UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Development Utilities Programs

BULLETIN 1724E-226

SUBJECT: Electric Transmission Guide Specifications and Drawings for Concrete Pole Construction - 34.5 to 230 kV

TO: All Electric Borrowers, Consulting Engineers, and Rural Development Electric Program Staff

EFFECTIVE DATE: Date of Approval

OFFICE OF PRIMARY INTEREST: Transmission Branch, Electric Staff Division

FILING INSTRUCTIONS: This is a new bulletin.

AVAILABILITY: This bulletin can be accessed via the Internet at

http://www.usda.gov/rus/electric/bulletins.

PURPOSE: This guide bulletin provides general construction requirements for representative concrete pole structures and assemblies for 34.5 through 230 kV transmission lines.

CONTRIBUTORS: The following current and former members of the Transmission Subcommittee of the Transmission and Distribution (T&D) Engineering Committee of the National Rural Electric Cooperative Association.

Ballard, Dominic, East Kentucky Power Coop., Winchester, KY
Beadle, Robert, North Carolina EMC, Raleigh, NC
Burch, John, Florida Keys Electric Coop., Tavernier, FL
Heald, Donald, USDA, Rural Development Electric Program, Washington, DC
Lukkarila, Charles, Great River Energy, Elk River, MN
McCall, Charles, Georgia Transmission Company, Tucker, GA
Mundorff, Steve, Tri-State Generation & Transmission Association, Inc., Denver, CO
Nicholson, Norris, USDA, Rural Development Electric Program, Washington, DC
Oldham, Robert (Retired), Hudson, FL
Saint, Robert, National Rural Electric Cooperative Association, Washington, DC
Shambrock, Aaron, South Central Power Company, Lancaster, OH
Smith, Art, Burns and McDonnell Engineering Co., Atlanta, GA
Turner, David, Lower Colorado River Authority, Austin, TX
Twitty, John, Alabama Electric Coop., Andalusia, AL

James R. Newby
Assistant Administrator
Electric Program

April 9, 2007
Date

TABLE OF CONTENTS

ABBREVIATIONS

ANSI	*American National Standards Institute*
CFR	*Code of Federal Regulations*
FAA	*Federal Aviation Administration*
IEEE	*Institute of Electrical and Electronics Engineers*
NESC	*National Electrical Safety Code*
OHGW	*Overhead Ground Wire*

DEFINITIONS

Borrower - An entity which borrows or seeks to borrow money from, or arranges financing with the assistance of the Agency through guarantees, lien accommodations or lien subordinations.

Rural Development Utilities Programs Forms – All forms and bulletins referred to in this bulletin are Rural Development Utilities Programs forms and bulletins, unless otherwise noted.

Form 830 – Electric System Construction Contract form

Rural Development Electric Program – An Agency within Rural Development, formerly Rural Utilities Service (RUS).

INDEX:

INTRODUCTION - GENERAL

1. Purpose: The intent of these guide specifications and drawings is to provide Rural Development Electric Program borrowers with a basis for constructing concrete pole structures and assemblies for 34.5 kV through 230 kV transmission lines.

The borrower or borrower's representative is responsible for preparing a complete construction contract consisting of the construction contract form (Form 830 – Electric System Construction Contract) and all applicable specifications, plans, and drawings to construct a specific transmission line project.

2. Scope: This suggested specification for construction covers right-of-way clearing and access, concrete poles, pole top assemblies, structure assembly and structure erection, guys and anchors, grounding and bonding, insulators and hardware, and phase conductors and overhead ground wires.

3. Preparation of the Construction Contract: Use of this bulletin does not set forth all the terms and conditions that are necessary for a specific construction contract. This bulletin provides guidance in the form of specifications and drawings for concrete pole structures and assemblies for 34.5 kV through 230 kV transmission lines.

a. If the borrower uses these specifications when preparing a construction contract, the borrower or borrower's representative should remove sheets i to viii of this bulletin and add to Part 1 of this bulletin, the following:

-Form 168b, Contractor's Bond
-Form 187, Certificate of Completion
-Form 224, Waiver and Release of Lien
-Form 231, Certificate of Contractor
-Form 307, Bid Bond
-Debarment Certificate
-Form 830, Electric System Construction Contract
-General Conditions
-Index of Drawings
-Structure Construction Drawings (Part 2 to the specifications)
-Plans Including Maps and Special Drawings
-Plan-and-Profile Drawings

b. The standard contract forms also need other attachments to clearly identify the scope to the contract and to provide other information to or by the contractor. These attachments may be found in Bulletin 1726I-602, Attachments to Electric Program Standard Contract Forms, and cover the following:

-Project Details
-List of Owner Furnished Materials
-Proposal Summary

c. The borrower or the borrower's representative is responsible for setting forth and including in sufficient detail the construction specifications and drawings. In the preparation of Part 1, Specifications, and Part 2, Drawings, the borrower or borrower's representative is responsible for assuring that the approved specifications and drawings for a transmission line project are set forth in sufficient detail in the construction contract and that the completed construction

project complies with the contract. The construction specifications have been arranged so that they may be expanded to include any specific borrower requirements or they may be reduced to exclude any sections that are not necessary (such as clearing, etc.) if the work will not be included in the contract.

PART 1

TECHNICAL SPECIFICATIONS

1. GENERAL

1.1 Standard of Work and Schedules

1.1.1 All work must be performed in a thorough and proficient manner in accordance with the plans, specifications, and construction drawings.

1.1.2 In accordance with the requirements of 7 CFR 1724, Subpart E, Electric System Design, the latest edition of the National Electrical Safety Code (NESC), American National Standards Institute (ANSI) C2, must be followed wherever applicable to the work, except where local regulations or specification requirements are more stringent, in which case the more stringent requirements must govern. The NESC may be obtained from the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, P.O. Box 1331, Piscataway, N.J., 08855-1331, USA, or at http://standards.ieee.org/nesc/.

1.2 Technical Specifications: The following sections form the technical specifications (engineer to complete):

General _____ _____

_____ _____

_____ _____

_____ _____

_____ _____

_____ _____

1.3 Drawing and Maps

1.3.1 All drawings and maps accompanying this specification or listed herein must be considered a part of these plans and specifications. The specific drawings included as part of this technical specification are listed and indexed in Section 12, Drawings, of this document.

1.3.2 If the drawings specify a requirement different from the written specifications, the specifications must govern.

1.4 Locations of Structures and Appurtenances: Structures, anchors, access roads, and other major items to be constructed must be placed in locations determined and staked by the owner and as shown on the plan and profile drawings. The contractor is responsible for verifying the location of structures and appurtenances to be installed.

