Bellcore

TECHNICAL AUDIT REPORT

AU-604, VOLUME 1

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TECHNICAL AUDITING

Features, Functions and Performance Analysis of the A.K. Stamping's Cable Shield Bonding Clamps

Bellcore Serial No. 03

Bellcore

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A.K. STAMPING COMPANY, INC.

1159 U. S. Route No. 22

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Attn: Ms. Marlene M. Kurz

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AUDIT SCOPE NOTICE

LIST OF POSSIBLE TECHNICAL AUDIT TOPICS FOR CABLE SHIELD BONDING CLAMPS

BELLCORE has reviewed the product class for the A.K. Stamping Inc. Cable Shield Bonding Clamps and has identified the following topics which in Bellcore's view, a complete analysis of this product would require. Please note that this Technical Audit Report does not include all of these topics. Rather, it includes only the topic(s) checked below. These topics are grouped into four main criteria areas.

Additional Technical Audits covering other listed topics may have been performed on the A.K. Stamping Inc. Cable Shield Bonding Clamps or may be performed in the future. If so, additional Audit Reports would have the same Audit Report number, but would be identified with separate volume or supplement number. Any such Audit Reports may be obtained directly from A.K. Stamping Company, Inc.

Features, Functions and Performance

- [X] General Requirements
- [X] Mechanical Requirements

- [X] Electrical Requirements
- [X] Functional Requirements
- [X] Environmental Requirements

Product Reliability

NA or not tested

Quality Technology

NA or not tested

Environmental Compatibility (refer to FFP)

Features, Functions and Performance Analysis, of A.K. Stamping's Cable Shield Bonding Clamps

CONTENTS

Executive Summary

Purpose

This Technical Audit Report (AU) provides the results of Bellcore's technical audit of AK Stamping Company, Inc. Cable Shield Bonding Clamps.

This Technical Auditing Report analyzes Cable Shield Bonding Clamps models, Mini B Bond Clamp, B1 Bond Clamp, B2 Bond Clamp, B3 Bond Clamp, D2 Bond Clamp, Gator Clamp, and Mini Gator Clamp. This audit was requested by AK Stamping Company, Inc.

Criteria

The samples provided were tested to determine conformance to Bellcore's Technical Reference TR-NWT-001075, *Generic Requirements for Outside Plant Bonding and Grounding Hardware,* Issue 1, August 1991 and TR-NWT-001001, *Generic Requirements for Cable Shield Bonding Clamps,* Issue 2, dated November 1993.

At the request of the customer, Bellcore developed "**Use and Reuse**" criteria to address issues related to the recognition that the cable bonding strap must be frequently assembled and disassembled to facilitate cable locating procedures. This criteria is not part of a Bellcore TR, but will be added to the issues list for future updates of TR-NWT-001001.

Test Results

The audit requested by AK Stamping Company, Inc. and reported upon in this AU is summarized in tabular form in Section 2 of this report, "Summary of Results." Specific details of each requirement and test result are provided in Sections 3. In addition, full details of Bellcore's and Supplier's Comments are included in Section 4. All requirements of TR-NWT-001001 were met.

1. Introduction

1.1 Scope of Work

This Technical Audit Report (AU) provides the results of Bellcore's Technical Audit of the cable shield bonding clamps, manufactured by AK Stamping Company, Inc.

The product was analyzed to determine how it conformed to applicable requirements and objectives contained in Bellcore Generic Requirements document TR-NWT-001001, *Generic Requirements for Cable Shield Bonding Clamps*, Issue 2, dated November 1993.

The audit requested by AK Stamping Company Inc., and reported upon in this AU is summarized in tabular form in Section 2 of this report, "Summary of Results." Specific details of each requirement and test result are provided in Section 3. In addition, full details of Bellcore's and Supplier's Comments are included in Section 5.

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1.1.3 Product Availability

The supplier states that the cable shield bonding clamps referenced in this report are available for purchase.

1.2 References

Bellcore Generic Requirements document TR-NWT-001001, *Generic Requirements for Cable Shield Bonding Clamps*, Issue 2, dated November, 1993.

1.3 Terminology

1.3.1 Terminology for Results

Definitions of Terminology for Results:

1. *Criteria Met.*
   The product is considered to have met the requirements, as evidenced by the test results or other data obtained in this analysis.
2. *Criteria Not Met.*
   The product did not meet the requirements, as evidenced by test results or other data obtained in this analysis.

This "Terminology for Results," section is used to help organize the data being reported. The significance of each analysis result should be determined by the user of this report in conjunction with his/her affiliated organization.

1.4 Product Description

The AK Stamping Company, Inc. cable shield bonding clamp consists of a shield bonding device and, when applicable, a bonding strap. The bonding clamps are intended principally for use with plastic sheath cables.

The bonding clamp types and their model number designations which are covered by this Technical Audit are listed in the table below.

Sample #	Bond Clamp Type	Model #
AKS1	B #1	400366332-2N
AKS2	B #1	400366332-2N
AKS3	Mini B	400366332MB-2N
AKS4	Mini B	400366332MB-2N
AKS5	B #3	400366357-2N
AKS6	B #3	400366357-2N
AKS7	B #2	400366340-2N
AKS8	B #2	400366340-2N
AKS9	Gator	A1037
AKS10	Gator	A1037
AKS11	Mini Gator	A1255
AKS12	Mini Gator	A1255
AKS13	D #2	400963757-2N
AKS14	D #2	400963757-2N
AKS15	Mini B	400366332MB-2N
AKS16	Mini B	400366332MB-2N
AKS17	B #1	400366332-2N
AKS18	B #1	400366332-2N
AKS19	B #3	400366357-2N
AKS20	B #3	400366357-2N
AKS21	B #2	400366340-2N
AKS22	B #2	400366340-2N
AKS23	Mini Gator	A1255
AKS24	Mini Gator	A1255
AKS25	Gator	A1037
AKS26	Gator	A1037
AKS27	D #2	400963757-2N
AKS28	D #2	400963757-2N
AKS29	Mini B	400366332MB-2N
AKS30	Mini B	400366332MB-2N

