



SPECIFICATION NO. L-500 kV

CONSTRUCTION  
OF  
500 kV TRANSMISSION LINE

ELECTRICITY GENERATING AUTHORITY OF THAILAND

TRANSMISSION SYSTEM ENGINEERING DIVISION

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## **STANDARDS AND REFERENCES**

All equipment, materials, fabrication and tests furnished under these specifications shall conform to the latest applicable standards, manuals and specifications contained in the following list or to equivalent applicable standards, manuals and specifications established and approved in the country of manufacture, and approved as equal by EGAT.

ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute, Inc.
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWS	American Welding Society
EEI	Edison Electric Institute
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFI	Industrial Fasteners Institute
ISO	International Standards Organization
NEMA	National Electric Manufacturers Association
TISI	Thai Industrial Standard Institute

Any details not specifically covered by these standards and specifications shall be subject to approval by EGAT. In the event of contradictory requirements between the standards and these specification requirements, the terms of the specifications shall apply.

Copies of the applicable standards and specifications may be purchased from the followings :

American Concrete Institute (ACI)  
P.O. Box 4745, Redford Station  
Detroit, Michigan 48219  
U.S.A.



American Institute of Steel Construction (AISC)  
400 North Michigan Avenue  
Chicago, Illinois, 60611  
U.S.A.

American National Standards Institute, Inc. (ANSI)  
1430 Broadway, New York  
New York 10018  
U.S.A.

American Society of Civil Engineers (ASCE)  
345 East 47<sup>th</sup> Street  
New York, N.Y. 10017  
U.S.A.

American Society of Mechanical Engineers (ASME)  
345 East 47<sup>th</sup> Street  
New York, N.Y. 10017  
U.S.A.

American Society for Testing and Materials (ASTM)  
1916 Race Street  
Philadelphia, Pennsylvania 19103  
U.S.A.

American Welding Society (AWS)  
33 West 39<sup>th</sup> Street  
New York, N.Y. 10018  
U.S.A.

Aluminum Association  
750 Third Avenue  
New York, N.Y. 10017  
U.S.A.

Edison Electric Institute (EEI)  
420 Lexington Avenue  
New York, N.Y. 10017  
U.S.A.

International Electrotechnical Commission (IEC)  
1, rue de Varembe  
Geneva  
Switzerland

Institute of Electrical and Electronics Engineers (IEEE)  
345 East 47<sup>th</sup> Street  
New York, N.Y. 10017  
U.S.A.

Industrial Fasteners Institute (IFI)  
1505 East Ohio Building  
1717 East 9<sup>th</sup> Street  
Cleveland, Ohio 44114  
U.S.A.

International Standard Organization (ISO)  
CASE Postale 56  
CH-1211 Geneva 20  
Switzerland

National Electric Manufacturers Association (NEMA)  
115 East 44<sup>th</sup> Street  
New York, N.Y. 10017  
U.S.A.

Thai Industrial Standard Institute (TISI)  
Ministry of Industry  
Bangkok 4  
Thailand

In some places, reference is made to certain manufacturers' products, name-brand materials and items identified by Registered Trade Marks. This has been done to define and establish standard of quality and/or performance, and is not intended to restrict the procurement of materials or equipment to a particular manufacturer.

Reference to standards and specifications, or to equipment and materials of a particular manufacture shall be considered as followed by "or equivalent". The Contractor may propose equivalent standards, specifications, materials of equipment which shall be equal in every respect to that specified. If the Contractor for any reason proposes equivalents to, or deviations from, the above standards, the Contractor shall state the exact nature of the change, the reason for making the change and shall submit complete specifications of the materials, as well as copies of pertinent standards, for the approval of EGAT. EGAT's decision in the matter of quality will be final.

## PART I - MATERIALS

## Section A

### 500 kV LATTICE STEEL TOWERS

#### A-1. General Instructions

This specification covers the design, shop detailing, and fabrication of 500 kV lattice steel transmission towers. EGAT may choose:

- a. to furnish design drawings and to require the Contractor to provide shop detailing and fabrication services; in such cases the provisions of Article A-3, Designs do not apply (Except as otherwise indicated.) but all other provisions do apply.
- b. to furnish only loading trees and critical electrical clearance dimensions and to require design, shop detailing and fabrication by the Contractor; in such cases all of the requirements of this specification apply.
- c. to furnish existing shop detail drawings and to require only materials supply and fabrication services in order to promote uniformity of appearance and /or standardization of structure types; in such cases the provisions of Article A-3, Design and A-4, Detailing do not apply but all other provisions do apply.

The Contractor shall assume full responsibility for the adequacy and accuracy of that portion of the work that he is required to provide.

All materials, designs, details, fabrications and tests shall comply with the requirements described hereafter and on the drawings.

All designs and details shall be subject to approval by EGAT. EGAT shall have the right to require the Contractor, without additional cost to EGAT, to make any changes in designs and details necessary to make the construction conform to the Contract Documents.

All materials shall be brand new. Any steel member with the trace of hole filling shall not be used.

No omission or ambiguity on the drawings or in these specifications will relieve the Contractor from the responsibility of furnishing first class materials and workmanship. Should any inaccuracy be found, any further work done before these discrepancies are corrected, will be at the Contractor's risk.

## A-2. Materials

Materials shall be as follows:

- a. Rolled Shapes and Plates. All materials shall be hot-rolled of structural and/or high-strength structural steel.
  - (1) Structural Steel. Structural steel shall conform to ASTM A36.
  - (2) High-Strength Structural Steel. High-strength structural steel shall conform to ASTM A441 or ASTM A572 grade 50. All high strength shapes and plates shall have a guaranteed minimum yield strength of 50 ksi (3,515 kg/sqcm).
  - (3) Steel Grade Substitution. Steel rolled for and released as structural grade shall not be used as a substitute for high strength grade regardless of test values.

Steel rolled for high-strength grade may be used for structural grade if it meets the required,specification.
- b. Connection Bolts and Nuts. All connection bolts and nuts shall conform to ASTM A394.
- c. Cable Attachment Devices. All cable attachment devices shall conform to ASTM A36 or ASTM A441 or ASTM A572 grade 50.
- d. Locking Devices. Lock washers shall be carbon steel conforming to ASA B27.1.

Locknuts shall be Palnuts or M-F nuts or approved equal, and shall conform to appropriate International Standards Organization (ISO) and Industrial Fasteners Institute (IFI) for Lock Nut Specifications.
- e. Anchor Rods. Anchor rods shall conform to ASTM A449. Nuts for anchor rods shall be ASTM A563, grade C.
- f. Step Bolts. Step bolts shall conform to ASTM A307.
- g. Ladders. Ladder steel shall conform to ASTM A36.
- h. Tower Signs. Tower signs, consisting of aerial patrol signs, phasing signs and danger signs shall be made of mild steel (See Article A-4.g). The thickness shall not be less than 2 mm.

### A-3. Designs

Designs shall be as follows:

- a. Tower Outline. The outlines of the towers shall, in general, conform to those indicated on the drawings, and shall be such as to provide the required minimum clearance between conductors, and between conductors and tower steel, indicated in the clearance diagrams.

Towers shall be designed for leg extensions of heights indicated on the drawings. Where tower body extensions are called for, the leg extensions shall be designed to be used interchangeably with either the basic tower body or body extensions. The design of tower members shall take in to consideration the use of any combination of leg extension heights up to a maximum leg extension height differential of six meters.

The included angle between any two connecting stressed members shall not be less than 15 degrees. Redundant members shall be so oriented with respect to the main members which they brace to provide sufficient restraint against buckling and shall be capable of supporting an axial tensile or compressive load of at least 2.5% of the maximum Computed Compressive load in the main member, applied perpendicular to the axis of the main member.

- b. Design Methods. Designs shall be in accordance with the ASCE Manual 52, "Guide for Design of Steel Transmission Towers.", Second Edition except as noted in these specifications.

The Contractor is required to use a three-dimensional indeterminate stiffness method of analysis for tower design. Any computer program to be employed, shall be prepared or approved by a recognized institute.

EGAT will use the ICES-STRUDL II or Bonneville Power Administration Tower Design System Computer Program for checking the tower designs of the Contractor.

If any other method of analysis is employed by the Contractor, he shall agree to make any change to meet the requirements of EGAT's three-dimensional analysis specified above without additional cost to EGAT.

- c. Loads. The loads used in the design of the tower shall be as specified in the loading diagrams.

- d. Unit Stresses. Unit stresses used in design shall be as follows:

<u>Stresses</u>	<u>Ultimate Stresses Allowed in Design</u>
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Members and Gussets:

Buckling	See Drawing No. TP-131
Tension on Net Section	1.00 Fy
Bearing on Bolts	1.80 Fy, but not to exceed 1.00 Fu.

Bolts:

Shear	0.60 Fu
Bearing	1.00 Fu

Remarks : Fy = Yield point.

Fu = Ultimate tensile stress.

In computing the net section for tension members, the diameter of the bolt hole shall be taken as 1.5 mm greater than the nominal diameter of the bolt. The determination of net section area shall be as specified in the ASCE, Guide for Design for Steel Transmission Towers.

- e. Limit of Effective Slenderness Ratio. The effective slenderness ratios of members shall not exceed the following limits:

Main leg members and main compression members in crossarms	120
Other members having computed compressive stresses	200
Secondary members without computed compressive stresses	250
Tension only members	375

Built-up members composed of two or more rolled shapes shall be connected with stitch bolts such that the slenderness ratio of either shape, between bolts, does not exceed the governing slenderness ratio of the built-up member as a whole.

- f. Minimum Thickness and Size of Steel Members. Minimum thickness (t) and sizes of steel members of towers shall be as follows:

Legs and main compression members in crossarms, mm	8
All members having computed stresses, mm	5
Secondary members (redundants) without computed stresses, mm	5
Gusset plates, mm	6
Minimum flange width of angles for use with 16 mm bolts only, mm	45
Minimum flange width of angles for use with 20 mm bolts only, mm	60

Furthermore, the minimum flange width of the connected leg of the angle section shall be such that the bolt head or nut does not bear on the fillet.

In order to facilitate transportation and handling, the length of any structural member should not exceed 8 meters.

- g. Connections.

- (1) Bolts. All connections shall be bolted. Bolts shall bear on the shank to the extent that not more than one full thread shall be in bearing. Rivets shall not be used. Welding may be used subject to the approval of EGAT.

For structural connections, only one bolt size per tower is permitted. The minimum bolt diameter shall be 16mm and the minimum number of bolts at each connection of a stressed member shall be two, except when the computed stress is less than one-half the capacity of a single bolt, in which case, a single bolt connection will be acceptable.

- (2) Connections and Splices. The number of splices shall be kept to a minimum. Connections shall develop the force due to the design load but not less than 70 % of the effective strength of the member based on the kind of stress that governs the selection of the member.



h. Design Drawings and Calculation. The design drawings shall show the following data and information:

- (1) Scaled line diagram of the tower including all redundant bracing members and their sizes completely dimensioned and in compliance with all clearance requirements.
- (2) All loadings and their manners of application including the determination of wind load on tower and ladder, - if any. Wind load on towers shall be applied at each panel point along the height of the towers.
- (3) Tables showing :
  - (a) Tensile or compressive stress in each member for each loading case and the maximum (critical) tensile and compressive stresses with associated loading case.
  - (b) The effective slenderness ratios, net tensile areas, calculated capacities and ratio of calculated capacities to maximum computed stresses for each member and connection.
  - (c) Size and type of steel for each member and number of bolts required for its connection.
  - (d) The calculated weight of the complete galvanized tower.
  - (e) The vertical compression and uplift reactions and corresponding horizontal shears at each leg of all towers for all loading cases.

i. Tower Erection and Maintenance Loading. Horizontal members, and members within  $15^{\circ}$  of horizontal, (with the exception of horizontal diaphragms in the tower body) shall be designed to support the weight of one man with construction tools at midspan without permanent deformation. This weight shall be taken as 150 kilograms (ultimate). This bending load need not be combined with member axial loads resulting from the basic tower loading conditions.

#### A-4. Detailing

Detailing shall be as follows:

- a. General. Tower dimensions, framing, member sizes and length, number, size and length of bolts, thickness of each filler, and other necessary details to fabricate each piece shall be shown on the approved detail drawings. Once approved by EGAT, no detailing changes shall be made without the written approval of EGAT.

All diagonals and struts shall be in one piece where practicable. All double diagonal web system members shall be connected at their point of intersection by at least one bolt.

Lowest bolt hole in stub for connection of the main diagonal member shall be at 50 mm above the top of concrete.

- b. Joints. All joints shall be detailed so that eccentricities are kept to a minimum.

Contact surfaces between members at joints shall be completely filled by fillers of proper thickness. Bevelled washers shall be furnished, where required, for bolted connections where the slopes of the mating surfaces of the connected members is substantially different.

Gusset plates, where used, are to be designed by the Contractor preparing the shop details, and shall meet the requirements of Article A-3.

- c. Bolt Spacing. Minimum bolt spacing and edge distance shall be as follows:

Nominal Bolt <u>Diameter</u>	Bolt Spacing		Minimum Edge Distance	
	<u>Minimum</u>	<u>Maximum</u>	<u>Rolled Edge</u>	<u>Sheared Edge</u>
mm	mm	mm	mm	mm
16	45	160	22	28
20	55	200	25	32

- d. Step Bolts. Step bolts shall be 16 mm diameter and shall have round or hexagonal head. Each step bolt shall be provided with two hexagonal nuts, two plain washers and one locking device. The minimum bolt length and length of unthreaded portion shall be 180 and 125 mm respectively. Step bolts shall not be used as connection bolts.

The step bolts shall be spaced alternatively on the inner gauge line on each face of the angle about 40 cm on centers unless otherwise specified. They shall be furnished for one leg of each tower from a point approximately 2.5 m above the top of concrete to the base elevation of the tower and (1) On single circuit towers: from the base elevation to the peak of the tower; (2) On double-circuit towers: from the base elevation to a point approximately 1.2 m above the bottom of the ladder (See Article A-4 f. Ladders).

- e. Cable Attachment Devices. Cable attachment devices shall be suitably furnished to suspend or terminate insulator strings or ground wire assemblies. The devices shall be capable of withstanding all specified cable loads with corresponding tower overload factors.
- f. Ladders. Ladders are required on double circuit towers. Ladders shall be fastened securely to the tower with sufficient intermediate supports to furnish a safe and rigid structure for climbing. Ladders shall be centered on a face of the tower which is perpendicular to the line (transverse face) and shall extend from the base elevation up to the peak of the tower. Rungs shall be spaced approximately 35 cm on centers.
- g. Tower Signs. The Contractor shall furnish all materials for tower signs as shown on Dwg. No. TP-150, including all bolts, nuts, washers, and supporting structures if required, for attaching tower signs to the towers as specified in the structure list.

The colors of figure and background shall be as described on Dwg. No. TP-150 and shall be weather-proof, baked enamel finish paint, vitreous or stove enamel.

The Contractor is required to make holes in the tower members for attaching tower signs at the locations described hereunder.

- (1) Aerial Patrol Signs. Aerial patrol signs shall be attached to upper member of the top crossarm or bridge.
- (2) Phasing Signs. Phasing signs shall be attached to upper member of each conductor crossarm or bridge.
- (3) Danger Signs. Danger signs shall be attached to bracing members at a level about one meter above top of concrete.
- (4) Circuit Name Signs. Circuit name signs shall be attached to upper member of the top crossarm or bridge.

- h. Detail Drawings. Detail drawings shall be complete with sizes and detail dimensions of all tower members. Drawings shall include all body and leg extensions, whether or not they are to be actually used for construction. At each joint, there shall be the number, size and length of bolts, number and size of fillers and detail dimensions of gusset plate, if any.

A proper cross-index shall be furnished, correlating the tower part numbers with the tower type and component and the drawing number.

- i. Bill of Material. Bill of material shall give the size, length and galvanized weight of each member and the total weights of body, body extension, leg extension and stub. It shall also include the number of bolts, nuts and washers per structure.

#### A-5. Fabrication

Fabrication of material shall be in accordance with the latest revision of "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings" published by the American Institute of Steel Construction (AISC). Fabrication shall not commence until approval of drawings and completion of successful tower tests unless otherwise directed by EGAT.

- a. Workmanship. Workmanship shall be first class throughout. All pieces must be straight, true to detail drawings and free from lamination flaws and other defects. All clipping, back-cuts, grindings, bends, holes and etc. must be true to detail drawings and free of burrs.

All identical pieces bearing the same erection number must be exactly interchangeable with each other and interchangeable in their relative position in all towers or structures of which they form a part.

Threads of bolts and nuts shall be cleanly roiled or cut and the face and head of nut shall be truly at right angle to the axis of the bolt.

- b. Bolts. Bolts shall be full-size in the shanks. The shanks shall be round and free of projected fins. The bolt heads shall be hexagonal, full proportions on all sides, properly centered on the shank, and have a bearing surface which is perpendicular to the axis of the bolt, of full area, free of burrs and reasonably smooth.
- c. Nuts and Locking Devices. Nuts shall be hexagonal and of dimensions adequate to develop full strength of the bolts. The bearing face of each nut shall be perpendicular to the axis of the threads, free of burrs and projections, and shall have chamfered corners.

All nuts shall be securely locked by the use of locknuts or spring lock washers or by other means approved by EGAT. The nuts and locknuts shall run freely (hand fit) for the entire length of the galvanized bolts.

The dimension of the spring lock washers shall meet the following requirements:

Nominal <u>Washer Size</u>	Basic <u>Inside Diameter</u>	Maximum Average	
mm	mm	<u>Outside Diameter</u>	<u>Thickness</u>
16	16.2	27.4	3.5
20	20.2	33.6	4.0

- d. Shearing and Cutting. Materials may be sheared to length, but the ends, unless otherwise noted, must be square with the flanges and faces and free of burrs so that difficulty of assembly caused by interference with other members at the time of assembling the steel tower shall not occur.

The use of a burning torch is permissible for cutting members providing all irregular edges are trimmed smooth before galvanizing. Stresses shall not be transmitted into the metal through a burned surface. The material adjacent to a burned surface for a distance equal to the thickness of the material shall not be considered a part of the net section for tension members. The use of a burning torch for cutting bolt holes will not be allowed.

- e. Punching and Drilling. Holes are to be punched with racks and jigs employed to ensure accuracy throughout. The punches and dies for this work must be maintained sufficiently sharp so as to produce clean round holes normal to the plane of material, free of burrs, folds, depressed or upset edges.

Special care is to be exercised to ensure exact spacing of holes and their distance from back of angle and to end of piece. Any member having holes or cut more than 0.8 mm from correct position will be subject to rejection. No welding, filling or plugging will be permitted unless approved by EGAT.

Holes may be punched up to a thickness equal to the hole diameter minus 1.6 mm for structural steel and the hole diameter minus 4.7 mm for high-strength structural steel, but, in mild steel over 19 mm thick and in high-strength structural steel over 16 mm thick holes must be drilled or subpunched and reamed.

Holes in bent members which may be affected by the bending operation shall be laid out and punched or drilled after bending. Holes which are elongated or otherwise distorted by bending will not be accepted.

The diameter of bolt holes shall not exceed the bolt diameter plus 1.5 mm except holes for embedded anchor rods, shall be approximately 6 to 7 mm larger than the bolt diameter.

- f. Bending. All bending of structural steel shall be done in accordance with AISC. Methods for bending utilizing heat shall be approved by EGAT.
- g. Welding. All welding shall be performed in accordance with "The Structural Welding Code", AWS D1.1, of the American Welding Society. A shielded arc-welding process shall be used. All welds shall be made in such a manner as to minimize residual shrinkage stresses. When extremely thick plates are welded (such as baseplates), pre-heating may be necessary to avoid formation of shrinkage cracks. If not previously qualified, the welding process and the welding operators employed in performing the work covered by the Contract Documents shall be qualified in accordance with the American Welding Society Standard Qualification Procedure. No field welding will be allowed.
- h. Markings. All individual pieces shall be marked with the correct designations shown on the approved detail drawings. Markings shall be done by stamping the marks into the metal before galvanizing, and details shall be clearly legible after galvanizing. The number and letter shall be a minimum of 12 mm in height. After galvanizing, marks shall be circled or bracketed with black paint. In designating members on drawings, the Contractor shall endeavor to use as few designations as possible, and each member of identical size and detail shall have the same designation, regardless of its position in the structure.

The member numbers shall be successively grouped on individual detail drawings. The groups of member numbers shall be indicated on the drawings.

- i. Cleaning and Galvanizing.
  - (1) Cleaning. After fabrication has been completed and accepted, all materials shall be clean of rust, loose scale, dirt, oil, grease and other foreign substances.
  - (2) Galvanizing. Unless otherwise indicated on the drawings, all materials shall be hot-dip galvanized after fabrication and cleaning.

Galvanizing for structural steel products shall meet the requirements of ASTM A123. In addition, welded assemblies, which may be particularly susceptible to cracking and/or distortion, shall be galvanized and tested in accordance with ASTM A143. All holes in material shall be free of excess spelter after galvanizing.

Galvanizing for bolts, step bolts, U-bolts, shackles, nuts locknuts, fillers, washers, spring washers and similar hardware shall meet the requirements of ASTM A 153 as follows:

Class of Material	Minimum Weight of Zinc Coating (g/m <sup>2</sup> ) of Surface	
	Average of Specimens Tested	Any Individual Specimen
Class C - Bolts (over 9.52 mm in diameter) and similar articles. Washers 4.76 to 6.35 mm thick	381	305
Class D - Washers under 4.76 mm thick	305	259

Excess spelter shall be removed by appropriate means acceptable to EGAT.

Nuts and locknuts shall be galvanized after threading. Retapping of nuts and locknuts after galvanizing, if required to insure free running of nut on bolt, shall be such that sufficient protective zinc or tapping oil will remain on threads in nuts and locknuts so as to prevent corrosion of the threads prior to tower erection.

Galvanized steel members shall be dipped into solution of dichromate after galvanizing for prevention of white rust during transportation and storage.

- (3) Uniformity of Coating. The uniformity of coating test shall be made in accordance with ASTM A239. The minimum repetition times for one minute dip in uniformity test shall be as follows:

Steel shapes and plates.....6

Bolts, nuts and similar hardware.....4

- (4) Minor Repair. Materials on which galvanizing has been damaged shall be redipped unless, in the opinion of EGAT, the damage is local and can be repaired by applying a coating of galvanizing repair paint or spraying.

Where such repair is authorized, the damaged area shall be cleaned by wiping with clean rags saturated with mineral spirits of xylene, followed by wire brushing. After wire brushing, the area shall be recleaned with solvent to remove residue, and shall be given one brush coat of galvanizing repair paint. The percentage of pure zinc by weight in dry film of galvanizing repair paint shall not be less than 85. Thickness shall be in accordance with manufacturers recommendations and as approved by EGAT.

- j. Shop Assembly. One tower of each type and height, including every combination of leg extensions, shall be assembled in the shop to such an extent as to ensure proper field erection. Towers that have been previously assembled for load testing will not be required to be reassembled in the shop, except as necessary to prove the satisfactory fit-up of every combination of body and leg extension. Reaming of unfair holes will not be permitted. No drifting will be allowed in assembling.

If any errors on the drawings or fabrication are discovered all incorrect drawings shall be revised and the corrected part refabricated and reassembled. All revised drawings shall be resubmitted to EGAT for approval.

- k. Quality Assurance Testing. The Contractor shall furnish with his bid a detailed Quality Assurance Procedure, and shall be responsible for performing all tests and inspections required during the production of the towers.

The Contractor shall identify all materials, including bolts and nuts, used on EGAT project on the appropriate mill test reports and/or material certifications, and shall furnish the mill test reports and/or certifications to EGAT.

The Contractor shall make dimensional checks of all structural materials for conformity to ASTM A6.



The Contractor shall make a visual inspection of all materials before and after galvanizing. Embrittlement tests shall be made in accordance with ASTM A143. Uniformity of coating tests shall be made in accordance with ASTM A239. Thickness of coating tests shall be made in accordance with ASTM A90. Size of test "lot" and number of tests shall be in accordance with the appropriate ASTM standards.

All full penetration welds (such as between stub angle and baseplate) shall be tested using either ultrasonic or radiographic techniques; testing shall cover the entire length of weld. The ultrasonic procedure shall be capable of demonstrating weld quality as required by AWS D1.1. Doubtful indications from ultrasonic inspections shall be checked by using the radiographic rejection criteria as set forth in AWS D1.1.

All baseplate to stub angle welds shall be ultrasonically inspected both before and after galvanizing.

All other welds shall be checked for visible defects and cracks as determined by magnetic particle or dye penetrant inspection.

In addition to above inspection and tests, the Contractor is required to perform the following tests at his own expense on samples selected at random by and at the presentation of EGAT or EGAT's representatives.

- a. Physical tests on samples of structural steel sections. The tests to be carried out shall include yield strength, ultimate tensile strength and percentage elongation. One set of tests shall be carried out for each 250 tons of steel passing through the fabrication plant.
- b. Galvanizing tests on samples of structural steel sections. The tests to be carried out shall include determination of weight of zinc coating, adherence of zinc coating and uniformity of zinc coating. One set of tests shall be carried out for each 250 tons of steel passing through the fabricating plant.
- c. Mechanical property and galvanizing tests on samples of bolts and nuts shall be carried out in accordance with the requirements of ASTM A394.