1.5 Safety

1.5.1 The work must be performed in accordance with all applicable Federal, State, and local safety laws and regulations. This includes but not limited to Federal and State OSHA (Occupational, Safety and Health Administration) regulations.

1.5.2 The contractor shall be responsible for the observance of proper safety practices and the avoidance of damage to property by all personnel engaged in the work.

1.5.3 The contractor shall take all steps necessary to prevent damage to or interference with existing power lines, communication facilities, roadways, railroads, waterways, buried cables, pipelines, and other facilities adjacent to or crossing the project right-of-way.

1.5.4 The contractor shall develop and maintain for the duration of this contract a safety program which will provide for compliance with applicable provisions of the National Electrical Safety Code and Federal, State, and local safety laws and regulations. The contractor shall designate a qualified employee to supervise the safety program and ensure compliance with applicable safety laws and regulations.

1.5.5 Structures and Conductors in the Vicinity of Airports or Exceeding 200 Feet in Height - In cases where structures or conductors will exceed a height of 200 feet, or are within 20,000 feet of an airport, the nearest regional or area office of the FAA must be contacted and if required, FAA Form 7460-1, "Notice of Proposed Construction or Alteration," is to be filed.

1.5.6 All temporary safety grounding installed during construction shall be removed by the contractor before the lines are ready for service.

1.6 Definitions

1.6.1 Borrower means an entity which borrows or seeks to borrow money from, or arranges financing with the assistance of the Agency through guarantees, lien accommodations or lien subordinations.

1.6.2 Construction unit means a specifically defined portion of a construction project containing materials, labor, or both for purposes of bidding and payment.

1.6.3 Contractor means a person or firm furnishing materials or performing construction at a specified price.

l.6.4 Engineer means a registered or licensed person who may be a staff employee of the owner or outside consultant who provides engineering services. Engineer also includes duly authorized assistants and representatives of the licensed person.

1.6.5 Owner means the borrower.

1.6.6 Owner-furnished materials means materials or equipment or both supplied by the borrower for installation by the contractor.

1.7 Abbreviations

ANSI	American National Standards Institute
CFR	Code of Federal Regulations
FAA	Federal Aviation Administration
IEEE	Institute of Electrical and Electronics Engineers
NESC	National Electrical Safety Code
OHGW	Overhead Ground Wire

1.8 Special Requirements (to be completed by the engineer):

2. CLEARING

2.1 General Requirements

2.1.1 Clearing units specified may cover full width right-of-way clearing, selective clearing, tree topping, spraying of herbicides, or other forms of right-of-way preparation. Only those areas shown on the drawings or specified by the owner shall be cleared in accordance with the applicable clearing units. Isolated ("danger") trees to be removed will be marked in the field by the engineer.

2.1.2 Only such vegetation should be removed as necessary to permit construction, operation, and maintenance of the transmission line. Care must be taken to prevent denuding of ground cover and erosion of the soil.

2.2 Clearing Methods and Equipment

2.2.1 Unless otherwise specified, all timber to be cleared must be felled. The removal of brush must meet State and/or Federal permit requirements and be in a manner so as to reduce the overall impact on the root structure of the ground cover.

2.2.2 Equipment must be in good repair and appropriate for the types of clearing specified.

2.2.3 When specified in the right-of-way construction units, stumps left in place must be treated with a heavy application of an appropriate herbicide approved by the engineer. Chemical treatment of stumps must occur as soon as possible after cutting. The chemical application must be sufficient to saturate the entire aboveground surface of the stump and cause a small amount to run down the sides and collect at the base to penetrate below the ground line into the roots. Any stumps showing resurgent growth prior to completion of line construction must be treated to kill all such growth.

2.2.4 Chemical sprays or herbicides must only be used with the approval of the engineer, and only in areas so designated for their use. Herbicides must be applied in accordance with the manufacturer's recommendations and only by a licensed/certified applicator. The chemical sprays and herbicides must meet the environmental requirements of all governing agencies. Spraying must be performed in such manner, at such pressure, and under such wind conditions that drift of spray material to adjacent plants, animals, or persons will be avoided.

Application of chemical sprays or herbicides must not be made:

a) when the ground is continuously frozen;
b) when the ground is adjacent to streams or other water bodies;
c) when the ground is or may be flooded during the period in which the herbicide retains its toxicity; or
d) when the ground is a marsh or other wetland.

2.2.5 If required by paragraph 2.3, "Special Requirements," stumps must be removed.

2.2.6 The landowner's written permission must be received prior to cutting trees outside the right-of-way.

2.2.7 Disposal of trees, brush, branches, and refuse must be in accordance with the methods specified in the construction units and must meet permit requirements.

2.2.8 Avoid clearing vegetation in riparian areas to the extent possible. A vegetative buffer zone should be left along creeks and streams to minimize siltation and sedimentation and prevent adverse impacts to riparian habitat.

2.3 <u>Special Requirements</u> (to be completed by the engineer):

3. ACCESS

3.1 Ingress And Egress

3.1.1 The activities of the contractor are to be restricted to the area along the right-of-way.

3.1.2 Where access to the right-of-way is across private property, the owner, tenant, or occupant shall be contacted to obtain permission for ingress and egress to the right-of-way. Such arrangements, including obtaining releases for damage, must be made by (engineer to check one):

a. The owner..... ☐
b. The contractor..... ☐
c. Other (specify) ..... ☐

3.1.3 Access across public land must be accomplished as described in paragraph 3.6, "Special Requirements."

3.2 Fences and Gates

3.2.1 Where fences must be cut to allow access for the work, gates must be installed as shown on the drawings or as directed by the engineer. All material and labor required for such installations must be furnished by the contractor per bid unit.

3.2.2 Types and details of gate construction must be shown on the drawings or approved by the engineer.

3.2.3 Brace posts must be installed at each fence cut to ensure that adjacent fence spans will not become slack. A wire fence must not be cut until it is secured to the brace post.

3.2.4 All gates must be closed and locked when required by the landowner.

3.2.5 Gate units may include removal of the gate after construction of the line is complete. In those cases as determined by the engineer, the contractor shall remove the gate and restore the fence. All labor and material required must be furnished by the contractor. If removal is required, gate material must be disposed of in a manner acceptable to the engineer.

