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IEEE Std 951-1996
(Revision of
IEEE Std 951-1988)

IEEE Guide to the Assembly and Erection of Metal Transmission Structures

Circuits and Devices

Communications Technology

Computer

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IEEE Power Engineering Society

Sponsored by the
Towers, Poles, and Conductors Subcommittee

Industrial Applications

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(Revision of IEEE Std 951-1988)

IEEE Guide to the Assembly and Erection of Metal Transmission Structures

Sponsor

Towers, Poles, and Conductors Subcommittee of the IEEE Power Engineering Society

Approved 10 December 1996

IEEE Standards Board

Abstract: Various good practices that will enable users to improve their ability to assemble and erect self-supporting and guyed steel or aluminum lattice and tubular steel structures are presented. Construction considerations after foundation installation, and up to the conductor stringing operation, are also covered. The guide focuses on the design and construction considerations for material delivery, assembly and erection of metal transmission structures, and the installation of insulators and hardware. This guide is intended to be used as a reference source for parties involved in the ownership, design, and construction of transmission structures.
Keywords: guyed structures, helicopters, lattice structures, metal transmission structures, tubular steel structures

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Introduction

(This introduction is not part of IEEE Std 951-1996, IEEE Guide to the Assembly and Erection of Metal Transmission Structures.)

This guide is one of several covering all aspects of overhead transmission line construction that have been prepared by the Working Group on Overhead Line Construction. This particular guide presents design and construction considerations for material delivery, assembly and erection of structures, and the installation of insulators and hardware. This guide was originally published as a standard in 1988.

The membership of the working group during the preparation of this guide was as follows:

Keith E. Lindsey, *Chair*

F. Leonard Consalvo	Chuck O'Malley	Ron Randle
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IEEE Guide to the Assembly and Erection of Metal Transmission Structures

1. Overview

1.1 Scope

This guide presents various good practices that will enable users to improve their ability to assemble and erect self-supporting and guyed steel or aluminum lattice and tubular steel structures. It also covers construction considerations after foundation installation (see IEEE Std 977-1991[1]), and up to the conductor stringing operation (see IEEE Std 524-1992).

1.2 Purpose

The purpose of this document is to assist the parties involved with the installation of steel transmission structures. This document focuses on the design and construction considerations for material delivery, assembly and erection of metal transmission structures, and the installation of insulators and hardware.

1.3 Application

This guide is intended to be used as a reference source for parties involved in the ownership, design, and construction of transmission structures. Since methods will be strongly influenced by the nature of each project, various methods that have been successfully employed are presented.

If any of the recommendations contained within this guide are to be adopted, they should be specifically stated in the owner's design and construction specifications. Any legal and environmental requirements of national, state, provincial, or local regulations shall be observed.

[1]For information about references, see Clause 2.

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1.4 Safety

Handling, assembly, and erection of metal structures may require conducting a safety and health program that takes all reasonable precautions to protect the safety and health of workers and members of the public. Workers should not be allowed to work in surroundings or under working conditions that are unsanitary, hazardous, or dangerous to their health or safety. Any safety requirements of national, state, provincial, or local regulations shall be observed (see [B5][2]).

1.5 Legal disclaimer

The support data for this guide were collected from a great number of sources and are believed to be reliable and true. Care has been taken during the compilation and writing to prevent error or misrepresentations. The authors make no warranty with respect to the accuracy, completeness, or usefulness of the information contained in the guide, nor do they assume any liabilities with respect to the applicability or use of any information, method, or process presented in this publication.

The use of trade names is for the information and convenience of the user of this guide and does not constitute an endorsement by the authors.

2. References

This guide shall be used in conjunction with the following publications:

IEEE Std 977-1991, IEEE Guide to Installation of Foundations for Transmission Line Structures (ANSI).[3]

IEEE Std 524-1992, IEEE Guide to the Installation of Overhead Transmission Line Conductors (ANSI).

ASTM A780-93a (1996), Standard Practice Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.[4]

3. Definitions

This clause contains key terms as they are used in this guide.

3.1 constructor: A party who undertakes the assembly and erection of a transmission structure. The constructor can be an owner or an agent acting for an owner. *Synonyms:* contractor, installer, construction agency, construction department.

3.2 line designer: A party who develops structure loading criteria, structure types, and structure locations based on line routing, maintenance, and construction requirements. The line designer establishes design criteria for construction and maintenance that will affect the structure designer and constructor. The line designer could be an owner or an agent acting for the owner.

3.3 owner: A party who owns the transmission line during the construction phase of the line and may include a person who acts for or on behalf of an owner as his or her his agent or delegate.

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[2]The numbers in brackets correspond to those of the bibliography in Annex A.

[3]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

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3.4 structure designer: A party who designs the structure based on criteria given by a line designer. The structure designer could be an owner, an agent acting for the owner, or a fabricator.

3.5 subcontractor: A party having a direct contract with the constructor for performing work covered by the Contract Documents, when the constructor is not the owner.

4. Project planning

The line designer should consider all aspects of the project before proceeding with design. This includes a review of all available options for construction techniques and equipment with respect to the specific conditions of the proposed line route. Access conditions, environmental restrictions, and/or schedule constraints may dictate the need to consider alternative, nontraditional construction techniques. If these requirements are understood early in the project, the selection, design, and detailing of structures and foundations can be tailored to accommodate these construction techniques. This early planning can result in a more cost-effective project.

The following factors can influence the selection of construction methods and equipment and should be considered in the early planning of a transmission line:

a) Line route and right-of-way conditions
b) Environmental constraints and public concerns
c) Accessibility of structure sites
d) Configurations, sizes, and weights of structures
e) Structure details and capability of sectionalizing
f) Foundation types and sizes
g) Availability and location of marshalling yards
h) Material delivery schedules
i) Constructor capabilities and available equipment (if known)
j) Inspection and maintenance requirements and practices

Clauses 7, 8, and 9 of this guide describe a number of different construction techniques. If the items listed above or any other considerations indicate that a particular technique and/or type of equipment will be most appropriate for a project, then this should be considered throughout the design and detailing of the line components to incorporate any special provisions that will facilitate construction operations. In particular, if helicopter construction is planned, qualified helicopter operators should be consulted to ensure that the line construction will be as efficient as possible.

At the time of line design, the constructor may not have been selected. However, the line designer should consult with knowledgeable construction and maintenance personnel and utilize their experience to develop a reasonable balance between design optimization, constructibility, and maintainability.

5. Structure design considerations

5.1 Construction and maintenance loads

The line designer should review and define limits for acceptable methods of construction and maintenance appropriate to the structure types, site conditions, applicable equipment, and skill level of the workers. Structural or other details that relate to the safety of construction and maintenance work should be considered in the design of the structure.

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The line designer should anticipate the more common operations of construction and maintenance and indicate the maximum allowable loads and acceptable loading or lifting points. The responsibility lies with the contractor to confirm with the line designer any lifting practices that deviate from those indicated.

Some of these loading considerations are

a) Partially assembled lattice structure sections will be subjected to dead-weight loads, dynamic loads, temporary guying loads for stability, worker loads, wind loads, and rigging loads during assembly and erection. Reasonable combinations of these loads should be anticipated by the designer and discussed with potential constructors to ensure safety and efficiency and prevent structural damage.

b) Members on which one or more workers are expected to climb or stand should be designed for a midspan load of the workers, their equipment, and an appropriate safety factor (see [B6] and Figure 1).

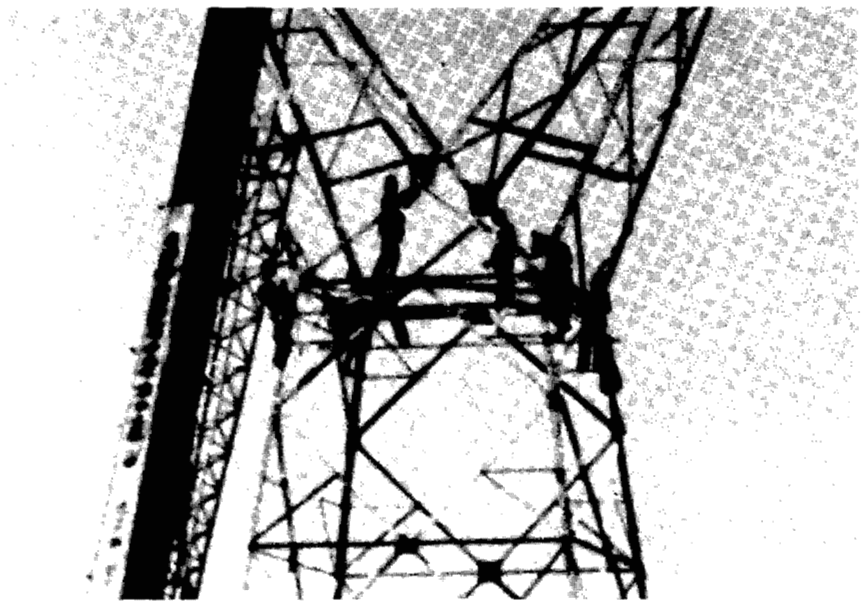

Figure 1—Portions of a structure subjected to additional loads due to one or more workers

c) Portions of a structure may be subjected to additional loads while they support one or more workers during construction and maintenance (that is, the end of a cross arm or at a leg splice) (see Figure 1). These loads, in addition to the normal wire loads anticipated during construction and maintenance, should be considered.

d) If fall arrest systems are required, attachment points should be designed for the anticipated load.

e) Rigging attachment points should be provided for lifting the structure, hoisting insulators and travelers, stringing, clipping in, deadending, and maintenance. All of these points should be explicitly identified. A diagram giving the allowable construction loads on the erected structure should be prepared and provided to the constructor.

Particular attention should be given to the following loading conditions:

— Rigging methods (see [B8]) used in hoisting may multiply the load at the attachment point.

— At the beginning and end of each conductor stringing setup, the conductors may be brought down to stringing equipment, anchors, or both. The vertical and horizontal components of tension imposed on the structure may become significant at these locations, and failures have occurred on both sus-

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pension and deadend structures. The positioning of the stringing equipment or anchors is critical, especially in mountainous terrain (IEEE Std 524-1992).

— Various deadending techniques will apply different loads. For example, aerial deadending techniques may impose lower vertical loads than deadending on the ground. Temporary back-guying may be required depending on the longitudinal strength and flexibility of the deadend structure and deadending technique used.

— Short spans between deadends with high conductor tensions are sensitive to overpulling and may result in loads in excess of maximum design tensions.

5.2 Material delivery

The design and detailing of the structures should consider limits on the length, size, and weight of individual members due to shipping, handling, erection, terrain, and equipment restrictions as well as manufacturing limits (see 6.4).

5.3 Constructability of structures

Construction can be enhanced by a number of considerations, both in the design of the structure and in detailing of the connections.

It should be noted that these considerations could increase material costs, although these costs may be offset by reduced field costs and improved safety. The following are applicable to all types of metal structures:

a) Each member should be clearly and permanently marked by stamping or welding. This mark should be legible after any coatings are applied to facilitate identification and possible field replacement. These permanent markings should be visible after the structure is erected. Stencilling with waterproof paint will further facilitate field identification; however, care should be taken to avoid adverse visual impact. See 6.4 regarding stencilling of weathering steel.
   Identification marks may include the following information:
   1) General location of the member in the structure by using a logical numbering sequence
   2) Structure type
   3) Special material types

b) The structure should be designed with a minimal assortment of bolt diameters and types.

c) Adequate clearance around nuts and bolt heads for wrenches or sockets should be provided.

d) For safety and ease of erection, a place for a worker to stand should be provided below each leg splice. As an example, two step bolt holes could be provided 1.37 m (4 ft, 6 in) below each splice for optional step bolts.

e) The bill of materials should provide an approximate finished (that is, galvanized or painted) weight of each structure item (that is, members, plates, fills, bolts, and nuts) in order to determine the loads to be lifted.

f) Legible erection drawings and data sheets for line sections should be provided. The drawings should show the member mark identification, bolt size, and length, bolt pattern, orientation of angle members, and whether a member is inside or outside its connecting member (that is, use hidden lines and detailed or enlarged views). In addition, these erection drawings should show the rigging attachment points identified in 5.1e).

g) Fabrication tolerances that are either too restrictive or too liberal can result in increased field costs.

h) Consideration should be given to the method of locking fasteners. The method selected will influence construction efficiency. Typical methods and devices are lock nuts, lock washers, pal nuts, punched threads, weathering steel, etc.

i) Designs should be checked for worker accessibility. Design of structures sometimes results in large spaces between members, making it difficult for workers to reach the joints. In such cases, it may be necessary to lift workers to install or check bolts.

