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KINECTRICS NORTH AMERICA INC. TEST REPORT FOR 3M TO DETERMINE THE SHEAVE CRITERIA FOR 774 KCMIL 3M™ COMPOSITE CONDUCTOR

Kinectrics North America Inc. Report No.: K-422132-RC-0006-R00

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INTRODUCTION

3M contracted with Kinectrics under PO # 1600000 to conduct a series of investigative tests on their 774 kcmil Aluminum Conductor Composite Reinforced (ACCR) Conductor. These tests are part of a larger series of tests to demonstrate the viability of ACCR conductors for use on overhead electric power transmission lines. 3M owns all data and copyright to this information.

The tests were performed from May 9 to October 11, 2005 by Kinectrics North America Inc. personnel at 800 Kipling Avenue, Toronto, Ontario, M8Z 6C4, Canada.

SUMMARY

Under conditions of combined tension and bending of the ACCR conductor, it is possible to overstress the conductor. These tests probe the relations between sheave diameter, tension and break-over angle (that may occur for example during field installation) to determine the correct combinations that should be used with the ACCR conductor.

The 36 inch root diameter sheave showed smaller break-over angles can support higher tensions for double-pass tests. Specifically, at 45° per sheave and 5% RTS, at 33° per sheave and 7.5% RTS, and at 25° per sheave and 15% RTS, the conductor behaves well.

The 7x7 inch roller array sheave showed smaller break-over angles can support higher tensions for double-pass tests. Specifically, at 60° per sheave and 10% RTS, and 33° per sheave and 15% RTS, the conductor behaves well.

The 774 kcmil ACCR conductor successfully completed 20 passes over the 7x7 inch roller array at the two selected break-over angles and tensions combinations of 33 degrees/15.0% RTS, and 60 degrees/10.6% RTS.

TEST OBJECTIVE AND STANDARD

The objective of the tests were to determine, in an indoor laboratory, the threshold combination(s) of sheave size(s), conductor angle(s) over sheave, and conductor tension(s) that cause breakage of the core wires on 774 kcmil 3M™ Composite Conductor during double-pass and multi-pass sheave tests.

The set-ups and procedures for the tests were based on the IEEE Std 1138-1994, "IEEE Standard Construction of Composite Fiber Optic Overhead Ground Wire (OPGW) for Use on Electric Utility Power Lines", Paragraph 4.1.1.6.

TEST CONDUCTOR

The ACCR 774-T53, 46/37 conductor is manufactured by 3M and is constructed of 46 aluminum alloy wires in 2 layers surrounding the core wires. The aluminum alloy wires contain a small quantity of zirconium for heat–resistance (resistance to annealing). The 37 core wires of the ACCR are made from a fiber-reinforced metal matrix composite material. The conductor diameter is 1.254 inches (31.852 mm). The RTS (Rated Tensile Strength) of the conductor is 71,010 lbf.

A data sheet on the ACCR conductor used in the sheave tests is contained in Appendix A.

PURPOSE OF TESTS

The ACCR conductor contains a core that exhibits no plasticity unlike traditional metals and alloys. Its stress-strain behaviour is linear-elastic to the failure stress. Thus there exists a bending radius at which the failure stress is reached. Furthermore combinations of axial tension and bending loads can lead to an overstressed condition. The purpose of the testing is to understand the interactions of tension, angle, and sheave size, and to understand which combinations do not overstress the conductor. Understanding the angle per sheave that may be tolerated is useful in designing and selecting the correct sheave size (or multi-sheave configuration) for conductor installation. This particular construction of 774 ACCR contains a very high core fraction and is especially stiff and requires extra attention be paid to it's bending characteristics.

Two separate tests were performed : a double-pass test and a multi-pass test.

The double-pass tests were performed on a 36 inch root diameter sheave and a 7x7 inch roller array sheave. The tests were performed to determine the threshold combination of tension and conductor angle over sheave that could be used for the multi-pass tests. The conditions that produced no broken core wires were used for the multi-pass tests.

The multi-pass tests were performed on the 7x7 inch roller array sheave only. The tests were performed to determine the threshold combination of tension and conductor angle over sheave that could be used during installation in the field.

TEST SET-UP

Double-Pass and Multi-Pass Tests

A schematic of the set-up for the Double and Multi-Pass Sheave Tests is shown in Figure 1a. Typical photos of the set-up for the 36 inch sheave are shown in Figures 1b and 1c. Typical photos of the set-up for the 7x7 inch Roller Array sheave are shown in Figures 1d, and 1e.

The Roller Array consists of 7 small sheaves each 7 inches in diameter with a 1 inch bottom groove radius. They are arrayed along an arc that sweeps a 60° angle and maintains a 60 inch radius. The Roller Array was built and supplied by Sherman & Reilly Inc. of Chattanooga, TN.

Test Apparatus

Double-Pass and Multi-Pass Tests

The test conductor was strung over the sheave assembly and tensioned using pulling grips and/or dead-end grips. Both ends were attached to a motor driven, chain link loop system. The conductor was passed back and forth over the sheave at a speed of about 0.515 ft/sec (0.157 m/sec). The sheave was fixed at the appropriate height to produce the desired “break over angle” over the sheave. A hydraulic piston was used to tension the conductor. A load cell was used to measure the conductor tension.

The test was carried out in a temperature-controlled laboratory at 21ºC ± 2ºC.

Instrumentation and Data Acquisition

The load cell was monitored on a data acquisition system. The unaided ear was used to listen for possible breaking core wires. A digital inclinometer was used to measure the break-over angle.

The measuring instruments used in this test are listed in Appendix B.

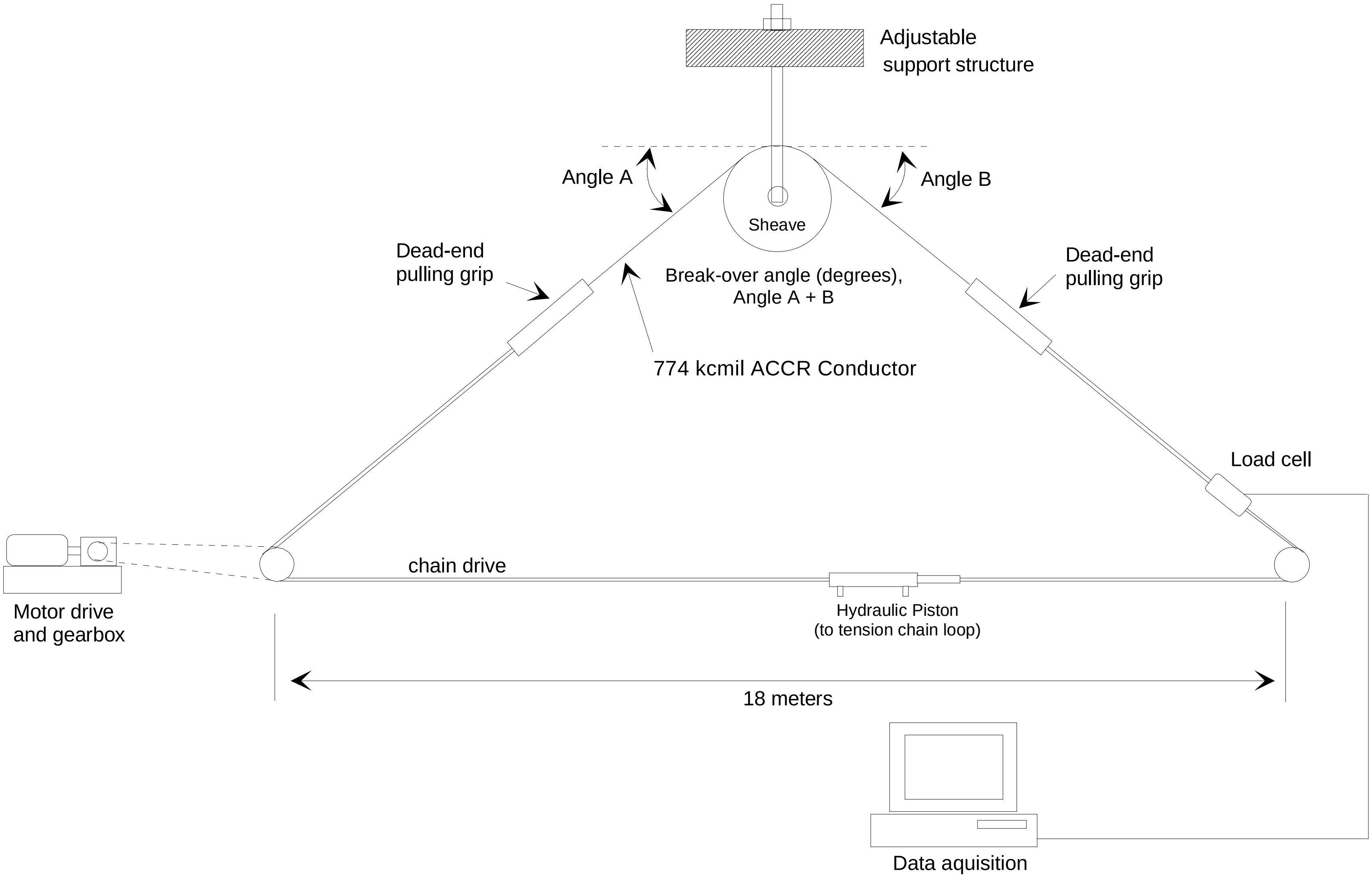

Figure 1a   Set-up for Double and Multi-Pass Sheave Tests (Schematic)

Figure 1b   Typical Set-up for 36” Sheave Test

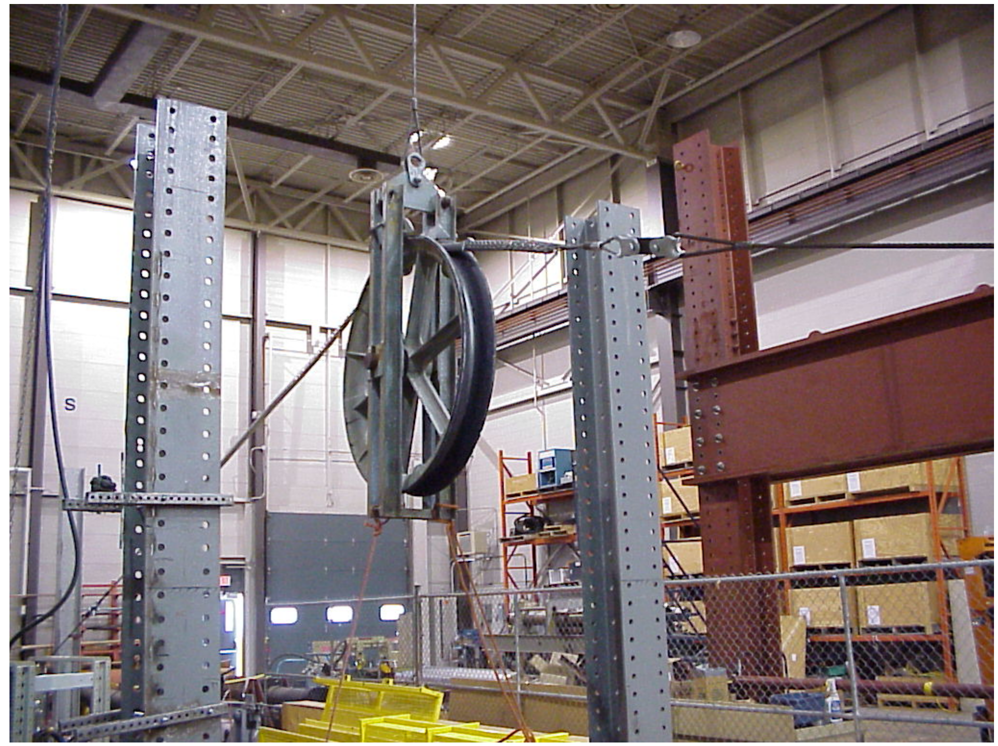

Figure 1c   Typical Set-up for 36” Sheave Test

Figure 1d Typical Set-up for 7x7" Roller Array Sheave Test (60 degree break-over angle shown in photo)

Figure 1e Typical Set-up for 7x7" Roller Array Sheave Test

TEST PROCEDURE

Double-Pass Test - 36 Inch Root Diameter Sheave

A 13 ft (4 m) length of test conductor was setup in the test apparatus. The test parameters were:

Sheave diameter:	36 inch root diameter
Break-over Angle:	45°, 33°, and 25°
Tension:	2.5, 5.0, 7.5, 10.0, 12.5, 15% of conductor RTS (71,010 lbf, 32,210 kgf)

The test sequence was based on the most to least severe condition for break-over angle. The starting tension was 2.5% of RTS (71,010 lbf, 32,210 kgf). A double pass of the conductor over the sheave was completed. A double pass is defined as two forward and backward movements of the conductor. The portion of conductor that actually passed over the sheave was about 6.5 feet (2 meters).

During the pass if there was no audible indication of broken core wires, then the tension was increased by 2.5%, and the test repeated. If there was an audible indication of broken core wires, the conductor was dissected and the core wires were visually examined over the test section for breaks or damage.

After completion of one test a new sample was installed in the facility, the break-over angle was decreased and the procedure was repeated.

Double-Pass Test - 7x7 Inch Diameter Roller Array Sheave

A 13 ft (4 m) length of test conductor was setup in the test apparatus. The test parameters were:

Sheave diameter:	7x7 inch roller array
Break-over Angle:	60°, 52°, 45°, and 33°
Tension:	2.5, 5.0, 7.5, 10.0, 10.56, 12.05, 12.5, 13.8, 15% of conductor RTS (71,010 lbf, 32,210 kgf)

Sheave Specifications:

Manufacturer:	Sherman and Reilly Inc.
Model:	261-030-03
Size:	60R
Maximum Working Load:	7,500 lbs, 60 degree

The ‘Maximum Working Load’ (7,500 lbs) of the roller array limited the amount of tension that could be applied at the various break-over angles. The following are the tension limits for each break-over angle, based on the calculated total vertical load on the roller array not exceeding 7,500 lbs.

For 33 degree : 15.0 % RTS
For 45 degree : 13.8 % RTS
For 52 degree : 12.05 % RTS
For 60 degree : 10.56 % RTS

The test sequence was based on the most to least severe condition for break-over angle. The starting tension was 2.5% of RTS (71,010 lbf, 32,210 kgf). A double pass of the conductor over the sheave was completed. A double pass is defined as two forward and backward movements of the conductor. The portion of conductor that actually passed over the sheave was about 6.5 feet (2 meters).

During the pass if there was no audible indication of broken core wires, then the tension was increased by 2.5%, and the test repeated. If there was an audible indication of broken core wires, the conductor was dissected and the core wires were visually examined over the test section for breaks or damage.

After completion of one test a new sample was installed in the facility, the break-over angle was decreased and the procedure was repeated.

<u>Multi-Pass Test</u> - 7x7 Inch Diameter Roller Array Sheave

A 13 ft (4 m) length of test conductor was setup in the test facility. Based on the results from the double pass tests, the test parameters were:

Sheave diameter:	7x7 inch roller array
Break-over Angle:	60° and 33°
Tension:	10.56% and 15% of conductor RTS (71,010 lbf, 32,210 kgf)

The portion of conductor that passed over the sheave was about 6.5 ft (2 m) in length.
The multi-pass test consisted of 20 passes of the conductor over the sheave.
The tested conductor was dissected after each test and the individual wires were visually examined over the test section for breaks or damage.

TEST RESULTS

Double-Pass Test - 36 Inch Root Diameter Sheave

The results for the various combinations of break-over angles and tensions are summarized in Table 1. Figure 2 shows a graph plotting break-over angle versus tension. This provides a double-pass threshold curve for the 36 inch sheave. The curve is based on the test results from Table 1 that had no broken wires after a double-pass.

Table 1 Double-Pass Test Results for 36 Inch Root Diameter Sheave (May 9-18, 2005)

Conductor Tension (% of RTS)	Break-over Angle		
	25 degree	33 degree	45 degree
2.5	No broken wires	No broken wires	No broken wires
5.0	No broken wires	No broken wires	No broken wires
7.5	No broken wires	No broken wires	One Broken wire on outer layer
10.0	No broken wires	One Broken wire on outer layer	-
12.5	No broken wires	-	-
15.0	No broken wires	-	-

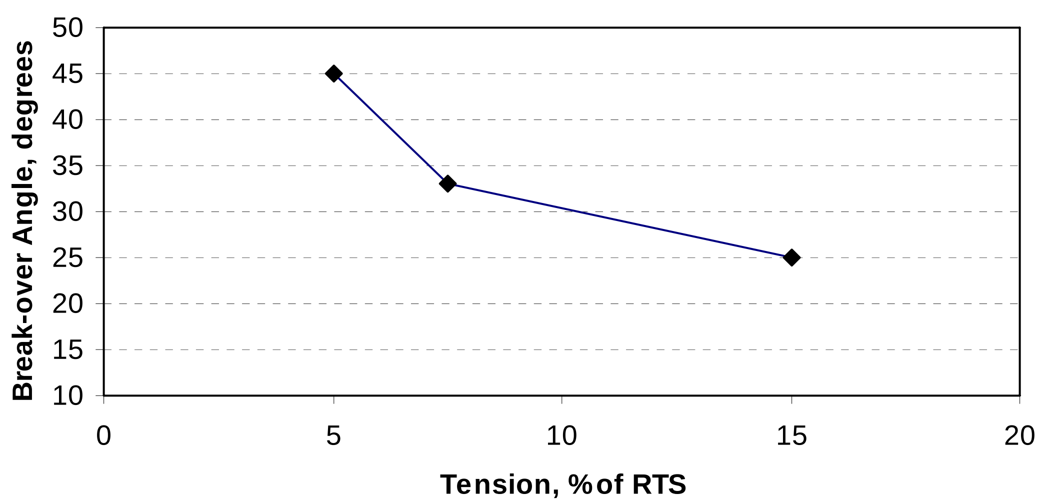

Figure 2 Threshold Curves for the 36 Inch Root Diameter Sheave Double Pass Test, May 9-18, 2005
(Results from Table 1 – based on a double pass with no broken core wires)

Double-Pass Test – 7x7 Inch Roller Array Sheave

The results for the various combinations of break-over angles and tensions are summarized in Table 2. Figure 3 shows a graph plotting break-over angle versus tension. This provides a double-pass threshold curve for the 7x7 inch roller array sheave. The curve is based on the test results from Table 2 that had no broken wires after a double-pass.

