



IEEE Standard for Testing and Performance of Hardware for Optical Ground Wire (OPGW)

IEEE Power and Energy Society

Developed by the
Power System Communications and Cybersecurity
Committee

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STANDARDS

IEEE Standard for Testing and Performance of Hardware for Optical Ground Wire (OPGW)

Developed by the

Power System Communications and Cybersecurity Committee
of the
IEEE Power and Energy Society

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IEEE SA Standards Board

Abstract: Hardware performance, test requirements, procedures, and acceptance criteria for a transmission line overhead ground wire (also known as shield wire, static wire, earth wire, and sky wire) with optical fibers commonly known as optical ground wire (OPGW) are covered. Functional requirements—such as electrical, mechanical, optical fiber, environmental, and test requirements related to design, installation, in service, and maintenance, including routine tests—are included.

Keywords: fiber optic ground wire, IEEE 1591.1™, laboratory tests, OPGW, optical ground wire, type tests

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Introduction

This introduction is not part of IEEE Std 1591.1-2023, IEEE Standard for Testing and Performance of Hardware for Optical Ground Wire (OPGW).

IEEE Std 1591.1 is the hardware test standard for optical ground wire (OPGW) applications. Hardware for OPGW is identified as hardware in direct contact with the OPGW cable in an OPGW hardware and cable system. This test standard provides standardization of terminology, performance, and test requirements for OPGW hardware. This hardware standard compliments IEEE Std 1138™ for OPGW, as many of the terms and tests requirements are common for consistency and testing efficiency.

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IEEE Standard for Testing and Performance of Hardware for Optical Ground Wire (OPGW)

1. Overview

1.1 Scope

This standard covers the construction, mechanical and electrical performance, test requirements, environmental considerations, and acceptance criteria for qualifying hardware for use with optical ground wire (OPGW).

1.2 Purpose

This standard provides standard manufacturing, testing, and procurement specifications for use with OPGW hardware in order to simplify procurement, standardize testing, assure product quality, and assist usage.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{6,7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

⁶The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

ASTM A153/A153M, Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.⁸

ASTM B117, Standard Practice for Operating Salt Spray (Fog) Apparatus.

AWS D1.1/D1.1M, Structural Welding Code—Steel.⁹

IEC 61897, Overhead Lines—Requirements and Tests for Stockbridge Type Aeolian Vibration Dampers.¹⁰

IEEE Std 664™, IEEE Guide for Laboratory Measurement of the Power Dissipation Characteristics of Aeolian Vibration Dampers for Single Conductors.^{11,12}

IEEE Std 1138™, IEEE Standard for Testing and Performance for Optical Ground Wire (OPGW) for Use on Electric Utility Power Lines.

ISO 1461, Hot dip galvanized coatings on fabricated iron and steel articles—Specifications and test methods.¹³

ISO 4892, Plastics—Methods of exposure to laboratory light sources.

ISO 9227, Corrosion tests in artificial atmospheres—Salt spray tests.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.¹⁴

hardware: Attachments or fittings that are in direct contact with the cable.

installation tension: *See:* **stringing tension (STT)**.

maximum design load (MDL): The maximum design load the cable is expected to experience in service under meteorological loading conditions (e.g., wind, ice loads, temperature). It is used in determining the maximum rated design tension (MRDT). *Syn:* **maximum working load (MWL)**.

⁸ASTM publications are available from the American Society for Testing and Materials (<http://www.astm.org/>).

⁹AWS publications are available from the American Welding Society (www.aws.org).

¹⁰IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch/>). IEC publications are also available in the United States from the American National Standards Institute (<http://www.ansi.org/>).

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¹⁴*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

maximum rated design tension (MRDT): The maximum tension rating of the cable so it will function over its lifetime without reducing the performance of the optical fibers. This tension rating will be determined by the cable manufacturer. It may be expressed in terms of tension or as a percentage of rated tensile strength (RTS). It may also be known as *maximum rated cable load* (MRCL).

maximum working load (MWL): *See:* **maximum design load (MDL).**

optical ground wire (OPGW): This cable has the dual performance functions of a lightning shield wire (overhead ground wire) and telecommunications capabilities.

optical time domain reflectometer (OTDR): Used to determine the degree and location of attenuation in optical fibers by transmitting a light source and measuring time of flight and strength of reflected optical signal.

optical unit: A component of the optical ground wire (OPGW), this unit is comprised of a protective mechanical support housing and/or buffer tubes and optical fibers contained internally.

pulling tension: *See:* **stringing tension (STT).**

rated tensile strength (RTS): The calculated tensile load that the cable shall withstand without mechanical failure.

sagging tension (SAT): The initial tension at which the cable is pulled during the sagging portion of the installation process. This tension is used to achieve the appropriate sag relative to other conductors and the ground.

stringing tension (STT): The tension used to pull the cable through sheaves during the stringing portion of the installation process. This is never greater than the sagging tension (SAT). *Syn:* **installation tension** or **pulling tension**.