3.3 Access Roads

3.3.1 Access road construction may be required as a part of the work. Where specified, roads must be of the type, dimensions, and grades shown on the drawings, and must be located as shown on the drawings and as staked by the engineer.

3.3.2 Borrowed material for access road fill must be a compactible granular material suitable for such a purpose, free of brush, refuse, or organic material. Fill must be compacted by the use of suitable heavy construction equipment. The finished road must be maintained smooth and free of ruts and sink holes until completion of construction. Water bars, drainage ditches, or other special requirements as called for on the drawings must be installed in accordance with the plans and specifications. All materials and labor required for such work must be furnished by the contractor.

3.4 Culverts: Culvert pipes must be installed as shown on the drawings or as directed by the engineer. Each pipe must be of a type, diameter, and length as specified and must be properly set, backfilled, and tamped. All required labor and material must be provided by the contractor.

3.5 Restoration: The contractor shall have a continuous cleanup program throughout construction. The contractor shall restore the land that is crossed to its original condition. This restoration includes the removal of deep ruts and the disposal of foreign objects such as stumps or chunks of concrete. It also includes smoothing and reseeding damaged vegetation areas with vegetation similar to the original, cleaning out gullies, and restoring terraces. Roads existing prior to construction must be restored to equal or better than their original condition.

3.6 Special Requirements (to be completed by the engineer):

4. CONCRETE POLES

4.1 Reference to Drawings

4.1.1 The pole lengths and designations shall agree with the Pole Units specified for the structures to be erected as tabulated in the Transmission Construction Units and shown on the plan and profile drawings.

4.2 Pole Inspection, Handling, and Distribution

4.2.1 The contractor shall inspect all poles upon delivery and immediately notify the owner of freight damage discovered or misfabrication of poles.

4.2.2 Poles shall be handled according to the manufacturer's instructions. The contractor will obtain the instructions from the manufacturer. The handling of the poles including loading, hauling, and unloading, shall be accomplished with care to prevent dropping poles and to prevent breaking, chipping, or overstressing. Care shall be taken to prevent impacts of any kind. The pole shall be handled at the lift points indicated by the manufacturer. Pole sections shall be properly blocked and secured to minimize movement or damage when transported by the contractor. Poles shall not be rolled nor dragged on the ground without approval of the engineer.

4.2.3 Poles or components damaged during handling by the contractor shall be replaced by the contractor at no expense to the owner. With the consent of the owner, minor chipping may be repaired with an epoxy grout acceptable to the pole manufacturer and the owner.

4.2.4 Spliced shaft segments will be properly identified so that the sections for each structure can be segregated upon arrival at their destination.

4.2.5 If poles are stored after delivery, they should be stored in a horizontal position with suitable cribbing on firm soil. Cribbing should be placed at intervals indicated by the manufacturer to prevent the pole from developing a permanent camber. Stacking of concrete poles is not allowed.

4.2.6 The contractor shall provide all cribbing and blocks for storing poles.

4.2.7 Poles spotted along the right-of-way near future setting locations shall be located away from traveled ways, residential areas, off the ground, and secured to prevent movement.

4.3 Field Drilling

4.3.1 The engineer and manufacturer must be notified and their approval must be obtained for drilling of any holes in a concrete pole. Where holes are required and drilling has been approved by the owner, the contractor shall carefully drill the required holes in the locations specified by the owner using a rotary hammer drill and carbide tipped bit or using wet coring methods. The hole should be made 1/16 inch larger than the diameter of the bolt to be inserted.

4.3.2 Holes should be drilled without cutting longitudinal steel strands. If a strand is inadvertently cut or nicked, the contractor shall notify the owner, who will provide further instructions.

4.3.3 Field drilled holes shall be drilled from the outside to the inside to prevent spalling of the concrete on the outside face of the pole. Drilling completely through the pole shall not be allowed.

4.3.4 After drilling, any exposed steel should be coated with a zinc rich or epoxy paint to protect the steel against corrosion.

4.3.5 If the holes are not drilled correctly and at specified locations, the owner may require the pole to be replaced at the Contractor's expense.

4.4 <u>Special Requirements</u> (to be completed by the engineer):

5. POLE TOP ASSEMBLIES

5.1 Reference to Drawings

5.1.1 The pole top assembly unit consists of all items shown in the list of materials in the transmission line structure drawings, Part 2.

5.1.2 Unless shown in the list of materials on the drawings, the pole top assembly unit does not include other units such as pole units, pole grounding units, foundation units, guying assembly units and anchor units.

5.2 Handling of Materials

5.2.1 Care shall be exercised in the handling of all materials. Defective or damaged material shall not be installed.

5.2.2 The contractor shall furnish the necessary equipment to load and haul to the job site all owner-furnished materials. The contractor shall bear the cost of all handling; such as loading, hauling, and unloading.

5.2.3 If framing members (crossarms, bracing, and X-braces) are stored after delivery, they must be arranged with care and placed on blocking at least one (1) foot above ground to prevent contact with standing water or the ground. No crossarm shall have an unsupported length greater than 20 feet. The blocking shall be provided by the contractor and included in the contract's unit prices. Materials sensitive to weather damage shall be protected.

5.2.4 Care shall be exercised in handling crossarm assemblies, pole band assemblies, and other factory subassemblies to prevent loss of components for which the contractor is responsible.

5.2.5 Materials or equipment shall not be placed where it will be damaged by or cause damage to vehicular traffic, livestock, persons, and property.

5.3 Special Requirements (to be completed by the engineer):

Blank Page

6. STRUCTURE ASSEMBLY (Concrete Poles)

6.1 Reference to Drawings

6.1.1 The contractor shall assemble each structure using the assemblies designated on the plan and profile drawings and as shown on the structure and assembly drawings in Part 2 of these specifications..

6.1.2 Connection details to assemble each structure are referenced on the structure drawings and included with the plans and specifications.

6.2 Structure Framing

6.2.1 The contractor shall frame poles on flat or uniformly sloping terrain located at or near the structure site. A structure may be framed after the poles are set, if approved by the engineer. Framing on rolling terrain where poles become unsupported shall be avoided. If assembly on uniform terrain is not possible, the contractor shall temporarily support the pole and its structural components with hardwood cribbing.

6.2.2 After the shaft sections are assembled, the crossarms, hardware, climbing devices, insulators, etc., can be attached to the structure. The contractor shall take extra care to avoid damaging climbing devices during lifting or handling.

