NVENT ERICO CADWELD PERMANENT GROUNDING CONNECTIONS MEET THE REQUIREMENTS OF IEEE STD. 837-2014

nVent is constantly investing, improving and verifying the performance of our products.

As the original inventor of exothermic welding for electrical connections, nVent ERICO continues to have the most comprehensive test program for compliance of Cadweld exothermically welded connections to IEEE Standard 837 2014 “Standard for Qualifying Permanent Connections Used in Substation Grounding.” nVent tested connections using AWG 4/0 copper conductors, 4/0 equivalent copper-bonded steel, and 19/#8 40% DSA copper clad steel conductors (all of which qualified smaller conductors of the same connection family). All of the submitted connections passed the Mechanical (EMF) and Sequential (Current Cycling, Freeze Thaw, Corrosion Salt, Acid Corrosion and Fault-Current) test requirements of IEEE Standard 837-2014.

nVent has recently completed additional mechanical (EMF) testing for 350 kcmil and 500 kcmil copper conductors. The EMF test is very demanding, with test currents of 65kA and 75kA respectively (175kA and 202kA 1st cycle positive peak current) that result in exposing the connections to severe heat and mechanical energy.

Cadweld products are held to the highest standards to ensure a secure connection in even the most extreme applications.

Powertech
Management System Registered to ISO 9001/14001

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Canada V3W 7R7
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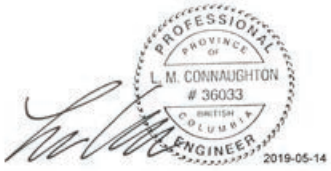
QUALIFICATION TESTS:
NVENT ERICO CADWELD PERMANENT GROUNDING CONNECTORS

Client:	nVent ERICO - 34600 Solon Road Solon, Ohio, 44139, USA
Project No.:	PL-26132 (Nov. 2014): 4/0 Equivalent Copper Clad Steel Cable 19/#8 40% Copper Testing PL-26207 (Jul. 2015): 4/0 Copper Cable Testing PL-01035 (Aug. – Nov. 2015): Sequential Testing
Test Standard:	IEEE Std. 837-2014
Tested Item:	13 designs of permanent connections used in substation grounding.
Type Identification:	A) 4/0 Equivalent Copper Clad Steel Cable 19/#8 40% Copper Testing Design 1: LAC9GEE Design 2: VSC9G Design 3: PTC9G9G Design 4: XBQ9G9G Design 5: TAC9G9G Design 6: GTC189G B) 4/0 Copper Cable Testing Design 7: VSC2Q Design 8: PTC2Q2Q Design 9: XBM2Q2Q Design 10: LAC2QEE Design 11: SSC2Q Design 12: HDPTC2Q2Q Design 13: GTC182Q
Results:	1. Designs 1 to 13 passed the Electromagnetic Force (EMF) test per clause 7.2 of IEEE Std. 837-2014. 2. Designs 8 and 13 were also submitted for sequential tests and passed the following tests in accordance with IEEE Std. 837-2014: a. Current-temperature cycling (Clause 8) b. Freeze-thaw (Clause 9) c. Corrosion- salt spray (Clause 10.2) d. Corrosion- acid (Clause 10.3) e. Fault current (Clause 11)
Remarks:	The tested samples were provided and identified by the client.

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

Reviewed by:



Logan Connaughton, P.Eng
Manager, High Power Technologies

Powertech

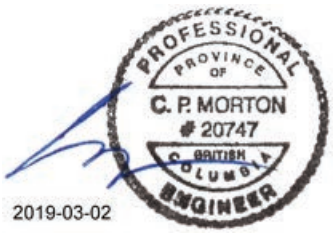
REPORT OF PERFORMANCE

CLIENT/ MANUFACTURER	nVent 34600 Solon Road Solon, OH, USA 44139
TEST OBJECTS	**Part Number** — **Conductor Size(s)** SSC3Q — 500 kcmil Copper SSC3D — 350 kcmil Copper
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
TEST RESULT	PASS

Prepared by:

Sebastian Werner, EIT
Junior Engineer, High Power Lab
Powertech Labs Inc.