3.2 Special term

system (OPGW system): The cable and hardware described in this standard functioning as one integrated unit, that is, the cable and hardware working together.

3.3 Acronyms and abbreviations

MDL	maximum design load
MRCL	maximum cable load
MRDT	maximum rated design tension
MWL	maximum working load
OPGW	optical ground wire
RTS	rated tensile strength
SAT	sagging tension
STT	stringing tension

4. Requirements for optical ground wire hardware

4.1 General

All OPGW hardware is to be of proper manufacture, unused, and free of defects that could be detrimental to its application.

System testing is typically conducted to demonstrate hardware and OPGW compatibility. This standard describes the type of test, performance requirements, and acceptance criteria for respective hardware referenced in [Clause 5](#).

Guidelines for optical measurements are established in [5.3](#). This subclause is referenced in hardware tests that require optical results as a measure of acceptance.

This standard covers requirements for hardware specifically designed for and in direct contact with OPGW cable such as dead ends and suspensions. Conventional hardware fittings that do not come in direct contact with the cable, such as Y-clevis, extension links, yoke plates, and so forth, are not covered under this standard.¹⁵

Every effort has been made to harmonize with IEEE Std 1138, IEEE Standard for Testing and Performance of Optical Ground Wire (OPGW) for Use on Electric Utility Power Lines;¹⁶ however, if any discrepancies occur, these can be resolved by agreement between the customer and manufacturer.

OPGW hardware design dimension tolerances shall ensure that the product components and interface areas meet their specified mechanical and electrical requirements.

4.2 Functional requirements

4.2.1 OPGW cable diameter and hardware range/interface

Suspension and dead-end hardware, some types of vibration damper hardware, and bonding clamps for OPGW cable are usually designed for a specific (narrow range) size and/or (specific) type of OPGW cable. Hardware is generally not designed to accommodate a large range of sizes of OPGW cable.

Factors that can influence the interaction of the hardware to the OPGW cable interface are as follows:

- a) Excessive contact pressure imposed by the hardware can impair the optical signal or cause localized mechanical damage or stress risers to the OPGW cable.
- b) The electrical transfer capability of the connection between hardware and OPGW cable could be deficient if there is insufficient contact area.
- c) Contact between dissimilar materials may cause excessive corrosion in some environments.

It is, therefore, recommended that hardware and other accessories connected electrically and mechanically to the OPGW cable be compatible for the OPGW cable being used.

¹⁵Consult IEC 61284 [\[B15\]](#) for conventional fittings; the numbers in brackets correspond to those of the bibliography in [Annex A](#).

¹⁶Information on references can be found in [Clause 2](#).

4.2.2 Functions specific to hardware types

4.2.2.1 Dead ends

Dead ends are required to hold cable tension—typically 95% of the rated tensile strength (RTS) of the OPGW.

Dead ends may have a provision for ground connection.

Dead ends have a provision to transfer cable load to the structure.

Dead ends may have provision for strain relief to protect against long-term fatigue.

Dead ends may have a method of mechanical protection to prevent crushing at the cable interface.

4.2.2.2 Suspension

Suspensions are required to support or suspend maximum vertical loads due to environmental conditions on the OPGW system and resultant loads due to turning angles on the OPGW system.

Suspensions are required to hold tensile loads to meet unbalanced load requirements—typically 10% to 20% of RTS.

Suspensions may have a provision for ground connection.

Suspensions have a provision to transfer cable load to the structure.

Suspensions may have provision for strain relief to protect against long-term fatigue and excess stress due to turning angles and sag angles.

Suspensions may have a method of mechanical protection to prevent crushing at the cable interface.

