Testing of THERMOLIGN® Suspension Assembly

For

1272-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 1272-kcmil 3M Brand Composite Conductor (also known as ACCR – Aluminum Conductor Composite Reinforced) manufactured by 3M.

The specific tests included in this report are:

- Aeolian Vibration Test
- Galloping Test
- Room Temperature Tensile Test (Sample from Galloping Test)
- Unbalanced Load Test
- Turning Angle Test (795 kcmil ACCR)
- Room Temperature Tensile Test (Conductor from Phoenix Installation)

The results for each test are reported separately.

Aeolian Vibration Test

The purpose of this testing is to demonstrate that the conductor accessories will protect the ACCR conductor when it is subjected to dynamic, wind induced bending stresses. 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 or dead-ended, this vibration activity produces bending stresses. The peak-to-peak amplitude of the vibration of the conductor in the span 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 conductor accessories 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 accessories 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 IEEE 1138.

The laboratory test arrangement for the aeolian vibration testing of the 1272 ACCR Suspension Assembly consisted of a 30 meter span of conductor with a Dead-End Assembly applied to each end, and a Suspension Assembly applied to the center of the span and secured to a rigid tower (Figure 1). During the test, the tension in the conductor was maintained at 25% RBS (10,919#)

using a tension beam/weight basket. A vibration shaker was used to initiate and maintain a vibration at a frequency of 23.7 hertz, with an amplitude of 0.46” peak-to-peak for a period of 100 million cycles (49 days). Visual Observations were made daily of the ACCR conductor and the Dead-End and Suspension Assemblies.

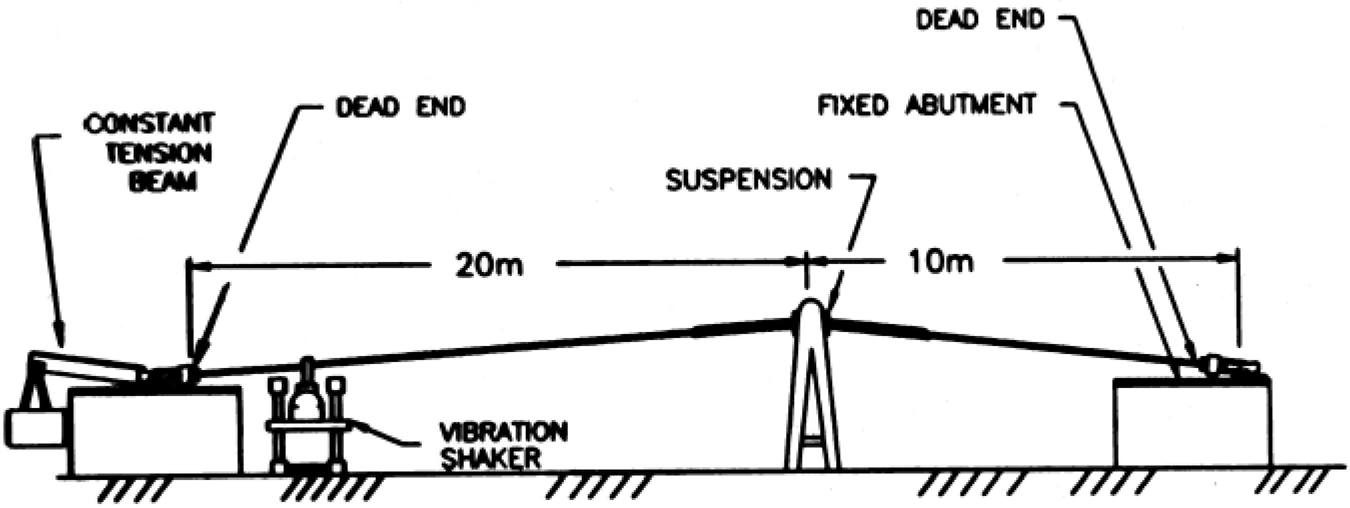

Figure 1 – Aeolian Vibration Test Arrangement

At the completion of the test period the Suspension Assembly was removed and carefully inspected for wear or other damage. The section of the 1272 ACCR Conductor at the Suspension Assembly was cut out of the span and dissected to determine if any wear or damage had occurred to the Al-Zr outer strands, the aluminum tape or to the composite core.

After 100 million cycles of severe aeolian vibration activity there was no wear or damage observed on the components of the ACCR Conductor, however, three outer rods of the Suspension Assembly were cracked.

The cracking of the Suspension Assembly rods was not related to any weakness in the material. It was a result of the severity of the test parameters, which were extrapolated from the testing for a much lighter OPGW (IEEE 1138).

The apparent bending strain on the ACCR conductor during this test remained well below the conductor’s endurance limit. This demonstrates that even if excessive vibration were present in the field, the Suspension Assembly will protect the conductor. Broken outer rods in the Suspension Assembly can be easily detected during routine line inspections, and can be easily replaced.