Reviewed by:



Chris Morton, P.Eng.
Specialist Engineer, High Power Lab
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IEEE Std 837™-2014

FREQUENTLY ASKED QUESTIONS

1. WHAT IS THE SCOPE AND PURPOSE OF THE IEEE 837 STANDARD?

PER IEEE STD 837™-2014:

SCOPE

- This standard 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.

PURPOSE

- The purpose of this standard is to give assurance to the user that a connection meeting the requirements of this standard will perform in a satisfactory manner over the lifetime of the installation, provided that the proper connection is selected for the application and that the connection is installed correctly. 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™ [B3].1
- To test the connection for heat and mechanical forces during a possible maximum fault current situation in a substation, under the configuration defined by the standard.

2. WHAT ARE THE MAIN DIFFERENCES BETWEEN THE 2002 AND 2014 EDITIONS?

- There is now a distinction between conductor-to-conductor connections (used to join grounding leads to the ground grid) and terminal connections (used to connect leads to equipment and structures).
- **In the 2002 edition of the standard** the magnitude of the test current for 4/0 AWG conductor was based on rms symmetrical value of fusing conductor current @ 1 sec, this is approx. 30 kA rms, the peak is 2.7 x 30 kA = 81 kA with an X/R ratio of 20. This current level was applied for 0.2 seconds, which equates to approximately 20% fusing capacity of the conductor.
- **In the 2014 edition of the standard** the magnitude of the symmetrical rms test current is set to 47 kA with a first half cycle peak of 126 kA, which is applied for 15 cycles (0.25 seconds) with an X/R ratio of 30. This is approximately 90% of the fusing capacity of the conductor. This results in a mechanical force, which is over two times greater compared to the 2002 edition tests for a 4/0 AWG copper conductor.
- The 2014 edition of the standard introduced a new test configuration for the EMF current test. The same test loop for the sequential tests was used for the EMF test in the 2002 edition. In the 2014 edition a test sample assembly is specified to be in the range of 48" – 72" in length. The testing can qualify only one connector at a time.
- The resistance pass/fail criteria for the EMF test has been removed from the 2014 edition, because the majority members of the working group felt that the resistance measurement is not relevant in this test. Instead, the following pass/fail criteria was added. The allowable movement for the conductor out of the connection shall not exceed 10 mm or the diameter of the conductor (whichever is smaller). nVent ERICO Cadweld connection creates a metallic bond between conductors during the exothermic welding process. A metallic bond by definition does not allow any conductor movement at all.
- The 2014 edition specifically states that connectors "shall be tested for all materials for which they are intended to be qualified per the standard". This means that if a connector can be used on copper and copper-clad steel, then it must be tested with both conductor types. The IEEE Std 837™-2014 EMF current test now requires all test assemblies to be mounted in a horizontal plane and they shall not be restrained – this results in a more rigorous test.

3. WHY DID THE EMF TEST CHANGE?

- The EMF test changed due to electrical load increases in transmission and distribution systems, and increases in available substation fault currents. Due to electrical load increase in transmission and distribution system, and increase available substation fault currents. In addition, these new more stringent testing current levels are now in alignment with the ASTM F855 "Standard Specifications for Temporary Protective Grounds to be Used on De-energized Electric Power Lines and Equipment".

IEEE Std 837™-2014

FREQUENTLY ASKED QUESTIONS

4. WHAT ARE THE REQUIREMENTS FOR THE NEW EMF TEST ASSEMBLY?

- For conductor-to-conductor connections used within the grid system, connections, used to join grounding leads to the grid system. These are below grade applications with the connector under test located in the center of the test assembly. Terminal connections, used to connect ground leads to equipment and structures are consider above ground connections. Terminal connections, used to connect grounding leads to equipment and structures, are considered to be above ground connections. One test sample at a time is connected directly across the high-current bus. The test current as described in question 2 above is then applied 2 times.

