor Bolts*—If the connection is made with anchor bolts through a base plate, the anchor bolts shall be designed by the ultimate strength procedure described in Reference #12†; or, for smooth anchor bolts, see Appendix A. Shorter anchor bolts may be used if the design provides for mechanical anchors at the bottom of the anchor bolts to increase the pullout resistance.

2. *Base Plate to Shaft*—Base to shaft welds shall be complete penetration groove welds. Additional fillet weld reinforcement may be needed to meet the requirements of 4.2.5. The joints shall be qualified in accordance with the procedures in Reference #14†.

2. *Base Plate to Shaft*—Base to shaft welds shall be complete penetration groove welds. Additional fillet weld reinforcement may be needed to meet the requirements of 4.2.5. The joints shall be qualified in accordance with the procedures in Reference #14†.

5.11.1.2 Embedded Type

See 2.1, Item 2,c.

5.11.2 Shaft Section to Shaft Section

5.11.2.1 Telescoping Joints

Telescoping joints shall develop the full required design strength. They shall be detailed for a minimum lap of 1.5 times the largest inside diameter of the female section with allowances for fabrication tolerances. Complete penetration welds shall be used in the splice area of the female section.

5.11.2.2 Circumferentially Welded Joints

Complete penetration welds shall be used for sections joined by circumferential welds.

5.11.3 Intersecting Welds

Any weld which intersects a complete penetration weld shall be a full penetration weld for at least 3 inches adjacent to the intersection of the complete penetration weld.

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† See Section 1.

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Section 6
DESIGN INFORMATION TO BE SUPPLIED BY THE MANUFACTURER

6.1 DESIGN INFORMATION

The following design information should be supplied by the manufacturer:

6.1.1 Preliminary Information

1. Calculated shipping weight of structure, excluding anchor bolts.
2. Calculated shipping weight of anchor bolts.
3. Maximum ground line reactions.
4. Anchor bolt size, length, and location.
5. Type of material of major components (ASTM designation, if applicable).
6. Description of pole shaft, including thickness, length, diameter, cross-sectional geometry, and method of fastening each shaft component.
7. Method of attaching appurtenances to structure.
8. Design exceptions or alternates.

6.1.2 Final Documentation

1. Design calculations for pole shaft, base plate, anchor bolts, crossarms and other appurtenances, including their connections for all structures.
2. Drawings of each structure type, including all of the information listed in the items in 6.1.1.
3. Identification and weight of each structure and component.

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Section 7
MATERIALS

7.1 GENERAL

All materials shall comply with the applicable requirements of ASTM unless otherwise specified.

NEMA Standard 10-21-1976.

7.2 IMPACT PROPERTIES

The impact properties in the longitudinal direction of the material which is essential to the strength of the structure shall be determined in accordance with the Charpy "V" notch test described in ASTM A 370 and, at a minimum, shall meet the requirements of Table 7-1. The absorbed energy requirements for subsize test specimens shall be in accordance with ASTM A 370 and A 673, Table 1 (see Reference #18†).

For plates ½ inch or less in thickness and for quenched and tempered or normalized plates of any thickness, heat lot testing shall be used to determine whether the product meets the impact property requirements.

Controlled rolled or as-rolled shapes and plates over ½ inch thick shall be tested on a slab (plate) testing basis. This entails a test on one plate of each separate slab.

NEMA Standard 7-12-1983.

7.3 ANCHOR BOLTS AND NUTS

Anchor bolts shall meet the impact requirements specified in 7.2. Anchor bolt nuts shall have a proof load equal to or greater than the yield strength of the anchor bolt.

NEMA Standard 10-21-1976.

7.4 OTHER BOLTS AND NUTS

Galvanizing shall not be used for bolts having an ultimate strength over 150 ksi. (Nuts may be galvanized.) Impact tests are not required for heat-treated nuts and bolts. Nut and bolt sizes and dimensions shall be in accordance with Reference #13†.

NEMA Standard 10-21-1976.

7.5 WELD MATERIAL

The material used for making welds shall be compatible with the parent material, as defined by American Welding Society, and shall meet the impact requirements specified in 7.2 for the lowest toughness requirements of the plates being joined.

