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Standard IEEE 837 and Compliant nVent Solutions

WHITE PAPER

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Introduction

This paper will discuss the IEEE-837 Standard for Qualifying Permanent Connections Used in Substation Grounding [1],[2], its relevance scope and the test procedures. It will briefly look at asperity model for connection to help build an understanding of various grounding connection types. Furthermore, it will investigate the nVent ERICO solutions that are tested to this standard. The paper is divided into two sections.

1. PART 1: What is in the Standard IEEE 837-2014 and 2024 and its Relevance
2. PART 2: Connector Theory and Suitable nVent Connections for Substations

PART 1: Standard IEEE 837-2014 Requirements and its Relevance to Substation Earthing

Scope & Purpose

“Standard IEEE 837 provides direction and methods for qualifying permanent connections used for substation grounding. It particularly addresses the connection used within the grid system, the connection used to join ground leads to the grid system, and the connection used to join the ground leads to equipment and structures [1]”.

When electrical professionals install grounding systems, they need to have confidence that the design and installation will assure protection reliably for the expected life of the system. Grounding connections are the most susceptible link in the grounding system to corrosion, especially connections that are buried in soil.

To confirm reliability of permanent grounding connections, IEEE 837 is the most rigorous and highly regarded grounding connection testing standard in the world [1],[2]. Specifically developed for substation grounding, this standard is considered state of the art for all who are concerned about the safety and reliability of grounding.

The Institute of Electrical and Electronics Engineers, Inc. (IEEE) is the world’s largest technical professional organization, and it boasts nearly 1,300 standards that are under development or in use.

The purpose of IEEE 837 is to a assure users that connections will perform reliably over the lifetime of an installation [1],[2]. It test connections for heat and mechanical forces using an Electromagnetic Force Test and for ageing using sequential tests. This standard defines a repeatable test program that enables connection manufacturers to qualify their products as permanent grounding connections. Upon passing the test, users can be confident that the qualified permanent grounding connection is capable of performing reliably over the lifetime of the installation.

Relevance of IEEE 837 Standard

Standards globally and customer specification commonly request compliance to Standard IEEE 837 for substations connections.

AS 2067 Substation and High Voltage Installation exceeding 1kVac states that “special considerations should be made to ensure the integrity of connection between and the critical equipment and the earthing system[15]. Many of the provisions are addressed in some detail in other guides such as ENA EG-1 and IEEE Std 80. Australian Substation Earthing Guide ENA EG-1 Australian Substation Earthing Guide ENA EG-1 provides guidelines for the design, installation, testing and maintenance of earthing systems associated with electrical substations [4]. Earthing systems that are covered in this guide include those associated with generating plant, industrial installations, transmission and distribution substations. ENA EG-1 states that grounding connector selection should be made on consideration of the following two criteria based on international standards that specify functional performance type test requirements for earthing connectors such as IEEE Std 837[1].[2]. These two criteria are to demonstrated performance in type test conditions relevant to the operating conditions, environment or installation location and secondly the connectors must adequately achieve the thermal and mechanical requirements of the design.

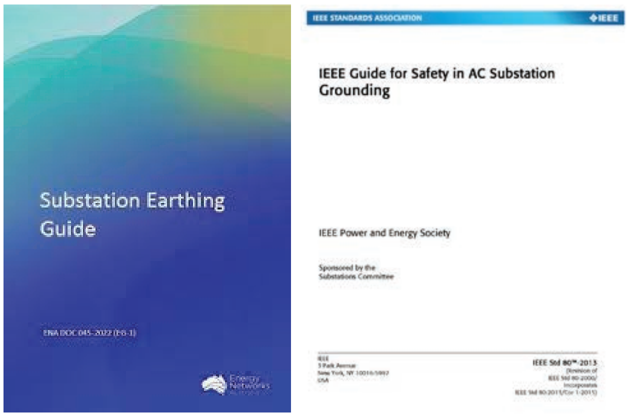


Figure1: Examples of Standards that Reference IEEE 837[3],[4]

IEEE 837 states that “grounding connections that meet the test criteria stated in this standard for a particular conductor size range and material should satisfy all of the criteria for connections as outlined in IEEE Std 80 IEEE Guide for Safety in AC Substation Grounding ”[1],[2],[3].

What is Standard IEEE 837

Last updated in 2024, IEEE 837 is the "Standard for Qualifying Permanent Connections Used in Substation Grounding"[2] As the name states, it provides direction and methods for qualifying permanent connections used for substation grounding.

The Standard IEEE 837 is one of the most difficult standards to pass for grounding connections [1],[2]. Traditional mechanical connectors have been found both within these tests, and by customers in real world, to fail or deteriorate significantly when subjected to faults and corrosive environments. Exothermic connections create a molecular bond between grounding conductors to form a single, solid connection, that is less susceptible to corrosion than mechanical grounding connections over the life of a grounding system

In particular, Standard IEEE 837 addresses:

- Connections used within the grid system.
- Connections used to join ground leads to the grid system.
- Connection used to join the ground leads to equipment and structures.

The standard applies to testing connections joining copper, steel, copper-bonded steel, copper-clad steel, galvanized steel and stainless steel.

In order to be qualified for full IEEE Std 837-2014 and 2024 compliance, there are three (3) sets of tests that need to be passed [1],[2].

