Testing of THERMOLIGN® Suspension Assembly

For

477-kcmil 3M Brand Composite Conductor

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Scope

This report will cover the description and results of laboratory testing of PLP's THERMOLIGN® Suspension and 477-kcmil 3M™ Composite Conductor (also called ACCR – Aluminum Conductor Composite Reinforced) manufactured by 3M.

The specific tests included in this report are:

- Aeolian Vibration Test
- Galloping Test
- Turning Angle Test
- Sustained Heat Test
- High Voltage (Corona) Test

The results for each test are reported separately.

Aeolian Vibration Test

The purpose of this testing is to demonstrate that the Suspension Assembly will protect the ACCR conductor when it is subjected to the dynamic, wind induced bending stress that are associated with aeolian vibration. It is well understood in the industry that conductors strung under tension will vibrate in standing waves when subjected to laminar wind flows in the range of 2 to 12 miles per hour. Within the span itself, this vibration activity has little or no influence on the conductor. However, at the structures where the conductors are supported, this vibration activity produces bending stresses. The peak-to-peak amplitude of the vibration is generally less than the diameter of the conductor itself, but over a number of years, if not properly protected, the conductor can experience fatigue failures. The field failure experience with various suspension assemblies on ACSR (Aluminum Conductor Steel Reinforced) conductors is well documented (e.g. Aeolian vibration of overhead transmission line cables: endurance limits Braga, G.E.; Nakamura, R.; Furtado, T.A.;Transmission and Distribution Conference and Exposition: Latin America, 2004 IEEE/PES, 8-11 Nov. 2004 Page(s):487 – 492). Laboratory aeolian vibration testing at higher levels of activity is commonly used to demonstrate the effectiveness of suspension assemblies under controlled and accelerated conditions.

There is no published industry test specification for aeolian vibration testing of conductors in the laboratory. However, a laboratory specification has been established by the IEEE for the vibration testing of Optical Ground Wire (OPGW). This specification is IEEE 1138. The testing of the ACCR conductor will be in accordance with this specification.

The laboratory test arrangement consisted of a 30 meter span of 477 ACCR conductor, terminated at each end with a PLP Dead-End Assembly (Figure 1). The Suspension Assembly was installed on the span at the mid-point, and secured to a laboratory tower. The Suspension Assembly was elevated to simulate a sag angle consistent with standard field spans. During the test, the tension was maintained at 25% RBS (4,685 lbs) using a tension beam/weight basket assembly. A vibration shaker was used to initiate and maintain a vibration at a frequency of 38 hertz, with an amplitude of 0.29" peak-to-peak, for a period of 100 million cycles (30 days). Visual observations were made twice daily of the ACCR conductor and Suspension Assembly.