4.2.2.3 Damper

Dampers are required to damp aeolian vibration—a high-frequency, low-amplitude cable vibration induced by laminar wind flow. This type of motion can be detrimental to the life of the OPGW system due to fatigue damage of the cable and/or hardware.

Methods of mechanical protection may be necessary at the interface to prevent crushing.

Stockbridge-type dampers shall be designed to meet the general requirements of IEC 61897. Stockbridge damper designs typically include damper weights mounted to messenger wire (stranded cable) that is secured to a clamp. The damper clamp provides a method of attaching the damper to the OPGW.

Impact-type dampers made from nonmetallic materials shall be designed to survive ultraviolet (UV) light exposure. The damper shall function without causing damage to the OPGW surface. A provision to secure the damper to the OPGW without damage is required.

4.2.2.4 Come-along

Come-alongs are required to hold cable sagging tension (SAT).

Come-alongs have a provision to transfer cable load to the structure or pulling equipment.

4.2.2.5 Grounding hardware

Grounding hardware electrically connects OPGW to structure grounding system.

Direct contact connections shall not damage the OPGW.

4.2.2.6 Downlead clamp

Downlead clamps train and secure the OPGW along the structure—typically to or from a splice enclosure.

Downlead clamps may have a provision for an electrical bond or insulation.

Downlead clamps may or may not interface directly with the OPGW cable. For those that do, the hardware is required to adequately secure the OPGW cable without introducing excess strain, stress risers, or fiber attenuation.

4.2.2.7 Repair device

Repair devices restore the mechanical strength and electrical conductivity of the OPGW cable.

4.3 Material requirements

4.3.1 Design selection

The material used in the fabrication of the OPGW hardware shall be selected to provide required durability, ductility, and compatibility with OPGW cable material for the OPGW system's service-life requirements.

In the case of nonmetallic material, selection shall be made to withstand degradation due to aging, ultraviolet radiation, and pollution for the expected range of service temperatures and service life. The materials shall not induce corrosion in contact with the attachment hardware or cable.

4.3.2 Finish/workmanship

Castings, forgings, or extrusions shall be uniform, without sharp edges or corners, free of cracks, and shall not contain defects to the extent that the strength or suitability is affected.

Holes shall be cylindrical and clean-cut. Holes in plates or terminal pads may be subpunched and reamed, drilled, or cast in place. The periphery of the hole shall be free from burrs.

The finish of all bearing surfaces shall be smooth and contoured and the outer edges and corners shall be rounded as required. The OPGW hardware shall be free of metal particles, dirt, and oils.

Aluminum oxide grit used to enhance mechanical holding for certain formed-wire hardware is not considered a contaminant.

Marking shall provide traceability for the product.

4.3.3 Fault current performance

Hardware for OPGW cables plays a dual role in overhead transmission and distribution systems, one of which is to provide a means for grounding the electrical system for protection against fault conditions or lightning. Fault currents are a result of system short circuits, and the hardware installed for use with OPGW is subject to the electromechanical and thermal energy associated with fault current conditions. Electromechanical forces can exert impact loads on the hardware, and the high thermal gradient (see 4.3.4) resulting from a fault condition can degrade the hardware material or interface between the hardware and the OPGW.

To meet the requirements of a specific OPGW system, the end user shall provide the initial cable temperature and at least two parameters: either a) (I^2t) requirement of the OPGW and its duration or b) I and t .

4.3.4 Thermal design requirements

The material used in the fabrication of the OPGW hardware shall be capable of withstanding steady-state temperatures from $-40\text{ }^{\circ}\text{C}$ ($-40\text{ }^{\circ}\text{F}$) to $70\text{ }^{\circ}\text{C}$ ($158\text{ }^{\circ}\text{F}$). Special consideration shall be made for hardware that will be installed in very cold climates. Customer-specified cold weather performance requirements/standards may require additional testing that goes beyond what is specified in this standard.

Materials shall be capable of withstanding transient temperatures up to fault current temperatures—typically $220\text{ }^{\circ}\text{C}$ ($428\text{ }^{\circ}\text{F}$) maximum. This transient temperature requirement does not apply to products such as come-alongs that are not designed to carry current. If customers require materials to operate outside the established range, those requirements shall be reviewed and agreed to with the manufacturer.