Table 2 Double-Pass Test Results for 7x7 Inch Roller Array Sheave (July 5-15, 2005)

Conductor Tension (% of RTS)	Break-over Angle			
	33 degree	**45 degree**	**52 degree**	**60 degree**
2.5	No broken wires	No broken wires	No broken wires	No broken wires
5.0	No broken wires	No broken wires	No broken wires	No broken wires
7.5	No broken wires	No broken wires	No broken wires	No broken wires
10.0	No broken wires	No broken wires	No broken wires	No broken wires
10.56	N/A	N/A	N/A	No broken wires
12.05	N/A	N/A	No broken wires	N/A
12.5	No broken wires	No broken wires	N/A	N/A
13.8	N/A	No broken wires	N/A	N/A
15.0	No broken wires	N/A	N/A	N/A

N/A – not part of the tension test parameters.

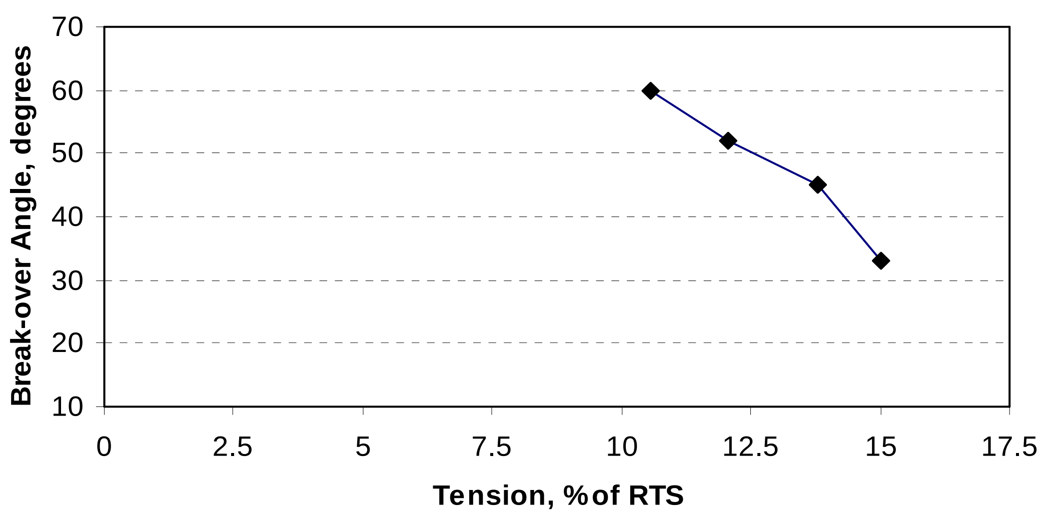

Figure 3 Threshold Curves for the 7x7 Inch Roller Array Sheave Double Pass Test, July 5-15, 2005
(Results from Table 2 – based on a double pass with no broken core wires)

Multi-Pass Test – 7x7 Inch Roller Array Sheave

Two test conditions were chosen for multi-pass testing that produced no broken core wires in double-pass testing.

The results for the two break-over angles and tensions are summarized in Table 3. Figure 4 shows a graph plotting break-over angle versus tension. This provides a multi-pass threshold curve for the 7x7 inch roller array sheave. The curve is based on the test results from Table 3 that had no broken wires after a 20 passes.

Table 3 Multi-Pass Test Results for 7x7 Inch Roller Array Sheave (October 6 & 11, 2005)

Conductor Tension (% of RTS)	Break-over Angle	
	33 degree	60 degree
10.56	N/A	No broken wires after 20 passes.
15.0	No broken wires after 20 passes.	N/A

N/A – not part of the tension test parameters.

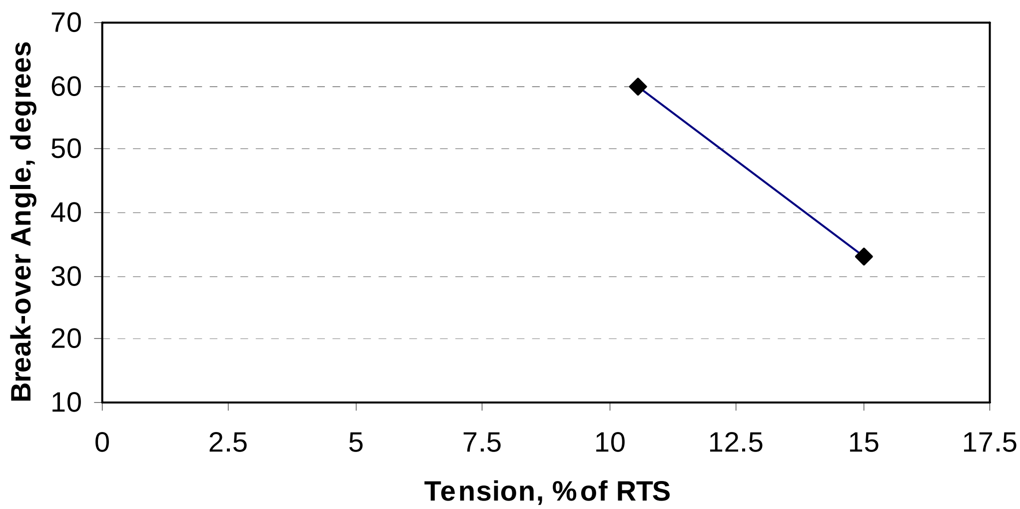

Figure 4 Threshold Curves for the 7x7 Inch Roller Array Sheave Multi Pass Test, October 6 & 11, 2005
(Results from Table 3 – based on a 20 passes with no broken core wires)

Dissection Observations – 36 Inch Sheave

Double-Pass Test - 36 inch Sheave, 45 degree angle, 7.5% RTS tension

Aluminum Outer Layer	–	inner surface had fret marks.
Aluminum 2nd Layer	–	outer surface had fret marks.
Aluminum 2nd Layer	–	inner surface had fret marks.
Core Wires	–	no observations made.

Double-Pass Test - 36 inch Sheave, 33 degree angle, 10.0% RTS tension

There were no visual observations made for fretting between the aluminum wires or the composite core wires.

Double-Pass Test - 36 inch Sheave, 25 degree angle, 15% RTS tension

There were no visual observations made for fretting between the aluminum wires or the composite core wires.

Dissection Observations – 7x7 Roller Array Sheave

Double-Pass Test – 7x7 Roller Array Sheave, 60 degree angle, 10.56% RTS tension

1st Layer Aluminum (26)	–	inner surface had fret marks – see photo 1a.
2nd Layer Aluminum (20)	–	outer surface had fret marks – see photo 1b.
2nd Layer Aluminum (20)	–	inner surface had fret marks – see photo 1c.
3rd Layer Core Wires (18)	–	outer surface had fret marks – see photo 1d.
2nd Layer Core Wire (12)	–	outer surface had fret marks – see photo 1e.
1st Layer Core Wire (6)	–	outer surface had fret marks – see photo 1f.
Center Core Wire	–	had fret marks – see photo 1g.

1st Layer Aluminum (26)	–	noticed some fretting between adjacent wires (side to side), see photo 1h.

All fret marks were more noticeable (larger or deeper) on the bottom side of the conductor. i.e. the side in contact with the sheave wheel. Unless otherwise labelled, all the photos taken were the most severe fretting observed, generally on the bottom side of the conductor.

The fret marks on the core wires looked more like indentations or impressions.

The fret marks for the aluminum and the core wires became longer in length for each layer into the conductor (i.e. as the lay-length became longer).

The fret marks for the core wires generally became lighter for each layer into the conductor.