6.2.3 Bolts shall be tightened such that the tightening does not crack the pole, overstress the bolts or pull out the inserts. The method and torque used in tightening the bolts shall be in accordance with the pole manufacturer's guidelines.

6.2.4 All hardware at a connection shall be compatible with the fastener diameter. The holes in the hardware shall be 1/16 of an inch greater than the fastener diameter, unless otherwise noted.

6.2.5 Fasteners shall be sized so that they extend not less than 1/2 of an inch nor more than 2-1/2 inches beyond the face of the last nut or locknut. Bolts shall not be cut off unless approved by the engineer.

6.2.6 Pole ground wires shall be installed when specified and as shown on the plan and profile and/or structure drawings.

6.2.7 Guying attachments, where specified, shall be oriented as shown on the transmission line structure drawings and as shown on the guying attachment drawings in Part 2.

6.2.8 The contractor shall check the end fittings of crossarms, davit arms, braces, X-braces, and other factory assembled components to verify that all factory-installed hardware is secured in accordance with manufacturer's specifications. The cost of retightening factory-installed hardware, if required, shall be included in the contractor's unit cost for pole top assemblies.

6.3 Special Requirements (to be completed by the engineer):

Blank Page

7. STRUCTURE ERECTION

7.1 Reference to Drawings

7.1.1 The contractor shall verify structure locations prior to erecting structures. Structures and specified assemblies must be erected at locations shown on the plan-and-profile drawings.

7.1.2 Tangent structures shall be erected as shown on the transmission line structure drawings in Part 2. Single pole structures or center of H-frames shall be placed on the survey centerline, unless offset to the left or right of the survey centerline by the dimension shown on the guying guide drawings or plan-and-profile drawings.

7.1.3 Angle structures and deadend structures shall be erected as shown on the structure drawings, guying guide drawings, and plan-and-profile drawings. The angle structure shall be offset to the left or right of the survey centerline so all poles are offset by the dimension shown on the guying guide or plan-and-profile drawings.

7.2 Structure Erection

7.2.1 Tangent structures with single crossarms must be erected with crossarms on alternating sides of the poles. At crossings and long spans, the crossarms shall be mounted on the face of the structure away from the crossing or long span. Crossings include highways, railroads and overhead utility.

7.2.2 The contractor shall not overstress any members or connections when installing structures.

7.2.3 The contractor shall ensure hardware, bolts, nuts and locknuts shall be tightened after erection of the structures as specified by the engineer per manufacturer's specifications.

7.2.4 Lifting and erection of the concrete pole shall be according to the manufacturer's instructions. Chokers must be tight around the pole and a positive stop against sliding shall be provided. Slings shall be composed of nylon unless approved by the engineer. Use of any other sling material shall be approved by the owner. Bare steel cables shall not be used as a sling.

7.2.5 After the shaft sections are assembled, crossarms, hardware, climbing devices, insulators, etc., can be attached to the structure. The contractor shall take extra care to avoid damaging climbing devices during lifting or handling.

7.2.6 During structure erection, slings, ropes, banding, tie downs, or other material shall not be applied to, or allowed to lie on insulators and/or components. For non-ceramic insulators, the sheathing material over the fiberglass rod shall be inspected, and if any damage (i.e., cuts, scrapes or tears in the rubber material) is found to be caused by the contractor and that could allow moisture to penetrate to the fiberglass rod, the contractor shall replace the insulators at the contractor's expense. Non-ceramic insulators and other fiberglass components shall not be bent or twisted.

7.3 Excavation, Setting, and Backfill

7.3.1 All poles shall be embedded in soil to a minimum depth of 10 percent of the pole length plus 2 feet or an embedment depth specified on drawings, whichever is greater. Depth of the hole shall not be less than that specified nor more than 3 inches deeper. Where the ground is sloping, the embedded depth of multiple pole structures shall be as shown on drawings.

7.3.2 Pole excavation shall be performed by auger, clamshell, or hand, and shall include removal of all materials necessary to provide a clean vertical hole to the required depth.

7.3.3 Blasting prior to excavating is only allowed with the engineer's and owner's approval; and only if an applicable permit is obtained. Care shall be exercised by the contractor when blasting in the vicinity of structures, utilities, etc., to prevent damage of any type. The contractor is responsible for any damage caused by blasting activity.

7.3.4 The stability of existing structures and facilities shall not be impaired or endangered by excavation work. Sheeting and shoring shall be provided by the contractor as required to protect and maintain the stability of existing structures and facilities and the sides of excavations and trenches until they are backfilled. Sheeting, bracing and shoring shall be designed and built to withstand all loads caused by earth movement or pressure, and shall maintain the shape of the excavation under all circumstances.

7.3.5 The contractor shall provide casing where required to maintain the stability of an excavated pole hole. Casing shall be designed and built to withstand all loads caused by earth movement or pressure and shall maintain the shape of the excavated pole hole under all circumstances. The casing shall be removed during backfill placement. Other methods to maintain stability of an excavated pole hole shall require prior approval of the engineer.

7.3.6 Poles shall be set and backfilled within 24 hours after excavation of the pole hole unless otherwise approved by the engineer. When poles are not immediately set and backfilled, the excavations shall be protected with a suitable barrier to prevent injury or damage to persons, equipment or livestock.

7.3.7 The contractor shall provide casing where required to maintain the stability of an excavated pole hole. Casing shall be designed and build to withstand all loads caused by earth movement or pressure and shall maintain the shape of the excavated pole hole under all circumstances. The casing shall be removed during backfill placement. Other methods to maintain stability of an excavated pole hole shall require prior approval of the owner.

7.3.8 Pole holes shall be a minimum of 8 inches larger in diameter than the butt diameter of the pole. When pole bearing plates are used, pole holes shall be the minimum diameter necessary for installation of the pole with the bearing plate. The excavated hole shall be at least as large at the bottom as at the top. Alternative methods of pole setting may be used only with the approval of the engineer.

7.3.9 After excavation of a stable pole hole, any accumulated water or frozen matter shall be removed from the hole prior to setting the pole. Contractor shall provide suitable granular backfill material (see drawing TM–101 in Part 2) to level the bottom of a water hole. Any soil added to level the bottom of a dray hole shall be compacted to a density greater than or equal to the density of the surrounding undisturbed soil before the pole is set.