1. Electromagnetic Force Test
2. Sequential Test for Salt Spray Conditions
3. Sequential Test for Acidic Conditions

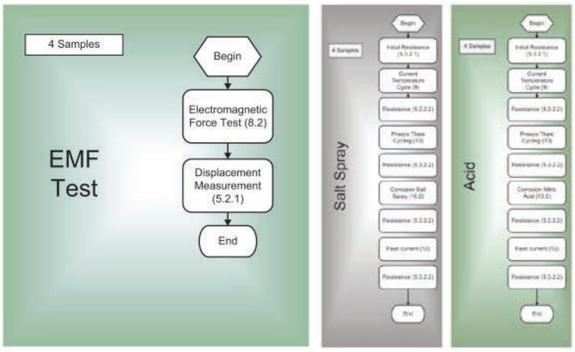


Figure2: 3 Sets of Tests in IEEE 837[1],[2]

The Electromagnetic Force Test

The mechanical test, or electromagnetic force (EMF) test, is conducted to determine if electromagnetic forces would damage the connection during a fault. During the test, four samples (each tested separately) are subject to two 15 cycles of a severe current.

The pass/fail criterion is based on the movement of the conductor. The connector must not fail– overheat, or allow cable slippage – and shall not exceed either 10 mm of slippage or the outer diameter of the conductor, whichever is less. The edge of the connection is marked prior to the testing, then measured to the connector following the tests. The magnitude and duration of the positive cycle peak value used for other size conductor are shown in the Table below extracted from IEEE 837-2024[1],[2].

- In the 2002 edition of the standard the magnitude of the test current for 4/0 AWG (95 mm²) was based on rms symmetrical value of fusing conductor current @ 1 sec, this is approx. 30.5 kA, the peak is 2.7 x = 82 kA, this current level was applied for 0.2 seconds, which is approximately 20% of the conductor.
- In the 2014 and 2024 edition of the standard the magnitude of the symmetrical rms test current is set to 47 kA and peak of 127 kA, applied for 15 cycles (0.25 seconds), this is approximately 90% fusing of the conductor. This results in a mechanical force which is 2.4 times greater for a 4/0 AWG (95 mm²) copper conductor as compared to the 2002 edition tests.

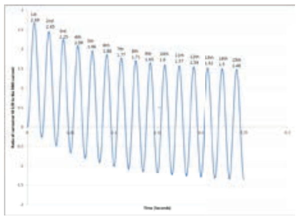


Figure3: Test Waveform for 4/0 or 95 mm² Conductor[1],[2]

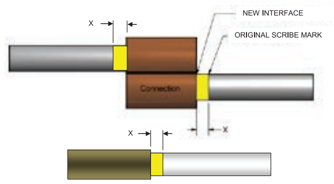


Figure4: Movement Illustration[1],[2]

			Positive cycle peak values (kA)														
Size (AWG, kcmil or trade sizes)	Test current (kA)	Cycles	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Hard Drawn Copper Conductor[b]																	
#2	15	15	40	37	34	31	29	28	27	26	25	24	24	23	23	23	22
1/0	23	15	62	56	52	48	45	43	41	39	38	37	36	35	35	35	34
2/0	29	15	78	71	65	61	57	54	51	50	48	46	46	45	44	44	43
3/0	37	15	100	91	83	77	73	69	65	63	61	59	58	57	56	56	55
4/0	47	15	126	115	106	98	92	87	83	80	78	75	74	72	71	71	70
250kcmil	52	15	140	127	117	109	102	97	92	89	86	83	82	80	79	78	77
Two 2/0[f]	52	15	140	127	117	109	102	97	92	89	86	83	82	80	79	78	77
300kcmil	59	15	159	145	133	123	116	110	104	101	97	94	93	91	90	89	87
350kcmil	65	15	175	159	146	136	127	121	115	111	107	104	102	100	99	98	96
Two 3/0[f]	65	15	172	157	144	134	125	119	113	109	106	102	100	99	97	96	95
500 kcmil	75	15	202	184	169	157	147	140	133	128	124	120	118	116	114	113	111
Two 4/0[f]	75	15	202	184	169	157	147	140	133	128	124	120	118	116	114	113	111
40% IACS Copper-Clad Steel[f]																	
7/#9	15	15	40	37	34	31	29	28	27	26	25	24	24	23	23	23	22
7/ #6	23	15	62	56	52	48	45	43	41	39	38	37	36	35	35	35	34
7/#5	29	15	78	71	65	61	57	54	51	50	48	46	46	45	44	44	43
19/#9	37	15	100	91	83	77	73	69	65	63	61	59	58	57	56	56	55
19/#8	47	15	126	115	106	98	92	87	83	80	78	75	74	72	71	71	70
19/#7	52	15	140	127	117	109	102	97	92	89	86	83	82	80	79	78	77
19/#6	65	15	175	159	146	136	127	121	115	111	107	104	102	100	99	98	96
19/#5	75	15	202	184	169	157	147	140	133	128	124	120	118	116	114	113	111
Copper Bonded Ground Rods																	
5/8" Trade Size	29	15	78	71	65	61	57	54	51	50	48	46	46	45	44	44	43
3/4" Trade Size	31	15	83	76	70	65	61	58	55	53	51	50	49	48	47	47	46

Table 1: Positive Cycle Peak Value for Various Conductor Sizes[1],[2].

EMF Test Configurations

“Each test sample shall consist of a 1.22 m to 1.83 m (48 inch to 72 inch) long section of bare conductor. The test assembly and connection shall not be restrained. A test configuration consists of a single connection used within the grid system, a connection used to join ground leads to the grid system (Figure 6), or a connection used to join the ground leads to equipment and structures (Figure 7). Markings shall be added at the connection/ conductor interface to aid in the measurement of conductor movement with respect to the connector/connection” [1],[2].

Four samples of the same design shall be tested. One connection sample shall be tested at a time to produce accurate determination of conductor movement. For Figure 6 test configurations, the bus connections (dead ends) shall be electrically and mechanically robust to prevent movement during the test. Figure 7 test configuration shall consist of one test sample connection and a dead-end bus connection. These test samples shall be connected to the rigid mounted plates and/or bus extensions. In both configurations, connections shall be mounted in the same horizontal plane and shall not be restrained [1],[2].

