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KINECTRICS NORTH AMERICA INC. TEST REPORT FOR 3M TO DETERMINE THE SHEAVE CRITERIA FOR 590TW KCMIL 3M™ COMPOSITE CONDUCTOR

Kinectrics North America Inc. Report No.: K-422121-RC-0002-R00

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INTRODUCTION

3M contracted with Kinectrics under PO # 1600000 to conduct a series of investigative tests on their 590TW kcmil Aluminum Conductor Composite Reinforced (ACCR/TW) 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 November 2 - 5, 2004 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 results from the Single-Pass Tests for the 8 inch root diameter and 18 inch root diameter sheaves showed good correlation between conductor angle over sheave and conductor tension.

All four sheaves tested reached 25% of the conductor RTS at a specified break-over angle with no conductor damage. The 25% RTS tension was sustained by using a 24-inch (root) diameter sheave for a 45° break-over angle, a 18-inch (root) diameter sheave for a 33° break-over angle, a 16.75-inch (root) diameter sheave for a 20° break-over angle, and a 8-inch (root) diameter sheave for a 12° break-over angle. This provides useful angle per sheave information for the design and further testing of sheave and multi-sheave configurations for 590TW ACCR.

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 590TW kcmil 3M™ Composite Conductor (ACCR/TW) during a single-pass 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/TW 590TW-T16, 20/7 conductor is manufactured by 3M and is constructed of 20 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 7 core wires of the ACCR are made from a fiber-reinforced metal matrix composite material. The conductor diameter is 0.86 inches (21.8 mm). The RTS (Rated Tensile Strength) of the conductor is 21,054 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. It's stress-strain behavior 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.

All the sheave tests were performed using the single-pass test method.

The single-pass tests were performed to determine the possible threshold combination of tension, sheave diameter, and conductor angle over sheave that could be used during installation in the field.

TEST SET-UP

A schematic of the set-up for the Single-Pass Sheave Tests is shown in Figure 1a. Typical photos of the set-up for the 8 inch diameter sheave are shown in Figures 1b and 1c. Typical photos of the set-up for the 16.75, 18, and 24 inch diameter sheave are shown in Figures 1d, and 1e. Diameters given are measured to the bottom of the groove and are not the flange diameter.

Test Apparatus

The test conductor was strung over the sheave wheel and tensioned using pulling 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. An accelerometer was attached on the conductor to listen acoustically for potential breaking of the core wires.

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 amplified accelerometer and headphones, and the unaided ear, were 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.