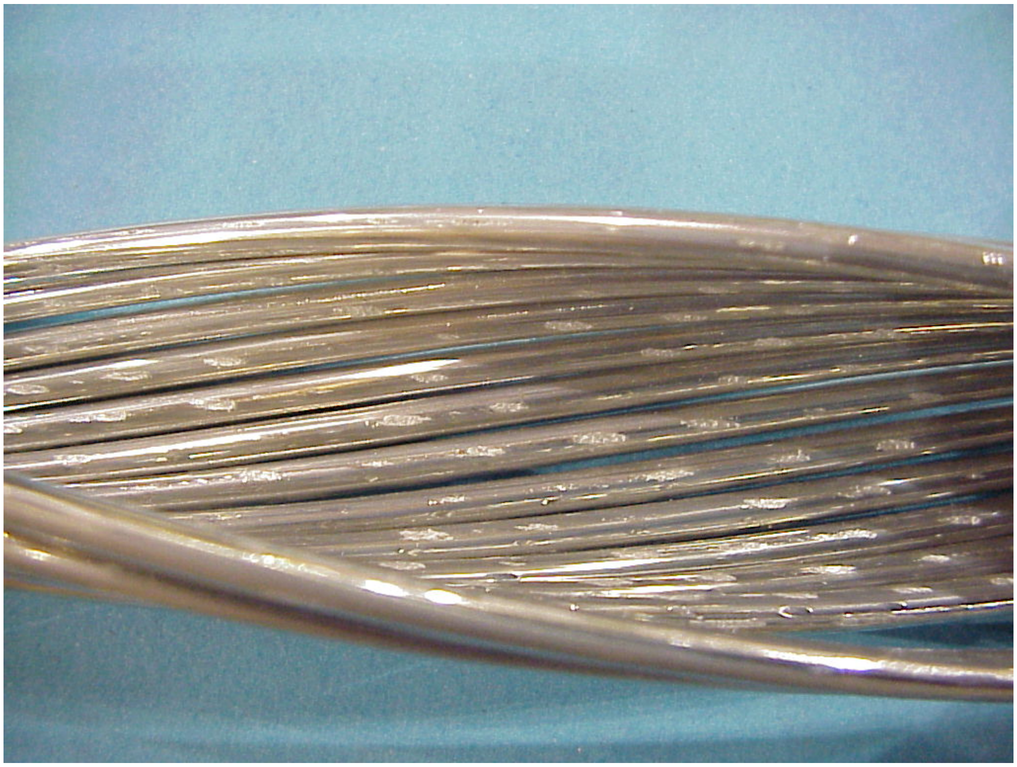

Photo 1a 1st Layer Aluminum – inner surface

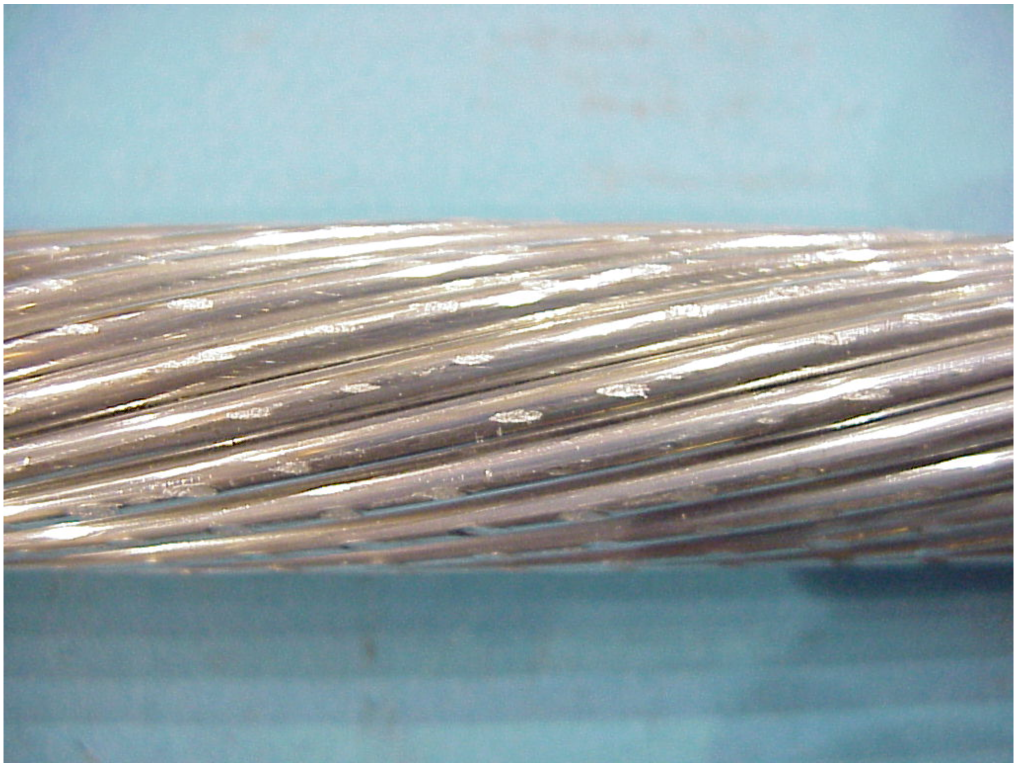

Photo 1b 2nd Layer Aluminum – outer surface

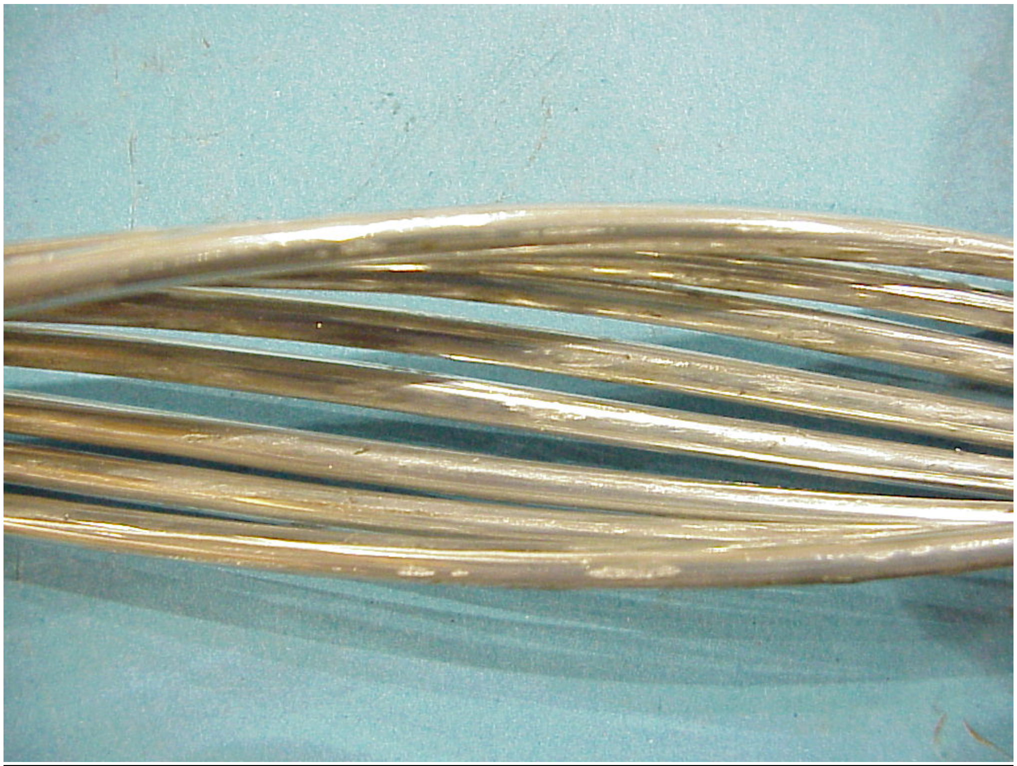

Photo 1c   2nd Layer Aluminum – inner surface

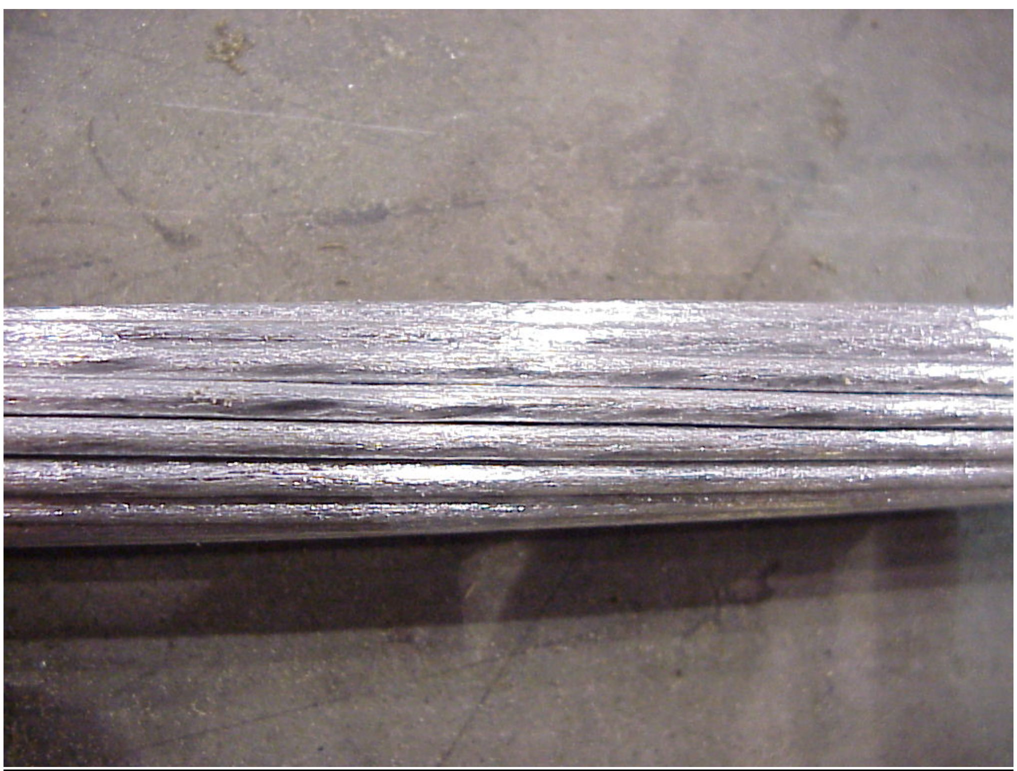

Photo 1d   3rd Layer Core – outer surface

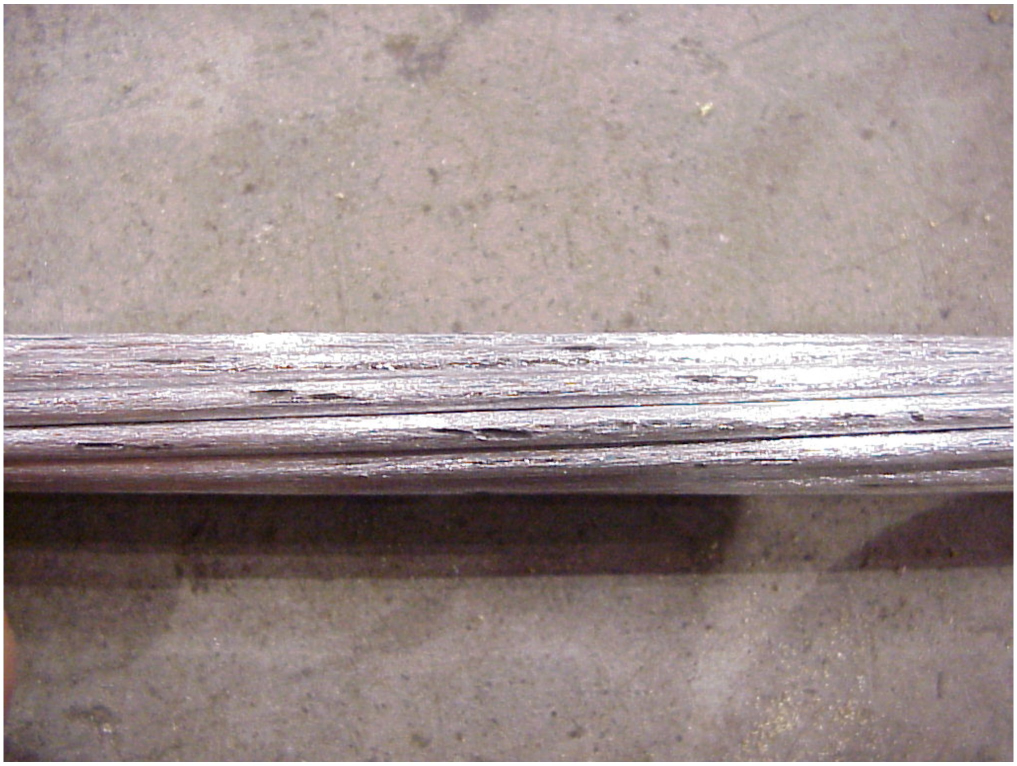

Photo 1e 2nd Layer Core – outer surface

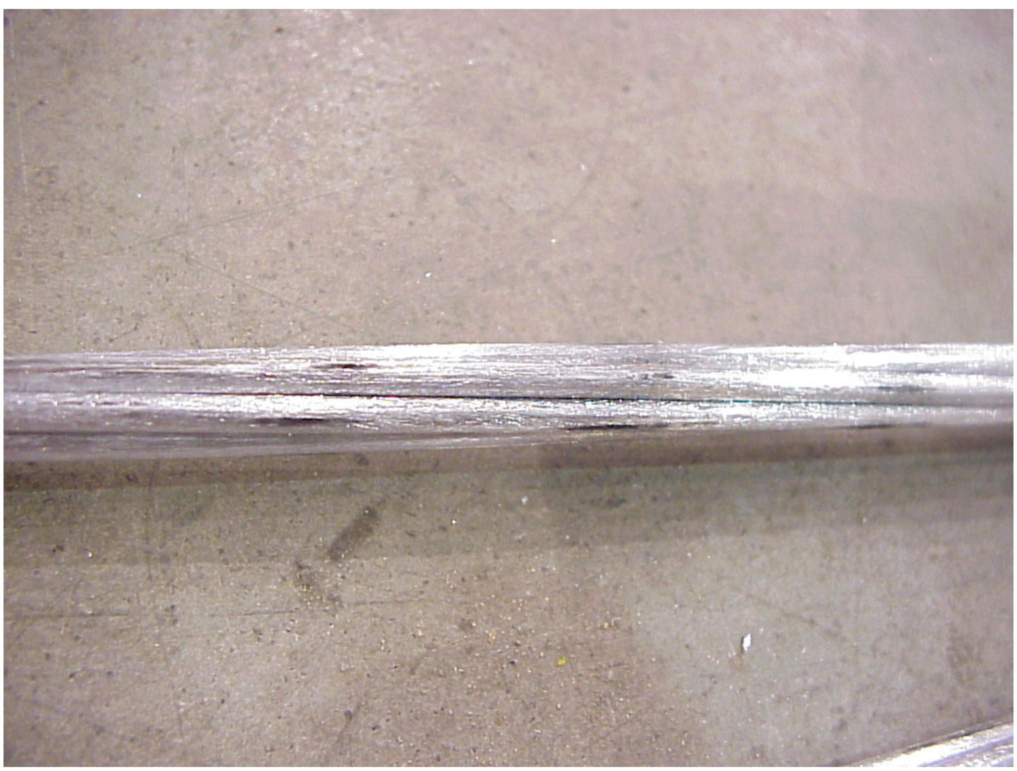

Photo 1f 1st Layer Core – outer surface

Photo 1g Center Core Wire

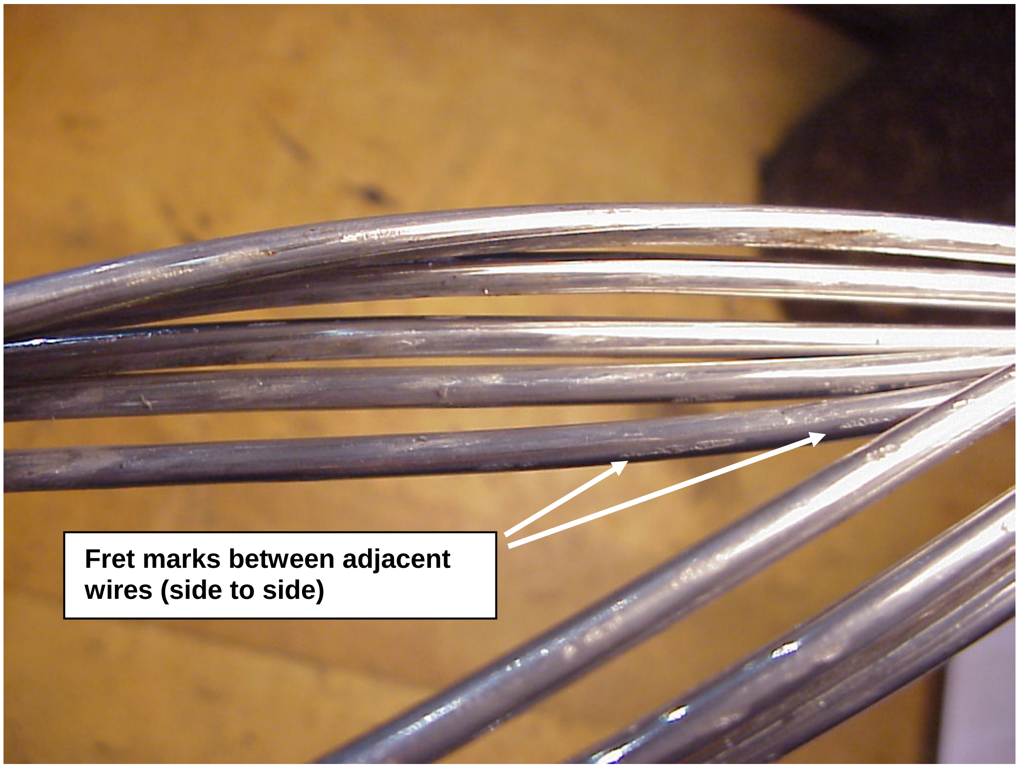

Photo 1h 1st Layer Aluminum – side to side fretting

Dissection Observations – 7x7 Roller Array Sheave

Double-Pass Test – 7x7 Roller Array Sheave, 52 degree angle, 12.05% RTS tension

1st Layer Aluminum (26)	–	inner surface had fret marks – see photo 2a.
2nd Layer Aluminum (20)	–	outer surface, top side had fret marks – see photo 2b.
2nd Layer Aluminum (20)	–	outer surface, bottom side had fret marks – see photo 2c.
2nd Layer Aluminum (20)	–	inner surface had fret marks – see photo 2d.
3rd Layer Core Wires (18)	–	outer surface had fret marks – see photo 2e.
2nd Layer Core Wire (12)	–	outer surface had fret marks.
1st Layer Core Wire (6)	–	had fret marks.
Center Core Wire	–	had fret marks.

1st Layer Aluminum (26) – noticed some fretting between adjacent wires (side to side), see photo 2f.

All fret marks were more noticeable (larger or deeper) on the bottom side of the conductor. i.e. the side in contact with the sheave wheel. Unless otherwise labelled, all the photos taken were the most severe fretting observed, generally on the bottom side of the conductor.

The fret marks on the core wires looked more like indentations or impressions.

The fret marks for the aluminum and the core wires became longer in length for each layer into the conductor (i.e. as the lay-length became longer).

The fret marks for the core wires generally became lighter for each layer into the conductor.

