Overhead Line Hardware and Connector Specification: 69 kV Through 765 kV

1. SPECIAL CONDITIONS FOR EACH RFQ

The Owner will indicate in the RFQ any of the following special conditions:

1.1.1 If the procurement covers hardware only, connectors only, insulators only, or complete insulator-hardware assemblies

1.1.2 The voltage class(es) and ampacities required, where applicable

1.1.3 If Charpy certification is required and to what level

1.1.4 If Magnetic Particle Inspection (MPI) is required on all ferromagnetic hardware as a standard deliverable or only when triggered

1.1.5 The inspection regime, if any: Owner witness, hold points, ITP review, independent testing rights, and required report forms

1.1.6 If preproduction and/or pre-shipment proof-of-fit is required

1.1.7 If there are any source-country or Manufacturer restrictions, and if BABA, Buy American, Federal Acquisition Regulation (FAR) domestic preference, USDA RUS, or any other federal, state, or local content or assembly clauses apply

1.1.8 If kitting by assembly is required or if standard packaging is acceptable

1.1.9 If High Temperature Low Sag (HTLS) or carbon fiber core conductor hardware will be used

1.1.10 Corona and RIV performance requirements, if any — voltage class threshold, test method, RIV limits, and number of assemblies to be tested

1.1.11 If certified test reports are required and how many copies

1.1.12 If spare hardware (nuts, bolts, U-bolts, cotter pins) is required, if it is to be shipped complete with the first assemblies, and the percentages required

1.1.13 If the Manufacturer shall make available a qualified field technician for advice and technical support during handling and installation

2. PURPOSE AND SCOPE

This specification defines the minimum requirements for the design, materials, manufacture, inspection,

testing, marking, packaging, shipment, and delivery of transmission line hardware, connectors, and polymer insulator assemblies for overhead lines operating at voltages from 69 kV through 765 kV (Extra-High Voltage).

2.1.1 This specification covers the following categories of hardware:

- Conductor connectors — compression, bolted, and mechanical types
- Suspension clamps — cushion-grip, armor-grip, and bolted types
- Dead-end/strain clamps — compression and bolted (quadrant) types for both conductor and shield wire
- Yoke plates
- Anchor shackles
- Extension links, clevis eyes, ball-socket fittings, socket eyes, thimble clevises, deadend tees, and connecting hardware
- Turnbuckles and sag-adjustment hardware
- Corona rings and corona shields
- Fasteners — bolts, nuts, washers, cotter pins, and locking devices
- Spacers and spacer-dampers
- Vibration dampers, armor rods, guy grips, and tie-wire assemblies
- Trunnion clamps and line post hardware

2.1.2 Where polymer insulator procurement is included in the RFQ, the requirements of Section 14 shall apply in addition to the hardware requirements of this specification.

2.1.3 When complete assemblies are purchased, the Manufacturer shall be responsible for the proper fitment and connection of all components. Strength coordination shall be applied across each assembly so that all hardware meets or exceeds the mechanical ratings of the insulator ratings.

3. GOVERNING STANDARDS

Where this specification and a referenced standard conflict, this specification governs.

3.1 Normative References

The following standards form a part of this specification to the extent referenced herein. Unless otherwise specified in the RFQ, the latest published edition, including amendments, shall apply.

3.1.1 ANSI C119.4 — Electric Connectors - Connectors for Use Between Aluminum-to-Aluminum and Aluminum-to-Copper Conductors Designed for Normal Operation at or Below 93°C and Copper-to-Copper Conductors Designed for Normal Operation at or Below 100°C

3.1.2 ANSI CC 1 — Electric Power Connection for Substations

3.1.3 ASTM A29/A29M — Standard Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought

3.1.4 ASTM A36/A36M — Standard Specification for Carbon Structural Steel

3.1.5 ASTM A123/A123M — Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

3.1.6 ASTM A143/A143M — Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement

3.1.7 ASTM A153/A153M — Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

3.1.8 ASTM A536 — Standard Specification for Ductile Iron Castings

3.1.9 ASTM A563 — Standard Specification for Carbon and Alloy Steel Nuts (Inch and Metric)

3.1.10 ASTM A576 — Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality

3.1.11 ASTM A668/A668M — Standard Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use

3.1.12 ASTM B26/B26M — Standard Specification for Aluminum-Alloy Sand Castings

3.1.13 ASTM B85/B85M — Standard Specification for Aluminum-Alloy Die Castings

3.1.14 ASTM B209 — Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate Plate

3.1.15 ASTM E709 — Standard Guide for Magnetic Particle Testing

3.1.16 ASTM E1444/E1444M — Standard Practice for Magnetic Particle Testing for Aerospace

3.1.17 ASTM E3024/E3024M — Standard Practice for Magnetic Particle Testing for General Industry

3.1.18 ASTM E709 — Guide for Magnetic Particle Testing

3.1.19 IEEE C135.80 — IEEE Standard for Fasteners for Overhead Line Construction

3.1.20 IEEE C135.100 — IEEE Standard for Line Hardware for Overhead Line Construction (Supersedes ANSI C135.61-64)

3.1.21 SAE J403 — Chemical Compositions of SAE Carbon Steels

4. DESIGN, MATERIALS, AND MANUFACTURING REQUIREMENTS

4.1 General Requirements

4.1.1 All work, workmanship, finish, and fabrication practices shall be consistent with the best modern practice for the materials and products being furnished. All materials shall be new, of recent manufacture, free from defects, and suitable for the intended mechanical, electrical, thermal, and environmental duty.