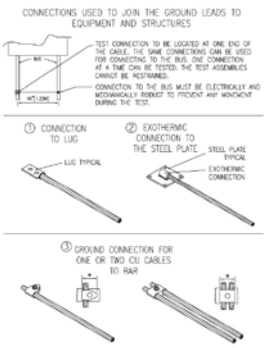


Figure5: Typical Loop Configurations Ground Grid Connections [1],[2]

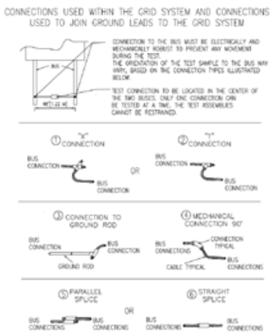


Figure6: Typical Loop Configurations Ground Lead to Equipment [1],[2]

Sequential Tests

These tests, performed in sequence and on the same samples, monitor accelerated corrosion, to determine the connection’s reliability and performance. There are four sequential tests as part of IEEE 837 for samples undergoing salt spray or alkaline test and similarly four sequential test for sample undergoing acidic test [1],[2].

- Current-temperature cycling. When fluctuating currents cause temperature changes, does the connection continue to conform to resistance criteria?
- Freeze-thaw test. When subjected to repeated cycles of freezing and thawing in water, is connection resistance maintained?
- Corrosion tests. These tests are designed to evaluate the corrosion resistance of the connections dependant upon their location:
  - Salt spray (for above ground applications). Measures the corrosive effect of salt spray (i.e. sodium chloride) on the connections.
  - Nitric acid (for direct burial applications). Measures the effects of acid attack, specifically nitric acid (HNO3), on connections.
  - Fault-current tests. Test to determine if connections subjected to the previous tests will withstand fault-current surges.

Final resistance measurements for each sample (R_{Final}) shall be measured as described in IEEE 837, along with the ambient temperature as required. Final resistance measurements shall be corrected to 20°C using equation provided in the standard and the pass criteria for final resistance results shall be such that the corrected value of (R_{Final}) does not exceed 1.5 times the initial (R_{Total}) value for each sample tested [1],[2].

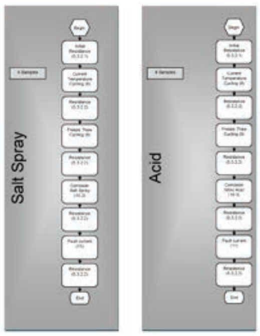


Figure7: Sequential Test[1],[2]

Current Temperature Cycling

For copper and copper bonded conductors a set of four samples of the connections will undergo 25 Cycles from ambient temperature to 350°C for 1 hour and back to ambient temperature. The standard describes the procedure for testing and measuring temperatures in details. The procedure for carrying out these tests on galvanized steel and materials other than copper is identical, however, the temperature for testing is 250°C instead of 350°C [1],[2]..

Figure8: Current Temperature Cycling Test[5]

Freeze Thaw Tests

Test connections are the same test samples previously subjected to the current-temperature cycling test. Containers resistant to freezing and heating temperatures and suitable for holding samples in a series loop configuration or as individual samples shall contain enough water to submerge and cover the connection by a minimum of 25.4 mm (1 inch) of water. The freezing and thawing cycle shall consist of lowering the temperature of the test connection samples to –10°C (50°F) or lower, and raising the temperature to at least 20°C (68°F). The test samples shall remain at both the low and high temperature for at least 2 hours during each cycle. The connection shall be subjected to a minimum of 10 freeze-thaw cycles[1],[2]..

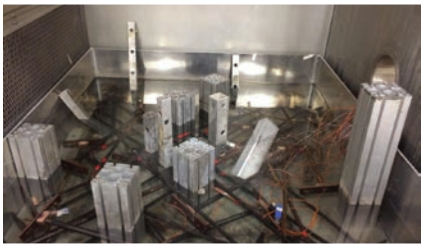


Figure9: Freeze Thaw Test[5]

Corrosion Test- Salt Spray Tests

This test method covers the procedure for determining the corrosive effects of salt spray (sodium chloride) on connections. This test shall be the third in a series of sequential tests. These samples are not subject to the acid test.

The test connection samples shall be the same connections tested in last two (current temperature and freeze thaw) tests. A total of four samples shall be tested according to ASTM B117. The test shall be conducted for a minimum of 500 hours. After completion of the salt spray test, the test samples shall be rinsed in fresh water. Prior to taking resistance measurements, samples shall be heated for 1 hour at 100°C (212°F) to help ensure dryness and then be returned to ambient temperature. Connections and conductors shall be visually inspected for the type of corrosion, if any, and this information shall be recorded in the test data, such as uniform corrosion, pitting, and galvanic action. Resistance measurements shall be used as the pass/fail criteria[1],[2].

Figure10: Salt Fog Corrosion Chamber[5]

Corrosion test-nitric acid (HNO3)

This test series shall be the second set of sequential tests. The test connection samples shall have been subjected to the previously described current temperature cyclic and freeze thaw tests. The test samples and conductor up to the equalizers shall be submerged in the acid solution. The equalizers may or may not be included in the submerged section. A control conductor shall be the same as used in past tests with these samples, and the submerged portion shall be equal in length to that of the submerged sample loop section. The beginning resistance of control conductors shall be recorded. The acid solution used is a 10% by volume concentration of nitric acid (HNO_3) and distilled water (H_2O) [1],[2].