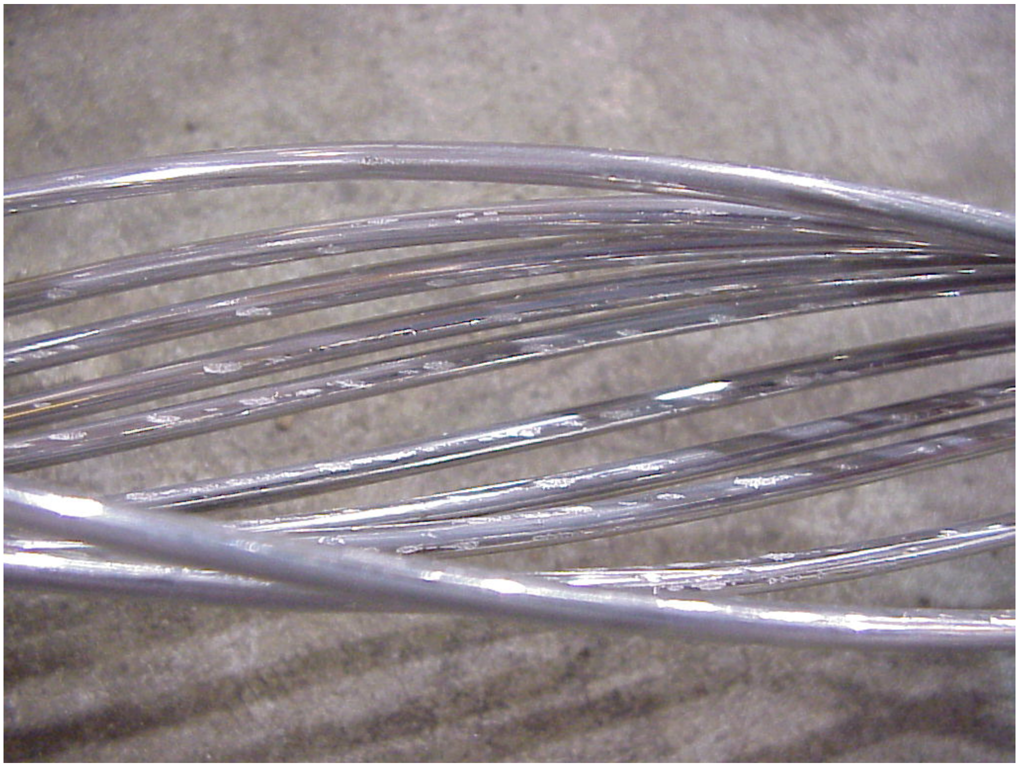

Photo 2a   1st Layer Aluminum – inner surface

Photo 2b   2nd Layer Aluminum – outer surface, top side

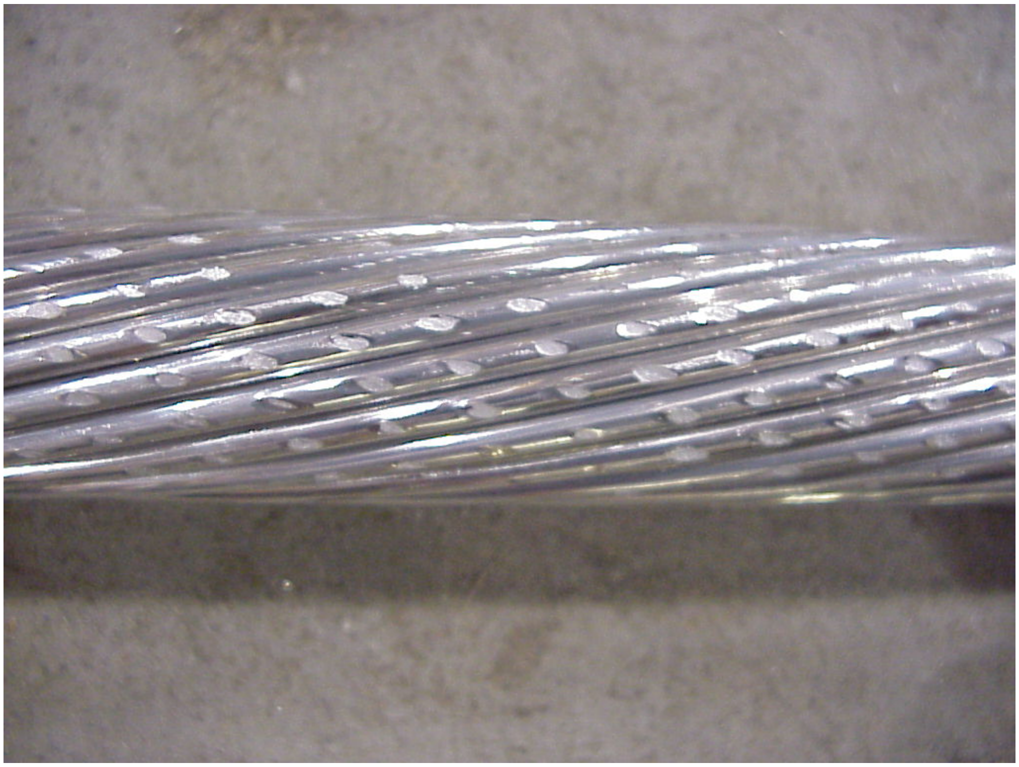

Photo 2c   2nd Layer Aluminum – outer surface, bottom side

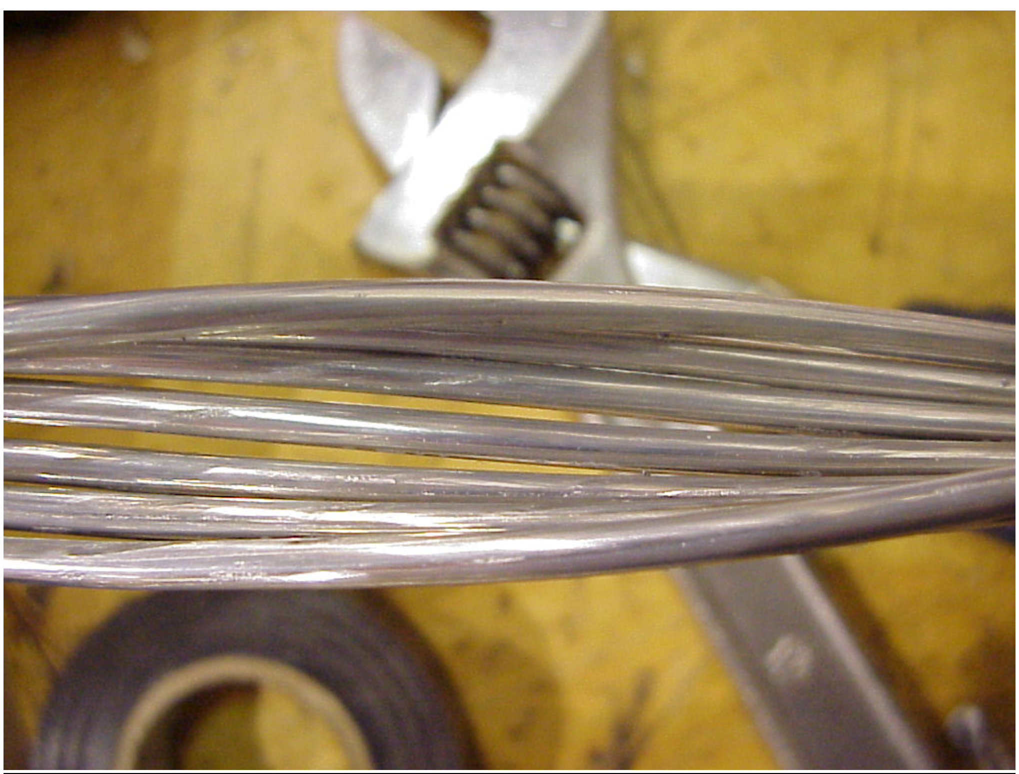

Photo 2d   2nd Layer Aluminum – inner surface

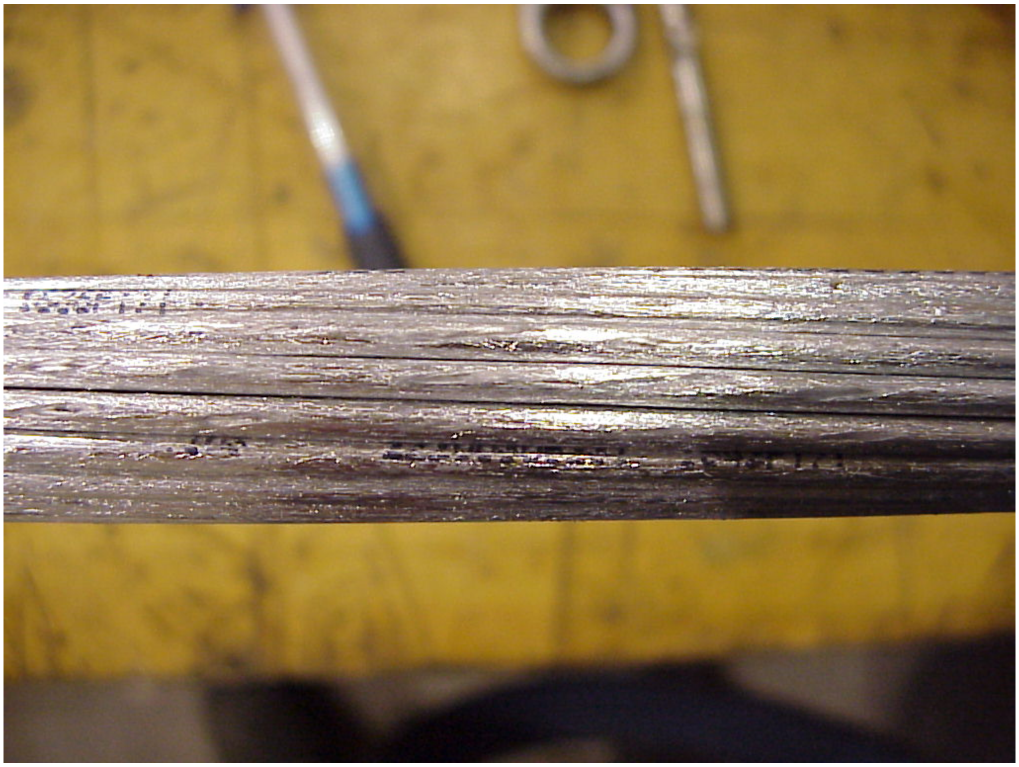

Photo 2e 3rd Layer Core – outer surface

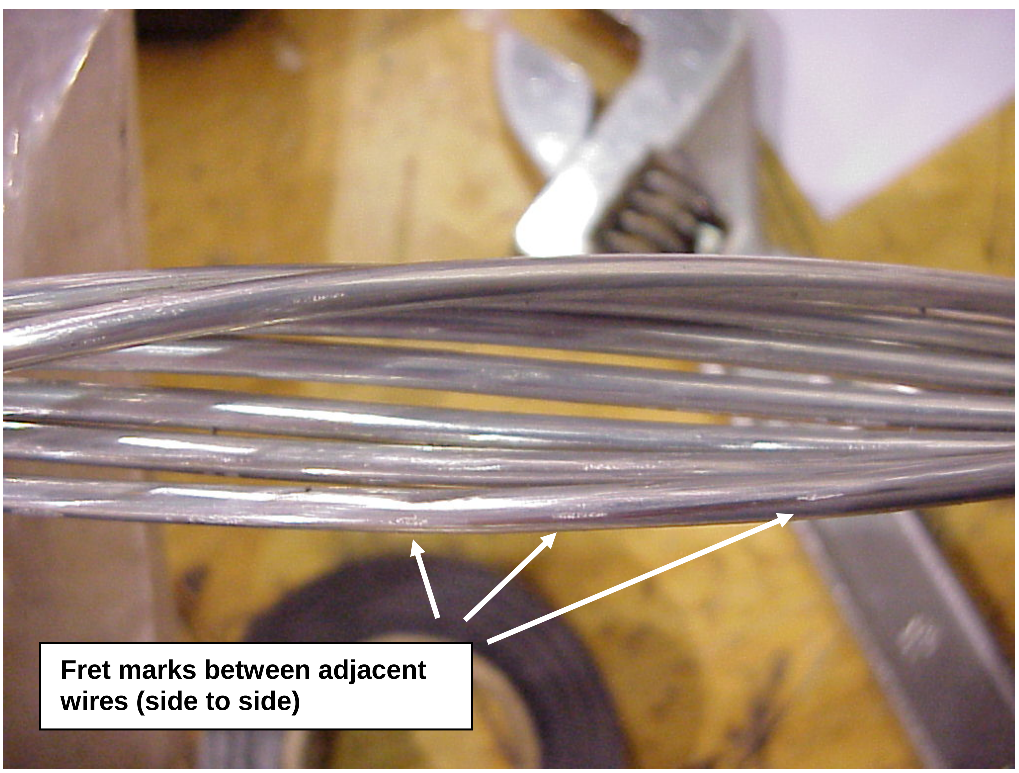

Photo 2f 1st Layer Aluminum – side to side fretting

Dissection Observations – 7x7 Roller Array Sheave

Double-Pass Test – 7x7 Roller Array Sheave, 45 degree angle, 13.80% RTS tension

1st Layer Aluminum (26)	–	inner surface had fret marks – see photo 3a.
2nd Layer Aluminum (20)	–	outer surface, top side had fret marks – see photo 3b.
2nd Layer Aluminum (20)	–	outer surface, bottom side had fret marks – see photo 3c.
2nd Layer Aluminum (20)	–	inner surface had fret marks.
3rd Layer Core Wires (18)	–	outer surface had fret marks – see photo 3d.
2nd Layer Core Wire (12)	–	outer surface had fret marks – see photo 3e.
1st Layer Core Wire (6)	–	outer surface had fret marks – see photo 3f.
Center Core Wire	–	had fret marks.

All fret marks were more noticeable (larger or deeper) on the bottom side of the conductor. i.e. the side in contact with the sheave wheel. Unless otherwise labelled, all the photos taken were the most severe fretting observed, generally on the bottom side of the conductor.

The fret marks on the core wires looked more like indentations or impressions.

The fret marks for the aluminum and the core wires became longer in length for each layer into the conductor (i.e. as the lay-length became longer).

The fret marks for the core wires generally became lighter for each layer into the conductor.

The outer rollers on each end of the roller array were barely in contact with the conductor during the sheave test.

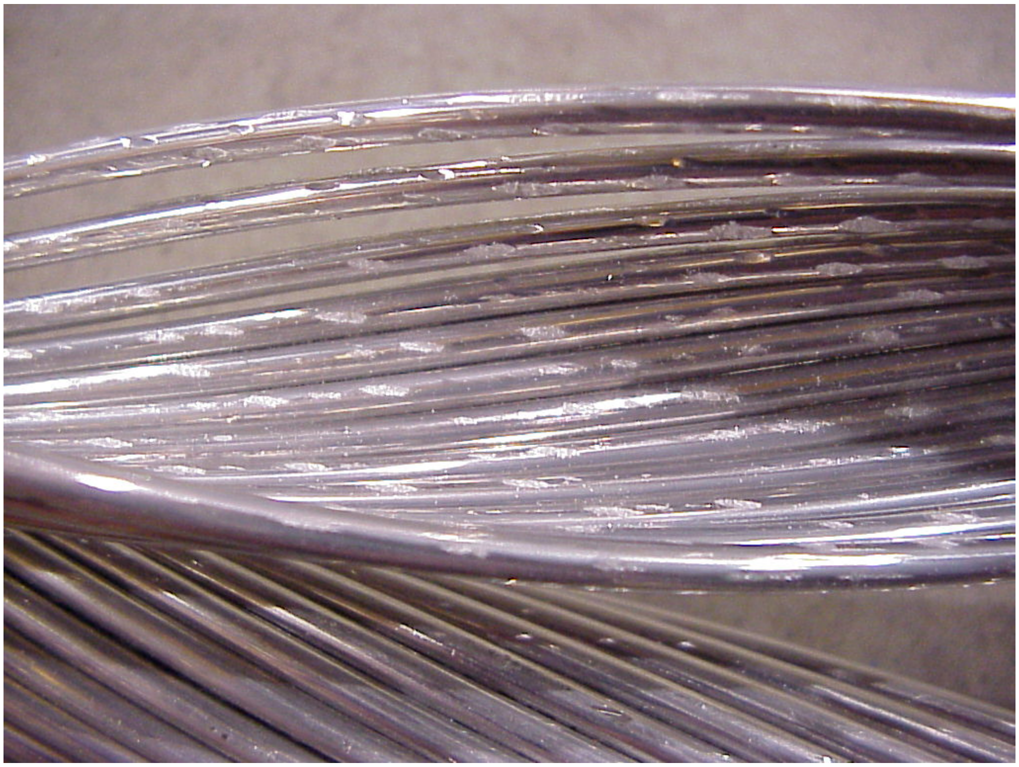

Photo 3a 1st Layer Aluminum – inner surface

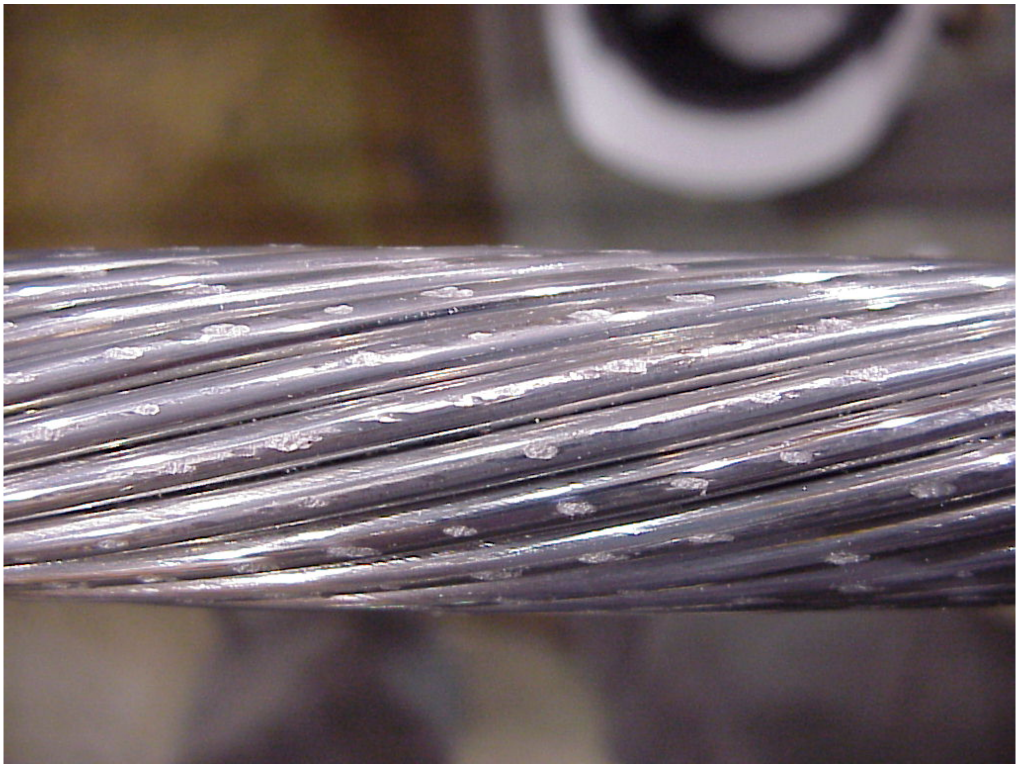

Photo 3b 2nd Layer Aluminum – outer surface, top side

Photo 3c 2nd Layer Aluminum – outer surface, bottom side

Photo 3d 3rd Layer Core – outer surface

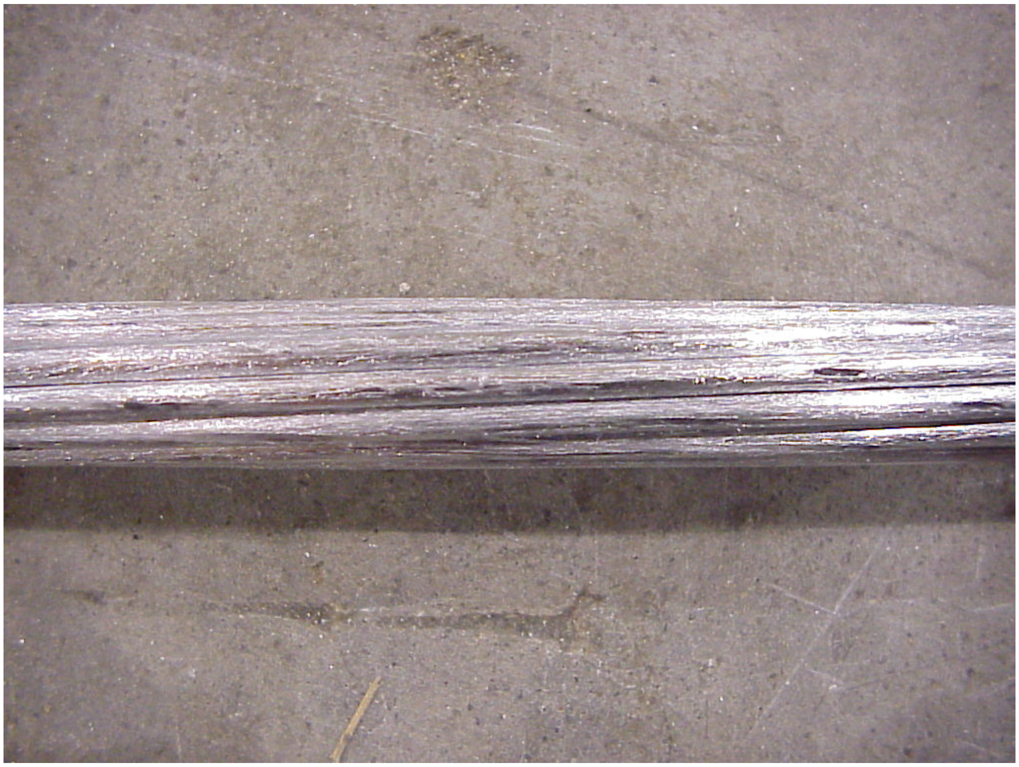

Photo 3e 2nd Layer Core – outer surface

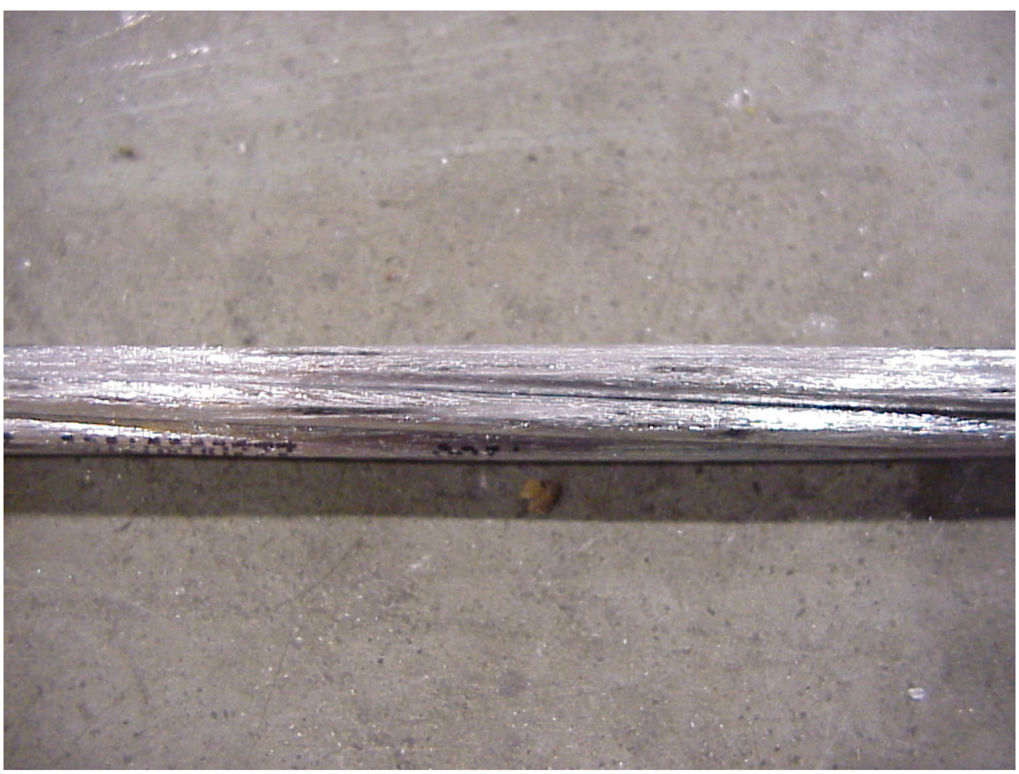

Photo 3f 1st Layer Core – outer surface

Dissection Observations – 7x7 Roller Array Sheave

Double-Pass Test – 7x7 Roller Array Sheave, 33 degree angle, 15.0% RTS tension

1st Layer Aluminum (26)	– inner surface had fret marks – see photo 4a.
2nd Layer Aluminum (20)	– outer surface, had fret marks – see photo 4b.
2nd Layer Aluminum (20)	– inner surface had fret marks – see photo 4c.
3rd Layer Core Wires (18)	– outer surface had fret marks.
2nd Layer Core Wire (12)	– outer surface had fret marks.
1st Layer Core Wire (6)	– outer surface had fret marks.
Center Core Wire	– had fret marks.