NEMA Standard 10-21-1976.

Table 7-1

Specified Yield, KSI	Plate Thickness or Bar Diameter, Inches	Absorbed Energy, Ft-Lb (J)	Temperature Degrees F° (C°)
≤42	≤½	None Required	None Required
	>½	15 (20.337)	+40(−4.94)
≥42	≤½	15 (20.337)	0(−17.78)
	>½	15 (20.337)	−20(−28.89)

† See Section 1.

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Section 8
FABRICATION

8.1 GENERAL

Fabrication includes cutting, bending, machining and welding. These standards do not specify the methods to be used to accomplish these operations, but do define the performance requirements.

NEMA Standard 10-21-1976.

8.2 CUTTING

Cut parts shall be in accordance with Reference #14†, Section 2.2.1 of Pub. No. D1.1.

NEMA Standard 10-21-1976.

8.3 FORMING

During forming, care shall be taken to prevent separation of the outer surface and reduction of the cross-sectional properties below those required for compliance with Section 5. If separation does occur, it shall be repaired in accordance with Reference #14†. Mill scale shall not be considered as the surface.

NEMA Standard 10-21-1976.

8.4 BOLT HOLES

Bolt holes shall be cylindrical, perpendicular to the member, free of burrs, and clean cut without torn or ragged edges.

NEMA Standard 10-21-1976.

8.5 WELDING

8.5.1 General

Welding operations shall be in accordance with Reference #14†, Pub. No. D1.1, Sections 1 through 8 (omitting Part II, Section 8), or Reference #20†, where applicable.

8.5.2 High-strength Anchor Bolts

If American Welding Society qualification procedures are not followed, structural resistance below the welded point of an anchor bolt shall not be included in design calculations.

NEMA Standard 7-12-1983.

8.6 STRAIGHTENING OR CAMBERING

If required, parts or assemblies may be straightened or cambered by mechanical means or the localized application of heat, provided that the integrity of the structure is not jeopardized.

NEMA Standard 10-21-1976.

† See Section 1.

8.7 TOLERANCES

The following tolerances shall apply to all component parts of structures. Other tolerances should be as specified by the manufacturers.

8.7.1 Cut Parts

With the exception of the length of tubular section members, cut parts shall be within ± ¼ inch of the dimensions specified.

8.7.2 Plate Bends

Plate bends shall be centered within ± ¼ of the dimension specified. The angle of bend shall be within ±5 degrees of the angle specified, except that it shall be within ±3 degrees for shaft and arm sections.

8.7.3 Bolt Holes

Punched or drilled bolt holes shall be within −0 inch and + 1/16 inch of the diameter specified. Burned holes shall be within −0 inch and + ⅛ inch of the diameter specified.

8.7.4 Threads

The threading process shall produce fastener fits within the tolerances given in Reference #13†. Thread lengths shall be within −0 inch to + ½ inch of the specified length. Nuts used on galvanized bolts shall be oversize in accordance with ASTM A 563 (see Reference #18†).

8.7.5 Shafts

The straightness of shafts shall be within ⅛ inch for every 10 feet of length, or fraction thereof.

8.7.6 Assembled Total Length of Pole Shafts

8.7.6.1 Single-pole Structures

1. *With Telescoping Joint Shaft Connections*—The overall length of the assembled structure shall be not less than the specified height less 6 inches per slip-joint connection. The overall assembled length shall be not less than 98.5 percent of that specified.

2. *With Butt Welded and/or Flanged Shaft Connections*—The overall length of the assembled structure shall be within +1 percent or −½ percent of the specified height.

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8.7.6.2 Multipole Structures

The overall length of the individual poles of a multipole structure shall be controlled to the extent dictated by the type of foundation, structure design and construcition methods used.

NEMA Standard 10-21-1976.

8.8 ARM SHAFTS AND CONNECTIONS

Manufacturing tolerances on arms and their connections shall not result in less than the specified electrical clearances.

NEMA Standard 10-21-1976.

8.9 ASSEMBLED STRUCTURE

The fabrication of components shall be such that, when assembled, the structure will conform to the geometry as specified on the drawings.