Sample #	Bond Clamp Type	Model #
AKS31	B #1	400366332-2N
AKS32	B #1	400366332-2N
AKS33	B #2	400366340-2N
AKS34	B #2	400366340-2N
AKS35	B #3	400366357-2N
AKS36	B #3	400366357-2N
AKS37	D #2	400963757-2N
AKS38	D #2	400963757-2N
AKS39	Gator	A1037
AKS40	Gator	A1037
AKS41	Mini Gator	A1255
AKS42	Mini Gator	A 1255

The device is a two-piece cable shield bonding clamp with a threaded stud fixed to the base plate and threaded nut(s) with captured star washers for clamping and retaining of a bond strap. The cable shield bonding clamps have two functions: 1) when used in pairs or multiple applications, they restore shield continuity to cable sheaths that have been cut primarily to accommodate splices; and 2) to connect the cable shield to ground through ground rods, messenger wires, pedestal housing, or splice closures. A maximum of 50 inch-pounds force should be sufficient to attach the nut to the ground strap when attached to the cable. The bonding clamp has one or more nuts with captured star washers for attaching ground wire straps. Each strap has a minimum current carrying capacity equivalent to that of a #6 AWG solid copper conductor. A hex drive wrench or similar tool is used to attach the cable shield bonding clamp and strap to a cable.

1.5 Analysis Tests

The audit is based on laboratory tests conducted at Bellcore's Chester, New Jersey facility. All test data is maintained by and is the property of Bellcore.

2. Summary of Results

A quick reference summation of the results is shown below.

AU Para.	Criteria	Criteria Met	Criteria Not Met
3.1	Sample Preparation	X	
3.2	Material	X	
3.3	Plating	X	
3.4	Visual Inspection	X	
3.5	Initial Connection Resistance	X	
3.6	Straps	X	
3.7	Torque Test	X	
3.8	Tensile Test	X	
3.9	Vibration Requirements and Test	X	
3.10	Temperature and Humidity Tests	X	
3.11	Salt Fog Test	X	
3.12	Stress Corrosion Cracking	X	
3.13	Pull Test	X	
3.14	AC Fault Test	X	
3.15	Lighting Surge Test	X	
3.16	Core-to-Shield Voltage Breakdown Test	X	
3.17	Use-Reuse	X	

3. Functional Requirements and Test Result

3.1 Sample Preparation

Criteria:

The sample shall be defined as one cable section with a cable bonding clamp at each end. A total of 84 bonding clamps were assembled on 42 sections (samples) of cable. The generic requirement specifies a minimum of 24 cable sections.

The samples were assembled on the cable sections using two methods supplied by the manufacturer. Samples 1 through 28 were assembled using Method One described below and samples 29 through 42 were assembled using Method Two, also described below.

Assembly Method One:

The cable sections are prepared following the method in TR-NWT-001001, Figure 1. The clamp is assembled using two nuts with captive star washers and one flat washer following the example diagram below (Figure 3-1). Each nut is torqued to 40 inch-pounds force. No protective wrap is applied to the prepared sample.

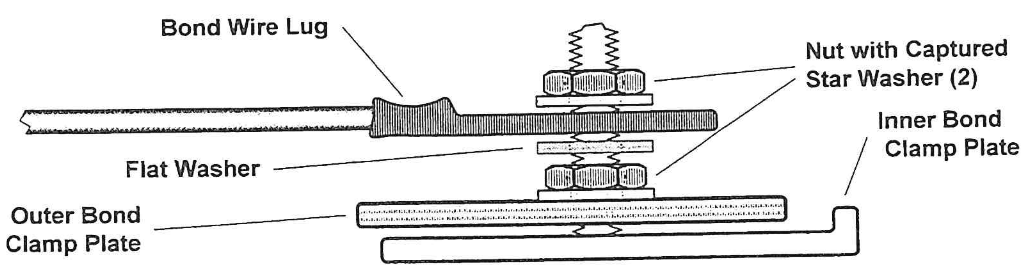


Figure 3-1.

Assembly Method Two:

The cable sections are prepared following the method in TR-NWT-001001, Figure 1. The clamps are assembled using a single nut with captive star washer and no flat washer. The nut is applied over the bond strap lug and tightened using hand force only with a 216-type (small body) tool. Hand force only, is used to tighten the nut. This assembly method yields a torque force of 8 - 10 inch pounds. See example diagram in figure 3-2 below.

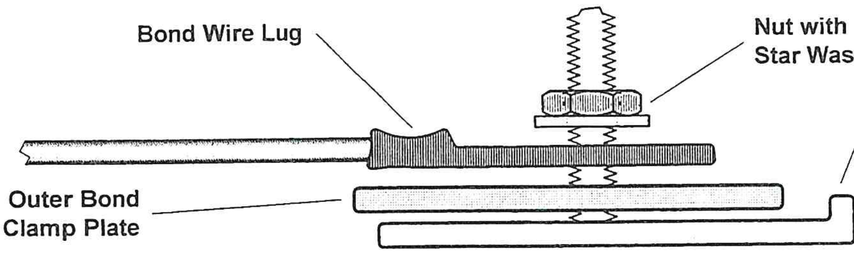


Figure 3-2.

Results:

Twenty-four samples are required for testing; forty-two samples were used in the test population.

Criteria Met.

3.2 Material

Criteria:

Bonding clamps manufactured to these requirements shall be compatible with both shields and wires indicated in Section 1.1 of TR-NWT-001001. The definition of compatibility is that any materials used to fabricate the bonding clamps shall not react chemically with any cables or wires to degrade the bonding connection and the clamp design shall be such as to not degrade the functional performance of the basic cable or wire to which clamps are applied.