#### A-6. Tower Load Test

Full scale load tests shall be performed on a prototype of each of the towers as specified. Load tests shall be made at the manufacturer's plant or at such location as may be mutually agreed on for each type of tower to be tested.

The Contractor shall give EGAT not less than 30 days advance notice, in writing or by wire, of the date when test towers will be ready for tests. EGAT reserves the right to eliminate the requirement for performing any or all tests. Should EGAT exercise this right, the applicable unit prices for performing the test will be deducted from the total contract price. The Contractor will not be entitled to any additional compensation by reason of such elimination.

Each test shall be performed in accordance with the following requirements:

- a. Tower. The tower shall be fabricated from approved detail drawings in a manner as close to final production procedures as is practicable. The tower shall be complete in every detail.
- b. Erection. The tower shall be erected on a rigid foundation using the specified tower bolts and nuts which shall be tightened to the specified torque.
- c. Rigging. The Contractor shall submit for EGAT's approval, diagrams showing the proposed methods of applying loads and measuring deflections.
- d. Loading. All test loads corresponding to conductor and overhead ground wire loading shall be applied directly to the regular attachment devices provided for these loads. Test loads equivalent to wind loads on the tower and ladder, if any, shall be applied where convenient and in such a manner that the summations of applied load and overturning moment are as close as possible to the actual behavior as designed. An extra compression member is not allowed for use in applying wind loads on tower. To ensure application of full-test loads to the tower, friction losses in rigging shall be computed and shall be added to the rigging loads.
- e. Load Programs. The Contractor shall program the tests to demonstrate that the towers will carry all design loads and conditions specified in the loading diagrams. Test wind loads on the tower shall be the same as applied in design calculation.
- f. Deflection Measurements. Deflections shall be recorded at the beginning and end of each loading period to provide longitudinal and transverse deflections and torsional deflection at all cable attachment points and at least one intermediate point of tower body.

- g. Design Load Tests. Loads for any loading condition shall be applied in increments of 50, 75, 90, 95 and 100 percent of the full design loads. Each load increment shall be maintained for not less than two minutes for each assumption except that under maximum (full) design loads, loads shall be maintained for a period of five minutes. During the period in which the increment of loading is being held, there shall be no slacking off of the loads. Should it become necessary to adjust the loading, the two or five minute period shall start after the loading is stabilized and constant. All test loads shall be removed completely before the loads for testing under a different loading condition are applied.
- h. Destruction Tests. After the successful completion of the load tests, the tower shall be further tested to destruction by increasing the transverse loads, under the loading case specified by EGAT, in increments not to exceed five per cent of full design transverse loads. The vertical and/or longitudinal load(s) shall be kept constant at their full design values. Each load increment shall be held at least five minutes while deflections are being recorded.
- i. Modification of Tower Components. Any conspicuous yielding or permanent deformation or any failure of any part of the tower under any of the tests specified in Item g shall be considered a defect. If a defect develops, the Contractor and/or EGAT representative shall modify the design of the tower and submit it to EGAT for approval. The modified tower shall then be retested.

The expenses associated with redesign and retest will be borne by the Contractor if made necessary by a defect in the Contractor's work; the expenses associated with redesign and retest will be borne by EGAT. if made necessary by a defect in the design or drawings furnished by EGAT.

- J. Materials Tests. Steel materials used for tested towers shall be subject to tension or bend tests in accordance with ASTM A370. Tests shall be performed by the Contractor at no additional cost to EGAT. The test specimens shall be selected as follows:
- (1) Two sets selected from the failed members of each tested tower.
  - (2) Two sets randomly selected from undisturbed members of each tested tower.
- k. Reports. The Contractor shall furnish four certified copies of full reports of all tower and material tests, the calibration of the dynamometers or gauges, including clear photographs of the test set-ups and nature of all failures, diagrams showing deflection of towers at each interval of loadings, detail diagrams showing the manner in which all the loads were applied and deflection records.

## Section B

### Conductor

#### B-1. General

This Specification covers the detail requirements for the design, fabrication, test and shipping of aluminum conductor, concentric-lay-stranded, coated steel-reinforced for use as subconductors of a four bundled conductor system.

It is intended that the conductor covered by this Specification shall be suitable for both tension and slack stringing. Any conductor which, when properly threaded, exhibits "bird caging" or popped strands during stringing may be rejected.

#### B-2. Standards

The materials covered under this Specification shall conform to the following standards and applicable standards referenced therein, except as specified herein.

ASTM B230 Specification for Aluminum Wire, EC-H19 for Electrical Purposes.

ASTM B232 Specification for Aluminum Conductors, Concentric-Lay-Stranded Coated Steel-Reinforced.

ASTM B498 Specification for Zinc-Coated (Galvanized) Steel Core Wire for Aluminum Conductors, Steel Reinforced.

ASTM B354 Standard Definitions of Terms Relating to Uninsulated Metallic Electrical Conductors.

NEMA Pub. 107 Methods of Measurement of Radio Influence Voltage (RIV)

IEEE Std. 524-1980 Guide to the Installation of Overhead Transmission Line Conductors.

#### B-3. Conductor Characteristics

The conductor to be furnished shall be aluminum conductor, concentric lay - stranded, reinforced with Class A zinc coated steel wire and shall have characteristics conforming to the following requirements.

(REV. 1)

Description		795 kcmil ACSR/GA	1272 MCM ACSR/GA
Complete Conductor :			
Code name		CONDOR	-
Nominal aluminum area	cmil	795,000	1,272,000
Outside diameter	mm	27.73	33.91
Stranding			
Aluminum (number & diameter in mm)		54 3.08	42 4.42
Steel (number & diameter in mm)		7 3.08	7 2.46
Minimum breaking strength	kg	12,800	14,050
Approximate weight	kg/m	1.523	2.040
Nominal length; returnable metal reel	m	3500	2,400
non-returnable wooden reel	m	1750	1,200
Component Aluminum Wire :			
Number		54	42
Diameter	mm	3.08	4.42
Minimum elongation in 254 mm (average)	%	1.8	2.0
Minimum tensile strength (average)	kg/mm <sup>2</sup>	17.58	16.87
Component Steel Wire :			
Number		7	7
Diameter	mm	3.08	2.46
Minimum elongation in 254 mm (average)	%	4.0	3.5
Minimum stress at 1 per cent extension	kg/mm <sup>2</sup>	127	130
Minimum tensile strength	kg/mm <sup>2</sup>	144	144
Minimum weight of zinc coating	g/m <sup>2</sup>	259	229

(REV.1)

#### B-4. Workmanship and Finish

- a. Forming. The make-up and lay of the wire shall be such as to produce a conductor essentially free from a tendency to untwist or spring apart when cut. The steel wires shall be so formed that, when the conductor is cut and the aluminum wires are stripped away from the core as required for splicing, the steel wires can be readily regrouped and easily held in place with one hand to allow a splicing sleeve to be slipped over the steel core wires at the cut end of the conductor. Similarly, the aluminum wires shall be so formed that the aluminum wires can be readily regrouped and easily held in place with one hand to allow the splicing sleeve to be slipped over the aluminum wires at the cut end of the conductor.

Post-forming of the steel core is permitted so long as such post-forming does not deform the individual steel wires and does not in any way scratch, scrape, remove or otherwise damage the zinc coating of the steel core wires, individually or collectively.

- b. Finishing. The finished conductor shall embody the highest quality of material, workmanship and design consistent with modern practice in the manufacture of transmission line conductors. The external form and surface shall be uniformly cylindrical upon completion of manufacture and shall remain so when erected in place on the line.

The permissible reduction from the unstressed circumference to the circumference when the conductor is subjected to a tension equal to 30 percent of its specified rated ultimate strength shall not be greater than two (2) percent.

The surface of the conductor shall be free from points, sharp edges, abrasions, or other departures from smoothness or uniformity of contour that would tend to increase radio interference and corona loss. When the conductor is subjected to tensions up to 50 percent of its rated ultimate strength, the conductor surface shall not depart from its general cylindrical form, nor shall any of the component parts move relative to each other in such a way as to get out of place and disturb the longitudinal smoothness of the conductor. With the conductor subjected to a tension equivalent to 50 percent of its rated ultimate strength, the longitudinal smoothness shall be checked by a straight-edge laid against the conductor parallel to its axis and the variation from straight-edge measured with metal feeler gauges. The straight-edge shall be at least twice the length of the lay of the wires of the outer layer. The variation from the straight-edge shall not exceed 0.50 millimeters above the cylindrical surface of the conductor. Repeated popped strands within a reel length, even if they protude less than 0.5 millimeters, will be cause for rejection.

The conductor shall be capable of withstanding the normal handling necessary for manufacture and erection, such as reeling, unreeling and pulling through stringing sheaves under sufficient tension to keep the conductor off the ground, etc., without being deformed from a cylindrical form in such a way as to increase radio interference and corona loss.

- c. Cleaning. The conductor shall be free from excessive amounts of die grease, metal particles and dirt. The Manufacturer shall describe in complete detail the method which he proposes to use in normal production to clean the conductor. The effectiveness of the cleaning process shall be subject to verification.

#### B-5. Tests and Reports

##### a. Component Wires

- (1) Aluminum wire, before stranding, shall be tested in accordance with the requirements of ASTM B230.
- (2) Zinc-coated steel wire, before stranding, shall be tested in accordance with the requirements of ASTM B498.

##### b. Finished Conductor

- (1) Dimension and Ultimate Strength Tests. A sample section of conductor shall be given a tensile strength test to determine the ultimate strength. At each 1,000 kilogram increment of load up to 50 percent of the rated ultimate strength and at the load values equal to 30 percent and 50 percent of the rated ultimate strength, circumference of the conductor shall be measured by the method specified in Article B-4.b. above to determine the variation of circumference with load. In addition, the condition of the exterior surface of the conductor as to its general form and smoothness shall be determined by the method specified in Article B-4.b. when stressed up to 50 percent of its rated strength.
- (2) Stress-Strain Tests. A sample section of the complete conductor and of the steel core shall be given tensile strength tests to obtain representative short-time and repeated stress-strain curves. The samples of conductor shall be obtained from the first satisfactory production run. The gage length shall be 12.5 meters. Test report shall include complete tabulated data and plotted stress-strain curves (or, if automatic recording extensionmeters have been used, only the plotted stress-strain curves need be supplied) so that initial and final modulus of elasticity values may be determined. Such stress-strain tests shall be performed in complete accordance with the standard method proposed and adopted by the Aluminum Association, 750 Third Avenue, New York, N.Y. 10017.

- (3) Creep Tests. Creep tests shall be run in complete accordance with the method proposed and adopted by the Aluminum Association, 750 Third Avenue, New York, N.Y. 10017.
- (4) Torsion Tests. A sample section of the conductor shall be pulled from no load up to 50 percent of the rated ultimate strength to determine the torque in kilogram-meters required to prevent the conductor from untwisting. Tests shall be made in a friction-free loading set-up. The length of the test sample measured from the mouth of the grip at the fixed end to the mouth of the grip at the opposite end shall be not less than 12 meters. Torque shall be measured at each 1,000 kilogram increment of load.
- (5) Corona and RIV tests. If required by EGAT and specified in the Contract, the Contractor shall perform corona and RIV tests for the acceptability of the surface finish and determine the voltage gradient at threshold of visual corona. The Contractor shall demonstrate that such voltage gradient is an acceptable level for the conductor furnished when corrected to 760 mm mercury pressure and 25°C temperature. Failure to meet such requirement shall be cause for rejection.

The corona inception level of the conductors, in clean and dry condition, shall exceed the maximum line operation voltage by 20 per cent when corrected for laboratory conditions and geometry. For a maximum operating voltage of 550 kV line-to-line, the corona inception voltage of a three phase system shall be at least 380 kV line-to-ground.

A ten meter length of a four bundle conductor system shall be assembled in the laboratory and approved by EGAT. Before any corona and RIV test is performed, the Contractor shall submit detail drawings showing the conductor systems that will be tested to EGAT for approval. The drawings shall show the distance from the ground plane, dimensions of the laboratory, location of the specimen with respect to nearby large pieces of equipment, and calculated corona inception voltage.

The test procedure shall be as follows :

- (a) Corona observation and RIV measurements shall be made in a darkened laboratory or other suitable location. The starting voltage for all tests shall be above the visual corona level.
- (b) The voltage shall be reduced slowly while visual corona just disappears from the conductor bundle, and until the bundle as a whole is free from visual corona. These levels shall be photographed with a minimum one minute time exposure, and voltage maintained on each assembly for a minimum of five minutes.



- (c) RIV readings shall be recorded at each voltage level. A curve of ambient RIV shall be obtained up to the maximum test voltage. The RIV measurements including definitions, test conditions and test circuit shall be made in accordance with NEMA Standard 107 or equivalent approved by EGAT.

As soon as possible but not later than 30 days before the date fixed for tests, the Contractor shall submit proposed procedures for each finished conductor test to EGAT for approval.

The Contractor shall furnish four certified copies of full reports of tests required under this Specification including clear photographs of the tests set up for finished conductor to EGAT prior to shipment of the conductor.

The Contractor shall also be required to furnish the following characteristics of the conductor for information.

- (i) Stress-strain curves with one hour, 24 hours, 30 days, one year, 10 year and 20 year creep curves superimposed.
- (ii) 50 hertz resistance in ohm per kilometer at 25, 50, 75 and 100 degree Celcius. If these values were calculated, detailed calculations for 100 degree Celcius indicating the increments assumed and the resistances calculated shall be furnished. The calculated resistances shall not be greater than the maximum guaranteed resistances specified in the Contract.

#### B-6. Packing

##### a. Reel Lengths.

- (1) The conductor shall be placed on reels provided by the manufacturer. The allowable tolerance of the reel lengths shall be within plus five percent (5%) of the standard lengths. Reel dimensions will be subject to verification by EGAT.
- (2) Only one length of conductor shall be placed on each reel.

##### b. Reels

- (1) Either returnable metal or non-returnable wooden reels as specified in the Contract, shall be used for shipment of the conductor. Lagging bound on the reels shall be held in position by two circumferential 32 mm x 0.8 mm galvanized steel straps. Straps shall be stapled to alternate slats. The reels shall be of such construction as to assure delivery of the conductor to the field, free of displacement and damage. They shall be constructed to withstand all normal stresses due to handling and stringing operations, and to prevent damage to the conductor during normal construction practices but are not

required to be designed to withstand the forces required for braking during tension stringing. There shall be no sharp objects that may damage the conductor. The increase or decrease of distance between reel flanges anywhere on the circumference due to forces applied during reeling, delivery, handling, and stringing shall be not more than two-thirds of the diameter of the conductor. Two or more dog holes shall be provided near the arbor hole.

- (2) Chemically inert and waterproof material shall be wrapped around the drum and strapped or glued to the flange surface of all reels. The material shall be at least 0.6 millimeter-thick and shall remain securely attached to the reel. Any glue used shall be chemically inert and shall be used in such a manner as not to harm the conductor at any time.
- (3) The conductor on each reel shall be securely fastened at both ends with the outer end of the conductor fastened under tension. The tension shall be such that no looseness will be transmitted to the internal layers. Winding of conductor on the reels shall conform to the left or right hand rule, as applicable, as detailed in Appendix F of IEEE Standard 524-1980. The conductor shall be tightly and uniformly spooled on the reel with each wrap laid snugly against the side of the preceding wrap, and the first and last wrap in each layer shall fit snugly against the flange of the reel. The transition from one layer to the next layer above shall be made with a minimum of void space.
- (4) Materials used in or on the reels and conductor shall neither adhere to the conductor nor produce corrosion during outdoor storage.

c. Marking

- (1) The following information shall be marked with paint on the reels and be clearly indicated on at least one metal tag firmly attached to the reel :
  - Manufacturer's name
  - Manufacturer's plant location
  - Factory reel number
  - Factory reel numbers making up the "group"
  - Destination
  - Description
  - Actual length
  - Gross weight and net weight
  - Contract number and consignee
- (2) At the perimeter of the reel, arrows shall be placed which shall show the direction in which the reel should be rolled and in which the outer end of the conductor points.

B-7. Shipping

- a. Reels shall be shipped in “groups” of twelve with the variation between lengths in a group of not more than 15 meters. It is intended that the stress-strain and creep properties of conductor in a given group of reels shall be identical insofar as is practical. Such groups of conductor shall be selected from those fabricated from the same lot of raw materials and wire rods, machine and process.
- b. The Contractor shall exercise every precaution to adequately protect all shipments against damage in transit. Cars in which material is shipped shall be reasonably clean and free from foreign material which could in any way injure the material. Reels shall be stored on blocks or pallets to reduce their exposure to water borne corrosive materials.

Section C  
SHIELD WIRE

C-1. General

This Specification covers the detail requirements for the design, fabrication, test and shipping of zinc-coated extra high strength steel shield wire and aluminum-clad steel shield wire.

It is intended that shield wire covered by this Specification shall be suitable for both tension and slack stringing. Any shield wire which, when properly threaded, exhibits either "bird caging" or popped strands when slack or tension strung may be rejected.

C-2. Standards

The material covered under this Specification shall conform to the following standards and all applicable standards referenced therein, except as specified herein.

ASTM A363 "Zinc-Coated (Galvanized) Steel Overhead Ground Wire Strand" shall apply to zinc-coated extra high strength steel shield wire.

ASTM B416 "Concentric-Lay-Stranded Aluminum-Clad Steel Conductors" shall apply to aluminum-clad steel shield wire.

ASTM B354 "Standard Definitions of Terms Relating to Uninsulated Metallic Electrical Conductors."

IEEE Std. 524-1980 "Guide to the Installation of Overhead Transmission Line Conductors."

C-3. Shield Wire Characteristics

The shield wire to be furnished shall be zinc-coated extra high strength steel wire and shall have characteristics conforming to the following requirements.

<u>Description</u>		<u>3/8" Zinc-Coated Extra High Strength Steel Wire</u>	<u>7 No. 8 AWG Aluminum-Clad Steel Wire</u>
Stranded Wires			
Number of wires		7	7
Nominal diameter	mm	9.144	9.78
Nominal cross sectional area	mm <sup>2</sup>	51.097	58.561
Minimum breaking strength	kg	6,985	7,227
Minimum elongation in 610 mm	%	4	
Final modulus of elasticity	kg/mm <sup>2</sup>		16,169
Coefficient of linear expansion	x10 <sup>-6</sup> /°C		12.96
Maximum calculated DC resistance at 20°C	ohms/km		1.463
Approximate weight	kg/m	0.406	0.390
Nominal length per reel	m	3,500	3,500
Component Wire :			
Nominal diameter of wire	mm	3,048	3,264
Minimum weight of zinc/ aluminum coating	g/m <sup>2</sup>	259(Class A)	463
Minimum elongation in 254 mm	%		1.5

#### C-4. Tests and Reports

The shield wire shall be subject to test in accordance with the following requirements.

- a. Before stranding, zinc-coated extra high strength steel shield wire shall be tested in accordance with the requirements of ASTM A363.

- b. Before stranding, aluminum-clad steel shield wire shall be tested in accordance with the requirements of ASTM B416.
- c. A sample section of finished shield wire shall be given a tensile strength test to determine the ultimate strength.

The Contractor shall furnish four certified copies of full reports of tests required under these Specifications to EGAT prior to shipment of the shield wire.

C-5. Packing

a. Reel Lengths

- (1) The strands shall be placed on reels provided by the manufacturer. The allowable tolerance of the reel lengths shall be within plus five percent (5%) of the standard length.
- (2) Only one length of wire shall be placed on each reel.

b. Reels

- (1) Either metal or wooden reels lagged with heavy wooden slats shall be used for shipment of the wire. Lagging bound on the reels shall be held in position by two circumferential 32 mm x 0.8 mm galvanized steel straps. Straps shall be stapled to alternate slats. The reels shall be of such construction as to assure delivery of the wire to the field free of damage. There shall be no sharp projections that may damage the strand inside the reel. Two or more dog holes shall be provided near the arbor hole. Dimensions of reels shall be subject to verification by EGAT.
- (2) Chemically inert and waterproof material shall be wrapped around the drum and strapped or glued to the flange surface of all reels. The material shall be at least 0.6 millimeter thick and shall remain securely attached to the reel where intended to be in contact with the same, during unreeling. Any glue used shall be chemically inert and shall be used in such a manner that will not harm the steel wire strand at any time.

- (3) The strand on each reel shall be securely fastened at both ends with the outer end of the wire fastened under tension. The tension shall be such that no looseness will be transmitted to the internal layers. Winding of conductor on the reels shall conform to the left or right hand rule, as applicable, as detailed in Appendix F of IEEE Standard 524-1980. The strand shall be tightly and uniformly spooled on the reel with each wrap laid snugly against the side of the preceding wrap, and the first and last wrap in each layer shall fit snugly against the flange of the reel. The transition from one layer to the next layer above shall be made with a minimum of void space.

c. Marking

- (1) The following information shall be marked with paint on the reels and be clearly indicated on at least one metal tag firmly attached to the reel:
  - Manufacturer's name
  - Manufacturer's plant location
  - Factory reel number
  - Factory reel numbers making up the "pair"
  - Destination
  - Description
  - Actual length
  - Gross weight and net weight
  - Contract number and consignee
- (2) At the perimeter of the reel, an arrow shall be placed which shall show the direction in which the reel should be rolled and in which the outer end of the conductor points.

C-6. Shipping

- a. Reels shall be shipped in matched pairs with the variation in length between the two not to exceed 15 meters.
- b. The Contractor shall exercise every precaution to adequately protect all shipments against damage in transit. Cars in which material is shipped shall be reasonably clean and free from foreign material which could in any way injure the material.

## Section D

### INSULATORS AND HARDWARE

#### D-1. General

This Specification covers the detail requirements for the design, manufacturing, test and shipping of insulators and hardware assemblies for use with the four bundled conductor system and shield wire. Insulators and hardware assemblies shall be furnished in accordance with the details shown on the drawings and the requirements hereafter described.

The following items are covered under this specifications. Manufacturing will be permitted only after successful completion of the required type tests and corona and RIV tests.

- a. Insulators for conductor suspension, deadend and jumper support assemblies.
- b. Hardware for attaching insulators to tower and for attaching conductors to insulators.
- C. Insulators for shield wire suspension and deadend assemblies.
- d. Hardware for attaching insulators to tower and for attaching shield wire to insulators.

#### D-2 Standards

The materials covered under this Specification shall conform to the following standards and applicable standards referenced therein, except as specified herein.

ANSI C29.1 Test methods for electrical power insulators

ANSI C29.2 Wet-process porcelain and toughened glass suspension insulators

ANSI C29.4 Wet-process porcelain Insulators (Strain type)

ASTM A153 Specification for Zinc coating on Iron and Steel Hardware

IEC Pub. 575 Thermal - Mechanical Performance Test and Mechanical Performance Test on String Insulator Units.

AWS D1.1 Structural Welding Code by the American Welding Society



### D-3. Detail Requirements for Insulators

- a. Strain Type Insulators. The strain type insulators shall be made of porcelain and shall meet all the requirements of ANSI C29.4 for Wet Process Porcelain insulators (Strain Type) except as otherwise specified herein.

<u>Particulars</u>	<u>Rating</u>
ANSI class	54 - 2
Dimensions :	
Minimum leakage distance, mm	47
Meachanical Values :	
Tensile strength, kg	5,400
Electrical Values :	
Low - frequency dry flashover, kV	30
Low - frequency wet flashover, kV	15
Color of glaze	brown

- b. Suspension Type Insulators. The insulator discs shall be porcelain or glass with cap and pin, ball and socket type, radio interference free. Each insulator disc shall meet all of the requirements of ANSI C29.2 for Wet-Process Porcelain and Toughened Glass Insulators (Suspension Type) except as otherwise specified herein.

- (1) Dimensions and Characteristics. Dimensions and characteristics of each type of insulator shall be in accordance with the following :

<u>Particulars</u>	<u>Rating</u>
ANSI class	52-4      52-8      Fog type      52-11
Dimensions:	
Maximum disc diameter, mm	273      298      298      311
Unit spacing, mm	146      146      146      156
Minimum leakage distance, mm	292      305      432      381

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<u>Particulars</u>		<u>Rating</u>			
ANSI class		52-4	52-8	Fog type	52-11
Mechanical Values:					
Combined mechanical and electrical strength,	kg	6,800	16,300	16,300	22,600
Mechanical impact strength,	m-kg	0.63	1.04	1.04	1.04
Tension proof,	kg	3,400	8,150	8,150	11,300
Time load,	kg	4,500	10,880	10,880	13,600
Electrical Values:					
Low-frequency dry flashover,	kV	80	80	80	80
Low-frequency wet flashover,	kV	50	50	50	50
Critical impulse flashover, positive,	kV	125	125	125	140
Critical impulse flashover, negative,	kV	130	130	130	140
Low-frequency puncture,	kV	110	110	110	125
Radio-Influence Voltage Data:					
Low-frequency test voltage, rms to ground,	kV	10	10	10	10
Maximum RIV at 1000 kHz,	V	50	50	50	50
Coupling Type:		-	K	K	K
Glaze Color: (if porcelain insulators are supplied)		brown	grey or brown	grey or brown	grey or brown

Note : Specific glaze color shall be as specified in the Contract.