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5.3.1 Constructability of lattice structures

Considerations specific to lattice structures include the following:

a) Where members are connected by one bolt at each end, the detailer should require a spud hole at the lower or main leg end. The tapered end of a spud wrench or drift pin is inserted into this hole to facilitate positioning of the member. This hole should be indicated as a spud hole on the erection drawing. The spud hole may indicate that the member was detailed slightly short in order to introduce prestress into the member. Spud holes in weathering steel should be bolted tight.

b) Depending on the method of erection, the location of leg and crossarm splices can affect the assembly and future maintenance of the structure. Leg splices located above the crossarm hanger or below the chord of the crossarm (not between them) will facilitate aerial erection as shown in Figure 2. If the structure is assembled on the ground, the leg splices may be located between the crossarm hanger and crossarm chord as shown in Figure 3. Aerial erection can also be helped if leg splices are located just above horizontal bracing as shown in Figure 4. This helps to maintain proper geometry and structural integrity of the lower body.

   Crossarm and ground wire peak splices located outside the body of the structure, as shown in Figure 2, may facilitate aerial assembly. In addition, arm and ground wire peaks can be removed or replaced without affecting the integrity of the remaining structure if their splices are located as shown in Figure 2, as opposed to Figure 3.

c) When tilting up structure sections diagonal braces extending below the main legs can be damaged. Two possible solutions are shown in Figures 5 and 6. The method shown in Figure 5 is necessary when helicopter erection is planned. The method shown in Figure 6 has the advantage of requiring no additional permanent material and is suitable for crane erection only.

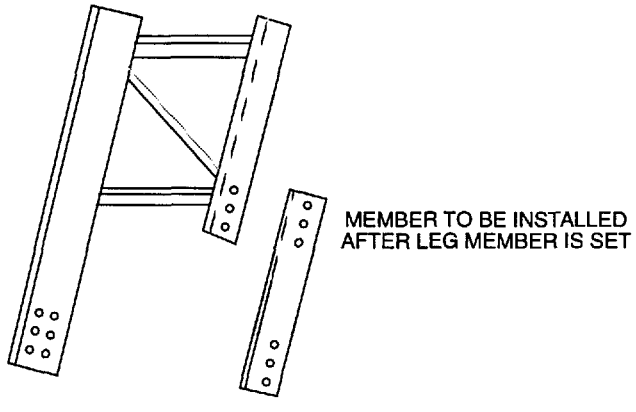

Figure 5—Leg splice detail recommended for helicopter erection

d) When butt splices are used on main structure legs, gin pole or crane assembly may be facilitated by bolting outside splice plates to the upper leg and inside splice plates to the lower leg as shown in Figure 7.

e) When using lap splices, assembly and erection with crane and helicopter techniques are facilitated by providing outside splices when the structure tapers inward (see Figure 8).

f) When helicopter erection is used, temporary stops are installed in both butt and lap splices. For lap splices, two additional holes on each face of the leg angle should be provided as shown in Figure 8.

g) Design internal structure leg bracing to facilitate its assembly and erection with each main structure leg as shown in Figure 9.

h) In order to facilitate raising and lowering tools and equipment with handlines, it may be unsuitable to obstruct the interior of the structure by using cross bracing for diaphragm bracing.

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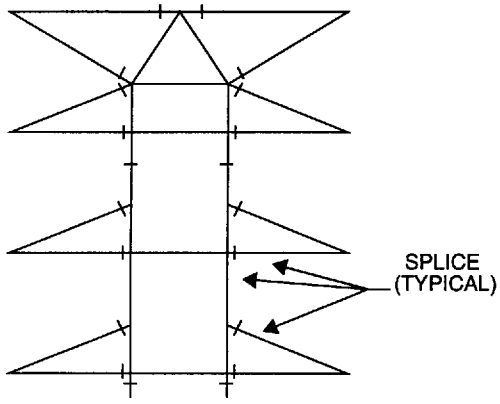

Figure 2—Splice location recommended for aerial erection

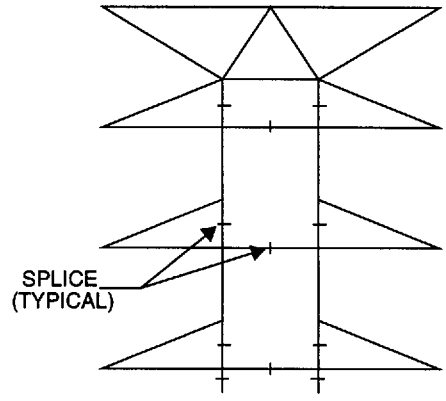

Figure 3—Splice location *not* recommended for aerial erection or future maintenance

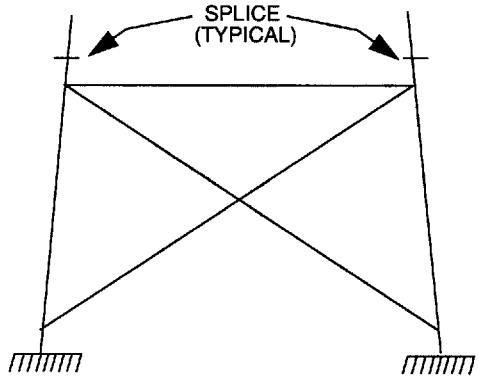

Figure 4—Recommended splice location for lower legs

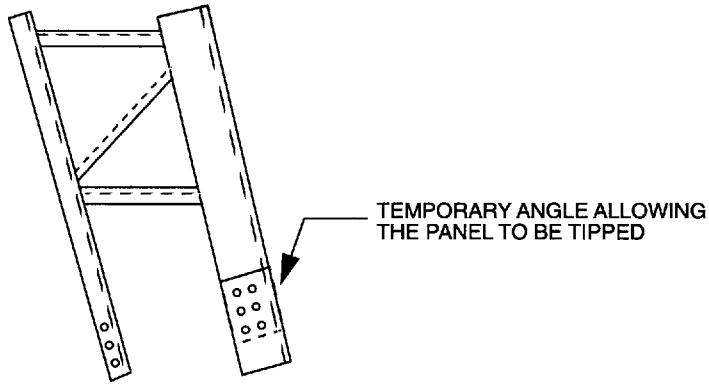

Figure 6—Leg splice detail recommended for crane erection

5.3.2 Constructability of tubular steel structures

Some specific considerations to tubular structures include the following:

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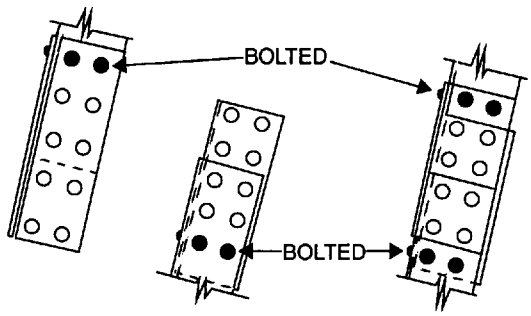

Figure 7—Recommended butt splice detail

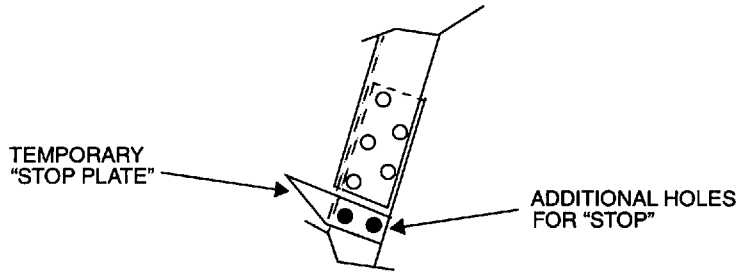

Figure 8—Leg spice recommended for helicopter or crane erection

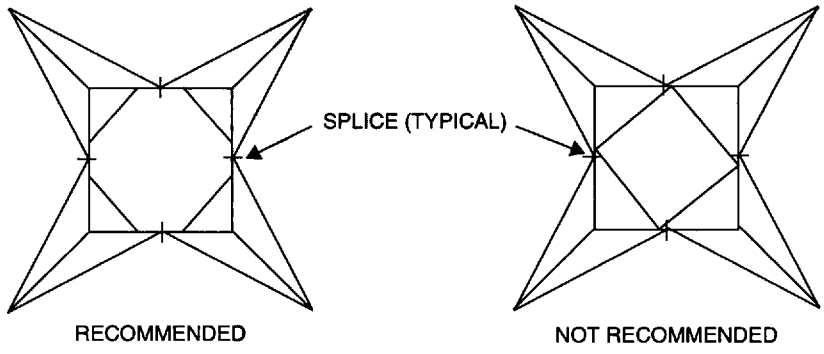

Figure 9—Internal leg bracing detail

a) Avoid structural detailing requiring workers to insert tools or their hands between large members during assembly.

b) Provisions for lifting eyes or pick points to minimize damage to the finish of the pole. Position of the lifting eyes or pick points should take into account construction methods, equipment, and site restrictions.

c) Provisions for the constructor to verify the lap joint distances and orientation as shown on the erection drawings. As an example, weld beads, inspection holes, or some other marks should be provided on the upper and lower pole sections.

d) Provisions for climbing devices, working and belting-off may be desirable for construction and maintenance on the structures.

e) Buoyancy of direct embedded steel poles should be considered. Details such as provisions for filling the embedment or temporary guying of the pole may be required.

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5.4 Trial assembly

A trial assembly of a lattice structure type can be a cost-effective method of checking detailing and fabrication as well as ensuring ease of assembly. A trial assembly should be considered for more complex tubular steel structures. Trial assembly is normally performed at the point of fabrication prior to painting or galvanizing (see Figure 10). Trial assembly after finishing may be justified if details may be affected by the finishing process (i.e., slip joints).

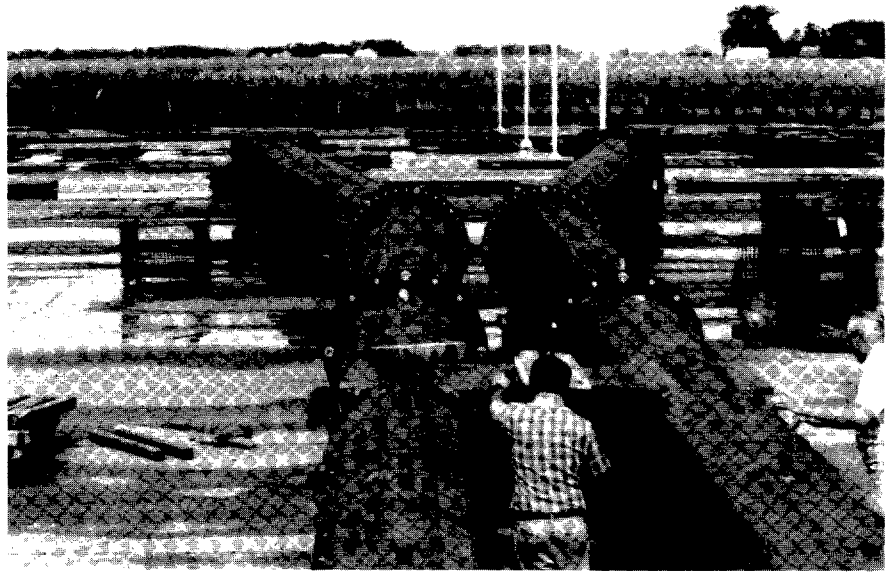

Figure 10—Trial assembly of complex tubular structure

If the structure is assembled in a horizontal position, provide a flat plane with blocking or cribbing to ensure that the structure is aligned. Boxed subassemblies should be attached to adjacent subassemblies to ensure proper fit and alignment.

6. Material delivery

6.1 Introduction

This clause covers recommended procedures for receipt and inspection of material, disposition of overages and surplus material, storage, handling, transportation, shortages, corrections, and replacements of material.