4.1.2 Strength coordination shall be applied across each assembly so that associated hardware meets or exceeds the mechanical ratings of the insulator. The Manufacturer shall design assemblies using the minimum number of components necessary to satisfy the specification while maintaining safety, maintainability, interchangeability, and articulation to prevent binding.

4.1.3 All hardware components shall be permanently identified with the Manufacturer's name or trademark and part number. Identification marks shall be stamped, cast, forged, engraved, or embossed. Decal markings are not acceptable as primary identification.

4.1.4 Individual items under the same material code number may be used in assemblies and therefore shall be physically interchangeable. All components of the same design and designation shall be identical and like components shall be interchangeable. Allowable dimensional variations shown on individual drawings shall be strictly followed.

4.1.5 Hardware parts which connect shall have comparably shaped mating surfaces for maximum bearing area. All applicable conductor hardware shall connect with insulators as shown on the drawings. Owner will indicate in RFQ if conductor suspension clamps and jumper clamps shall be sized to include armor rods.

4.1.6 Provision shall be made in hardware for draining water if it is likely to collect or pool.

4.1.7 Assemblies shall be designed for convenient use of hot-line tools.

4.1.8 Any shielding rings necessary to meet the requirements of this specification shall be furnished as part of the hardware assemblies. Shielding rings shall be capable of being removed and reinstalled while the line is energized.

4.2 Material Requirements by Component Type

Forged Hardware:

4.2.1 Forged steel load-rated components shall be forged from carbon or alloy steel suitable for the rated mechanical load, galvanizing, fabrication process, and intended service environment. Finished forged components shall conform to ASTM A668/A668M or an approved equivalent forged-steel specification, unless otherwise specified. Steel bar stock used for forging may conform to ASTM A576, ASTM A29/A29M, SAE J403, or an approved equivalent material specification, provided the finished forged component meets the required mechanical properties and design rating.

4.2.2 Shackles, ball fittings, socket fittings, oval-eye extension links, clevises, yoke fittings, and similar load-rated fittings shall be drop-forged, upset-forged, or otherwise hot-forged steel. Forged components shall be heat treated as required to achieve the specified grade, rated load, ductility, and mechanical performance. Material certifications shall be provided upon request and shall identify the applicable heat, lot, material grade, heat-treatment condition, and mechanical test results.

4.2.3 Forged steel components shall be sound, clean, and free of cracks, laps, seams, bursts, scale inclusions, forging folds, injurious decarburization, or other discontinuities that may impair fit, galvanizing quality, or mechanical performance. Forging flash, fins, gates, sharp projections, and parting-line irregularities shall be trimmed, sheared, machined, or ground to within +/-30,000th of an inch with the adjacent surface. Load-bearing surfaces, bearing areas, clevis areas, bolt holes, pin holes, and fitting-contact surfaces shall be smooth and free of sharp edges, burrs, notches, or stress risers.

4.2.4 Load-bearing welds are not permitted on load-rated forged steel components without Owner approval and qualified by design review, weld procedure qualification, inspection, and mechanical testing. Non-load-bearing welds, when approved, shall not impair fit, galvanizing quality, fatigue performance, or mechanical rating.

4.2.5 Flat plate load-rated hardware shall be ASTM A36/A36M steel or an approved higher-strength steel suitable for the rated mechanical load, galvanizing, forming, and intended service environment. Steel plate material shall be free from laminations, seams, laps, cracks, excessive scale, inclusions, or other defects that may impair fabrication, galvanizing, or mechanical performance.

4.2.6 All hardware shall be hot-dip galvanized after fabrication unless otherwise specified. Galvanizing shall conform to ASTM A123/A123M for fabricated iron and steel products or ASTM A153/A153M for iron and steel hardware, as applicable. Components shall be designed and fabricated to permit proper venting, drainage, coating adhesion, and dimensional fit after galvanizing. For heat-treated or high-strength steel components, materials, fabrication methods, cleaning, pickling, and galvanizing practices shall be selected to minimize the risk of hydrogen embrittlement or galvanizing-related embrittlement. Safeguards against embrittlement shall follow ASTM A143/A143M where applicable.

Ductile Iron Hardware:

4.2.7 Load-rated ductile iron components shall be cast from ductile iron conforming to the requirements of ASTM A536. Unless otherwise specified on the engineering drawing or purchase order, the material shall be one of the following ASTM A536 grades, as appropriate for the intended application: 60-40-18, 65-45-12, 80-55-06, or 100-70-03.