7.3.10 Pole backfill material shall be approved by the engineer. The engineer's approval will be based on the compactibility of the native soil and its suitability for providing a dense supportive soil mass, free of voids, organic, or other deleterious material and, not frozen. Where excavated material is not suitable for backfill as required by the engineer, the contractor shall furnish suitable granular imported material for this purpose which shall be paid in accordance with the unit price for granular backfill for poles. (See drawing TM-101, Part 2)

7.3.11 Poles shall be set plumb before and after the backfill is placed. If the poles are out of plumb, the backfill shall be removed and replaced. Plumbing of poles by pushing or pulling the structure shall not be permitted. The tolerance for plumbness shall be 1/2 inch in 10 feet of height.

7.3.12 Structures, prior to backfilling, shall be aligned with the conductor support at right angles (±1°) to the centerline of the transmission line except at angle structures where the arm shall bisect the angle (±1°). Install crossarms level, except for raked structures, regardless of the terrain by varying the setting depths of the poles. The maximum deviation of the crossarm from the horizontal measured from end to end shall not exceed ½ inch for each 10 feet of arm length.

7.3.13 Backfill shall be placed around the pole in layers not exceeding 6 inches in depth, with each layer mechanically tamped before the next layer is added. The backfill shall be compacted to a density equal to or greater than that of the surrounding undisturbed soil.

7.3.14 Backfill and compaction shall be done at a rate no faster than one laborer shoveling fill and two others using mechanical or pneumatic tampers. If imported granular backfill (TM-101, Part 2) is used, two mechanical or pneumatic tampers or two vibrating rods may be used to compact the imported granular backfill.

7.3.15 Backfill soil shall be banked up and tamped around the pole to a height of 6 inches above the natural grade, and shall be sloped away from the pole.

7.3.16 Structures shall be grounded as soon as practical after they are erected.

7.3.17 After completion of wire stringing, all poles shall be reinspected to verify that poles remain plumb and the backfill has not settled. If settlement occurs, the engineer shall determine if the backfill shall be added and tamped or if the backfill shall be completely removed and replaced. Added backfill shall be recompacted as previously specified. If required by the engineer, the backfill is to be completely dug out and replaced, the pole shall be readjusted, if necessary, and the backfill compacted as previously specified. This work shall be done at no additional cost to owner.

7.3.18 All excess excavated material and unused imported materials shall be disposed of properly after backfill operations are completed. When approved by the owner, surplus excavated soil may be carefully spread and leveled on the surface of the ground near the structure and in a manner to minimize damage to the surrounding environment

7.4 <u>Special Requirements</u> (to be completed by the engineer):

Blank Page

8. Guys and Anchors

8.1 Reference to Drawings

Guys and anchors shall be installed at locations shown on the drawing or specified by the engineer. The engineer will stake all anchor rod locations. The contractor shall check locations of anchors before installation.

8.2 General Installation Requirements

8.2.1 Anchor rods shall be installed in line with the guy wire and installed so that not more than 8 inches of rod (including eye) remain out of the ground after guy tension is applied. In cultivated fields or other locations deemed necessary, the projection of the anchor rod above earth may be increased to a maximum 12 inches to prevent burial of the rod eye.

8.2.2 Anchors shall be of the type, size, and depth as shown on the drawings.

8.2.3 Slope of the anchor rod shall be the same as the guy**.**

8.2.4 The engineer may require the use of other type anchors whose installation shall follow the manufacturer's recommendations if ground conditions make the installation of the anchors shown on the construction drawings impossible.

8.2.5 The engineer must approve in writing, the excavated hole and anchor before the anchor hole is backfilled. The holes shall be backfilled and tamped in the same manner as is required for concrete pole backfilling. Onsite suitable native soil or approved imported granular material shall be used for anchor backfill.

8.2.6 Power installed screw anchors shall be installed with the appropriate size and type of equipment in accordance with the engineer's requirements and manufacturer's recommendations. Screw anchors shall not be reversed to meet the requirements of projection of the rods above the ground. The engineer shall approve the final projection and witness all installations.

8.2.7 Where required by the engineer, anchors shall be tested to 50 percent of their designated ultimate rated capacity. All material and labor required for testing of the anchors shall be furnished by the contractor and included in the unit costs for testing anchors.

8.2.8 Guys shall be installed and attached to the structures as shown on the transmission line structure drawings before conductors or overhead ground wires are strung. Each guy shall be pre-tensioned to remove any slack in the guy. Guys will be re-tensioned after the conductors and overhead ground wires are installed to plumb the poles and to equalize tensions in the guys. If slack guys are found, they shall be re-adjusted so that all guys in any structure have approximately equal tension. The final tension in the guys and the plumb of the poles shall meet the approval of the engineer.

8.3 Special Requirements (to be completed by the engineer):

Blank Page

9. GROUNDING AND BONDING

9.1 Reference to Drawings: All structures must be grounded as shown on the plan-and-profile drawings and transmission line structure drawings, and subject to the following provisions.

9.2 Structure Grounding

9.2.1 The engineer may require that ground resistance measurements be made for each structure and that additional grounding be added to that already provided by the basic structure grounding assemblies.

9.2.2 Where structure grounding tests are required by the engineer, the contractor shall measure the ground resistance of the external ground after the structure is erected, but before the ground rod is attached to the pole. The method of measuring ground resistance must be subject to the approval of the engineer. The contractor shall provide a written report and a sketch of the ground resistance tests at each structure.

9.2.3 All labor and materials for ground resistance measurements and installation of additional grounding must be provided by the contractor and must be covered by the unit costs for testing and for grounding units.

9.2.4 The contractor shall install counterpoise only after approval of the engineer.

9.2.5 Overhead ground wire and optical ground wire (OPGW) shall be bonded to the pole ground wire as required by the drawings**.** Concrete poles shall be bonded from the pole ground wire to the ground rod or counterpoise as specified by the drawings.

9.3 Bonding of Ground Wire

9.3.1 The pole ground wire must be continuous and not spliced from top of pole to the pole butt grounding assembly. Should damage occur during erection of the structure, the pole ground wire may be spliced with the engineer's approval.

9.3.2 Hardware must be bonded to the pole ground wire as shown on the drawings. The ground wire must clear any unbonded hardware by at least 3 inches.

9.4 Fence and Gate Grounding: Fence and gate grounds must be installed as shown on the drawings. All labor and material required must be furnished by the contractor at the unit prices for fence and gate grounding.

9.5 Special Requirements (to be completed by the engineer):

Blank Page

10. INSULATORS AND HARDWARE

10.1 Reference to Drawings: Insulator and hardware assemblies must be fully assembled and installed as shown on the drawings. Items of hardware and insulators must be inspected for missing parts, defects, and proper fit before installation. Defective or missing pieces must be replaced.