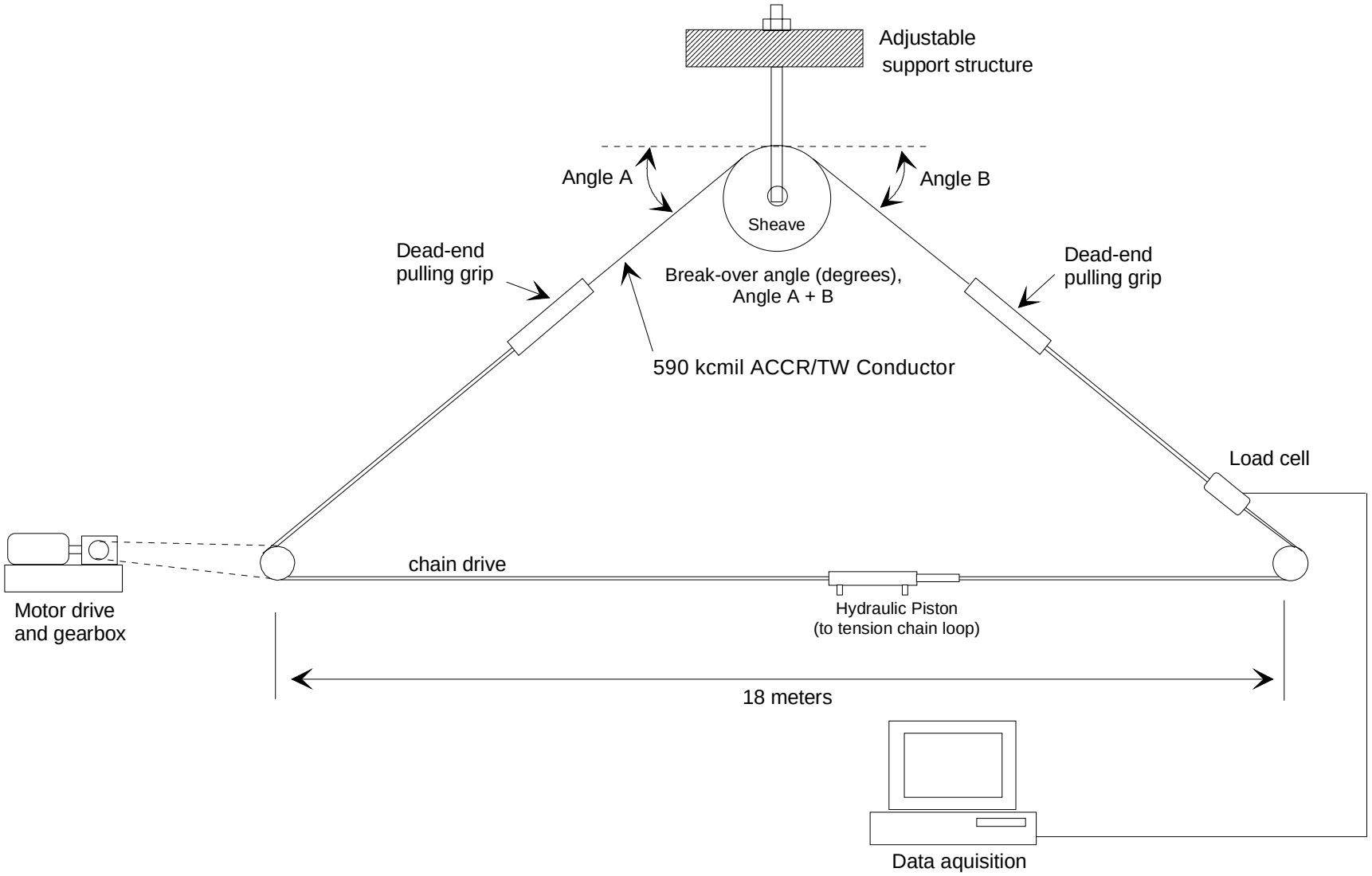


Figure 1a Set-up for Single-Pass Sheave Test (Schematic)

Figure 1b Typical Set-up for 8 inch Single-Pass Test

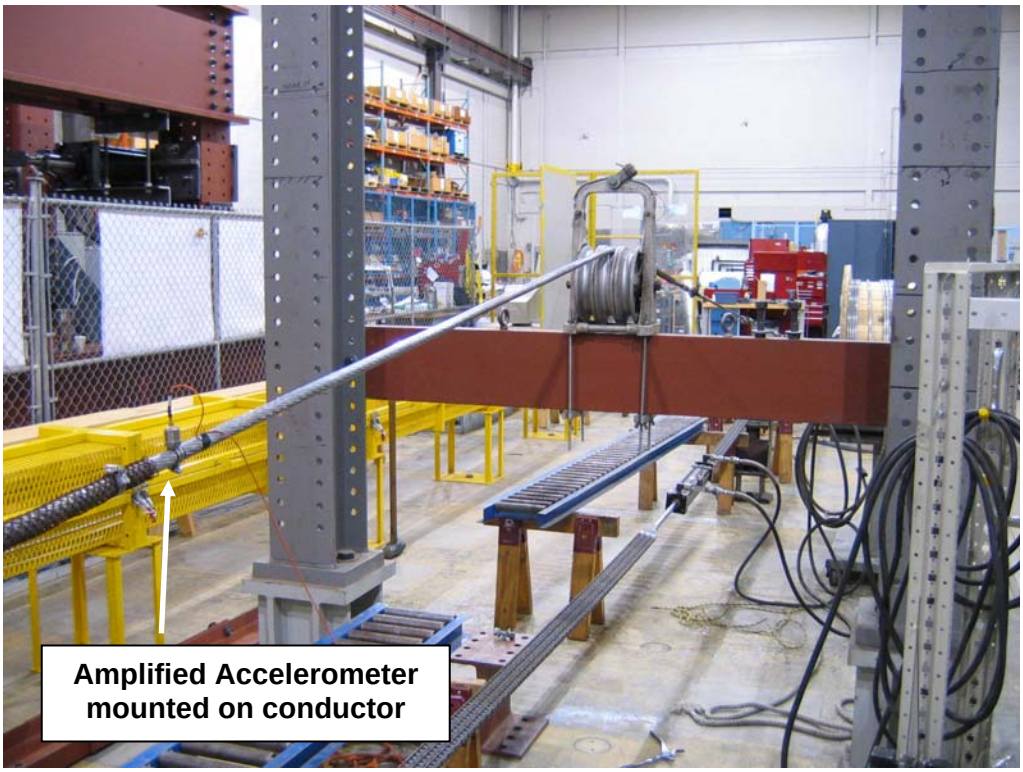


Figure 1c Typical Set-up for 8 inch Single-Pass Test

Figure 1d Typical Set-up for 16.75, 18, and 24 inch Single-Pass Sheave Test (24 inch Sheave shown in photo)

