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Aging test: integrated vs. non-integrated splices shield continuity systems.

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Abstract

To maximize long-term splice performance, the implications of the field conditions must be understood before an application is chosen, including the shield continuity connection.

Currently, there is no technical comparison between a crimped and non-crimped shield connection. Testing in a lab against standard field conditions doesn't tell us the full story when evaluating the reliability of an electrical splice and its shield connection. In fact, our tests show that you should strongly consider the environment before choosing your splicing solution.

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Introduction

Traditionally, the utility industry has rebuilt the shielding continuity of jacketed concentric neutral (JCN) cables by bundling up the concentric neutral (CN) wires and crimping them with one or two connectors.

In certain special applications, such as steel-wire armour submarine cables, each individual concentric neutral wire is connected with one connector to the concentric neutral wire of the other cable. Most splicing solutions offered by manufacturers today involve re-jacketing for mechanical and environmental protection. This type of bundled and crimped connection has been used for decades by utilities and industrial customers with very good results.

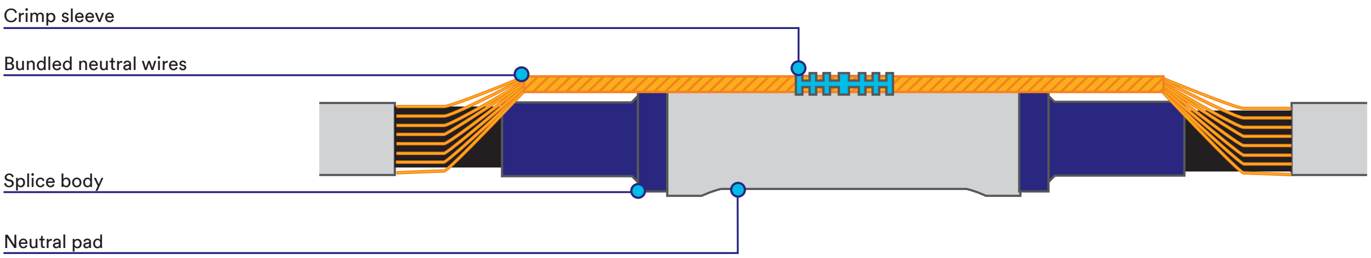
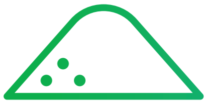


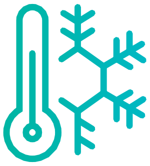
Figure 1: Shows bundled and crimped wires over a splice body.

Today, JCN cables are used most often, but in the past, unjacketed CN cables were also used. From a shield continuity perspective, crimped and bundled neutral wires have proven to perform well in the field, even with unjacketed cables that are exposed to the environment. The crimped shield connection was and still is being used in various environments (e.g., heavy salt, different de-icing substances, water, etc.) with both jacketed and un-jacketed distribution cables.