Products that incorporate elastomers or nonmetallic materials may be used outside the specified range as long as the design allows for adequate thermal transfer without any detrimental effects to the OPGW system. The elastomer and nonmetallic material shall have adequate resistance to the effects of ozone, ultraviolet radiation, and infrared radiation over the steady-state temperature range.

4.3.5 Metallic welds on hardware

Welding shall be in accordance with AWS D1.1, latest edition or an equivalent that meets or exceeds this standard (formed wire hardware excluded). All welds shall be smooth, uniform, and without overlaps or excessive undercutting. Rough surfaces, scale, slag or splatter shall be removed by grinding, sanding, or other acceptable practices. Distortions and stresses, if occurring due to welding, shall be properly corrected. Welders and welding operators shall be qualified in accordance with AWS D1.1, latest edition or an equivalent that meets or exceeds this standard. Proper stress relief methods shall be employed where necessary.

4.3.6 Corrosion resistance protection

Adequate corrosion-resistant treatment shall be applied to all ferrous materials as agreed to by the customer and manufacturer. Special requirements are necessary for threaded fasteners. If no other specifications are referenced, ferrous materials shall be hot-dip galvanized in accordance with ASTM A153 or ISO 1461, latest edition or equivalent.

4.4 Environmental corrosion

4.4.1 General

The hardware must be able to withstand the natural elements that exist at its installation location. The corrosive nature of installation sites can vary vastly from location to location. Therefore, some hardware designs are more suitable for certain locations than other designs. High-corrosion sites such as high-moisture zones, saltwater zones, industrial corrosion zones, volcanic sulfur zones, or combinations of zones require special protection from corrosion for the hardware.

4.4.2 Low-corrosion installation sites

These areas are defined as installation locations that have low or very low levels of corrosive materials such as moisture, salts, industrial pollution, volcanic pollution, naturally occurring atmospheric/animal corrosive pollutants, or any combinations of these materials. Care must still be taken when considering hardware that may be affected by other corrosive or damaging elements such as windblown sand.

In general, most types of OPGW hardware defined in this standard can be installed in low-corrosion installation sites. These include, but are not limited to, designs of similar and dissimilar materials such as: aluminum, galvanized steel, stainless steel, brass, or copper.

4.4.3 High-corrosion installation sites

These areas are defined as installation locations that contain high or very high levels of corrosive materials such as moisture, salts, industrial pollution, volcanic pollution, naturally occurring atmospheric/animal corrosive pollutants or any combinations of these or other nonlisted corrosive materials. Care must be taken when considering hardware that may be affected by additional corrosive or damaging products such as agricultural aerial spraying, windblown salt and sand, and burning carbons from petrochemical activities, burning agricultural crop fields, forest fires, and so forth.

Corrosion-resistant hardware (CR-hardware) must pass the qualification tests as described for respective hardware in [5.6.2.4.5](#), [5.6.3.3.6](#), [5.6.4.4.3](#), [5.6.6.4.2](#), and [5.6.7.2.3](#).

Not all types of hardware defined in this standard can be installed in high-corrosion installation sites. Only designs that have passed the appropriate *CR-hardware corrosion qualification tests* can be installed in these locations. These generally include, but are not limited to, designs that are made of complete or nearly complete similar noble materials as shown in the chemical electromotive series, such as all aluminum, some stainless steels, coated galvanized steel, brass, or copper. Galvanized steels are not normally acceptable in high-corrosion zones; hence, the user must clearly communicate if the hardware will be installed in a high-corrosion zone, and the manufacturer must be clear on the limitations of galvanized hardware being supplied. New or novel designs that pass the appropriate corrosion qualification test are acceptable.

4.5 Installation

Suppliers shall provide documented procedures and supporting illustrations with the product for proper installation.

5. Tests

5.1 General

The tests described in this standard for OPGW hardware are based on the intended overhead installation of the OPGW system. Overhead installations encounter physical phenomena that affect the operation and performance of any line hardware included in the OPGW system.

Testing to this standard is based on design, manufacture, installation, and application variables that may affect the performance of hardware for use on OPGW. As a result, tests were selected to provide some assurance to the user that the hardware is suitable for the expected lifetime of the application.

OPGW hardware shall successfully pass a number of mandatory tests in order to be qualified per this standard. Any test(s) may be waived if an OPGW cable and hardware of sufficiently similar design has been previously tested to demonstrate the hardware and cable compatibility and performance. The definition of *similar design* shall be agreed upon between the supplier and the user.