6.2 Material yard

Detailed planning for development and preparation of the material yard results in efficient loading and unloading operations as well as accurate identification and inventory of material in the yard. In choosing the location of the material yard, due consideration shall be given to the proximity of the yard to the project, accessibility to the storage site from all weather roads for material to be transported by truck, and the location and condition of rail sidings for the receipt of material to be delivered in this manner. A suitable receiving yard should be selected and prepared for the anticipated climatic conditions that may be encountered during the project.

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During the course of the project, the material yard should be kept relatively neat and clean and the growth of vegetation kept to a minimum. Good housekeeping minimizes damage and loss of material in the yard, and facilitates material handling, periodic physical inventories, and safety. It may also help assure that the project complies with environmental regulations.

Consideration should be given to the type, size, and quantity of equipment to be utilized within the yard in determining the layout, width, turning radii, and surface of the roadways. With the increasing problem of vandalism and material pilferage from the yard, the use of security personnel, perimeter fencing, and lighting should be considered during the planning stage.

Length of the line, structure type and quantity, terrain, construction sequence, and the construction methods to be utilized are generally the factors that determine if more than one material yard will be established for the project. The use of multiple yards requires additional coordination considerations to ensure that the correct type and quantities of material are delivered to and disbursed from each yard.

Materials should be arranged by type, taking into consideration the order in which the items will be received and used. Proper arrangement will facilitate hauling the material to the structure site or to the helicopter staging areas (see Figure 11).

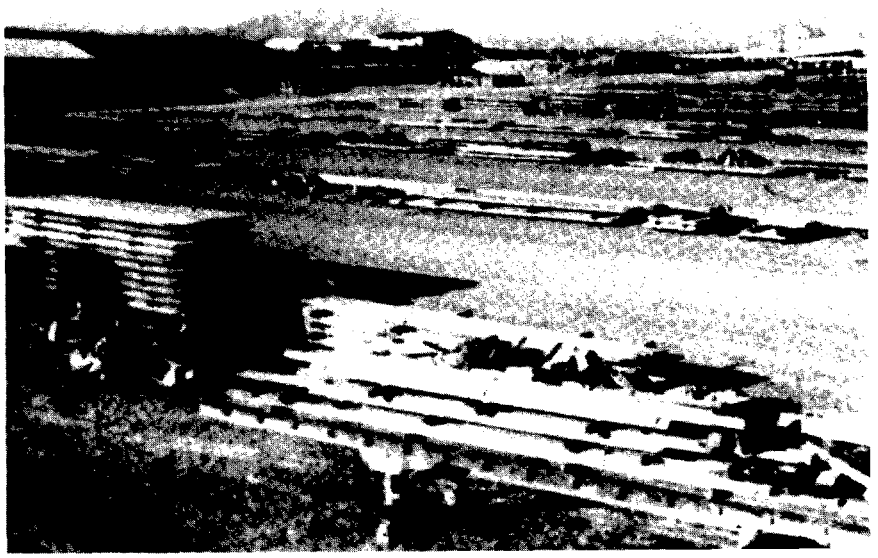

Figure 11—Typical material yard layout

6.3 Receipt and inspection of material

The constructor should maintain a current inventory, by location, of all material for the project. It is recommended that the construction specifications for the project contain a statement requiring the constructor to have a material coordinator assigned to receive, store, and disburse all material. This coordinator should remain assigned in this capacity for the duration of the project. This procedure is in the best interest of both the constructor and the owner to maintain continuity for receiving and disbursement of material.

Prior to the delivery of material, an itemized tabulation showing the quantity and description of the items to be received should be furnished to the constructor by the owner.

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All material delivered to the project should be promptly unloaded to avoid or minimize demurrage charges. However, unloading procedures should not decrease safety to personnel or increase potential damage to the materials. It is recommended that the constructor's material coordinator and owner's representative inspect and inventory all material received against the manifest or bill of lading and itemized tabulation referred to above, indicating all missing, extra, or damaged items. If possible, discrepancies and damage should be indicated on the appropriate document before signing the delivery ticket. Problems encountered during the delivery should be communicated to the fabricator/vendor through the owner as quickly as possible to minimize possible delay to the constructor.

Inventory methods will be dependent upon how the material is shipped. In the case of lattice structure members, it is recommended that bundles be opened and inventoried at the material yard if the delivery is by like pieces. If the structure is delivered by structure components, inventory of members should not be done until the bundles are taken to the structure site, allowing only the number of bundles to be verified at the time of delivery. It may be advantageous to open and inventory one bundle of each component type upon delivery to provide an early indication of shortages. If inventory is taken at the structure site, time should be allowed for acquiring replacements. If damages are noticed at the material yard, immediate steps should be taken to obtain replacement even if bundles must be opened. Opening of barrels, kegs, crates, etc., should be done at the structure site to minimize potential losses.

Upon receipt of insulators and hardware assemblies, the constructor and owner should make a check for compliance with the specifications, quantity, fit, and condition of all components (see 10.2).

Bar-coding techniques are often used for the receipt and inventory of material. The use of bar coding helps expedite receipt and disbursement of materials and aids in keeping an accurate inventory. The use of this method requires availability of portable computers and, at this time, may limit the number of vendors to those capable of implementing this system.

6.4 Handling and storage of materials

In the unloading, handling, and storage of structures, care should be exercised so as not to damage the surface coating or deform the members. Bare wire rope or steel chains should not be used for handling without adequate protection of the surface coating (see Figure 12). Structural members should not be dumped, dragged, rolled, dropped, nor used as loading or unloading skids or blocking. Heavy members should not be stacked on the top of lighter members. The maximum weight of steel bundles should not exceed a specified weight, typically 1600 kg to 1800 kg (3500 lb to 4000 lb), to facilitate handling and unloading. Members with dissimilar finishes should not be stored over one another to minimize discoloration of the lower members.

All members should be placed on wood blocking or other suitable material to ensure that the material to be stored is not in contact with the ground. Blocking should also be used to separate layers of stacked material. It should be noted that oak wood blocking or oil-treated timbers can bleed and stain a structure finish. Members should be supported in such a manner as to prevent bending and distortion as well as to allow water to drain from the material (see Figure 13).

Failure to provide for proper drainage of stacked, galvanized steel members could result in the formation of white rust. White rust (zinc oxide) forms when two galvanized surfaces are closely nested for an extended time without adequate ventilation. Ingress of water between the surfaces forms an electrolytic cell that may, in time, erode some or all of the zinc layer. The white rusting action will stop after exposure to air. Two methods can be used to prevent the oxide formation when extended transport or storage is anticipated. Spacers placed between the nested pieces ensure adequate ventilation, or galvanized members may be treated with a solution that will inhibit oxide formation for six months to one year.

Weathering steel fasteners and other material subject to deterioration should be protected from the elements during storage.

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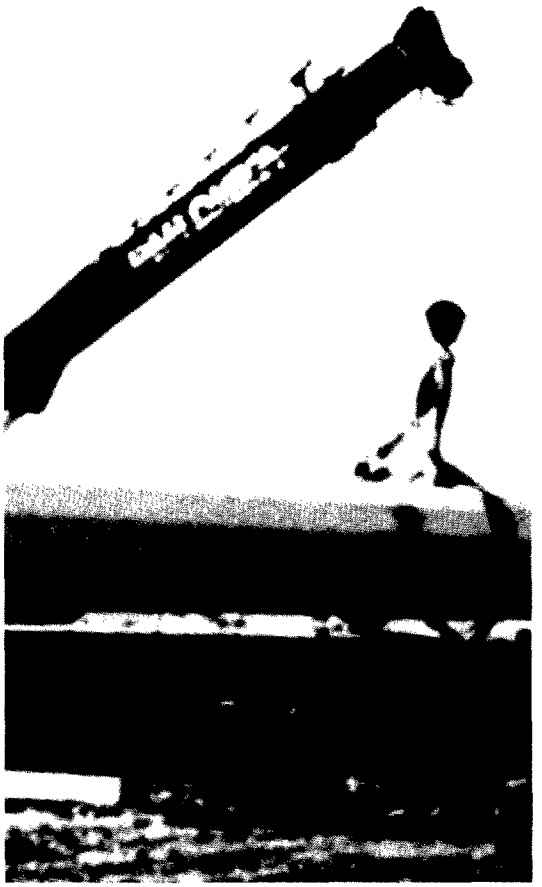

Figure 12—Proper use of slings to avoid damage to surface finish when lifting material

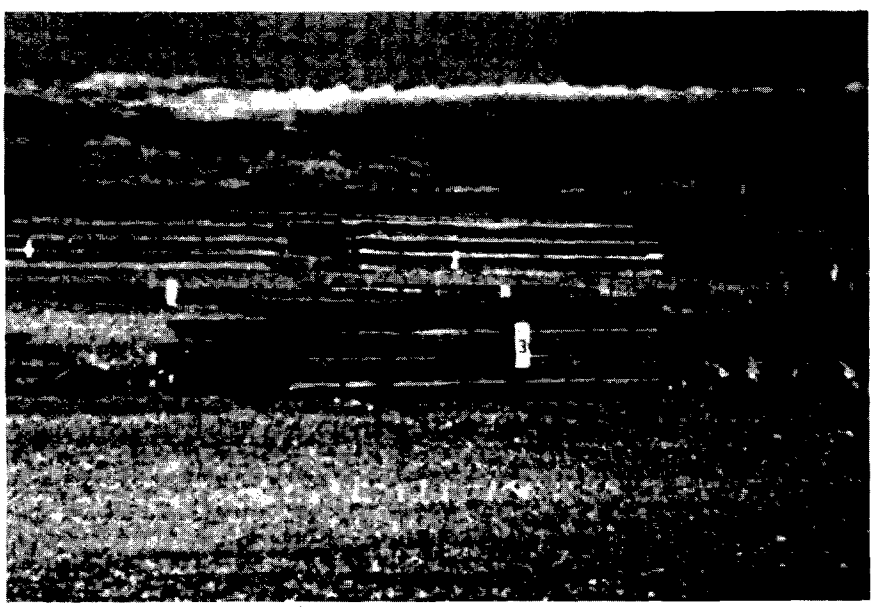

Figure 13—Proper blocking and storage of structural members

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Weathering steel members should not have any markings as a result of the constructor's operations. Foreign material on the surface may prevent the formation of a weathered surface.

Truck delivery of complete structures from the fabricator directly to the structure site may be advantageous since it eliminates at least one unloading and loading cycle. If delivery of material is made initially to the structure site for storage, care should be taken to avoid interference with foundation construction, access roads, or drainage.

6.5 Overages, shortages, and replacement material

It is the responsibility of the vendor to deliver the specified quantity and types of materials. Shortages of materials may also result from damage during delivery and installation, misfabrication, and losses. It is the responsibility of the owner to ensure that the required quantities and types of materials are furnished to the constructor. Information regarding shortages or damaged material shall be promptly communicated to the owner in writing to allow sufficient time for replacement material to be ordered, fabricated, and delivered.

Depending on a number of factors (project location, size, and ease of obtaining replacement quantities), it is common practice for the owner to order overages of small hardware such as fasteners, conductor hardware, insulators, etc. For structures, it is common that an overage of nuts, bolts, washers, and fills in the range of 3% to 5% be ordered. Overages of insulators are dependent upon the type and quantity of insulators required for the line. For a medium size project, an insulator overage of 3% is practical, while on a large project an overage of 1% to 2% is generally adequate.

6.6 Surplus material

After completion of construction, all surplus material furnished by the owner should be inventoried and returned to the location stated in the construction specification. The material should be sorted, counted, and tabulated by quantity and description. Material items that are not complete (missing nuts, cotter keys, etc.) should be identified and stored separately from complete items. Material returned in this manner will enable the owner to inspect the condition of the surplus material and determine the disposition of the items.

7. Assembly and erection of lattice structures

7.1 Introduction

This clause covers the various methods and practices employed in assembling and erecting self-supporting and guyed lattice structures.

The field assembly and erection methods chosen will be influenced by such variables as line and structure design, line route, terrain, climatic or seasonal weather conditions, the impact of any environmental restrictions, line route access, schedule requirements, and the availability of critical resources in both manpower and equipment.

For example, where a line route traverses terrain over which movement of a large erection crane would be difficult and expensive, methods utilizing a helicopter or a gin pole might be considered. In contrast, level or rolling terrain might lend itself to preassembly of a structure in large components and then lifting them with a mobile crane.

Whenever possible, efficient field procedures will include attaching all insulator assemblies on the structure during erection. Stringing travelers and finger lines installed during erection can greatly expedite the wire-stringing operation.