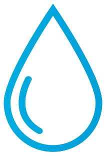
Heavy salt



Different de-icing substances

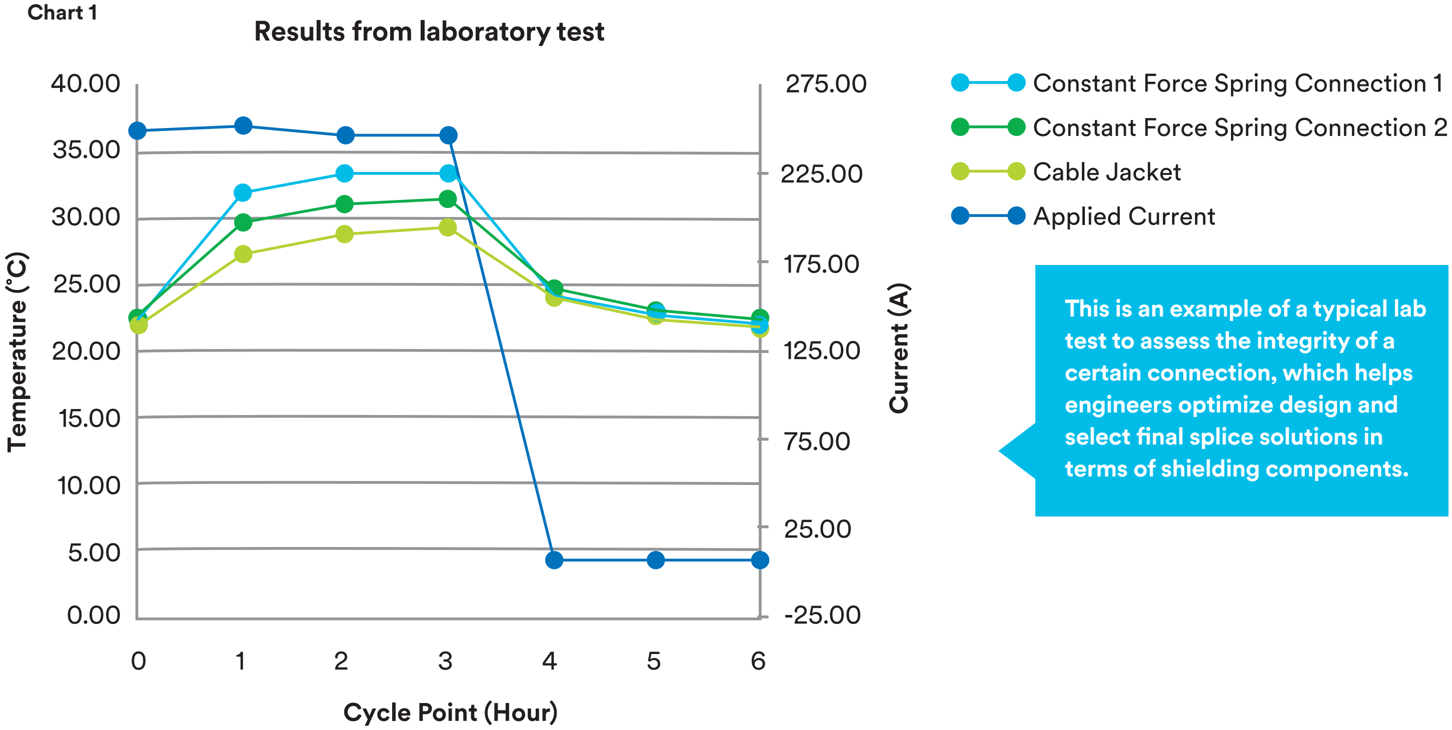


Water accumulated in the cable chambers



However, recently the utility industry introduced integrated joints.[1] The integrated joint design requires the CN wires to be cut and the shielding sleeve (that provides electric continuity) to be attached by constant force springs to the CN wires, on both sides of the splice. Manufacturers, like 3M, have tested this assembly in the lab with very good results. For example, a 3M laboratory test (see **Chart 1**) shows that after 550 current cycles (three-hours "on": three-hours "off") at an applied current of approximately 250A, the connections remained stable and the temperatures of the constant force springs stayed in the range of 31-34°C (recorded jacket temperatures in the range of 29-30°C).[2]

Chart 1



This is an example of a typical lab test to assess the integrity of a certain connection, which helps engineers optimize design and select final splice solutions in terms of shielding components.

Once a splice is installed in the field, it could be subject to non-standard service conditions and/or adverse environments, some of which are outside the control of the installers, owner-operators, or splice manufacturers. These installation inconsistencies can affect the long-term performance and life expectancy of an installed splice. Examples of such elements include corrosive water, higher or lower circulating currents through the shielding system, system transients, deviations from the recommended installation instructions, etc.

As a result, a laboratory test was designed to assess some of the non-standard conditions that may occur in certain environments, such as underground cable chambers and vaults, windfarms, or other industrial locations.

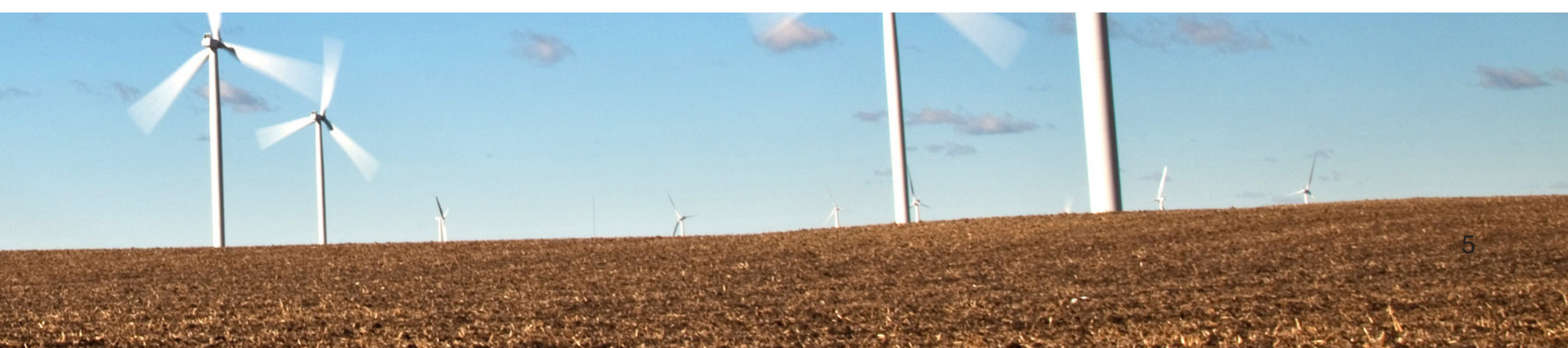
The goal of this technical comparison test is to equip the reader with the research to help answer: ***which splice is right for my field condition(s)?***