4.2.8 Heat treatment shall be performed, as required, to achieve the specified ASTM A536 grade and the required mechanical properties. Material certifications shall be furnished upon request and shall identify, at a minimum, the applicable heat number, lot number, material grade, and certified mechanical test results demonstrating compliance with the specified requirements.

4.2.9 Castings shall be free of cracks, cold shuts, shrinkage cavities, excessive porosity, sand or slag inclusions, misruns, and other discontinuities that could adversely affect mechanical strength, service performance, dimensional accuracy, or the quality of the galvanized coating.

4.2.10 In general, ductile iron casting dimension tolerances shall comply with CT9 (ISO 8062). Casting parting lines shall be +/-.030” to adjacent surfaces. Contact areas, including gates and risers, shall be +/-.060” to adjacent surfaces. Load-bearing surfaces, bearing areas, clevises, pin holes, bolt holes, and hardware contact surfaces shall be free from stress concentrating defects. All casting surfaces shall be free of burrs, sharp edges, and considerable voids.

4.2.11 Unless otherwise specified, all ductile iron hardware shall be hot dip galvanized after production operations are complete. Galvanizing shall conform to ASTM A123/A123M or ASTM A153/A153M for ductile iron, iron and steel hardware items, as applicable. Castings shall be designed and manufactured with adequate venting and drainage to facilitate proper galvanizing, ensure complete coating coverage and adhesion, and maintain specified dimensional tolerances after galvanizing.

Aluminum Hardware:

4.2.12 Suspension clamps, dead-end clamps, and conductor contact surfaces intended for use with aluminum or aluminum alloy conductors shall be fabricated from aluminum alloy conforming to ASTM B26 (sand castings), ASTM B85 (die castings), or ASTM B209 (sheet and plate). Aluminum alloy grades shall be A356-T6 or A380 for castings, or 6061-T6 for wrought forms, unless otherwise specified.

4.2.13 Material certifications shall be furnished upon request and shall identify, at a minimum, the applicable heat number, lot number, material grade, and certified mechanical test results demonstrating compliance with the specified requirements.

4.2.14 Castings shall be free of cracks, cold shuts, shrinkage cavities, excessive porosity, sand or slag inclusions, misruns, and other discontinuities that could adversely affect mechanical strength, service performance, or dimensional accuracy.

Stainless Steel:

4.2.15 Cotter pins shall be Type 304 or 316 stainless steel. Unless otherwise specified in the purchase order, cotter pins shall be the humpbacked type with ends cut at 90 degrees. The nominal diameter of cotter pins designed for securing suspension clamps shall not be less than 1/4 of the diameter of the pins or bolts in which they are to be installed. Pins or bolts with diameter more than one inch shall use a 1/4-inch cotter pin.

4.2.16 Holes for cotter pins in the heads of sockets shall be recessed so that the head of the cotter pin does not protrude beyond the general outside curvature of the socket. These holes shall also be shaped to facilitate use of hot-line tools. The cotter pin shall be humped and shall have the ends spread so that the cotter pin cannot be pulled completely from the socket.

4.2.17 When loop-type cotter keys are specified, they shall have one leg of reduced length not protruding beyond the pin; the remaining leg shall form a loop with a diameter not smaller than the head of the key. Loop-type cotter keys shall be installed on the pin and spread sufficiently to prevent falling out during shipping and handling, and they shall produce a low-corona loop profile.

4.3 Component-Specific Design Requirements

Suspension Clamps:

4.3.1 Suspension clamp type(s) shall be specified by the Owner in the RFQ.

4.3.2 For cushion-grip and armor-grip suspensions, the initial slip load shall be approximately 20% of the conductor rated breaking strength for standard conductors, and approximately 10% of RBS for EHS steel strands.

Dead-End and Strain Clamps:

4.3.3 Dead-end (strain) clamps shall be either compression or bolted as specified in the RFQ.

4.3.4 Bolted quadrant strain clamps for ground wire and shield wire applications shall be of ductile iron, galvanized per ASTM A153.

4.3.5 Slip and pull-out strength testing shall conform to IEEE C135.64 for bolted dead-end strain clamps.

4.3.6 Compression dead-end fittings shall be furnished with the correct die index and installation instructions per the conductor size and stranding specified.

Yoke Plates:

4.3.7 Yoke plates may be fabricated from structural steel plate, ductile iron, or aluminum, as specified in the RFQ. All corners and edges shall be well rounded and all surfaces smooth. Steel or malleable iron yokes and attachment fittings shall be hot-dip galvanized in accordance with ASTM A153.

4.3.8 All holes shall be drilled or cut to +1/64 in. machining tolerance to the dimension shown. All holes shall be perpendicular to the surface. Holes in yoke plates shall not be punched. All holes designed for bent bolt connections shall have a 1/8" 45 Degree chamfer. Load-bearing holes shall be free from burs and shall provide a load bearing area suitable to the strength rating. Load bearing welds are not acceptable.