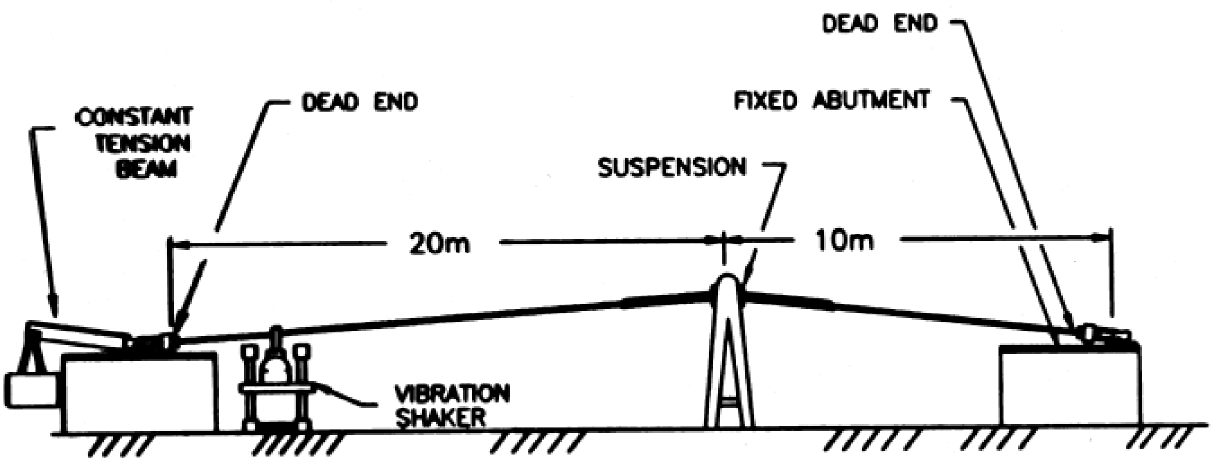

Figure 1 – Aeolian Vibration Test Arrangement

At the completion of the test period the Suspension Assembly was removed and carefully inspected for wear or other damage. The section of the conductor within the Suspension Assembly was cut out of the span and dissected to determine the condition of the Al-Zr strands, the aluminum tape and the composite core.

Figure 2 – Outer Strands & Aluminum Tape After Aeolian Vibration Test

Figure 3 – Core After Aeolian Vibration Test

After 100 million cycles of severe aeolian vibration activity there was no wear or damage observed on the components of the Suspension Assembly, on the Al-Zr outer strands, nor on the composite core (see Figure 2 and Figure 3).

Simulated Galloping Test

The purpose of this testing is to demonstrate that the Suspension assembly will protect the ACCR conductor when it is subjected to the potentially high bending stresses associated with conductor galloping. Conductor galloping is generally associated with a coating of ice or wet snow on the conductor. This coating usually forms on the windward side of the conductor surface, creating an aerodynamically unstable profile. Moderate to high winds blowing across the iced conductor can cause the conductor to lift. As the conductor lifts, it rotates slightly, changing the aerodynamic profile, allowing the conductor to fall. This lift/fall action generally "locks" into the fundamental (single loop) natural frequency of the span or into one of the first few natural frequencies (double or triple loop). The resulting motion can be at very large amplitudes, which can produce damaging bending stresses at the conductor support locations.

Galloping is a very random occurrence in the field, and therefore must be simulated in the laboratory. However, as with aeolian vibration, there have been no industry test specifications established for conductors. The IEEE has however, established a laboratory galloping test for Optical Ground Wire (OPGW) as part of IEEE 1138, which will be used for the ACCR.

The laboratory test arrangement consisted of two 25 meter spans of 477 ACCR conductor, terminated at each end with a PLP Dead-End Assembly. The Suspension Assembly was installed on the span near the 1/3rd-point, and secured to a laboratory tower. The Suspension Assembly was elevated to simulate a sag angle consistent with standard field spans (Figure 4). During the test, the tension was maintained at 8% RBS (1560 lbs) using a tension beam/weight basket. An offset crank mechanism (see Figure 5) was attached to the conductor to drive the span into its fundamental (single loop) natural frequency (1.8 hertz, in this case). A peak-to-peak amplitude of 39" was maintained for a period of 100,000 cycles (15.4 hours).

At the completion of the test period the Suspension Assembly and the section of the conductor within the Suspension Assembly were dissected to determine their condition. After 100,000 cycles of galloping activity there was no wear or damage to the components of the Suspension Assembly or to the components of the ACCR conductor.