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Section 9
FINISHES

9.1 SURFACE PREPARATION

Prior to any chemical conditioning, all welds shall be mechanically cleaned to remove any weld flux residue.

After fabrication and prior to painting, surfaces which are to be painted shall be conditioned in accordance with Reference #15† or in accordance with the paint manufacturer's recommendations.

NEMA Standard 10-21-1976.

Weathering steel should be pickled or prepared in accordance with Reference #15† to provide a uniform initial weathering surface.

Authorized Engineering Information 10-21-1976.

9.2 GALVANIZING

Galvanizing shall be in accordance with ASTM A 123 and A 143 (see Reference #18†). Fasteners, hardware, and anchor bolts shall be galvanized in accordance with ASTM A 153 and A 143 (see Reference #18†). Damaged galvanized surfaces shall be repaired by the application of at least 3½ mils dry film thickness of zinc-rich paint or the application of at least 3½ mils of zinc metal. The repair shall be made in accordance with the coating manufacturer's recommendations.

NEMA Standard 10-21-1976.

9.3 PAINTING

The paint coating shall be applied to the specified thickness in accordance with Reference #16 or the paint manufacturer's recommendations. Hermetic sealing shall be permitted to protect interior surfaces.

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† See Section 1.

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Section 10
INSPECTION

10.1 FABRICATION

Each fabrication process shall be inspected for conformance with Section 8.

10.1.1 Cutting

Cut edges shall be inspected visually for conformance with 8.2 and 8.7.1.

10.1.2 Bending

Bent surfaces shall be visually inspected for conformance with 8.3. Questionable areas shall be inspected by the liquid penetrant or magnetic particle method.

10.1.3 Threading

Threads shall be checked for fit, and thread lengths shall be measured for conformance with 8.7.4.

10.1.4 Bolt Holes

Bolt holes shall be inspected visually for conformance with 8.4 and 8.7.3. Questionable areas shall be inspected by the magnetic particle or liquid penetrant method.

10.1.5 Welding

Welding practices and procedures shall be inspected for compliance with 8.5 prior to welding. Welding defects shall not exceed the requirements of 10.3 and 10.4.

10.1.5.1 Base Plate to Pole Shaft Weld

The weld shall be inspected for internal defects by normal and shear wave ultrasonic methods for conformance with 10.3. The normal beam ultrasonic method shall be limited to the thickness of the base plate and for heat-affected-zone (HAZ) defects only. Plied construction consisting of more than two plies, or of two plies if inaccessible for inspection from the inside, will also require radiographic inspection.

There shall be no surface cracks in or near the weld. The weld shall be free of overlap. The weld shall be inspected visually. Questionable areas shall be inspected by the magnetic particle or liquid penetrant method.

There shall be no undercutting in the pole shaft in excess of 0.01 inch except that a 1/32-inch undercut is allowed for 2 inches in any 12 inches of weld length. There shall be no undercutting in the base plate in excess of 1/32 inch. Inspection shall be visual.

Welds shall be spot checked for delayed cracking in the heat affected zone. Structures that are galvanized shall be spot checked after galvanizing in accordance with 10.5.

10.1.5.2 Circumferential Groove Welds

The weld shall be inspected for internal defects by shear wave ultrasonic or radiographic methods for conformance with 10.3.

There shall be no surface cracks in or near the weld. The weld shall be free of overlap. The weld shall be inspected visually. Questionable areas shall be inspected by the magnetic particle or liquid penetrant method.

There shall be no undercutting in excess of 0.01 inch except that a 1/32-inch undercut is allowed for 2 inches in any 12 inches of weld length. Inspection shall be visual.

10.1.5.3 Longitudinal Weld in the Female Telescoping Joint

The weld shall be inspected for internal defects by shear wave ultrasonic or radiographic methods for conformance with 10.3.

There shall be no surface cracks in or near the weld. The weld shall be free of overlap. The weld shall be inspected visually. Questionable areas shall be inspected by the magnetic particle or liquid penetrant method.

There shall be no undercutting in excess of 0.01 inch except that a 1/32-inch undercut is allowed for 2 inches in any 12 inches of weld length. Inspection shall be visual.