5. HOW MANY SAMPLES NEED TO BE TESTED?

- In order to be qualified for the IEEE Std 837™-2014, 4 samples must be tested and each test sample has to be tested with two surges. If one of these samples does not meet the passing criteria, the IEEE Std 837™-2014 allows for a retest with 4 new samples. If all of the second set of 4 passes, then the connector is qualified. If there is a failure in the second set, the connector design cannot be qualified.
- Test summary: the test includes 4 test samples and each sample is exposed to 2 surges:
  - Surge #1
  - Conductor cooled to 100°C
  - Surge #2

6. ARE THERE SPECIFIC CONNECTION TYPES REQUIRED FOR THE IEEE STD 837™-2014 TESTS?

- See section 7 for more information, Figures 4a and 4b outlines as follows:
  - Connections used within the grid system and connections used to join ground leads to the grid system
    - Bus to bus connection: “X” or “T” connection
    - Connection to ground rod
    - Mechanical 90 degree (not applicable to Cadweld)
    - Parallel Splice or Straight Splice

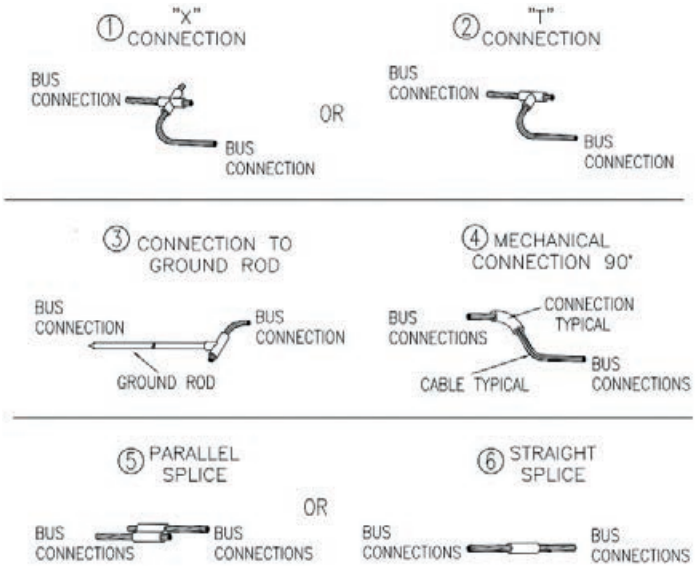

Figure from IEEE Std 837™-2014 Section 7.2.2

  - Connections used to join the ground leads to equipment and structures
    - Connection to lug
    - Connection to steel plate
    - Ground connection for one or two copper cables to bar (not applicable to Cadweld)

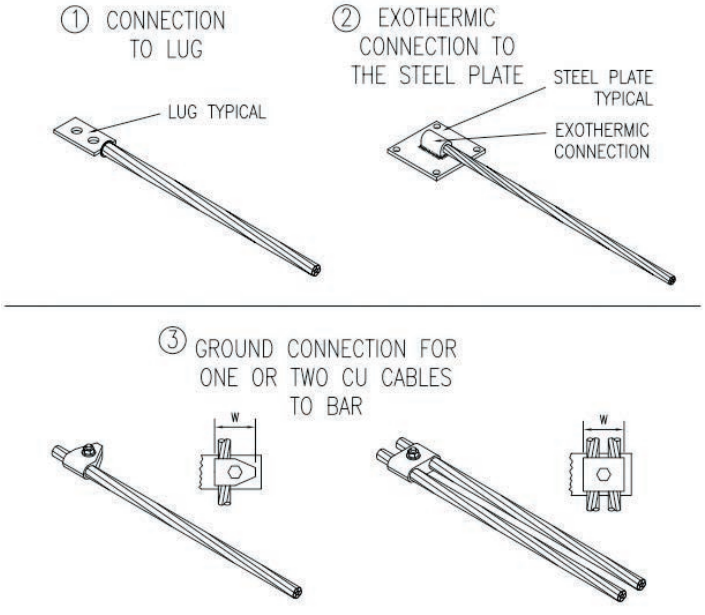

Figure from IEEE Std 837™-2014 Section 7.2.2

IEEE Std 837™-2014

FREQUENTLY ASKED QUESTIONS

7. DOES THE STANDARD DESCRIBE HOW THE TERMINATIONS ARE MADE TO THE HIGH-CURRENT BUS?

- The standard does not specifically detail these connection requirements. For conductor-to- conductor connections (used to join grounding leads to ground system) the bus connections (where connector under test is located in the middle of the test assembly), the bus connections (dead ends) "must be electrically and mechanically robust to prevent movement during the test". For terminal connections (used to connect leads to equipment and structures), the test samples (lug or direct exothermic connection to steel) shall be connected to the rigid mounted plates and/or bus extensions. These mounting plates or bus extensions are secured directly to the high current bus. The method of connection of the other end of the test assembly again is not specified.