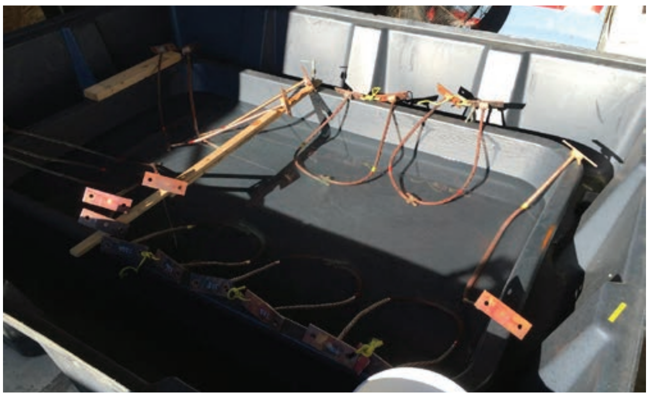


Figure11: Test Setup for Nitric Acid Test[5]

Sample conductor loops (i.e., conductors of a single, uniform material such as copper) shall be submerged in the acid solution for a time that will reduce the control conductor to 80% (minimum of 20% reduction) of its original cross-sectional area. The reduction shall be determined by weight reduction per unit length or increase in resistance of the control conductor. When multiple metals or non-copper metals are being tested the standard defines further criteria[1],[2].

After completion of the acid test, the test samples shall be rinsed in fresh water and heated for 1 h at 100°C (212°F) to help ensure dryness and then be returned to ambient temperature. Connections and conductors shall be visually inspected for the type of corrosion, if any, and this information shall be recorded in the test data, such as uniform corrosion, pitting, and galvanic action. Resistance measurements shall be used as the pass/fail criteria[1],[2].

Fault Current Tests

The purpose of this test is to determine if connections conditioned as part of the salt-spray or acid tests will withstand fault-current surges. This test shall be the fourth test in a series of sequential tests. The test loop is subjected to 90% of the calculated fusing current of the remaining cross-section of the conductor for a 10 second duration. This current is applied three times and the conductor is allowed to cool down below 100°C prior to the application of the subsequent fault current. Resistance measurements shall be used as the pass/fail criteria[1],[2].

Figure12: Fault Current Test Setup[5]

nVent ERICO Cadweld Fully Complies with IEEE 837-2014

Thirteen designs of permanent connections used in substation grounding were subjected to and passed electromagnetic force (EMF) tests in accordance with IEEE Standard 837-2014, section 7. Designs PTC2Q2Q and GTC182Q were also subjected to and passed sequential tests per section 4 of IEEE Standard 837-2014, including current-temperature cycling, freeze-thaw, corrosion- salt spray, corrosion acid and fault current tests or the sequential test. The sequential tests are primarily testing ageing and hence the pass results obtained on PTC and GTC connections can also be applied to the other samples as they will age identically [5].

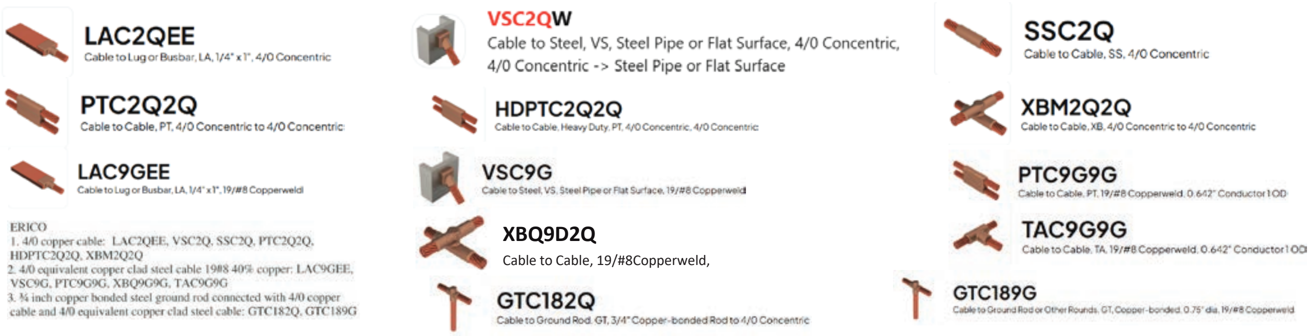
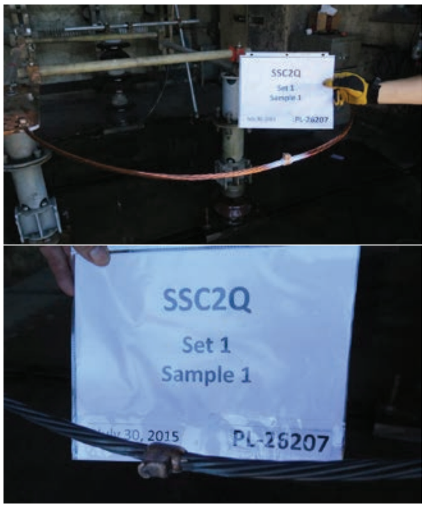
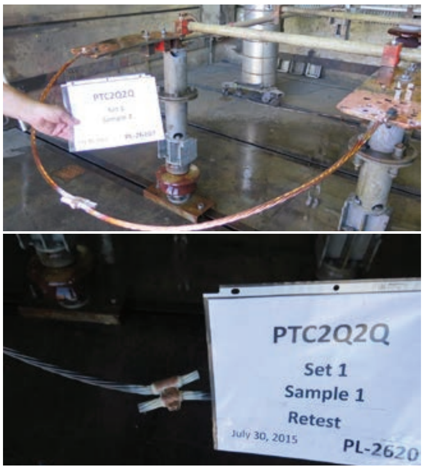