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 a 30 meter span of 1272 ACCR conductor, terminated at each end with a PLP Dead-End Assembly (Figure 1). 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. During the test, the tension was maintained at 8% RBS using a tension beam/weight basket. An offset crank mechanism (see Figure 3) was attached to the conductor to drive the longer 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 carefully inspected 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.

This sample will be tensile tested to demonstrate that the severe galloping activity will not result in any reduction in strength of the conductor at the Suspension Assembly location.

Room Temperature Tensile Testing (1272 Sample from Galloping Test)

The Galloping Test of the 1272 Suspension Assembly was reported above. The ACCR conductor and Suspension Assembly were subjected to 100,000 cycles (15.4 hours) of single loop galloping at an amplitude of 39" in the 30 meter active span.

After the Galloping Test, the Suspension Assembly was removed, and the conductor was visually inspected for signs of damage. However, the conductor was not dissected. Instead, it was tensile tested at room temperature to verify that there was no loss of strength due to the galloping activity.

After applying new Dead-End Assemblies to both ends of the conductor sample, it was loaded to failure. At a load of 45,122# (103% RBS), the conductor failed. The failure location was not within the area that the Suspension Assembly had been applied.

Unbalanced Load Test

The purpose of this testing is to demonstrate that the Suspension Assembly will protect the ACCR conductor at a support location which is subjected to unbalanced tension loading. By using roller type stringing blocks, the horizontal tension component of the conductor on both sides of a suspension tower are equal when the Suspension Assembly is installed. However, if ice or wet snow builds-up on the conductors and falls off of one span before the other, a substantial unbalance of the tensions on either side of the suspension can occur. The Suspension Assembly will rotate from its vertical position towards the higher tension. A similar condition will exist at the suspension towers adjacent (in both directions) to a broken conductor.

To simulate the effects of unbalanced loading in the laboratory, a 30 ft. span of 1272 ACCR was terminated at one end with a PLP Dead-End Assembly and attached to the hydraulic ram of the 55K Tensile Equipment. The Suspension Assembly was installed near the far end of the span in an inverted position, and secured to a short tower on the tensile equipment test frame (Figure 2).

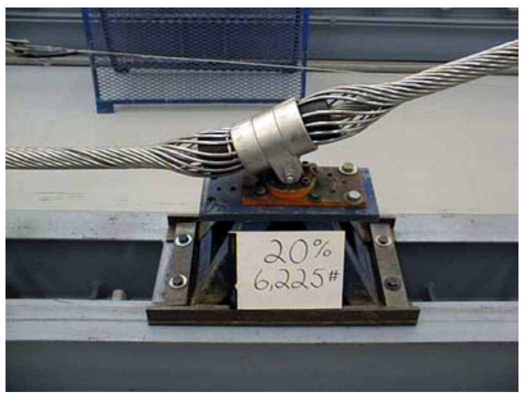

Figure 2 – Unbalanced Load Test Arrangement

The unbalanced load is applied to the conductor in increments of 5% of the RBS , until a continuous slip at the Suspension assembly occurs. Each load increment is held for 5 minutes. As the unbalanced load increases, the angle of rotation of the Suspension Assembly on the attachment plate also increases. Specifically, the tilt angle was 14 degrees for a 5% load, and 18 degrees for a 10% load.

Continuous slipping of the conductor relative to the Suspension Assembly occurred at 10% RBS. Afterward, the conductor and Suspension Assembly were dissected, and no damage was observed on any of the conductor or Suspension Assembly components.

Turning Angle Test (795 kcmil ACCR)

The 30° turning angle test was not performed on the 1272 kcmil ACCR conductor because of previously successful testing on the 477 kcmil and 795 kcmil sizes. The results of the 795 kcmil test is presented here for information purposes.

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 3).

Figure 3 – Turning Angle Test

For the laboratory turning angle test on the 795 Suspension Assembly for the ACCR conductor, the sample was subjected to a balanced turning angle of 32°, at a conductor tension of 12,460# (40% RBS). The load and angle was held for 5 minutes.

At the completion of the test, the Suspension Assembly and the conductor were dissected, and no damage or distortion was observed on any of the components.

Room Temperature Tensile Testing (1272 Conductor from WAPA Phoenix Installation)

To verify that the equipment and procedures used during the WAPA Phoenix installation did not affect the strength of the conductor, conductor samples were removed from the bottom phase. The first sample was cut out between the Bull Wheel and the first dead-end structure (Figure 4). The second sample was removed from the section of conductor at the second dead-end structure between the Sheave Wheel and the Puller (Figure 5). There was a steep break over angle at the stringing block at this location. The ends of the conductor samples were secured with clamps prior to cutting, and carefully loaded onto a reel for shipping back to PLP for testing.

New PLP Dead-End Assemblies were installed on both ends of each 50' +/- conductor sample.

The maximum load for the conductor adjacent to the Bull Wheel was 44,959# (103% RBS). For the conductor adjacent to the Puller, the maximum load was 45,233# (103% RBS).

Figure 4 – Bull Wheel

Figure 5 – Puller (Tensioner)

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Disclaimer

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