Results:

Forty-two samples were tested for Salt Fog Exposure and Stress Corrosion. None of the samples reacted chemically with any cables or wires to degrade the bonding connection and the functional performance of the basic cable or wire to which clamps are applied.

Criteria Met.

3.3 Plating

Criteria:

The plating of cable shield bonding clamps, and straps shall be of sufficient thickness to provide corrosion protection to the base material and to ensure that the connection resistance remains within specification requirements.

Results:

After the Temperature/Humidity and Salt Fog Exposure, the clamp plating was of sufficient thickness to provide corrosion protection to the base material and to ensure that the connection resistance remained within specification requirements.

The Table below list the connection resistance after both test. Samples 1 through 28 were assembled using two nuts with captured star washers, one flat washer, and a ground strap. Each nut was torqued to 40 inch-pounds. Samples 29 through 42 were assembled with one nut with a captured star washer, and a ground strap. Each nut was tightened by hand force with a 216-type tool.

See section 3.5 of this document for the contact resistance criteria.

Connection Resistance After Temperature Cycling With Humidity, and After Salt Fog Test

Sample #	Connection Resistance After Temperature Cycling with Humidity	Connection Resistance After Salt Fog Test
	milliohms	milliohms
1	1.14	1.63
2	1.06	1.95
3	1.95	1.33
4	1.35	1.87
5	1.20	2.21
6	1.11	1.63
7	1.26	1.44
8	1.19	3.51
9	1.28	1.82
10	1.22	1/46
11	1.00	1.33
12	1.08	3.27
13	1.07	1.87

Sample #	Connection Resistance After Temperature Cycling with Humidity	Connection Resistance After Salt Fog Test
	milliohms	milliohms
14	1.03	2.18
15	1.08	1.51
16	1.01	1.82
17	1.01	1.49
18	1.02	1.70
19	1.19	3.76
20	1.08	1.86
21	1.02	8.12
22	1.09	2.22
23	1.37	2.87
24	1.38	2.26
25	1.23	2.45
26	1.03	1.36
27	0.87	3.22
28	0.85	4.32
29	1.15	8.29
30	1.24	7.24
31	1.04	7.24
32	1.16	3.18
33	1.16	4.35
34	1.29	1.89
35	1.18	2.79
36	1.57	5.70
37	1.06	1.31
38	1.05	3.79
39	1.28	3.03
40	1.21	2.26
41	1.15	1.71
42	2.01	1.36

Criteria Met.

3.4 Visual Inspection

Criteria:

When examined under a magnification of 10X, the bonding and grounding hardware systems shall be free of flash, cracks, plating flaws in functional areas (pinholes and blisters) and foreign material.

Results:

Forty-two samples were examined under 10X magnification and were found to be free of flash, cracks, plating flaws (pinholes and blisters), foreign material and other defects deemed detrimental to its performance.

Criteria Met.

3.5 Initial Connection Resistance Test

Criteria:

The resistance shall be measured through each sample from strap to strap with a meter probes attached as near as practical to the connectors. Each consecutive measurement of a particular sample shall be made with the probes in approximately the same location and shall not exceed:

1. Five milliohms after initial assembly.

2. Ten milliohms after Vibration test, Temperature and Humidity Cycling Test, and Salt Fog Test.

3. A change of five milliohms over the previous measurement after the AC Fault Test and Lightning Surge Test.

Results:

Samples 1 through 28 were assembled using two nuts with captured star washers, one flat washer, and a ground strap. Each nut was torqued to 40 inch-pounds. Samples 29 through 42 were assembled using one nut with a captured star washer, and a ground strap. Each nut was tightened by hand force with a 216-type tool.

Initial Connection Resistance

Sample #	Initial Connection Resistance
	milliohms
1	1.11
2	0.97
3	0.42
4	1.27
5	0.84
6	1.31
7	1.05
8	0.96
9	0.87
10	0.89
11	1.41
12	0.60
13	0.96
14	0.65
15	0.56
16	0.76
17	1.10
18	0.68
19	0.96
20	0.80
21	0.71
22	0.73
23	1.01
24	0.67
25	0.76
26	0.63
27	0.65
28	0.98
29	0.81

Sample #	Initial Connection Resistance
	milliohms
30	1.03
31	1.25
32	1.10
33	1.03
34	1.09
35	1.24
36	1.19
37	1.06
38	1.04
39	1.18
40	1.15
41	1.79
42	1.36

Criteria Met.

3.6 Straps

Criteria:

The connection between the bonding clamp and the strap shall be the compression type and have a minimum current carrying capacity equivalent to that of a #6 solid copper wire, and shall be such that the connection will not loosen, break, or deteriorate during normal installation and service.

Results:

The connection lugs for the tested sample straps were of a compression type and had a minimum current carrying capacity equivalent to that of a #6 solid copper wire. The connection did not loosen, break, or deteriorate during assembly or Environmental Testing.

Criteria Met.

3.7 Torque Test

Criteria:

Any bonding clamp using nuts and/or bolts for installation shall be capable of being tightened to 50 inch-pounds minimum torque without breaking or stripping the threads.

Results:

Fourteen samples were assembled on two different cables (aircore and filled) using the supplied nuts with captured star washers and torqued to 50 inch-pounds. No threads were stripped or studs broken; the star washer takes on a (expected) permanent set. The stud, which is staked into the bottom plate, did not loosed or rotate.

Criteria Met.

3.8 Tensile Test

Criteria:

The bonding clamp and straps with attached bonding clamps shall remain attached and fully engaged to the cable sheath under stress of a sustained load of 100 pounds-force for one minute minimum.

Results:

Forty-two samples were tested. The samples remained attached and fully engaged to the cable sheath under stress of a sustained load of 100 pounds-force for one minute. Connection resistance was measured after the tensile test; see the table on the following page.

Samples 1 through 28 were assembled using two nuts with captured star washers, one flat washer, and a ground strap. Each nut was torqued to 40 inch-pounds. Samples 29 through 42 were assembled using one nut with a captured star washer, and ground a strap. Each nut was tightened using hand force with a 216-type tool.