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7.2 Foundation tolerances

Acceptable tolerances should be established to ensure control of the interface between the foundation and the structure. Some levels of error can produce significant built-in stresses in the completed structure. Many of the problems in the erection of lattice structures begin with improperly located stub angles. Specifications are common that require the plumbing of erected structures to close tolerances, a result that has little to do with the erection of the structure and much to do with the setting of the stub angles.

The following are suggested as acceptable tolerances; these are suitable for very heavy and rigid structures, while larger tolerances may be acceptable for lighter and more flexible structures.

The tolerance should be a function of the length or distance between the points being checked.

A tolerance rate of 3 mm in 3 m (1/8 inch in 10 ft) or 1/1000 can be used to check the horizontal distance between stub angles (on the square and diagonal).

Elevation tolerances should be the same 1/1000 of the horizontal distance between stub angles, with the understanding that a small tilting of the base, either transverse, longitudinally or diagonally, will have negligible effect on the structure. Warping of the plane of the stub angles can reduce the strength of the structure and cause assembly problems. The degree of warping can be controlled by ensuring that the sums of the elevations of the diagonal pairs should not differ by more than 1/1000 of the diagonal measurement.

Batter of the stub angles shall be within 1.6 mm per 300 mm (1/16 in/ft) of the specified batter measured over the exposed stub.

The setting tolerances allowed for guyed structures can be greater, the more liberal tolerances being one of the cost advantages of guyed structures.

Because the guys are usually cut and fitted after the anchors are set and resurveyed, most guyed structures have threaded devices in the guys, allowing the tolerances on elevation to be less significant; even the specifics of position usually permit placement within a cone of about 1 degree rotated about the guy and its upper attachment point. Thus on a 30.5 m (100 ft) guy, the placement tolerance would be a circle of about 600 mm (2 ft) radius.

7.3 Field assembly

7.3.1 Storing and handling of members

See 6.4.

7.3.2 Damaged and misfabricated members

Bent, twisted, damaged, or misfabricated members that prevent proper assembly and fit should be immediately reported to the owner for corrective action. The damaged or misfabricated members should not be repaired by the constructor without written approval from the owner. Members may be damaged to such a degree that replacement rather than repair is necessary.

Field punching, or drilling of holes and field clipping by the constructor, is generally accepted by the owner if the hole or clip was missed in the fabrication of the member but was called for on the fabrication detail drawings. The edges of clipped angles, new or reamed holes, or any member that has its coating scratched or damaged should be repaired with a coating approved by the owner [see ASTM A780-93a (1996)]. If field fabrication of a member is permitted, the bolt spacing and edge distances shall be in accordance with the fabrication detail drawings. Field welding and flame cutting should be approved by the owner.

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A certain number of damaged and misfabricated members should be expected by both the owner and the constructor, and the specifications in procurement and construction contracts should address this problem.

7.3.3 Assembly

Preassembly techniques are generally influenced by site terrain and available equipment. Generally, the larger the section that can be preassembled, the more efficient the assembly/erection operation. Preassembly techniques should consider placement of the assembled sections to provide for the safest and most efficient lifting for erection. Structural assemblies that are not sufficiently rigid to be raised in one piece shall be stiffened by means of temporary bracing.

Structures assembled on the ground should be placed on suitable blocking so as to be kept free of dirt, mud, or other foreign material that might adhere to the structure or damage the coating. Blocking should be placed in such a manner as to provide a flat surface in order to prevent overstressing or distortion of members and to maintain the true geometric shape of the assembled members. Mud, dirt, white rust, and foreign material should be removed from the contact surfaces of joints prior to assembly.

The structures should be assembled in accordance with the fabricator's erection and detail drawings. The diameter, type, and length of bolts as shown on these drawings should be used for each connection.

Orientation of bolts can facilitate access, final tightening, installation of locking devices, and subsequent checking of the erected structure. Color coding may facilitate installation and inspection of bolts.

Nuts may be tightened during ground assembly to assure that the structure is geometrically correct, or they may be partly tightened followed by final tightening before stringing. For long slender columns, the nuts should be tightened before lifting to minimize deflections during the lifting operation. The owner should set forth requirements in the specification if there is a preference to when bolts are tightened. Retightening of nuts may be required after stringing and sagging.

Various types of wrenches can be used to tighten nuts—spud, adjustable, ratchet, torque, box end, or impact (electric, pneumatic, or hydraulic). Impact wrenches should have adjustable torque limiters, which should be checked periodically, to prevent inadvertent over- or under-tightening of nuts. The use of any wrench that may deform nuts or cut or flake the coating on the nut should not be permitted. There are several acceptable methods of specifying bolt and nut tightness, depending upon application. Snug-tight and quoting a specific torque value are two commonly used methods.

During assembly and erection, members should not be forced into place by being bent or overstressed. In extremely cold weather, care shall be exercised by the assembly or erection workers to avoid subjecting members to sudden stresses that could cause brittle fractures.

Tension members are often detailed slightly short in order to introduce a prestress in the member; therefore, a reasonable amount of drifting, utilizing tools such as drift pins or spud wrenches, is generally acceptable during assembly and erection. These members may be identified on the drawings or by the addition of a spud hole (see 5.3.1). Care should be taken to avoid distorting the hole with a drift pin. Holes should not be reamed for alignment unless approved by the owner. Bolts should not be driven in any manner that will distort them or damage the threads. Prior to assembly, all joint surfaces, including those adjacent to the bolt heads and nuts, should be free of any material that would prevent solid seating of the parts.

7.4 General method of erection

Structures may be erected by any suitable method in the sequence best adapted to the equipment, worker experience, and site conditions that will not overstress structure members.

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The assembly and erection methods proposed by the constructor should be submitted to the owner for review, prior to commencing assembly. These methods should be reviewed to ensure that members are not overstressed.

When handling assembled portions of the structure, a spreader bar or other device with proper points of attachment should be used to avoid distorting or overstressing members and to maintain the true geometric shape of the section.

Temporary guying may be required when erecting a structure in sections (see Figure 14). Any temporary guying system should be checked to ensure that the structure section is stable before workers are allowed on the section.

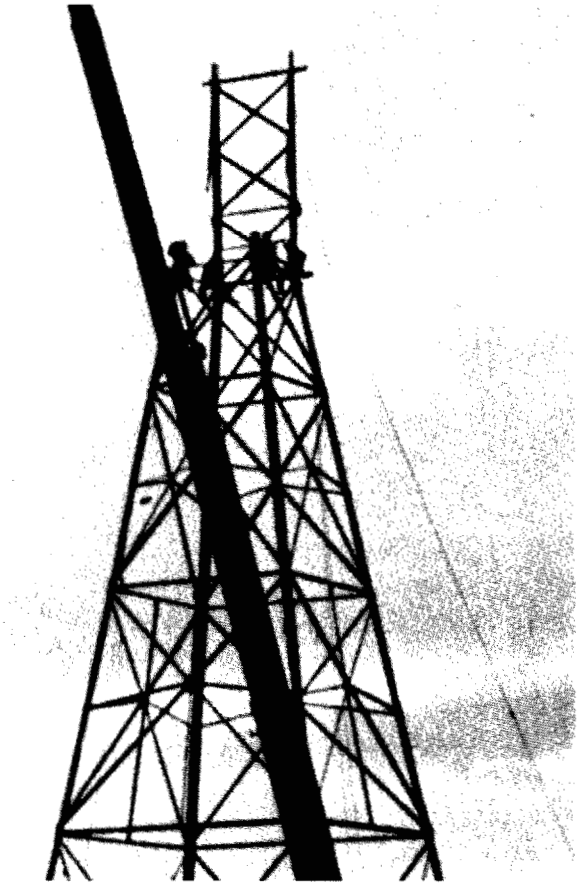

Figure 14—Temporary guys on partially erected structure

Structures should be completely erected, correctly oriented, with all members in place, all bolts installed and properly tightened, and the entire structure checked in accordance with the specifications prior to the installation of conductor and shield wires.

Guyed structures should be erected with the guys pretensioned as specified by the owner or structure designer. After stringing, the guy tensions may require adjustment to final values.

When erecting structure members or sections in the vicinity of energized lines, care should be taken to guard lines or structures to prevent electrical contact, and to ground these members or sections, or drain the static charge, before any workers come in contact with them (see 1.4 and IEEE Std 524-1992).

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STD.IEEE 951-ENGL 1996 ■ 4805702 0547947 453 ■

7.5 Crane erection

The use of a crane is generally an efficient method for erecting lattice structures (see Figures 1, 15, and 16). With ground preassembly of sections, the time spent in final erection time can be greatly reduced (see Figure 17).

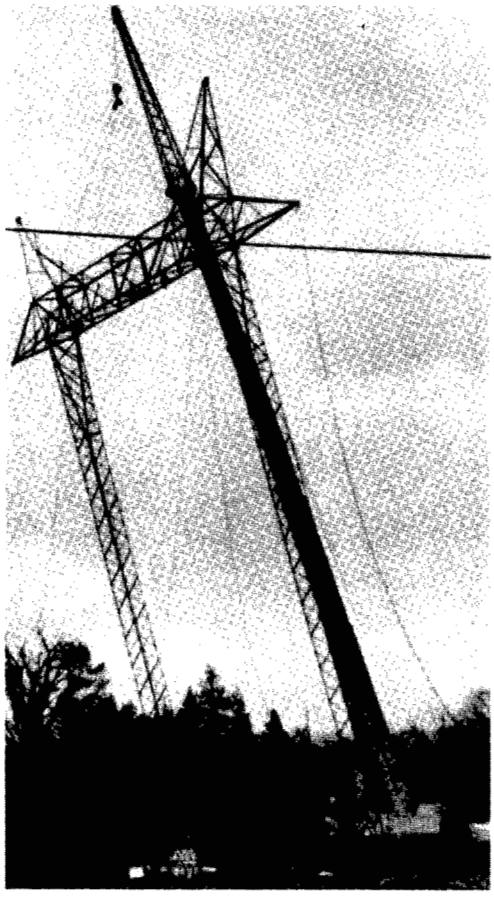

Figure 15—Crane erection of complete structure

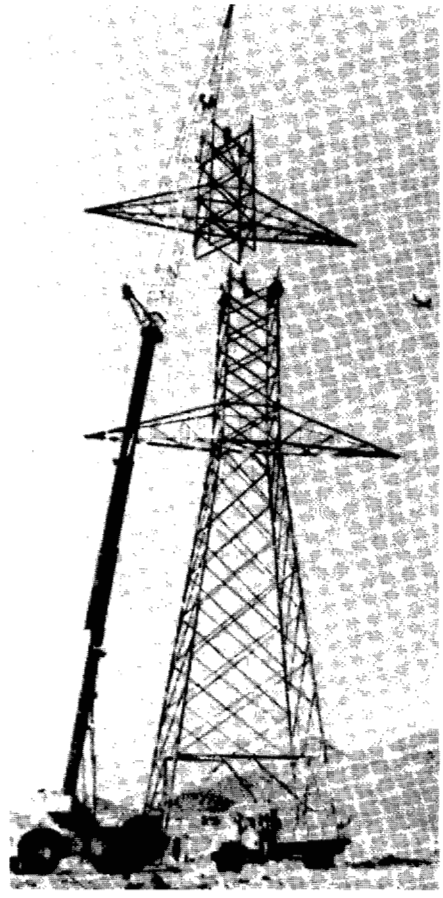

Figure 16—Crane erection of subassembly

Cranes with telescoping booms may be more efficient than rigid boom cranes in rough terrain. Considerable productive time can be lost in the process of assembly and disassembly of rigid boom cranes. In addition, continuous handling of boom sections can lead to boom damage. Preplanning of the crane location at the structure site allows for any necessary grading work (building of ramps, soil stabilization, etc.) to be accomplished during the foundation construction operations when suitable equipment is available at the site. Caution should be used when cutting into hillsides as this may precipitate slope failures. Depending on soil conditions, additional bearing support may be required under outriggers, tracks, and tires. All sites should be returned to a condition acceptable to the owner after erection. Extreme caution has to be exercised when using cranes in the vicinity of energized lines (see 1.4).

