Testing of THERMOLIGN® Dead-End

For

477-kcmil 3M™ Composite Conductor

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Scope

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

The specific tests included in this report are:

- Room Temperature Tensile Test
- Sustained Load Test
- Sustained Heat Test
- Aeolian Vibration
- High Voltage Corona Test

The results for each test are reported separately.

Room Temperature Tensile Test

A series of tests were conducted to verify the room temperature holding strength of the PLP Dead-End Assembly for 477 ACCR . For these tests a length of 477 ACCR conductor was terminated at both ends with a PLP Dead-End Assembly. The overall length of the test samples was about 25 ft (7.6 m). The samples were placed in a 55K Tensile Test Machine (see Figure 1), and loaded at a rate of 10,000# per minute. In all tests the conductor failed completely in the mid-span. The load values at failure are shown in Table 1.

Figure 1. Test set-up for Tensile Test

Sample	Max. Load (lbs)	% RBS	Location of Failure
1	20,214	104	Mid-Span
2	21,222	109	Mid-Span
3	20,846	107	Mid-Span

Table 1 – Room Temperature Tensile Testing of
477 Dead-End Assembly

Sustained Load Test

The purpose of this test is to demonstrate that the Dead-End Assembly will hold at a high tension level (77% RBS) at room temperature for an extended period of time (168 continuous hours) per ANSI C119.4. This test also provides the opportunity to measure short term creep data for the conductor. The test was actually run for 212 hours.

The test span consisted of a length of 477 ACCR, terminated at both ends with a PLP Dead-End Assembly. The overall span length was 50 ft. The tension was applied and maintained throughout the test period using a constant tension beam arrangement. A gage length of 25 ft. was established at the beginning of the test to measure the elongation (creep) of the conductor at various times throughout the test period (see Table 2).

Hours	Elongation
168	0.079%
212	0.081%

Table 2 – Elongation (Room Temperature)

After the completion of the 212 hour test period, there was no observed slippage of the Dead-End Assembly on the conductor and no observed damage to either the conductor or Dead-End Assembly.

The span of conductor with Dead-End Assemblies was than tensioned until a failure occurred. At a load of 20,980# (108% RBS), the conductor completely failed in mid-span.

Sustained Heat Test

The purpose of this test is to demonstrate that the performance of the conductor Dead-End will not be affected by continuous conductor operation at an elevated temperature. Specifically, after being exposed to 240°C for a period of 168 hours.

The test span consisted of a 65 ft (19.8 m) length of 477 ACCR Conductor, terminated at both ends with a PLP Dead-End Assembly and cut and spliced at mid-span with a PLP Splice Assembly. A tension of 15% RBS (2915 lbs) was maintained throughout the test using a tension beam/weight basket (see Figure 2). The conductor was heated by applying approximately 1,000 Amps of AC current, supplied by a pair of heavy duty power supplies (see Figure 3).

Figure 2 – Sustained Load Test Arrangement

Figure 3 – Dual Power Sources

Thermo-couples were mounted to the conductor and to locations along one dead-end to monitor temperature. With the conductor at 242°C, the maximum temperature on the dead-end elements remained at 140°C or below. This was recorded on the single layer of structural rods that extended beyond the second layer of rods. The maximum temperature recorded at the attachment point Clevis Pin was 27°C.

After completion of the 168 hour test period at 240°C, the complete sample was removed from the Heat Test Area and installed in the 55K Tensile Equipment to determine the maximum load at failure.

When loaded at a rate of 10,000# per minute, the conductor broke at mid-span (between one Dead-End and the Splice) at a load of 20,666 lbs (106% RBS). During this test, there was no slippage of or damage to the PLP Dead-End Assemblies or the PLP Splice Assembly. The failure of the conductor is shown in Figure 4.

Figure 4 – Mid-Span Failure of Conductor

Aeolian Vibration

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 conductors is well documented. 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 477 ACCR Dead-End Assemblies consisted of a 30 meter span of conductor with a Dead-End Assembly applied to each end. During the test, the tension in the conductor was maintained at 25% RBS (4857 lbs) using a tension beam/weight basket. A vibration shaker was used to initiate and maintain a vibration at a frequency of 33 hertz, with an amplitude of 0.29" peak-to-peak for a period of 100 million cycles (35 days). Visual Observations were made daily of the ACCR conductor and the Dead-End Assemblies.

At the completion of the test period the Dead-End Assemblies were removed and carefully inspected for wear or other damage. The section of the 477 ACCR Conductor at the Dead-End Assemblies 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 Dead-End or on the components of the ACCR Conductor (See Figures 5 & 6).

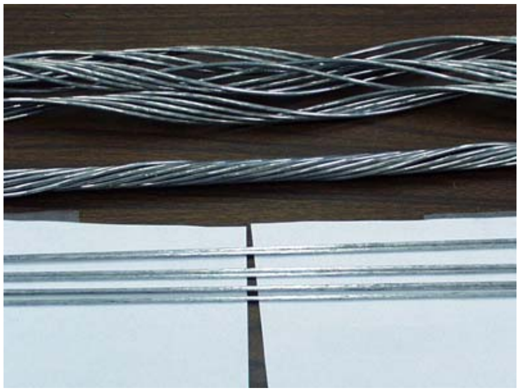

Figure 5 – ACCR Components After Testing

Figure 6 – Dead-End After Testing

High Voltage (Corona) Testing

The purpose of this testing is to verify that the 477 ACCR Dead-End 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 Dead-End Assembly was installed over a 0.835" diameter smooth pipe, and suspended vertically from an insulator, with the ends of the Inner Structural Rods positioned at about 16 feet above the ground plane (floor).

One Dead-End Assembly was tested with standard cut and de-burred rod ends, and a second assembly was tested on which the rods ends were "ball ended" as shown in Figure 7.

Figure 7 – Ball End Rod Treatment

With the ball end treatment, the assembly was corona free to a line to ground voltage of 170 KV (which is equivalent to a phase to phase voltage of 294 KV). Based on this testing, PLP will produce all Dead-End Assemblies with ball-end rods for applications up to and including 230 KV. For 345 KV applications a parrot-bill rod end treatment will be used. This is the same rod treatments and application guidelines currently being used for PLP's ARMOR-GRIP® Suspensions and Armor Rods.

Acknowledgement

This material is based upon work supported by the U.S. Department of Energy under Award No. DE-FC02-02CH11111.

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