

Advanced Conductor Testing – 1098 kcmil TS AECC Ruddy

Fire Testing Processes and
Performance Results

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1. Background

The United States electric grid is undergoing a transformative period as utilities and policymakers work to ensure reliable energy delivery to ever-growing loads such as data centers. A large barrier to achieving these goals is the expansion of transmission capacity. To address this issue, utilities are turning to advanced conductor technologies as a short- to mid-term solution to increase grid capacity and reliability without the need for full-scale infrastructure rebuilds, prior to any new infrastructure builds.

Advanced conductors represent a significant evolution in transmission line technology. These conductors utilize innovative materials, such as composite cores, ultra-high-strength steel, and heat-dissipating coatings, to offer improved performance compared to traditional Aluminum Conductor Steel Reinforced (ACSR) designs. By reducing sag at high temperatures, increasing current-carrying capacity, and enhancing durability, advanced conductors provide a cost-effective and efficient option for reconductoring existing transmission lines. This approach allows an increased capacity while maintaining existing structures, saving time and resources compared to constructing new transmission lines. However, the deployment of these technologies has so far been limited. As each conductor comes with nuances in test setup and specifications, a standard test is not readily available to apply to all advanced conductors. Idaho National Laboratory's (INL) Advanced Conductor Testing project, sponsored by the Department of Energy (DOE) Office of Cybersecurity, Energy Security, and Emergency Response (CESER) and Office of Electricity (OE), focuses on developing and implementing testing protocols and plans for advanced conductor technologies to assess and demonstrate physical performance under varying operational conditions, including extreme environmental stressors such as wildfires.

Wildfires pose a significant and growing threat to the reliability and safety of the electric grid. Overhead conductors are particularly vulnerable to fire exposure, which can cause material degradation, structural damage, and system faults. To address these risks, the Idaho National Laboratory (INL) has undertaken fire testing to evaluate the mechanical performance of advanced conductors under controlled fire conditions. This testing is critical to understanding the behavior of advanced conductor materials when exposed to high temperatures and flames, as well as their ability to maintain mechanical integrity after exposure.

By advancing the understanding of fire exposure performance in advanced conductors, INL's research contributes to the grid's ability to withstand environmental challenges, ensuring the safe and reliable delivery of electricity. This work supports utilities in deploying innovative conductor technologies that align with national energy dominance goals while addressing the unique risks posed by wildfire conditions. This report contains the fire testing results of a 1098 kcmil AECC TS Ruddy Conductor.

2. Wildfire Testing Process

Conductor Preparation and End Attachment:

Conductor preparations were conducted according to procedures developed by project partners at the National Electric Energy Testing, Research & Applications Center (NEETRAC). The preparation of conductors for fire testing was identified as a critical step to ensure accurate and reliable results. For this test, a 1098 kcmil TS AECC conductor was used. The AECC conductor is an aluminum encapsulated carbon core conductor. The first step involved marking the conductor to cut a sample. Duct tape was applied at the desired cut location for 6-foot samples. When cutting an AECC conductor, the specific characteristics of the conductor required the use of the correct tools to achieve the best cut. In this case, a cable cutter was employed to cut the samples. A vertical band saw was also identified as a possible tool but with the strength of the core, it was kept as the second choice. To ensure optimal results, a clean and precise cut was made to minimize damage to the core and outer strands.

After the sample was cut, the conductor was marked approximately 9 inches below the cut, and another piece of duct tape was wrapped around the core. A hose clamp was then placed over the duct tape and tightened to prevent the sample from unraveling. The tape from the first cut, located at the edge of each side of the sample, was removed. Each end of the sample was then broomed out, meaning the strands were unraveled and spread in a broom-like fashion from the edge up to the duct tape and hose clamp. This step created space to access the core without pulling the strands past the tape or causing a 90-degree bend. The aluminum strands and core of the AECC conductor were cleaned using a heavy-duty degreaser to remove any oils, grease, or other contaminants from the conductor surface.

Once the conductor was cleaned, a 1-1/8-inch-thick steel pipe with an inner diameter of 5/8 inch was cut into a 7-inch-long section and slid over the carbon core of the AECC conductor. A 100-ton hydraulic press was then used to crimp the steel pipe onto the core, providing additional mechanical strength for the epoxy dead-end assembly. To achieve uniform compression, the pipe was rotated 90 degrees after each crimp, and each successive crimp overlapped the previous one by approximately 1/4 inch. During the crimping process, the core extended beyond the top of the steel pipe due to the applied compression. The excess core material was trimmed flush with the end of the steel pipe to produce a uniform surface. After the crimping and trimming operations were complete, the aluminum strands were cleaned once again using a heavy-duty degreaser to remove any contaminants introduced during the preparation process and ensure adequate adhesion between the conductor components and the epoxy during the sample preparation process.

