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respectively. The results of the endurance test suggest that the combination of thermal and mechanical stresses do not cause a reduction in mechanical strength of the Tokyo Rope core ACCS C^7 conductor or conductor-connector assemblies.

Table 3-8. Summary of Southwire conductor's performance

Composite	Test temp	Endurance test	Breaking Load test
Celanese/ Southwire (2015)	180±5°C	Pass	Pass (UTS equal to 124.1% RBS)
Celanese/ Southwire (2016)		Fail (Core failed after 300 cycles by pull-out- insufficient radial gripping strength of the connector on the core)	N/A
Celanese/ Southwire (2017)		Pass	Fail (93.8% RBS due to dead-end connector pull-out)
Tokyorope/ Southwire (2020)		Pass	Pass (UTS equal to 106.6% RBS)

Nexans CFCC (Lo-Sag)

This chapter describes the qualification test conducted on a Nexans carbon fiber composite core conductor. The technical specification of the conductor is provided in Table 3-9.

Table 3-9. Technical specification of Nexans conductor

Conductor	Type	Core	Aluminum	Overall Diameter	Kcmil	Core Diameter	RBS (lbf)	Connectors
Nexans	Lo-Sag CFCC	Single Carbon Fiber Core surrounded by Plastic Sheathe	Two layers of 22 fully annealed trapezoidal AL alloy strands	1.06 inch (27 mm)	920.5	7.7 mm	22,930	Dervaux

Endurance Test

The Nexans Lo-Sag CFCC test conductor passed 500 thermo-mechanical cycles and underwent the breaking load test afterwards.

The conductor's Breaking Load Test results are as follows:

1. The Nexans Lo-Sag CFCC test conductor broke at 29,617 lbf (13,434 kgf), which is equal to 129.2% of conductor's RBS. The test conductor broke 0.13 m from mouth of compressed dead-end. This is shown in Figure 3-20.

2. The Nexans Lo-Sag CFCC dummy conductor broke at 31,442 lbf (14,262 kgf), which is equal to 137.1% of conductor's RBS. The dummy conductor broke at the mouth of the epoxy resin dead-end. This indicates that the Nexans Lo-Sag CFCC conductor may withstand even higher loads if the resin termination would permit.

It can be seen from the above results that the test and dummy conductors breaking load significantly exceeded the RBS value (129.4% and 137.1% of the RBS) for Nexans Lo-Sag CFCC conductor. The Thermo- Mechanical Cycling Test and 70% of the RBS holding test did not affect the Nexans Lo-Sag CFCC test conductor strength or the conductor's breaking load is rated very conservatively.

Except for loosened annealed aluminum strands of the outer layer, no visible conductor deterioration was noticed. The loosening of the outer aluminum strands was more articulated near compression dead-ends of the dummy conductor. Figure 3-21 demonstrates the condition of the Nexans Lo-Sag CFCC test conductor on completion of 500 thermo-mechanical cycles.

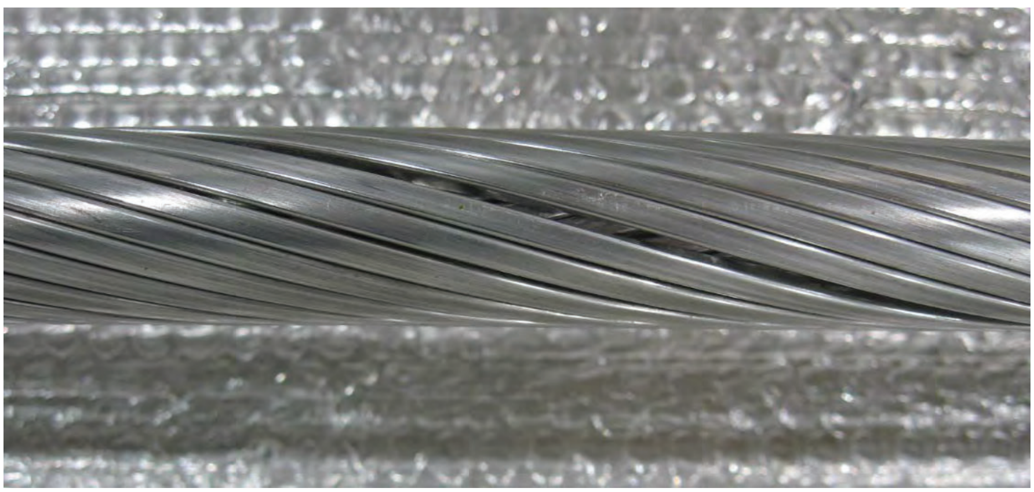

Figure 3-18. Section of Nexans Lo-Sag CFCC test conductor after 500 thermo-mechanical cycles