Figure13: Tested nVent ERICO CADWELD Samples[5]


LAC2QEE
Set 1
Sample 1
July 30, 2015
PL-26207

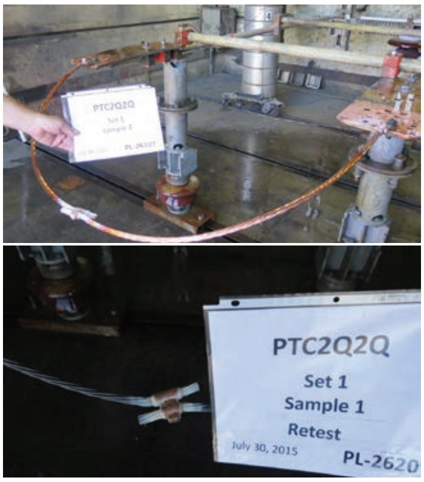

VSC2Q
Set 1
Sample 1
VSC2Q
Set 1
Sample 2
July 30, 2015
PL-26207


SSC2Q
Set 1
Sample 1
PL-26207


PTC2Q2Q
Set 1
Sample 1
Retest
July 30, 2015
PL-2620


HDPTC2Q2Q
Set 1
Sample 1
July 31, 2015
PL-26207

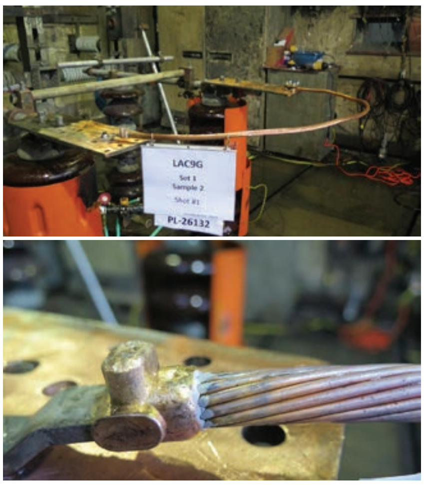

GTC182Q
Set 1
Sample 1
July 31, 2015
PL-26207

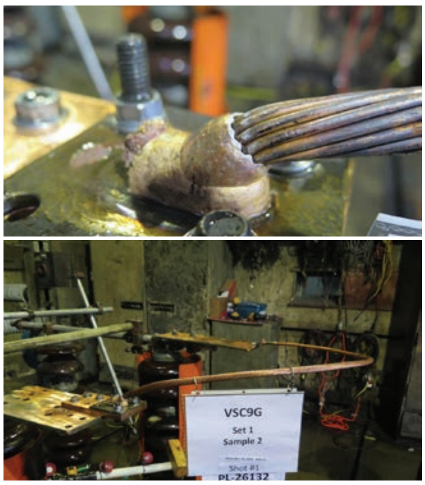

PTC2Q2Q
Set 1
Sample 1
Retest
July 30, 2015
PL-2620


HDPTC2Q2Q
Set 1
Sample 1
July 31, 2015
PL-26207


XBM2Q2Q
Set 1
Sample 1
July 30, 2015
PL-26207


GTC182Q
Set 1
Sample 1
July 31, 2015
PL-26207


LAC9G
Set 1
Sample 2
PL-26132


VSC9G
Set 1
Sample 2
PL-26132

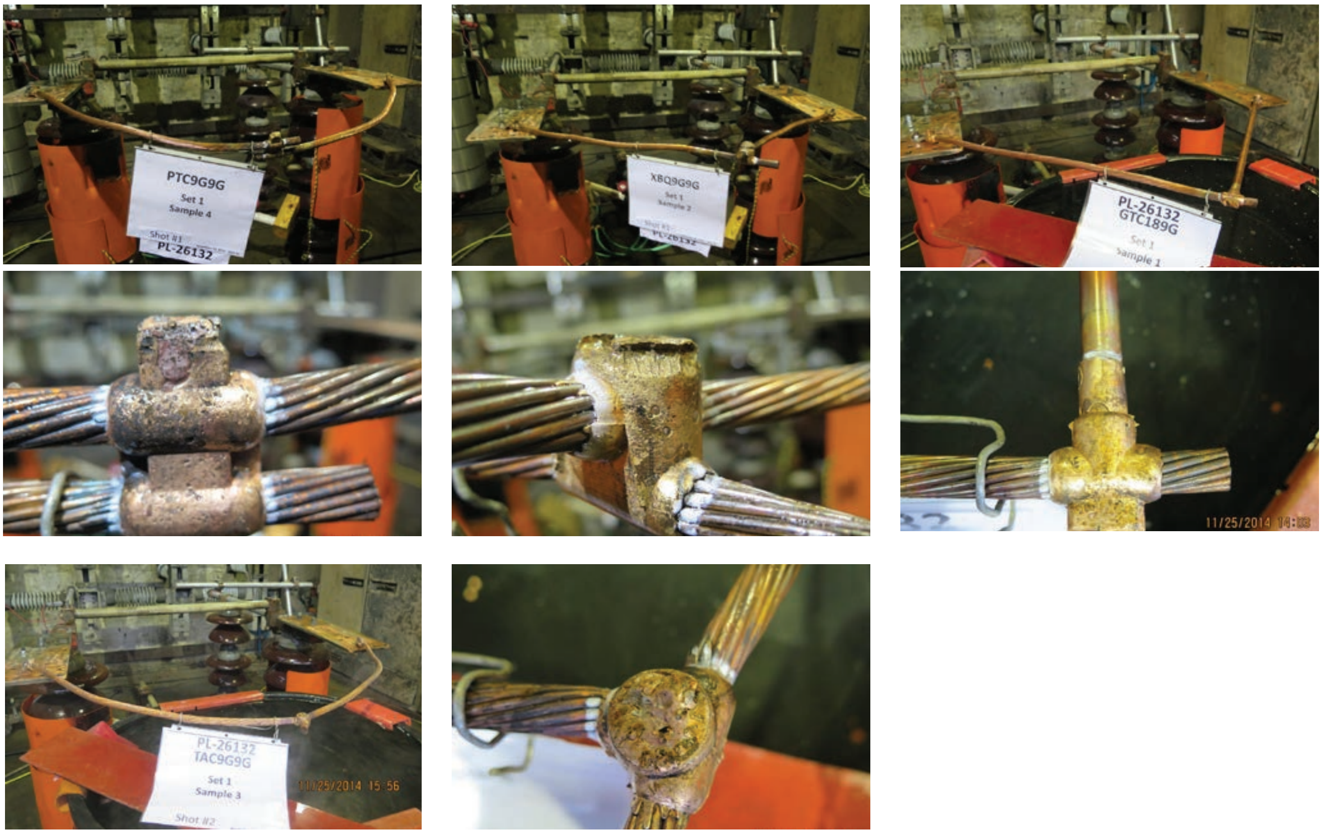


Figure14: Some Examples of Tested nVent ERICO Cadweld Connections[5]

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POWERTECH LABS INC.

Report on Performance № PL-26207-2

ELECTROMAGNETIC FORCE AND SEQUENTIAL TESTS
ON ERICO CADWELD PERMANENT GROUNDING CONNECTIONS
PER IEEE STANDARD 837-2014

ABSTRACT

At the request of Pentair, thirteen designs of permanent connections used in substation grounding were subjected to and passed electromagnetic force (EMF) tests in accordance with IEEE Standard 837-2014, section 7. Designs PTC2Q2Q and GTC182Q were also subjected to and passed sequential tests per section 4 of IEEE Standard 837-2014, including current-temperature cycling, freeze-thaw, corrosion- salt spray, corrosion- acid and fault current tests.

Powertech Powertech Labs Inc. • 12388 - 88th Avenue, Surrey, B.C. Canada • V3W 7R7

Report on Performance № PL-26207-2

Client:	Pentair - 34600 Solon Road Solon, Ohio, 44139, USA
Project No.:	• PL-26132 (Nov. 2014): 4/0 equivalent copper clad steel cable testing 19/#8 40% copper testing • PL-26207 (Jul. 2015): 4/0 copper cable testing • PL-01035 (Aug. – Nov. 2015): Sequential testing