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- (2) Porcelain. Where porcelain insulators are used, they shall be made of the highest grade, dense, homogeneous, wet-process porcelain, cylindrical headed with sanded surface, completely and uniformly vitrified throughout to produce uniform mechanical and electrical strength and long life service. The porcelain shall be free from warping, roughness, cracks, blisters, laminations, projecting points foreign matter and other defects, except those within the limits of standard accepted practice.
- (3) Toughened glass. Where glass insulators are used, they shall be made of the highest grade, dense, homogeneous, toughened glass possessing uniform mechanical and electrical strength and suitable for long life service. The glass shall be free from warping, roughness, cracks, blisters, laminations, projecting points, foreign matter and other defects, except those within the limits of standard accepted practice.
- (4) Cap and pin. The cap and pin shall be of such design that it will not yield or distort under the specified mechanical load in such a manner as to change the relative spacing of the insulators or add other stresses to the shells. The insulator caps shall be of the socket type for ANSI Class 52-11, ANSI Class 52-8 and Fog type, and clevis type for ANSI Class 52-4, provided with stainless steel cotter pins. The cap shall be made of good commercial grade malleable iron, open hearth or electric furnace steel or ductile iron, hot-dip galvanized in accordance with ASTM A153. The cap shall be truly circular, with the inner and outer surfaces concentric, and shall be free from cracks, shrinks, air holes, burrs, and rough edges to minimized field concentrations and radio disturbances. The insulator pins shall be made of malleable iron or drop-forged or machine steel and free from cracks and air-holes. All bearing surfaces shall be smooth and uniform so as to distribute the loading stresses evenly. Pins for fog type insulators shall be corrosion proof type.
- (5) Glaze. All porcelain surfaces exposed to the weather shall be glazed with reasonably uniform color as specified. The glaze shall be smooth, hard, dense, and properly fitted to the porcelain and shall be unaffected by the weather, ozone, nitric acid, nitric oxides, alkali, dust, or sudden changes in temperature within the atmospheric range.
- (6) Cementing. High quality cement shall be used for cementing the insulator body to the cap and pin.

#### D-4. Detail Requirements for Hardware Assemblies

All assemblies shall be designed and manufactured to meet the following requirements.

##### a. General

- (1) The hardware assemblies shall include all the necessary clamps, links, yoke plates, clevises, shackles, pins, bolts, hold down weights and locking devices necessary to attach the conductors to the insulators, to connect the insulators to the tower fixtures and to support and attach the shield wires to the towers.
- (2) All assemblies shall be easily assembled and all fittings shall be suitable for hot-line maintenance.
- (3) Suspension assemblies shall be so constructed that no corona or grading rings are required.
- (4) All plates shall have an appropriate smooth radius chamfer on all holes to prevent a binding condition under normal operation leading to fatigue failure of the attachment hardware.
- (5) All conductor and shield wire suspension clamps shall be free to swing in either direction from the vertical.
- (6) All types of assemblies shall be tested for fit and mechanical and electrical integrity.

##### b. Conductor Assemblies

- (1) Insulator strings will use hardware with a minimum strength equal to that of the insulator as specified on the drawings. In multiple strings, all yoke plates and associated hardware will have a minimum strength of the assembly rating.
- (2) All components attaching to the conductor insulators shall fit and be compatible with standard ball and socket insulators of the M&E rating specified on the drawings.
- (3) All yoke plates shall be notched and detailed to facilitate hot-line maintenance.

c. Shield Wire Assemblies

- (1) All hardware for shield wire suspension assemblies shall fit in such a manner as to insure that the mechanical strength of the assembly is adequate for the intended application as specified on the drawings.
- (2) The size of stainless steel washers to be used for providing an arcing gap shall be determined such that the length of the gap provides a low frequency wet insulation strength of approximately 1200 Volts.

D-5. Materials and Workmanship for Hardware

All hardware assembly components may be malleable iron, steel, stainless steel or aluminum, or any combination of these materials which are recommended as best suited to meet the mechanical and electrical performance required by this specification. All metal shall be free from burrs, sharp edges, lumps and dross, and shall be smooth so that interconnecting parts will fit properly and so that parts may be assembled and disassembled readily. All ferrous metal shall be hot-dip galvanized in accordance with ASTM A153 . All threaded steel parts, nuts and locknuts shall be galvanized after threading. Retapping of nuts and locknuts after galvanizing is permitted, provided protective zinc or tapping oil remains full length on the threads. All nuts and locknuts shall be capable of being turned on the bolt threads the entire length without use of a wrench. All cotter pins shall be made of stainless steel and shall be self-locking. All welding shall conform to AWS D1.1.

D-6. Detail Drawings

- a. Insulators. Detail drawings shall show dimensions and characteristics as required per Article D-3.a. and D-3.b.(1), description of materials and unit weight.
- b. Hardware.
  - (1) Detail drawings shall show dimensions, weights, mark numbers and strength rating.
  - (2) Assembly drawings shall show a view of the complete assembly with overall dimensions, weights and strength and a Bill of Material identifying parts by mark number. All assemblies shall reference the assemblies as shown in the specification drawings.

## D-7. Tests

Insulators, hardware components and complete insulator and hardware assemblies shall be subject to test in accordance with the following requirements. The costs of all tests, test samples and test reports shall be borne by the Contractor.

### a. Complete Conductor Insulator and Hardware Assemblies.

- (1) Corona and RIV Tests. The Contractor shall perform full-scale corona and RIV tests in accordance with the following requirements :

- (a) Type of Test Assemblies. A complete set of each of the following assemblies shall be tested to satisfy the requirements specified.

<u>Type of Assembly</u>	<u>Reference Assembly</u>
Conductor suspension assemblies "V-String"	3, 5, 8A, 9A and 18
Conductor dead end assemblies	13, 14 OR 13A, 14A and 15
Jumper support assembly "V-String"	-
Jumper support assembly "I-String"	17

- (b) Test Station. The test station shall be subject to EGAT's approval. Such test station shall possess an excellent and wide reputation, having at least 10 years of experience in conducting electrical performance tests of insulators, hardware and complete insulator and hardware assemblies including extensive knowledge and experience in conducting tests at the 500 kV voltage level.

- (c) Test Arrangement. Before performance of any corona and RIV test the Contractor shall submit detail drawings showing the assemblies to be tested to EGAT for approval. The drawings shall be complete and show the arrangement of all hardware, insulators, suspension unit with armor rod installed and any accessories such as weights which will be used in the actual test. The drawings shall show the calculated corona inception voltage, distance from the ground plane, dimensions of the laboratory and location of the test specimen with respect to nearby large pieces of equipment. Test arrangements shall be in accordance with the following requirements:

- (1) Corona observation and RIV measurements shall be made in a darkened laboratory or other suitable location.
- (2) The test shall be performed on a simulation arrangement of the tower that will actually be used. If the test is to be performed in an outdoor laboratory, the assemblies shall be placed on a mock-up of the ground plane that simulates the tower to be actually used. The mock-up configuration shall include complete tower window.
- (3) Each conductor suspension and conductor deadend assembly to be tested shall be completely assembled with hardware, insulators and conductors in accordance with the drawings approved by EGAT.
- (4) The conductor dead end assembly shall be tested complete with compression dead-ends, jumper terminals and a partial jumper loop.
- (5) The test arrangement shall consist of a four conductor bundle configuration of 1272 MCM ACSR/GA. The length of the conductor to be used shall be approved by EGAT. The conductor to be used for the tests shall be provided by the Contractor at his own expense and shall be in clean and good conditions.
- (6) It is intended that the basis for establishing the corona levels of these assemblies in clean and dry condition shall be by comparison with the corona inception level of the conductor when in clean and dry condition.

The geometry of the test with single phase voltage shall be such as to reproduce the electrical surface gradients on the conductors which would be obtained when in the geometry of 3-phase voltages of the actual line.

- (d) Test Procedure. Test shall be performed in accordance with the following requirements.

- (1) Before performing the test the Contractor shall submit a proposed voltage range to be applied during the test to EGAT for approval. The starting voltage for all tests shall be above the visual corona level.

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- (2) The voltage shall be reduced slowly while visual corona just disappears in turn from each identifiable item of the assembly, and until the assembly as a whole is free from visual corona. These levels shall be photographed with a minimum one minute time exposure, and voltage maintained on each assembly for a minimum of five minutes.
- (3) RIV readings shall be recorded at each voltage level. A curve of ambient RIV shall be obtained up to the maximum test voltage. The RIV measurements including definitions, test conditions and test circuit shall be made in accordance with NEMA Standard 107 or an equivalent approved by EGAT.
- (4) The general criterion for acceptance of the hardware assemblies, or of any item thereof, shall be that all visual corona just disappears at a voltage not less than the apparent corona level of the conductors, both hardware and conductors being observed simultaneously. This apparent corona level of the conductors is defined as that test voltage at which the general corona just disappears, leaving only isolated spots on the conductor due to minor surface imperfections.
- (e) Modification of Hardware Components. Any component of hardware or portion thereof not meeting the requirements specified above shall be modified or replaced to the satisfaction of EGAT at the Contractor's expense. The entire group of assemblies shall then be retested at the Contractor's expense until satisfactory results are obtained.
- (2) Lightning Impulse, Switching Surge and Power Frequency Flashover Tests. The Contractor shall perform full-scale lightning impulse, switching surge and 50 hertz power frequency flashover tests in accordance with the following requirements :

Simulation arrangement and test procedures shall be submitted for EGAT's approval prior to performing the tests.

  - (a) Type of Test Assemblies. Each of the following insulator assemblies shall be subject to test.



<u>Type of Assemblies</u>	<u>Reference Assembly</u>
Conductor suspension assemblies "45°/45° V-String"	3
Conductor deadend assemblies	14 OR 14A
Jumper support assemblies	17
(b) <u>Test Station</u> . Test station shall be the same as required in Article D-7.a.(l)(b).	
(c) <u>Test Arrangement</u> . Simulation arrangement for these tests shall be as follows :	
(1) Assembly 3 shall be tested on a full-scale mock-up of a DL (3') tower. This assembly shall be fixed at a swing angle which results in a conductor to tower clearance of 4 meters for these tests.	
(2) Assemblies 14 and 17 shall be tested on a full-scale mock-up of the DT40 tower.	
(d) <u>Test Procedure</u> . Tests shall be performed in accordance with the following requirements :	
(1) <u>Lightning Impulse and Switching Surge Tests</u> .	
(i) Lightning impulses shall be modeled with a standard 1.2 x 50 microsecond wave.	
(ii) Switching surges shall be modeled with a double exponential or equivalent wave having a time to crest of approximately 250 microseconds.	
(iii) Flashover voltages shall be determined by the up-and-down" method.	
(iv) Flashover paths, weather data and all other pertinent information shall be recorded.	

- (2) Power Frequency Flashover Test. The intent of this test is to determine the pollution performance of the insulator strings for equivalent salt deposit densities of up to 0.03 milligrams per square centimeter. Withstand voltages shall be determined by means of a "clean fog" test. A layer of contaminant, consisting predominantly of kaolin, water and salt, shall be evenly applied to the insulator strings and allowed to age for a suitable period. The assemblies shall then be uniformly wetted in a steam fog. Withstand voltages shall be determined when the conductivity of the contaminant layer reaches a maximum. Tests shall be repeated as frequently as necessary to provide statistically reliable results.

- b. Complete Shield Wire Insulator and Hardware Assemblies. The Contractor shall demonstrate that all shield wire assemblies meet the mechanical and electrical strength requirements of the intended use. The test procedure shall be submitted to EGAT for approval prior to performing the tests.

- (1) Type of Test Assemblies. A complete set of each of the following assemblies shall be subject to test.

<u>Type of Assembly</u> <u>Assembly</u>	<u>Reference</u>
Shield wire (insulated) suspension assembly	1
Shield wire (insulated) deadend assembly	11

- (2) Test Requirements. A sample of each assembly will be subject to ten 1.2 x 50 microsecond impulses of sufficient magnitude to cause flashover. A 50 hertz voltage of 1200 volts will be applied to the assembly for the duration of the test. The time between impulse applications shall be no more than two minutes. All arcs shall be self-extinguishing and no damage to the assemblies shall occur.

After the same sample of shield wire (insulated) suspension assembly has been tested for electrical insulation strength specified above, it shall be subject to incremental tension loads to failure to determine its mechanical strength.

- c. Insulators. All types of insulators shall be subject to test at the Contractor's expense in accordance with the following requirements:

(1) Design Tests. Submission of previous test certificates of design tests in accordance with all the requirements of ANSI C29.2 and ANSI C29.4 for suspension type and strain type insulators respectively, shall be regarded as evidence of compliance except the three design tests specified in Article D-7.c.(4), (5) and (6) shall be carried out regardless of whether or not the Contractor can furnish previous test certificates as evidence that these design requirements can be met. For insulators of new designs, design tests shall be performed in accordance with all the requirements of aforementioned ANSI standards.

(2) Quality Performance Tests. Tests shall be performed in accordance with all the requirements of ANSI C29.2 and ANSI C29.4 for suspension type and strain type insulators respectively except that the criteria of judgement for acceptance for the combined mechanical and electrical strength test shall be as follows :

$$3 \leq Q = (R-R_s)/S$$

Where Q = Criteria of judgement for acceptance

R = Mean value obtained on the sample of ten insulator units tested

R<sub>s</sub> = Rated mechanical and electrical strength value of the insulator

S = Standard deviation for the ten insulator units tested

Each value measured shall not be lower than the specified mechanical and electrical strength. In addition, electrical puncture shall not occur before reaching ultimate failure.

For the purposes of sampling and testing, the lot size shall not be more than 3000 units. The Contractor shall furnish certified copies of all tests whether or not inspection is waived.

(3) Routine Tests. All insulators shall be subjected to routine tests in accordance with all the requirements of ANSI C29.2 and C29.4 for suspension type and strain type respectively.

- (4) Power Arc Test. Three strings of insulators, each containing six units randomly selected from the first lots brought forth for acceptance, shall be assembled in a vertical configuration without conductors for each 52-8 and 52-11 type of insulator. The strings shall be energized at the bottom and grounded at the top. The insulator strings shall be subject to a 50 hertz power arc of 20,000 amps rms sustained for five cycles. The insulators shall be tensioned to 40 per cent of their rated strength prior to initiation of the arc and this tension shall be maintained for the duration of the arc and for five minutes following its extinction. There shall be no separation of cap and pin during this portion of the test.

After arcing, each string of insulators shall be mechanically tested in accordance with paragraph 5.1 of ANSI C29.1, except that the load may be increased rapidly to only 45 per cent of the rated strength of the insulator. The rate of increase of load from 45 per cent to failure shall be as given in Table 1 of ANSI C29.1. If any insulator fails at less than 60 per cent of its rated strength, the insulator design fails to meet these specifications.

- (5) Thermal - Mechanical Performance Test. Ten insulator units of ANSI class 52-8 and 52-11 shall be selected for testing at random from the first lots brought forth for acceptance. The test shall be performed in accordance with all the requirements of Clause 3 of IEC Publication 575: Thermal - Mechanical Performance Test and Mechanical Performance Test on String Insulator Units except that the concluding stage of the test shall be the combined mechanical and electrical strength test of ANSI C29.1 and the criteria of judgement for acceptance shall be as follows :

$$3 \leq Q = (R-R_s)/S$$

Where Q = Criteria of judgement for acceptance

R = Mean value obtained on the sample of ten insulator units tested

R<sub>s</sub> = Rated mechanical and electrical strength value of the insulator

S = Standard deviation for the ten insulator units tested

Each value measured shall not be lower than the specified mechanical and electrical strength. In addition, electrical puncture shall not occur before reaching ultimate failure. The results of the Thermal-Mechanical Performance Test shall match the results of the ordinary combined mechanical and electrical strength test of paragraph D-7.c.(2), and the fracture pattern shall not change.

(6) Steep Wave Front Impulse Test.

Ten (10) insulator units of each suspension type insulator of ANSI class 52-8 and 52-11 shall be selected by EGAT at random from the first lot brought forth for acceptance. These units shall be tested as follows :

- (a) The insulator units shall be subjected to five successive positive impulse flashovers followed by five successive negative impulse flashovers. Each wave impulse shall have an effective rate of rise of 2,500 kV per microsecond. The insulators shall be tested singly.
- (b) Each unit shall then be subjected to three flashovers of the low frequency dry flashover test of ANSI C29.1 and shall have a flashover value not less than 95% of the rated value.
- (c) Upon failure of any one unit to pass either the steep wave front of the dry flashover test, an additional quantity of twenty (20) randomly selected units shall be tested in accordance with (a) and (b) above.
- (d) Failure of any one unit of the second group of samples to pass either test shall constitute failure of the insulator design and evidence that the requirements of this specification are not met.

d. Individual Hardware Tests.

- (1) Classification of Tests. In the following Articles, the requirements for the various types of fittings are given. The tests are divided into three groups:
  - (a) Type Tests. The tests are intended to establish design characteristics. They are normally made once only and repeated only when the design or the material of the fitting is changed.

- (b) Sample Tests. Sample tests are intended to verify the quality of materials and workmanship. They are made on fittings taken at random from the various lots offered for acceptance.
- (c) Routine Tests. Routine tests are intended to eliminate defective fittings. They are performed on every fitting of the type to which they are applicable.

(2) General Requirements for Tests.

- (a) Type Tests. Unless otherwise agreed, test certificates giving the results of the appropriate type tests, made on not less than three fittings identical in all essential details with those to be supplied, shall be regarded as evidence of compliance.
- (b) Sample Tests. The number of samples for these tests shall be selected in accordance with the table below:

Number in the lot N*	Number of Samples
$N \leq 100$	1
$100 < N \leq 300$	5
$300 < N \leq 1200$	10
$1200 < N \leq 3000$	14
$3000 < N \leq 10000$	20
$N > 10000$	By arrangement between the parties concerned, a comprising between 3000 and 10000 fittings will be made up.

\*N is number of fittings offered for inspection.

The samples shall be selected at random from fittings which have passed the appropriate routine test (if any). EGAT has the right to make the selection.

If these samples meet the test requirements, the lot is deemed to comply with the requirements of the standard. In the event of a sample not meeting the test requirements, twice the original number of new samples shall be tested. If all of these new samples meet the test requirements, the lot is deemed to comply with the requirements of the standard, but if any fail to do so the lot is deemed not to comply with the requirements of the standard.

(c) Routine Tests. Where routine tests are specified in the following Articles, they shall be applied to every fitting.

- (3) Verification of Dimensions. It shall be verified either that the test samples comply with the requirements of these specifications or that they are in accordance with the approved drawings, particularly as regards any dimensions to which special tolerances apply and details affecting interchangeability (e.g. dimensions for which gages are specified).

Unless otherwise agreed, the following tolerances are allowed on all dimensions:

<u>Dimension</u> mm	<u>Tolerance</u>
Up to and including 35	$\pm 1.0$ mm
Over 35	$\pm 2.5\%$

- (4) Test Method.

(a) Type Test. The fitting shall be held in a tensile testing machine in a manner approximating, as nearly as possible, the arrangement to be used in service. A tensile load equal to 75 % of the specified minimum failing load shall be applied and increased at a steady rate. Failure of the fitting shall not occur at a load less than the specified minimum failing load.

(b) Sample Tests.

(i) Verification of Dimensions. The dimensions of the samples shall be verified as specified in Article D-7.d.(3).

(ii) Mechanical Test. This test shall be the same as the type test specified in Article D-7.d.(4)(a).

- (iii) Magnetic Particle Test. Samples of ferrous cast or forged yoke paltes, connecting hardware including bolts and pins, and welds shall be tested before galvanizing by the magnetic particle inspection process specified in ASTM E138 using the continuous method of examination and circular or longitudinal magnetization or both as required.

All surfaces of an article shall be inspected using fluorescent magnetic particles as the inspection medium. The magnetizing current shall be direct or rectified alternating current of sufficient strength to detect the defects of, but not limited to, any pipe, flakes or beat checks, seams, laps, cracks, slag, porosity, slivers, scabs, rolled-in scale, and fissures.

Defective articles may be repaired if the defect is on the surface and can be removed by grinding or polishing only, without reducing the dimensions or strength below the design requirements. All repaired articles shall be reinspected. Each article with an unrepairable defect shall be rejected, permanently marked, and discarded.

- (iv) Galvanizing Test. Galvanized parts shall be tested in accordance with ASTM A153 and shall comply with the requirements of that standard.

(c) Routine Test.

- (i) Mechanical Routine Test. This test shall be applied only to castings and to fittings which are fabricated by welding in which the weld is stressed when the fitting is in service. A tensile load equal to 50 % of the specified minimum failing load shall be applied to the fittings and maintained for 30 seconds. The fitting shall not be damaged by the test.

D-8. Marking

- a. Insulators. Each insulator unit shall bear legible and durable symbols identifying the manufacturer, the year of manufacture and the rated combined mechanical and electrical strength. Marking on porcelain shall be printed, not impressed, and shall be applied before firing.



- b. Hardware. Each hardware part shall be permanently marked by casting or die-stamping to indicate the manufacturer's name and catalog number.

D-9. Packing

All insulators or hardware shall be packed in sturdy wooden cases suitable for both ocean and inland transportation and shall be clearly marked with the following informations :

- a. Description of the items
- b. Number of pieces
- c. Net weight and gross weight
- d. Contract number
- e. Project name
- f. Destination

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## Section E

### LINE ACCESSORIES

#### E-1. General

This Specification covers the detail requirements for the design, manufacturing, test and shipping of the following conductor and shield wire accessories.

- Compression deadend fittings
- Full tension splices
- Conductor repair sleeves and preformed patch rods
- Armor rods

Detailed requirements for shield wire dampers, spacer-dampers and rigid spacers for conductor are included in a separate Specification.

#### E-2. Standards

The material covered under this Specification shall conform to the following standards and applicable standards referenced therein, except as specified herein.

ASTM A153 Specification for Zinc coating on Iron and Steel Hardware.

AWS D1.1 Structural Welding Code by the American Welding Society.

#### E-3. Materials and Workmanship

Conductor and Shield wire accessories shall be of the best material suited to meet the mechanical and electrical performance required by this Specification. All metal shall be free from burrs, sharp edges, lumps and dross, and shall be smooth so that interconnecting parts will fit properly and so that parts may be assembled and disassembled readily. All ferrous metal shall be hot-dip galvanized in accordance with ASTM A153. All threaded steel parts, nuts and locknuts shall be galvanized after threading. Retapping of nuts and locknuts after galvanizing is permitted, provided protective zinc or tapping oil remains full length on the threads. All nuts and locknuts shall be capable of being turned on the bolt threads the entire length without use of a wrench. All cotter pins shall be made of stainless steel and shall be self-locking. All welding shall conform to AWS D1.1.

#### E-4. Compression Deadend Fittings

- a. All deadends for conductors and shield wires shall be of the compression type.
- b. Deadends intended for use on conductor shall be complete with jumper pad, jumper terminal and associated hardware. All jumper pads and terminals shall be drilled in accordance with applicable NEMA Standards or equivalent.
- c. All outer aluminum surfaces shall be protected against abrasion and all surfaces of current carrying parts shall be coated with an easily removed plastic to inhibit corrosion on such surfaces.
- d. Joint compound shall be supplied with all deadend fittings.
- e. All deadends shall be capable of developing a minimum of 95 per cent of the conductor's (or shield wire's) rated strength. The complete assembly shall have a conductance per unit length and ampacity not less than that of the conductor or shield wire itself.
- f. Following installation, deadends shall have a corona inception voltage not less than that of the conductor itself.

#### E-5. Full Tension Splices

- a. All conductor and shield wire splices shall be of the compression type.
- b. The tension splice for ACSR conductor shall consist of a steel compression splice for the steel core, an aluminum or aluminum alloy compression splice for the complete conductor, appropriate joint compound and aluminum plugs for sealing the holes in the aluminum compression splices through which the joint compound is to be injected.
- c. Shield wire splices may be of either two-part or single part construction, all with appropriate filler compound and filler plugs if required.
- d. All joints shall develop at least 95 per cent of the rated strength of the conductor or shield wire.
- e. The conductance per unit length and ampacity of all splices shall not be less than that of the conductor or shield wire itself.
- f. After compression, the aluminum splice shall have a corona inception voltage not less than that of the conductor itself.

E-6. Conductor Repair Sleeves

- a. Repair sleeves shall be of the aluminum alloy compression type and of two-piece construction.
- b. Joint filler compound shall be supplied with all conductor repair sleeves.
- c. When properly applied, repair sleeves shall achieve 95 per cent of the rated strength of the conductor when 1/3 of the aluminum wires of the outer layer of ACSR are damaged.
- d. The conductivity and ampacity of the repair sleeves shall not be less than that of the conductor itself.
- e. The corona inception voltage of the conductor with repair sleeve installed shall not be less than that of the conductor alone.

E-7. Armor Rods

- a. Armor rods will be used in all conductor and shield wire suspension and jumper support assemblies. They shall be of the preformed type and so designed as to protect the conductor from damage due to installation of the suspension clamp, flashover or vibration.
- b. Armor rods for use on the conductors shall be made of aluminum or aluminum alloy. Those to be used on the shield wires shall be of a material that is corrosion resistant in itself and electrochemically compatible with the shield wire type on which it is to be used.
- c. The corona inception voltage of the conductor with the armor rods applied shall not be less than that of the conductor itself.

E-8. Preformed Patch Rod

The patch rod shall be of the preformed type. They shall be of aluminum alloy and shall be designed to restore full conductance and strength of the damaged conductor where the damage does not exceed 25 per cent of the outer strand layer.