Materials and methods

A test was conducted in a controlled laboratory environment to determine which splicing method – integrated connection or traditional crimp connection – is most effective when the splice is exposed to non-standard conditions.

Effectiveness was determined using two measures: speed of degradation and temperature.

The comparison: A shield connection that uses taped and non-taped constant force springs attached to a shielding sleeve overlapping CN wires versus a connection that uses the traditional crimped connector method of the CN shield wires.



Test setup

Loop configuration

- 1 assembly shielding sock with constant force springs, covered with vinyl electric tape* (see **Figure 2**)
- 1 assembly shielding sock with constant force springs, not covered with vinyl electric tape* (see **Figure 3**)
- 1 crimped connector connecting the CN wires. The connector used is 10006 2/0 CU (see **Figure 4**) (e.g., traditional crimp connection)

Figure 2: Assembly shielding sock with constant force springs, covered with vinyl electrical tape*

Figure 3: Assembly shielding sock with constant force springs, not covered with vinyl electrical tape*

Figure 4: Crimped connector connecting the CN wires. The connector used is a 10006 2/0 CU

Note: the shielding sock has been connected to the CN wires of a 4/0 AL, 35 KV, 20x12 AWG CN wires cable by means of two constant force springs (shown in Figure 2 and 3). This shield connection procedure is in compliance with the installation instructions of the 3M™ Cold Shrink QS4 Integrated Splice Series shown in **Figure 5**.

**Two half-lapped layers of Scotch® Electrical Shielding Tape 24 was applied to the cable semi-con, the CN wires were then laid on top and the ends were wrapped with aluminum tape to hold them in place.*

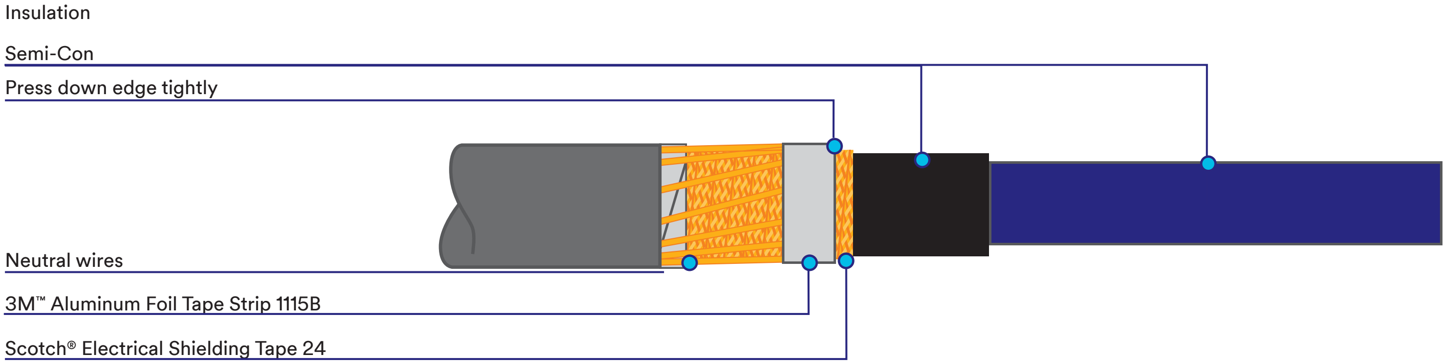


Figure 5: 3M™ Cold Shrink QS4 Integrated Splice Series

Test procedure

Approximately 200A were circulated through the CN wires of the test loop, which ran on a three-hours “on” and three-hours “off” current cycle. At the beginning of each of the two current cycles during an eight-hour workday, a salt/water solution with a concentration of 300 μS/cm was sprayed over the connections (vinyl taped constant force springs, non-vinyl taped constant force springs, and crimp connector).