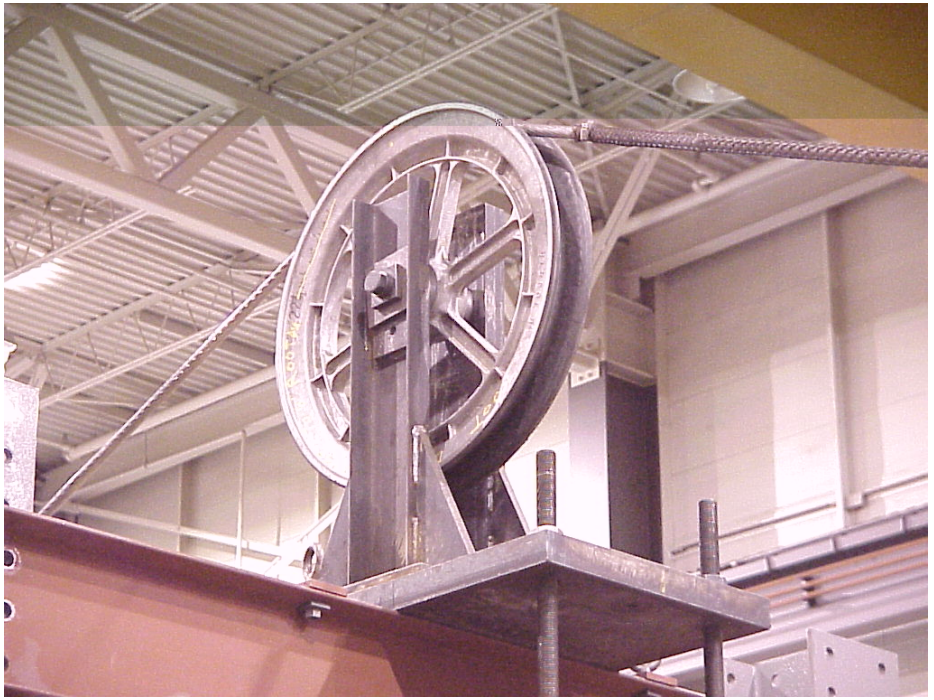


Figure 1e Typical Set-up for 16.75, 18, and 24 inch Single-Pass Sheave Test (24 inch Sheave shown in photo)

TEST PROCEDURE

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

Sheave Diameters:	8 inch, 16.75 inch, 18 inch, and 24 inch (at the bottom of the groove)
Break-over Angle:	45°, 33°, 20°, and 12°.
Tension:	5%, 10%, 15%, 20% and 25% of conductor RTS (21,054 lbf, 9,550 kgf)

The test sequence was based on the most to least severe combination of sheave diameter and break-over angle. The starting tension was 5% of RTS (31,134 lbf, 14,122 kgf). A single pass of the conductor over the sheave was completed. A single pass is defined as one forward and backward movement 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 5% RTS, and the test repeated. If there was any audible indication of broken core wires, the conductor was dissected and the core wires were visually examined over the test section for breaks.

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

TEST RESULTS

The results for the various combinations of sheave diameters, break-over angles, and tensions are summarized in Table 1. Figure 2 shows a graph plotting break-over angle versus tension for the 8, 16.75, 18, and 24 inch root diameter sheaves. This provides a single-pass threshold curve for the sheave diameter. The curve is based on the test results from Table 1 that had no broken wires after a single-pass. There were no visual observations made for fretting between the aluminum wires or the composite core wires.

Table 1 Single-Pass Test Results for 8, 16.75. 18, and 24 Inch Root Diameter Sheaves (November 2-5, 2004)

Conductor Tension (% of RTS)	Root Diameter of Sheave and Break-Over Angle					
	8 Inch		16.75 Inch	18 Inch		24 Inch
	12 degree	20 degree	20 degree	33 degree	45 degree	45 degree
5	No broken wires	No broken wires	No broken wires	No broken wires	No broken wires	No broken wires
10	No broken wires	No broken wires	No broken wires	No broken wires	No broken wires	No broken wires
15	No broken wires	No broken wires	No broken wires	No broken wires	No broken wires	No broken wires
20	No broken wires	No broken wires	No broken wires	No broken wires	No broken wires	No broken wires
25	No broken wires Note: made 2 passes	Broken wires	No broken wires	No broken wires Note: 1 wire broke on a 2nd pass	5 Broken wires	No broken wires

