Raychem
Energy Division

Report

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GCA QUALIFICATION REPORT	14
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Tested by: John Bramfitt	[signature]	20 May 86
Prepared by: Jeffry P. Mackevich	JP Mackevich	20 May 86
Approved by: Jeffry P. Mackevich for Product Management	JP Mackevich	20 May 86
Approved by: Frank J. Fitzgerald for Technical Operations	Frank Fitzgerald	20 May 86

Raychem Corporation
Energy Division

I. OBJECTIVE

To demonstrate the functional performance of Raychem's type GCA Ground Clamp Assembly when applied to copper tape shielded cables subjected to thermal cycling, shield short-circuit and tensile testing.

II. SUMMARY

High Voltage terminations and splice combinations with installed GCA kits were performance tested for this evaluation.

Testing was conducted to evaluate tensile pull-out, thermal deformation and contact resistance initially and after thermal cycling and shield short-circuit testing.

All test samples passed specific design criteria.

III. CONCLUSION

By passing these design tests to prove functional performance, it is concluded that the GCA kit is suitable for use as an accessory shield grounding attachment for copper tape shielded cables.

IV. SAMPLES

A detailed description of cable types selected for this qualification appears in Appendix I.

V. TESTING

The following tests were performed to qualify the GCA kit: tensile strength, thermal deformation and thermal cycling and short-circuit testing. Each specified test used samples independent of the other tests.

A. Tensile Strength

The ability of a mechanical device to secure a tinned copper braid in contact with the cable shield and resist reasonable pull-out forces without shield damage is an important consideration.

To evaluate the mechanical strength of the tinned copper braid and clamp assembly in combination, a series of pull-out tests were conducted. One series of tests evaluated the pull-out strength of the GCA kit on a prepared cable. The second series of tests evaluated the pull-out strength of the GCA kit in conjunction with a properly installed termination. The exterior nontracking heat shrinkable tube and high temperature sealant increased the pull-out resistance of the braid attachment assembly.

Copper tape shielded cables were prepared using the standard installation procedures for the GCA kit. A tensile testing apparatus utilizing a constant 0.5 inch per minute separation rate was used to evaluate the strength of the mechanical attachment. Soldered connections were used for comparative data. (Results appear in Table 1.)

B. <u>Thermal Deformation</u>

Indentations or constriction of the cable shielding layer during thermal cycling can create serious deformation of the extruded conductive layer, adversely affecting the in-service electrical performance of the cable.

Soldering and the localized heat associated with this attachment method can create indentations that can prematurely affect the service life of cables.

The GCA kit maintains a constant securing force against the grounding braid to maintain electrical contact. The system design allows for expansion and contraction during thermal cycling, and therefore does not create a mechanical constriction that may cause localized deformation of the cable shielding and insulation system.

A total of twelve test samples were prepared to evaluate deformation effects of the GCA system and conventional soldering techniques on terminated shielded cables that were thermally cycled for 21 cycles at 90°C. A cycle profile was 8.0 hours on/4.0 hours off. At the conclusion of the test one-half of the samples were removed for evaluation. The remainder of the test set was subjected to one cycle of 36 continuous hours at 130°C.

All samples were carefully disassembled in order to take measurements to evaluate deformation. Indentations into the extruded conductive area were taken directly at the attachment contact area under the copper tape shield. The cable jacket was also removed to visually inspect the shield area of the remaining cable.

The sample set subjected to the additional 36 hours at 130°C visually displayed evidence of the conductive layer extending into the overlapped areas of the copper tape shields where the cable jacket was removed.

Deformation for both temperature considerations did not exceed 5% for the GCA system. Results for the GCA systems and soldered connections appear in Table 2.

C. Thermal Cycling and Short-Circuit Testing

Contact resistance measurements were conducted prior to thermal cycling and at the conclusion of the shield short-circuit testing. Cables with terminations and with terminations and splices utilizing the GCA system were sequentially subjected to thermal cycling followed by shield short-circuit testing.

Thermal cycling for this qualification report was con ducted in accordance with Raychem Energy Division Report PPR 515 entitled, "Master Specification PPS 3013 for Cable Accessories for Power Cables up to 72kV and Flexible Cables up to 36kV," paragraph 4.5.5 entitled, "Load Cycling," Section (a).