3h ON → OFF 3h

Study methodology

The reason for vinyl taped connections versus non-vinyl taped connections was to understand the performance difference that taping the constant force spring introduces. The omission of the tape or the use of incorrect taping technique (e.g., tape not properly stretched, or tape applied on the shielding sleeve as opposed to over the constant force springs, or only one layer of tape applied as opposed to two) are frequent mistakes in the field.

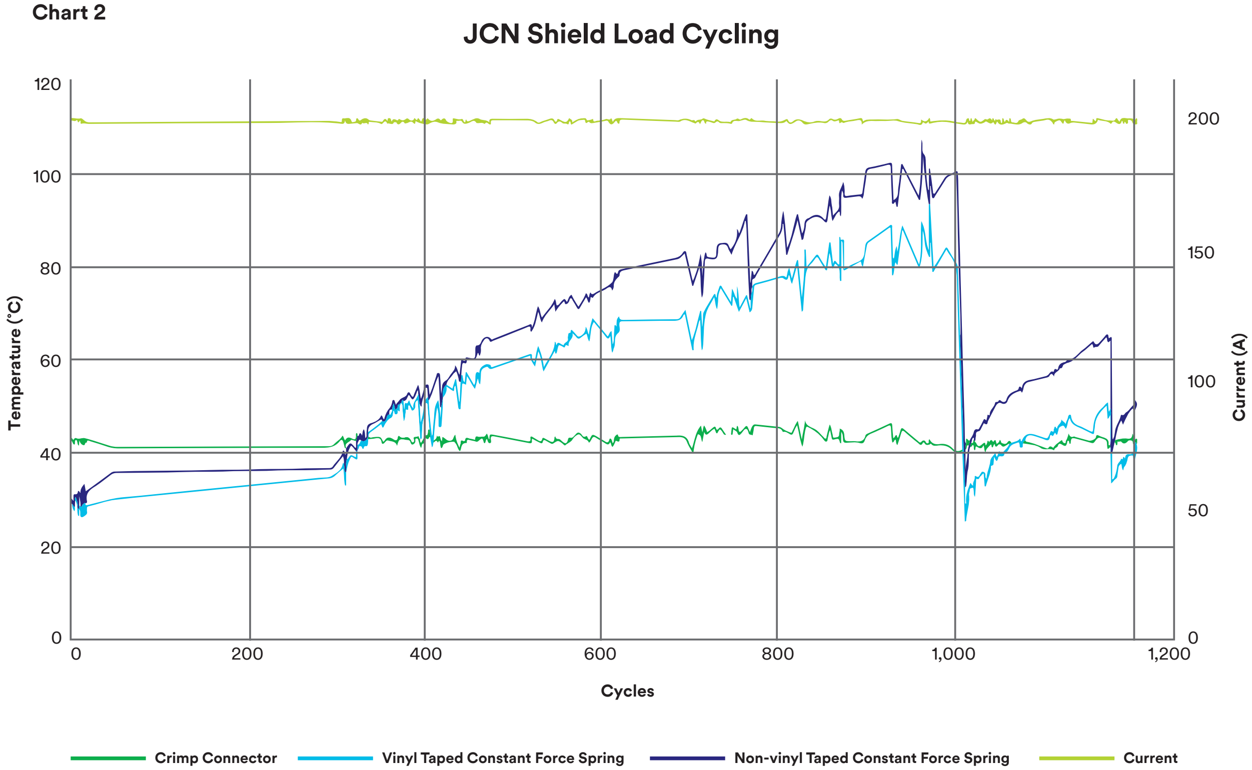
The reason for running 200A RMS through the loop was to age the connections faster as opposed to testing with lower ampacities necessitating more cycles. The application of the salt/water solution was intended to simulate field corrosion conditions and to faster age/degrade the connections.

Results

The test results show (see **Chart 2**) that the crimped CN connection is stable over time, while the taped and non-taped constant force spring connections to the shielding sleeve have the tendency to degrade faster as measured through temperature increases over the duration of the cycles.

The graph below shows results for 1013 cycles completed from 07/20/2017 to 04/03/2018 with an additional 194 cycles for a total of 1207 cycles to 05/22/2018 with the test setup and procedure described above.

Chart 2



Results (cont'd)

1.0

As can be seen in **Chart 2**, the crimp connector is stable and running at a temperature below 47.2°C (the range of temperature measurements is 41.03°C-47.16°C) for 1,207 cycles, well below the taped and non-vinyl taped connections, over the same number of cycles.

2.0

The vinyl taped connections reached an average of 80.61°C and the non-vinyl taped connections reached an average exceeding 100°C after 1,013 cycles.