Tested Devices:	13 designs of permanent connections used in substation grounding 1. 4/0 copper cable: LAC2QEE, VSC2Q, SSC2Q, PTC2Q2Q, HDPTC2Q2Q, XBM2Q2Q 2. 3/4 inch copper bonded steel ground rod connected with 4/0 copper cable: GTC182Q 3. 4/0 equivalent copper clad steel cable 19/#8 40% copper: LAC9GEE, VSC9G, PTC9G9G, XBQ9G9G, TAC9G9G 4. 3/4 inch copper bonded steel ground rod with 4/0 equivalent copper clad steel cable: GTC189G
Results:	1. The 13 connection designs passed the Electromagnetic Force (EMF) tests performed in accordance with IEEE Standard 837-2014, Section 7 • 4/0 copper cable and 4/0 equivalent copper clad steel cable 19/#8 40% copper at: 47 kArms, 126 kApeak for 250 ms • 3/4 inch copper bonded steel ground rod at: 31 kArms, 83 kApeak for 250 ms 2. Designs PTC2Q2Q and GTC182Q were also subjected to sequential tests and passed the following tests: • Current-temperature cycling per IEEE Standard 837-2014, Section 8 • Freeze-thaw test per IEEE Standard 837-2014, Section 9 • Corrosion- salt spray test per IEEE Standard 837-2014, Section 10.2 • Corrosion- acid test per IEEE Standard 837-2014, Section 10.3 • Fault current test per IEEE Standard 837-2014, Section 11
Test Witnesses:	Mr. Mike Rabinovich — Pentair Mr. Martin Havelka — Pentair Mr. Ryan Bucio — Pentair
Remarks:	• The tested samples were identified by the client.

Prepared by: June 16, 2016
Kamran Tabarraee, M.A.Sc., P. Eng.
Project Leader, T&D Services

Reviewed by: June 16, 2016
Logan Connaughton, P.Eng.
Manager, High Power Lab

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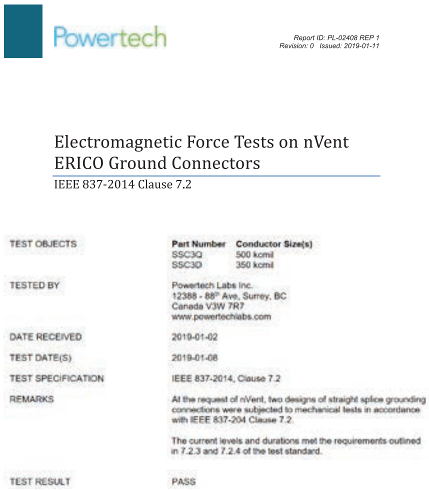
Figure15: Test Report – Full Compliance [5]

The Electromagnetic test have subsequently been carried out on 185 mm^2 (350KCMIL) and 250 mm^2 (500 KCMIL) conductors since this full IEEE 837 testing and both have passed. These larger conductor sizes will pass the sequential test with greater ease than 95 mm^2 or 4/0 due to increased sizes and the proportionate increased in all parameters [6].

