

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

IEEE Power & Energy Society

Sponsored by the
Power System Communications Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 1591.1™-2012

29 February 2012

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

Sponsor

Power System Communications Committee
of the
IEEE Power & Energy Society

Approved 6 February 2012

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*, *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

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

Copyright © 2012 by The Institute of Electrical and Electronics Engineers, Inc.
All rights reserved. Published 29 February 2012. Printed in the United States of America.

IEEE is a registered trademark in the U.S. Patent & Trademark Office, owned by The Institute of Electrical and Electronics Engineers, Incorporated.

National Electrical Safety Code and NESC are both registered trademarks and service marks of The Institute of Electrical and Electronics Engineers, Inc.

PDF: ISBN 978-0-7381-7199-9 STD97206
Print: ISBN 978-0-7381-7220-0 STDPD97206

IEEE prohibits discrimination, harassment and bullying. For more information, visit <http://www.ieee.org/web/aboutus/whatis/policies/p9-26.html>.
No part of this publication may be reproduced in any form, in an electronic retrieval system or otherwise, without the prior written permission of the publisher.

IEEE Standards documents are developed within the IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association (IEEE-SA) Standards Board. The IEEE develops its standards through a consensus development process, approved by the American National Standards Institute, which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and serve without compensation. While the IEEE administers the process and establishes rules to promote fairness in the consensus development process, the IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

Use of an IEEE Standard is wholly voluntary. The IEEE disclaims liability for any personal injury, property or other damage, of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance upon this, or any other IEEE Standard document.

The IEEE does not warrant or represent the accuracy or content of the material contained herein, and expressly disclaims any express or implied warranty, including any implied warranty of merchantability or fitness for a specific purpose, or that the use of the material contained herein is free from patent infringement. IEEE Standards documents are supplied “**AS IS**.”

The existence of an IEEE Standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE Standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard. Every IEEE Standard is subjected to review at least every five years for revision or reaffirmation, or every ten years for stabilization. When a document is more than five years old and has not been reaffirmed, or more than ten years old and has not been stabilized, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE Standard.

In publishing and making this document available, the IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity. Nor is the IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing this, and any other IEEE Standards document, should rely upon his or her independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

Interpretations: Occasionally questions may arise regarding the meaning of portions of standards as they relate to specific applications. When the need for interpretations is brought to the attention of IEEE, the Institute will initiate action to prepare appropriate responses. Since IEEE Standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to interpretation requests except in those cases where the matter has previously received formal consideration. A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered the official position of IEEE or any of its committees and shall not be considered to be, nor be relied upon as, a formal interpretation of the IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE.

Comments for revision of IEEE Standards are welcome from any interested party, regardless of membership affiliation with IEEE. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Recommendations to change the status of a stabilized standard should include a rationale as to why a revision or withdrawal is required. Comments and recommendations on standards, and requests for interpretations should be addressed to:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854
USA

Authorization to photocopy portions of any individual standard for internal or personal use is granted by The Institute of Electrical and Electronics Engineers, Inc., provided that the appropriate fee is paid to Copyright Clearance Center. To arrange for payment of licensing fee, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Introduction

This introduction is not part of IEEE Std 1591.1-2012, IEEE Standard for Testing and Performance of Hardware for Optical Ground Wire (OPGW).

IEEE Std 1591.1-2012 is the hardware test standard for optical ground wire (OPGW) applications. Hardware for OPGW is identified as hardware in direct contact with the OPGW in an OPGW and hardware 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.^a

Notice to users

Laws and regulations

Users of these documents should consult all applicable laws and regulations. Compliance with the provisions of this standard does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

This document is copyrighted by the IEEE. It is made available for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making this document available for use and adoption by public authorities and private users, the IEEE does not waive any rights in copyright to this document.

Updating of IEEE documents

Users of IEEE standards should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect. In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE Standards Association web site at <http://ieeexplore.ieee.org/xpl/standards.jsp>, or contact the IEEE at the address listed previously.

For more information about the IEEE Standards Association or the IEEE standards development process, visit the IEEE-SA web site at <http://standards.ieee.org>.

^a Information on references can be found in Clause 2.