10.2 Handling and Storage for all Insulators

10.2.1 Insulators and hardware must be stored in their appropriate shipping containers until installation. They must be properly supported and stacked so as not to damage the individual items. They must be blocked up off the ground so that they cannot come in contact with the ground or standing water.

10.2.2 Insulators must be carefully handled to prevent damage to the porcelain skirts, pins, galvanizing, and cotter keys. A cradle or other suitable device must be used to hoist all insulator strings whenever the quantity exceeds 6 units per string.

10.2.3 Insulators that are cracked, chipped, or damaged in any way must be replaced with units that are not defective. The cost for replacement of previously accepted units must be borne by the contractor.

10.2.4 All insulators must be wiped clean with a clean, soft, nonabrasive cloth.

10.3 Additional Handling and Storage for Polymer Insulators

10.3.1 Handling practices for non-ceramic composite insulators are different from those used for ceramic insulators. A single cut, puncture, or tear in the polymeric housing material covering the fiberglass reinforced plastic (FRP) rod may expose the rod to moisture and eventually cause mechanical failure of the insulator. The contractor shall be careful not to cut, puncture or tear polymer insulators.

10.3.2 Polymer insulators shall be stored and transported to the job site in their original shipping containers. If the insulators are stored outside of their shipping containers, the polymers should never be lying down against the ground, walked on, stacked on top of each other, or transported hanging over the tailgate of a pickup truck. Composite insulators shall be stored in a manner to prevent damage by rodents.

10.3.3 Care should be taken when unpacking polymer insulators to ensure that the polymeric housing is not cut or punctured. Insulators should be inspected for damage after removal from shipping containers. Any damage found shall be reported to the engineer immediately.

10.3.4 Composite insulators shall not be lifted by their weathersheds. Long suspension insulators shall be carried by two workers and, if lifting with a rope or strap, attach it only to the insulator end fittings. Long suspension insulators should also be supported in the middle by workers to avoid bending since suspension insulators are generally not designed for bending or compressive loads.

10.3.5 Composite insulators should be stored and transported in their shipping cartons, or equivalent protection. If composite insulators are removed from their original shipping containers and then transported to the job site, extreme care should be taken at all times to avoid damaging the polymeric housing material. No sharp objects, materials, tools, or corona rings should be placed either on top, or situated below the insulators. Insulators should not be stacked

directly on one another (the end fitting of one may cut into the polymer housing or another).

10.3.6 Composite insulators should not be tied down with rope over the housing material during transport or transported on overhead racks of line crew trucks where bending of the insulator occurs.

10.4 Installation of All Insulators

10.4.1 All connections must be made in accordance with the drawings. Bolts must be torqued to the manufacturer's specifications. Cotter keys, where required, must be fully inserted.

10.4.2 Cotter key eyes on insulators and hardware items must be oriented toward the structure, or in such a way as to facilitate easy removal during hot line maintenance.

10.4.3 Pins and bolts to insulator string assemblies must be oriented with the head upright wherever possible.

10.4.4 Pin-type insulators must be tight on the pins. On tangent structures, the top groove must be in line with the conductor after tying in.

10.4.5 After installation, insulators should not be climbed on. Conductors should not be temporarily laid on the sheds or housing of composite or on the bells or posts of porcelain. Insulators should be kept clean of dirt and contaminants, specifically electrical contact compounds.

10.5 Additional Installation Requirements for Polymer Insulators

10.5.1 During installation, composite insulators should not be subjected to any loads that it would not normally see in service. Composite insulators shall not be subjected to any torque forces.

10.5.2 Insulators should not be lifted by their polymer sheds. Slings or pulling ropes should never be place over the sheds or housing.

10.5.3 The insulator should be thoroughly inspected before and after installation. Damaged insulators should not be used and should be marked for inspection by qualified utility personnel.

10.5.4 Corona or grading rings shall be installed per manufacturer’s recommendations.

10.6 Special Requirements (to be completed by the engineer):

11. CONDUCTORS AND OVERHEAD GROUND WIRES

11.1 General

11.1.1 All conductor and overhead ground wire installation work must be done in accordance with the manufacturer's recommendations and the IEEE Standard 524, Guide to the Installation of Overhead Transmission Line Conductors. If there is a discrepancy between the guide and the manufacturer's recommendation, the contractor should follow the manufacturer's recommendation. The following provisions are for tension stringing of conductors and overhead ground wires. IEEE Standard 524 may be obtained from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, N.J., 08855-1331, USA or at http://shop.ieee.org/ieeestore/

11.1.2 It is very important to avoid damaging the wire or the associated fittings in any way. It is the contractor's responsibility to protect the wire and fittings against damage. If the wire and associated materials are damaged due to the contractor's mishandling, negligence, or faulty equipment, the contractor shall repair or replace the damaged sections, including furnishing of necessary materials, in a manner satisfactory to the owner and at no additional cost to the owner.

11.2 Handling and Storage

11.2.1 Reels of wire must be stored off the ground and adequately supported so as to avoid damage to the reel, protective covering, and wire. Wire and reels must be kept free of standing water, excessive dust, and mud, and stored no closer than 50 feet from an energized portion of a substation or transmission line. The conductor must be covered.

11.2.2 Protective covering must be removed at the job site and the outside layer of each reel must be examined by the contractor and the owner to be sure that the wire is in good condition and that no nails, staples, or other sharp objects, which could damage the wire during unreeling, protrude on the inside of the reel heads.

11.2.3 Identification tags and markers must be retained on the reels. For future reference, the contractor shall record on forms supplied by the engineer, the reel number, length of wire, net weight, and the structure numbers where the wire was installed.

11.2.4 Conductor reels should not be rolled. They should be lifted or transported by a reel dolly. If they do need to be rolled to a location where they can be easily handled, they should be rolled in the direction that would tend to tighten rather than loosen the conductor on the reel.

11.3 Tools and Equipment

11.3.1 Tools and equipment for wire work must be of the proper size and type for the job and must be in good working condition. Sheaves, tensioners, pullers, wire grips compressors, and dies must be properly sized for the specific wires to be installed.

11.3.2 Stringing blocks must be neoprene lined, free running, and of the proper diameter and groove size for the wire being pulled.

11.3.3 Tensioner bullwheels must be neoprene lined and of the proper size and design for the wire being pulled.

11.3.4 V-Groove pullers shall not be used for annealed aluminum conductors including but not limited to ACSS (Aluminum Conductor Steel Supported) and ACSS/TW (Trapezoidal Shaped Strand Concentric - Lay Stranded Aluminum Conductors, Steel Supported) wire.