The test for conductors larger than 95 mm^2 are easier and certain to pass as the conductors are more robust and currents get limited. The test carried out on 95 mm^2 is the most onerous. (95 mm^2 4/0 is worst case due to the derating of the test current for anything greater than 4/0)

For smaller conductors there are proportionately smaller test currents (less robust test), same design methodology and a molecular bonded exothermic connection and using the nVent ERICO Cadweld we get repeatability.



Powertech

Report ID: PL-02408 REP 1
Revision: 0 Issued: 2019-01-11

Electromagnetic Force Tests on nVent ERICO Ground Connectors

IEEE 837-2014 Clause 7.2

TEST OBJECTS	**Part Number** **Conductor Size(s)** SSC3Q 500 kcmil SSC3D 350 kcmil
TESTED BY	Powertech Labs Inc. 12388 - 88th Ave, Surrey, BC Canada V3W 7R7 www.powertechlabs.com
DATE RECEIVED	2019-01-02
TEST DATE(S)	2019-01-08
TEST SPECIFICATION	IEEE 837-2014, Clause 7.2
REMARKS	At the request of nVent, two designs of straight splice grounding connections were subjected to mechanical tests in accordance with IEEE 837-204 Clause 7.2. The current levels and durations met the requirements outlined in 7.2.3 and 7.2.4 of the test standard.
TEST RESULT	PASS

Figure16: Test Report, Larger Conductors [6]

Conclusion PART 1

Standard IEEE 837-2014 and 2024 are the most rigorous test standard for qualification of connections used for substation applications. Other standards like IEEE Std 80- IEEE Guide for Safety in AC Substation Grounding and ENA EG-1 Substation Earthing Guide require connections to qualify to Standard IEEE 837. nVent ERICO has had multiple permutations of Cadweld connections tested by a third-party accredited lab to demonstrate full compliance to Standard IEEE 837-2014. These include not only cable to cable connections but connections like cable to flat steel and to tape or lug connections.

PART 2: Connector Theory and Suitable nVent Connections for Substations

Explanation of the Asperity

When two metals are in contact with one another in a connection, a perfect connection is never possible.

These imperfections can be seen at microscopic level. The asperity contact points (or A-Spots) are very small, of the order of microns in diameter. These points are distributed across an apparent contact area. The electrical current across the contact interface must flow through the asperity contact points, resulting in a resistance called constriction resistance. Constriction Resistance is also called electrical contract resistance or ECR. These contact points or A-Spots are very small, in the order of micrometers in diameter and are distributed across an apparent contact area of a connection. These A-Spots can be observed when connections are examined at a microscopic level using specialized test equipment.

In connectors, the roughness on the contact surfaces causes added electrical resistance (known as electrical contact resistance (ECR)). These asperity spots and electrical contact resistance or ECR will exist even if similar metals are used for connections such as copper to copper.

The level of asperity spots are expected to vary for different connection types like mechanical connections, compression connections and exothermic connections. These A-spots will also vary with torque and forces used with the tools that are utilized to make the connections.

If the asperity interfaces are compromised by corrosion films or contaminants, the electrical contact resistance will increase. This is the reason why corrosion is a degradation mechanism for connectors that needs to be considered. Loss of asperity contact area, or of asperity contacts, due to corrosion or contamination can result in contact interface resistance increases leading to connection failures over a period of time[7].

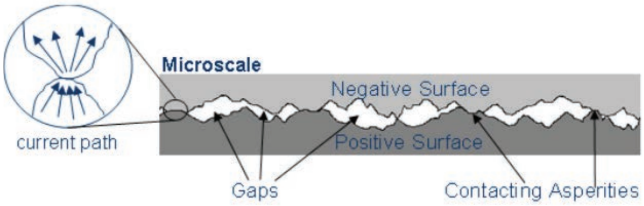


Figure17: Schematic of "bottlenecked" current flow[7]

Even if corrosion and contamination was not present, the electrical contact resistance can also increase over time in grounding connection due to application of repeated fault currents and in live line connections due to the currents flowing continuously and concentrating at these A-spots. This ECR increase over time occurs due to localized heating or thermal fatigue and mechanical stresses, that can loosen the connector and further reduce the number of A-spot or contact points. Connection failures will be minimized if connections selected provide the greatest possible Asperity spots. Conversely poor connections with less A-Spot will degrade faster from these electrical current concentration effects[8].

Field Repeatability with nVent ERICO Cadweld Connections

For over 80 years, nVent ERICO Cadweld has been a trusted component of utility grounding systems, playing a critical role in grid safety, reliability, and resiliency. nVent ERICO Cadweld and Cadweld Plus exothermic welds form a permanent molecular bond that won't loosen or corrode over time, minimizing maintenance/replacement costs and system downtime. Committed to quality, nVent ERICO has a comprehensive test program for Cadweld, ensuring compliance with IEEE Standard 837-2014 "Standard for Qualifying Permanent Connections Used in Substation Grounding." This standard is key to ensuring safe and reliable grounding systems for the full life of the substations. Cadweld has a life greater than the copper conductor, which could be ranging from 80 to 100 years in a wide range of soil conditions nVent ERICO Cadweld connections are highly repeatable, ensuring consistent performance in the field and excellent asperity.

Figure18: nVent ERICO Cadweld System

These connections when used with nVent ERICO Cadweld Molds and Weld Metal guarantees that the connections made in the field will have similar asperity to those tested under IEEE837 standards. Hence these connections are highly repeatable.

nVent ERICO Compression Connections

nVent ERICO PermaGround Compression Grounding Connectors provide a comprehensive range of high-quality copper extruded compression connectors for all grounding applications. The available C- and E-Crimp connections are designed to bond grounding conductors to other grounding conductors or grounding electrodes within a grounding system. Once the grounding conductors are inserted into the connector, they are crimped using a 12-ton compression tool (nVent ILSCO TaskMaster Tools - 12-Ton Crimping Tool), creating a permanent and long-lasting electrical connection. This offers a reliable alternative when exothermic or mechanical connections are not suitable or specified.