Section (a) defines a requirement of 63 electrical heat cycles, each of 8 hours duration. Each cycle shall consist of 5 hours heating up to rated 90°C conductor temperature +5°C (95°C) by passing current through the test sample and 3 hours without current to allow it to cool down to the ambient temperature. This test provides a total cycled exposure of 315 hours (63 cycles) at 95°C, and was selected as the test profile that subjected the test specimens to a more severe conditioning than is defined in the AEIC specifications.

For comparative information the 90°C thermal cycle as set forth in AEIC No. 5-75 entitled, "Specification for Polyethylene and Crosslinked Polyethylene Insulated Shielded Power Cables Rated 5 Through 69kV" (5th Edition), and AEIC No. 6-75 entitled, "Specification for Ethylene Propylene Rubber Insulated Shielded Power Cables Rated 5 Through 69kV (2nd Edition)," require a total of 168 hours (21 cycles) exposure 90°C.

The shield short-circuit tests were conducted in accordance with Raychem's Master Specification PPS 3013 for Cable Accessories, paragraph 4.5.6(b) entitled, "Thermal Short Circuit, Earth Fault."

Section (b) defines the test sample shall in each cable be subjected to two 1-second short-circuit currents to attain the specified temperature. The samples shall be allowed to cool between tests. Section (b) further states that the shield temperature shall be in accordance with the appropriate cable specification. Specifications AEIC No. 5-75 and AEIC No. 6-75 were selected for this section.

These specifications state that the maximum short circuit operating temperature of the conductor is 250°C for crosslinked polyethylene and ethylene propylene rubber insulated cables.

Fourteen (14) cable samples representing four different diameters that provided the extremes in application usage were prepared for this test sequence.

The cable shield cross-sectional area was calculated to establish the necessary ampacity for each 1-second (60 Hz) exposure.

Photographs of each test set appear in Appendix II. Test data results appear in Table 3.

TABLE 1

TENSILE STRENGTH TESTING (POUNDS TO YIELD)

SAMPLE IDENTIFICATION	SHIELD DIAMETER	TERMINATION YES/NO	BRAID AWG	POUNDS	ATTACHMENT METHOD GCA/SOLDER*
A	0.75	No	8	80	GCA
B	0.75	No	8	85	GCA
C	0.75	No	8	80	GCA
D	0.75	Yes	8	>200	GCA
E	0.75	Yes	8	>200	GCA
F	0.75	Yes	8	>200	GCA
G	0.75	No	8	55	Solder
H	0.75	No	8	65	Solder
I	0.75	No	8	60	Solder
J	0.75	Yes	8	140	Solder
K	0.75	Yes	8	145	Solder
L	0.75	Yes	8	130	Solder
M	1.80	No	4	110	GCA
N	1.80	No	4	120	GCA
O	1.80	No	4	110	GCA
P	1.80	Yes	4	>200	GCA
Q	1.80	Yes	4	>200	GCA
R	1.80	Yes	4	>200	GCA
S	1.80	No	4	70	Solder
T	1.80	No	4	80	Solder
U	1.80	No	4	75	Solder
V	1.80	Yes	4	175	Solder
W	1.80	Yes	4	160	Solder
X	1.80	Yes	4	170	Solder

*Solder connections without terminations damaged the shield by deformation and tearing.

TABLE 2

DEFORMATION

SAMPLE NUMBER	CABLE CLASS	INSULATION (MILS)	CONDUCTOR (AWG/MCM)	BRAID AWG	SEMICONDUCTOR LAYER THICKNESS (MILS)	ATTACHMENT METHOD	THERMAL CYCLE (°C)	DEFORMATION (MILS)	DEFORMATION (%)
11a	15 kV	220	#2	8	45	Soldered	90	3.8	8.4
33a	15 kV	220	#2	8	45	GCA	90	1.9	4.2
44a	15 kV	220	#2	8	45	GCA	90	1.7	3.8
55a	22 kV	295	350	4	65	Soldered	90	6.8	10.5
77a	22 kV	295	350	4	65	GCA	90	2.6	4.0
88a	22 kV	295	350	4	65	GCA	90	2.8	4.3
11b	15 kV	220	#2	8	45	Soldered	130	4.9	10.9
33b	15 kV	220	#2	8	45	GCA	130	2.1	4.7
44b	15 kV	220	#2	8	45	GCA	130	1.9	4.2
55b	22 kV	295	350	4	65	Soldered	130	8.4	12.9
77b	22 kV	295	350	4	65	GCA	130	2.7	4.2
88b	22 kV	295	350	4	65	GCA	130	2.9	4.5