E-9. Detailed Drawings

Detailed drawings shall show dimensions, weights, mark numbers and strength rating.

#### E-10. Joint Compound

The compound shall be applicable for both aluminum to aluminum and aluminum to galvanized steel mating surfaces. The compound shall be chemically inert of a petroleum grease base. It shall include titanium dioxide for high electrical efficiency and zinc chromate as an oxide inhibitor. It shall remain workable through a temperature range of 0° C to 110° C. It shall be non-toxic and insoluble in water.

#### E-11. Tests

All line accessories shall be subject to test in accordance with the following requirements :

- a. Type Tests. These tests shall be made on not less than three compression deadend fittings and full tension splices identical in all essential details with those to be supplied.

- (1) Mechanical Type Test. The fitting shall be assembled in accordance with the manufacturer's recommendations on conductors of the size and type with which it is to be used. The assembly shall be mounted in a tensile testing machine and anchored in a manner approximating, as nearly as possible, the arrangement to be used in service, precautions being taken to avoid birdcaging of the conductor. The length of conductor between the fitting under test and any other clamp or joint in the test assembly shall be not less than 100 times the overall diameter of the conductor.

A tensile load of about 50% of the breaking load of the conductor shall be applied and the conductor shall be marked in such a way that movement relative to the fitting can easily be detected. Without any subsequent adjustment of the fitting, the load shall be steadily increased to 95% of the breaking load and then reduced to 90% of the breaking load and maintained for 1 min. There shall be no movement of the conductor relative to the fitting due to slip during this period of 1 min and no failure of the fitting.

Full details of the conductor used in the test, including details of the greasing, if any, shall be stated on the test certificate.

- (2) Electrical Type Tests

- (a) Resistance Test. This test shall be made on full tension splices and also on compression deadend fittings (including any jumper connections which form part of the fitting), if the design is such that the conductor is not continuous through the clamp.

The fitting shall be assembled in accordance with the manufacturer's recommendations on conductors of the size and type with which it is to be used. The electrical resistance shall be measured between points on the conductors on either side and 25 mm clear of the fitting and shall not exceed 75% of the measured resistance of the equivalent length of conductor. Where a fitting is composed of several parts, electrically in series, the resistance of each part, shall not exceed 75% of the measured resistance of the equivalent length of conductor.

The test shall be made with direct current. The current connections shall be at a distance not less than 50 times the diameter of the conductor from the fitting and shall be made so that effective contact is made with all those strands of the conductor which would be taken into account in calculating its equivalent resistance.

The test shall be repeated with the polarity reversed and the average of the two results taken as the measured value.

- (b) Heating-cycle Test. This test shall be made on full tension splices and also on compression deadend fittings (including any jumper connections which form part of the fitting), if the design is such that the conductor is not continuous through the clamp.

The test current shall be that power frequency current which raises the surface temperature of the conductor 40 °C above the ambient temperature (27 °C) and maintains the temperature at a steady value. The minimum length of conductor used for determining this current shall be 2 meters and the conductor temperature shall be measured near the center of the test length.

The fitting shall be assembled in accordance with the manufacturer's recommendations on conductors of the size and type with which it is to be used. The assembly, to which a tensile load not exceeding 20% of the breaking load of the conductor may be applied, shall be erected indoors so that the conductor is roughly horizontal. Air shall be able to circulate freely around the assembly which shall not, however, be exposed to drafts. The minimum length of conductor on each side of the fitting shall be 2 m.

The test current shall be passed continuously through the assembly for a period of 30 minutes or such longer period as may be necessary to bring the conductor to a temperature 40°C above the ambient temperature (27°C ). The current shall then be interrupted and the conductor shall be allowed to cool to within 5°C above the ambient temperature (27°C ). This sequence of operations shall be repeated so that 250 cycles of heating and cooling are applied. The fitting shall not be tightened or adjusted during the test.

During the last five cycles the maximum temperature, measured when the test current is flowing, at any point on the surface of the fitting, shall not exceed that of the conductor. At the end of the test the fitting shall meet the requirements of the resistance test specified in (a). The fitting shall afterwards be opened and there shall be no sign of local heating, burning or fusing of any part of the fitting or of the conductor, as a result of the test.

- b. Sample Tests. These tests shall be made on each lot of line accessories offered for acceptance.

- (1) Verification of Dimensions. It shall be verified either that the test samples comply with the requirements of the Specifications or that they are in accordance with the approved drawings, particularly as regards any dimensions to which special tolerances apply and details affecting interchangeability (e.g. dimensions for which gages are specified).

Unless otherwise agreed the following tolerances are allowed on all dimensions, except special tolerances:

<u>Dimension</u>	<u>Tolerance</u>
mm	
Up to and including 35	$\pm 1.0$ mm
Over 35	$\pm 2.5$ %

- (2) Galvanizing Test. Galvanized parts shall be tested in accordance with ASTM A153 and shall comply with the requirements of that standard.

The number of samples for these tests shall be selected in accordance with table below:

Number in the lot N*	Number of Samples
$N \leq 100$	1
$100 < N \leq 300$	5
$300 < N \leq 1200$	10
$1200 < N \leq 3000$	14
$3000 < N \leq 10000$	20
$N > 10000$	By arrangement between the parties concerned, a minimum number of lots comprising between 3000 and 10000 fittings will be made up.

\* N is number of fittings offered for inspection.

The samples shall be selected at random from fittings which have passed the appropriate routine test (if any). EGAT has the right to make the selection.

If these samples meet the test requirements, the lot is deemed to comply with the requirements of the standard. In the event of a sample not meeting the test requirements, twice the original number of new samples shall be tested. If all these new samples meet the test requirements, the lot is deemed to comply with the requirements of the standard, but if any fail to do so the lot is deemed not to comply with the requirements of the standard and shall be rejected.

- c. Routine Test. This test shall be made on compression deadend fittings which are basically castings and those which are fabricated by welding, in which the weld is stressed in normal service.

Where a compression deadend fitting is provided with an attachment point for use during erection and maintenance, the test load shall be applied between this point and the anchor point. Otherwise the test load shall be applied as nearly as possible between the points of attachment used in normal service.



A tensile load, which shall be equal to 50% of the specified minimum failing load unless otherwise specified, shall be applied to the fitting and maintained for 30 seconds. The fitting shall not be damaged by the test.

The Contractor shall inform EGAT if the form of fitting is such that a test load cannot be applied.

E-12. Marking

Each part of line accessories shall be permanently marked by casting or die-stamping to indicate the following:

- a. The manufacturer's name
- b. The type and nominal cross-sectional area or diameter of the conductor or shield wire for which it is suitable.

E-13. Packing

All line accessories shall be packed in sturdy wooden cases suitable for both ocean and inland transportation and shall be clearly marked with the following information:

- a. Description of the items
- b. Number of pieces
- c. Net weight and gross weight
- d. Contract number
- e. Project name
- f. Destination

## Section F

### DAMPERS, SPACER - DAMPERS AND RIGID SPACERS

#### F-1. General

This Specification covers the detail requirements for the design, manufacturing, test and shipping of dampers for shield wire for controlling of shield wire aeolian vibration, corona free spacer-dampers for use on a four bundled conductor system for maintaining the 457 mm. square bundle configuration of the subconductors and controlling aeolian vibration and wind-induced subconductor oscillation, and rigid spacers for maintaining bundle configuration of the subconductors in jumper loops.

#### F-2. Standards

The materials covered under this Specification shall conform to the following standards and all applicable standards referenced therein, except as specified herein.

ANSI B 18.2.1 Standard for Square and Hex Bolts and Screws

ANSI B 18.2.2 Standard for Square and Hex Nuts

ANSI MH1.1.2 Pallet Definitions and Terminology

ASTM A153 Specification for Zinc Coating on Iron and Steel Hardware

IEEE Paper No. 31 CP65-156 Standardization of conductor vibration measurement.

ASTM D1043 Test Method for Stiffness Properties of Plastics as a function of Temperature by Means of a Torsion Test.

Standards equal to or better than the standards referenced above are acceptable.

#### F-3. Design Data

Climatological data observed in the vicinity of the transmission line route, plan and profile drawings, conductor and shield wire sag and tension data and a table of anticipated span lengths are included in the drawings. This information is intended to be used as a guide for determining the required damper and spacer-damper designs and spacings. The design of dampers, and spacer-dampers for the entire transmission line route shall be based on the worst case maximum steady wind velocity shown in the climatological data and a threshold wind velocity of up to 40 km/hr.

F-4. Materials and Workmanship

Materials shall be of recent manufacture, new and free of defects or irregularities. All components of the same design and designation shall be identical and like components shall be interchangeable.

Workmanship shall be good and craftsman-like following the best modern practices of the industry.

All ferrous metal shall be galvanized in accordance with ASTM A153.

F-5. Detail Requirements for Spacer-Dampers

- a. The spacer-damper shall be designed so that during operation, the conductor is not damaged by its movements.
- b. The spacer-damper shall be capable of being installed and easily removed without completely separating components. In addition, the clamp shall be capable of being removed and reinstalled on the conductor at the design torque.
- c. Where elastomers or other non-metallic materials are used, they shall be capable of withstanding conductor temperatures of up to 90 °C without permanent loss of essential properties. The energy absorbing assembly shall be designed to provide effective damping throughout a temperature range of 0 °C to 75 °C.
- d. The elastomer or other energy absorbing assembly shall have adequate resistance to the effects of ozone, ultra violet radiation and other atmospheric contaminants over the entire temperature range.
- e. Clamp bolts shall be of the "break-away" type designed to shear off at the proper clamp tightness. The appearance of the fractured bolt surface will be such as to facilitate inspection from the ground.
- f. The energy absorbing assembly shall be electrically conductive. The contractor shall specify the measured resistance between clamps.

(REV.1)

- g. The spacer-damper shall maintain the proper subconductor spacing in the span under everyday conditions and prevent contact between subconductors during conditions of wind up to 30 meters per second. The spacer-damper must also control wind-induced subconductor oscillation and aeolian vibration to the extent that damage to the spacer-damper, conductor or insulator and hardware assemblies will be prevented. The bending strain along the spans shall not exceed 200 microstrain peak to peak for aeolian vibration control and shall not exceed 600 microstrain peak to peak for subspan oscillation control. Spacing of spacer dampers shall be staggered to provide optimum control of wake-induced subspan oscillation.
- h. The Contractor shall specify the location of spacer-dampers within the various span lengths and the limit of the longest subspan that will enable the system to meet the requirements of this Specification. This data shall be for suspension to suspension, suspension to dead-end and dead-end to dead-end spans. All spacing data shall be furnished to EGAT for approval. The Contractor shall furnish all necessary information to show that its recommendation regarding type, the number, and the position, of spacer dampers is based on solid experimental and analytical data.
- i. Rigid spacers shall be used to maintain the configuration of jumper loops. Spacer dampers may be used if approved by EGAT.

F-6. Detail Requirements for Shield Wire Vibration Dampers

- a. Vibration dampers for shield wire shall be of the Stockbridge type.
- b. Dampers shall be designed to prevent the accumulation of moisture anywhere in the device.
- c. The damper clamp shall be designed to permit ease of installation and removal. The Contractor shall recommend the proper torque to be applied to the bolts of damper clamps such that no slipping of the clamps and damage to the shield wires will occur. Clamp bolts shall be furnished with a locking system acceptable to EGAT.
- d. The Contractor shall provide his recommendation for the location and quantity of dampers required within various span lengths for effective protection of the shield wires and hardware against damage due to aeolian vibration.

#### F-7. Rigid Spacers

- a. 2-Bundle Rigid Spacers. Two 2-bundle rigid spacers shall be used in each jumper loop. The dimensions and subconductor spacings shall be in accordance with the drawings.
- b. 4-Bundle Rigid Spacers. 4-bundle rigid spacers used to maintain the configuration of jumper loops shall be capable of being installed and easily removed without completely separating components. In addition, the clamp shall be capable of being removed and reinstalled on the conductors at the design torque.

Rigid spacer bolted clamps shall be furnished with a locking system acceptable to EGAT.

The dimension and subconductor spacings shall be in accordance with the drawings.

#### F-8. Detail Drawings

Detail drawings of the dampers and spacer-dampers and all component parts shall include the following information:

- a. Dimensions and tolerances for all parts and the assembly in metric units.
- b. Material fabrication details including any weld details, and any specified finishes and coatings.
- c. Catalog or part numbers for each component part and the total assembly.
- d. Assembly drawing shall include:
  - (1) Installation instructions.
  - (2) Design installation torque recommended for the bolt.
  - (3) Withstand torque that may be applied to the bolt without failure of component parts.
  - (4) Weight of assembly.

F-9. Test Requirements for Dampers, Spacer-Dampers and Rigid Spacers

The supplier shall perform the following laboratory and field tests to verify that the spacer-dampers and rigid spacers will perform acceptably during service.

- a. Laboratory Test. Laboratory test qualifications shall be based on the testing of five samples of spacer-dampers and two samples of rigid spacers. The samples will be tested individually and wherever possible, the same spacer-damper or rigid spacer will be used in all tests. Conductor samples used for all tests shall be supplied by the Contractor. Laboratory testing costs shall be borne by the Contractor and shall be included in the cost of the spacer-dampers and rigid spacers.

(1) Corona and RIV Test.

- (a) Corona observation and RIV measurements shall be made in a darkened laboratory or other suitable location. The starting voltage for all tests shall be above the visual corona level.
- (b) Before any corona and RIV test is performed, the Contractor shall submit detail drawings showing the conductor systems that will be tested to EGAT for approval. The drawings shall show the distance from the ground plane, dimensions of the laboratory, location of the specimen with respect to nearby large pieces of equipment and calculated corona inception voltages.
- (c) A ten meter long section of four bundle phase conductor will be carefully installed in the proper configuration without spacer-dampers or rigid spacers, then cleaned.
- (d) The voltage shall be raised to well above 320 kV (line-to-ground) so that corona is clearly visible along the length of the conductor.
- (e) The voltage shall be reduced slowly while visual corona just disappears from the conductor bundle, and until the bundle as a whole is free from visual corona. These levels shall be photographed with a minimum one minute time exposure, and voltage maintained on each assembly for a minimum of five minutes.
- (f) The same test procedure will be followed with the spacer-dampers (and rigid spacers in a separate test) installed on the same section of bundle conductor.
- (g) The disappearance level of visual corona on all parts of the system shall be equal to or greater than the disappearance level for the conductor alone on the previous test.

- (h) RIV readings shall be recorded at each voltage level. A curve of ambient RIV shall be obtained up to the maximum of 450 kV rms to ground. The RIV measurements including definitions, test conditions and test circuit shall be made in accordance with NEMA Standard 107 or equivalent approved by EGAT.
  - (i) All tests shall be run on the same day with the humidity at approximately the same level for each test.
- (2) Longitudinal Deflection Test. The spacer-damper shall be installed on four lengths of conductor which have been tensioned to 2,800 kg. This tension will be maintained throughout the test. The spacer-damper shall be subject to a longitudinal deflection between upper and lower pairs of clamps. The amount of deflection will be 25 millimeters in each direction from the normal position for 50,000 cycles and 15 millimeters for 2,000,000 cycles. The frequency of movement shall be approximately two hertz. At the conclusion of the test, neither the spacer-damper nor the conductor shall show any signs of damage or wear.
- (3) Vertical Deflection Test. Three clamps of one of the spacer dampers that have successfully passed the longitudinal deflection test shall be attached to lengths of conductor that have been tensioned to 2,800 kg. The fourth conductor will be subject to a vibration of 2.5 millimeters amplitude above and below a plane parallel to the conductors at a frequency of approximately 20 Hertz for  $10^7$  cycles. The conductors shall not be damaged at the clamp and the spacer-damper components shall not show any sign of deterioration.
- (4) Transverse (Torsional) Deflection Test. One of the spacer-dampers that have successfully passed the longitudinal deflection test shall be subject to a reciprocating load of  $\pm 30$  kilograms. The load shall be applied between the upper pair of clamps and normal to the vertical axis of the spacer-damper. After  $10^7$  cycles of approximately 2 hertz, the spacer-damper should show no visible sign of damage or fatigue.
- (5) Clamp Slip Test. One rigid spacer and separately, one of the spacer dampers that have successfully passed the longitudinal and vertical deflection tests of (2) and (4) above, should be installed, with bolts tightened to their design torque, on four lengths of conductor tensioned to 2,800 kilograms. The clamps shall withstand, without slipping, a minimum axial load of 200 kilograms.
- (6) Mechanical Strength (Short Circuit) Test. The spacer-damper and rigid spacer shall be capable of withstanding short circuit currents of 40,000 amperes RMS for a minimum of 6 cycles at 50 hertz without damage to the spacer-damper or subconductors. Upon removal of short circuit forces it shall restore all wires to normal spacing. A mechanical test may be used to satisfy this test requirement. Each sample shall be subject to 1,000 kilograms compression and 1,000 kilograms tension applied between diagonally opposite and then

adjacent clamps. All compression and tension loads are to be held for a minimum of one minute.

- (7) Elastomer Properties Test. The stiffness characteristics of elastomer damping pads shall be tested in accordance with ASTM D1043.

- b. Field Test. Field testing of spacer-dampers shall be performed to demonstrate their effectiveness in limiting conductor aeolian vibration magnitudes. This testing shall be performed over a period of time not less than 14 days in duration and will commence as soon as possible following construction of the span or spans to be tested. Selection of the test span or spans and the actual date of test will be subject to mutual agreement between the Contractor and EGAT. It is recommended that the Contractor prepare his construction schedule in such a manner that field tests can be performed as soon as possible following commencement of conductor stringing work. Any conductor stringing work performed prior to field tests shall be entirely at the Contractor's risk.

All tests shall be performed in accordance with the methods specified in IEEE Transaction Paper No. 31 CP 65-156, "Standardization of Conductor Vibration Measurements" and shall demonstrate that the maximum bending strain along the spans does not exceed 200 microstrain peak to peak.

In the event that the results of the test fail to meet this requirement, the Contractor shall modify his design and submit it to EGAT for approval. The modification shall then be retested at the Contractor's expense until satisfactory results are obtained.

- c. Wake-Induced Oscillation Tests. The Contractor shall furnish previously performed conclusive and detailed test reports demonstrating the effectiveness of his staggered spacing selection methods for spacer dampers in limiting the magnitude and degree of wave propagation to adjacent subspans due to wake-induced oscillation.

The Contractor shall furnish four certified copies of all laboratory and field test reports, including clear photographs of the tests for EGAT's approval.

- d. Sample Tests. Sample tests shall be made on each lot of dampers, spacer-dampers and rigid spacers offered for acceptance.
- (1) Verification of Dimensions. It shall be verified either that the Test samples comply with the requirements of the Specifications or that they are in accordance with the approved drawings, particularly as regards any dimensions to which special tolerances apply and details affecting interchangeability (e.g. dimensions for which gages are specified).



Unless otherwise agreed the following tolerances are allowed on all dimensions, except special tolerances:

<u>Dimension</u> mm	<u>Tolerance</u>
Up to and including 35	$\pm 1.0$ mm
Over 35	$\pm 2.5$ %

- (2) Galvanizing Test. Galvanized parts shall be tested in accordance with ASTM A153 and shall comply with the requirements of that standard.

The number of samples for these tests shall be selected in accordance with table below:

Number in the lot N *	Number of Samples
$N \leq 100$	1
$100 < N \leq 300$	5
$300 < N \leq 1200$	10
$1200 < N \leq 3000$	14
$3000 < N \leq 10000$	20
$N > 10000$	By arrangement between the parties concerned, a minimum number of lots comprising between 3000 and 10000 dampers or spacer-dampers will be made up.

\* N is number of dampers, spacer-dampers or rigid spacers offered for inspection.

The samples shall be selected at random from dampers, spacer-dampers or rigid spacers which have passed the appropriate routine test (if any). EGAT has the right to make the selection.

If these samples meet the test requirements, the lot is deemed to comply with the requirements of the standard. In the event of a sample not meeting the test requirements, twice the original number of new samples shall be tested. If all these new samples meet the test requirements, the lot is deemed to comply with the requirements of the standard, but if any fail to do so the lot is deemed not to comply with the requirements of the standard and shall be rejected.

F-10. Marking

Each damper, spacer-damper and rigid spacer shall be permanently marked by casting or die-stamping to indicate the following:

- a. The type and nominal cross-sectional area of the conductor or shield wire on which it is to be installed.
- b. The manufacturer's name.
- c. The upper side of spacer-dampers and rigid spacers.

F-11. Packing

Dampers, spacer-dampers and rigid spacers shall be packed in sturdy wooden cases, suitable for both ocean and inland transportation and shall be clearly marked with the following information :

- a. Description of the items
- b. Number of pieces
- c. Net weight and gross weight
- d. Contract number
- e. Project name
- f. Destination

Section G  
GROUNDING MATERIALS

G-1. General

Grounding materials to be furnished shall be as shown on Drawing No. 500-EHV-T-15.1 (REV.1) "Tower Grounding" and No. 500-EHV-T-15.2 (REV. 1) "Fence/Metal Object Grounding". Unless described herein, all materials shall be standard commercial quality suitable for the intended use.

G-2. Standard

The materials covered under this Specification shall conform to the following standard and applicable standards referenced therein, except as specified herein.

ASTM A153 Specification for Zinc coating on Iron and Steel Hardware.

G-3. Ground Rod

- a. The standard ground rod for lattice steel towers shall be copper clad steel of circular cross section 1.6 cm in nominal diameter and 3.0 m long. Each ground rod shall have a conical wedge point at one end, shall be chamfered at the other end and shall have a continuous smooth copper covering of at least 0.25 mm standard thickness molten-welded or copper bonded (electro-deposited) to a steel core.
- b. The sectional ground rod for lattice steel towers shall have the same properties as the standard ground rod except that the rod shall provide threaded ends for coupling. The coupling shall have the same properties as the ground rod and shall be so designed as to fit the ground rods properly and effectively. Driving studs shall properly fit the ground rod coupling.
- c. The ground rod shall be subject to a bend test without any sign of cracking. The diameter of pin around which the rod is to be bent shall be 40 times the diameter of the rod, and the angle of bend shall be 30°.
- d. The standard ground rod for fence and metal object grounding shall be galvanized steel of circular cross section, 1.6 cm in nominal diameter and 3.0 m long. Each ground rod shall have a conical wedge point at one end and shall be chamfered at the other end.

G-4. Ground Connecting Wire

- a. The ground connecting wire for lattice steel towers shall be No. 2 AWG solid copper-clad steel wire with 30 per cent conductivity.
- b. The ground connecting wire for fence and metal object grounding shall be 8 mm diameter, 7-strand galvanized steel wire.

G-5. Ground Connectors

- a. All grounding connections for lattice steel towers shall be heavyduty type exothermic welding.
- b. Ground rod clamps for fence and metal object grounding shall be complete with galvanized steel U-bolt, clamping piece, nuts and lock-washers.

G-6 Counterpoise

The counterpoise shall be No.2 AWG solid copper-clad steel wire with 30 per cent conductivity.

G-7. Galvanizing

All grounding materials made of steel shall be hot-dip galvanized in accordance with ASTM A153 with the weight of zinc coating being 30 per cent heavier than that specified in ASTM A153.

G-8. Marking

All components of grounding material except wire shall be marked by means of legible relief process or impress process into the metal mold or die to indicate the manufacturer's name and catalog number or description of the materials.

## PART II - CONSTRUCTION AND INSTALLATION

Section AA  
LAND PREPARATION

AA-1. Survey and Staking

The location survey of the transmission line has been performed by EGAT. Two (2) copies of key map, plan and profile drawings and structure list for the work covered by this Contract will be furnished to the Contractor after award of the Contract. All points of reference such as angle points, points on tangent and termination points, throughout the entire route of the project have been established with concrete posts by EGAT.

The Contractor shall assume full responsibility for the following work:

- a. Check Surveys. The Contractor shall perform all survey work required to establish a true tangent line between angle points. Should an angle point marker be disturbed or destroyed, it shall be reestablished by the Contractor, using reference ties set by EGAT. The Contractor shall determine the overall length of each tangent and any discrepancy from the plan and profile length in excess of  $5\sqrt{k}$  meters, where k is the length in kilometers, shall be prorated equally among all of the span lengths in that tangent. Where a major distance measurement error can be isolated to a certain span or spans or where the cumulative error over the entire tangent is in excess of  $10\sqrt{7}$  meters, the matter shall be referred to EGAT for resolution. The Contractor shall confirm the accuracy of all vertical control points shown on the plan and profile sheets. The Contractor shall check the minimum clearance of the conductor crossing existing highways, railways, major waterways, telecommunication lines, power lines etc. Where unequal tower legs are required, the Contractor shall perform site surveys and prepare diagonal profile and plan drawings for the final selection of individual leg extensions.

During the final check survey, if not enough side clearance is found, the Contractor shall perform side clearance surveys and submit the results to EGAT along with recommendations for solution of the problem.

- b. Tower Location. The Contractor shall locate all towers at the station shown on the plan and profile drawings. During staking of the location of towers, if the site of any tower as spotted in the plan and profile drawings is not suitable by reason of topographical, geological or any other affecting conditions, the Contractor shall be required to recommend a new location to EGAT for consideration. The Contractor shall carry on the work in accordance with EGAT's decision.