All fret marks were more noticeable (larger or deeper) on the bottom side of the conductor. i.e. the side in contact with the sheave wheel. Unless otherwise labelled, all the photos taken were the most severe fretting observed, generally on the bottom side of the conductor.

The fret marks on the core wires looked more like indentations or impressions.

The fret marks for the aluminum and the core wires became longer in length for each layer into the conductor (i.e. as the lay-length became longer).

The fret marks for the core wires generally became lighter for each layer into the conductor.

The outer rollers on each end of the roller array were not in contact with the conductor during the sheave test.

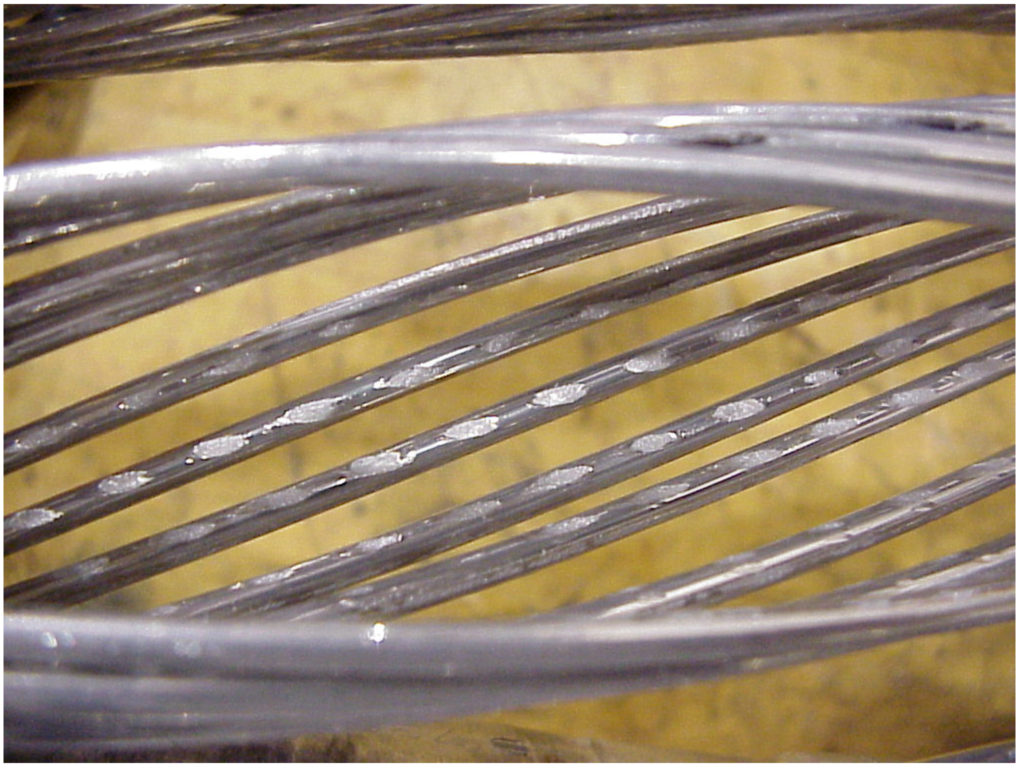

Photo 4a 1st Layer Aluminum – inner surface

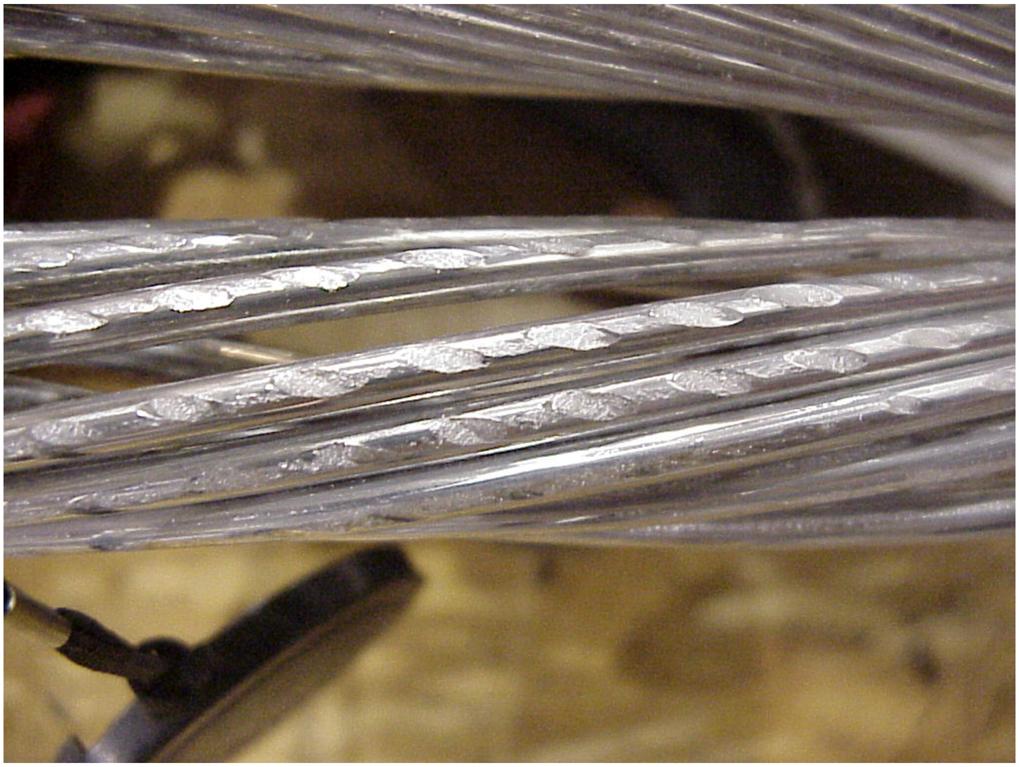

Photo 4b 2nd Layer Aluminum – outer surface

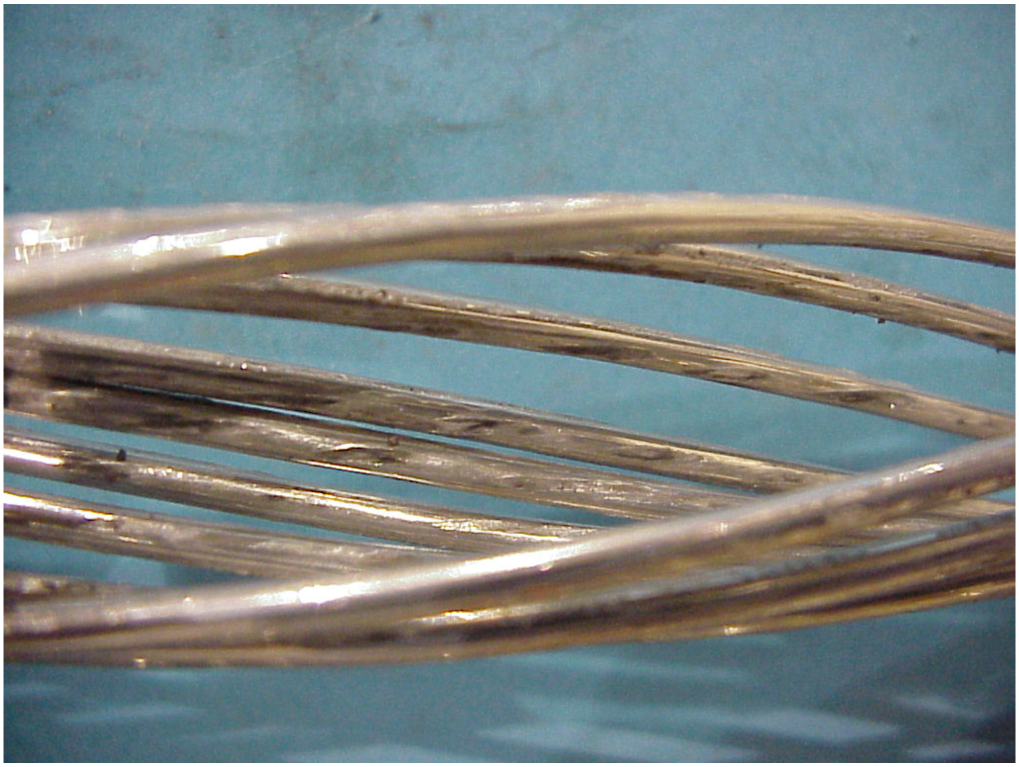

Photo 4c   2nd Layer Aluminum – inner surface

Dissection Observations – 7x7 Roller Array Sheave

<u>Multi-Pass Test</u> – 7x7 Roller Array Sheave, 60 degree angle, 10.56% RTS tension, 20 passes

1st Layer Aluminum (26)	– outer surface, no fret marks – see photo 5a.
1st Layer Aluminum (26)	– inner surface, top side had fret marks – see photo 5b.
1st Layer Aluminum (26)	– inner surface, bottom side had fret marks – see photo 5c.
2nd Layer Aluminum (20)	– outer surface, top side had fret marks – see photo 5d.
2nd Layer Aluminum (20)	– outer surface, bottom side had fret marks – see photo 5e.
2nd Layer Aluminum (20)	– inner surface, top side had fret marks – see photo 5f.
2nd Layer Aluminum (20)	– inner surface, bottom side had fret marks – see photo 5g.
3rd Layer Core Wires (18)	– outer surface, top side had fret marks – see photo 5h.
3rd Layer Core Wires (18)	– outer surface, bottom side had fret marks – see photo 5j.
2nd Layer Core Wire (12)	– outer surface, had fret marks – see photo 5k.
1st Layer Core Wire (6)	– outer surface, had fret marks – see photo 5m.
Center Core Wire	– had fret marks – see photo 5n.

All fret marks were more noticeable (larger or deeper) on the bottom side of the conductor. i.e. the side in contact with the sheave wheel. Unless otherwise labelled, all the photos taken were the most severe fretting observed, generally on the bottom side of the conductor.

The fret marks on the core wires looked more like indentations or impressions.

The fret marks for the aluminum and the core wires became longer in length for each layer into the conductor (i.e. as the lay-length became longer).

The fret marks for the core wires generally became lighter for each layer into the conductor.

The outer rollers on each end of the roller array were barely in contact with the conductor during the sheave test.