TABLE 3

THERMAL CYCLING/SHORT CIRCUIT TESTING
CONTACT RESISTANCE (MICRO-OHMS)

SET NO.	SAMPLE NO.	SHIELD DIAMETER (INCHES)	BRAID (AWG)	AMPS.	CONTACT RESISTANCE* INITIAL µ	CONTACT RESISTANCE* AFTER SHORT CIRCUIT µ	SPLICE
1	1	0.59	8	1300	17.0	16.8	No
1	2	0.59	8	1300	17.0	16.1	No
1	3	0.59	8	1300	14.0	12.3	Yes
1	4	0.59	8	1300	14.0	12.8	Yes
2	5	1.00	8	720	7.0	8.6	No
2	6	1.00	8	720	7.0	7.5	No
2	7	1.00	8	720	7.2	8.9	Yes
2	8	1.00	8	720	7.2	8.5	Yes
3	9	1.33	4	1400	17.0	10.4	No
3	10	1.33	4	1400	17.5	7.2	No
4	11	1.59	4	1900	4.8	6.1	No
4	12	1.59	4	1900	5.2	6.7	No
4	13	1.59	4	1900	5.1	7.3	Yes
4	14	1.59	4	1900	5.2	8.8	Yes

*Contact Resistance for soldered connections was within the range of 4-12 micro-ohms.

APPENDIX I

CABLE TYPES

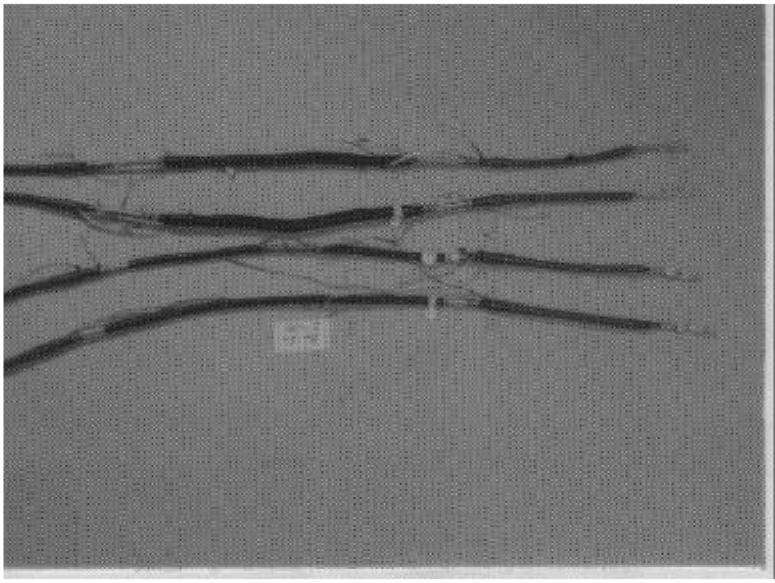
A. Deformation Test

- #2 AWG Copper tape shielded, extruded conductive layer, 15kV 220 mil XLPE insulation (0.85 inch shield diameter)
- 350 MCM Copper tape shielded, extruded conductive layer, 22kV 295 mil XLPE insulation (1.42 inch shield diameter)