- c. Tower Staking. A minimum of three(3) stakes shall be provided at each tower location. One (1) stake at the center of the tower and two (2) stakes located along the longitudinal center line, 10 meters ahead and behind the center stake. The top of the center stake shall be driven to an elevation to be known as the working point from which the line and grade of the tower shall be established. The line station and elevation of the top of the stake shall be marked on the sides. The Contractor shall provide adequate protection for these stakes to prevent disturbance during right-of-way clearing, site preparation and tower construction.
- d. Survey Personnel. The check surveys and tower staking shall be performed by qualified and experienced personnel and supervised by a qualified surveyor. Not less than 15 days prior to the commencement of the work, the Contractor shall submit qualifications of personnel, work program, and list of survey equipment for approval by EGAT.

One (1) copy of corrected key map, plan and profile drawings and structure list including diagonal profile and plan drawings for hillside towers, if any, shall be submitted to EGAT with check survey data.

AA-2. Clearing of Right-of-Way and Danger Trees

All right-of-way clearing and trimming of danger trees shall be as specified herein and shown on Drawing No. TP-135C unless specifically directed by EGAT. The area to be cleared shall be determined from the check survey approved by EGAT.

- a. Within 8 Meters of Any Tower Leg. All trees, brush and stumps within 8 meters of any tower leg shall be cut off as close to the ground as practicable except trees to be stamped "Forest Department" according to the applicable Forest Act. These trees shall be cut to a height of not more than 30 centimeters above the ground.
- b. Outside 8 Meters of Any Tower Leg. All trees, brush and stumps within the right-of-way but not within 8 meters of any tower leg shall be cut to a height of not more than 30 centimeters above the ground with the exception of trees, crops and other vegetation of commercial value which shall be cut according to the following guidelines or as directed by EGAT.
- c. Commercial Vegetation. No clearing is required for trees, crops and other vegetation of commercial value that have :
  - (1) A maximum mature height above the center line elevation of not more than 3 meters if within the area 18 meters either side of the transmission line center line; or

- (2) A maximum mature height above the center line elevation of not more than 5 meters if outside the area 18 meters either side of the transmission line center line; or
  - (3) A maximum mature height above the center line elevation of not more than 7 meters if outside the area 22 meters either side of the transmission line center line; or
  - (4) A maximum mature height above the center line elevation of not more than 10 meters if outside the area 27 meters either side of the transmission line center line.
- d. Construction Clearing. If it is necessary to cut or trim any trees for the purpose of construction operations or maintenance of the transmission line to a greater degree than specified in a through c, they shall be cut or trimmed to the minimum necessary.
  - e. Outside of Right-of-Way. The clearing shall include the cutting or trimming of all danger trees outside of the right-of-way.
  - f. Minimum Damage. All trees to be cut must be cut and disposed of in such a manner as to minimize damage to other trees. Felled trees stamped "Forest Department" shall be trimmed and piled at the side of the right-of-way or as directed by EGAT. All other materials shall be disposed of as approved in writing by EGAT. All materials to be burned shall be piled and when in suitable condition shall be completely burned. Piling for burning shall be done in such a manner and in such location as will cause no fire risk, and all materials which cannot be completely burned as the work proceeds shall be piled in approved locations and thereafter completely disposed of by burning prior to any tower erection within one kilometer of the burning. The Contractor shall at all times take special precautions to prevent fire spreading to areas beyond the limits of the clear areas, and shall be liable for any fire damage.
  - g. Orchards and Gardens. Where the right-of-way is through well-developed areas such as orchards and garden areas, clearing will be confined to the tower sites, except that EGAT will require trimming or removal of all trees and obstructions that interfere with operation of the transmission lines. The Contractor shall make provisions for maintenance of existing irrigation throughout these areas. The construction operations must be performed in a manner to keep property damage to a minimum and in a manner approved by EGAT.
  - h. Deep Valleys. Where the transmission line crosses deep valleys, right-of-way clearing may be to a width of 15 meters either side of the transmission line center line when "special clearing" is noted on the plan and profile and approved by EGAT. No other clearing need be performed in such valleys except as directed by EGAT to assure line security.



- i. Buildings. All buildings and dwellings within the right-of-way will be removed by the owners under agreements reached when EGAT obtained right-of-way permits. The Contractor will not be required therefore to remove buildings and dwellings from the right-of-way. If any buildings remain in the right-of-way at the time the Contractor is ready to clear, he shall so inform EGAT and request a decision on removal of such buildings.
- j. Final Clearing. The Contractor shall, upon completion of the entire transmission line and prior to the work being delivered to EGAT for acceptance, cut and clear the entire right-of-way. This work shall be done as part of the clearing of right-of-way and the Contractor shall include it in the Bid Price Schedule.

AA-3. Subsoil Tests

The Contractor shall perform subsoil tests at tower locations, to a depth, and by the method of test specified by EGAT. The details of performing the test, and tools and equipment to be used, shall be submitted to EGAT for approval.

Subsoil tests shall be carried out by one or more of the methods stated hereafter under the supervision of a qualified person, who shall be subject to the approval of EGAT.

- a. Light Ram Sound (Kunzelstab) Test. This method shall be used for tests to the depth of not more than 10 m from ground level. The test shall be performed in such a manner that the number of blows per 20 cm of penetration can be obtained continuously along the boring depth. The data obtained shall be prepared to show the penetration record including recommended bearing capacity of soil along the boring depth. "Procedure for Conducting the Light Ram (Penetrometer) Sound (Kunzelstab) Test" are attached in Appendix 1.
- b. Standard Penetration Test. This test method shall be used primarily for taking samples in addition to making penetration tests. Unless otherwise directed by EGAT, soil samples need not be collected except at tension tower locations and potential test sites for individual piles or foundations. Penetration and sampling shall be done in accordance with ASTM D1586. The test shall be performed in such a manner that the number of blows per foot of penetration can be obtained at every change in stratum but at intervals not greater than 1 m. The data obtained shall be prepared to show the penetration record including recommended bearing capacity of soil along the boring depth.
- c. Dutch Cone Test. Primarily for relatively soft soils, this method shall conform to ASTM D3441 using a friction cone penetrometer and can be used for tests at any depth. The test shall be performed in such a manner that the cone resistance and the side friction of the friction sleeve can be obtained separately at every change in stratum but at intervals not greater than 50 cm. The data obtained shall be prepared to show the values of cone resistance, side friction, the ratio of side friction to cone resistance including recommended bearing capacity of soil along the boring depth. For plotting the graph of cone resistance, the scale shall be Tons/m<sup>2</sup>.

- d. Vane Shear Test. This method shall be performed in accordance with ASTM D2573 and used only for very soft to medium clay at any depth depending on the capability of the equipment. The test shall be performed in such a manner that the maximum and minimum torque required to rotate the blade of the vane embedded in soil can be obtained at every change in stratum but at intervals not greater than 1 m. The data obtained shall be prepared to show the undisturbed and remold shear strength of soil along the boring depth.
- e. Chemical Analysis. At selected locations, the Contractor shall determine the concentration of sulphates, the degree of alkalinity in soils and ground water and chlorides as c1 at a depth specified by EGAT. The values of sulphate concentration shall be expressed in per cent Of  $SO_4$  for sulphates in soils and in parts of  $SO_4$  per million for sulphates in ground water. Alkalinity shall be expressed as a pH and parts  $CaCO_3$  per million and the Cl content of water in soil as parts per million (ppm).
- f. Laboratory Tests. Laboratory tests shall be made on relatively undisturbed soil samples taken in accordance with ASTM D1587. Minimum tests shall be as follows (but not necessarily for each layer of soil or each sample). Samples shall be chosen to give a representative profile for the site.
- (1) Unit weights
  - (2) Gradation of cohesionless soil
  - (3) Atterberg's Limits for cohesive soil
  - (4) Unconfined compression tests
  - (5) Consolidation tests
  - (6) Direct shear tests
  - (7) Tri-axial tests
  - (8) Chemical contents of soil and water, as requested
  - (9) Other tests deemed necessary by the Contractor and approved by EGAT.

The data obtained over the entire range of depth of each subsoil test shall include date of test, structure number, station, ground surface condition, test method, sample elevation, natural density of soil, limit of strata, maximum water level, ground water level, soil classification and the depth of subsoil test. The data thus obtained shall be prepared to show the nature and extent of the soil strata over the area under consideration and submitted to EGAT.

EGAT has designed each type of foundation in accordance with the results of preliminary data. Selection of a particular foundation shall be made by the Contractor in an approved form for each tower to suit its particular site conditions and shall be submitted for the review and approval of EGAT. EGAT reserves the right to make final selection of foundation type for each tower site based upon its judgement of the nature of subsoil conditions or other factors affecting construction or operation of the transmission line.

All of the subsoil tests described under this Article shall be made as soon as possible after award of the Contract, and the submission of the test results and final foundation list shall be made within six (6) months after award of the Contract.

AA-4. Preliminary Measurement of Earth Resistivity

The Contractor is required to perform a preliminary earth resistivity test at every tower location. Method of measurement, tools and instruments shall be submitted to EGAT for approval.

The measurement of earth resistivity expressed in ohm-meter shall be performed in accordance with Article 8.02, Four-Point Method of IEEE Standard No. 81.

The Contractor shall prepare and submit to EGAT for review and approval a summary of resistance data measured at each site and a description of the method of grounding (in accordance with drawing 500-EHV-T-15.1 REV. 1) recommended for each site.

AA-5. Boundary Posts

The Contractor shall supply and install one boundary post on each side of the right-of-way at each tower location or as specified. The boundary posts shall be as shown on drawing TP-602A. The quality and processing of materials used in boundary posts shall be equal to that specified for tower foundations.

AA-6. Tower Site Preparation and Protection

Prevention and control of soil erosion at tower sites is of prime importance.

During the construction of his access roads, the Contractor shall grade and slope his roads to prevent any unnecessary water flow across the tower site and to minimize soil erosion.

The tower sites shall also be sloped as necessary to protect against erosion due to water flow. If there is a natural flow of water across the tower site, the water flow shall be diverted around the site or the site shall be suitably protected against erosion by grading and/or placing of rip-rap or other erosion barriers.

No access roads shall be cut into a hillside immediately below a tower site where it may threaten the stability of the site and the tower foundations. Plans for access' roads in the immediate vicinity of tower sites in steep mountainous terrain shall be submitted to EGAT for approval.

In mountainous terrain, the stability of slopes greater than 30 degrees shall be individually checked and this information given to EGAT prior to final selection of the foundation to be used.

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Section BB  
TOWER FOUNDATIONS

BB-1. General

This specification covers the design, supply of materials, locating and installation of foundations for 500 kV lattice steel transmission towers in accordance with the drawings and specifications furnished and/or approved by EGAT. EGAT may choose to furnish design drawings. In such cases the provisions of paragraphs BB-2a, BB-2b, BB-2c and BB-2d of Article BB-2. Design of Foundations, do not apply but all other paragraphs and provisions do apply.

Foundations will consist of spread footings or driven piles.

The soil classification used to differentiate among foundation types is shown on Drawing 500-EHV-C-1.

The driven pile type of foundation is for use in soils that are unsuitable for spread footings. The detailed design and fabrication of the prestressed concrete piles shall be the complete responsibility of the Contractor and shall be in accordance with applicable Articles of this specification and the project drawings.

The final selection of the types of the foundations to be constructed for each particular tower will be dictated by the results of the subsoil tests as described in Article AA-3.

Foundations shall be located and staked by the Contractor. Excavation, backfill, compaction and concrete work shall be in accordance with the appropriate Articles of this specification and the project drawings. All jigs, templates and accessories for proper foundation alignment shall be furnished by the Contractor. The Contractor shall furnish all equipment, labor, concrete, reinforcing steel, forms and other materials required to construct foundations.

BB-2. Design of Foundations

Foundations shall be designed for each type of tower to be constructed based on the criteria and basic data for calculation and selection of foundations shown on the drawings. The design shall be such that the tower structure shall be securely supported and unbalanced displacement that may cause harmful effect to the tower structure shall not be produced. The following procedures shall be used:

- a. Loads. The loads acting on the foundation shall be the maximum loads determined from each of the loading conditions for each tower type and shall take the tower and leg extension heights into consideration (including the potential for use of leg extensions of various heights on the same tower).
- b. Design Basis. Foundations shall be designed in accordance with the following requirements.
  - (1) Foundation outline and dimensions shall conform in general to those shown on the drawings supplied by EGAT.
  - (2) Stability of foundations (i.e. foundation/soil interactions) shall conform to factors of safety required in paragraph BB-2c. These factors of safety shall be applied to reactions devoid of tower design overload factors.
  - (3) Stresses in concrete and in steel reinforcement shall be in accordance with the Ultimate Strength Design methods outlined in ACI Standard 318. Minimum overload factor (on top of stresses resulting from tower reactions devoid of tower design overload factors) shall be 1.50.
  - (4) Design drawings shall be submitted for approval together with the Detail Calculations required by paragraph BB-2d.
- c. Factors of Safety. The foundations shall be designed in such a manner that the factors of safety relating to foundation/soil interactions shall not be less than the following requirements:

Type of Foundation	Type of Stability	Factor of Safety
Spread Footing	Maximum net soil pressure resisting compression loads with associated horizontal loads	2.0
	Resistance to vertical uplift loads	1.5
Pile Foundations	Resistance to compression loads with associated horizontal loads	2.0
	Resistance to uplift loads with associated horizontal loads	2.0

- d. Detail Calculations. Detail calculations for each type of foundation shall be submitted for approval. Such calculations shall include the following.
- (1) Detail calculations of forces acting on foundation for each loading condition.
  - (2) Actual safety factors for each type of stability and condition as specified in BB-2c.
  - (3) Maximum stresses in concrete and in steel reinforcement at all critical sections.
  - (4) Loads acting on each pile for each loading condition.
  - (5) Detail calculations for anchorage and reinforcing bar areas, embedments, spacings, etc.
- e. Shop and Construction Drawings. Details of each type of foundation submitted for EGAT's approval shall be as shown on the approved design drawings and shall conform to the requirements described hereafter. Once approved, no change shall be made without the written approval of EGAT. The shop and construction drawings shall at least include:
- (1) Detail dimensions of foundations.
  - (2) Details of setting dimensions of foundation for every type of leg extension.
  - (3) Details of placing of all reinforcing steel which shall conform to the Building Code Requirements for Reinforced Concrete (ACI 318) and Manual of Standard Practice for Detailing Reinforced Concrete Structures (ACI 315) unless otherwise specified herein and shown on the drawings. Also, details of type, size and length of all reinforcing steel including details of bar bending. This includes prestressed concrete piles.
  - (4) Details of concrete used, including type and size of aggregate, cement used, water/cement ratio, slump, additives, methods of placing, form work used, strengths, testing cylinders, etc. This includes the prestressed concrete piles.
  - (5) Details of concrete covering for protection of steel reinforcement which shall not be less than 5 cm for structure exposed to weather or backfill or submerged, and 7.5 cm for concrete placed directly against ground, rock and surfaces subjected to corrosion caused by sulphates or corrosive chemicals.

- (6) Details of cut off elevation of piles which shall be embedded a minimum of 15 cm into the pile cap.
- (7) Details of spacing of piles which shall not be less than 3 times the diameter of the pile or the largest side of the pile. Detail of inclination of batter piles shall also be included.
- (8) Details of size and length of dowel bars embedded in pile cap.
- (9) Details of stub setting template for setting all four stub angles and jig for setting individual stub angles for each type of tower foundation for the approval of EGAT.
- (10) Details of placing of grounding system which shall conform to the details shown on drawing No. 500-EHV-T-15.1 (REV.1).

**BB-3. Foundation Orientation**

The Contractor shall assume full responsibility for the accuracy of the location and orientation of each tower foundation. The foundation of each tower shall be placed in such a manner that the position of the longitudinal axis of the tower crossarms will lie as follows :

- a. In a plane perpendicular to the traverse of the line in a tangent section.
- b. In a plane bisecting the interior angle formed by the intersection of the adjacent tangents for each angle tower.
- c. In a plane perpendicular to the tangent of the line (regardless of the angle of the slack span) for foundations of each substation terminal tower except where otherwise indicated on the drawings.

**BB-4. Line and Grade**

The Contractor shall provide all lines and grades or elevation of the ground at each footing and set the necessary stakes that are required for the work and will be held responsible for their accuracy. EGAT may check lines and levels set by the Contractor from time to time but the responsibility for their accuracy shall rest entirely. with the Contractor.



## EARTHWORK FOR TOWER FOUNDATIONS

### BB-5. Excavation

- a. General. Excavation for foundations shall include all excavation required for installation of foundations, leveling around the individual tower foundations, and grading or preparation for construction at the tower site. Where necessary, or as directed by EGAT, adequate drainage shall be provided around the tower site. Generally, excavated material shall be laid aside to be used for backfill and embankment at the tower site from which it was excavated and the excess material shall be spread evenly around the site after completion of the foundation back filling. Where excavation is on farm or cultivated land, the top soil should be stripped and laid aside, separate from other excavated soil, and placed back on top of the backfill after the foundation has been constructed.

Foundation excavation shall be sufficient to result in concrete footings with lines and dimensions as shown on the drawings and within the tolerances herein specified.

Embedment depths shown on the drawings shall be maintained at the shallowest part of an excavation, if on sloping ground.

The excavation shall extend a sufficient distance from foundations to allow for placing and removal of forms and for inspection, except where concrete is authorized to be deposited directly against the sides of the excavation. When concrete is to rest on a surface other than solid rock, special care shall be taken not to disturb soil at the bottom of the excavation. Excavation to the final level shall not be made until just before the concrete is to be placed. Grading shall be done as may be required to prevent surface water from flowing into the excavation. The excavation shall be shored as required to retain the hole and to protect the workers. The shoring shall be removed as the hole is backfilled. Any mud, silt, or other objectionable materials which accumulate in the bottom of the excavation shall be removed prior to placement of concrete. In case of overexcavation without specific direction or required to remove loose, muddy, or objectionable material which has accumulated in the bottom of the excavation, the base of concrete shall be extended to the bottom of the excavation. All additional work of this nature shall be at the Contractor's expense.

Foundation excavations shall be sufficiently protected to prevent injury to humans, livestock or wildlife when unattended. Excavation subject to caving shall be properly shored before allowing workmen to enter.

- b. Rock Excavation. The Contractor shall furnish all materials and equipment to perform all work required for excavation of rock at the location where concrete foundations are to be constructed. Rock excavation may be made by drilling, barring, wedging, approved blasting or compressed-air tools.

If the Contractor chooses to propose a special rock type foundation for any tower location, the characteristics and extent of rock encountered shall be determined by the Contractor at the time of performance of subsoil testing and all such data shall be supplied to EGAT along with the Contractors proposed rock type foundation design.

Disintegrated rock or other types of rock such as soluble limestone, soft shale, slate, hard pan and organic rocks may not be suitable for construction of rock type foundations. If any doubt exists in selecting the type of foundation for such types of rock encountered, EGAT reserves the right to approve and/or select the suitable type of foundation.

The surface of all rock foundations upon or against which concrete is to be placed shall be prepared to provide for an adequate bond between the rock and concrete. All loose or unsound rock, dirt or other undesirable material shall be removed from the prepared rock surfaces. Bearing planes shall be predominantly horizontal.

- c. Blasting Blasting will be permitted only when proper precautions are taken for the protection of persons, work and public or private property. Any harm or damage done to persons, work or property by blasting shall be the sole responsibility of the Contractor. Hauling, storage and handling of explosives shall be carried out in strict compliance with the requirements of applicable laws and regulations.

Plans and methods of operation for blasting including sites and schedules shall be submitted to EGAT for approval prior to implementation. Caps, exploders, or fuses shall not be kept or transported in the same place as dynamite or other explosives. An inventory of all explosive materials shall be kept and EGAT shall be notified immediately of loss or theft. EGAT shall be notified a minimum of 48 hours prior to each use of blasting. The Contractor shall not be reimbursed for expenses related to blasting other than the applicable unit price for rock excavation.

BB-6. Backfill

- a. General. Backfill shall be placed around the tower foundations. The material used for backfill, the amount thereof, and the manner of depositing the material shall be approved by EGAT. The excavation shall be kept dewatered during placement and compaction of backfill. If concrete curing compound is used after forms are removed from concrete, the backfill shall not be placed until 8 hours after the curing compound has been applied to the concrete. Material removed in excavation, which is not suitable or is not required for backfill and embankment, shall be spread evenly over the site. Suitable borrow material, as determined by EGAT, shall be used in backfill to replace such unsuitable soil removed during excavation, as required. Except for foundations requiring embankments, all surfaces of the backfill around the concrete shall be carried beyond the excavation boundary to an elevation approximately 20 cm above the natural ground level and shall be gently sloped away from the footing pedestals to blend into the surrounding natural grade. All top soil shall be replaced at the surface where towers are on cultivated land. Care should be taken to avoid damage to the concrete when depositing backfill. Where curing compound is not used, backfill shall not be placed around any foundation for at least 7 days after the completion of the foundation concreting operation. Backfill material shall be clean and free from vegetation, pieces of timber, large stones, or other foreign matter.
- b. Compacting Backfill. The material to be compacted shall contain no stones greater than 10 cm in diameter. The material to be compacted shall be deposited in horizontal layers having a thickness of not more than 20 cm after being compacted as hereinafter specified. The distribution of materials shall be such that the compacted material will be homogeneous and free from clods, pockets, streaks or other imperfections. Placing operations shall be such that the materials will be blended sufficiently to secure the required degree of compaction, impermeability, and stability. Prior to and during compaction operations, the backfill material shall have the optimum practicable moisture content required for the purpose of compaction. The moisture content shall be uniform throughout the layers of backfill. If borrow material is being used, moistening shall be performed at the site of excavation, but such moistening shall be supplemented, as required, by sprinkling at the site of compaction. When excavated material becomes so wet that it is not suitable for achieving the required degree of compaction when placed as backfill, it shall be spread and aerated until the proper moisture content is attained before backfilling and compaction. After the material has been conditioned as herein specified, it shall be placed all around the concrete uniformly to approximately the same elevation and shall be compacted by tamping machines. This requirement shall be strictly adhered to. Special care shall be taken to prevent wedging action against the concrete. The material shall be compacted to at least 85 per cent of the maximum density obtainable in the Standard Proctor density test as specified in ASTM D698 (Method A). EGAT will periodically perform backfill soil density tests to insure that the Contractor is achieving the required degree of backfill compaction. Any foundation

backfill so determined to be inadequately compacted shall be removed and re-backfilled at the Contractor's expense.

BB-7. Embankment

If required, the Contractor shall construct temporary embankments to dewater tower sites where foundations are located in standing water of rice paddies, sloughs, pot holes or marshes. No plowing or scarifying of the ground surface under the embankments will be required. Where required, embankments shall be placed in water. The embankments shall consist of suitable materials, obtained from required excavations or from borrow. If there is a choice of material placed in the embankments, the coarse material shall be placed in the outer slopes of the embankments. The face of slope of embankments for leveling of ground slopes shall not be less than 1.2 horizontal to 1.0 vertical. The Contractor shall route his hauling equipment over the areas of embankment in place and shall distribute the travel evenly over the entire embankment area so as to distribute compacting effect of the equipment to the best practicable advantage. No other compaction of the embankment will be required. The Contractor shall maintain embankments until acceptance of the portion of the work under the Contract. Unless otherwise determined by EGAT, embankments shall be leveled after acceptance and the borrow material returned to the borrow area or disposed of by the Contractor in a manner acceptable to EGAT.

BB-8. Excavation from Borrow for Embankments

The location of borrow areas where suitable material for embankment may be obtained will be designated by EGAT. The Contractor shall strip the borrow area of all unsuitable material as may be necessary to obtain required quantities of borrow materials. The surface of borrow areas shall be left in a reasonably smooth and even condition.

BB-9. Dewatering Excavations

The Contractor shall furnish all materials and equipment and perform all work required for dewatering the excavations as required to permit construction of the foundations as indicated on the drawings. During the placement of concrete, the water level in the excavation shall be kept below the bottom surface of the excavation.

BB-10. Subbases for Pile Caps

Gravel and lean concrete subbases shall be placed respectively under the concrete pile caps for driven pile foundations. The subbases shall be placed just prior to the placing of the concrete. The Contractor shall perform all excavation below the elevation of the underside of the pile cap required to place the gravel and lean concrete subbases. The gravel and lean concrete subbases shall be placed to a depth of approximately 10 cm each. The gravel subbases shall consist of pit run, free draining gravelly material containing no stone larger than 6 cm in size and shall be clean and free from vegetation, pieces of timber, or other foreign matter. Sand or crushed stone may be used for gravel subbase if approved by ECAT. Both subbases shall be tamped and levelled. The top surface of the completed lean concrete shall conform to the established elevation of the underside of the concrete pile cap.

PILES FOR TOWER FOUNDATIONS

BB-11. Types of Piles

Unless otherwise approved, piles for tower foundations shall be precast prestressed concrete piles that have been manufactured by the pretensioning method. The Contractor shall design, manufacture and install piles in accordance with ACI 543 R-74, Recommendations for Design, Manufacture, and Installation of Concrete Piles, and as specified herein and on the drawings.

BB-12. Size and Length of Piles

Two pile sizes have been selected. They are 35 cm x 35 cm square and 40 cm x 40 cm square is cross section. Only solid square cross sections are acceptable.

After approvals, as required, of the design and detail of piles, pile load tests and results of subsoil tests, the Contractor shall submit to EGAT the length of piles to be used for each foundation for approval before proceeding with piling work.