11.4 Guard Structures

11.4.1 Guard structures must be furnished and installed by the contractor, where required, to prevent the conductor or overhead ground wires which are being pulled from coming into contact with existing overhead electric supply lines, communication lines, roads, highways, and railroads crossed by the transmission line. All labor and materials required must be furnished by the contractor and included in the unit cost for conductor units.

11.4.2 If not part of the right-of-way agreement previously executed, permission to install guard structures on private property or public highway right-of-way must be obtained by (engineer to check one):

	Private	Public
a. The engineer	☐	☐
b. The contractor	☐	☐

11.4.3 After completion of all wire work, the contractor shall remove the guard structures, fill and tamp all pole holes, and restore the right-of-way and access to its original condition.

11.5 Stringing

11.5.1 The method of installing the conductor and the overhead ground wire must be as designated by the engineer. When controlled tension stringing is specified, it must be performed in accordance with IEEE Standard 524, Guide to the Installation of Overhead Transmission Line Conductors, and subject to the manufacturer's concurrence (owner to check one for each):

Conductor Installation

a. Controlled Tension Stringing ..... ☐
b. Other (specify) ..... ☐

Overhead Ground Wire Installation

a. Controlled Tension Stringing ..... ☐
b. Other (specify) ..... ☐

11.5.2 The precise stringing procedure which the contractor intends to use must be submitted to the owner for review and approval prior to any wire work. This procedure must include a description of all major pieces of equipment to be used, number of crews, composition and responsibilities of each crew, proposed equipment set up locations, wire reel locations, locations of all splices, and locations and descriptions of temporary snubs and anchors.

11.5.3 Extreme care must be exercised during the wire stringing operation to avoid damage to conductor or overhead ground wire strands. If damage is found, the stringing must be stopped. Damage is defined as any deformity of the wire which can be detected by sight or touch. Kinked, twisted, abraded, "bird-caged," or flattened wire will not be allowed to remain on the line. Any wire so damaged must be repaired or replaced by the contractor at his own expense and to the satisfaction of the engineer.

11.5.4 The contractor shall continuously inspect the wire as it leaves the reels. If the wire has an accumulation of dirt, oil, grease, or any other foreign substance, such substance must be removed as the wire leaves the reels during the stringing operation by a method approved by the engineer.

11.5.5 Wire tension during stringing must be high enough to ensure that the wire does not drag across the ground, underbrush, trees, towers, fences, guard structures, or any other surface other than the stringing sheaves. A stringing tension of not less than 50 percent nor more than 80 percent of the initial sagging tension should be used.

11.5.6 No more than two reels of wire per phase may be pulled at a time. Full tension compression splices must not be pulled through the stringing blocks.

11.5.7 When stringing wire on H-frame structures, the center phase must always be pulled first. The outside phases must be pulled alternately in successive pulls. If all three phases are strung in one pull, the middle phase must lead the outer phases by not less than 100 feet.

11.5.8 Wire must not be pulled during adverse weather conditions or when such conditions are imminent as determined by the engineer.

11.5.9 The air temperature at the time and place of stringing must be determined by a certified thermometer.

11.5.10 For conductor wires with more than one layer of annealed aluminum strands (i.e. – ACSS, Aluminum Conductor Steel Supported), the contractor shall use a minimum of two grips per wire.

11.6 Sagging

11.6.1 Wires must be sagged to the proper tensions in accordance with the initial stringing sag and tension tables provided by the engineer. Sags will be checked by sighting with target and transit as indicated in the IEEE Standard 524. Sags must be within a tolerance of +3 and -0 inches of the specified values. When approved by the engineer, sags may be checked by the return wave method.

11.6.2 The air temperature at the time and place of clipping in must be determined using a certified thermometer. The temperatures at which the conductor is sagged in and the spans in which sags are measured must be recorded, and the information given to the engineer.

11.6.3 In hilly or mountainous terrain, the offset clipping method may be required in order to ensure equalized tensions and plumbing of insulators on suspension structures. Calculations for offset clipping/sag corrections must be done and values for sagging must be furnished by the engineer. The contractor shall furnish all stringing set up information to the owner at least 6 weeks prior to the sagging operations. The contractor shall keep a record of sag data.

11.6.4 The contractor shall select the length of each sag and the sag-checking spans, subject to the review and approval of the engineer. The contractor's sagging method must result in uniform tensions throughout the sag and the allowable sag tolerances must not be exceeded.

11.6.5 The contractor shall budget the stringing time so that a reel of wire is sagged within 72 hours after the start of the stringing operation. If this is not possible in isolated areas, the owner shall be consulted regarding the necessity of using creep correction factors with the specified chart sags.

11.6.6 The contractor shall make any necessary adjustments in the wires or clamps at any time during the construction period to ensure that the wire is at the proper tension, sags are within tolerance, suspension insulator strings and overhead ground wire assemblies hang plumb.

11.7 Clipping, Deadending, and Splicing

11.7.1 The contractor shall take into consideration the strength limitations of all structures in so far as the application of temporary wire stringing loads. All temporary back snubs and pull-downs on structures other than strain structures must be carefully planned and must meet the approval of the engineer.

11.7.2 Use of wire reels must be carefully planned to minimize the number of full tension splices. There must never be more than one compression fitting per wire in any span and splices must not be located within 25 feet of a conductor support. Splices must not be located in spans over roads, railroads, and utility crossings, or in the spans adjacent to the crossing span. Splices must also not be located in the span where the conductor is to be deadended.

11.7.3 Compression deadends and splices must be installed in accordance with the manufacturer's recommendations. Conductor strands within the splice area must be carefully cleaned with a steel brush, cotton rags, and solvents. Filler compound must be furnished and pressure installed by the contractor. Special care must be exercised in making compression fittings to ensure use of proper die size, accurate cutting of wire, complete insertion of the cable strands, and pressing to produce a straight, uniform fitting. The contractor shall make up one splice and deadend to use as a sample in order to determine how much wire needs to be cut back.

11.7.4 After completion of pressing operations, the contractor shall clean the wire and fittings of excess grease and compound. All burrs and die flash marks must be removed with emery cloth.

11.7.5 U-bolts on suspension clamps and strain deadend clamps must be evenly torqued to the manufacturer's recommended values. Keeper plates must be in place and properly seated. Conductor strands within the area of the fitting must be clean. The recommended cleaning method is to use a steel brush, cotton rags, and solvents.

