White Paper

April 2014

Comparing Crimp and Exothermic Welded Connections

Comparing Quality, Cost, and Testing of Connections
in
Substation Grounding Applications

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Comparison between Crimp Connections and Exothermic Welded Connections

There has a long standing debate as to whether a crimp connection is as effective as one made using exothermic welding. This debate intensifies when these systems are compared for use in substation grounding because they are subject to greater destructive forces than standard NEC compliant ground connections. In addition to the consequences of a poor ground, this can lead to costly repairs and life threatening safety concerns.

The electrical industry has attempted to mitigate these risks by coming up with a standard test procedure to qualify ground connections in substation applications. The standard used is the **IEEE 837-*2002 Standard for Qualifying Permanent Connections Used in Substation Grounding.***

With most suppliers claiming to pass the IEEE 837-2002 test as it stands, it has done little to differentiate the products available on the market. In this paper we will attempt to differentiate the two processes and the different products in the following ways.

- Process Descriptions
- Advantages and Disadvantages
- Comparing average costs
- Substation Cost Comparison
- The **IEEE 837-*2002 Standard for Qualifying Permanent Connections Used in Substation Grounding*** and how it relates to these products
- Summary

Description of Process and End Product

Mechanical Crimp Systems – Burndy, Panduit, T&B, and others

Description of Process- these manufacturers use a mechanical means (mechanical or pneumatic), to compress a copper connection fitting to the point where it is intended to deform the conductors they crimp to. These fittings also use a conductive compound to reduce corrosion and enhance conductivity. Typically this compound is a mixture of Zinc and a derivative of castor oil.

Positives of Hydraulic or Mechanical Crimp –

- No hot work permit required
- Fairly easy to use, but not always used correctly
- The same fitting used for multiple connections
- Good longitudinal strength

Negatives of Mechanical crimps –

- Startup Costs (Tools and Dies are extremely expensive)
- Possibility of using the wrong die.
- With Panduit, there is the possibility that it will not be crimped all three times.
- Cost of Connections (putting in a system with crimp will cost 2 to 3 times more than the same system in exothermic).
- Electrical conductivity of the connection is only as good as the cleanliness of the conductors being pressed together. Dirty or oxidized conductors will increase the resistance of the connection.
- Space requirements (Can be hard to do in a trench)
- Increase in resistance over time (Due to the nature of the crimp there will always be and interface between materials being crimped where corrosion could occur).
- Crimps to steel are suspect at best. Steel does not deform at the pressures used in these crimping systems.
- Conductivity is a function of the amount of surface area in contact between the conductor and the connector. With uneven surfaces, ie. rebar and steel I-beams, the conductivity can increase due to decreased surface area.
- Once connection is made, it is very hard to inspect the quality of the connection at the interface between conductors and connector.
- Both systems are dependent on the preparation of the conductors.
- Over paying for connections in the lower end of the range.

Ultraweld Exothermic Welding Materials – Harger Lightning & Grounding

Description of Process- All of the Ultraweld processes (NUWTube, UltraShot, and Uni-Shot) use the same, time proven method to connect conductors at the molecular level. This process involves the reduction of copper oxide by aluminum which creates Aluminum Oxide, copper, and enough heat to melt the copper for the connection. This high conductivity connection is close to pure copper and is designed so that the connection will carry a greater amount of current than the conductors themselves. There is no interface between the connection and the conductors to separate or increase in resistance. The reaction is encapsulated by a graphite or ceramic mold that is designed for specific conductors. These molds provide a portable and economical means to make a superior electrical connection.

Positives of Exothermic Welding –

- Relatively inexpensive when compared to crimp connections
- Lasts longer than the conductors they are attached to.
- Current carrying capacity greater than the conductors.
- No increase in resistance over time.
- Made with materials that are portable, and require little training.
- Easily inspected through nondestructive means.