BB-13. Materials for Piles

- a. Concrete. The concrete for piles shall have a minimum compressive strength,  $f_c'$ , of 350 kg/sq.cm and a minimum cement content of 400 kg/cu.m for type I portland cement.

- b. Reinforcing Steel. The prestressing wires, deformed bars and plain round bars shall conform to Thai Industrial Standard: TIS 95-2517, TIS 24-2516 and TIS 20-2520 respectively.

**BB-14. Concrete for Piles Exposed to Sea Water or Sulphates in Soils**

The Contractor shall follow the requirements listed in the following table for concrete piles exposed to sulphate attack caused by sea water or sulphate in soil:

Case	Classification of Condition		Prestressed Concrete Piles Zero Slump	
	Sulphate as SO <sub>4</sub> in Soil (%)	Sulphate as SO <sub>4</sub> in ground water (ppm)	Type of Portland Cement	Minimum Cement Content (kg/cu.m.)
1	0.1 - 0.5	150 - 1200	I	400
			II	310
2	0.5 - 1.0	1200 - 2500	II	350
			V	340
3	Above 1.0	Above 2500	V	340

**BB-15. Structural Designs of Piles**

- a. Capacity of Piles. Minimum pile strengths shall be as follows:

<u>Size of Piles</u>	<u>Rated Tension</u>	<u>Rated Compression</u>	<u>Rated Moment</u>
	T (1000 kg)	T (1000 kg)	T-cm
35 cm x 35 cm solid square	25	50	500
40 cm x 40 cm solid square	35	70	747

The design of the piles shall also provide adequate structural strength to resist the expected driving stresses without damaging the piles.

- b. Longitudinal Reinforcement. Prestressing steel for prestressed concrete piles shall be selected to give an effective prestress after losses of not less than 20 per cent of the specified standard 28 day cylinder strength.
- c. Lateral Reinforcement. Lateral reinforcement for prestressed concrete piles shall be spiral or equivalent hoops with minimum diameter of 4 mm. The spacing shall be 5 turns of 2.5 cm pitch at each end, 7.5 cm pitch for the next meter and a maximum pitch of 15 cm for the intermediate section.
- d. Lifting Points. Lifting points of piles shall be designed in such a manner that these points shall be those which theoretically produce the least bending moment throughout the length of the piles.

In the design of lifting points, the minimum of 33 per cent impact during handling and transportation shall be taken into account.

- e. Splicing. In general, piles shall be of continuous, single length. If splicing is required and permitted by EGAT, the Contractor shall submit the design and detail of splices for EGAT's approval. Pile splices must be capable of developing the full tensile, bending, and compressive strengths of the piles.

#### BB-16 Details of Piles

In addition to the dimensions of pile and steel reinforcement arrangement, the detail drawings submitted for EGAT's approval shall conform to the following requirements:

- a. Pile Tip. The pile tip shall be flat.
- b. Covering. Minimum clear covering of concrete over steel reinforcement shall conform to the following requirements:

<u>Type and Exposure</u>	<u>Minimum Clear Covering</u>
- normal exposure	3.5 cm
- marine or corrosive substance exposure	4.0 cm

- c. Edges and Corners. The top edges and corners of the precast prestressed concrete piles shall be chamfered.

- d. Lifting Points. Lifting points of piles shall be clearly marked by a band of paint or by providing holes with steel pipe sleeve to indicate the points of attachment of the handling slings.
- e. Dowel Bars. Dowel bars shall be used to anchor each pile into the cap and shall be capable of developing the rated tensile and bending strengths of the piles. The length of the dowel bars pre-embedded in the top part of pile during manufacturing shall conform to the following requirements:

<u>Size of Piles</u>	<u>Minimum Pre-embedded Length</u>
140 cm and 160 cm effective perimeter	3.3 m

BB-17. Manufacture of Reinforced and Prestressed Concrete Piles

Manufacture of reinforced and prestressed concrete piles shall conform to the requirements specified in ACI Recommendation of Concrete Piles for Design, Manufacture and Installation of Concrete Piles and shall conform to the following requirements :

- a. End Forms. End forms shall be securely fastened to the pile form so that the pile head will remain in a true plane perpendicular to the pile axis.
- b. Hollow Cores. Hollow cores in pile must be concentric with the pile center line throughout the entire length of the hollow section. Forms shall be of an approved water resistant material and shall resist breakage or deformation during the placing of the concrete.
- c. Embedded Dowel Bars. Dowel bars shall be accurately set in the forms parallel to the axis of the pile and secured to prevent movement during concrete placing. Particular care shall be used to insure proper cover of embedded dowel bars.
- d. Curing. Concrete piles shall be maintained in a moist condition for at least 5 days after placing or until design strength is obtained. Curing shall be done by means of water curing, membrane curing or steam curing.
- e. Manufacturing Tolerances. Piles shall be manufactured to the following dimension tolerances :
  - (1) Length  $\pm 10$  mm per 3 meter of length
  - (2) Cross section



- Wall thickness of hollow section -3 mm to +10 mm
- Solid section -3 mm to +12 mm
- (3) Deviation from straight line of not more than 4 mm per 3 meter of length
- (4) Deviation of internal core from true position  $\pm 10$  mm
- (5) Pile head  $\pm 2$  degrees to the true plane
- f. Prestressed Wire Cutting. Prestressed wires shall not be cut off until the concrete strength reaches 250 kg per square centimeter. The cutting shall be such that all prestressing steel are flush with the end of the pile otherwise they shall be ground out.
- g. Handling, Transportation and Storage. Piles shall not be handled, transported or stored in any way which will result in damage to the pile. Piles shall be lifted and blocked for storage at predesignated points in such a manner that bending stresses will be within acceptable limits specified in the design of piles. Piles with any crack shall be rejected.

#### BB-18 Installation of Piles

Piles shall be installed accurately to the required position, alignment and depth with gravity, steam, internal combustion hammers or by other means approved by EGAT. The drop length of the hammer shall not exceed 90 cm. The proposed hammer and striking part shall be subject to the approval of EGAT and shall develop an energy per blow of not less than 3 kg-m per 10 kg of weight driven.

The transportation, storage, handling, and pile driving methods shall not subject piles to excessive and undue abuse producing crushing and spalling of the concrete, injurious splitting, deformation of the steel or misalignment. The top face of the pile to be driven shall be perpendicular to the longitudinal axis of the pile and no steel reinforcement or dowel bars shall protrude from the head. EGAT reserves the right to reject any pile at any time throughout the delivery and installation if it determines that the pile may be unsuitable due to improper fabrication, handling, storage, or installation. In this case, the Contractor shall promptly remove and replace the pile in question and shall have no claim for additional compensation for this work nor for delays which may result.

Piles being driven shall have an adequate driving head to distribute the blow of the hammer to the head of the pile. The driving head shall be axially aligned with the hammer and the pile. Between the driving head and the hammer, there shall be a capblock to protect the pile and the hammer from damage. Capblocks may be made of hard wood or other materials capable of transmitting the energy to the pile effectively without excessive elastic energy losses.

The top of the piles shall be covered by suitable cushions while they are being driven. Cushions shall be at least 10 cm thick of soft wood block or 16 layers of gunny sacks. A new cushion shall be provided for each pile, or replaced during driving when the cushion becomes highly compressed, charred or burned.

Piles shall be secured against lateral movement during driving by leads or other suitable means. Excessive manipulation of piles during or after driving to force them into proper positions will not be permitted. All piles pushed up by the driving of adjacent piles or by other causes shall be driven down. The top of the piles at cut-off elevation shall not be out of the position shown on the drawings more than 1 per cent of pile length nor more than 15 cm after driving.

Any pile damaged by reason of internal defects, or by improper driving, or driven out of its proper location shall be corrected at the Contractor's expense by one of the following methods approved by EGAT for the pile in question:

- a. The pile shall be withdrawn and replaced by a new one and, if necessary, a longer pile.
- b. A second pile shall be driven adjacent to the defective pile.

All materials forced up between the piles shall be removed to the base elevation approved by EGAT before gravel subbase for pile cap is placed.

All piles, except the reinforcement therein, shall be cut-off at the specified elevation; vertical piles shall be cut-off to true horizontal planes, and batter piles shall be cut-off to planes normal to the axis of the piles. Dowel bars shall be left extending from all piles above the specified cut-off planes for anchorage into the pile cap as shown on the drawings.

During driving, an accurate record of the penetration and blow count of each pile driven shall be kept by the Contractor. These records shall be available to EGAT at all times.

For estimating and evaluation purpose, the ultimate resistance of vertical piles shall be determined by the Danish formula:

$$Q = \frac{\infty WH}{S_o + \frac{S}{2}}$$

$$S_o = \sqrt{\frac{2\infty WHL}{AE}}$$

Where

Q = Ultimate resistance to driving in kg

W = Weight of striking parts of hammer in kg

H = Height of drop for the hammer in cm

S = Average penetration, in cm per blow for the last 5 blows

S<sub>o</sub> = Elastic compression of pile in cm if all available hammer energy is used for compression of pile

L = Length of pile as driven in cm

A = Cross-sectional area of pile in sq.cm

E = Modulus of elasticity for pile material in kg/sq.cm (recommended value of 2.2 x 10<sup>5</sup> kg/sq.cm)

∞ = Efficiency of hammer. Values given below may be substituted by manufacturer's efficiencies or net delivered energies if based on actual tests:

Diesel hammer : 100%

Single-acting air or steam hammer : 80%

Gravity hammers : 100% for hammers released by triggers

75% for hammers actuated by rope and friction winch

When driving batter piles with gravity hammer, the effective height of drop is reduced and friction also occurs in the guides. Taking the coefficient of friction as 0.1, the effective value of drop H' to be used in the formulas in place of H shall be taken as follows:

$$H' = H (\cos \theta - 0.1 \sin \theta)$$

Where

$\theta$  = angle between the batter and the vertical

The Contractor shall furnish to EGAT the data required for use in the aforementioned formula. The minimum penetration or ultimate resistance to which the piles shall be driven for the towers shall be as instructed by EGAT.

#### BB-19. Pile Extension

When the top of the pile has been driven to a short distance below grade, lowering of the pile or splicing cap may be employed. If the extension of pile is exercised, the use of epoxy grout and a doweled splice is recommended.

Splices shall develop the requisite strength in compression, bending, tension, shear and torsion at the point of splicing during driving and in service.

### REINFORCED CONCRETE WORK FOR TOWER FOUNDATIONS

#### BB-20. Scope

Concrete work described herein applies to spread footings, pile caps for driven piles, and any other concrete foundation type which may be required.

#### BB-21. Composition

- a. General. Quality of concrete shall conform to the requirements of ACI 318 and this specification. Concrete shall be composed of cement, fine aggregate, coarse aggregate, water and admixtures (if required) all well mixed and brought to the proper consistency. The specified minimum cylinder strength required for cast in place concrete placed above water for all types of foundations is 210 kg/sq.cm in 28 days. The mix proportions shall be submitted to EGAT for approval on the basis of producing concrete having suitable workability, density, impermeability, durability, and required strength, without the use of an excessive amount of cement and without exceeding a net water to cement ratio (exclusive of water absorbed by the aggregates) of 0.58 by weight without any admixtures. Air-entrainment may be used with reduced water to cement ratio. Proportions shall be established based on field experience or trial batches. Strength tests shall conform to requirements of Article BB-31c.

- b. Consistency. The amount of water used in the concrete shall be regulated as required to secure concrete of the proper consistency and to adjust for any variation in the moisture content or grading of the aggregates as they enter the mixer. Addition of water to compensate for stiffening of the concrete before placing will not be permitted. Uniformity in concrete consistency from batch to batch will be required. The slump of concrete at time of placement, but before it has been consolidated, shall be between 5 and 7.5 cm for concrete not placed under water.

BB-22. Cement

To prevent undue aging of sacked cement after delivery, the Contractor shall use sacked cement in the chronological order in which it was delivered on the job. Each shipment of sacked cement shall be stored so that it may readily be distinguished from other shipments.

Bins in which bulk cement is stored shall be weathertight. The bins shall be emptied and cleaned by the Contractor when so directed: however, the intervals between required cleanings will normally not be less than 4 months. The cement shall be free from lumps and shall be otherwise undamaged when used in concrete.

The cement shall conform to Thai Industrial Standard for Portland Cement, TIS 15 Vol. 1-2514. The Contractor shall inform EGAT in writing, at least 30 days before first shipments are required, concerning the mill or mills from which the cement is to be shipped; whether cement will be ordered in bulk or in sacks; in order to identify the cement to be used by the Contractor. Brands of cement or the same brand from different mills shall not be mixed. Proportions used to establish mixes shall not be changed without approval of EGAT.

If required, cement will be sampled and tested by EGAT in accordance with TIS 15. Cement not meeting test requirements will be rejected. Rejected cement shall be replaced with acceptable cement and the Contractor shall be entitled to no adjustments in price or completion time by reason of any delays occasioned thereby.

BB-23. Water

Water used in mixing concrete, mortar and grout shall be clean and free from injurious amounts of oils, acids, alkalis, salts, organic materials or other substances that may be deleterious to concrete and steel. Mortar cubes made with nonpotable mixing water shall have 7-day and 28-day strengths equal to at least 90 per cent of the strengths of similar specimens made with potable (drinkable) water.

BB-24. Fine Aggregate

- a. General. The source of supply for fine aggregate shall be subject to the approval of EGAT. The term "fine aggregate" is used to designate aggregate in which the grading of particle size is as described in paragraph BB-24c below.
- b. Quality. The fine aggregate shall consist of hard, dense, durable uncoated rock fragments and shall be free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, loam, mica, and other deleterious substances. The percentage of material passing the No.200 standard screen shall not exceed 5 per cent. The sum of the percentages of all deleterious substances shall not exceed 7 per cent by weight. The fine aggregate shall be free from injurious amounts of organic impurities. Fine aggregate producing color darker than the standard in the calorimetric test for organic impurities may be rejected.
- c. Grading. The fine aggregate, as batched, when tested by means of standard sieves shall be graded within the limits specified hereunder:

Size of Sieve with <u>Square Opening</u> mm	Percentage by Weight <u>Passing</u>
9.5 (3/8 inch)	100
4.8 (No.4)	95 - 100
2.4 (No.8)	80 - 100
1.2 (No.16)	50 - 85
0.6 (No.30)	25 - 60
0.3 (No.50)	10 - 30
0.15 (No.100)	2 - 10

In addition, its fineness modulus shall be not less than 2.3 nor more than 3.1.

- d. Tests. EGAT will test the fine aggregate in accordance with the provisions of ASTM C33. The Contractor shall furnish EGAT with samples of fine aggregate from each source at least 30 days before it is required for use. Samples shall be a minimum of 25 kg each; samples shall be representative of the material to be used; and shall be obtained in accordance with ASTM D75.

BB-25. Coarse Aggregates

- a. General. Coarse, aggregates may be obtained from any EGAT approved source. The term "Coarse Aggregate" is used to designate aggregate that is reasonably well-graded from 4.8 mm to 38.0 mm (3/16 inch to 1-1/2 inch) or any size or range of sizes within such limits.
- b. Quality. Coarse aggregate shall consist of hard, dense, durable, uncoated rock fragments and shall be free from injurious amounts of soft, friable, thin, elongated, or laminated pieces; alkali; organic matter; or other deleterious substances. The percentage of material passing the No. 200 standard screen shall not exceed 2 per cent. The sum of the percentages of all deleterious substances in any size, as delivered to the mixer, shall not exceed 6 per cent by weight.

Coarse aggregate may be rejected if it fails to meet the following test requirements:

- (1) Los Angeles rattler test (ASTM C131) - if the loss exceeds 50 per cent by weight.
- (2) Sodium sulphate test for soundness (ASTM C88) - if the weighted average loss after 5 cycles is more than 12 per cent by weight.

- c. Sizes and Gradings. The coarse aggregate shall be as follows:

<u>Designation of Size</u>	<u>Range of Size</u> mm
38 mm aggregate (1-1/2 inch aggregate)	19 to 38 (3/4 to 1-1/2 inches)

The coarse aggregate shall be well graded within the limit specified:

<u>Designation of Size</u>	<u>Size of Sieve with Square Opening mm</u>	<u>Per Cent by Weight Passing</u>
38 mm aggregate	50 (2 inch)	100
(1-1/2 inch aggregate)	38.0 (1-1/2 inch)	95 - 100
	19.0 (3/4 inch)	35 - 70
	9.5 (3/8 inch)	10 - 30
	4.8 (No. 4)	0 - 5

- d. Tests. EGAT will test the coarse aggregate in accordance with the provisions of ASTM C33. The Contractor shall furnish EGAT with samples of coarse aggregate from each source at least 30 days before the aggregate is required for use. The samples shall be a minimum of 50 kg each; samples shall be representative of the material to be used; and shall be obtained in accordance with ASTM D75.

BB-26. Concrete for Foundations Exposed to Sea Water or Sulphates in Soils

The Contractor shall follow the requirements listed in the following table for concrete foundations exposed to sulphate attack caused by sea water or sulphates in soils:

Case	Classification of condition		Type of portland cement	Minimum cement content kg/cu.m
	Sulphate as SO <sub>4</sub> in soil %	Sulphate as SO <sub>4</sub> in ground water ppm		
1	0.1 - 0.5	150 - 1,200	I	355
			II	310
2	0.5 - 1.0	1,200 - 2,500	II	355
			V	310
3	Above 1.0	Above 2,500	V	355

Remarks : The cement contents recommended in the above table are suitable for concrete mixes having a slump of approximately 2.5 cm. The concrete must be capable of being fully compacted to produce a dense impermeable mass.



BB-27. Concrete for Foundations Exposed to Alkaline or other Corrosive Agents

Where concrete is subject to attack from alkaline soils or alkaline ground water, special cement containing a low amount of tricalcium aluminate shall be used. Such concrete shall have a minimum 28 day compressive strength of 250 kg/cm<sup>2</sup> and shall contain not less than 355 kg of cement per cubic meter of concrete in place. In exceptional cases where extremely corrosive soil conditions are encountered, or as directed by EGAT, all below grade surfaces of the concrete shall be treated with two coats of an approved type of bituminous (asphalt-based) sealing compound prior to backfilling.

BB-28. Concrete Admixture

Water-reducing admixtures, retarding admixtures, accelerating admixtures, water-reducing and retarding admixtures, and water-reducing and accelerating admixtures, if used, shall conform to ASTM C494. Air-entraining admixtures shall conform to ASTM C260. No admixtures shall be used without approval. No admixtures containing more than a trace of chlorides shall be used.

BB-29. Batching

The Contractor shall provide equipment and shall maintain and operate the equipment as required to accurately determine and control the amount of each separate ingredient entering the concrete. All batches of concrete shall be proportioned on the basis of integral sacks of cement, unless the cement is weighed. The amounts of fine aggregate and each size of coarse aggregate entering each batch of concrete shall be determined by weighing, and the amount of water shall be determined by weighing or volumetric measurement. Weighing equipment of the beam type shall be used. Batching equipment shall be operated so that the combined inaccuracies in feeding and measuring the materials will not exceed 1.5 per cent for water or weighted cement and 2 per cent for each size of aggregate. The Contractor shall provide standard test weights and any other auxiliary equipment required for checking the operating performance of each scale and shall make periodic tests, in the presence of EGAT, in such a manner and at such intervals as directed; provided, that unless otherwise directed such check tests of equipment in operation shall be made at least once every month. The Contractor shall, if required, furnish EGAT with copies of the complete results of all check tests made, and shall make such adjustments, repairs or replacements as may be necessary to meet the specified requirements for accuracy of measurement. Water tanks on portable mixers shall be constructed so that the indicating device will register, within the specified limit of accuracy, the quantity of water discharged, regardless of the inclination of the mixer setting.

EGAT has the option to permit batching of concrete by volumetric measure. If this method of batching is permitted, the Contractor shall calibrate, by weight, the measuring devices used for each of the ingredients. Periodic checks of the measures will be required. Misuse of, or failure to use, properly calibrated measuring devices will be sufficient cause for rejection of concrete by EGAT. Removal and replacement of concrete under such circumstances shall be entirely at the expense of the Contractor.

BB-30. Mixing

Concrete ingredients shall be mixed in a batch mixer for not less than 1-1/2 minutes after all the ingredients, except the full amount of water, are in the mixer. EGAT may direct an increased mixing time when the charging and mixing operations fail to produce a concrete batch throughout which the ingredients are uniformly distributed and the consistency is uniform. The concrete, as discharged from the mixer, shall be uniform in composition and consistency throughout the mixed batch and from batch to batch except where changes in composition or consistency are required. Mixing for a period of time longer than one hour after water has been added or any excessive over-mixing requiring addition of water to preserve the required concrete consistency will not be permitted. Ready-mixed concrete, if used, shall be mixed and transported in accordance with the requirements in ASTM C94 and shall also conform to Articles BB-21 through BB-30.

BB-31. Field Control of Concrete Strength

- a. Forms for Test Cylinders. The control test cylinder forms shall be durable and be made of steel and constructed in such a manner that repetitive use can be accomplished. The inside dimensions of the cylindrical forms shall be 15 cm in diameter and 30 cm high. Sufficient forms shall be furnished to meet the requirements of paragraph b of this Article.
- b. Sampling, Curing and Testing. The Contractor shall provide testing equipment and one set of three cylinders taken from fresh concrete for each tower foundation but not less than three cylinders for each day of concreting. The test cylinders shall be made and cured in accordance with ASTM C31 and shall be tested in accordance with ASTM C39 under the supervision of EGAT and at the Contractor's expense. Slump test results shall conform to paragraph BB-21b. If air entrainment is used, tests shall be made and results shall conform with the agreed mix design percentage.

- c. Strength Tests. The strength of concrete shall be represented by at least five sets of tests (15 specimens). To conform to the requirements of the specification, the average of any five consecutive strength tests shall be equal to or greater than the specified strength and not more than 20 per cent of the strength tests shall have values less than the specified strength.

If strength tests fail to conform to the requirements, EGAT may require such changes in concrete proportion as will be necessary to secure the required strength.

Furthermore, EGAT may require compression tests on hardened concrete in accordance with ASTM C42 for that portion of the foundation where the questionable concrete has been placed. All expenses incurred in the performance of additional tests shall be borne by the Contractor.

#### BB-32. Forms

Forms shall be used, wherever necessary, to confine the concrete and shape it to the required lines. Forms shall have sufficient strength to withstand the pressure resulting from placement and vibration of the concrete, and shall be maintained rigidly in position. Forms shall be sufficiently tight to prevent loss of water from the concrete. Forms may be removed 24 hours after completion of placement of concrete. The use of forms will not be required where the character of the earth cut is such that it can be trimmed to the prescribed lines and will stand without caving or sloughing.

At the time the concrete is placed in the forms, the surfaces of the forms shall be free from encrustations of mortar, grout, loose rust, or other foreign material. Before concrete is placed, the surfaces of the forms shall be oiled with a commercial form oil that will effectively prevent sticking and will not stain the concrete surfaces.

#### BB-33. Preparations for Placing

No concrete shall be placed until all form-work, installation of parts to be embedded, and preparation of surfaces involved in the placing have been approved. Except as provided below for tremie concrete, all surfaces of foundations upon or against which concrete is to be placed shall be free from standing water, mud, and debris. Where requested by the Contractor and approved by EGAT a layer of lean concrete may be placed in the bottom of excavations to facilitate the Contractor's work.

Absorptive surfaces against which concrete is to be placed shall be moistened thoroughly so that moisture will not be drawn from the freshly placed concrete. A plastic sheet, not less than 0.10 mm thick, shall be placed on top of cohesionless soil subases for spread footing foundations. All rock surfaces of foundations upon which concrete is to be placed shall be prepared by roughening, where necessary, and thorough cleaning. Loose and muddy rock, dried grout, flaky and scaly coatings, organic deposits, and other foreign material must be removed. Cleaning shall be accomplished by the use of stiff brooms, picks, jets of water and air applied at high velocity, wet sandblasting, or other effective means, followed by thorough washing. Construction joints shall be cleaned thoroughly of all loose or defective surface concrete, coatings, sand, sealing compound if used, and other foreign material, by approved means and shall be thoroughly moist before concrete is placed. Where concrete is permitted to be placed in water, the excavation within the required neat lines shall be free of all mud and debris immediately before placing of concrete, and all such mud and debris shall be kept out of the excavation during the placing of concrete.

BB-34. Placing

- a. Placing of Concrete. The Contractor shall advise EGAT at least 24 hours in advance as to when placing of concrete will be performed. Unless inspection of concrete is waived in each specific case, placing of concrete shall be performed only in the presence of EGAT. The methods and equipment used for transporting concrete and the time that elapses during transportation shall be such that no appreciable segregation of coarse aggregate, or slump loss will occur.