10.1.5.4 Longitudinal Welds in Areas Other Than Those Covered in 10.1.5.3

The weld shall have a minimum penetration of 60 percent. Inspection shall be visual.

There shall be no surface cracks in or near the weld. The weld shall be free of overlap. The weld shall be insepcted visually. Doubtful areas shall be inspected by the magnetic particle or liquid penetrant method.

There shall be no external surface porosity in excess of that specified in 10.3 nor any undercutting at the external surface in excess of 1/32 inch. Inspection shall be visual.

10.1.5.5 Arm Shaft to Pole Connection Plate Weld

There shall be no cracks in or near the weld. The weld shall be free of overlap. The weld shall be inspected by the magnetic particle, liquid penetrant or ultrasonic method.

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There shall be no external surface porosity in excess of that specified in 10.3 nor any undercutting in the arm shaft in excess of 0.01 inch, except that a 1/32-inch undercut is allowed for 2 inches in any 12 inches of weld length. There shall be no undercutting in the connection plate in excess of 1/32 inch. Inspection shall be visual.

10.1.5.6 Other Welds

There shall be no surface cracks in or near the weld. The weld shall be free of overlap. The weld shall be inspected visually. Questionable areas shall be inspected by the magnetic particle or liquid penetrant method.

There shall be no external surface porosity in excess of that specified in 10.3 nor any undercutting in excess of 1/32 inch. Inspection shall be visual.

10.1.6 Closed Sections

Formed and welded closed sections shall be inspected for conformance with 8.7.1 and 8.7.2.

10.1.7 Straightness

Sections shall be inspected for conformance with 8.7.5.

NEMA Standard 10-21-1976.

10.2 INSPECTION METHODS

10.2.1 Visual Inspection

Visual inspection shall be in accordance with Reference #14†.

10.2.2 Magnetic Particle Inspection

Magnetic particle inspection shall be in accordance with ASTM E 109 (see Reference #18†).

10.2.3 Liquid Penetrant Inspection

Liquid penetrant inspection shall be in accordance with ASTM E 165 (see Reference #18†).

10.2.4 Radiography Inspection

Radiography inspection shall be in accordance with Part II of Section 6 of Reference #14†. A fine-grain type 2 or a higher contrast film in accordance with Reference #19 Section V Recommended Practice SE 94-1974 shall be used.

10.2.5 Ultrasonic Inspection

Ultrasonic inspection shall be in accordance with Reference #14†, except as follows:

1. Piezoelectric materials shall be permitted as follows:

   a. *Angle beam transducers*—lead zirconate titanate type E2.

   b. *Straight beam transducers*—barium titanate or lead zirconate titanate type E2.

2. Paragraph 6.16.7 shall be amended to permit the use of normal beam transducer frequencies of 1 to 5 megahertz.

3. Paragraph 6.19.2 shall be amended to permit calibration for normal beam testing which shall be performed as follows:

   a. The horizontal sweep shall be adjusted for distance calibration to present the equivalent of at least two plate thicknesses on the CRT screen.

   b. The sensitivity shall be adjusted by the use of the gain control (attenuator) so that a horizontal reference level (mid-screen) trace deflection results on the CRT screen from the first reflection from the far side of the plate. The transducer located on the plate shall be inspected in an area free of defects. The gain control shall be increased 10 decibels. This shall be the scanning sensitivity.

4. Paragraph 6.19.3 shall be amended to permit calibration for angle beam testing which shall be performed as follows:

   a. The sensitivity shall be adjusted by the use of the gain control (attenuator) so that a horizontal reference level (mid-screen) trace deflection results on the CRT screen with the maximum indication from the 0.06-inch diameter hole in the International Institute of Welding (IIW) block or from the equivalent reference reflector in other calibration blocks recognized by the American Welding Society (AWS).

   b. The gain control shall be increased by the appropriate attenuation factor (see Table 10-1). The sound path travel in the first and second node shall be the deciding factor as to the decibel gain used.

Table 10-1

Sound Path Travel, Inches	Attenuation Factor
1	0
2	2
3	4
4	6
5	8
6	10
7	12
8	14
9	16
10	18

   c. In addition to the attenuation factor, the gain control shall be increased to the minor reflector level for the applicable weld throat shown in Table 8.15.3 of Reference #14†.