Negatives of Exothermic Welding –

- It is welding, so a hot work permit is usually required.
- Both systems are dependent on the preparation of the conductors.
- Must have multiple molds to do different types of welds. (This can be reduced by having a good working knowledge of exothermic connections.)

Connections Used in a Substation Grounding Application

There are 7 different types of connections found in most substations. These include:

- **Cable to Cable T / Parallel Tap Connections**
- **Cable to Cable Cross Connections**
- **Cable to Ground Rod**
- **Cable to Equipment steel / I beams**
- **Cable to Rebar**
- **Cable Fence Posts**
- **Gate Grounding**

We will look at each one of these connections for a typical 4/0 system from the different crimp manufacturers and comparisons will be made with regards to:

- **Cost**
  - ***UltraShot pricing is based on list pricing and estimated 50 shots per mold.
  - All competitor pricing is based on an average of pricing found on the internet.
- **Issues and comments**

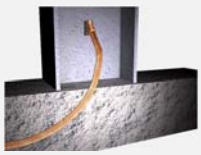
Cable to Cable T or Parallel Tap Connection Comparison:

	UltraShot RT4/04/0B	**Burndy YGHC29C29**	**Panduit GCE250-250**	**T & B CTP250250**
Picture				
Cost	**$17.78**	**$32.46**	**$31.12**	**$30.38**
Issues	**Only connection with no interface between conductors to loosen or corrode**	**Takes 1 person to hold and 1 to crimp**	**Must crimp 3 times**	**Takes 1 person to hold and 1 to crimp**

Cable to Cable Cross Connection Comparison:

	UltraShot XO4/04/0Q	Burndy YGL29C29	Panduit GCC6X6250-250	T & B 54875L
Pictures				
Cost	**$24.92**	**$81.00**	**$82.00**	**$117.27**
Issues	**Only connection with no interface between conductors to loosen or corrode**	**Takes 1 person to hold and 1 to crimp**	**Must crimp 6 times**	**Takes 1 person to hold and 1 to crimp**

Cable to Steel Connection Comparison:

	UltraShot VA4/0B	Burndy GSTUD34HY & YGHP34C34	Panduit GUBC500-6 & LCC4/0-38W-X	T & B IBG20-40
Pictures				
Cost	**$15.40**	**$83.00**	**$241.95**	**$319.06**
Issues	**Only connection with no interface between conductors to loosen or corrode**	**Must have Crimp and welding equipment**	**Has three Mechanical connections. Lug not IEEE837. Requires torque wrench**	**Two Mechanical connections and just pressing lug to steel surface**

Cable to Ground Rod Connection Comparison:

	UltraShot GS584/0P	Burndy YGLR29C58	Panduit GCC6X6250-1/0	T & B 54875L
Pictures				
Cost	**$18.79**	**$120.25**	**$73.30**	**$117.27**
Issues	**Only connection with no interface between conductors to loosen or corrode**	**Must pre-knurl the ground rod for proper connection**	**Must crimp 6 times**	**Takes 1 person to hold and 1 to crimp**

Cable to Fence Post Connection Comparison:

	UltraShot VD4/0B	Burndy GSTUD34HY & YGHP34C34	Panduit GPL-40-3	T & B FG2040R25
Pictures				
Cost	**$18.79**	**$83.00**	**$102.77**	**$220**
Issues	**Only connection with no interface between conductors to loosen or corrode**	**Must have Crimp and welding equipment**	**Not an IEEE 837 fitting. Easily removed**	**Not an IEEE 837 fitting. Easily removed**

Substation Cost Comparison

Typical requirements for a small substation:

4/0 to I-beam or Equipment Leg	Quantity Required	10
4/0 T or Parallel	Quantity Required	20
4/0 Cross	Quantity Required	60
4/0 to Ground Rod	Quantity Required	20
4/0 to Fence Post	Quantity Required	25
4/0 Fence Post Jumper	Quantity Required	3

Estimated cost for the connections in this substation example:

Estimated costs for the requirements above			
Panduit*	Burndy*	T &B*	UltraShot
$12,736.59	$11,779.68	$20,122.62	$4,107.29

*Does not include tooling cost for the crimp connections.