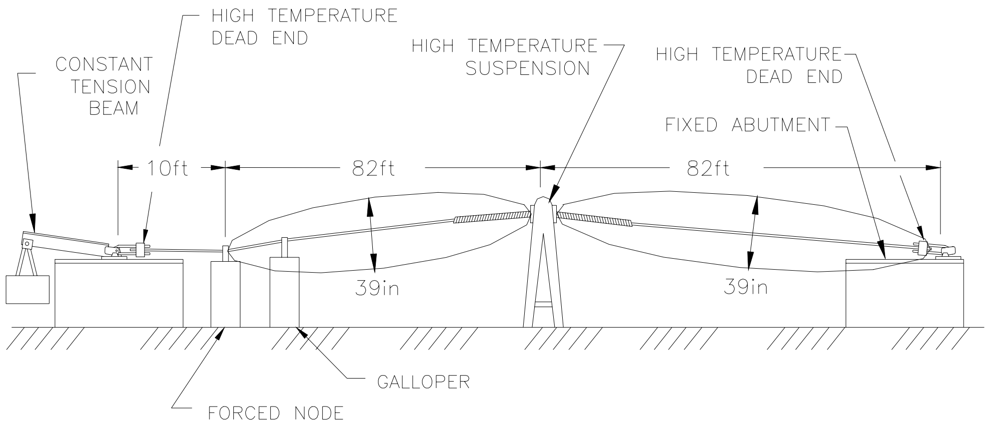

Figure 4 – Galloping Test Arrangement


Figure 5 – Offset Crank Mechanism

Turning Angle Test

It is common practice in the industry to utilize Suspension Assemblies on non-tangent applications for line angles up to and including 30 degrees. For these applications, the supporting structures are configured to allow the insulator string to rotate off of the vertical towards the inside of the angle in the line. The transverse center line of the supporting structure is positioned so that the line angle is split into equal amounts on either side. This produces a balanced turning angle on the Suspension Assembly (15 degrees on each side).

In the laboratory, the turning angle is simulated in the 55K Tensile Equipment. The Suspension Assembly is attached to a tall tower, which is secured to the tensile equipment test frame (see Figure 6).

Figure 6 – Turning Angle Test

For the laboratory turning angle test on the 477 Suspension Assembly, the sample was subjected to a balanced turning angle of 32° and an axial tension is applied to the conductor. The load and angle was held for 5 minutes. Two separate tests were run at tensions of (i) 11,685 lbs (5311 kg) (60% RBS), and (ii) 17,485 lbs (7948 kg) (90% RBS).

At the completion of each test, both the Suspension Assembly and the Conductor were entirely dissected. No damage or distortion was observed on any of the components of either test.

The suspension assemblies are rated for turning angles of approximately 30° (maximum 34°). For angles greater than this, in the range of 30-60°, a double suspension assembly is recommended.

Elevated Temperature Profile

The purpose of this test is to demonstrate that the performance of the Suspension Assembly will not be affected by continuous operation at an elevated temperature. Specifically, by exposure to temperatures above 200°C.

The test span consisted of a 65 ft length of 477 ACCR conductor, terminated at both ends with a PLP Dead-End Assembly. The conductor was heated by applying approximately 1,000 Amps of AC current, supplied by a pair of heavy duty power supplies.

Thermo-couples were mounted to the conductor and to locations on and within the Suspension Assembly. The maximum temperatures recorded during the test period are shown in Table 1.

Location	Max. Temperature
Conductor	215°C
Under Elastomer Insert	36°C
Structural Rods	118°C
Ear of Housing	31°C

Table 1. Maximum Temperatures recorded on a 477 ACCR Suspension Assembly

The maximum temperatures shown in Table 1 are well below the maximum rated temperatures of the individual components of the Suspension Assembly. Furthermore, there was no observed deformation or damage to any of the Suspension Assembly components as a result of the sustained heat exposure.

High Voltage (Corona) Test

The purpose of this testing is to verify that the 477 ACCR conductor Suspension Assembly from PLP will have acceptable performance when subjected to typical transmission line voltages.

The testing was conducted at the NEETRAC indoor high voltage laboratory.

The 477 ACCR Suspension Assembly was installed on a 20' length of 0.840" diameter tubing to simulate the conductor (see Figure 7). The Suspension and tubing were positioned at 12 feet above the ground plane.

Based on both visual observations and radio interference voltage (RIV) measurements, corona onset for the Suspension Assembly was at 255 KV (phase to phase).

For a single conductor configuration, a 477 conductor would be commonly used on lines operating at voltages up to 169 KV. The results of these high voltage tests show that the electrical performance of the Suspension Assemblies is acceptable for these applications. Further, the results allow us to conclude that these Suspension Assemblies will have acceptable electrical performance if used in a twin configuration at 230 KV.

Figure 7 – Corona Test Arrangement for Suspension Assembly

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