4.3.9 Yoke plate dimensions and hole spacing shall be compatible with standard hardware fittings (clevis eyes, ball-socket ends, anchor shackles) used in the assembly.

4.3.10 Optional suspension attachments on yoke plates for running corner assemblies shall be clearly noted on drawings.

4.3.11 The specific mounting attachment required for angle assemblies will be specified in the RFQ and drawings.

Anchor Shackles:

4.3.12 Shackle body shall be forged steel, hot-dip galvanized.

4.3.13 Shackles shall be furnished with pin, bolt, nut, and cotter pin pre-assembled. Bolts and Clevis pins will be Grade 5 Steel, cotter pin shall be stainless steel.

Extension Links, Socket Eyes, Y-Clevises, Thimble Clevises, and Deadend Tees:

4.3.14 Extension links, clevis eyes, socket eyes, Y-clevises, ball eyes, and deadend tees shall be fabricated from forged steel or ductile iron and shall be hot-dip galvanized.

Turnbuckles:

4.3.15 Turnbuckles shall be fabricated from forged or machined steel with hot-dip galvanized or mechanically galvanized finish.

4.3.16 Jam nuts shall be furnished with all turnbuckles unless otherwise indicated in the RFQ.

4.3.17 The Manufacturer shall state the minimum and maximum extended length, take-up range, and rated load in the submittal data.

Fasteners — Bolts, Nuts, Washers, and Lock Devices:

4.3.18 Bolts, nuts, and associated hardware shall conform to IEEE C135.1, IEEE C135.80, ASTM A563 as applicable. Fasteners shall be hot-dip galvanized per ASTM A153. Nuts, bolts, studs, and screws shall conform to the ANSI Standards of pitch, thread shapes, dimensions, and tolerances.

4.3.19 Bolt length: Fasteners shall extend not less than 1/2 in. nor more than 2-1/2 in. beyond the face of the last nut after final assembly. Galvanized bolts shall not be cut after being galvanized.

4.3.20 Holes in hardware shall be nominally 1/16 in. greater than the fastener diameter unless otherwise noted.

4.3.21 Spring (Belleville) washers shall be provided where specified.

4.3.22 All pinned connections shall be made with hex head bolt, button head clevis pin, or hex head clevis pin and include stainless steel cotter pins.

4.3.23 Shackles, clevises, and similar components shall be shipped pre-assembled with the mating bolt

or pin in place together with the cotter pin or other lock device.

4.3.24 Hump-back cotter pins used for shipment-ready assemblies shall fit snugly in the hole when preassembled and remain tight during shipment and handling.

4.3.25 All threaded components shall be capable of hand pre-assembly without wrenches.

4.3.26 The Manufacturer shall indicate the Manufacturer's recommended torque values for the relevant bolt diameters and material types.

Guy Grips (Automatic Dead-End Grips):

4.3.27 Manufacturer shall size preformed-wire grip dead ends to meet the wire diameter range and rated breaking strength as provided in the RFQ documents. Guy grips are intended for a single (one-time) use only for the specified application.

4.3.28 OPGW assembly grips shall include the grip, extension link, grounding assembly for #4 copper wire, and anchor shackle where specified.

Corona Rings and Corona Shields (EHV Applications):

4.3.29 Corona protection is required at 345kV and above.

4.3.30 Manufacturer shall design components of 345 kV assemblies to minimize corona discharge and shall include a corona ring and/or shield as needed at the line end. RIV for the complete assembly shall not exceed 500 microvolts at 1,000 kHz, based on an operating voltage of 230 kV line-to-ground. The corona threshold voltage shall be equal to or above 230 kV line-to-ground for all components of the insulator assembly included in the specification.

4.3.31 For 500 kV assemblies, all items used in construction shall minimize corona discharge and include a corona ring and/or shield as needed at the line end and a corona ring on the tower end. RIV for the complete assembly shall not exceed 500 microvolts at 1,000 kHz when tested at 350 kV line-to-ground. No visible corona shall occur at 350 kV line-to-ground.

4.3.32 Where the project requires a higher conductor-hardware corona-extinction threshold (765 kV systems or other long-line designs), all conductor hardware assemblies shall be designed for a corona extinction voltage not less than 510 kV line-to-ground, with RIV from any hardware assembly not exceeding 1000 microvolts at 1,000 kHz when tested at 510 kV line-to-ground.

4.3.33 Corona rings shall be fabricated from 6061-T6 or equivalent aluminum alloy. The torus and tube diameter shall be selected to limit surface gradient below the corona inception threshold.

4.3.34 Any shielding rings necessary to meet the corona/RIV requirements of this specification shall be furnished as part of the hardware assemblies and shall be capable of being removed and reinstalled while the line is energized.

4.3.35 Manufacturer shall key or index rings to ensure they are not installed by others upside-down relative to the insulator and hardware.