As show in the above example, one will pay over three times the price for a system that includes mechanical clamps that do not meet the IEEE 837 requirements for a permanent connection. In addition, it will always have an interface that could loosen or corrode and thus increase in resistance.

IEEE 837 *Standard for Qualifying Permanent Connections Used in Substation Grounding*

The standard by which substation connections are judged to be suitable for use.

Comments on IEEE 837:

1. There are **NO** IEEE 837 approved fittings! IEEE is not a governing body and does not approve fittings, and will not dispute a manufacturer that states their fittings pass the test. Manufacturers test their series of parts to the standard and interpret those results.
2. There is much ambiguity in the test procedures that allow some room for test methods and for interpretation of the results.
3. There is currently only one outside lab qualified to do all the tests required for this standard. Therefore, it is extremely expensive to have these tests completed and also very expensive to disprove other manufacturer's claims to meeting the IEEE requirements.
4. If a manufacturer claims to meet the IEEE 837 standard, ask to see results from an independent lab that show all the results for the different types of connections.
5. A new version of this test is scheduled to be published in 2014.

The IEEE 837-2002 standard is made up of three major components. These components will be discussed along with the ambiguity in the standard that could be manipulated to give a passing result.

A mechanical pull test

A test to verify that the connection can withstand physical forces that may be applied to the system. If connections are made to fit a range of conductors, they must pass the test with every combination of largest to smallest conductor sizes and types that may be used in the connection.

Ambiguity – There are no procedures in this part of the test for how to pull the samples given the most common connections in a ground grid are at right angles to each other.

Advantage – In the pull out test the mechanicals have the advantage due to the grip they have on the deformed conductor. There are no published test results from any of the crimp manufacturers on crimping to an I-Beam or how that test is performed.

An electromagnetic force test –

Made to reproduce the effects of a major fault or lightning strike on the system. This is accomplished by connecting the test connectors into a ring and passing a defined current through the connections. If connections are made to fit a range of conductors, they must pass the test with every combination of largest to smallest conductor sizes and types that may be used in the connection.

Ambiguity – The procedures in this test are fairly well defined. It does say to set up the test to put the most heat in the connection, but doesn't address what to do when multiple connections are used in the test loop.

Advantage – Because of the lower resistance of the exothermic connections, this test is easier to pass for the welded connections.

Sequential Testing –

This testing is meant to reproduce the effects of freeze and thaw, and harsh environments on the resistance of the connection and is the hardest to pass for the mechanical connections. This tests involves a current cycling test, freeze thaw test, and then either a salt spray or acid corrosion test.

Ambiguity in this test – With the sequential tests, the test sample requirements state only that four connections of each size and type must be tested. It does not mention anything about testing the range of conductor sizes that the other tests require. Therefore, a manufacturer is required to only test the conductors they feel have the best chance of passing this test.

Advantage – This series of tests is designed to attack the interface between materials in a connection. Since exothermic welding doesn't have an interface to attack, this is a test that exothermic welding passes very easily. Whereas, crimp connections have a hard time passing with their complete product range.

Summary on the IEEE 837 Standard for Qualifying Permanent Connections Used in Substation Grounding:

1. The IEEE 837 test is very cost prohibitive to have completed.
2. If a manufacturer says they meet this standard, make sure to ask for the complete test results and make sure the connections you are going to use, have been tested according to the standard.
3. The tests were completed in an independent lab.

Summary:

- Both exothermic and crimp connections have installation instructions that need to be followed.
- There are advantages and disadvantages to both systems.
- The exothermic connection delivers a lower resistance connection without an interface to corrode or loosen.
- Material cost for a crimp system is approximately three times more than one done by exothermic welding.
- Due to the cost prohibitive nature of the IEEE 837 standard, it is being used as more of a sales tool than a means to qualify connections for use in substations.