11.7.6 Wires must be clipped into suspension clamps within not less than 12 hours and not more than 72 hours after the start of each individual wire pulling operation. Cables must be lifted from the sheaves using standard suspension clamps or plate hooks 8 inches or larger to provide adequate support for the cables without damaging individual strands or kinking the wire.

11.7.7 With pin-type insulators, the conductors must be tied in the top groove of the insulator on tangent poles and on the side of the insulator away from the strain at angles. Factory formed ties must be installed in accordance with the manufacturer's recommendations.

11.7.8 Following completion of clipping or deadending wire, contractor shall install dampers according to manufacturers and/or engineers drawings and instructions.

11.8 Jumper

11.8.1 Jumpers must be installed as shown on the drawings. Compression jumper terminals must be used with compression deadends and compression jumper connectors must be used with strain clamps. The cost of installation of these items must be included with the bid units for installing conductors. All jumpers must be installed in accordance with the manufacturer's recommendations.

11.8.2 Jumper wire loops must be of sufficient length to present a smooth, uniformly curving appearance, and which do not put the jumper string of insulators in compression. Excess length of conductor from the wire stringing operation may be used to make up the jumper loops.

11.9 Temporary Grounds

11.9.1 During the wire work, the contractor shall take all necessary steps to ensure proper temporary grounding of the structures, cables, and equipment. All applicable Federal, State, and local safety regulations must be strictly followed.

11.9.2 A record of all temporary conductor grounds must be kept to ensure that they are all removed and the line can be safely energized at the end of the construction period.

11.10 Reels and Excess Conductor

11.10.1 When wire is furnished by the owner, the contractor shall be responsible for salvaging the wire reels and all excess conductor and overhead ground wire. All such wire must be inventoried, placed on reels, and returned to the owner or disposed of as directed by the engineer.

11.10.2 Returnable reels must be shipped back to the wire fabricators in accordance with the engineer's instruction. Nonreturnable wood reels must be disposed of in a manner meeting the approval of the engineer.

11.10.3 All costs associated with the receiving, handling, shipping, or disposal of excess wire and reels must be in the labor costs for installation of wire units.

11.11 Special Conditions (to be completed by the engineer):

Blank Page

12. DRAWINGS

12.1 Index of Drawings: The following drawings are part of the technical specification (engineer to complete):

Blank Page

PART 2

DRAWINGS

Blank Page

Selected SI-Metric Conversions

AREA

To Convert From	To	Multiply by	
circular mil (cmil)	square meter (m^2)	5.067075	E-10
square centimeter (cm^2)	square meter (m^2)	*1.000	E-04
square foot (ft^2)	square meter (m^2)	*9.290304	E-02
square inch (in^2)	square meter (m^2)	*6.451600	E-04
square kilometer (km^2)	square meter (m^2)	*1.000	E+06
square mile (mi^2)	square meter (m^2)	2.589988	E+06

FORCE

To Convert From	To	Multiply by	
kilogram force (kgf)	newton (N)	*9.806650	
Kip	newton (N)	4.448222	E+01
pound force (1bf)	newton (N)	4.448222	

FORCE PER LENGTH

To Convert From	To	Multiply by	
kilogram force (kgf) meter (kgf/m)	newton per meter (N/m)	*9.806650	
pound per foot (1b/ft)	newton per meter (N/m)	1.459390	E+01

DENSITY

To Convert From	To	Multiply by	
pound per cubic inch ($1b/in^3$)	kilogram per cubic meter (kg/m^3)	2.76790	E+04
pound per cubic foot ($1b/ft^3$)	kilogram per cubic meter (kg/m^3)	1.6014	E+01

LENGTH

To Convert From	To	Multiply by	
foot (ft)	meter (m)	3.048	E-01
inch (in)	meter (m)	*2.540	E-02
kilometer (km)	meter (m)	*1.000	E+02
mile (mi)	meter (m)	*1.609344	E+03

LINEAR DENSITY

To Convert From	To	Multiply by	
pound per foot (1b/ft)	kilogram per meter (kg/m)	1.488164	
pound per inch (1b/in)	kilogram per meter (kg/m)	1.785797	E+01

LOAD CONCENTRATION

To Convert From	To	Multiply by	
pound per square inch ($1b/in^3$)	kilogram per square meter (kg/m^3)	7.030696	E+02
pound per square foot ($1b/ft^3$)	kilogram per square meter (kg/m^3)	4.882428	
ton per square foot (ton/ft^3)	kilogram per square meter (kg/m^3)	9.071847	E+02

* Exact Conversion.

MASS

To Convert From	To	Multiply by	
pound (avoirdupois) 1b)	kilogram (kg)	4.535924	E-01

PRESSURE

To Convert From	To	Multiply by	
kip per square inch (kip/in^2)	pascal (Pa)	6.894757	E+06
kip per square foot (kip/ft^2)	pascal (Pa)	4.788026	E+04
newton per square meter (N/m^2)	pascal (Pa)	*1.000	
pound per square foot ($1b/in^2$)	pascal (Pa)	4.788026	E+01
pound per square inch ($1b/in^2$)	pascal (Pa)	6.894757	E+03

BENDING MOMENT

To Convert From	To	Multiply by	
kilogram force meter (kgf-m)	newton meter (N-m)	*9.806650	
kip-foot (kip-ft)	newton meter (N-m)	1.355818	E+02
pound per foot (1b/ft)	newton meter (N-m)	1.459390	E+01

VELOCITY

To Convert From	To	Multiply by	
foot per second (ft/s)	meter per second (m/s)	*3.048	E-01
kilometer per hour (km/h)	meter per second (m/s)	2.777778	E-01
mile per hour (mi/h)	meter per second (m/s)	4.470400	E-01
meter per hour (m/h)	meter per second (m/s)	2.777778	E-04

VOLUME

To Convert From	To	Multiply by	
cubic foot (ft^3)	cubic meter (m^3)	2.831685	E-02
cubic inch (in^3)	cubic meter (m^3)	1.638706	E-05
cubic kilometer (km^3)	cubic meter (m^3)	*1.000	E+09
cubic millimeter (mm^3)	cubic meter (m^3)	*1.000	E-09

TEMPERATURE

	°C	°F
X°C =	---	$\frac{9}{5}X + 32$
X°F =	$\frac{5}{9}(X - 32)$	---

* Exact Conversion.