The overall temperature measurements taken from the compression connectors used in the test. show that while the temperature of dead-end connector pads was in the range of ~43°C to 50°C, the Nexans Lo-Sag CFCC conductor entrance (mouth) of the dead-end was running at higher temperatures of ~69°C to 80°C. As expected, areas located further from the electrical contact zones - the eye-bolt crimp and pad - ran cooler during the entire length of the test. Towards the end of the test, the dead-end connectors displayed slightly higher temperatures in general.

The high temperature Thermo-Mechanical Cycling Test was performed to demonstrate the 467.24 mm^2, Lo-Sag conductor performance during high temperature operation. The results demonstrate that the combination of 70% RTS holding period and thermo-mechanical cycling for 500 cycles does not degrade the strength of the Nexans Lo-Sag CFCC conductor below 100% RTS as evaluated. The Nexans Lo-Sag CFCC test conductor did not break during the Thermo-Mechanical Cycle Test. The Nexans Lo-Sag CFCC test conductor and the dummy conductor had significantly higher breaking strength compared to the published breaking load of the conductor.

Initial and Final Characterization of the Composite Core – Diagnostic Tests

Two tests were done in the case of Nexans conductors. Tg measurement and bending mechanical test to analyze the limit to the practical operating temperature and mechanical performance of the conductors.

T_g Test

Table 3-10. DMA Results for the Nexans Core

Section	Tg (°C)
Initial	240.48± 1.26
Final	239.84± 0.86

Table 3-10 shows both initial and final DMA results of Nexans core. The initial and final Tg values before and after aging tests were found to be almost the same suggesting that the temperature range suggested as the maximum operating temperature is probably accurate for this conductor.

Bending Mechanical Test

The result of the initial and final bending mechanical test of Nexans Lo-Sag CFCC conductor sample is shown in Table 3-11. The overall results of mechanical measurements indicate there is no change in the properties of the conductor, taking the experimental tolerance into consideration.

Table 3-11. Nexans Lo-Sag CFCC bending mechanical test results

Sample	Max Stress (MPa)	Max Deflection (mm)	E (GPa)
Initial	731.8±15.98	1.792±0.056	53.78±0.96
Final	852.6±26.66	2.0925±0.08	53.67±0.89

Summary

Table 3-12. Summary of Nexans Lo-Sag CFCC conductor's performance

Composite	Test temp	Endurance test	Breaking Load test	Tg and Bending mechanical test
Nexans (2011)	180±5°C	Pass	Pass (UTS equal to 129.4% RBS)	Pass Tg(final)-Tg(initial) ~1°C

Mercury Cable HVCRC (2010)

In this test, the conductor HVCRC was installed and subjected to the same thermal and mechanical stresses as CTC conductor. It was the first qualification test undertaken on the Mercury cable conductor. The technical specifications of the conductor are provided below.

Table 3-13. Technical specifications for Mercury cable conductors

Conductor	Type	Core	Aluminum	Overall Diameter	Kcmil	Core Diameter	RBS (lbf)	Connectors
Mercury Cable / GC	HVCRC/ TW	Single composite glass and fiber core	Two layers of 22 fully annealed trapezoidal AL alloy strands	1.108 inch (28.15 mm)	1020	9.53 mm	41,000	FCI/Burndy

Endurance Test

The HVCRC/TW test assembly completed 100 thermo-mechanical cycles. The HVCRC/TW test conductor had about 7-10°C lower steady-state temperature (190-193 °C) then the ACCC/TW conductor. This might be since HVCRC/TW conductor had loose strands in the outer layer because of forward crimping compression dead-ends. During tensioning the HVCRC/TW test assembly to 70% RBS (28,700 lbf), the test tension dropped suddenly to zero. The HVCRC/TW conductor was not pulled apart, but a cracking sound was noticed at the south compression dead-end along with carbon fiber odor. It was suspected that the composite core slipped in the south dead-end. After this, this test assembly was removed from the test program, and it was dissected.

Photo showing the HVCRC/TW conductor and core condition taken after 100 thermo-mechanical cycles is given in Figure 3-22. No bird caging was noticed during the first 100 thermo-mechanical cycles. The core was not broken or cracked between compression dead-ends. The color of the core did not change significantly (like the core in new condition) after being exposed to 100 thermo-mechanical cycles.