The connectors are made from high-quality copper, ensuring low resistance, while their robust design guarantees a secure connection. The entire range of PermaGround connectors has undergone rigorous testing to ensure that their connection strength and current-carrying capability meet and exceed CSA and UL 467 grounding standards. Additionally, the PermaGround connectors are designed to accommodate multiple conductors and various configurations. They support both metric and imperial conductor sizes, making them adaptable to a wide range of applications. Each connection can be completed in minutes and used in any weather conditions, saving time

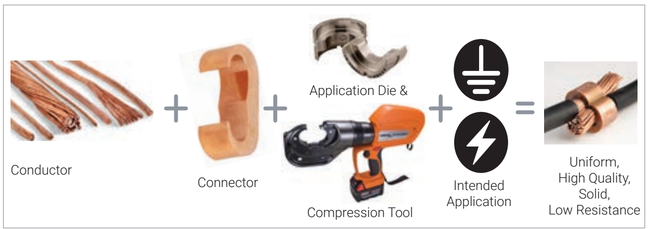


Figure19: nVent ERICO PermaGround Compression Connections System

When using nVent ERICO Compression Connections or other brands' compression connections exactly as per instructions with the same tools and dies, the asperity achieved in testing can be closely replicated.

However, in real-life scenarios, there can be more variability in compression conductor alignment, conductor range, tooling, and die used, making it challenging to achieve the same asperity as in the test setup. nVent ERICO E Crimp range in a two-crimp arrangement is used to compensates for these uncertainties.

Commonly used nVent ERICO E-Crimps have undergone IEEE 837-2014 EMF testing with a range of conductor sizes in the two crimp arrangement shown in Fig 21 and independent test reports are available upon request for these tests [13].

Furthermore, nVent ERICO E Crimps have undergone Current Temperature Cycling testing in an independent lab to meet

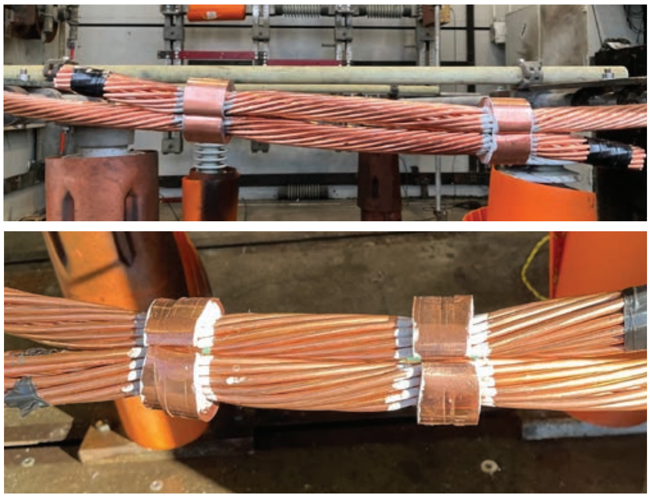
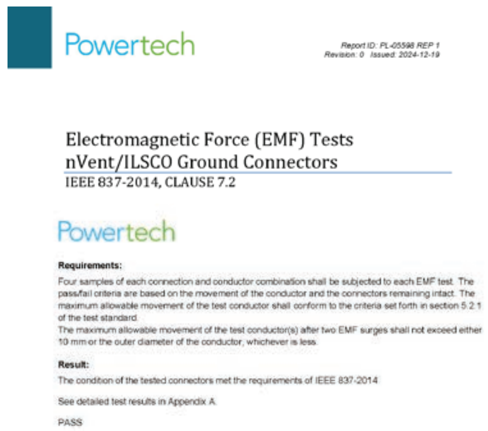


Figure21: nVent ERICO Compression E Crimps Tested with 2 Crimp Configuration [13]



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Report ID: PL-05598 REP 1
Revision: 0 Issued: 2024-12-19

Electromagnetic Force (EMF) Tests
nVent/ILSCO Ground Connectors
IEEE 837-2014, CLAUSE 7.2

Powertech

Requirements:

Four samples of each connection and conductor combination shall be subjected to each EMF test. The pass/fail criteria are based on the movement of the conductor and the connectors remaining intact. The maximum allowable movement of the test conductor shall conform to the criteria set forth in section 5.2.1 of the test standard.

The maximum allowable movement of the test conductor(s) after two EMF surges shall not exceed either 10 mm or the outer diameter of the conductor, whichever is less.

Result:

The condition of the tested connectors met the requirements of IEEE 837-2014

See detailed test results in Appendix A

PASS

Figure20: Test Report EMF Test IEEE837-2014 on nVent ERICO Compression E Crimps[13]

these requirements of IEEE 837-2014 and the test reports for these are also available for the select range that has been tested.

It should be noted that some of the required substation connections are not possible to execute using compression connections. Common connections that can be performed using compression connections include cable to cable and cable to ground rod connections. Some common connections that are difficult or impossible to achieve are cable to busbar, cable to lug and cable to flat or vertical steel surface.

Conclusion: PART 2

The understanding of the asperity model for electrical connection provides an excellent insight into connector behaviour and performance of the connector over its lifetime in its environment. While nVent ERICO Cadweld is the ultimate connection method that meets the highest standard, connections like nVent ERICO PermaGround Compression can also meet some of the more stringent test requirements in Standard IEEE 837-2014/24. These connectors can be considered as an alternative connection method in many applications such as pole mount and pad mount distribution substations.

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