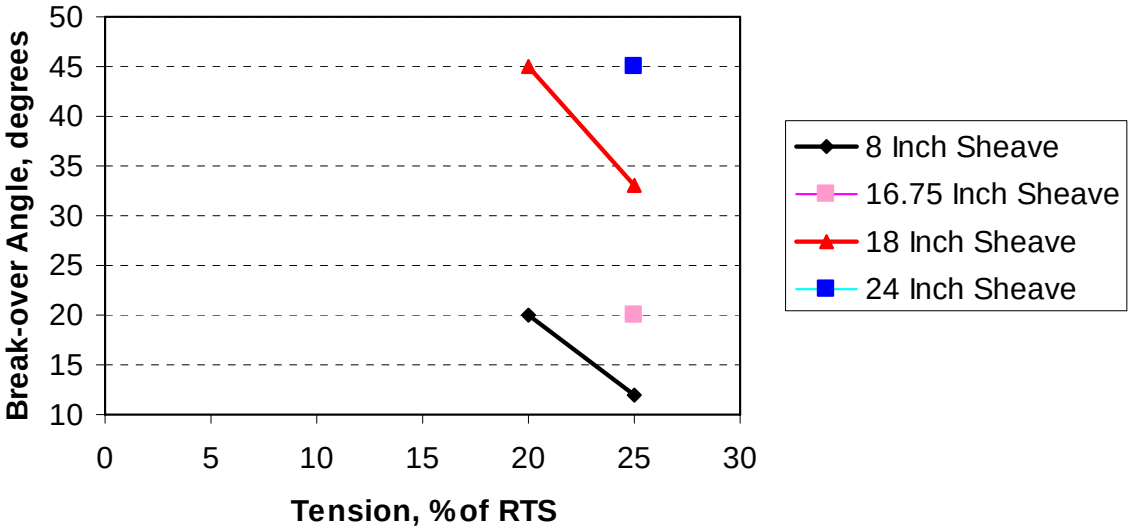


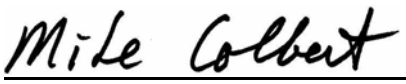
Figure 2 Threshold Curves for the 8, 16.75, 18, and 24 Inch Root Diameter Sheaves. Single Pass Test, November 2-5, 2004
(Results from Table 1 – based on a single pass with no broken core wires)

SUMMARY

The results from the Single-Pass Tests for the 8 inch root diameter and 18 inch root diameter sheaves showed good correlation between conductor angle over sheave and conductor tension.

All four sheaves tested reached 25% of the conductor RTS at a specified break-over angle with no damage to the conductor. The 25% RTS tension was sustained by using a 24-inch (root) diameter sheave for a 45° break-over angle, a 18-inch (root) diameter sheave for a 33° break-over angle, a 16.75-inch (root) diameter sheave for a 20° break-over angle, and a 8-inch (root) diameter sheave for a 12° break-over angle. This provides useful angle per sheave information for the design and further testing of sheave and multi-sheave configurations for 590TW ACCR.

Prepared by:



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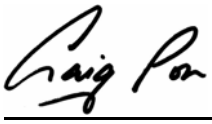

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DISCLAIMER

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 590TW KCMIL ACCR/TW COMPOSITE CONDUCTOR

3M Composite Conductor Specification

Conductor Physical Properties		
Designation		ACCR-TW_590-T13
Stranding		20/7
kcmils	kcmil	590
Diameter		
indiv Core	in	0.105
indiv Al	in	0.172
Core	in	0.31
Total Diameter	in	0.86
Area		
Al	in^2	0.463
Total Area	in^2	0.524
Weight	lbs/linear ft	0.644
Breaking Strength		
Core	lbs	11,519
Aluminum	lbs	9,535
Complete Cable	lbs	21,054
Modulus		
Core	msi	31.4
Aluminum	msi	8.2
Complete Cable	msi	10.9
Thermal Elongation		
Core		6
Aluminum		23
Complete Cable		17
Heat Capacity		
Core	W-sec/ft-C	13
Aluminum	W-sec/ft-C	240
Conductor Electrical Properties		
Resistance		
DC @ 20C	ohms/mile	0.1495
AC @ 25C	ohms/mile	0.1530
AC @ 50C	ohms/mile	0.1682
AC @ 75C	ohms/mile	0.1833
Geometric Mean Radius	ft	0.0412
Reactance (1 ft Spacing, 60hz)		
Inductive Xa	ohms/mile	0.3871
Capacitive X'a	ohms/mile	0.0988

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

APPENDIX B
INSTRUMENT SHEET
3M SHEAVE TESTS on 590 kcmil ACCR/TW CONDUCTOR

Test Description: 3M Sheave Tests on 590 kcmil Conductor
Project Number: 422121
Test Start Date: November 2, 2004
Test Finish Date: November 5, 2004

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	CCC6EE	±0.1% of reading	January 9, 2004	January 9, 2005	Data Acquisition
	Load Cell	Eaton	3124	17952-0	±1% of reading	December 17, 2003	December 17, 2004	Conductor Tension (Sheave)
	Load Conditioner	Daytronics	3170	11148-0				
	Digital Protractor	Mitutoyo	Pro 3600	19693-0	0 to -0.1 degree	January 7, 2004	January 7, 2005	Conductor Angle (Sheave)

DISTRIBUTION

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