Connection Resistance After Tensile Test

Sample #	Connection Resistance After Tensile Test
	milliohms
1	0.82
2	0.69
3	0.71
4	0.76
5	0.81
6	0.69
7	0.69
8	0.74
9	0.62
10	0.62
11	0.69
12	0.56
13	0.61
14	0.45
15	0.44
16	0.50
17	0.58
18	0.39
19	0.47
20	0.67
21	0.39
22	0.47
23	0.54
24	0.54
25	0.81
26	0.82
27	0.77
28	0.87
29	0.85

Sample #	Connection Resistance After Tensile Test
	milliohms
30	1.00
31	0.96
32	0.90
33	1.02
34	1.00
35	1.13
36	1.16
37	1.03
38	1.00
39	1.13
40	1.19
41	1.06
42	1.39

Criteria Met.

3.9 Vibration Test

Criteria:

The samples shall be subjected to a simple harmonic motion having an amplitude of 0.03 inch minimum, 0.06 inch maximum total excursion, the frequency range varied uniformly between the limits of 10 and 55 Hz. The entire frequency range, from 10 to 55 Hz and return 10 Hz shall be traversed in approximately one minute. This motion shall be applied for a period of two hours in each of three perpendicular directions.

Following the vibration test, the connection resistance shall be tested and shall not exceed 10 milliohms.

Samples 1,2,9,12,14,19,22,26, were assembled using two nuts with captured star washers, one flat washer, and ground a strap. Each nut was torqued to 40 inch-pounds. Samples 36,37,38,39,40, 41,and 42 were assembled using one nut with a captured star washer, and ground a strap. Each nut was tightened using hand force with a 216-type tool.

Results:

Connection Resistance After Vibration Test

Sample #	Resistance Before Vibration Test	Resistance After Vibration Test
	milliohms	milliohms
1	1.14	1.42
2	1.17	5.45
9	1.44	3.34
12	1.11	2.38
14	1.25	1.47
19	1.25	0.98
22	1.05	1.03
26	2.77	1.17
36	1.35	2.58
37	1.36	1.63
38	1.14	4.22
39	1.58	2.19
40	1.15	2.16
41	1.09	2.64
42	1.31	2.03

Criteria Met.

3.10 Temperature and Humidity Cycling Test

Criteria:

The bonding clamp samples shall be subjected to the temperature and humidity cycles specified in Figure 3 of TR-NWT-001001 for 30 days. After the 30 days of cycling the samples shall be allowed to return to ambient temperature of 23 degrees centigrade, 50% relative humidity and stabilize for 24 hours.

Following the temperature and humidity cycling test, the connection resistance of any cable shield bonding clamp, shall not exceed 10 milliohms.

Any component of the bonding clamp showing visual evidence of corrosion shall be qualified as non-conforming.

Results:

After the 30 days of temperature and humidity cycling, there was no evidence of corrosion. Connection Resistance was measured after the Temperature and Humidity Cycling Test.

Samples 1 through 28 were assembled using two nuts with captured star washers, one flat washer, and ground a strap. Each nut was torqued to 40 inch-pounds. Samples 29 through 42 were assembled using one nut with a captured star washer, and ground a strap. Each nut was tightened using hand force with a 216-type tool.

Connection Resistance After Temperature and Humidity Cycling

Sample #	Resistance Before Temperature/ Humidity Cycling	Resistance After Temperature/ Humidity Cycling
	milliohms	milliohms
1	0.82	1.14
2	0.69	1.06
3	0.71	1.95
4	0.76	1.35
5	0.81	1.20
6	0.69	1.11
7	0.69	1.26
8	0.74	1.19
9	0.62	1.28
10	0.62	1.28
11	0.69	1.27
12	0.56	1.00
13	0.61	1.07
14	0.45	1.03
15	0.44	1.08
16	0.50	1.01
17	0.58	1.01
18	0.39	1.02
19	0.47	1.19
20	0.67	1.08
21	0.39	1.02

Sample #	Resistance Before Temperature/ Humidity Cycling	Resistance After Temperature/ Humidity Cycling
	milliohms	milliohms
22	0.47	1.09
23	0.54	1.37
24	0.54	1.38
25	0.81	1.23
26	0.82	1.03
27	0.77	0.87
28	0.87	0.85
29	0.85	1.15
30	1.00	1.24
31	0.96	1.04
32	0.90	1.04
33	1.02	1.16
34	1.00	1.29
35	1.13	1.18
36	1.16	1.57
37	1.03	1.06
38	1.00	1.05
39	1.13	1.28
40	1.19	1.21
41	1.06	1.15
42	2.03	2.01

Criteria Met.

3.11 Salt Fog Test

Criteria:

The bonding clamp shall be subjected to a salt fog test, with uncovered samples (not taped up) for a duration of 30 days, and in accordance with ASTM B117. The Salt Fog Test is an accelerated corrosion laboratory test that simulates the effects of seacoast atmospheres on the bonding clamp connection, and establishes the presence of galvanic incompatibility on connectors made of more that one metal. Following the Salt Fog Test, and drying at 40 degrees C and 10% R.H. for 24 hours, and then stabilization for 24 hours at room temperature, the cable shield bonding clamp connection resistance shall not exceed 10 milliohms.

Any component of the bonding clamp showing visual evidence of corrosion shall be qualified as non conforming.

Results:

There was no corrosion after the 30 days of Salt Fog Test. Following the test, connection resistance was measured after 24 hours stabilization at room temperature.

Samples 1 through 28 were assembled using two nuts with captured star washers, one flat washer, and ground a strap. Each nut was torqued to 40 inch-pounds. Samples 29 through 42 were assembled using one nut with a captured star washer, and ground a strap. Each nut was tightened using hand force with a 216-type tool.