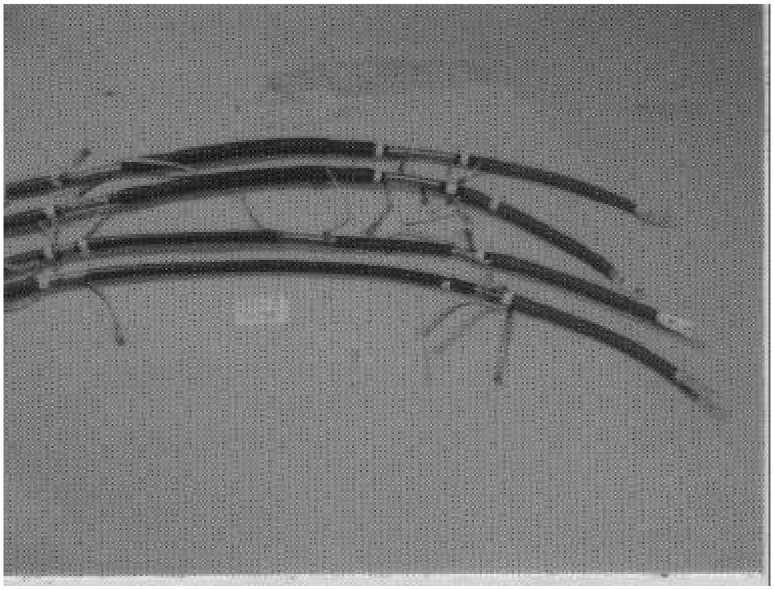
B. Thermal Cycling and Short-Circuit Testing

- #1 AWG Copper tape shielded, tape wrapped conductive layer, 8kV 195 mil XLPE insulation (0.59 inch shield diameter)
- 400 MCM Copper tape shielded, extruded conductive layer, 8kV 115 mil XLPE insulation (1.00 inch shield diameter)
- 500 MCM Copper tape shielded, extruded conductive layer, 15kV 175 mil XLPE insulation (1.33 inch shield diameter)
- 1000 MCM Copper tape shielded extruded conductive layer, 15kV 175 mil EPR insulation (1.59 inch shield diameter)