8. WHICH CONNECTIONS WERE TESTED?

- 4/0 copper cable
  - Parallel Splice or Straight Splice
    - HDPTC2Q2Q
    - PTC2Q2Q
    - SSC2Q2Q
  - Ground rod
    - GTC182Q
  - Bus to bus connection: "X" or "T" connection
    - XBM2Q2Q (XB32Q2Q is the same design, but with a different mold frame)
  - Connections used to join the ground leads to equipment and structures
    - VSC2Q (Connection to steel plate)
    - LAC2QEE (Connection to lug)
- 4/0 Equivalent Copper-clad Steel Conductor
  - Parallel Splice or Straight Splice
    - PTC9G9G
  - Ground rod
    - GTC189G
  - Bus to bus connection: "X" or "T" connection
    - XBQ9G9G
    - TAC9G9G
  - Connections used to join the ground leads to equipment and structures
    - VSC9G (Connection to steel plate)
    - LAC9GEE (Connection to lug)
- All samples were assembled by nVent ERICO using production material together with standard Cadweld molds. nVent ERICO used standard practices to assemble the samples, as outlined in nVent ERICO Instruction Prints that are included with the mold and welding material, and Installers and Inspectors Guide for Cadweld Electrical Connections.

9. WHAT WELDING MATERIAL WAS USED TO MAKE THE CONNECTIONS?

- The IEEE Std 837 – 2014 testing focusses on the connection. The test report is applicable for both traditional welding material and Cadweld Plus. The difference between traditional Cadweld welding material and Cadweld Plus in the ignition process. The resulting connection would be the same.

10. IS THE TEST REPORT FROM AN INDEPENDENT LAB?

- All tests were completed by Powertech, an independent lab. Accreditation is provided at the end of the document.

11. IS A COMPLETE TEST REPORT AVAILABLE?

- A summary report is available at this time. A full test report will be available in the near future.

12. ARE ANY OTHER CONNECTIONS QUALIFIED TO THE IEEE STD 837™-2014 EMF TEST OTHER THAN THE CONNECTIONS THAT WERE TESTED?

- **IEEE Std 837™-2014 Section 4:**
  Within a family of connectors, more robust connectors need not be tested. For example, bolted pressure plate lugs using four (4) bolts need not be tested if two (2) bolts lugs have been tested successfully for the same size.
- After 4/0 AWG copper or 19/#8 copper clad steel connections have been qualified (at 90% of fusing test current for the EMF test), the smaller conductors (from #2 up to 4/0) in the same connector families can be qualified by only performing the resistance test outlined in section 5.3.2.1 of the standard. No additional tests are required for smaller sizes.

IEEE Std 837™-2014

FREQUENTLY ASKED QUESTIONS

13. HOW DOES IEEE 837 APPLY TO MARKETS OUTSIDE OF UTILITIES?

- Cadweld connections are used in many markets including telecommunications, petrochemical, rail, commercial and industrial structures to name a few. Most markets do not have specific connection test requirements. Substation grounding connections are designed to handle severe conditions unlikely to be seen in other markets. The IEEE Std 837™-2014 tests require the highest level of performance for qualification. nVent ERICO does not alter connection designs between markets. By meeting the test requirements in IEEE Std 837™-2014, design engineers and owners will have confidence in the reliability and performance of the grounding products they specify for other markets.

POWERTECH LAB ACCREDITATION

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http://www.powertechlabs.com/

ISO 9001:2008

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http://www.powertechlabs.com/temp/20132447473/ISO_9001_certificate1.pdf

ISO/IEC 17025:2005

Powertech is an accredited laboratory in the Standards Council of Canada (SCC) Program for the Accreditation of Laboratories (PALCAN). A number of tests are accredited under this program.

http://palcan.scc.ca/specs/pdf/612_e.pdf

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