Vibration Dampers and Armor Rods, Spacers and Spacer-Dampers:

4.3.36 Armor rods shall protect the conductor at the clamp point if helical suspension clamps or MacLean Power Systems™ ACFS formulary clamps are not used.

4.3.37 Owner will indicate if spacers or dampers shall have elastomeric conductor cushions and will provide with the RFQ the span length, conductor type, and wind loading parameters to allow for proper sizing and placement locations.

4.3.38 Spacers shall conform to IEC 61854 and shall be compatible with the Owner-provided conductor diameter range, bundle geometry, and wind environment.

4.3.39 Spacer-damper arm hinges shall be designed to prevent locking under extreme bundle motions.

4.4 High-Temperature Conductor Applications

4.4.1 Owner will indicate in the RFQ if high-temperature or carbon core conductors will be used. If required, hardware shall be suitable for the specified operating temperature without reduction in strength, electrical performance, or service life.

4.4.2 Manufacturer shall indicate if armor rods are a necessary heat sink used to meet the high temperature requirement.

5. GALVANIZING AND SURFACE PROTECTION

5.1 Hot-Dip Galvanizing Requirements

5.1.1 All ferrous hardware shall be hot-dip galvanized in accordance with ASTM A123/143/A153 as applicable. In lieu of hot-dip galvanizing, weights may be painted with a zinc-rich organic paint having a dry-film weight of 92 through 95 percent zinc, with a dry-film thickness of not less than 3 mils.

5.1.2 The galvanizing process shall be controlled to avoid hydrogen embrittlement, warpage, distortion, over-pickling, or excess zinc accumulation in threads, holes, or load-bearing connection surfaces.

5.2 Coating Quality

5.2.1 The galvanized coating shall adhere firmly to the base metal and shall be free from blisters, flux deposits, rough edges, flaking zinc, uncoated areas, and other defects that would impair corrosion protection or interfere with assembly.

5.2.2 Galvanization shall take place after all machining, bending, punching, drilling, and other working operations are complete.

5.2.3 Threads shall be clean-cut and free of zinc buildup that prevents hand assembly.

5.2.4 Load-bearing holes shall be beveled, smooth-finished, and free from burs. Holes shall be sized to maximize the load-bearing surface of the bolt or pin.

5.2.5 All pieces requiring galvanizing shall be visually inspected for defects prior to galvanizing.

5.2.6 When requested in the RFQ, and for an additional cost, wet magnetic particle testing of ferrous parts shall be performed after fabrication and die stamping, and prior to galvanization.

5.3 Zinc Coating Weight Verification

5.3.1 When specified in the RFQ, coating weight testing shall be performed per ASTM A153 or ASTM A123 and certified results shall be submitted. Zinc certification reports shall be furnished when requested in the RFQ.

6. CONNECTOR REQUIREMENTS

6.1 Scope and General

6.1.1 This section provides requirements for electrical connectors including compression (alloy one-piece and tubular two-piece), bolted, and mechanical connectors for phase conductors, overhead ground wire, and OPGW. Connector performance shall conform to ANSI C119.4. Items covered by this specification shall be permanently marked to show Manufacturer or Manufacturer's symbol, catalog number, conductor size or range, and die index or section number for compression items. Marking shall remain visible after installation.

6.2 Compression Fitting Types

6.2.1 RFQ shall indicate if one-piece alloy compression fittings, two-piece tubular fittings, or implosive connectors will be used.

6.2.2 Each compression fitting shall be permanently marked with the die index required for proper compression. Manufacturer shall provide sufficient oxide-inhibitor with fittings.

6.3 Electrical Performance

6.3.1 All connectors shall comply with ANSI C119.4 current cycle, thermal cycle, and current-temperature tests.

6.3.2 Resistance after installation shall not exceed 110 percent of the resistance of an equivalent length of conductor.

6.3.3 Pullout strength: Bolted conductors shall meet ANSI CC 1 requirements. Compression connectors shall meet minimum tension, partial tension, or full tension requirements as applicable.

6.3.4 Heat cycle test: Compression items shall meet ANSI C119.4 heat cycle test requirements.

6.3.5 Mechanical test: Suspension clamps and bolted dead-end clamps shall be tested to demonstrate they meet the specified ultimate body strength.

7. SUBMITTALS, DRAWINGS, AND RECORDS

7.1.1 The Manufacturer shall submit electronically standard detail and assembly drawings in PDF format for each item and each assembly furnished. Drawings shall include dimensions, materials, catalog numbers, and rated mechanical and electrical loads.

7.1.2 Whether from the Manufacturer or any sub-Manufacturers, all correspondence, drawings, tests, and calculations shall be in English and use imperial units.

7.1.3 Manufacturer shall indicate lead times in the quotation for each individual item in the bill of

material. Owner will indicate in the RFQ if formal approval of the materials and drawings are required prior to manufacturing. However, review by the Owner does not relieve the Manufacturer of the responsibility for meeting all specification requirements.