APPENDIX ii

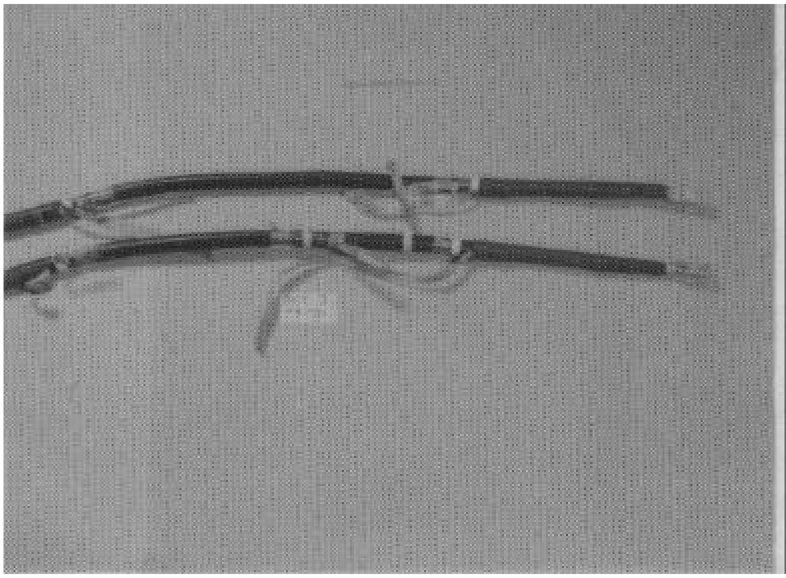


Set 1
Samples 1-4

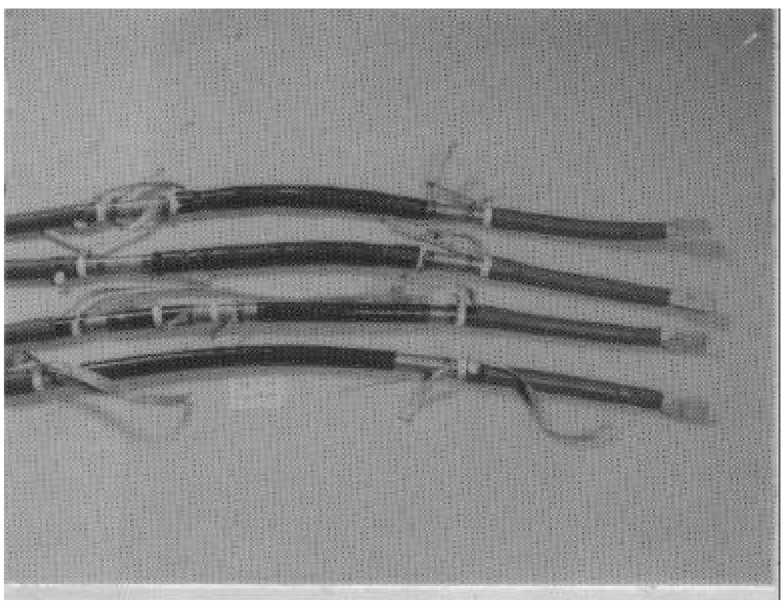


Set 2
Samples 5-8

APPENDIX ii



Set 3
Samples 9, 10



Set 4
Samples 11-14

APPENDIX III

I. BACKGROUND

The portion of this test report written on October 13, 1980 sought to verify GCA performance under a wide variety of application conditions. Users of the GCA accessory have requested additional data regarding the fault current capabilities of the product. This Appendix addresses this topic.

II. SYSTEM SHORT-CIRCUIT CAPABILITY DISCUSSION

ICEA Publication P-45-482, 1979 "Short-Circuit Performance of Metallic Shields and Sheaths of Insulated Cable (2nd Edition)" provides formulas to determine maximum allowable short-circuit current as a function of initial pre-load and fault duration.

Cable system permissible short-circuit is based upon cable construction and permissible shield temperature (350°C for a cross-linked insulation shield and cross-linked jacket or 200°C for a thermoplastic jacket which may not be equal to available short-circuit current levels or overall system design parameters, for example, all components rated 10 ka rms symmetric for 10 cycles withstand).

III. TEST SAMPLES

Four 4-foot pieces of 15kV Pirelli 750 kcmil aluminum XLPE insulated 5-mil copper tape shield cable, 25 percent overlap, PVC jacketed power cable were prepared. Raychem GCA accessories, constant force spring clamp and No. 4 AWG equivalent ground braid were secured, making eight (8) GCA samples.

IV. COMPONENT CAPABILITIES

Calculations based upon ICEA P-45-482 showed the following possibilities for the described cable for 6000A and 4000A.

Shield Pre-load (°C)	Max Shield Temp (°C)	6kA Allowable Duration (cycles)	4kA Allowable Duration (cycles)
20	200	6.8	105.5
65	200	4.8	10.8
85	200	3.9	8.9

Calculations for the GCA ground braid show higher allowable time durations to reach the same maximum shield temperature. This is due to the larger equivalent cross section of the ground braid conductor. Short-circuit testing will verify the adequacy of the contact between braid and tape shield using the constant tension spring clamp. Note that if the cable described in Section III had a 50 percent overlap, a worst case condition, its 4 kA allowable 200°C fault duration would be 23.2 cycles for 20°C preload, 16.2 cycles for 65°C and 13.4 cycles for 85°C shield preload.

V. TESTING

Tests were conducted at British Columbia Hydro's Research Station in Vancouver, Canada. Various times and fault levels were applied, and the results are tabulated below:

Test No.	Sample No.	Test Set Time (Hz)	Actual Run Time (Hz)	I_{max} (kA rms)	Comments
1	1	20	20	4.24	Pass
2	1	40	40	4.24	Pass
3	2	40	28	4.95	Copper tape failed
4	3	40	9	4.24	Copper tape failed
5	4	30	30	4.24	Pass
6	4	40	40	4.24	Pass

The oscilligram for Test 6 is attached. Note that except for Test 4, cable shield capacity was exceeded in all tests (15.5 cycles at 4kA for initial ambient temperature).

VII. FAILURE DISCUSSION

Test 3 on Sample 2 experienced failure in the tape shield next to jacket cutback some 1/2 inch to 3/4 inch away from the GCA at 28 cycles. This is 29-percent longer than P-45-482 permits.

Test 4 on Sample 4 failed at 9 cycles. Examination of the cable showed obvious tape shield corrosion, resulting in overheating due to increased contact resistance from tape shield layer to layer.

VIII. CONCLUSION

The GCA assembly is suitable for grounding metallic tape shields and can withstand fault currents equal to that allowed for cable metallic tape shield system.