Errata

Errata, if any, for this and all other standards can be accessed at the following URL: <http://standards.ieee.org/findstds/errata/index.html>. Users are encouraged to check this URL for errata periodically.

Interpretations

Current interpretations can be accessed at the following URL: <http://standards.ieee.org/findstds/interps/index.html>.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA website <http://standards.ieee.org/about/sasb/patcom/patents.html>. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this standard was submitted to the IEEE-SA Standards Board for approval, the Fiber Optics Standards Working Group had the following membership:

William Byrd, *Chair*
Robert Bratton, *Vice Chair*

Thomas Alderton
Gregory Bennet
Donda Bishop
Bhatnagar Chitrangad
Corrine Dimnik
Robert Emerson
Brian Herbst

John Jones
Delavar Khomarlou
Eric Miller
Mark Naylor
John Olenik
Craig Pon
Jon Potter

James Ryan
Lluis-Ramon Sales
Tewfik Schehade
Tarlochan Singh
John Tillman
Monty Tuominen
Curt Turner

The following members of the individual balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention.

William J. Ackerman
Gregory Bennett
Robert Bratton
William Byrd
James Chapman
Bhatnagar Chitrangad
Robert Christman
Corrine Dimnik
Gary Donner
Douglas Dorr
Randall Dotson
Gary Engmann
Denise Frey
George Gela
David Gilmer
Waymon Goch
Edwin Goodwin

Randall C. Groves
Lee Herron
Werner Hoelzl
Magdi Ishac
John Jones
Gael Kennedy
Yuri Khersonsky
Morteza Khodaie
Robert Kluge
Joseph L. Koepfinger
Jim Kulchisky
Chung-Yiu Lam
William McBride
Adi Mulawarman
Michael Newman
Charles Ngethe
Gary Nissen
John Olenik

Carl Orde
Lorraine Padden
Bansi Patel
Percy Pool
Craig Preuss
Jerry Reding
Stephen Rodick
James Ryan
Bartien Sayogo
Tarlochan Singh
Jerry Smith
John Spare
Gary Stoedter
Monty Tuominen
Curt Turner
John Vergis
Robert Whatley

When the IEEE-SA Standards Board approved this standard on 6 February 2012, it had the following membership:

Richard H. Hulett, *Chair*
John Kulick, *Vice Chair*
Robert M. Grow, *Past Chair*
Judith Gorman, *Secretary*

Masayuki Ariyoshi
William Bartley
Ted Burse
Clint Chaplin
Wael Diab
Jean-Philippe Faure
Alexander Gelman
Paul Houzé

Jim Hughes
Joseph L. Koepfinger*
David J. Law
Thomas Lee
Hung Ling
Oleg Logvinov
Ted Olsen

Gary Robinson
Jon Walter Rosdahl
Sam Sciacca
Mike Seavey
Curtis Siller
Phil Winston
Howard L. Wolfman
Don Wright

*Member Emeritus

Also included are the following nonvoting IEEE-SA Standards Board liaisons:

Satish K. Aggarwal, *NRC Representative*
Richard DeBlasio, *DOE Representative*
Michael Janezic, *NIST Representative*

Don Messina
IEEE Standards Program Manager, Document Development

Matthew J. Ceglia
IEEE Standards Project Manager

Contents

1. Overview	1
1.1 Scope	1
1.2 Purpose	1
2. Normative references.....	2
3. Definitions	2
3.1 Special terms.....	3
4. Requirements for optical ground wire hardware	3
4.1 General	3
4.2 Functional requirements	4
4.3 Material requirements.....	5
4.4 Environmental corrosion	7
4.5 Installation	8
5. Tests	8
5.1 Classification of tests.....	8
5.2 General guidelines for optical measurements	8
5.3 Retesting.....	10
5.4 Sample selection for hardware characteristics tests	11
5.5 Qualification tests	11
Annex A (informative) Corona considerations for OPGW hardware.....	42
Annex B (informative) Bibliography.....	43

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

IMPORTANT NOTICE: This standard is not intended to ensure safety, security, health, or environmental protection. Implementers of the standard are responsible for determining appropriate safety, security, environmental, and health practices or regulatory requirements.