7.6 Gin pole erection

A gin pole is a boom of steel or aluminum pipe, wood pole, or lattice truss secured at its base and usually inclined at a slight angle to the vertical. Two guys (see Figure 18) about 60 to 90 degrees apart in the plan

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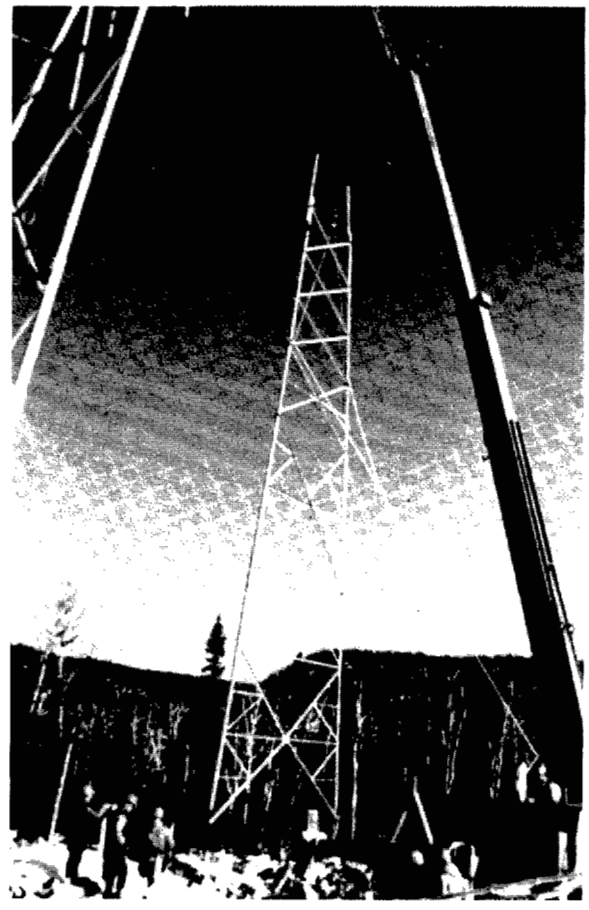

Figure 17—Crane erection of pre-assembled section



Figure 18—Typical gin pole being used to tilt-up a structure

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view, are attached to the top of the gin pole to resist or support the load to be lifted. For safety, a third, and preferably a fourth guy, are installed in front to prevent the pole from falling over backward in the event of an unexpected impact or the sudden release of the load. Temporary guys may be secured to the permanent anchors of guyed structures or to temporary anchors such as power-installed helical or dead-man anchors at self-supported structures.

This once most common method of erection is being quickly replaced by the use of motorized cranes and helicopters. The method can be used when structure heights and weights exceed the capability of a crane or where access to the site is restricted. The lattice structure can be erected by gin pole, piece by piece, section by section, or tilted up as a complete structure. It should be noted that experienced, knowledgeable workers are required for a safe and efficient operation.

7.6.1 Piecemeal method

Three techniques are commonly used for this method. The first method is to install a lifting line from one of the erected legs for use in lifting other members. The second is to rig a small boom to one of the erected legs for hoisting purposes, if the design allows (see Figure 19). The third method is to position the base of a single gin pole in the center of the structure by suspending it from the leg members at any elevation using bridle slings (see Figures 20 and 21). This is sometimes referred to as a basket or floating gin pole. The attachment points for slings and any guys should be checked for structural integrity.

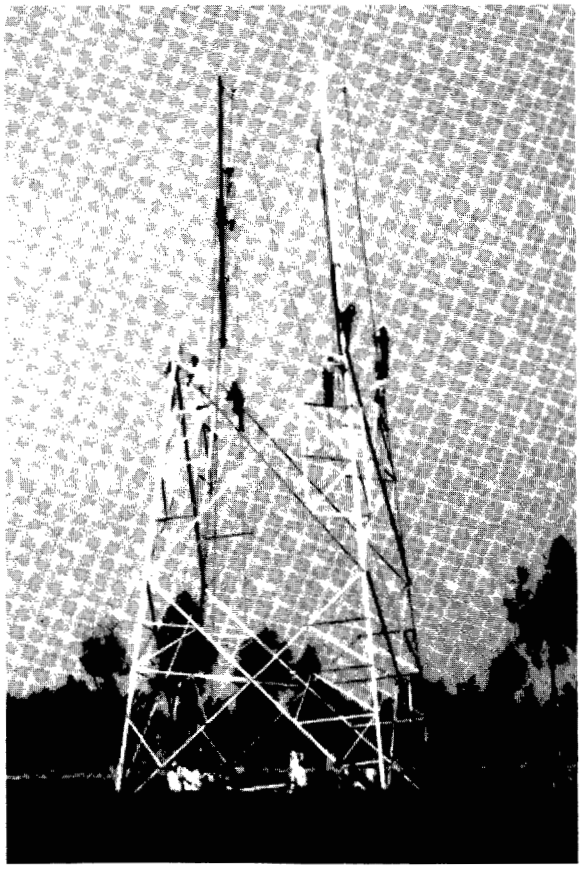

Figure 19—Piecemeal erection using two gin poles

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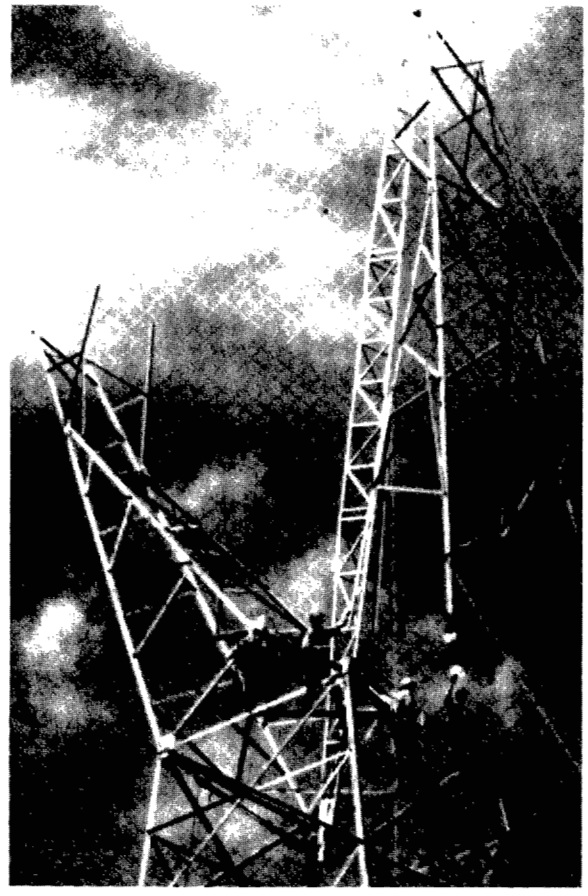

Figure 20—Basket gin pole being used to raise a tower section



Figure 21—Basket gin pole

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7.6.2 Section method

Another method using the gin pole is commonly referred to as the section method. Partially assembled structure sections are hoisted into position by gin pole and bolted in place (see Figure 20). The procedures for using the gin pole are the same as in the piecemeal method. Temporary guying of the sections may be necessary.

7.6.3 Tilt-up method

In this method, entire structures or subassemblies, assembled on the ground, can be raised into position by using a gin pole (see Figure 18). Note that this method may cause additional shear load on the foundation, and additional temporary guys may be required to ensure stability of the structure during erection.

7.7 Helicopter erection

See Clause 9.

8. Assembly and erection of tubular steel structures

8.1 Introduction

This clause covers the recommended assembly and erection procedures for tubular steel structures (poles). These procedures may also apply to single shaft and H-frame lattice structures. The process will be divided into two main categories:

a) Single pole structures
b) Framed structures (two or more poles joined by rigid members)

Erection techniques vary greatly depending on the specific job variables. An erection crane with self-erecting and self-storing boom is an efficient method for structure erection. If extensive preassembly is used, the time spent in final erection is greatly reduced.

Preplanning of desired crane locations at the structure site allows for any necessary grading work (building of ramps, soil stabilization, etc.) to be accomplished during the foundation construction operations, when suitable equipment is available at the site. Caution should be used when cutting into hillsides, as it may precipitate slope failures. Depending on soil conditions, additional bearing support may be required under outriggers, tracks, and tires. All soil should be returned to a condition acceptable to the owner after erection.

High reach aerial lifts can be effective in providing a safe work position for workers handling large connection bolts to make aerial connections. The aerial lift can eliminate the need to install a variety of either temporary or permanent rigging and climbing devices on each structure. Whenever possible, efficient field procedures will include attaching all insulator assemblies on the structure during erection. Stringing travelers and finger lines installed during erection can greatly expedite the wire-stringing operation.

Various types of wrenches can be used to tighten nuts—spud, adjustable, ratchet, torque, box end, or impact (electric, pneumatic, or hydraulic). The use of any wrench that can deform nuts or cut or flake the coating on the nut should not be permitted. There are several acceptable methods of specifying bolt and nut tightness, depending upon application. Turn-of-the-nut and snug-tight are two commonly used methods (see [B1]).

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8.2 Handling and transportation of poles, arms, and component parts

When delivering poles from the storage area to the erection sites, special care should be taken during the loading, hauling, and unloading to prevent any damage to the surface of the poles and arms. Slings for handling the poles and arms should be made of or covered with nylon or some other nonmetallic material to protect the finish (see Figure 12). Weathering steel structures should not have any markings (e.g., grease, pencil, or paint) above the groundline because foreign material on the surface may prevent the formation of a weathered surface. Poles should be handled in such a manner that no portion of the pole is dragged along the ground or against the pole trailer or other objects that could damage the structure.

A check of each component's identification marking and the required quantities during this phase of work can minimize potential lost time during the assembly of the structure.

Proper initial placement of pole sections can increase the efficiency of the assembly operation.

Poles and arms should be placed on suitable cribbing to prevent damage and provide a level plane that will prevent overstressing of the structure components.

8.3 Single pole structures

8.3.1 Assembly on the ground

All assembly should be as shown on the drawings, using methods and equipment that will not cause damage or distortion of any part of the structure. Methods of assembly and erection may be subject to review by the owner.

Whether the pole is assembled on the ground or in the air depends on right-of-way considerations and the constructor. Most constructors assemble the structure on the ground.

When pole sections, arms, and other miscellaneous hardware are assembled prior to erection, assembly shall be on level blocking placed outside the splice areas so as to maintain the true alignment of the assembled structure.

The sections should be oriented so that all attachment points are accessible and all attachments can be added without the need to rotate the structure.

All finish touch-up should be done prior to erection. Insulators, hardware, travelers, and climbing devices (if specified by owner) may also be attached while the structure is on the ground. (See Clause 10 for precautions against damage during erection.) Once the structure is totally assembled, it should be thoroughly inspected. Climbing devices, where they may interfere with the erection process, should be temporarily removed from the structure.

8.3.1.1 Slip-jointed sections

For slip-joint assembly, pole sections should be jacked together in accordance with the structure designer's recommendations. While it is possible to perform this jacking operation following the pole's erection, it is most commonly done prior to erection.

During the jacking operation, proper safety precautions should be exercised at all times. During assembly, hands should be kept clear of the joint. Prior to assembly, orientation marks should be placed on the lower section to denote the minimum and maximum permissible engagement lengths. (This information should be found on the fabricator's erection drawings.) The mating pole sections should be blocked so that they are

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level and in correct alignment with respect to each other. Care should be exercised to ensure that proper alignment of arms, hardware, climbing devices, etc., will result.

The mating surfaces should be inspected prior to assembly to ensure they are clean and free of debris. A dimensional check should also be made to ensure the pole sections are within tolerance and have not become distorted during shipping or handling. Lubricants as recommended by the structure designer may be used to facilitate assembly. A crane or forklift may be used to make as much of the lap as possible prior to jacking.

Any of several methods of jacking may be used provided the following conditions are met:

a) Proper slip joint engagement is achieved, within allowed tolerances shown on the drawings;

b) A reasonably tight fit is achieved without major gaps or a misalignment between the pole sections; and

c) The minimum specified jacking force is used to join the sections.

All of the above conditions must be met to ensure satisfactory joint assembly.

The most common form of jacking involves the use of hydraulic jacking devices (see Figure 22). Two jacks are secured to permanent attachments strategically positioned on each pole section. The jacks are engaged to ensure that each imparts equal load to the joint. To facilitate this process, vibrating and/or up and down movement of the upper section is permissible. Workers should stand a safe distance from the jacking units during their operation.