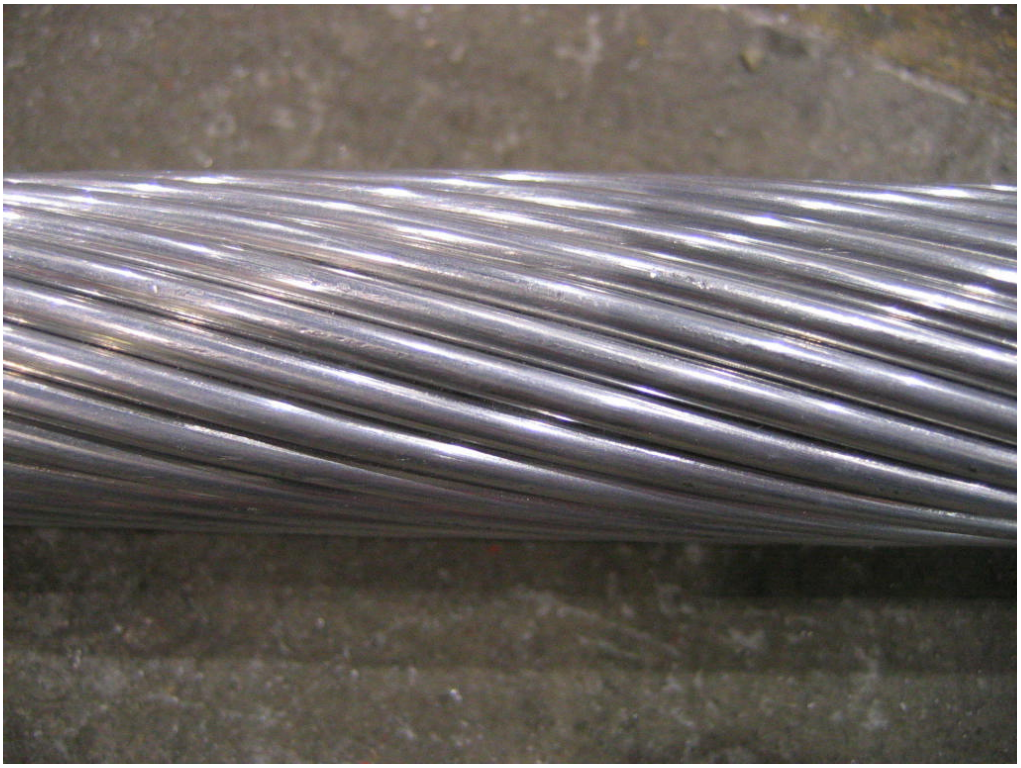

Photo 5a   1st Layer Aluminum – outer surface

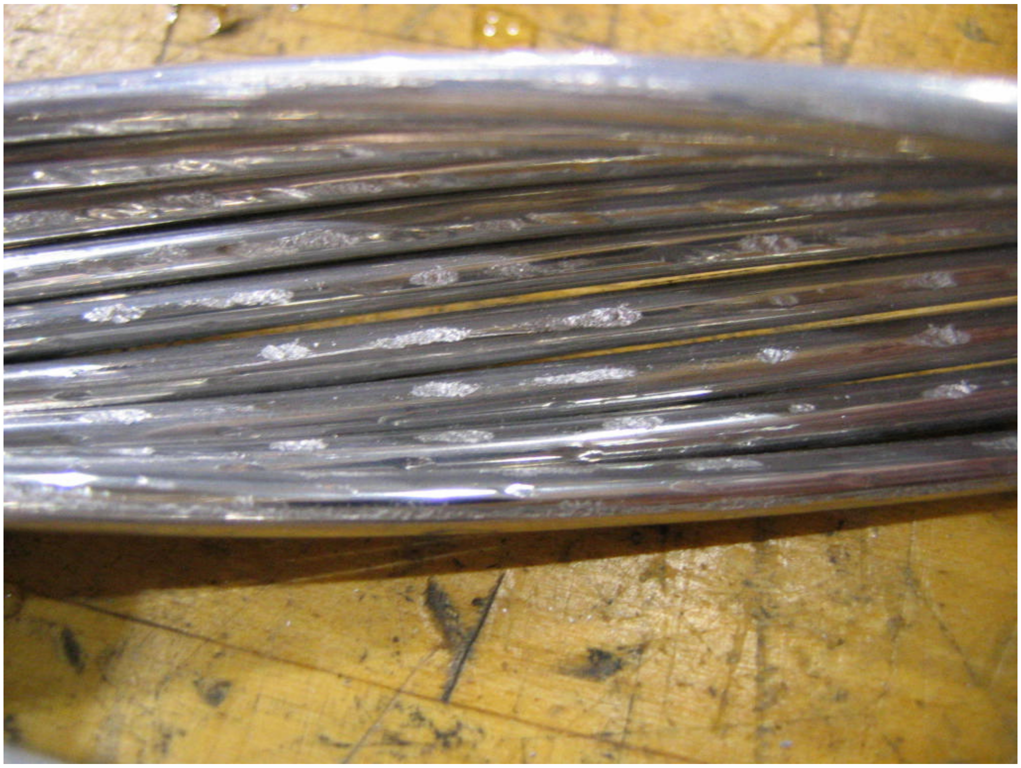

Photo 5b   1st Layer Aluminum – inner surface, top side

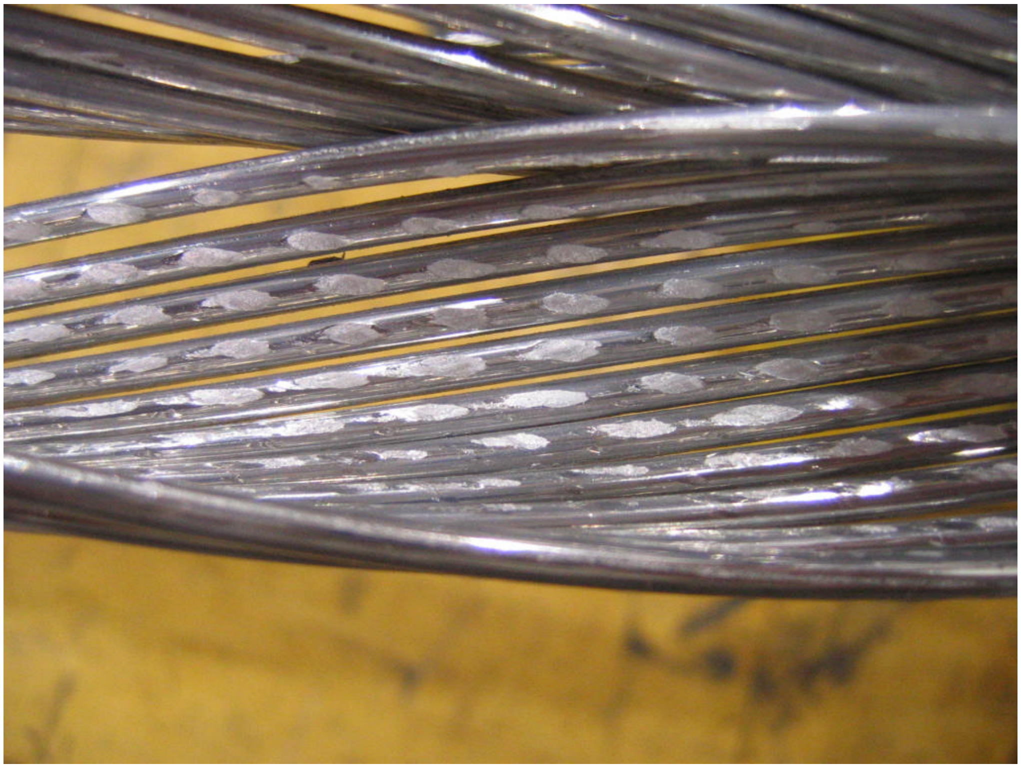

Photo 5c 1st Layer Aluminum – inner surface, bottom side

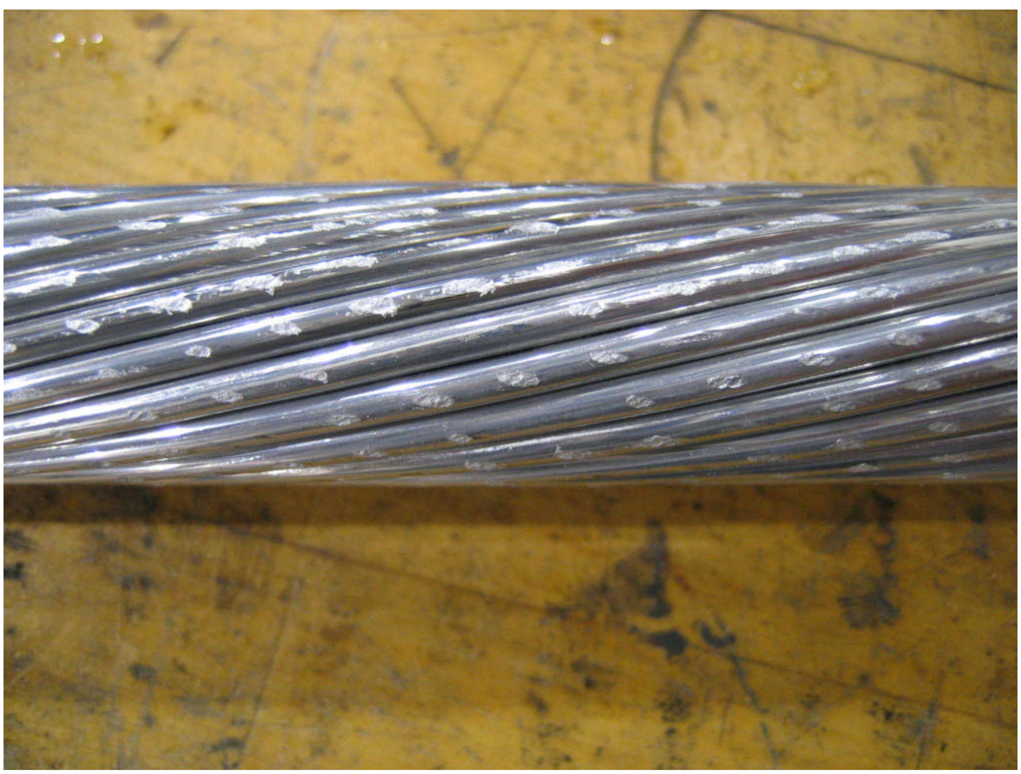

Photo 5d 2nd Layer Aluminum – outer surface, top side

Photo 5e 2nd Layer Aluminum – outer surface, bottom side

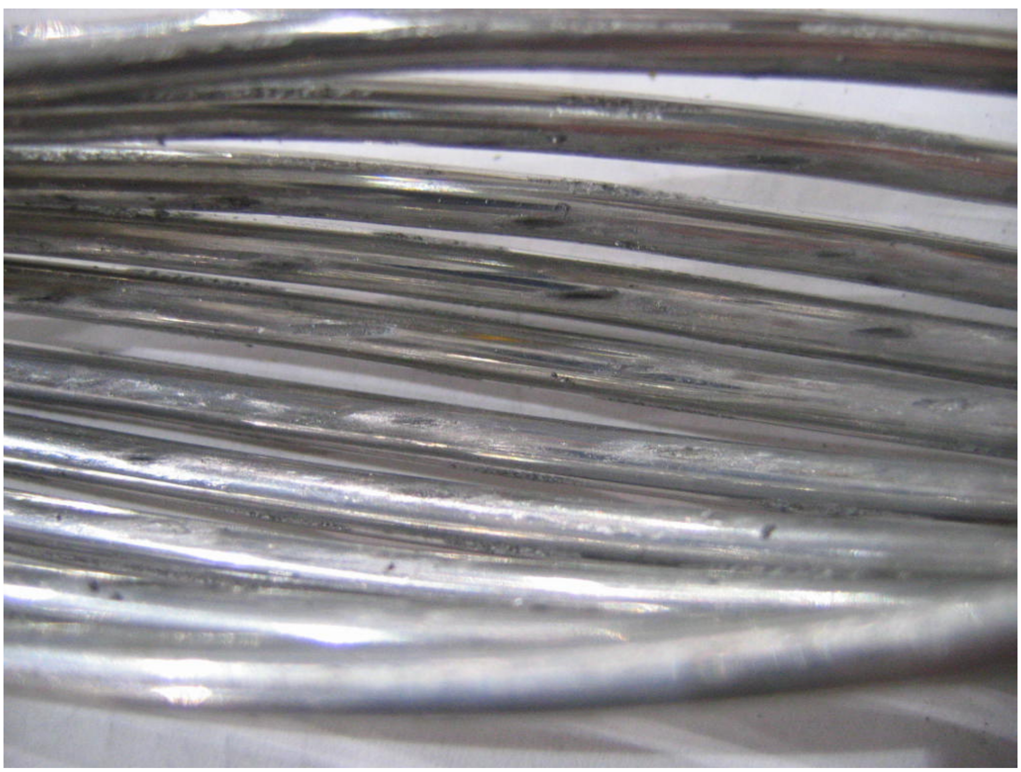

Photo 5f 2nd Layer Aluminum – inner surface, top side

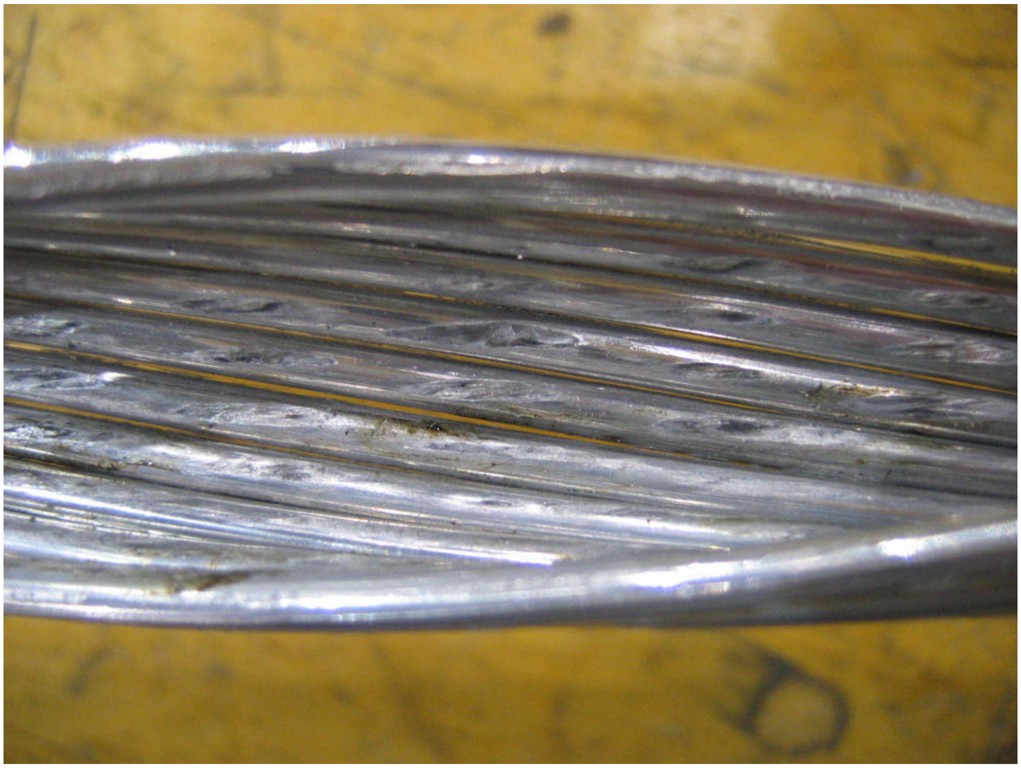

Photo 5g   2nd Layer Aluminum – inner surface, bottom side

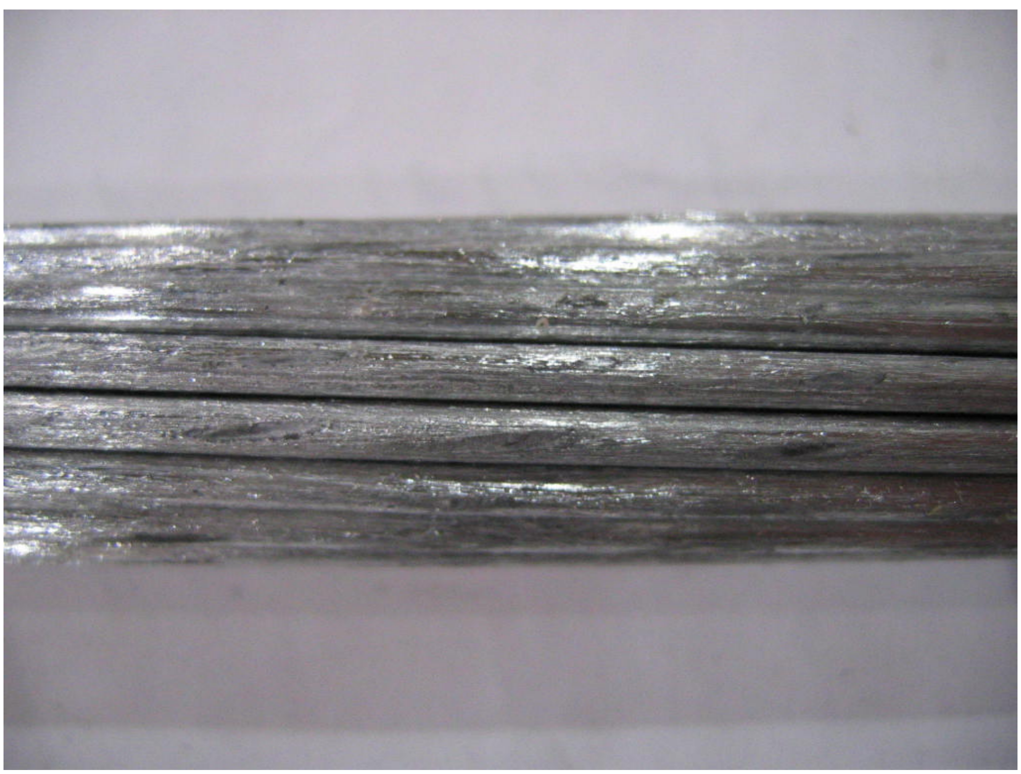

Photo 5h   3rd Layer Core – outer surface, top side

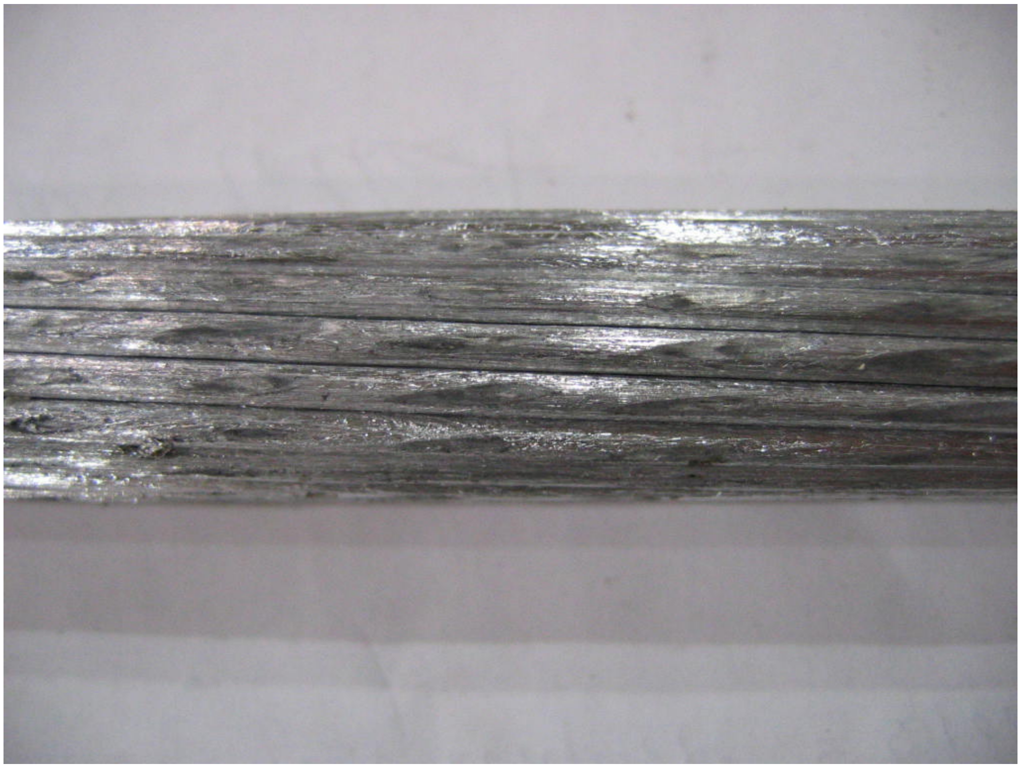

Photo 5j 3rd Layer Core – outer surface, bottom side

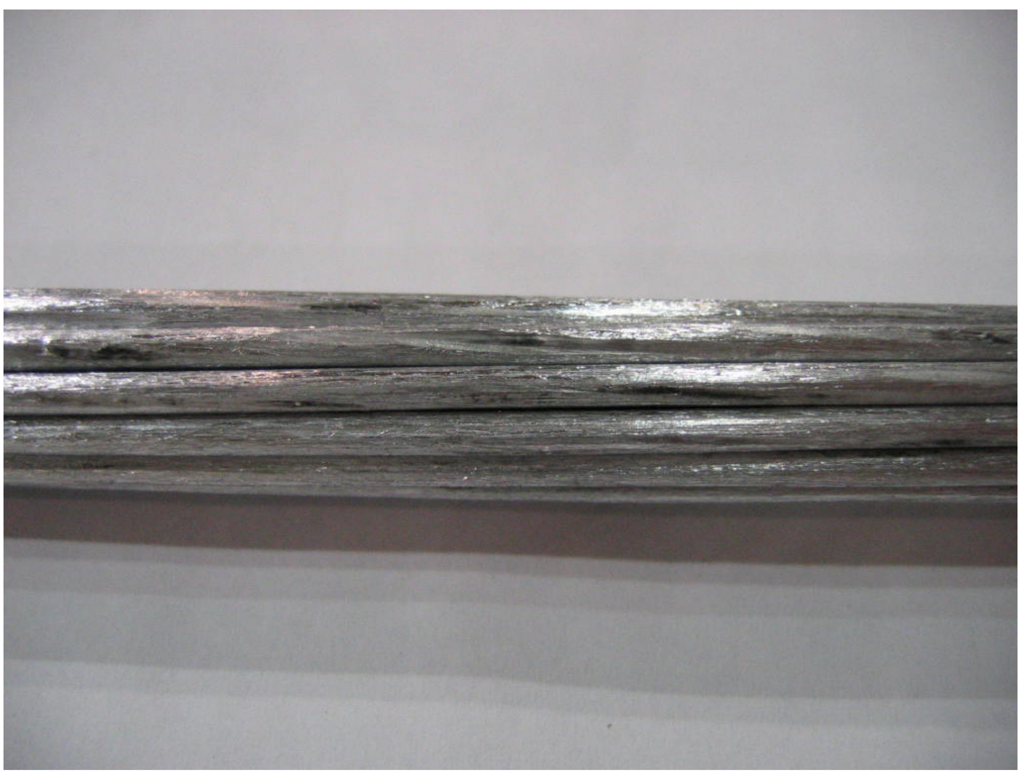

Photo 5k 2nd Layer Core – outer surface

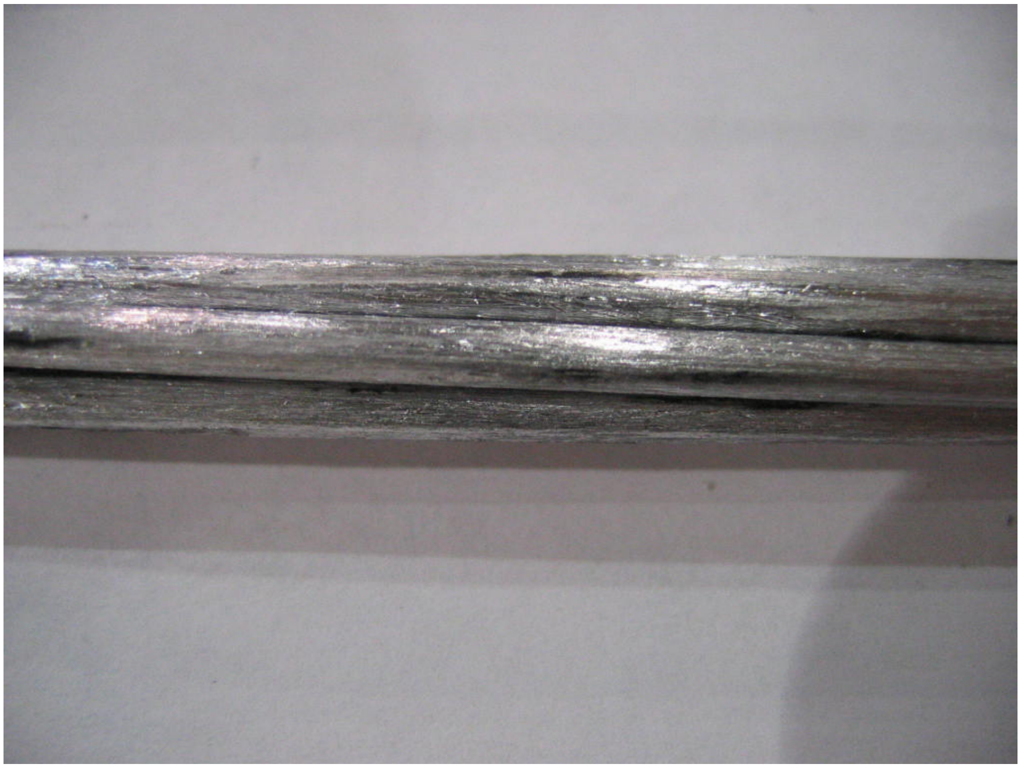

Photo 5m   1st Layer Core – outer surface

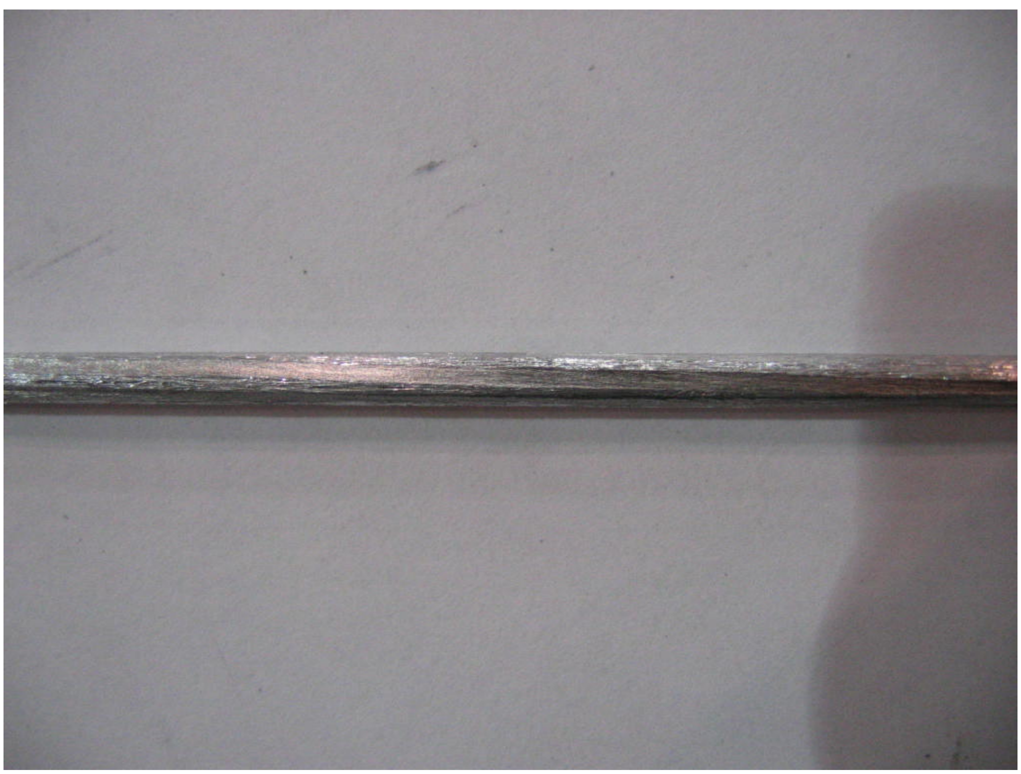

Photo 5n   Center Core Wire

Multi-Pass Test – 7x7 Roller Array Sheave, 33 degree angle, 15.0% RTS tension, 20 passes

1st Layer Aluminum (26) – outer surface, no fret marks – see photo 6a.
1st Layer Aluminum (26) – inner surface, bottom side had fret marks – see photo 6b.
2nd Layer Aluminum (20) – outer surface, bottom side had fret marks – see photo 6c.
2nd Layer Aluminum (20) – outer surface, bottom side had fret marks – see photo 6d.
2nd Layer Aluminum (20) – inner surface, bottom side had fret marks – see photo 6e.
3rd Layer Core Wires (18) – outer surface, top side had fret marks – see photo 6f.
3rd Layer Core Wires (18) – outer surface, bottom side had fret marks – see photo 6g.
2nd Layer Core Wire (12) – outer surface, had fret marks – see photo 6h.
1st Layer Core Wire (6) – outer surface, had fret marks – see photo 6j.
Center Core Wire – had fret marks – see photo 6k.

All fret marks were more noticeable (larger or deeper) on the bottom side of the conductor. i.e. the side in contact with the sheave wheel. Unless otherwise labelled, all the photos taken were the most severe fretting observed, generally on the bottom side of the conductor.

The fret marks on the core wires looked more like indentations or impressions.

The fret marks for the aluminum and the core wires became longer in length for each layer into the conductor (i.e. as the lay-length became longer).

The fret marks for the core wires generally became lighter for each layer into the conductor.

The outer rollers on each end of the roller array were not in contact with the conductor during the sheave test.