† See Section 1.

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d. The following example will serve as a guide in using the attenuation factor to evaluate discontinuities:

Example—Using a 70-degree transducer to inspect a butt weld in a plate ½ inch thick, the sound path travel for node one would be approximately 1½ inches and would require zero decibel increase. The sound path travel for node two would be approximately 3 inches and would require a 4-decibel increase for evaluating a discontinuity at the end of node two. The decibel gain should be decreased to the nearest decibel for sound path distance when evaluating discontinuities.

5. Table 8.15.3 shall be modified so that the following criteria will be used for both straight beam and angle beam testing.

a. A discontinuity that exceeds an amplitude of 50 percent of screen height shall not exceed ¾ inch in length.

b. A discontinuity that exceeds an amplitude of 70 percent of screen height shall not exceed 3/16 inch in length.

NOTE—Caution must be exercised in evaluating reflectors to be sure that they are actual discontinuities and not spurious signals from joint configurations or back-up strips, etc.

6. If the ultrasonic test results appear questionable, the weld shall be inspected by the radiographic method or by destructive sectioning to verify that the requirements of 10.3 are met.

NEMA Standard 10-21-1976.

10.3 WELD DEFECTS

The weld shall have no cracks, and porosity shall not exceed ⅜ inch in any linear inch of weld. Weld defect sizes shall not exceed those shown in Figure 10-1.

NEMA Standard 10-21-1976.

10.4 VISUAL INSPECTION

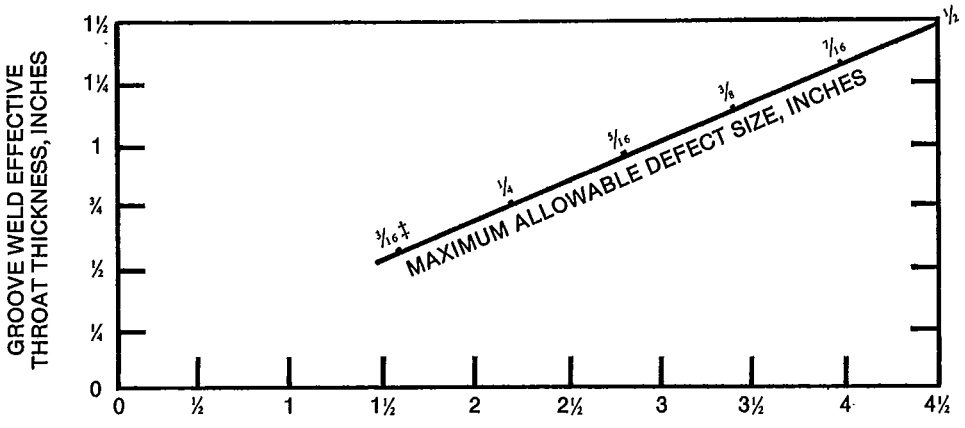
A weld which is subjected to visual inspection shall comply with the following:

1. The weld shall have no cracks.
2. Thorough fusion shall exist between weld metal and base metal.
3. All craters shall be filled to the full cross-section of the weld.
4. Weld sizes shall be in accordance with design drawings.
5. Fillet welds in any single continuous weld may be less than the nominal fillet size by 1/16 inch without correction provided that the undersize weld does not exceed 10 percent of the length of the weld.
6. Porosity shall not exceed ⅜ inch in any linear inch of weld.

NEMA Standard 10-21-1976.

10.5 INSPECTION FOR DELAYED CRACKING OF GALVANIZED STRUCTURES

Shaft to base plate welds shall be inspected by the ultrasonic method for evidence of cracking in the shaft or base plate heat affected zone. This shall be accomplished by a 70°-angle beam inspection from the shaft side and a 45°-angle beam and normal beam inspection from the underside of the base plate.



‡ 3/16 inch or ⅓ the effective weld throat, whichever is less.

Example—for a throat thickness of ¾ inch, the maximum allowable defect size is ¼ inch, and the minimum clearance between defects is 2¼ inches.

† See Section 1.

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The scanning level shall be 16 decibels above the horizontal reference level (midscreen). Angle and normal beam reference level from the base side shall be determined using a backwall reflector.