3.0

Both the vinyl taped, and non-vinyl taped connections have the tendency to degrade faster compared to the crimp connector, but the vinyl taped connections behave somewhat better (slower rate of degradation) compared to the non-vinyl taped connections. This can be explained by the fact that the applied vinyl tape adds pressure to the constant force springs and makes it more difficult for either the salt/water spray solution to reach the constant force spring/shielding sock connection, or for the spring connections to loosen during the heat cycling, or both.

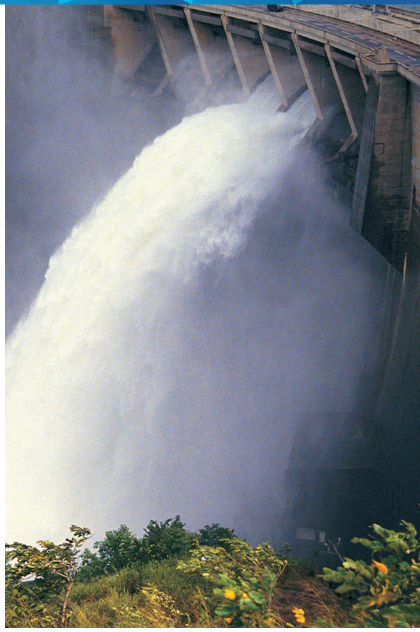
4.0

The reason for completing the additional 194 cycles after the first 1,013 cycles was to understand if the same trend is confirmed (increase in temperature of the constant force spring connections versus the stable crimp connections) if we tighten up the constant force springs after loosening up during the 1,013 cycles testing. As can be seen on **Chart 2**, both the vinyl taped, and non-vinyl taped constant force spring connections exhibit a similar temperature increase trend from cycle 1,014 to 1,207. The temperature of the non-vinyl taped constant force spring connection at the end of cycle 1,207 was 51.16°C (33.06°C at the beginning of cycle 1014) and the temperature for the vinyl taped connection at the end of cycle 1,207 was 41.38°C (25.57°C at the beginning of cycle 1,014).

Table 1 gives a summary of the temperature measurements:

Cycle number	Avg. taped connections temperature	Avg. un-taped connections temperature	Avg. crimped connector temperature
End of 1,013	80.61°C	100.74°C	40.29°C
Cycle 1014/End of cycle 1,207	25.57/41.38°C	33.06/51.16°C	40.29/43.2°C
Avg. temperature range (from MIN. to MAX. readings) over 1,207 cycles	27.81-90.11C	28.87-104.86C	40.29-47.16°C

Table 1: Temperature measurements for accelerated aging test on CN wires with shielding sleeve and constant force springs.



5.0

Since no visible signs of corrosion were observed during visual examination after cycle 1,013, it is difficult to understand the impact of the salt/water spray applied at the beginning of each current “on” cycle and its impact on connection degradation of the constant force spring connections. It is possible that the salt/water produced some contact degradation, but not to the degree that the corrosion becomes visible.

Note: the installation of the shielding sock, constant force springs and the vinyl tape has been performed by qualified lab personnel in compliance with the 3M™ Cold Shrink QS4 Integrated Splice installation instructions. The scope of the test (aside from the vinyl verus non-vinyl taped connections) was not to evaluate a combination of installation inconsistences (e.g., constant force springs not tightened properly; missing one or more constant force springs; some constant force springs taped, some not; vinyl tape present between shielding sleeve and springs preventing a good connection, etc.), but to try to understand the speed of degradation in a somewhat corrosive environment.

Discussion

From splice body to material to installation, the end user should carefully consider all advantages and disadvantages of integrated versus non-integrated splices[1] and the specific operating conditions of the electric system it is part of.

The design of the grounding system (e.g., type, cross-bonding, potential circulating currents, etc.) can also have an impact on the longevity of the shielding system of the splice and cable.

Conclusion

The end-user should evaluate and understand not only the differences in installation steps between an integrated and non-integrated splice but should also try to determine which environmental factors may impact the long-term performance of the cable/splice assembly.

This type of aging test demonstrates that crimped CN connections typically used with non-integrated splices are more stable compared to the constant force spring/shielding sleeve connections used with integrated splices under the described test conditions.

For more information about 3M electrical products and solutions contact us at: **3Menergysolutions@mmm.com**.

References

[1] White paper “How do you take your splice? Integrated or not?”, May 2015
[2] Test report “Cold shrink integrated splice kits, metallic shield restoration sock continuous current evaluation” TRQSIII-IJ_MS-CC, February 2009

Important Notice

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