After the surfaces have been cleaned and dampened as specified and immediately before concrete is placed, construction joints shall be covered, wherever practicable, with a layer of mortar approximately one centimeter thick. Retempering of concrete will not be permitted. Concrete shall be placed as quickly as practicable after the proper amount of mixing. Any concrete which has become so stiff that proper placing cannot be assured shall be wasted. Concrete shall be deposited in all cases as nearly as practicable directly in its final position and shall not be caused to flow such that the lateral movement will permit or cause segregation of the coarse aggregate, mortar or water from the concrete mass. (Concrete shall not be allowed to fall freely more than two meters.) Aluminum pipes or chutes shall not be used for delivery or placement of concrete. Formed concrete shall be placed in continuous horizontal layers of approximately 0.50 m or less. EGAT may require shallower layers where concrete in 0.50 m layers cannot be placed in accordance with the requirements of these specifications. Concrete shall be consolidated to the maximum practicable density so that it is free from pockets of coarse aggregate and closes snugly against all surfaces of forms and embedded materials. Consolidation of concrete shall be by electric or pneumatic-driven, immersion type vibrators operating at speeds of at least 7,000 revolutions per minute when immersed in concrete. Concrete shall not be placed until previously placed layers

have been worked and vibrated thoroughly as specified. Care shall be exercised to avoid excessive contact of the vibrating head with surfaces of the forms.

b. Placing of Concrete Under Water.

Concrete may be placed under water only after it has been determined by EGAT that placing of concrete in an unwatered excavation cannot be practically accomplished by any means and only with prior written approval of EGAT. All such concrete shall be placed by means of a chute with tremie pipe (tremie method). The tremie shall be equipped with a foot valve capable of controlling the discharge of concrete so that the level of concrete in the tremie will not be allowed to drop below the level of water outside. Under no circumstances shall concrete be allowed to drop through water within the tremie. The tremie shall be water-tight and sufficiently large to permit free flow of concrete. The bottom of the tremie shall be as near to the surfaces against which the concrete is to be placed as practicable and the tremie shall not be raised until a seal has been established by the concrete sufficient to prevent entry of water into the tremie. The discharge end of the tremie shall be kept submerged in the concrete a sufficient depth to maintain an adequate seal during under water placement. Placing of concrete shall proceed without interruption until under-water placement in the foundation has been accomplished. As placing of concrete under water progresses, the Contractor shall remove water displaced by the concrete. When the top of the concrete being placed by tremie reaches the water-table level, no further placement by tremie shall be performed. Concrete placed above the water-table level shall be placed in accordance with the requirements of paragraph a. of this Article. The Contractor shall submit for EGAT's approval a special mix design for all concrete to be placed under water by the tremie method. Such concrete shall have a specified 28 day compressive strength of at least 315 kg/sq. cm and a slump in the range of 13 to 18 cm.

BB-35. Tolerances for Concrete Construction

The Contractor shall be responsible for setting and maintaining forms and earth cuts used to establish outside dimensions of foundations in accordance with the drawings and within the following tolerances :

- a. Variation from plumb or specified vertical slope shall not be greater than 13 mm in a vertical length of 3.0 meters nor greater than 26 mm overall for any specified vertical length.
- b. Cross-sectional dimensions of pedestals and heights of pads and pile caps shall be within a tolerance of plus 26 mm and minus 7 mm from those indicated on the drawings.
- c. Overall plan dimensions of pads and pile caps shall be within a tolerance of plus 52 mm and minus 13 mm from those indicated on the drawings.
- d. Misplacement or eccentricity of pedestals with respect to pads or pile caps shall be within a tolerance of 2 percent of the minimum pad or pile cap width, but shall not exceed 52 mm.

Concrete work which exceeds the tolerance limits specified herein will be inspected by EGAT, who will determine what effect the deviations may have upon the operational functioning of the structure and who will determine what remedies may be necessary. If after such inspection, the Contractor is directed to repair or remove and replace such defective work, all costs associated with this will be borne by the Contractor.

#### BB-36. Repair of Defective Concrete

Repair of defective concrete shall be performed by skilled workmen. The Contractor shall keep EGAT advised as to when repair of defective concrete will be performed. Unless inspection is waived in each specific case, repair of defective concrete shall be performed only in the presence of EGAT. Unless otherwise approved, repair of imperfections in formed concrete shall be completed within 24 hours after removal of forms. Concrete that is damaged in any manner such as fractured and honey combed shall be cut out to a depth at which sound concrete is exposed and filled with dry pack, mortar or concrete matching that of the structure. All concrete used for patching shall be bonded tightly to the surface of the sound concrete and shall be sound and free from shrinkage cracks and rough areas after curing and drying. All areas to be patched shall be coated with an approved concrete bonding agent in accordance with the manufacturers printed instructions.

#### BB-37. Finishing

Finishing of concrete surfaces shall be performed only by skilled workmen. The Contractor shall keep EGAT advised as to when finishing of concrete will be performed. Unless inspection is waived in each specific case, finishing of concrete shall be performed only in the presence of EGAT. Exposed unformed surfaces of concrete shall be brought to uniform surfaces and worked with suitable tools to a reasonably smooth woodfloat finish. Concrete on the top of pedestals shall be sloped to provide drainage away from the steel stub angles. Excessive floating or trowelling of surfaces

while the concrete is plastic will not be permitted. Edges that will be exposed to view shall be chamfered 2 cm.

BB-38. Curing

Concrete shall be cured by water curing or by application of an approved concrete membrane curing compound. If concrete is cured by water curing, the concrete shall be kept continuously moist, for at least the first 7 days after being placed, by sprinkling or spraying or by other methods approved by EGAT. Membrane curing of concrete shall be made by the application of a sealing compound which forms a water-retaining membrane on the surfaces of the concrete. The sealing compound shall conform to ASTM C309 (Type 2), and its method of application shall be approved or directed by EGAT. In general, two coats of curing compound shall be applied to all exposed surfaces of fresh concrete as soon as possible after concrete placement and finishing and in no case later than one hour after placement. Formed concrete surfaces shall have two coats of curing compound applied within one hour after form removal and/or repair of concrete surfaces in accordance with Article BB-36. Any sealing membrane that is damaged or that peels from concrete surfaces within 7 days after application shall be repaired without delay and in an approved manner.

The costs of furnishing and applying all materials used for curing concrete shall be included in the unit price for the foundations.

BB-39. Protection

The Contractor shall protect all concrete against injury until final acceptance by EGAT.

BB-40. Reinforcement

Reinforcing Steel shall conform to "Thai Industrial Standard for Reinforced Concrete" for deformed bars, TIS 24-2516. All reinforcement bars shall be certified for compliance with the applicable standard specified above.

BB-41. Placing of Reinforcement

Reinforcing bars shall be placed as shown on the drawings or as directed by EGAT. Bending of all bars, where required, shall be to smooth curves. Standard hooks shall have a 180-degree bend and extend 4 bar diameters parallel to the main leg of the hook. Kinked bars shall not be used.

Reinforcing bar splices not shown on the drawings will be permitted only with prior approval of EGAT and shall be placed at points of minimum stress, if possible. All reinforcing bar splices shall meet the requirements of ACI standard 318.

Before the reinforcing bars are placed, the surfaces of the bars and any bar supports shall be cleaned of heavy or flaky rust, loose mill scale, dirt, grease or other foreign substance. After being placed, the reinforcing bars shall be maintained in a clean condition until they are completely embedded in the concrete.

Reinforcing bars shall be accurately placed on concrete or metal chairs or spacers and secured in position so that they will not be displaced during the placing of the concrete. Special care shall be exercised to prevent any disturbance of the reinforcement in concrete that has already been placed.

All bars, dowels, spacers and stirrups shall be securely tied at all intersections with not less than No. 16 gage (1.59 mm $\pm$ ) black, annealed tie wire.

Reinforcing bars will be inspected for compliance with the requirements for size, shape, grade, length, position and amount after they have been placed and prior to the placing of concrete.

All reinforcing bars shall be placed and spaced in the foundations such that the concrete cover indicated on the drawings is maintained within a tolerance of plus or minus 7 mm and the center-to-center bar spacings are maintained within a tolerance of plus or minus 26 mm.

BB-42. Stub Angles

- a. Types. The drawings show two types of stub angles. One type is a projection of an embedded angle and the other type is a projection of the angle from a base plate with a welded connection and supported by embedded anchor rods.
- b. Setting. Stub angles shall be placed in the foundation pedestals and pile caps and set accurately to the grade and alignment designated on the drawings. The stub angles shall be supported in the proper position by means of a rigid frame or equivalent suitable device to prevent displacement during the placing of concrete and to insure placement of the stub angles within the tolerances specified.



- c. Vertical Dimensions. The difference in elevation between identical points of any two stub angles shall not exceed 6 mm. The actual elevation of any stub angle shall not differ from the prescribed elevation by more than 50 mm.
- d. Horizontal Dimensions. The difference in horizontal distance from the computed dimension between identical points of any two stub angles shall not exceed 6 mm.
- e. Batter. The batter of the stub angles shall not differ from the batter shown on the drawings by more than 5/1000.
- f. Rotation. Stub angles shall be placed so that the transverse axis of each tower does not deviate from the bisector of the interior line angle or the intended orientation, if otherwise shown on the drawings, by more than 30 minutes of arc.

### PILE TESTS

#### BB-43. Pile Tests

- a. Individual Pile Tests. The Contractor may be required to perform load tests on piles driven for pile type tower footings to determine the load-deflection relationship for individual piles. EGAT will select the piles and determine the number of piles to be tested. The Contractor shall provide all labor, material, equipment, and apparatus for performing load tests. Loading tests shall not be started until at least 7 days have elapsed after driving.

Test piles shall be of the same cross section dimensions and materials as the permanent piles and shall be driven with the same equipment and in the same manner as specified for such piles. Test piles shall be driven in advance of final driving of permanent piles to assist in determining final lengths. These piles shall be of greater length than the length assumed in the design in order to provide for possible variation of soil conditions. During driving, an accurate record of the penetration and blow count of each pile shall be kept by the Contractor. Test piles will not be used in an actual tower foundation.

The piles shall be tested in accordance with ASTM D1143, Standard Method of Testing Piles Under Static Axial Compressive Load or ASTM D3689, Standard Method for Testing Individual Piles Under Static Axial Tensile Load, as applicable. The following loading procedures shall be performed:

- (1) Compressive Tests in accordance with section 5 of ASTM D1143-
  - (a) Using "Standard Loading Procedure."
  - (b) In accordance with "Loading in Excess of the Standard Test Load." until 300% of the design load is reached, provided failure has not occurred.
- (2) Uplift Tests in accordance with section 5 of ASTM D3689-
  - (a) In accordance with the description of the "Standard Loading Procedure."
  - (b) To failure in accordance with the description of "Loading in Excess of 200% of Pile Design Uplift Load."
- (3) Shear Tests in accordance with the description of the "Standard Loading Procedure" of section 5 of D1143 except that the loading shall be in 500 kg increments until failure occurs. A total deflection of 25 mm will be considered as failure.

Tests shall be witnessed by EGAT or EGAT's representative. The tests shall be interpreted and the reports shall be written by, or under the supervision of, a professional expert in soil mechanics and foundation design who is familiar with the local soil conditions.

The Contractor shall submit details of procedures he intends to use for applying loads, measurements of deflections, anchorage, etc. for approval.

- b. Testing Sequence. In accordance with paragraph a. above, the sequencing shall be as follows :

- (1) 70 Ton pile - Type I soil
- Loading (1)(a)
  - Loading (2)(a)
  - Loading (1)(b)
  - Loading (2)(b)
  - Loading (3)
- (2) 50 Ton pile - Type I soil
- Loading (3)
  - Loading (1)(a)
  - Loading (2)(a)
  - Loading (1)(b)
  - Loading (2)(b)
- (3) 50 Ton pile - Type II soil
- Loading (1)(a)
  - Loading (2)(a)
  - Loading (1)(b)
  - Loading (2)(b)
  - Loading (3)
- (4) 70 Ton pile - Type II soil
- Loading (3)
  - Loading (2)(a)
  - Loading (1)(a)
  - Loading (1)(b)
  - Loading (2)(b)
- (5) Optional Pile Foundation
- Loadings (1)(a) and (3) Simultaneously
  - Loadings (2)(a) and (3) Simultaneously

## GROUNDING

### BB-44. Tower Grounding

In general, the use of a single-section ground rod at each tower leg will provide adequate grounding. In areas having high resistance soils, supplementary counterpoise or additional ground rods may be required. Stub angles shall be bonded to the grounding rod attachment and the foundation reinforcing steel.

The Contractor shall measure the ground resistance of individual foundations with the measuring instruments and methods approved by EGAT. The records of these measurements shall be submitted to EGAT who will determine the necessity for additional grounding. Date, temperature, resistance and soil condition will be recorded whenever ground resistance is measured. All towers shall have a ground resistance of 10 ohms or less unless specified by EGAT.

All towers shall be grounded in accordance with the drawing 500-EHV-T-15.1 (REV.1) Materials to be installed include ground rods, counterpoise and necessary fittings, as shown. Grounding shall be installed in steps as shown to attain the necessary resistance. Readings of tower resistance shall be furnished to EGAT after each step.

### BB-45. Driving of Ground Rods

Ground rods shall be driven to the required depth by hand-operated weight pipe. If the soil is hard for hand-operated weight pipe driving or where it is required to drive extendable ground rods, the Contractor is required to use mechanically operated hammers, either electric, pneumatic or gasoline engine driven. The hammer shall be mounted on a rig which provides guides for the rod and a winch for control of the hammer. Descriptions of the ground rod driving tools shall be submitted for the approval of EGAT. Driving of ground rod by hand hammering is not permitted.

In the driving of sectional ground rods, the coupling shall be tightly fitted on the unpainted end of the first section of the rod, and the driving head fitted to the top end of the coupling. The first section is then driven into the ground. The driving head is removed from the coupling, and then the second rod fitted into the coupling. Another coupling is then placed on the top of the second section, the driving head is inserted as before and driving continued. The driving head and coupling shall be removed after the last section of the rod is driven to the required depth.

Where soil conditions prevent driving of ground rod to the required depth, the Contractor shall follow EGAT's instructions.

BB-46. Installation of Counterpoise

The counterpoise system, if required, will be installed as shown on drawing 500-EHV-T-15.1 (rev.1) and as directed by EGAT.

The counterpoise shall be buried to a minimum depth of 50 cm in soil within the right-of-way. If solid rock is encountered at a lesser depth than required, the counterpoise shall be laid on top of the solid rock and covered with soil. Where solid rock is encountered on the surface, the wire shall be laid on the surface or in cracks with loose rock placed on the wire and anchored with a rock anchor to prevent displacement. The wire shall be laid in as straight a line as possible, without sharp bends.

BB-47. Metallic Object Grounding

Where required and directed by EGAT, fences and other metallic objects or structures in close proximity to the transmission line shall be grounded as shown on drawing 500-EHV-T-15.2 (REV.1).

Fences will be grounded by the driving of ground rods at intervals specified on the drawing. Conducting objects will normally be bonded to a single driven ground rod.

Section CC  
ERECTION OF TOWERS

CC-1. General

The Contractor shall erect the towers and accessories in accordance with the approved detail shop and construction drawings. Towers shall be complete with all members in place and bolts including step bolts and ladders, if any, securely tightened before any stringing work is started. No steel tower shall be installed until at least seven days after the placing of the concrete in the footing and after back-filling has been completed.

CC-2. Handling and Storage

In storage and at tower site, all tower steel shall be kept clear of the ground in a clean and tidy condition. Contact with standing water or other substances likely to attack galvanizing shall be avoided.

Care shall be taken during handling and storage to prevent structural injury to members or damage to galvanized or other protective surfaces. No steelwork shall be dragged over the ground surface or handled in such a manner as to damage the galvanized surfaces. Throwing of tower steel into piles on conveyances, onto the ground, or skidding of steel members over each other is not permitted.

All superficial rust stains, corrosive salts and other foreign materials deposited prior to or during installation of the towers shall be removed without causing damage to the protective surfaces.

CC-3. Erection Procedures

The towers may be erected by assembling in sections on the ground and hoisting or lifting successive sections into place, or they may be erected in place on the footings by installing individual members at the option of the Contractor. The tower erection procedures shall be submitted to EGAT for approval in advance of actual erection.

Slings and other equipment used for picking up members, portions of towers or complete towers, shall be of such materials or shall be cushioned in such a manner as to prevent cutting into the corners of members, damaging the finish, or distorting or overstressing members when lifts are made.

Members, portions of towers, or complete towers shall be raised in such a manner that no dragging on the ground surface or against portions of towers already erected will occur.

Contact surfaces of members forming joints shall be clean before members are assembled.

Where field drilling of holes for attachment of special equipment to individual towers is required, all holes shall be cleanly drilled to the proper size and in the proper location. Galvanizing repair paint shall be applied immediately following completion of drilling.

CC-4. Bolt Tightening

During tower erection, bolts shall be finger-tightened only. After the complete tower is erected, the nuts for ASTM A394 bolts shall be tightened to the following torque:

<u>Size of Bolts</u> mm	<u>Tightening torque</u> kg-cm
16	1,000 - 1,200
20	1,400 - 1,800

Bolt tightening torque for bolts other than ASTM A394 shall be submitted to EGAT for approval.

Wrenches used for bolt tightening shall be subject to the approval of EGAT. The use of any wrench which may deform the nut or cut or flake the galvanizing will not be permitted.

After torquing, all nuts shall be locked in place with locknuts or by other approved means. The bolts shall be installed in such a way that locknuts and nuts are in the "Up" or "Out" position.

EGAT will selectively check bolts for proper tightening before acceptance. If bolt torques are less than specified, the Contractor may be required to retorque all bolts on the tower.

CC-5. Misfabricated Members

If shop errors in the steel members are discovered, the Contractor shall notify EGAT who will decide whether the errors may be corrected in the field, or the members returned to the fabricator for correction or replacement at the Contractor's expense.

No drifting will be allowed in assembling towers. Reaming for correction of mismatched holes due to shop errors will not be permitted.

CC-6. Damaged Members

Members that are bent, twisted or otherwise deformed in storage, transportation, handling or erecting operations shall be straightened or replaced by the Contractor. Straightening shall be done only by the use of methods that will not injure the galvanized coating. The method of straightening shall be approved by EGAT. Tolerances for lateral variations of straightened members shall be as follows:

<u>Member Type</u>	<u>Tolerances</u>
Compression Members	$\pm 2/1000$
Tension-only Members	$\pm 6/1000$

Members that are injured in a manner causing reduction in their strength shall be replaced.

CC-7. Damaged Galvanizing

All galvanizing damage shall be repaired by the Contractor. The damaged area shall be cleaned by wiping with clean rags saturated with mineral spirits of xylene followed by wire brushing.

After wire brushing, the area shall be recleaned with solvent to remove residue and shall be given a minimum of two coats of an approved galvanizing (zinc-rich) repair paint.

The amount of pure zinc by weight in dry film of the galvanizing repair paint shall not be less than 85 per cent.

If damage to galvanized coating of members cannot be repaired at the site, the Contractor shall re-galvanize the damaged member at the manufacturer's factory or in another place approved by EGAT.



CC-8. Tower Signs

The Contractor shall install the tower signs on the towers in a manner described hereunder and as specified on drawing No. TP-150B.

Field drilled holes in tower members shall be painted with galvanizing repair paint as specified in Article CC-7 above.

- a. Tower-Number Signs. The Contractor is required to stencil each tower with a number (final) as indicated on the plan & profile drawings on legs designated by EGAT at a height of about 4 m above the ground level. The letters shall be 8 cm high in black paint over a two-coat yellow background. The background shall extend 2.5 cm above and below the numbers and shall be the full width of the numbers.
- b. Aerial Patrol Signs. Aerial patrol signs shall be installed on the first tower in each station kilometer as specified in the structure lists.
- c. Phasing Signs. Phasing signs shall be installed on terminal towers, the first tower in each ten station kilometers and both towers adjacent to a transposition tower.
- d. Danger Signs. Danger signs shall be installed on each tower located at the terminal, near roads, railways and on the river banks or where directed by EGAT in such a manner that they can be seen by passers-by.
- e. Circuit name signs. Circuit name signs shall be installed on the top crossarm or bridge at the terminal towers approaching substation.
- f. Energized Parts Warning Signs. Suitable warning signs shall be provided on all towers to which OPGW joint boxes and similar items which shall be energized above ground potential are mounted. Such signs shall be in the Thai language and attached in a conspicuous location below any energized part.

CC-9. Water-Proof Painting of Bottom Part of Towers

For protection of the stub angles and the bottom part of the tower up to 0.50 m above the top of concrete, two coatings of bituminous paint shall be applied on each pedestal or pier top and each bottom part of the tower. Before proceeding with the paint coating operation, all objectionable surface irregularities shall be removed, and the surfaces cleaned of dirt and grit. Preparation of surfaces and method of application of paint coatings shall be done in accordance with manufacturer's recommendation, or as directed by EGAT.

The paint shall conform to ASTM D1187 : "Asphalt-Base Emulsions for Use as Protective Coatings for Metal". The Contractor shall be required to submit full details of the paint, inhibitor, cleaning solvent and other related materials, together with recommended method of application for approval by EGAT. No paint coating operation shall be done before approval by EGAT.

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## Section DD

### INSTALLATION OF INSULATOR AND HARDWARE ASSEMBLIES FOR CONDUCTOR AND OVERHEAD SHIELD WIRE

#### DD-1. Handling and Transportation

The insulators shall be handled carefully to avoid damage of any kind. Insulators and hardware shall be stored in their appropriate shipping containers until installation. They shall be properly supported and stacked so as not to damage the individual items and shall be blocked up off the ground so that they can not come in contact with the ground or standing water. All assembled insulator strings shall be properly cradled or supported during installation to prevent chipping or bending of pins. All insulators shall be clean, the porcelain shall be bright and all other parts shall be free from dirt and dust. Only clean rags free from any abrasive material shall be used for cleaning insulators. Wire brushes shall not be used for the cleaning of any parts. Workmen shall not climb on insulator strings at any time.

If the insulators are damaged in any way, the Contractor shall replace the damaged insulators as directed by EGAT at no expense to EGAT and the Contractor shall be liable for the cost of the replaced insulators.

#### DD-2. Insulator and Hardware Assemblies for Conductor

Insulators will be installed in quantities and strengths required for use in the assemblies. The insulator assemblies shall be assembled and attached in accordance with the Drawings and these Specifications. Insulator strings shall be assembled so that every tenth unit, counting from the crossarm, is brown in color. The remainder of the string shall consist of grey-colored units. The strength of insulator and hardware assemblies to be used on each tower is shown on the drawings furnished by EGAT.

#### DD-3. Overhead Shield Wire Assemblies

The overhead shield wire set shall be assembled and attached by the Contractor in accordance with the details as shown on the drawings.

#### DD-4. Cotter Keys

All cotter keys shall be carefully installed and checked to insure that they are properly seated. All insulator cotter key eyes shall face to "Up" or "In" position.

Humpback cotters shall be spread to a minimum opening of 45 degrees. Straight cotters shall have the ends spread and turned back to an opening of 180 degrees.

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Section EE  
STRINGING OF CONDUCTOR

EE-1. General

The Contractor shall string and sag the conductors in accordance with the Drawings and Specifications. All four sub-conductors shall be pulled simultaneously by the use of one pulling line only. After sagging, the point of attachment shall be marked on each conductor in a manner satisfactory to EGAT. The insulator assemblies shall be attached to the conductors at the points marked on the conductors.

EE-2. Handling and Storage

Care shall be taken during handling and storage to prevent abrasion or other damage to the conductor. Prior to installation, reels of conductor shall be stored blocked-up off the ground and adequately supported so as to avoid damage to reel, lagging, and conductor. Conductor and reels shall be kept free of standing water, dust, and mud.

Lagging or other protective covering shall be removed at the job site and the outside layer of each reel shall be examined by the Contractor and EGAT to ensure that the conductor is in good condition and that no nails, staples, or other sharp objects, which would damage the conductor during unreeling, protrude on the inside of the reel heads. At no time shall the conductor be dragged over the ground or any other rough surface.

EE-3. Stringing Plan

Not later than 2 months before commencing conductor installation work, the Contractor shall submit a general stringing plan to EGAT for approval. The plan shall describe the Contractor's proposed work schedule, method of stringing, temporary guying, scaffolding, personnel required in performing the work and a list of tools, communications equipment and stringing equipment to be employed.

In addition, not later than 2 weeks before commencing stringing work in any section of the line, the Contractor shall submit details of the unreeling section, location of reels, pullers, tensioners, snubs and temporary guying, scaffolding, splices and lengths of conductors to be strung to EGAT for approval.

EE-4. Conductor

At each stringing site the Contractor shall use sets of twelve reels of conductor matched in length. It is very important that these matched sets are installed in the same section of line; consequently, the Contractor shall exercise every precaution to prevent mixing sets during handling and installation.

EE-5. Stringing

Conductor shall be strung by the controlled tension method. The method of controlled tension stringing and type of equipment proposed by the Contractor is subject to review and approval by EGAT. Such action by EGAT does not relieve the Contractor of full responsibility for producing a complete, acceptable transmission line. Any procedure used during the stringing operations which will scratch, groove, kink, mar, twist or otherwise damage the conductor will not be permitted. If the conductors are damaged during the Contractor's operation, he shall replace the damaged sections at no expense to EGAT and be liable for the cost of the conductor so damaged. Slightly damaged or abraded sections which may result in corona discharge, as determined by EGAT, shall be repaired by polishing with emery cloth or equal, by repair sleeves or other means, all in a manner satisfactory to EGAT. No steel wool shall be allowed. Sections of the conductor damaged by the application of gripping attachments shall be removed and replaced before the conductors are sagged in place.

The placing of tensioning and pulling equipment during the stringing operation shall be such that the slope of the pulling lines shall not be greater than 1 vertical to 3 horizontal, and the combination of loads on a cross arm, multiplied by an overload factor of 1.3, shall not be more than the maximum design loads shown on the tower drawings.