7.1.4 Manufacturer shall maintain traceable records of manufacturing, lot identification, inspections, and tests.

8. QUALITY ASSURANCE, INSPECTION, AND FACTORY FIT-UP

8.1 Scope and General

8.1.1 The Manufacturer shall maintain a documented QA/QC program covering incoming material inspection, in-process inspection, final inspection, calibration, and nonconformance control.

8.1.2 Raw materials, components, and completed products as well as production processes shall be subject to inspection by the Owner and/or the Owner's representative.

8.1.3 The Owner and/or the Owner's designated representatives reserve the right to witness any and all tests. Testing schedules for all tests beyond routine tests shall be submitted to the Owner a week or more prior to testing. Owner will indicate in the RFQ if source inspection, ITP review, or in-person witness is required.

8.1.4 Any nonconformance, technical deviation, or concession affecting compliance shall be documented and submitted to the Owner for disposition before the affected item is shipped.

8.2 Magnetic Particle Inspection

8.2.1 When requested in the RFQ, and for an additional cost, the Manufacturer shall conduct Magnetic Particle Testing on all ferromagnetic assembly hardware to verify that no defects are present. Upon request, the Manufacturer shall provide testing procedure conforming to ASTM E1444 or ASTM E709.

8.2.2 When requested in the RFQ, wet magnetic particle tests shall be performed after completion of fabrication and die stamping, and prior to galvanization. Indications of cracks, inclusions, or surface defects in a part will be cause for rejection. Rejected parts shall not be reworked and resubmitted for acceptance.

8.3 Fit-Up Verification

8.3.1 When requested in the RFQ, and for an additional cost, the Manufacturer shall perform a proof-of-fit test to minimize connection or mating problems for EHV assemblies.

8.3.2 Owner will indicate in Purchase Order if fit proof-of-fit test is required prior to production

8.4 Spare Hardware Provision

8.4.1 When requested in the RFQ, and for an additional cost, the following minimum percentages of spare hardware shall be bulk-packed and shipped with the first hardware assemblies sent to each specified destination. The percentages apply to the total quantity of hardware shipped to that destination:

- 1% of all nuts and bolts, including U-bolts, of all sizes.
- 3% of all cotter pins of all sizes.

9. MECHANICAL, ELECTRICAL, AND FACTORY TEST REQUIREMENTS

9.1 Test Classification

9.1.1 Tests under this specification are classified as: (1) Design Tests — performed on completion of a new design to establish performance data; (2) Conformance Tests — performed on each production lot; (3) Routine Tests — performed on all pieces.

9.1.2 Mechanical acceptance testing of load-rated line hardware shall conform to IEEE C135.100-2024, IEEE Standard for Line Hardware for Overhead Line Construction as applicable.

9.2 Design Tests

9.2.1 When requested in the RFQ, and for an additional cost, the Manufacturer shall submit certified evidence that design tests have been completed, along with the test results. Design tests shall include the following, as applicable:

9.2.2 Mechanical strength test: demonstrating the item meets or exceeds the specified strength rating.

9.2.3 Temperature rise test: item shall meet the requirements of Section 5 of this specification.

9.2.4 Resistance test: resistance of the item shall be less than 110% of the resistance of an equivalent length of conductor.

9.2.5 Pullout strength test: bolted conductors per ANSI CC 1; compression connectors per minimum/partial/full tension requirements.

9.2.6 Corona and RIV tests: demonstrating compliance with this specification. Corona and RIV tests shall be made only the first time a part is purchased. Unless the physical shape changes, corona and RIV tests will not be required on subsequent purchases. All corona and RIV tests shall include RIV and phase-to-ground voltage for corona onset, offset (extinction), and two RIV readings at the specified phase-to-ground voltage (increasing and decreasing). Tests for new parts shall be made on the complete assembly even if only one part is new or changed.

9.2.7 Heat cycle test: compression items shall meet ANSI C119.4 heat cycle requirements.

9.3 Conformance (Production Lot) Tests

9.3.1 Conformance tests shall be performed on each lot of load-rated forged and cast hardware. Conformance tests on flame-cut steel plate hardware and non-load-rated hardware shall be performed only when called out in the RFQ and PO.

9.3.2 Routine tests shall be performed on all pieces of line hardware prior to shipment. All pieces requiring galvanizing shall be visually inspected for defects before galvanizing.

Sample Size Requirements:

9.3.3 When the RFQ requests lot-based statistical sampling and lot acceptance/rejection criteria, it will adhere to IEEE C135.100-2024. Sample sizes and lot acceptance and rejection decisions shall

follow the applicable single- or double-sampling plan. A tested unit failing below its specified rated ultimate strength shall be classified as defective. Any unit failing below 85% of its specified rated ultimate strength shall constitute a major defect and shall be cause for rejection of the entire lot.