Following the cleaning process, the prepared AECC conductor was carefully placed in resin blocks. To ensure that the epoxy fully encapsulated and gripped the conductor components, care was taken to properly position the conductor within the mold before pouring the epoxy. Epoxy was then poured into the resin block, ensuring complete contact around the prepared conductor assembly.

The epoxy was allowed to dry and cure for a full 24-hour period. This curing time was considered essential to allow the epoxy to achieve its full strength and provide a durable bond for

tensile testing. During the curing period, the sample remained undisturbed in a stable, temperature-controlled environment to ensure proper curing. Once the epoxy had fully cured, the prepared AECC conductor was ready for further testing.

Following the preparation of the first AECC sample, a rated breaking strength (RBS) test was performed to verify that the epoxy dead ends met the manufacturer's specified rated breaking strength prior to wildfire testing.

WildFire Test:

The wildfire testing of the AECC conductor was conducted in a controlled fire chamber designed to replicate the extreme thermal conditions that may occur during a wildfire. The test chamber was equipped with a fire testing table featuring six burners, a 2' x 4' burn area, adjustable height for flame exposure, and thermocouples for precise temperature monitoring. Prior to testing, the epoxy-prepared AECC conductor with resin blocks was carefully hung in the fire chamber at the designated height to ensure proper alignment with the flame source.

The wildfire testing included four separate tests at specific radiant temperature levels: 250°C, 300°C, 350°C, and 400°C. For each test, the conductor was hung at a pre-determined height from the burners to reach the desired radiant temperatures. The burners were then ignited to generate flames/height, and the conductor was exposed to the target temperature for a duration of 20 minutes. Thermocouples recorded temperature data throughout each test. The temperature levels were chosen to represent a range of thermal conditions reflective of wildfire scenarios allowing for a comprehensive evaluation of the conductor's performance. After completion of each test, the conductor was allowed to cool prior to removal from the fire chamber for further analysis.

Rated Breaking Strength (RBS) Test:

Following the fire exposure, a Chant Engineering Horizontal Test Bed was utilized for tensile testing of each sample. This testing was designed to compare the manufacturer's rated breaking strength of the conductor to its actual breaking strength after exposure to fire and elevated temperatures. Prior to conducting the fire tests, one sample was prepared and pulled on the Horizontal Test Bed to ensure that the end attachment procedure was executed correctly and that the conductor could meet the manufacturer's specifications before any thermal stresses were applied. This initial test served as a baseline, verifying the conductor's integrity under standard conditions.

Once the specimen successfully passed the preliminary test, the fire tests were conducted. After experiencing the intense heat and thermal exposure, each conductor was subjected to tensile testing in the horizontal test bed, where it was pulled to failure. This data provides insight into fire exposure effects on the mechanical properties of the conductors, specifically their breaking strength. The results of the RBS tests are essential for evaluating the performance of advanced conductors in wildfire scenarios and assessing their reliability in real-world applications.

AECC Results:

The results of the fire testing and subsequent RBS tests for the 1098 kcmil TS AECC Ruddy conductor can be seen in Table 1. These results provide valuable insights into the performance of advanced conductors under extreme thermal conditions. Table 1 summarizes the key findings,

including the temperature exposure experienced by each conductor sample during the fire tests, as well as the corresponding breaking strength measured after exposure. These results illustrate the impact of fire on the mechanical properties of the conductors and highlight their resilience or vulnerabilities in wildfire scenarios.

In Table 2, you can see the results for the baseline conductor, ACSR, as it is the most widely used conductor in electrical applications. This baseline allows for a comparison of the AECC conductor as an advanced conductor to the ACSR baseline.

AECC	Manufacturer's RBS	RBS @ Failure	(+/-) % of RBS	Pass/Fail
No Temperature	42,510 <u>lbs</u>	46,430 <u>lbs</u>	+9.22%	Pass
250 °C	42,510 <u>lbs</u>	47,390 <u>lbs</u>	+11.48%	Pass
300 °C	42,510 <u>lbs</u>	45,730 <u>lbs</u>	+7.57%	Pass
350 °C	42,510 <u>lbs</u>	44,600 <u>lbs</u>	+4.91%	Pass
400 °C	42,510 <u>lbs</u>	48,510 <u>lbs</u>	+14.11%	Pass

Table 1: 1098 kcmil TS AECC Ruddy results from RBS before and after exposure to wildfire.

ACSR	Manufacturer's RBS	RBS @ Failure	(+/-) % of RBS	Pass/Fail	Notes
No Temperature	31,500 lbs	31,860 lbs	+1.14%	Pass	Deadends – Limited pull to 32k
250 °C	31,500 lbs	35,500 lbs	+12.70%	Pass	Deadends w/o fail
300 °C	31,500 lbs	35,380 lbs	+12.32%	Pass	Deadends w/fail
350 °C	31,500 lbs	34,040 lbs	+8.06%	Pass	Deadends w/fail
400 °C	31,500 lbs	30,460 lbs	- 3.3 %	Fail	Deadends w/fail

Table 2: ACSR results from RBS before and after exposure to wildfire.