Connection Resistance After Salt Fog Test Exposure

Sample #	Resistance Before Salt Fog Test Exposure	Resistance After Salt Fog Test Exposure
	milliohms	milliohms
1	1.14	1.63
2	1.06	1.95
3	1.95	1.33
4	1.35	1.87
5	1.20	2.21
6	1.11	1.63
7	1.26	1.44
8	1.19	3.51
9	1.28	1.82
10	1.28	1.46
11	1.27	1.33
12	1.00	3.27
13	1.07	1.87
14	1.03	2.18
15	1.08	1.51
16	1.01	1.82

Sample #	Resistance Before Salt Fog Test Exposure	Resistance After Salt Fog Test Exposure
	milliohms	milliohms
17	1.01	1.49
18	1.02	1.70
19	1.19	3.76
20	1.08	1.86
21	1.02	8.12
22	1.09	2.22
23	1.37	2.87
24	1.38	2.26
25	1.23	2.45
26	1.03	1.36
27	1.56	3.22
28	0.87	4.32
29	0.85	8.29
30	1.15	7.24
31	1.24	7.24
32	1.04	3.18
33	1.16	4.35
34	1.29	1.89
35	1.18	2.79
36	1.57	5.70
37	1.06	1.31
38	1.05	3.79
39	1.28	3.03
40	1.21	2.26
41	1.15	1.71
42	1.24	1.36

Criteria Met.

3.12 Stress Corrosion Cracking Test

Criteria:

This requirement helps to ensure that the copper-base alloy components (including those that are coated with tin, solder or nickel) of cable shield bonding clamps are not constructed of the type that is susceptible to stress corrosion cracking. And that the manufacturing and or application stresses are sufficiently low that ammonia or ammonium compounds will not cause cracking or weakening of the screw member.

The samples shall be immersed in a solution of Mattsson's pH 7.2 (ASTM G37) for a period of seven days. After removal from the solution, the tested bonding clamps shall be washed with running tap water and dried. The samples tested shall show no signs of cracks or weakening of the screw member while examined under 10X magnification.

Results:

Thirty-five samples were tested, there was no signs of cracking or weakening of the screw member while examined under 10X magnification.

Criteria Met.

3.13 Pull Test

Criteria:

After the completion of the stress corrosion cracking test the assemblies shall be subjected to a pull force of 100 pounds-force, applied for one minute between the bonding clamp base and the screw member. There shall be gradual application of the pull force.

There shall be no displacement of the screw member as a result of the Pull Test.

Results:

Thirty-five samples were tested, there was no displacement of the screw member.

Criteria Met.

3.14 AC Fault Test

Criteria:

Bonding clamps for cables whose outer metallic shield diameter can exceed 0.75 inch (19 mm).

One of the clamps of a test sample shall be connected to one terminal of a 60 Hz source using a wire or wires equivalent to a No.4 AWG copper conductor. The other clamp shall be connected to the second terminal of the ac source with a No.6 AWG bare solid copper conductor. A current of 1000A rms shall be applied to the sample for a minimum of 20 seconds or until the No.6 wire fuses open.

There shall be no arcing between the clamps and the cable or wire shield. There shall be no damage to the bonding clamps, such as charring, deformation, melting, or pitting when examined by normal vision or corrected to normal vision. The shield in the vicinity of the clamps shall show no evidence of the thermal damage. The connection resistance of the clamps after the test shall not exceed a change of five (5) milliohms from the previous measurement.

Results:

Samples 1 through 28 were assembled using two nuts with captured star washers, one flat washer, and ground a strap. Each nut was torqued to 40 inch-pounds. Samples 29 through 42 were assembled using one nut with a captured star washer, and ground a strap. Each nut was tightened using hand force with a 216-type tool.

There was no arcing between the clamps and the cable or wire shield. There was no damage to the bonding clamps, such as charring, deformation, melting, or pitting when examined by normal vision or corrected to normal vision. The shield in the vicinity of the clamp showed no evidence of thermal damage. The connection resistance of the clamps after the test shall not exceed a change of five (5) milliohms from the previous measurement.

Connection Resistance after AC Fault Test

Sample #	Connection Resistance Before AC Fault	Connection Resistance After AC Fault	Time to #6 AWG fuse open (seconds)
	milliohms	milliohms	
1	1.63	1.11	15.6
2	1.95	2.77	17.8
3	1.33	1.06	19.0
4	1.87	1.12	18.2
5	2.21	1.31	12.6
6	1.63	1.35	19.7
7	1.44	1.01	18.6
8	3.51	1.05	19.6
9	1.82	1.36	18.2

Sample #	Connection Resistance Before AC Fault	Connection Resistance After AC Fault	Time to #6 AWG fuse open (seconds)
	milliohms	milliohms	
10	1.46	1.25	12.0
1	1.33	1.09	18.3
12	3.27	1.58	18.6
13	1.87	1.14	19.0
14	2.18	1.15	18.6
15	1.51	0.97	17.5
16	1.82	4.24	9.4
17	1.49	1.06	18.6
18	1.70	1.32	17.4
19	3.76	1.26	18.2
20	1.86	1.06	18.0
21	8.12	1.24	19.6
22	2.22	0.96	14.6
23	2.87	1.16	19.1
24	2.26	1.04	18.0
25	2.45	1.26	18.3
26	1.36	3.76	12.0
27	3.22	0.98	18.6
28	4.32	1.21	18.6
29	8.29	1.45	18.2
30	7.24	1.62	18.2
31	7.24	2.43	17.3
32	3.18	1.03	18.6
33	4.35	0.86	18.2
34	1.89	0.97	19.1
35	2.79	1.35	19.3
36	5.70	1.45	19.0
37	1.31	0.82	18.3
38	3.79	1.54	19.6

Sample #	Connection Resistance Before AC Fault	Connection Resistance After AC Fault	Time to #6 AWG fuse open (seconds)
	milliohms	milliohms	
39	3.03	1.51	18.3
40	2.26	1.70	19.6
41	1.71	1.90	18.3
42	1.36	1.58	19.0

Criteria Met.