Tensile Test Acceptance Criteria — Forged and Cast Hardware:

9.3.4 When a conformance test is required, it shall be the tensile test. Test setup shall use pins or bolts normally furnished with the hardware. Load shall be started at zero and brought smoothly to the failure point. The load may be increased rapidly to 75% of ultimate strength; from 75% to failure, the rate shall not exceed 25% of ultimate strength per minute.

9.3.5 For forged or cast items, acceptance criteria shall be:

- $\bar{X}n - 2\sigma \geq$ Exhibit (drawing) ultimate strength rating.
- $Sn \leq 1.25 \times \sigma$ (manufacturer's sigma value).

9.3.6 For flame-cut plate hardware:

- $\bar{X}n \geq XL$ (lowest strength established by design test or shown on the exhibit).
- $Rn \leq Rmax$ (range of test values shall not exceed maximum range established by design test).

9.4 Assembly Mechanical Test:

9.4.1 When requested in the RFQ, and for an additional cost, complete assemblies shall be loaded to mechanical failure. Two assemblies of each type shall be tested. Assemblies shall be complete with the exception that a minimum of two insulator bells (where applicable) may be substituted for the full string. Loads shall be applied in the directions specified on the project assembly drawings.

9.4.2 Steel attachment plate thickness on test frames shall be 3/8 in. less than the minimum specified hardware assembly shackle openings.

9.4.3 The load shall be applied equally to each point of conductor attachment.

9.4.4 Assemblies shall be loaded to 75% of rated strength and held for five minutes. After removal, assemblies shall show no evidence of cracks, deformation, or incipient failure. It shall be possible to disassemble by hand (small hand tools may be used to remove cotter pins and initially back off nuts).

9.4.5 The load shall then be applied to the same assemblies and increased until failure. Failure loads shall be recorded.

9.4.6 If any component shows defects or fails at less than rated strength, the design of the entire assembly shall be rejected.

9.5 Corona and RIV Testing

9.5.1 Where corona or RIV performance is specified, testing shall be performed per the requirements of the RFQ and conform to IEC 61284, CISPR 18, or NEMA 107 (NEMA 107-1987). The Manufacturer shall perform corona testing on the quantities specified in the RFQ. Testing shall be performed on the complete assembly in its intended configuration, including all grading hardware.

9.5.2 Insulator and hardware assemblies shall be subjected to a 60 Hz voltage to determine that the

corona extinction voltage level is not less than 15% above Vmax, with a ground plane a maximum of 15 feet from the assemblies. Care shall be taken to eliminate corona from all sources other than the test sample.

9.5.3 In a dark laboratory, the test specimen shall first be energized with a high enough voltage to create detectable positive corona discharge on the specimen, to prove the detection system is working. Then, with an applied voltage higher than the specified threshold (high enough to create positive corona) and the ground plane in place, the voltage shall be lowered to the specified extinction voltage. The test specimen shall be viewed from at least two directions approximately 180° apart, on the plane of the building floor that has the best view of the flat plane(s) of the test specimen. There shall be no visible positive corona on the test specimen at the specified extinction voltage.

9.5.4 RIV characteristics shall be determined as follows: a 60 Hz voltage shall be raised to a level where substantial positive corona activity is detected. A RIV measurement shall be taken using the procedure specified by NEMA 107-1987. The voltage shall then be reduced in steps until the measured RIV level reaches the background level. RIV measurements shall be recorded at each voltage step, and a plot of RIV versus applied voltage shall be made.

9.6 Test Reports

9.6.1 When requested in the RFQ, copies of test reports shall be provided. Test reports shall contain at minimum:

- Date and location of test
- Catalog number and description of components tested
- Hardware component ratings (ultimate)
- Test procedure and description of test setup
- Date of last calibration of test equipment
- Test values at which failure occurred and a description of the failure or defect
- Number of units tested
- Average test value Xavg = $(X_1 + X_2 + ... + X_n) / n$
- A statement that the hardware conforms, or does not conform, to the requirements of this specification
- Signature of certification

9.6.2 Hardware may be shipped prior to approval of the test report at the Manufacturer's risk; if the report is rejected, hardware shall be returned at the Manufacturer's expense.

10. MARKING, TRACEABILITY, AND ASSEMBLY IDENTIFICATION

10.1.1 Each hardware component shall be permanently marked with the Manufacturer's name or trademark and part number. Marking shall be so located as to be visible when the item has been installed.

10.1.2 Compression connectors shall be so marked that sufficient residual identification remains after installation/compression to identify the Manufacturer and item. Die index or section number shall be included.

10.1.3 Each shipment, package, assembly kit, or crate shall be traceable to the applicable purchase order, assembly type, and component list. Lot and date coding shall be used where needed to

maintain traceability of production and testing.

10.1.4 Where appropriate, a copy of the assembly drawing or equivalent assembly identification sheet shall accompany each assembly package or kit.

10.1.5 Vendor's catalog numbers shall be indicated for each component with complete details and dimensions for each assembly and each component of the assemblies.