The tensioning machine should be of the neoprene or teflon lined double bull wheel type with a bull wheel of 115 cm diameter minimum. Equipment capacity shall exceed the sagging tension as approved by EGAT. Stringing equipment shall conform to the recommendations of "A Guide to the Installation of Overhead Transmission Line Conductors", IEEE Guide No. 524-1980. Tools and stringing equipment shall be tested and inspected by EGAT after approval of the stringing plan but prior to commencement of the stringing work. Typical dimensions and capacities of stringing blocks are:

Minimum sheave diameter at bottom of groove - 45 cm

Minimum depth of groove - 3.5 cm

Minimum radius of groove - 1.5 cm

Maximum radius of groove - 2.0 cm

Grooves of sheaves shall flare between 15 and 20 degrees from vertical.

Initial sagging tension for a 490 and 420 meter ruling span is 3060 and 3140 kg per subconductor respectively at an everyday temperature of 27°C.

Brakes shall be controlled by electrical, hydraulic or pneumatic devices such that the desired tension will be held so long as the brakes are left at the proper setting. The heat on the brakes shall not be transmitted to the conductor.

Stringing blocks will be multi-sheave type for stringing four conductors simultaneously. These sheaves shall be equipped with high quality bearings with provisions for lubrication if applicable and shall have conductive neoprene or other suitable lining approved by EGAT. EGAT will retain the right to inspect and reject any stringing block which in its opinion is not functioning properly or otherwise might damage the conductor or adversely affect the conductor sag.

The stringing blocks, when suspended on the transmission structure for sagging, shall be so adjusted that the conductor will lie on the sheave at approximately the same height as the suspension clamp to which it would be secured. Upon completion of the sagging operation, the conductors shall be clipped in.

Conductors shall not be prestressed above initial sagging tensions during the pulling operation. The tensioner should be set to maintain tensions sufficient to clear all obstructions by 2-3 meters yet remain considerably below the initial sagging tensions. This clearance shall be confirmed by observation. The maximum pulling tension should not greatly exceed the minimum required tension. If the required tension is significantly higher than 65 per cent of the sagging tension, the possibility of prestressing the conductor, based upon the combined effects of tension and time, must be considered and any necessary corrections applied. Excessively slow or high stringing speeds must be avoided. Acceptable speeds are between 4 and 10 km/hr. The length of a section of line to be sagged at one time is usually governed by the terrain, the number of angles, road crossings and other obstructions, and finally by the length of conductor that can be uniformly sagged.

#### EE-6. Sagging

The conductors shall be sagged in accordance with initial sag and tension data to be furnished by EGAT. The calculation of sag correction and offset clipping shall be done by the Contractor as required.

The conductor temperature shall be determined by mounting a thermometer at each sag span as follows:

- (1) Pull the core from a 0.6 m length of conductor, removing sufficient strands to insert the thermometer into the vacant space. Expose the length of conductor to the full sun at the approximate sagging height above ground. Ensure the conductor is located in free air and is not in the shade nor protected from wind or rain.
- (2) Read the temperature after it reaches its final value at each sag span. Select the temperature to be used for sagging. The choice of sagging temperature shall be subject to EGAT's approval.

No minus sagging tolerance will be allowed. A plus sagging tolerance of 4 cm per 100 meters of span length will be allowed, but in no case shall the tolerance exceed 20 cm in any span. The sag of a subconductor may not vary over one wire diameter from the other conductors in the same bundle. Sag checks will be done by the use of levels or transits.

The Contractor shall submit data on such instruments and obtain EGAT's approval prior to beginning of stringing work. Location of instruments and targets shall be as approved by EGAT. Sagging spans will be selected as close to the ruling span as practicable. It will usually be satisfactory to sag in one span near the middle of the section for section lengths less than one and one-half kilometer. For lengths over one and one-half kilometer, one sagger shall be provided in each full one and one-half kilometer section of line being pulled, as approved by EGAT.

The pulling and adjusting of the conductor to the final sag position shall be by means of a hand or power operated hoist and not by pulling directly with truck or tractor. Once the conductor is pulled into position, it should be sagged immediately or left at less than 65 per cent of the sagging tension. Work shall be planned so that all four subconductors in a bundle can be pulled and sagged as specified within a 24 hour period. If for some reason this cannot be done, the conductors must be left at reduced tension as directed by EGAT.



Sagging operations shall not be carried on when in the opinion of EGAT, wind, or other adverse weather conditions prevent satisfactory sagging.

EGAT reserves the right to check sag at its discretion. The Contractor shall furnish men and equipment necessary to assist in these checks.

EE-7. Clipping

After being sagged, the conductors shall hang in the stringing blocks for a minimum of two hours before the clipping operation is started. During this 2 hour time period the Contractor shall mark the plumb point on the conductors (the plumb point is defined as that point on the conductor directly below the transverse centerline of the structure). The conductor must be clipped in within 96 hours after the conductor is sagged. Extension beyond 96 hours must be approved in writing by EGAT. Suspension insulator strings shall not be more than 70 millimeters out of plumb as measured from the plumb point after the conductors are "clipped in".

In line sections where clipping offsets are required all conductors shall be marked at a point vertically below the attachment point of "I" -strings or below a line between the attachment points of "Vee" -strings and at a distance along the conductor from the first mark as required by the offset data.

Any marking which may damage the conductor shall not be used. All marking of a sag section shall be completed immediately after sagging and before clipping in or lowering of conductor for application of deadend commences.

Clipping offsets, where required, shall be calculated by the Contractor.

All suspension assemblies out of plumb from the vertical by more than the specified limit shall be re-plumbed to the satisfaction of EGAT.

EE-8. Scaffolding

The Contractor shall, at his own expense, provide suitable scaffolding at the places where his work may cause injury or damage to persons, livestock or property of value to a third party.

The scaffolding shall be of sufficient strength to withstand wind pressure, vertical loads and all other loads which may be anticipated, and shall prevent the conductor from coming within 5 meters of railroad tracks and roads and 1 meter from telecommunication lines and distribution lines of less than 33 kV during unreeling of the conductor. The scaffolding if self shall also have the aforementioned clearance.

EE-9. Stringing Near or Crossing Energized Lines

The Contractor shall take all precautions necessary to prevent accidents and injuries to persons and property due to induction or physical contact when stringing operations are being carried out in close proximity to or crossing energized lines. All pulling and tensioning equipment shall be effectively grounded and a running ground shall be installed on the bare conductor between the tensioning reel and the first tower.

Each conductor of the line being strung shall be grounded to all steel towers by means of traveler grounds or ground cables. The grounds shall be left in place until conductor installation is completed and shall be removed as the last phase of the work. Grounds shall be placed and removed with a hot stick.

A ground shall be located at each side and within 3 meters of working areas where conductors are being spliced at ground level. The two ends to be spliced shall be bonded temporarily to each other during the splicing operation.

When performing work from the towers, clipping crews and all others working on conductors shall be protected by individual grounds installed at every working location.

All grounding devices must be sized to carry the largest currents likely to be encountered. The clamps shall be capable of clamping positively on the object being grounded, as distinct from being spring loaded only.

EE-10. Communications

The Contractor shall maintain good communications between personnel at the tensioner end, the puller end and intermediate points at all times during stringing operations. Running boards shall be observed as they pass through each traveler. The running board observers shall have reliable communications with both pulling and tensioning ends. Dual systems of communication shall be available during stringing in case one system fails.

## Section FF

### STRINGING OVERHEAD SHIELD WIRES

#### FF-1. Shield Wire Installation

The Contractor shall install the insulated overhead shield wires of 3/8 inch extra high strength galvanized steel in accordance with the Drawings and Specifications. The overhead shield wires shall be strung, sagged and clipped-in before the phase conductors are strung. The stringing sheave shall have a bottom of groove diameter of not less than 12 cm and a minimum groove radius of 0.6 cm. The overhead shield wire shall not be damaged and particular care shall be taken to insure that the wires do not become kinked, twisted or abraded in any manner.

The overhead shield wire shall be strung by the controlled tension method which will keep the shield wire off the ground. The pulling tension shall not prestress the shield wire and shall not exceed the sagging tension for the ambient temperature. Strain plates on suspension type towers shall not be used as anchors for pulling wire or as a temporary dead end for the shield wire.

#### FF-2. Shield Wire Insulation and Grounding

The two shield wires are divided into line sections approximately 12 kilometers long as indicated on the Structure List. At the ends of the sections each shield wire shall terminate on an insulator which is connected in strain to the tower as indicated on the drawings. In general, where strain towers occur, they shall constitute the end of a section regardless of the section length. At the approximate center of each section, where indicated on the structure list, each shield wire shall be attached to the tower to obtain a solidly connected ground as detailed. At all towers in the last two kilometers at substations, both shield wires shall be grounded to all towers.

## Section GG

### INSTALLATION OF CONDUCTOR AND SHIELD WIRE ACCESSORIES

#### GG-1. Conductor & Shield Wire Accessories

All compression tools shall be of standard manufacture approved by EGAT and shall be of sufficient capacity to close the die completely as recommended by the manufacturer. All compression tools are to be inspected and tested before use. The Contractor is to maintain tools in good working order at all times.

All conductor and shield wire splices, dead ends, jumper terminals and repair sleeves shall be of the compression type made in accordance with the supplier's recommendations. All joints or splices shall be made no closer than 30 meters from a suspension point and no splice shall be made in dead end spans or in spans crossing over important roads, railroads, rivers or utility lines without approval of EGAT. No more than one repair sleeve and/or splice will be allowed in any one span on a single conductor. All splices and dead ends will be completed in EGAT's presence. The Contractor will notify EGAT in advance of all such operations.

#### GG-2. Conductor Splicing

In making full tension splices, the conductor shall be laid out straight for a distance of at least 10 meters each way and the ends straightened before preparation for splicing. The wire shall be placed on lagging or on supports and, if necessary, protective sheets shall be placed over the supports to keep the conductor clean.

The dies used to compress the compression joint shall be of the proper size and all presses must be made in the proper sequence as specified by the manufacturer of the joint. Joint compounds which aid electrical contact and prevent corrosion must be used as specified by the manufacturer.

During the splicing operation and depending upon the degree of exposure to electrical hazards from induction, accidental contact or lightning, the Contractor shall protect his personnel by appropriate grounding measures.

If compression splices are prepared at the tensioning site, the compression splice must be of a design suitable to pass through the travelers. A preliminary study of the line to determine the maximum stringing tension and roll-over angles that will be encountered must be undertaken and the compression joint manufacturer must be consulted.

GG-3. Vibration Protection Devices

The Contractor shall install all spacer-damper units in accordance with the requirement, of these specifications, the instructions furnished by the manufacturer, and as directed by EGAT. Installation may be done from mobile carts supported equally by all four wires of the conductor bundle. Carts and all cart accessories, lines, etc. shall be furnished by the Contractor. The Contractor shall furnish for approval complete data, drawings and other descriptive information for the carts prior to their use.

Spacer-dampers shall be installed immediately after the clipping-in process of conductors has been completed.

Vibration dampers for shield wires shall be installed in accordance with the requirements of these Specifications, the instructions furnished by the manufacturer and as directed by EGAT. Vibration dampers shall be installed immediately after the clipping-in of shield wires has been completed.

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## Section HH

### AIR NAVIGATION OBSTRUCTION MARKING AND LIGHTING

#### HH-1. General

If required by EGAT, the Contractor shall furnish and install or apply materials for marking of towers and overhead shield wires and for lighting of towers as shown on the drawings and specified hereafter.

#### HH-2. Marking of Steel Tower

The Contractor shall apply all cleaning and painting materials for the air navigation obstruction marking of the required steel towers according to the following requirements.

- a. Paints. The color of the paint shall be orange and white. Standard color of the paint shall be as follows:

<u>Color</u>	<u>Munsell's Number</u>
Orange (Yellowish-red)	2.5-YR 6/13
White	N - 9.5

The primer paint shall be zinc dust zinc oxide.

- b. Painting. All painting operations shall be performed after the steel towers have been completely erected and the air navigation obstruction lighting installed, if any. All oil, grease and dirt shall be removed from surfaces before paint is applied. No painting shall be done in cold, damp, foggy or dusty atmospheres.

One coat of priming paint followed by two coats of finish paints shall be applied to all exposed surfaces of the required steel towers. The colors of finish coats shall be applied alternatively orange and white in equal vertical sections, beginning at the top with orange. Each section of finish coat shall be approximately equal to the tower base width. Section lines between color shall be sharply defined and in no case shall there be less than seven sections.

The quantity of paint and thickness of each coat shall not be less than the following values:

<u>Coat</u>	<u>Quantity</u> kg/sq.m	<u>Minimum Thickness</u> Microns
Primer	0.07 - 0.09	10
First finish	0.13 - 0.16	30
Second finish	0.13 - 0.16	30

Each coat shall be allowed to dry or harden thoroughly before the next coat is applied. A minimum of 4 days are required for drying of each coat.

Prior to commencement of the painting work, the Contractor shall submit a work program including the surface preparation, quality of paint and dimension of painting sections for the approval of EGAT.

#### HH-3. Marking of Overhead Shield Wire

Where required, the overhead shield wires shall be marked with orange and white colored fiber glass spheres. The spheres shall be 300 to 400 mm in diameter. Any metal parts, if used, for holding the spheres in position shall not cause corrosion or harmful effects to the overhead shield wire.

The position of the spheres shall meet the following requirements:

- a. The spheres on the two overhead shield wires of any span shall be so staggered that the maximum distance between any two spheres is not greater than 40 m.
- b. The first and the last spheres in any span shall be approximately 10 m from the towers defining the span.

#### HH-4. Lighting of Steel Towers

The Contractor shall furnish beacon lighting for installation on towers in accordance with the following detailed requirements :

- a. Lighting. One beacon light complete with solar energy generator is required for each tower. The Contractor shall furnish all conduits, conduit fittings, outlets, wiring, lighting fixtures, lamps, control devices, circuit breaker and all other materials necessary for the beacon light. Equipment shall be appropriate for 12 volt direct current operation. All equipment shall be marine products of recognized manufacturers who regularly supply beacon lighting equipment and solar energy generators. All work shall be done according to standard practice for weather proof installation in a marine environment. All metal parts shall be rust-resisting materials or hot-dip galvanized.

1. Beacon. A flashing electric red code beacon shall be equipped with one 12V, 24 watt bulb with 5 spare bulbs enclosed in an aviation red color lens globe. The spare bulbs shall replace the outaged bulb by means of an automatic control rotating bulb changer. Detailed specifications shall be as follows :

Operating Voltage	: 12.0 + 15% Volt D.C.
Luminous intensity, horizontal beam	: 491 Candelas
Flashing rate, approximately	: 0.3 sec. on/2.2 sec. off
Lens	: 155 mm. red, single piece Fresnel vertical divergence 4 degree at 50% intensity
Mouting base	: Polyester resin plastic fiber glass reinforced

2. Control. The beacon light shall be switched by a photoelectric control and load contactor. The photoelectric control shall provide automatic switching of the contactor so that the lights will be turned on at a sky intensity level about 35 foot-candles and off at about 58 foot-candles.

- b. Power-Supply Circuit Breaker. Circuit breaker for termination of the tower lighting circuits shall be automatic, fuseless, thermally operated, 2-pole, 100 volt D.C., with an interrupting power rating not less than 1,000 VA and thermal overload current of 15 Amp. Each circuit breaker shall be enclosed in a weather proof metal housing or control panel suitable to be for installation in a marine environment.



c. Power Supply Source. The power supply for beacon lights shall be from a 12 V.D.C. battery which is to be charged by a solar energy generator.

1. Battery. The battery shall be 12 volts, lead calcium grid type, sealed at the top with single gas vent, capable of service without the need for water addition for the entire period of battery life. The battery shall have a capacity of not less than 90 ampere hours at 90 hour rating and a self-discharge rate not less than 5 ampere hours per month. The battery container shall be made of high quality polypropylene.
2. Battery charge and discharge controller. The battery charge and discharge controller shall have a 12 VDC 5 A. minimum rating. Charge controller cut-off voltage shall be adjustable between 13.8 - 14.5 V. Discharge controller cut-off voltage shall be 10.5 V and initial discharge shall be not less than 12.5 V.
3. Solar energy generator. The solar energy generator for generating D.C. power to charge batteries shall consist of a set of solar cells contained in one panel. Each solar panel shall contain not less than 36 silicon photovoltaic cells. Silicon wafers shall be positioned in two closely fitted plates molded of borosilicate crown glass or equivalent. The solar cell shall have a high clarity tempered glass plate permitting transmission of unused infrared. Detailed specifications shall be as follows:

Power	:	not less than 35 peak watts at 25°C
Open circuit voltage	:	not less than 20 volts
Terminals	:	noval brass coated with tin or equivalent
Fixing solar cells in panel	:	fixed by suitable mounting with bolts in array frames and with the solar cell positioned in order to be able to have the terminals connected in series/ parallel
Solar generator panel mounting	:	15 degree angle from the horizontal mounting plane and facing south

- d. Lighting Cable and Conduit. The lighting cable shall be 4 mm 750 volts, 75°C PVC, insulated single conductor. Positive polarity :red, Negative polarity : black; the connection wiring lead shall be of standard joint wiring with protective insulation suitable for use in conduit. The conduit shall be 3/4 inch, with 30% heavier galvanizing than required by ASTM and appropriate for use in a marine environment. Flexible conduit shall be made of galvanized corrugated steel, covered with polyvinyl chloride (PVC).
- e. Battery and Necessary Equipment Cabinet. The battery and necessary equipment cabinet shall be made of 30% heavier hot-dip galvanized steel, with weather-proof and well ventilated design suitable for installation in a marine environment, with access door and lock.

## Section II

### CLEAN-UP

#### II-1. General

Completion of the work shall be followed immediately by clean-up of the work site. The Contractor shall remove from the vicinity of the work, all plant, building, equipment, rubbish, concrete forms and other like materials. Unused materials shall be incinerated or disposed of at, places which will not be unsightly or objectionable to the inhabitants of the area and as aproved by EGAT.

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## PART III - APPENDIX

## APPENDIX 1

### PROCEDURE FOR CONDUCTING THE LIGHT RAM (PENETROMETER) SOUND (KUNZELSTAB) TEST

#### 1. Scope

The light ram sound is used to determine some characteristics of soil stability as found in its natural stratification. It gives information about the degree of compaction of the soil and can be used successfully in all sand and gravel soils, even those with some mixtures of clay or loam. This test supplements knowledge of the soil previously gained from samples at more remote locations.

The extent to which soils are suitable for testing is shown in the following comparison: ,

<u>Suitable soils</u>		<u>Unsuitable soils</u>
Gravel	Silty-sand	Clay
Sand-gravel	Sandy-silt	Clay-silt
Sand	Clayey-silt	

With the light ram sound it is possible to investigate soils and determine the degree of compaction or strength up to a depth of approximately 10 m.

#### 2. Description of the Instrument

The instrument is called light ram sound or "KUNZELSTAB" and is shown in Figure 1. The Kunzelstab consists of round steel rods of 2 cm diameter and 1 m length, connected by threaded studs. Both ends of the rods have flats for wrenching. For recording and controlling the penetration of the sound while testing, the rods are marked circumferentially in 10-cm increments. The lower end of the first rod is a special round piece of 25.25 mm diameter having a cross sectional area of 5 cm<sup>2</sup> and a 60° conical end. The upper end of the rod consists of a hollow anvil (that is screwed on), a guide-rod and a pile-hammer. The pile-hammer weighs 10 kgs and falls 50 cm, guided by the rod. The pile-hammer is raised by two supporting arms. For pulling out the rods after ramming there is a lifting arrangement with special flap jaws.

### 3. Operation of the Kunzelstab

Two men are required to operate the instrument, one for ramming and the other for recording the results. To start the operation, the parts of the instrument are screwed together as shown in Figure 1 with the base plate slipped onto the rod just above the conical end. The assembly with the base plate is placed on a leveled area of the ground with the rod in a vertical position. In this way the light ram sound penetrates the ground under its own weight, more or less. It must be held at the top end while the pile-hammer is raised to the upper position for the free fall to the anvil.

During the ramming procedure, count the strokes and record the total number of strokes necessary for each 20 cm penetration. The pile-hammer shall be moved with a speed of about 30 strokes per minute. The ramming must be executed without an interruption. Pauses which cannot be avoided, must be recorded. The ramming speed does not play a big role in well graded sand and gravel soils, but it influences the results of small grained, porous soil.

After the initial length of rod is driven approximately 90 cm, remove the guide-rod, pile-hammer and anvil; attach the second rod, reposition the anvil, pile-hammer and guide-rod and continue with the sounding. Repeat the procedure, adding rods until the sounding has reached the required depth.

When the test is finished, remove the guide-rod, pile-hammer and anvil and pull out the rods with the lifting arrangement. If the static force is insufficient, assemble the anvil and hammer on the embedded rods so that the pile-hammer can be used to strike upwards against the anvil.

During the sounding, care must be taken to keep the rod connections tight so that the blows are not resisted by the threads but by the shoulders of the rods; otherwise the instrument will be damaged and the test will have to be repeated. If the blow count suddenly increases, indicating no penetration, as would happen with a large stone, then the sound must be removed and the test repeated at a nearby location.

### 4. Report

Note the location of the sounding, weather, party, date, name of recorder and any other local conditions. Record the estimate of ground water table and soil descriptions. Record the number of blows per 20 cm penetration continuously. Record any special problems concerning performance of the equipment, damage to equipment, etc.

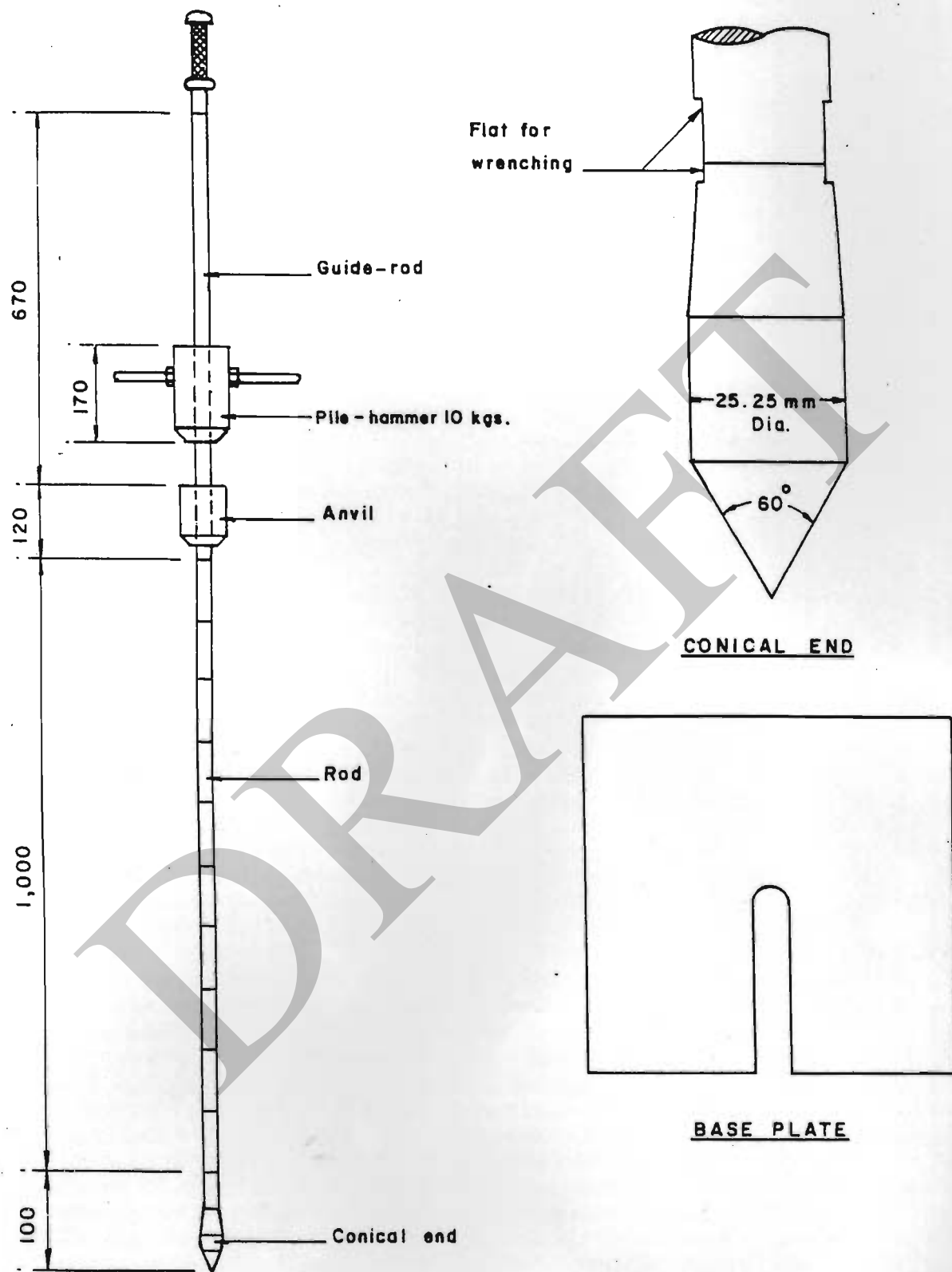


Figure 1.

LIGHT RAM SOUND (KUNZELSTAB)