3.15 Lightning Surge Test

Criteria:

Test shall be performed on samples assembled form cables or wires whose shields are representative of the designs for which the bonding clamp is intended. The method of installation shall conform to the instructions of the clamp manufacturer. The length of the cable or wire of a test sample shall be sufficient to allow proper installation of the clamps.

The bonding clamps of a test sample shall be attached to the terminals of a surge generator and a surge current of having a peak value of 20kA shall be applied. The waveform of the current shall have a rise time not greater than 8 microseconds and a time to half-value not less than 20 microseconds. There shall be no arcing between the clamps and the shield. There shall be no damage to the bonding clamps such as charring, deformation, melting or pitting when examined by normal vision or corrected to normal vision. The shield in the vicinity of the clamps shall show no evidence of thermal damage. The connection resistance of the clamps after the test shall not increase more than five (5) milliohms from the previous measurement.

Results:

Samples 1 through 28 were assembled using two nuts with captured star washers, one flat washer, and ground a strap. Each nut was torqued to 40 inch-pounds. Samples 29 through 42 were assembled using one nut with a captured star washer, and ground a strap. Each nut was tightened using hand force with a 216-type tool.

There was no arcing between the clamps and the shield. There was no damage to the bonding clamps such as charring, deformation, melting or pitting when examined by normal vision or corrected to normal vision. The shield in the vicinity of the clamp showed no evidence of thermal damage. The connection resistance of the clamps after the test did not increase more than five (5) milliohms from the previous measurement.

Connection Resistance after Lightning Surge Test

Sample #	Connection Resistance Before Lightning Surge Test	Connection Resistance After Lightning Surge Test
	milliohms	milliohms
1	1.11	0.84
2	2.77	0.96
3	1.06	0.82
4	1.12	0.78
5	1.31	0.81
6	1.35	0.96
7	1.01	0.81
8	1.05	0.73
9	1.36	1.21
10	1.25	4.51
1	1.09	2.56
12	1.58	1.56
13	1.14	1.84
14	1.15	1.45
15	0.97	1.44
16	4.24	2.51
17	1.06	1.58
18	1.32	1.39
19	1.26	1.47
20	1.06	1.67
21	1.24	1.96
22	0.96	2.47
23	1.16	1.54
24	1.04	1.61
25	1.26	0.81
26	3.76	1.63

Sample #	Connection Resistance Before Lightning Surge Test	Connection Resistance After Lightning Surge Test
	milliohms	milliohms
27	0.98	1.45
28	1.21	1.32
29	1.45	1.65
30	1.62	0.94
31	2.43	1.45
32	1.03	1.87
33	0.86	1.32
34	0.97	1.21
35	1.35	1.41
36	1.45	1.85
37	0.82	1.63
38	1.54	1.74
39	1.51	1.65
40	1.70	1.32
41	1.90	1.65
42	1.58	1.74

Criteria Met.

3.16 Core-to-Shield Voltage Breakdown Test

Criteria:

There shall be no evidence of dielectric breakdown when a 3kV RMS 60 Hz voltage is applied between copper-pair cable conductors and installed bonding clamps.

Results:

Forty-two samples were tested using a 3kV RMS 60 Hz potential for five (5) seconds between the copper-pair cable conductors and the installed bonding clamps. There was no breakdown of the copper-pair cable conductors to the installed bonding clamps.

Criteria Met.

3.17 Use and Reuse Test

Criteria:

To facilitate buried cable locating operations, the bonding strap may be temporarily removed from the bond clamp. This requirement ensures that a bond clamp can withstand frequent removal and replacement of the nut that retains the bond strap. To simulate progressive environmental exposure; the nut is loosened and then re-torqued to 50 inch-pounds after successive environmental stresses. No parts are replaced during the performance of this test.

The samples required for the use and reuse test are not part of another test population, this test is applicable to copper base alloys only. Following the manufacturers printed instructions, ten (10) bonding clamps shall be assembled on section of appropriate cable. The cable section shall be held in a suitable fixture and then the nut that retains the cable bonding strap shall be loosened at least one turn and then re-torqued to 50 inch-pounds. This pre-conditioning procedure of loosening and re-torquing the nut shall be repeated ten (10) times. The nut and/or bolt shall not strip or break.

The pre-conditioned samples shall be immersed in Mattsson's solution for a period of seven (7) days using the procedure in section 4.4.3, TR-NWT-001001. Then an axial pull test shall be performed using the procedure in section 4.3.4, of the same document. Following the pull test, the cable section shall then be held in a suitable fixture and the nut that retains the cable bonding strap shall be loosened at least one turn and then re-torqued to 50 inch-pounds. This procedure shall be repeated ten (10) times. The nut and/or bolt shall not strip or break.

The samples shall then be subjected to salt fog exposure using the procedure in section 4.3.2, TR-NWT-001001, except the exposure duration shall be limited to 15 days. Following the salt fog exposure, the use and reuse samples shall be allowed to dry in ambient air for 24 hours. Following the salt fog exposure, the cable section shall then be held in a suitable fixture and the nut that retains the cable bonding strap shall be loosened at least one turn and then re-torqued to 50 inch-pounds. This procedure shall be repeated ten (10) times. The nut and/or bolt shall not strip or break.

Results:

Thirty-five samples were tested to the Use and Reuse Test criteria. All clamps sustained a torque and re-torque to 50 inch-pounds for the entire test cycle without failure.

Criteria Met.

4. Comments

4.1 Bellcore Comments

4.1.1 Visual Inspection

This requirement helps to ensure that the hardware is free of foreign materials, plating flaws such as pinholes and blisters, cracks and flash.

4.1.2 Tensile

This test helps to ensure that the bonding and grounding hardware is firmly attached and fully engaged to their conductive elements.