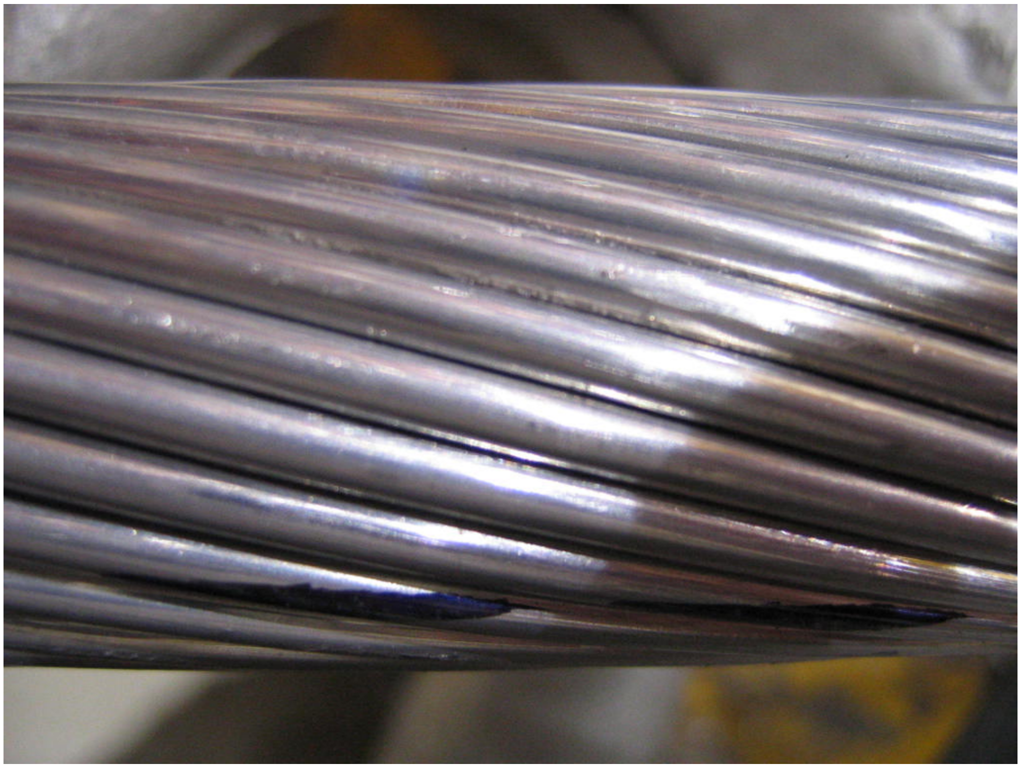

Photo 6a 1st Layer Aluminum – outer surface

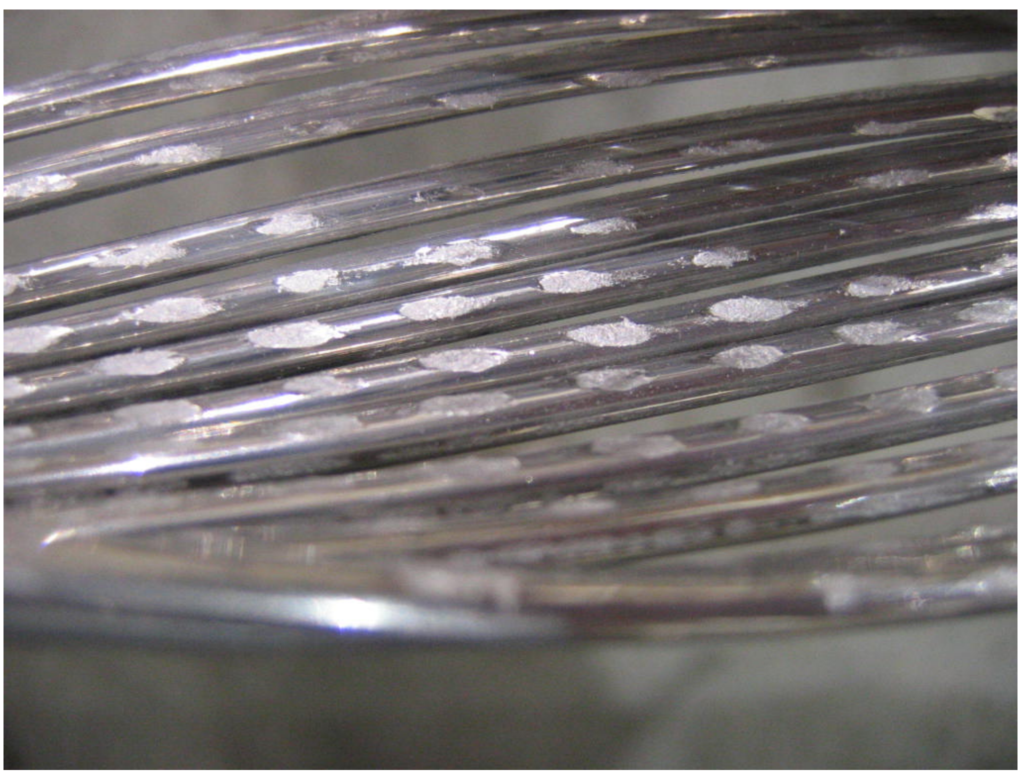

Photo 6b 1st Layer Aluminum – inner surface, bottom side

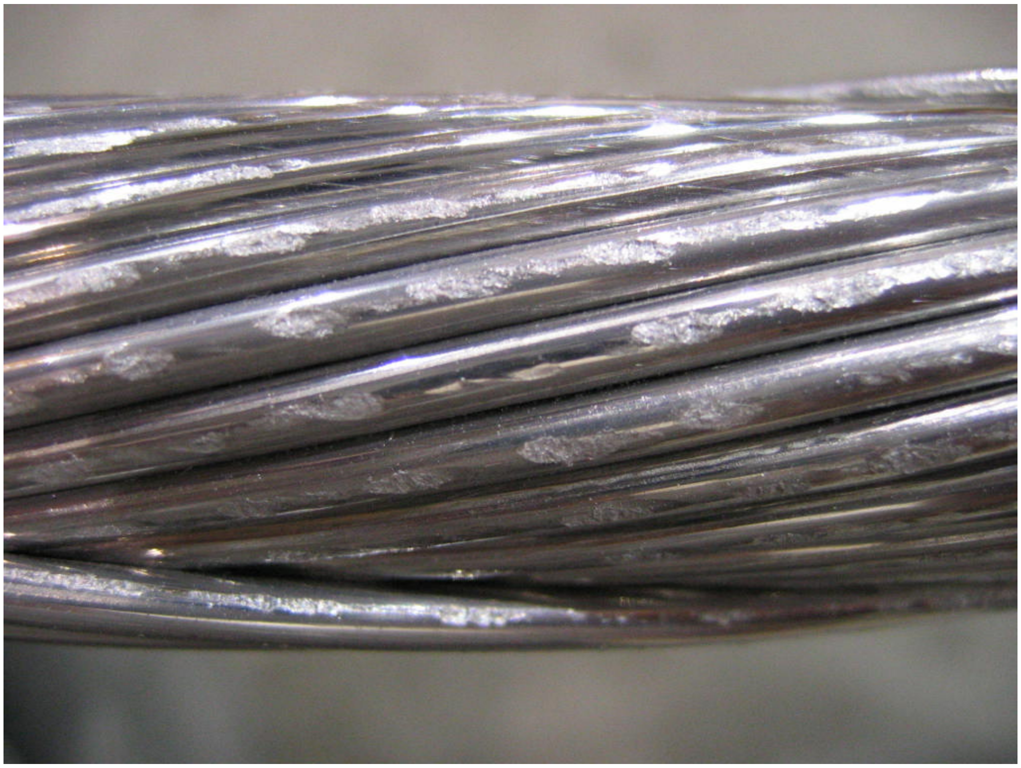

Photo 6c   2nd Layer Aluminum – outer surface, top side

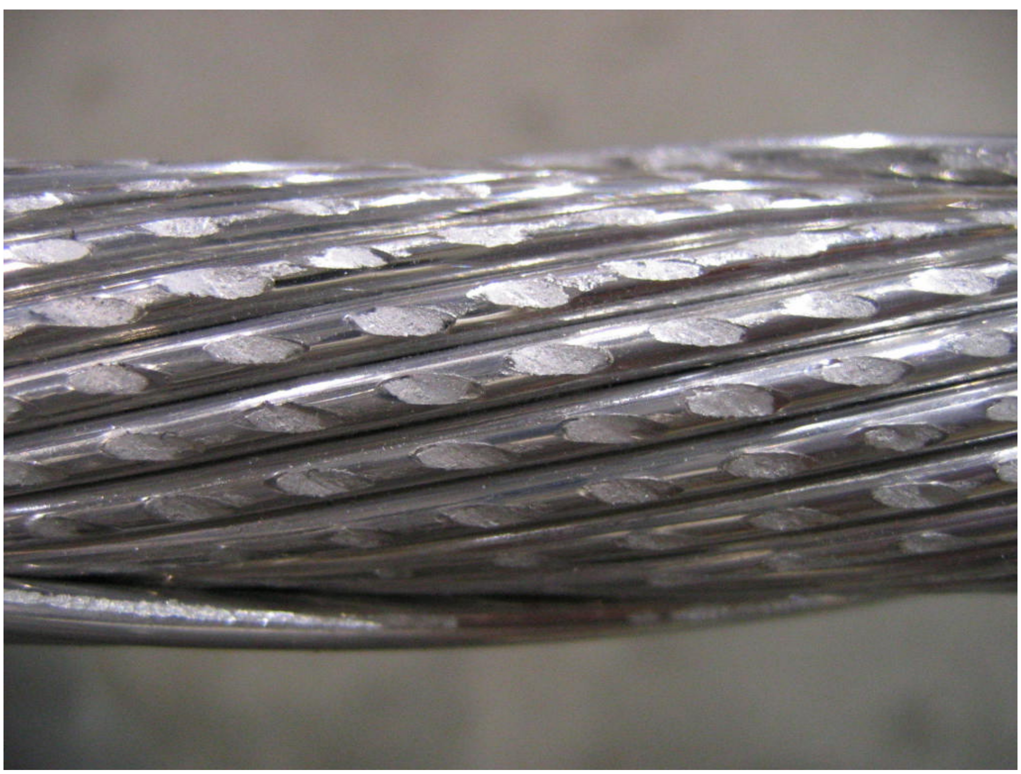

Photo 6d   2nd Layer Aluminum – outer surface, bottom side

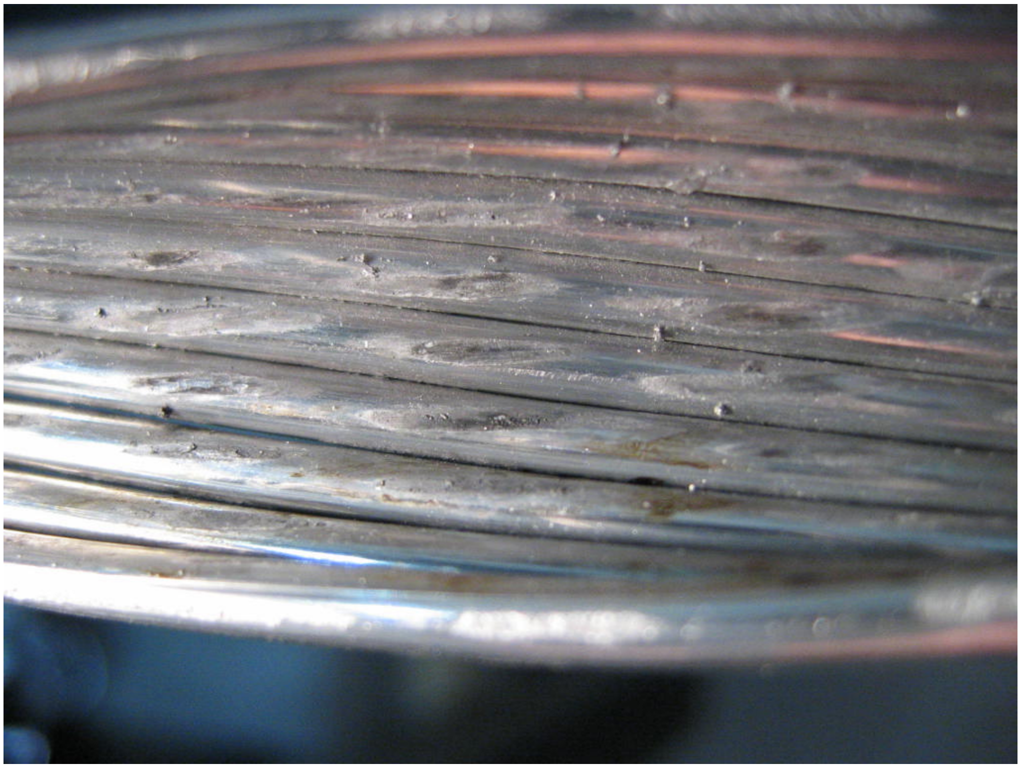

Photo 6e 2nd Layer Aluminum – inner surface, bottom side

Photo 6f 3rd Layer Core – outer surface, top side

Photo 6g 3rd Layer Core – outer surface, bottom side

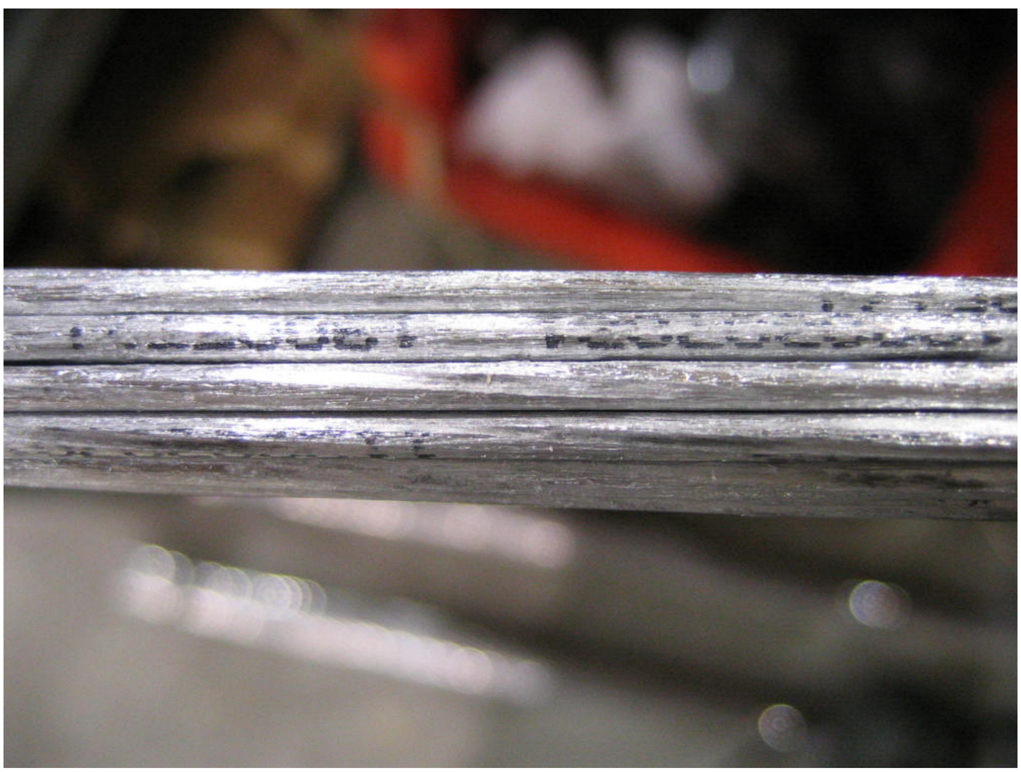

Photo 6h 2nd Layer Core – outer surface

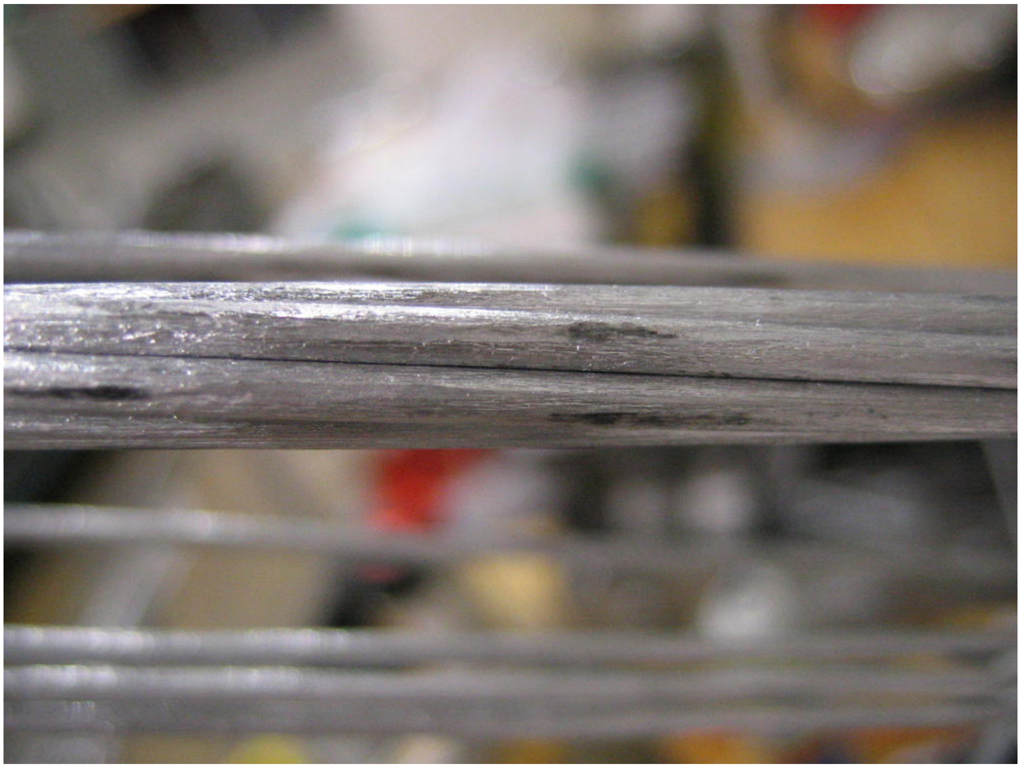

Photo 6j 1st Layer Core – outer surface

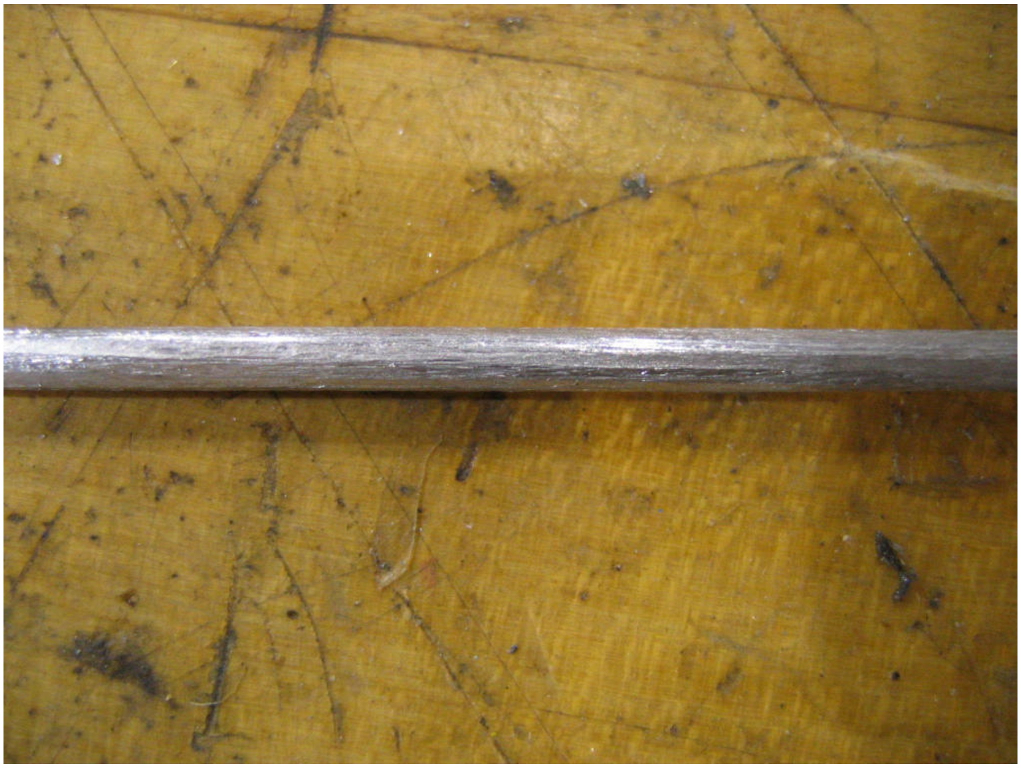

Photo 6k Center Core Wire

SUMMARY

Double-Pass Test

The 36 inch root diameter sheave showed smaller break-over angles can support higher tensions for double-pass tests. Specifically, at 45° per sheave and 5% RTS, at 33° per sheave and 7.5% RTS, and at 25° per sheave and 15% RTS, the conductor behaves well.

The 7x7 inch roller array sheave showed smaller break-over angles can support higher tensions for double-pass tests. Specifically, at 60° per sheave and 10% RTS, and 33° per sheave and 15% RTS, the conductor behaves well.

Multi-Pass Test

The 774 kcmil ACCR conductor successfully completed 20 passes over the sheave at the two selected break-over angles and tensions combinations of 33 degrees/15.0% RTS, and 60 degrees/10.6% RTS.

The dissections showed there was fretting evident on all aluminum layer cross-over interfaces and all the core wires cross-over interfaces.

All fret marks were more noticeable (larger or deeper) on the bottom side of the conductor. i.e. the side in contact with the sheave wheel.

The fret marks for the core wires generally became lighter for each layer into the conductor.

The fretting appears to become more severe at the higher conductor tensions and/or conductor angle over the sheave.

The degree of fretting appears to increase with increased passes over the sheave.

The fret marks for the aluminum and the core wires became longer in length for each layer into the conductor (i.e. as the lay-length became longer).

The heavy fret-marks in some instances suggest more support is required for the conductor (e.g. larger sheaves), so as to reduce the point loads at the cross-over points.

Understanding the angle per sheave that may be tolerated is useful in designing and selecting the correct sheave size (or multi-sheave configuration) for subsequent tests. Thus, this data will be used as a starting point in selecting sheave (and multi-sheave) configurations for outdoor installation experiments while using full installation rigging.

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DISCLAIMER

Kinectrics North America Inc. has prepared this report in accordance with, and subject to, the terms and conditions of the contract between 3M, dated August 9, 2004.

This material is based upon work supported by the U.S. Department of Energy under Award No. DE-FC02-02CH11111. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Department of Energy.

APPENDIX A

DATA SHEET FOR 3M 774 KCMIL ACCR COMPOSITE CONDUCTOR

3M River-X ACCR Specification

Conductor Physical Properties		
Designation		ACCR_774-T53
Stranding		46/37
kcmils	kcmil	774
Area Fraction Core	%	34.52%
Weight Core	lb/ft	0.48
Diameter		
indiv Core	in	0.105
indiv Al	in	0.130
Core	in	0.735
Total Diameter	in	1.254
Area		
Al	in^2	0.6077
Total Area	in^2	0.9280
Weight	lbs/linear ft	1.202
Breaking Strength		
Core	lbs	57,885
Aluminum	lbs	13,125
Complete Cable	lbs	71,010
Modulus		
Core	msi	32.9
Aluminum	msi	8.8
Complete Cable	msi	17.1
Thermal Elongation		
Core	$10^{-6}/C^{o}$	6.35
Aluminum	$10^{-6}/C^{o}$	23.00
Complete Cable	$10^{-6}/C^{o}$	11.96
Heat Capacity		
Core	W-sec/ft-C	84
Aluminum	W-sec/ft-C	272

Conductor Electrical Properties		
Resistance		
DC @ 20C	ohms/mile	0.0970
AC @ 25C	ohms/mile	0.0993
AC @ 50C	ohms/mile	0.1091
AC @ 75C	ohms/mile	0.1190
Geometric Mean Radius	ft	0.0366
Reactance (1 ft Spacing, 60hz)		
Inductive Xa	ohms/mile	0.4013
Capacitive X'a	ohms/mile	0.0876

ISO-9001
Form: QF11-1
Rev 0, 97-10

APPENDIX B
INSTRUMENT SHEET
3M SHEAVE TESTS on 774 kcmil ACCR CONDUCTOR

Test Description: 3M Sheave Tests on 774 kcmil ACCR Conductor
Project Number: 422132

Test Start Date: May 9, 2005
Test Finish Date: October 11, 2005

TEST DESCRIPTION	EQUIPMENT DESCRIPTION	MAKE	MODEL	ASSET # or SERIAL #	ACCURACY CLAIMED	CALIBRATION DATE	CALIBRATION DUE DATE	TEST USE
Sheave	A/D Board	National Instruments	PCI-6034E	CA1C1A	±0.1% of reading	January 7, 2005	January 7, 2006	Data Acquisition
	Load Cell Load Conditioner	Eaton Daytronics	3124 3170	17952-0 11148-0	±1% of reading	December 21, 2004	December 21, 2005	Conductor Tension for Double-Pass Tests
	Load Cell Load Conditioner	Aries Daytronics	1000 TRC 3170	11137-0 10718-0	±1% of reading	February 10, 2005	February 10, 2006	Conductor Tension for Multi-Pass Tests
	Digital Protractor	Mitutoyo	Pro 3600	19693-0	0 to -0.1 degree	February 15, 2005	February 15, 2006	Conductor Angle

DISTRIBUTION

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