Figure 22—Typical hydraulic jacking device

The allowed slip-joint engagement lengths, fit-up tolerances, and jacking forces should be as recommended by the structure designer (see Figure 23). Problems encountered with slip-joint assembly should be communicated to the owner and structure designer.

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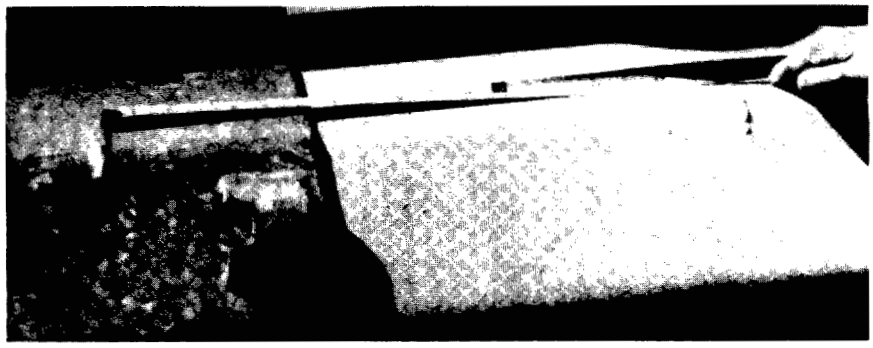

Figure 23—Following structure designer's tolerances for slip-joint assembly

8.3.1.2 Flange-plated pole sections

Contact surfaces of joints should be clean and free of foreign matter before assembly. Flange-plated pole sections should be aligned to the orientation marks and the bolts tightened as specified (see Figure 24). The bolt-tightening sequence should ensure that proper alignment between the two pole sections is maintained throughout the tightening sequence. Gaps between flanges at bolt locations may be filled by use of shims if allowed by the owner and structure designer.



Figure 24—Typical flange joint

Alignment of the pole should be checked after all flanged joint bolts are installed and tightened as specified.

8.3.1.3 Attachments to pole sections

Arms or other attachments should be blocked and leveled to the proper position. Attachment bolts and nuts should be tightened as specified.

If conductor and static arms are assembled to the structure and the wire is not installed in a reasonable period of time, there may exist a potential of fatigue failure due to wind-induced vibration. These arms can have their natural frequency or damping characteristics modified sufficiently to eliminate this type of damage. Two acceptable methods are suspending weights or insulators from the ends of the arms or tying the arm tips together and to the structure (see Figure 25).

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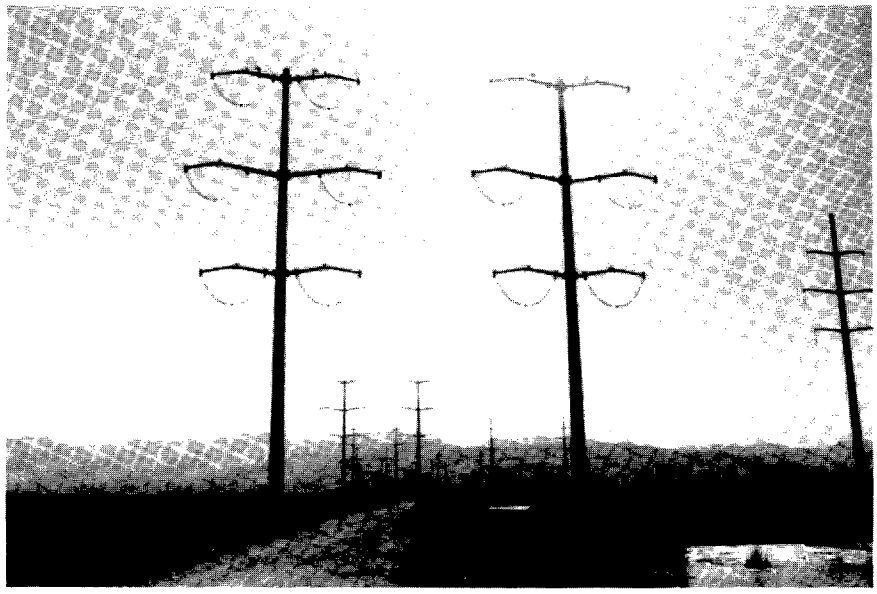
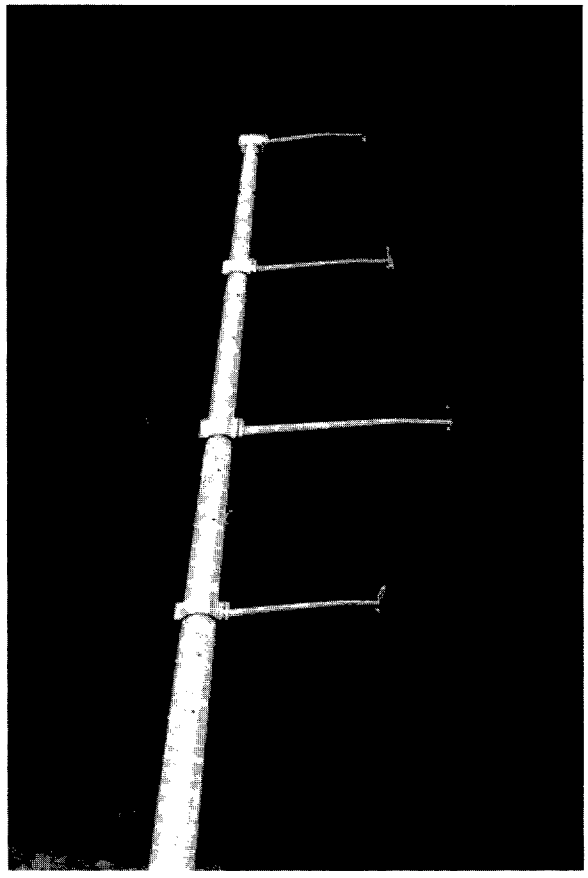


a) Method 1



b) Method 2

Figure 25—Recommended methods for preventing arm fatigue prior to wire stringing

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8.3.2 Erection of assembled structures

The structure should be laid out in accordance with a predetermined plan to minimize effort and maximize safety during the erection of the structure.

As a safety precaution, it is good practice to secure any slip joints below the lift point with a link between the jacking lugs on mating sections during erection.

Steel poles may be erected by using the lifting lug(s) (if provided) (see Figure 26) or by rigging the pole with a padded cable choker. When a choker is used, the location of the lift point may be supplied by the fabricator or determined in the field. Tall, slender structures, such as guyed structures, may require a two-point lift to prevent overstressing during erection.

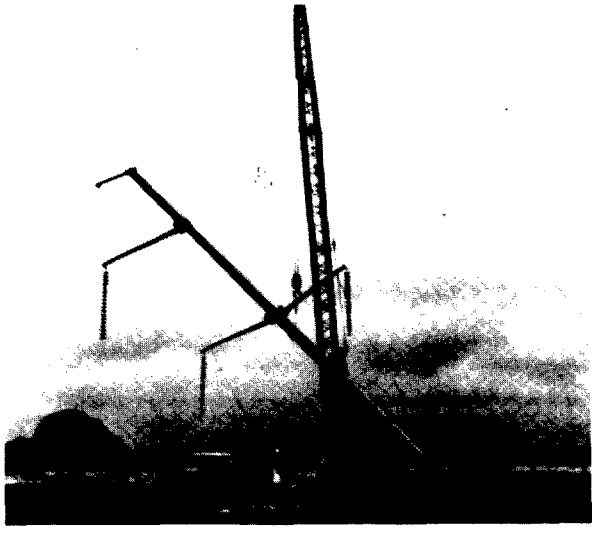

Figure 26—Erecting structure using lifting lug attached to pole

As the structure is being lifted, tag lines can be used to guide the structure to its foundation. Once the structure is in place, it should be checked for plumb, preferably with a transit. At times, deflection limitations are imposed on some angle structures. This requirement can be met by precambering the pole shaft during fabrication or by field raking the structure during erection. In these cases, the poles are set with the camber to the outside of the angle or the structures are raked by adjusting the leveling nuts in accordance with the erection drawings (see Figure 27). Refer to Clause 9 for helicopter erection.

Deflection caused by uneven solar heating in tubular steel poles is common and should be considered during assembly and final plumbing of the structure. Steel poles are in their most natural state of straightness on cloudy days or in the very early morning hours when the temperature of the steel is the same on the full circumference of the pole.

8.3.3 Assembly in the air

At times, the terrain and environment dictate the need for aerial assembly. Close inspection of all parts to ensure proper fit is recommended prior to the lift operation.

The bottom pole section is set first, inspected for plumbness and alignment, and secured to the foundation. As each subsequent pole section is stacked, the joint is secured. Because of impact loads, insulators should not be installed until the sections are stacked.

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Figure 27—Raked pole using anchor-bolt nuts

8.4 Framed structures

The most common example of a framed structure is the H-frame with moment connections and/or bracing. The assembly process is very similar to that of a single pole structure. Permanent locking devices may be required at slip joints to prevent joint movement after the structure is erected and loaded. Maximum adjustability in a framed structure is maintained by leaving all connections, except flanged joints, loosely bolted until it is totally assembled.

8.4.1 Assembly on ground

Assemble poles as described in 8.3.1. It is recommended that slip-jointed poles of framed structures be assembled on the ground. Minor variations in assembled pole lengths can be accommodated by adjusting the leveling nuts on base plate type foundations or the depth of the excavation of direct embedded structures prior to setting the structure.

After the poles have been assembled, the poles should be placed in proper relation to each other and level. The arms and then the x-braces (if required) should be installed, leaving all connections loosely bolted. Special care shall be taken to maintain the structure geometry when installing x-braces with adjustable bands. The correct distance between pole shafts shall be verified before tightening the bands. Squareness of the framed structure should be checked. All bolts and nuts should be tightened as specified.

Whenever possible, finish touch-up to the protective coating of the structure should be done prior to erection. Insulators, hardware, travelers, and climbing devices (if specified by the owner) may also be added while the structure is on the ground. (See Clause 10 for precautions against damage during erection.) Once the structure is totally assembled, it should be thoroughly inspected. Climbing devices, where they may interfere with the erection process, should be temporarily removed from the structure.

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8.4.2 Erection

A spreader bar or yoke should be used between the two legs of an H-frame type structure when being lifted (see Figure 28). On some structures it may be necessary for a smaller crane to lift the base of the structure, due to site conditions or weight of the structure.

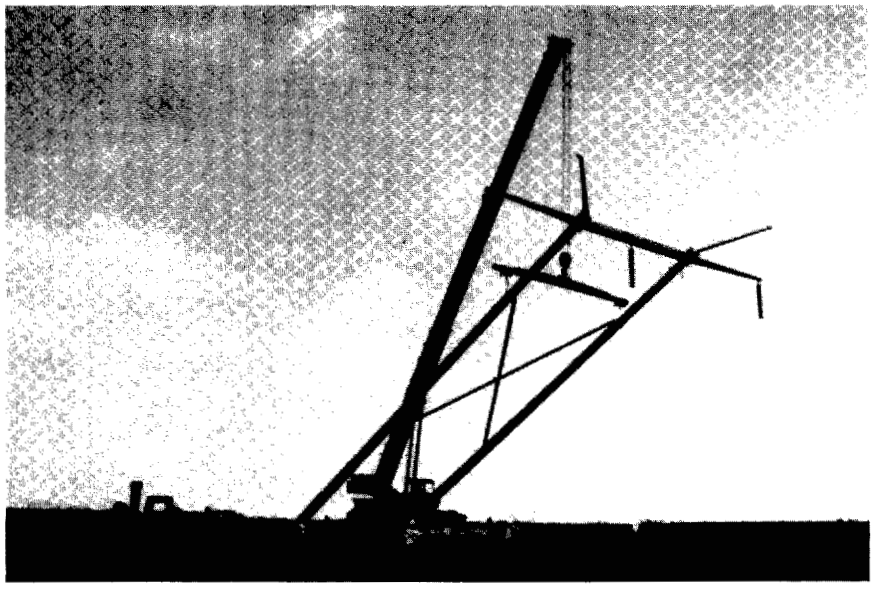

Figure 28—Use of spreader bar or yoke to lift an H-frame

Tag lines can be used to guide the structure to its foundation. Equipment, such as a bulldozer, tractor, or truck, may be required to guide the structure.