4.1.3 Initial Connection Resistance

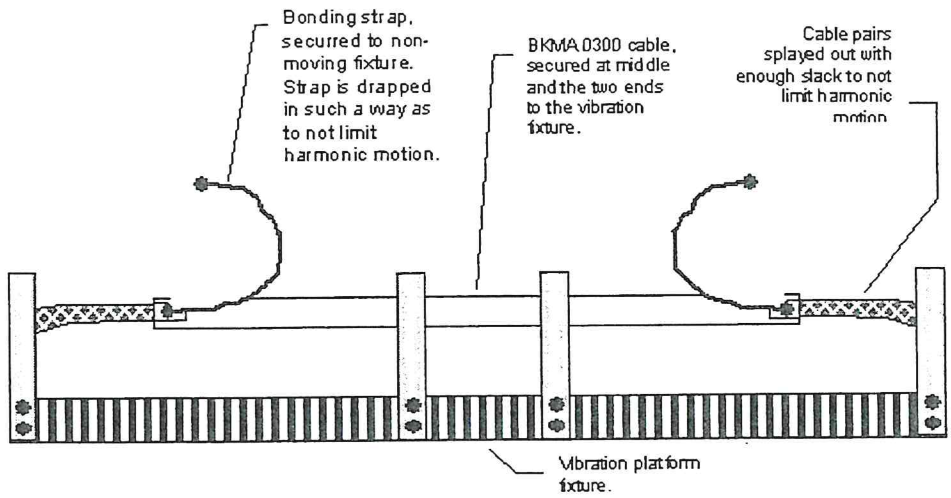
The connection resistance must be low to insure a good electrical continuity of the cable shield. Poor contact resistance can lead to shield continuity problems or bond failure during lightning or ac fault events.

4.1.4 Vibration

Telecommunications equipment may be subjected to low-level vibration that is typically caused by nearby rotating equipment, rail or truck traffic or construction work in adjacent locations. This vibration could cause malfunctions, service interruptions or equipment failures.

At the request of A. K. Stamping Company, Inc. an additional vibration test was developed and performed as follows:

- Two, six foot long sections of BKMA0300 cable were prepared as follows. The middle one foot segment was rigidly secured to a suitable vibration fixture. One foot of shield was removed from each end of this cable, the exposed pairs were spread out and then rigidly clamped in vibration fixtures near each end. One cable section was assembled using type B2 clamps on each of the two exposed cable shield ends and a seven strand No.6 AWG copper bonding strap was attached to each clamp. The other cable section was assembled in a similar way using type D clamps. The other end of each bonding strap was attached to rigid and non-moving fixture. See the figure below for a diagram of the mounting method.



- These samples were subjected to a simple harmonic motion using the requirements of section 4.2.4 of TR-NWT-001001. During the two hour test cycle, resistance is continuously monitored.
- During and following the test the connection resistance shall not exceed 10 milliohms and the nuts that retain the bonding strap shall not loosen.

This test is designed to simulate both the horizontal and vertical modes of vibration that bonding clamps may be subjected to when used with buried cable in ready access pedestals near a road with heavy truck traffic. It is the intent of the test to determine if the clamp body or retaining nut will loosen or if the connection resistance will increase to more than 10 milliohms under this stress.

The mounting method used in this test causes the two ends to repeatedly go through a worse case harmonic motion while the far end of the bonding strap is held motionless. This allows the bond strap to twist and pull on the clamp.

Both samples met this additional test criteria.

4.1.5 Temperature and Humidity Cycling Test

During transportation, storage or in operation, the hardware may be exposed to extremes in ambient temperature and humidity. This test simulates the effects of exposure to temperature and humidity cycling on the bonding and grounding systems hardware connection. This test helps to establish that the hardware and connection does not sustain any damage or deterioration in functional performance after it has been exposed to temperature and humidity cycling. The results from this test should provide a estimate of the product life in the outside plant environment.

4.1.6 Salt Fog Test

The Salt/Fog test is an accelerated corrosion exposure test that simulates the effects of seacoast atmospheres on the bonding and grounding system hardware connections, and establishes the presence of galvanic incompatibility on connections made from more that one metal.

Frequently, outside plant hardware fails this test due to the use of ferrous or other non-copper alloy metals. All component of the tested cable shield bonding clamps were composed of copper alloys with a Western Electric type of tin plating. The clamps exhibited excellent resistance to the salt fog exposure.

4.1.7 Hydrogen Sulfide Test

This test is no longer a part of the TR-NWT-001001 generic requirements and was not performed for this analysis. It could be performed at a later date if requested.

4.1.8 Stress Corrosion Cracking

This requirement helps to ensure that the copper-base alloy components (including those that are coated with tin, solder or nickel) of cable shield bonding clamps are not susceptible to stress corrosion cracking and that the manufacturing and or application stresses are sufficiently low that ammonia or ammonium compounds will not cause cracking or weakening of the screw member.

4.1.9 Pull Test

The purpose of this test is to establish that there is no hidden damage or weakness as a result of the stress corrosion test.

4.1.10 AC Fault Test

This requirement helps to ensure that there is no arcing between the bonding clamp or grounding systems hardware and the connected conductive element. Although, there were no failures one observation indicates melting of the jacket material under the bonding clamp. When tested using the No.4 AWG conductor and No.6 AWG solid conductors specified in the requirements, the bonding clamps met the requirement. Typically after approximately 19 seconds the No.6 solid copper conductor fuses open (as expected).

As part of this analysis many additional samples were prepared and tested. Included were samples of type ASP cable. ASP cable consists of a corrugated aluminum shield, a corrugated steel shield, and an outer polyethylene jacket. A flooding compound is applied over and under the aluminum shield to resist water entry and inhibit corrosion. We observed that these samples, which were subjected to the entire environmental exposure cycle, performed better in the AC fault test by exhibiting slightly less thermal (joule) heating during the test. We conclude that although TR-NWT-001001 specifies an aluminum shield and aircore (such as ALPETH) cable, the bonding clamps are suitable for use with the more typical pic-waterproof (jelly-filled), multi-shield cable used for direct burial.