This IEEE document is made available for use subject to important notices and legal disclaimers. These notices and disclaimers appear in all publications containing this document and may be found under the heading “Important Notice” or “Important Notices and Disclaimers Concerning IEEE Documents.” They can also be obtained on request from IEEE or viewed at <http://standards.ieee.org/IPR/disclaimers.html>.

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.

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.¹

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

AWS D1.1/D1.1M, Structural Welding Code—Steel.²

IEC 61897, Overhead Lines—Requirements and Tests for Stockbridge Type Aeolian Vibration Dampers.³

IEEE Std 664™, IEEE Guide for Laboratory Measurement of the Power Dissipation Characteristics of Aeolian Vibration Dampers for Single Conductors.^{4, 5}

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.⁶

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

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

3. Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary: Glossary of Terms & Definitions* [B22] should be consulted for terms not defined in this clause.^{7, 8}

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

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). The MDL is used in determining the maximum rated design tension (MRDT). *Syn:* **maximum working load (MWL).**

¹ ASTM publications are available from the American Society for Testing and Materials (<http://www.astm.org/>).

² AWS publications are available from the American Welding Society (www.aws.org).

³ IEC 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/>).

⁴ IEEE publications are available from The Institute of Electrical and Electronics Engineers (<http://standards.ieee.org/>).

⁵ The IEEE standards or products referred to in Clause 2 are trademarks owned by The Institute of Electrical and Electronics Engineers, Incorporated.

⁶ ISO publications are available from the ISO Central Secretariat (<http://www.iso.org/>). ISO publications are also available in the United States from the American National Standards Institute (<http://www.ansi.org/>).

⁷ The *IEEE Standards Dictionary: Glossary of Terms & Definitions* is available at <http://shop.ieee.org/>.

⁸ The numbers in brackets correspond to those of the bibliography in Annex B.

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. MRDT may be expressed in terms of tension or as a percentage of rated tensile strength (RTS). MRDT may also be known as *maximum rated cable load* (MRCL).

optical ground wire (OPGW): OPGW cable has the dual performance functions of a ground wire with 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), the optical unit is comprised of a protective mechanical support housing and/or buffer tubes and optical fibers contained internally.

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** or **pulling tension**.

3.1 Special terms

system: The cable and hardware described in this standard functioning as one integrated unit, i.e., the cable and hardware working together.

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 5.2. This subclause is referenced in hardware tests that require optical results as a measure of acceptance.

This standard, IEEE Std 1591.1-2012, 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*, etc., are not covered under this standard.⁹

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.

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 system and resultant loads due to turning angles on the 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.

⁹ Consult IEC 61284 [B21] for conventional fittings.

- 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 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 61897.¹⁰ 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

- Electrically connects OPGW to structure grounding system.

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.

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 system's service-life requirements.

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

¹⁰ Information on references can be found in Clause 2.

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 sub-punched 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 system, the end user shall provide (1) a description of short-circuit fault current adequate for establishing the required I^2t requirement of the OPGW, or (2) the I^2t requirement.

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 $70\text{ }^{\circ}\text{C}$ ($158\text{ }^{\circ}\text{F}$).

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 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

Welding shall be in accordance with AWS D1.1, latest edition or an equivalent that meets or exceeds this standard. 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

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.

4.4.1 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 wind blown 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.

4.4.2 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 non-listed corrosive materials. Care must be taken when considering hardware that may be affected by additional corrosive or damaging products such as: agricultural aerial spraying, wind blown salt and sand, and burning carbons from petrochemical activities, burning agricultural crop fields, forest fires, etc.

Corrosion resistant hardware (CR-hardware) must pass the qualification tests as described for respective hardware in 5.5.2.3.5, 5.5.3.3.6, 5.5.4.3.3, 5.5.6.3.2, and 5.5.7.3.1.

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. This generally includes, 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. Unless they pass the appropriate corrosion qualification test, designs of dissimilar materials, as shown in the chemical electromotive series, are in general not allowed. Galvanized steels are not normally acceptable in high-corrosion zones, hence, the user and manufacturer must be clear on the limitations of galvanized hardware being supplied for use in high-corrosion zones. New or novel designs can be acceptable if they are such as to allow the Hardware to pass the appropriate corrosion qualification test.