On an anchor-bolted H-frame structure, it may be necessary to position one pole on its foundation and slightly rotate the other pole using a chain hoist or other means to line up the holes in the base plate with the anchor bolts. Care should be taken not to damage the anchor bolt threads. Once the structure is in position, the top anchor-bolt nuts may be installed and the structure plumbed. Refer to Clause 9 for helicopter erection.

8.4.3 Assembly in the air

Single piece poles or flanged joints are recommended for structures requiring assembly in the air. Aerial assembly should not be used in the erection of slip-jointed, framed structures as it is very important that the structure's legs be of equal length.

On smaller framed structures, each lower pole section can be set, then the entire upper frame can be preassembled on the ground and erected as one unit. On larger framed structures, each piece may have to be lifted and attached independently. When erecting these structures in the vicinity of energized lines, care should be taken to ground these pieces before any workers come in contact with them.

It is very important to note that in the case of framed structures, each joint shall be loosely connected until all parts of the structure are installed. This is necessary to allow adjustments while positioning and attaching each subsequent part.

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The bolt-tightening operation should begin only after all parts are assembled and all bolts are installed. Joints should be methodically tightened while plumb, level, and orientation of each part are continually checked. Refer to 8.3.1.2 for flange joints.

8.5 Attaching pole structures to various foundations

Two basic foundations are normally used for tubular steel structures: anchor-bolt/base-plate type and direct embedded.

8.5.1 Anchor bolt/base plate

In the case of the anchor bolted concrete type foundation with a base-plated structure, the structure is simply lifted onto the anchor bolts.

The leveling nuts should be threaded on each bolt sufficiently down on the threads to allow for the addition of the base plate and top nut. These lower nuts should be positioned so that when the base plate is set on top of them, the base plate will be level and as close as practical to the foundation (see Figure 29). After the top nuts are added, the structure should be checked to ensure that it is oriented and aligned correctly. If the structure requires raking to allow for load deflections, the nuts above and below the base plate can be readjusted to move the structure out of plumb to the required position (see Figure 27).

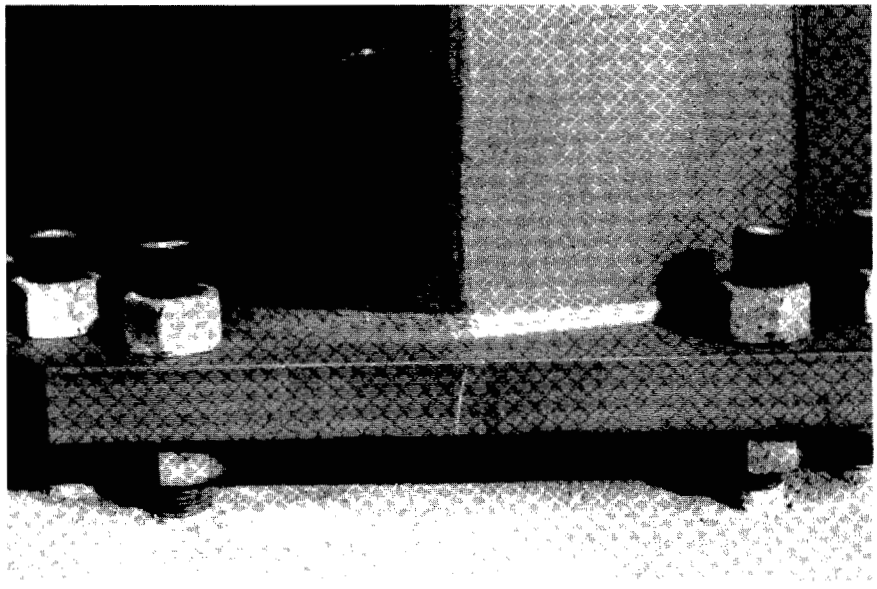

Figure 29—Pole properly installed on anchor-bolt foundation

When tightening anchor-bolt nuts, all nuts on the top side of the base plate should be brought to a snug-tight condition, then the nuts on the bottom side of the base plate should be brought to a snug-tight condition and checked to make sure that they are bearing completely against the base plate. It is important that the bottom nuts under the base plate be tightened. If required, final tightening of the nuts may proceed as specified. It is common practice to secure anchor-bolt nuts by welding to the base plate or by other means to prevent unauthorized turning or removal.

Upon completion of pole erection, the void between the base plate and the concrete foundation may be filled with nonshrinking, flowable grout or dry packing with a sand/cement mixture, or they may be left open.

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Special care shall be used when installing grout, if specified, so that the pole drains, if present, will not be dislodged or plugged. After the grout has set and the forms removed, each drain should be cleared to assure that it is open and free to allow drain water to flow.

8.5.2 Direct embedded

The pole section is placed in the excavation, aligned, oriented, and backfilled. If compaction of backfill is required, it should be done in accordance with the specifications. Care should be taken during the compacting operation to minimize damage to the protective coating on the embedded portions of the structure (see Figure 30).

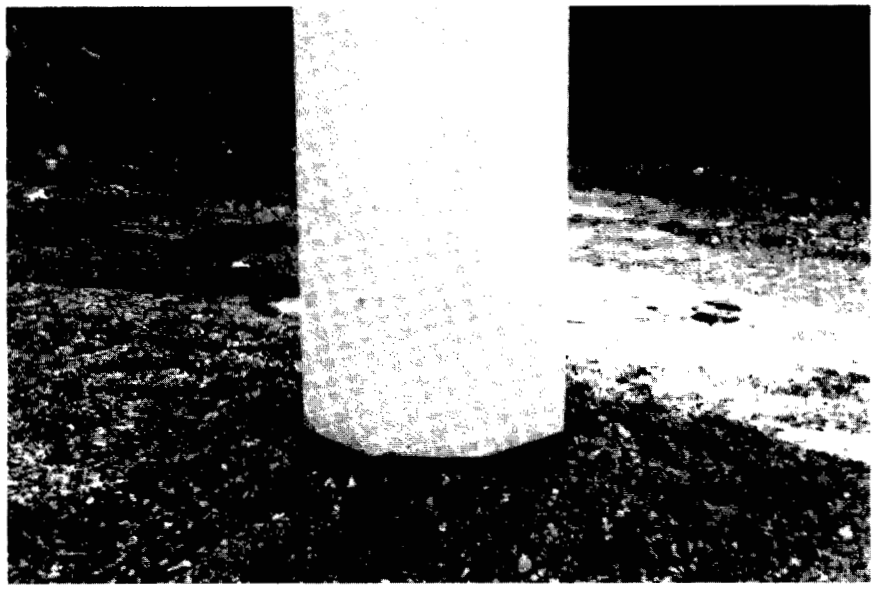

Figure 30—Direct-embedded pole

8.6 Helicopter methods (refer to Clause 9)

8.7 Post-erection

As soon as possible after erection, the constructor should connect the previously installed ground wire to the grounding attachment on the pole. The wire should be shaped to fit closely to the foundation and base of the pole, and any excess length should be trimmed.

Structures should be completely assembled with all bolts securely tightened before the start of conductor or shield wire stringing operations. Steps or ladders should be removed from the lower portions of all structures after completion of construction to discourage unauthorized climbing.

8.7.1 Galvanized coating repair

The damaged area should be cleaned using a wire brush and solvent if necessary to remove rust, grease, and other foreign matter. When dry, the area should then be coated, using a brush or spray can, with a cold galvanizing compound approved by the owner. As many coats as necessary should be applied to obtain a minimum dry thickness as specified by the owner. See ASTM A780-93a (1996).

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8.7.2 Painted coating repair

The fabrication specification should specify that an adequate quantity of touch-up paint be provided with the structures when painting is factory-applied. This touch-up paint shall be readily field-applied and compatible with the factory-applied coating. Unless otherwise recommended by the paint manufacturer, the damaged area should be cleaned using a wire brush, scraper, or solvent as necessary to remove rust, grease, and other foreign matter. It may be desirable to lightly sand the edges of the area to be repaired to feather the touch-up paint into the existing coating. The damaged areas should be dry prior to coating. If damage is confined to the finish coat, apply one coat of properly mixed paint to attain the minimum dry film thickness required. If damage is through the coating to bare steel, the appropriate primer should be applied to the required dry film thickness and allowed to properly cure prior to top-coat application. Care should be taken to ensure that the paint manufacturer's recommendations are observed during field application.

9. Helicopter methods of construction

9.1 Introduction

The availability of helicopters with larger load capacities, innovations in helicopter construction and maintenance techniques, and the increasing need to construct and maintain transmission lines with the least possible environmental impact have led to more widespread use of helicopters for both line construction and maintenance. Additionally, the project schedule or an appraisal of overall project costs may suggest the use of helicopters.

9.2 Economic considerations

Whether to use helicopters as the prime tool for structure erection should be decided as early as possible. Helicopter construction may provide the following benefits:

- Reduction in the amount of right-of-way preparation, including minimizing the requirements for access roads and site preparation. This can result in lower project costs and can allow for improved compliance with environmental regulations.
- Increased efficiency and shortened schedule for structure assembly and erection.
- Cost-effective solutions to difficult construction situations, such as locations where conventional ground-based equipment cannot gain access (islands, wetlands, very steep terrain, etc.), and erection of extremely tall structures.

However, the use of helicopters may require additional planning and/or provisions for the following:

- Structure design and detailing to facilitate sectionalizing into liftable components and mating of those components during erection.
- Additional marshalling yards to provide for acceptable flight distances during the structure erection process.
- Careful planning and scheduling of material shipments and ground crews to coordinate with the helicopter operation.
- If helicopters are being used to eliminate the need for access roads, consideration of the methods of inspection and maintenance to be used during the life of the line.

When helicopters are to be used, the following should be considered:

- The line designer and structure designer should become familiar with the costs and availability of the different types of helicopters. They should be aware of the actual lift capacitities of the different

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types of available helicopters based on the actual elevations of the line and the forecast temperatures during the construction period.

Maximum lift capacities for different helicopter types (Figures 31, 32, and 33) are shown in Table 1. This table is based on sea level and an ambient air temperature, 15 °C [60 °F]. Higher elevations, temperature changes, type of load, and specific tasks will have an impact on this lifting capacity.

It is recommended that line designers and structure designers consult with helicopter specialists who are experienced in the transport and setting of transmission structures.

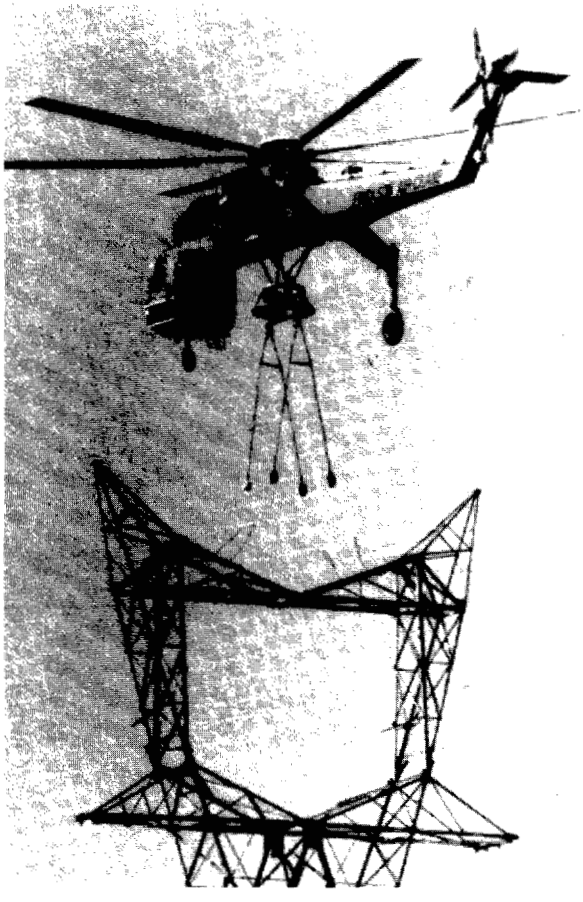

Figure 31—Sikorsky S-64 with typical helicopter attachment scheme

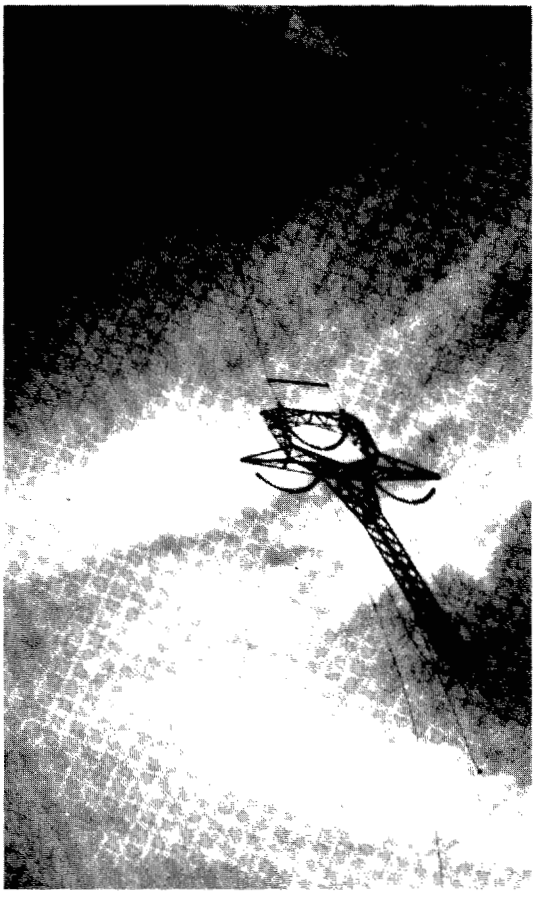

Figure 32—Boeing 234UT with guyed structure (note that guys can be seen hanging loose to ground)

— The assembly or modification of large components or even total towers can be performed in marshalling yards conveniently located near existing road networks (Figure 34).