4.1.11 Lightning Surge Test

This requirement determines that the bonding and grounding systems hardware will not deteriorate or arc when carrying the 20,000 Ampere surge current of the lightning surge test.

4.1.12 Use and Reuse

This requirement helps to ensure that a bond clamp can withstand frequent removal and replacement of the retaining nut that secures the bond strap. This requirement has become very important due to the increased frequency of cable locating operations (which often require removal and replacement of the bonding strap).

Bellcore developed "**Use and Reuse**" criteria to address issues related to the recognition that the cable bonding strap must be frequently assembled and disassembled to facilitate cable locating procedures. This criteria is not part of a Bellcore TR, but will be added to the Issues List for future updates of TR-NWT-001001.

4.1.13 Torque Test

This requirement ensure that the threaded fasteners are capable of withstanding tightening to 50 inch-pounds. To be valid, this test must occur after the environmental exposure test sequence. Testing after the environmental exposure sequence reveals components that have loosened or weakened due to corrosion, vibration, joule heating, etc.

At the request of A K Stamping Company, Inc., the sample population that was subject to the TR-NWT-001001 environmental exposure test sequence, was assembled using two types of assembly procedure. The first (Method One, section 3.1 of this AU) is the manufacturer's recommended assembly method. The second (Method Two, section 3.1 of this AU) is a 'short cut' method that does not require the use of a torque wrench.

Although there were no nonconformance, it was noted that the bond strap on some of the samples that had been tightened with a 216-type tool, became loose after the samples were exposed to 30 days of Temperature Cycling with Humidity and 30 days of Salt Fog Exposure. Bond straps on samples that were assembled according to the manufacturer's procedure were not loose. We also noted that contact resistance following the Salt Fog Exposure was higher for the samples assembled using just the 216-type tool.

Some users of this type of product, do not use a flat washer under the bond strap when assembling the clamp. Although we think that the manufacturers recommendation is valid; we do not think it would alter the outcome of this analysis if the flat washer was not used. Note, that the samples that were assembled using Method Two, met the test criteria.

At the request of A K Stamping Company, Inc. the failure point of the clamp stud and nut was determined for the seven types of clamps that were submitted for testing. In addition, to determine if the threaded stud rotates due to poor attachment of the stud within the bottom plate, the end of the stud was always scribed to provide an indicator.The following table shows that the all types of clamp met the generic requirement. The manufacturer's assembly instructions recommend that the clamp be assembled with 40 inch-pounds of torque.

Sample #	Clamp Model	50 inch-lbs	60 inch-lbs	70 inch-lbs	80 inch-lbs	90 inch-lbs	100 inch-lbs
K1	B Bond -1	Met	Stripped	Met	Met	Stripped	Stripped
K2	D Bond -2	Met	Met	Met	Nut Stripped	Stripped	Stripped
K3	B Bond -3	Met	Stripped	Stud Sheared	Stud Sheared	Stripped	Stripped
K4	Mini Gator	Met	Met	Met	Met	Met	Stripped

Sample #	Clamp Model	50 inch-lbs	60 inch-lbs	70 inch-lbs	80 inch-lbs	90 inch-lbs	100 inch-lbs
K5	Mini B1	Met	Met	Met	Stripped	Stripped	Stripped
K6	Gator	Met	Met	Met	Stud Sheared	Stud Sheared	Stud Sheared
K7	B Bond -2	Met	Met	Stud Sheared	Stud Sheared	Stud Sheared	Stud Sheared

At the request of A. K. Stamping Company,Inc. a comparison was made between different types of mounting methods and cable to determine if this influenced the strength of the nut or threaded stud. The following table summarizes the finding.

Sample #	Clamp Model	Clamp Not Attached to Cable	Clamp Attached to ALPETH (aircore)	Clamp Attached to Filled Cable (lubricated)
M1	B Bond 1/2	Met	Met	Met
M2	D Bond 2/2	Met	Met	Met
M3	Gator	Met	Met	Met
M4	B Bond 2/2	Met	Met	Met
M5	B Bond 3/2	Met	Met	Met
M6	Mini Gator (2)	Met	Met	Met
M7	Mini B Bond (2)	Met	Met	Not Met

Each sample was tightening five times to 50 inch-pounds. The column heading 'Clamp Not Attached to Cable' indicates the clamp body was held in a vise. The ALPETH cable is the type required in section 3.4 of TR-NWT-001001.

The Filled Cable was waterproof cable, which is flooded with polyethylene-petrolatum jelly. The jelly acts as an effective lubricant and the threads of the threaded stud were purposefully coated with it. The decreased friction between the nut and stud causes additional axial tension to be applied to the stud. One stud sheared due to this additional stress. The manufacturer recommends an assembly torque of 30 inch-pounds for clamps used with filled cables. This provides a safe margin.

4.2 Supplier Comments

We are pleased to share with you the test results of A. K. Stamping's cable shield bonding clamps based on Bellcore's technical reference TR-NWT-001001, *Generic Requirements for Cable Shield Bonding Clamps*. This analysis, performed by Bellcore, attests to the outstanding performance of our products beyond the generic requirements for cable shield bonding clamps. The results also indicate compliance with the recently introduced field simulation of cable bonding clamp "Use And Reuse". Our product is the only one offered to the telecommunications industry which has undergone this test and passed all other requirements. We further added a low-level vibration test, which simulates pedestal vibration in areas near heavy equipment such as railroad and or truck traffic (see section 4.1.4).

A.K. Stamping uses for all components a copper based alloy that is resistant to stress corrosion cracking as well as any other forms of corrosion such as galvanic corrosion due to dissimilar metals. This alloy also provides maximum electrical fault current carrying capability.

Following our recommended installation procedure our cable shield bonding clamps will outperform any other products offered for the same application.