All indications from the shaft heat affected zone at the toe area and from the base heat affected zone which produce a signal equal to or exceeding 50 percent of the screen height shall be investigated further, as follows:

1. Remove the coating by grinding the area in question and
2. Test by the liquid penetrant or magnetic particle method.

NEMA Standard 10-21-1976.

10.6 NONDESTRUCTIVE TESTING

Nondestructive testing shall be conducted in accordance with Reference #17†.

NEMA Standard 10-21-1976.

10.7 FINISHES

10.7.1 Painting

1. *Surface*—Surface preparation shall be visually inspected for conformance with 9.1.
2. *Coating*—Each coat shall be visually inspected for conformance with 9.3.

10.7.2 Galvanizing

Galvanizing shall be inspected for conformance with 9.2.

NEMA Standard 10-21-1976.

10.8 TEST AND INSPECTION RECORDS

It is recommended that the manufacturer include the following information in his test and inspection records:

1. Material certification (see Section 7.)
2. Welder qualification (see Reference #14†).
3. Inspector certification (see Reference #17†).
4. Results of inspection for compliance with Section 10.

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† See Section 1.

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Section 11
LOAD TESTING

11.1 DEFINITION

Load testing is the application of design loads to the structure to verify the adequacy of the design, material and fabrication.

NEMA Standard 10-21-1976.

11.2 GENERAL CONSIDERATIONS

The test load shall be the design load including overload factors.

Loading conditions which govern the design of any or all parts of the structure shall be applied.

The test procedure shall include loading conditions, method of test, data to be recorded, and a diagram of the test arrangement.

Load measuring devices shall have an accuracy within ± 2 percent and shall be calibrated prior to test.

NEMA Standard 10-21-1976.

It is recommended that the calibration be done no more than 30 days prior to test.

Authorized Engineering Information 10-21-1976.

11.3 TEST PROCEDURE

When the structure under test is not oriented in the position for which it was designed, the load shall be compensated to account for gravity and eccentricity and restraints caused by rigging.

Load measuring devices shall be so located as to indicate loads being applied to the structure.

Loads shall be applied incrementally up to 100 percent of the test load which shall be held for a minimum of 5 minutes.

Deflection readings shall be taken under the initial no-load condition (including the dead loads of the structure and the necessary rigging) and after each incremental load. A no-load deflection reading shall be taken after the removal of the 100 percent test load.

NEMA Standard 10-21-1976.

11.4 TEST RESULTS

After the test is completed, the structure shall be dismantled and inspected for conformance with the design.

The results shall be reported in a written test report.

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Section 12
PACKING AND SHIPPING

12.1 PACKING

12.1.1 Materials and Procedures

All packing materials should be suitable for their intended purpose under normal shipping conditions. Selection of load carrying packing material should take into account the abrasion resistance and strength requirements of the particular load.

12.1.2 Anchor Bolts

Anchor bolts should be identified appropriately.

12.1.3 Shafts

Due precautions should be taken when handling and loading tubular steel members to prevent damage to the shafts or their finishes. Shaft sections should be properly blocked and secured to minimize movement during shipment. Blocks and straps should be properly padded to minimize abrasion of the shaft finish.

Spliced shaft segments should be properly identified so that the sections for each structure can be segregated upon arival at their destination. If shafts have slip joints, flanged splices or field butt-weld splices which have been prefit prior to shipment, the individual sections should be match-marked so that they can be oriented properly and reassembled in the field. Plate edges of sections that have been prepared for field welding should be suitably covered and protected during shipment and until they are assembled in the field. Each section of the shaft should carry its individual identification. Nesting a smaller shaft section within larger diameter tubes is not recommended.

12.1.4 Crossarms

Crossarms should be bundled or packed individually for shipment. They should be properly identified and marked for attachment to the structure in their correct location.

12.1.5 Hardware

All necessary hardware for assembling structures should be securely packed and marked. The hardware container should be adequately secured to minimize damage during shipment.

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12.2 SHIPPING

Any shipping damage or shortages should be reported to the manufacturer and carrier. Arrangements should be made for inspection of the damaged material prior to unloading by the carrier and other parties concerned.