  The use of marshalling yards can create an assembly line process through which further savings can be realized with the use of air-powered tools and jigs.

  Less material is lost at marshalling yards than individual tower sites.

— To realize economic benefits, helicopter construction will require proper scheduling, timely delivery of materials, and sufficient ground support personnel.

— Weight to be lifted should include the structure and all of the attachments (i.e., insulators and rigging).

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Figure 33—Hughes 500E helicopter flying-in components



Figure 34—Helicopter marshalling yard

9.3 Helicopter structure placement

The line designer should work with the structure designer to determine weights and centroids, and with the helicopter specialist to determine fabrication details and to pick points for lifting each subassembly.

Typically, the tower is attached to the helicopter with four electrically operated hooks controlled by the pilot (see Figure 31). In some cases, a single four-legged sling is attached to the tower and this sling is attached to the helicopter main hook that is electrically controlled by the helicopter pilot.

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Table 1—Maximum lift capacities for helicopter types

Helicopter type and model	Maximum certified external load[a]	Availability
Boeing 234 UT	12 700 kg (28 000 lb)	Asia/Europe/N. America/S. Pacific
Sikorsky S-64F	11 340 kg (25 000 lb)	Asia/Europe/N. America/S. Pacific
Sikorsky S-64E	9 070 kg (20 000 lb)	Asia/Europe/N. America/S. Pacific
Boeing 107II	5 220 kg (11 500 lb)	Asia/Europe/N. America/S. Pacific
Kamov KA 32	4 990 kg (11 000 lb)	Eastern Europe/S. America
Sikorsky S-61S	4 540 kg (10 000 lb)	N. America
Eurocopter 332C/L	3 990 kg (8 800 lb)	Asia/Europe/N. America/S. America
MIL MI 17	3 990 kg (8 800 lb)	Eastern Europe/S. America
Sikorsky S-61L	3 630 kg (8 600 lb)	Widely available
Bell 214B[b]	3 630 kg (8 000 lb)	Asia/Europe/N. America
Eurocopter 330J	3 310 kg (7 300 lb)	Africa/Asia/Europe/S. America
MIL MI 8	3 000 kg (6 600 lb)	Eastern Europe/S. America
Sikorsky S-58T	2 270 kg (5 000 lb)	N. America
NOTE—Weight capabilities are generic to types and are based on sea level and 16 °C (60 °F). Weights will vary with changes in elevation, temperature, and task.		

[a]The "maximum certified external load" is the helicopter manufacturer's projected weight. Consult with helicopter operators before using these loads on specific projects.
[b]This is a single engine aircraft.

If workers are required to help set the structure, it should be grounded to dissipate any electrical charge before any workers come in contact with the structure.

Good radio communication and crew coordination is essential during helicopter erection. Ground crews not involved in the flying operation should be on a separate radio frequency.

9.3.1 Lattice structures

The helicopter erection of self-supported lattice structures may be facilitated by the use of guides and chutes that are installed on the structure prior to erection (see Figures 8 and 35). These devices can eliminate the need for workers to be on the structure as it is being erected. These sections should be secured the same day the helicopter releases the load.

9.3.2 Guyed structures

On guyed structures, the guy tails can be temporarily attached to the base of the structure (see Figure 32). Each guy should be marked or color-coded to identify the proper anchor locations during the landing operation. The structures are set on their base (the guy tails have already grounded the tower to discharge any static build-up) and leaned toward two anchors. Two guy wires are permanently attached to their anchors. The helicopter then leans the structure in the opposite direction and the remaining guys are permanently attached to their anchors (i.e., using rope blocks, chain hoists, etc.). The helicopter then releases the structure

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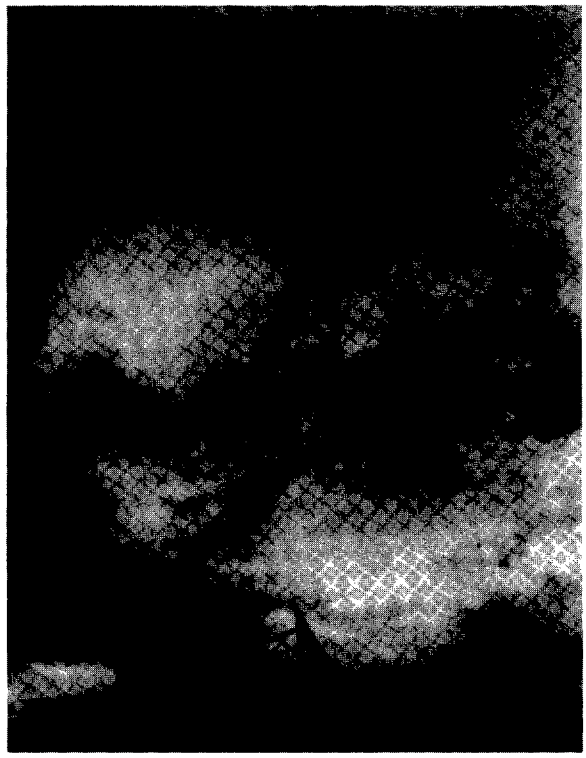

Figure 35—Typical guides and chutes used for helicopter assembly

and it is plumbed and guys tensioned at a later time. The guy wires may be precut so permanent hardware can be used to install the structure.

9.3.3 Tubular steel structures

Helicopter placement techniques vary when multi-section tubular steel structures are involved (see Figure 36). This is true for either slip-jointed or flanged structures. The owner, the helicopter specialists performing the placement, and the structure designer should be in consultation to develop a placement technique.

Care should be taken when lifting tubular structures that approach the lift capacity of the helicopter to check the actual weight of each assembly. Mill tolerances may significantly increase the actual weight, by as much as 18%, over the calculated weights shown on the drawings.

9.3.3.1 Single pole structures with anchor-bolt foundations

The bottom leveling nuts should be properly set. Typically thread protectors shaped like bullets are placed on three anchor bolts to guide the structure base. The structure should be grounded to discharge the static build-up before workers touch the structure. Typically, workers assist the helicopter in placing the base on the anchor bolts. Prior to the helicopter releasing the structure, sufficient top anchor-bolt nuts should be installed and hand tightened to secured the structure.

9.3.3.2 Framed structures with anchor-bolt foundations

When setting a framed structure, one leg is first secured as with a single pole structure and then the remaining leg is set and secured.

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Figure 36—Helicopter assembly of tubular structure with slip joints

10. Assembly and installation of insulators and hardware

10.1 Introduction

This clause covers the suggested procedures for the handling, inspection, assembly, and installation of insulators and hardware.

10.2 Assembly of insulators and hardware

Insulator and hardware assemblies for both conductors and shield wires should be assembled and installed as specified on the drawings. Care should be taken in handling and assembling insulators to avoid impact loads that may cause internal damage, to avoid chipping or cracking the ceramic or glass surface, or to avoid excessively deforming or marking the sheds of synthetic insulators. Any insulator having a damaged surface should be removed and disposed of after inspection.

Insulators and hardware, when properly aligned, should fit together without requiring the use of undue force. Care should be taken to ensure that all hardware and insulators are compatible [that is, conforming to applicable American National Standards Institute (ANSI) or International Electrotechnical Commission (IEC) standards]. It is advisable to preassemble one of each assembly type prior to actual installation to ensure compatibility and fit of components. Nuts that do not run freely on bolts should not be used. All nuts should be torqued or otherwise secured as specified on the drawings. Powered torque wrenches should not be used.

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10.3 Installation of cotter keys

In all cases, hardware should be installed so that cotter keys or bolts can be removed with the use of hot sticks. All cotter keys in suspension insulator units and hardware should be oriented to meet the maintenance requirements of the owner. In general, the cotter keys are turned so that the eye is toward the structure or upward. All cotter keys should be properly installed and spread (if required) to prevent accidental uncoupling of insulator units. The heads of all bolts and clevis pins used in the vertical position on hardware should be up.

Self-locking or humpback cotter keys should not be inserted into a bolt or clevis pin by hammering the head of the cotter key or other means that can cause deformation of the cotter key. If deformed, these cotter keys may lose their self-locking characteristics.

When cotter keys, bolts, or clevis pins are replaced, a cotter key, bolt, or pin supplied by the manufacturer of the insulator or hardware should be used since the cotter keys, bolts, and pins of different manufacturers are not necessarily interchangeable.

An inspection should be made of each assembly to assure proper installation and that cotter keys are properly in place.

10.4 Installation of assemblies

Extreme care should be exercised in the installation of all insulators and hardware to prevent damage of any kind. During construction, loads may be imposed on insulator strings in excess of their tension proof load rating. Any insulators subjected to these overloads should be removed and, if damaged, disposed of. Special care should be exercised with extremely high frequency (EHV) hardware, since surface damage of components may increase line noise when energized.

The surface of the insulators should be clean and the metal portions free of contaminants and corrosion. Ceramic, glass, and metal surfaces should be wiped clean with a hard cotton canvas cloth prior to installation. Wire brushes or abrasive material should not be used to clean the surfaces.

Insulator strings or assemblies being installed should be supported or restrained in a manner to prevent the possibility of bending of ball or pin shanks or deformation of cotter keys in order to prevent uncoupling of the joints. Polymer insulators also have limited flexibility and should be handled in accordance with the manufacturer's recommendations. Suitable cradles or other alignment supports should be used for this purpose where necessary. It is not uncommon to erect structures, either by helicopter or by crane, with insulators and hardware attached. The lower end of the insulator strings should be tied to the structure during structure erection. Particular care should be exercised to assure that the weight of the insulators and hardware does not cause bending of the ball shanks.

If post or strut insulators are used, care should be taken to avoid bending or impact loads. Lifting the post or strut insulators with the structure can produce impact loads on the insulators and should be avoided. If post or strut insulators are installed on poles with slip joints, care should be taken to ensure the proper engagement of the slip joint and that no further slip of the pole will occur prior to installing the insulators.

If travelers are to be installed with the insulators and hardware, care should be taken to ensure that they are in proper working order, oriented correctly, and any finger lines placed. Where required, dampers and spacers may also be temporarily positioned on the structure for final installation.

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11. Quality assurance

Inspection of both material and workmanship is required at each stage of the work, focusing attention on such items as the following:

a) Proper installation of foundations
b) Material, weld, and test certifications
c) Material coatings
d) Missing or incorrect items
e) Fit or engagement of members and bolts
f) Bent, deformed, or otherwise damaged items (that is, deformed members may reflect mislocated footings)
g) Field modifications and repairs
h) Bolt and nut tightness
i) Installation of locking devices
j) Length and type of bolts
k) Tubular crossarms secured against vibration damage
l) Plumb of poles and orientation of erected structures
m) Pretension of guys
n) Installation of grout
o) Installation of structure ground
p) Installation of miscellaneous attachments (that is, signs, anticlimbing devices, climbing devices, insulator washing pipe, etc.)

Annex A

(informative)

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