11. PACKAGING, CRATING, AND SHIPMENT PROTECTION

This section establishes detailed minimum requirements for packaging, crating, and shipment of all transmission line hardware (and, where included, polymer insulators) furnished under this specification.

11.1 Packaging Construction

11.1.1 All hardware shall be packaged in fully enclosed wooden crates except for armor rods, yoke plates, and other large pieces that are impractical to box. Cardboard boxing is not acceptable.

11.1.2 Crate frame lumber shall be solid, kiln-dried (or equivalent), straight, sound, and free of splits or knots in critical areas.

11.1.3 Crate sides, top, and bottom shall be OSB or plywood or solid wood. Plywood or solid wood sides shall be used when longer storage is requested by the Owner or when the weight on the bottom side requires reinforcement.

11.1.4 Each crate shall be strong enough to support two additional, fully loaded crates on top while resting on level dirt or crushed rock. Stacking loads shall transfer through corner posts/uprights, not through panels.

11.1.5 Crate base and pallets shall resist bottom panel failure when racking, forking, and slinging. The base shall provide a minimum of 2-way standard fork pockets and shall have ground clearance suitable for outdoor storage.

11.2 Crate and Pallet Weight Limits

11.2.1 Crates of mixed line hardware (load-rated and non-load-rated combined) shall not exceed 2,500 lb gross weight when shipped on flat-bed carriers, or 400 lb. gross weight when shipped as wire-bound boxes on pallets.

11.3 Internal Bracing and Fasteners

11.3.1 Fasteners (nails, screws, bolts, and staples) shall be of proper length such that ends are not exposed either internally or externally and do not create safety or material hazards.

11.3.2 Loose parts in crates shall be contained internally and secured with 2x3 or larger bracing. If mixed parts are shipped, small components shall be segregated and secured to prevent migration into other parts. Other than packing materials, there shall be no unnecessary loose materials in the crate.

11.3.3 Fasteners and small hardware within a crate or container (cotter pins, nuts, washers, lock washers) shall be also packaged in bags or boxes.

11.4 Crate Lid and Banding

11.4.1 The lid shall be designed for multiple, controlled openings and closings using original screws and screw locations. Lids shall be secured with screws having the same head type for the entire crate and all boxes. Screw heads shall be standard sized Square, Phillips, or Torx.

11.4.2 Lid screws shall be spaced 16 to 24 inches on the crate ends and every 24 to 48 inches on the crate sides. One screw shall be used to secure the lid at each corner and at each vertical framing board.

11.4.3 The crate shall be banded with heavy-duty polyester banding for primary closure. Where the RFQ permits or specifies, metallic bands may be used to secure containers to pallets only.

11.4.4 Vertical banding around the crate shall be secured every 24 to 48 inches, and at least one horizontal band shall be placed around the midsection.

11.4.5 Bands shall be tight, properly crimped/sealed, and shall not contact corona-sensitive hardware surfaces.

11.4.6 If wooden boxes are used for smaller parts, they should be resealable by reusing screws or wire binding.

11.5 Load Distribution and Stowage

11.5.1 Materials shall be loaded so that the combined center of gravity (CG) of the crate and contents remains between the fork pockets/skids. Weight shall be distributed keeping the heaviest items low and directly over the base runners.

11.5.2 All materials and boxes inside the crate shall be packaged and secured to prevent tipping, sliding, or exiting their packaging during vehicular acceleration, deceleration, swerving, or emergency braking.

11.5.3 If crates/containers/boxes are stacked during transport, they shall be properly designed, constructed, stacked, and strapped to prevent damage from sudden impacts.

11.5.4 Packaging shall safeguard all transporters, handlers, and the public from falling, shifting, or settling materials and from any sharp edges.

11.6 Protection of Corona, Aluminum, and Galvanized Hardware

11.6.1 All hardware designed to minimize corona (corona rings, grading rings, large-radius hardware) shall be protected to prevent being nicked, cut, scraped, or worn during transport. Bare metal of corona hardware shall not contact the crate, crossmembers, banding, or other components without a protective layer in between.

11.6.2 Aluminum components shall be segregated from ferrous hardware to prevent damage from harder ferrous parts. Ferrous hardware shall likewise be packed to prevent any damage to its galvanized coating.

11.7 Container Marking and Labeling

11.7.1 All containers, crates, and packages shall be clearly marked in English. All hardware containers shall be marked clearly and legibly with waterproof markings. Marking shall be on two sides or on two locations on opposite sides of the container and/or pallet, to allow reading while stacked and while using a forklift.

11.7.2 Labels shall be affixed with staples on all four corners. Labels shall be placed on sides of the crate to allow for reading while stacked and while using a forklift.

11.7.3 Container markings shall include:

- Manufacturer's name and trademark
- Catalog number for each item type in the crate
- Assembly name and number
- Item description
- Quantity
- Container ____ of ____ (sequence and total)
- Gross weight and tare weight

END OF SPECIFICATION