Unloading should be carried out with due precautions for protecting the structures and their finishes.

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Section 13
ASSEMBLY

13.1 MODIFICATIONS

No modifications should be made to the structure in the field without consulting the manufacturer.

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13.2 ANCHOR BOLTS

Individual anchor bolts or preclustered assemblies are normally shipped in advance of the structures.

Preclustered bolt assemblies should be handled with care to insure that their alignment with the base plate will not be impaired. The assemblies should be properly oriented in the foundation excavation in accordance with the manufacturer's instructions, and the dimensions of the anchor-bolt pattern should be checked prior to pouring the concrete.

Individual anchor bolts require devices such as templates for aligning them with their respective base plate over the excavation.

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13.3 SHAFT ASSEMBLY

Structures are usually shipped in one of the following ways:

1. In sections with telescoping joints.
2. In sections with flanged joints.
3. In sections for field butt welding.
4. In one piece.

13.3.1 Shaft Assembly with Telescoping Joints

Most commonly, the bottom shaft sections are first joined together and then the upper sections are joined to complete the shaft assembly. The sections should be blocked up so that they are relatively level and horizontal, taking care not to put a block in a splice area. The bottom section should be so oriented that conductor arms, steps, etc., may be added later without having to rotate the structure.

Hydraulic jacking devices or ratchet chain hoists "comealongs" may be used for pulling the sections tightly together. Minimum and maximum jacking forces should be determined prior to the jointing operation. Regardless of the method used for pulling the sections together, force should be exerted on both sides of the joint simultaneously. The sections should be telescoped the predetermined distance.

After the shaft sections are assembled, crossarms, hardware, climbing devices, insulators, etc., can be attached to the structure. Climbing devices should be omitted in areas on the structure where they may interfere with lifting the structure during erection. The recommended torquing should be provided for bolts to be fastened in the field.

13.3.2 Shaft Assembly with Flanged Joints

The assembly of shaft sections with flanged joints should follow the same general procedure which is utilized in assembling structures having telescoping joints. Particular attention should be paid to the match markings at the flanges so that a proper vertical alignment will be maintained when sections are bolted together. The recommended torquing for bolting the sections together should be provided. Shim plates may be used to obtain proper bearing and alignment of the joined sections.

13.3.3 Structure Assembly with Field-butt-weld Shaft Sections

Shaft sections may be welded together in the prone or upright position. Temporary erection clips (lugs) should be provided on the structure to facilitate alignment and welding. The plate edges should be cleaned of all rust, galvanizing, paint, oil, scale, etc., before welding. Materials being welded should be protected from rain, snow and other climatic conditions that might affect the quality of the weld. All field welding should be done in accordance with these standards.

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13.4 STRUCTURE ASSEMBLY

The attachment of crossarms, hardware, climbing devices, insulators, etc., will complete the assembly of the structure.

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Appendix A
BOND STRESSES FOR SMOOTH TENSION ANCHOR BOLTS

For smooth (plain) tension anchor bolts, the allowable bond stresses shall be determined by the following formulas but shall not exceed 250 psi :

Tops Bars† $$\frac{6.7\sqrt{f'_c}}{2\,D}$$ (Equation A-1)

Bars other than Top Bars $$\frac{9.5\sqrt{f'_c}}{2\,D}$$ (Equation A-2)

Where—
f'_c = compressive strength of concrete, psi
D = nominal diameter of bar, inches

† Top bars, in reference to bond, are horizontal bars so placed that more than 12 inches of concrete is cast in the member below the bar.

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NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status are set forth in certain clauses of the NEMA Bylaws, which are quoted below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for its particular need. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

(Bylaw—Art. V, Sec. 1)

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Bylaw—Art. V, Sec. 2, Subsection A)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the standards publication may be capable of otherwise equivalent performance.

(NEMA Policy Memorandum 84-2, dated June 7, 1984)

Classes of Standards

National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Bylaw—Art. V, Sec. 2, Subsection B)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design.

(Bylaw—Art. V, Sec. 6, 1st Sentence)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment and/or approval.

(Bylaw—Art. V, Sec. 4, Subsection A)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

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