Attachment 2 - 3M ACCR Technical Information

3M High Capacity Conductors

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June 30, 2008
Doc. 3342008A

Attn: Rexford Wait
The Nevada Hydro Company, Inc. (TNHC)
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Provided below and in the attached documents for your review is information for your transmission project designated as Talega - Escondido (TE) Project. Please contact me at 818-368-7383 or sljames-king@mmm.com with any questions you may have regarding this quotation. Thank you for your continued interest in 3M ACCR.

Best regards,

Suzanne James-King
Western Regional Account Manager
3M High Capacity Conductor

3M High Capacity Conductor

Talega - Escondido (TE) Project

Project objective

To supply information about the reconductoring and installations of cable and accessories for an overhead transmission line using 3M's ACCR conductor.

Scope of work to be completed

3M – (1) To supply transmission material and accessories (2) To provide technical support to include final design meetings, manufacturing progress reports and on site training for installation crews in addition to on site support during the installation as needed.

The Nevada Hydro Company, Inc. (TNHC) – (1) To supply complete technical requirements for the installation, maintenance, performance and reliability of the installed solution, (2) To verify and comply with all local, state, federal and any other government agency, regardless of jurisdiction, as to the suitability and compliance with said authority, by the installation of the herein offered products and solution, (3) To provide the means to monitor (if so desired) and install the products and solution to include, but not limited to, labor, equipment and other materials required, but not supplied, as part of this information request.

The cost for the materials required for this project will be detailed in a separate correspondence. 3M requires that only accessories designed for high temperature operation from ACA Conductor Accessories, a division of AFL Telecommunications (ACA), or Preformed Line Products Company (PLP) be used.

Attachments:

1) 3M ACCR physical specification
2) Project Summary and ACCR Review

Any purchase order issued for this project will only be accepted after a final review of all the system and installation requirements. Such acceptance is at the sole discretion of 3M. Any information incorporated in this document is for reference only and is based on the information available at the time of the request.

Delivery

If final design and material requirements are established to the satisfaction of both 3M and TNHC and an order is received and accepted on or before August 4, 2008, 3M will deliver the 3M ACCR High Capacity Conductor in four (4) shipments of approximately equal quantity. The prospective delivery dates are: January 5, 2009; February 16, 2009; March 31, 2009; and May 29, 2009.

Attachment 1

Material Specifications for Aluminum Conductor Composite Reinforced (ACCR)

Rev. June 23, 2008 3M ACCR 1033-T13 (Non-Specular) -3M Material Spec

CONFORMANCE TO NATIONAL STANDARDS

All materials provided under this Specification shall conform to the applicable American National Standards Institute (ANSI) C119.4, American Society for Testing and Materials (ASTM) Standards B193, B557, B941, International Annealed Copper Standard (IACS), "IEEE Standard for the Testing of Overhead Transmission and Distribution Line Hardware", and Aluminum Association Guidelines for "A Method of Stress-Strain Testing of Aluminum Conductor and ACSR", and Aluminum Association Packaging Standards.

CONDUCTOR

Physical Characteristics: The ACCR conductor furnished under this specification shall meet all requirements of TABLE A.

Aluminum Strands: Electric butt-welds, cold-pressure welds, and electrical-butt-upset welds may be made during final drawing or in the finished wire per ASTM B941. The decision to use welds is a Supplier option during the manufacturing process. The aluminum strands shall conform to the properties listed in TABLE C.

Conductivity: The minimum conductivity of any individual aluminum strands shall be not less than 60 percent of the International Annealed Copper Standard (IACS).

Aluminum Matrix Core Strands: No joints shall be allowed in the finished composite core strands. The core strands shall conform to the properties listed in TABLE D.

Conductor Stranding: Aluminum strands shall be layed concentrically and tightly so there is no appreciable slackness in the outer layer at temperatures below 100^0 F. The outer layer is right-hand lay. The conductor shall conform to the stranding in TABLE B.

TABLE A: Conductor Properties

Conductor designation	1033 – T13 ACCR
Conductor finish	Non-Specular
Conductor construction	Outer Layer Right-Hand Lay
Nominal conductor size	1036 kcmil (aluminum strands only)
Aluminum strands	54 each
Core strands	19 each
Outer strand material	Aluminum-zirconium alloy
Outer strand shape	Round
Layers of outer strands	3 each
Core material	Aluminum matrix wire
Conductor diameter	1.247 inches (±2%)
Conductor weight	1.134 pounds/foot (±4%)
Rated strength	35,600 pounds
DC resistance @ 20C	0.0859 ohms/mile (±2.5%)
AC resistance @ 25C	0.0879 ohms/mile (±2.5%)
AC resistance @ 75C	0.1053 ohms/mile (±2.5%)
Maximum cumulative time duration at emergency operating temperature	1000 hours

The operating temperature for the conductor shall never exceed the Maximum Emergency Operating Temperature.

Maximum Cumulative Lifetime Operating Time above Maximum Continuous Operating Temperature (210°C) and below the Maximum Emergency Operating Temperature (240°C) shall not exceed a total of 1000 hours.

Any warranties that the conductor shall meet the specification set forth in this document will be null and void if the operation of the conductor falls outside the foregoing parameters.

TABLE B

Ratio of Length of Lay of a Layer to Nominal Outside Diameter of That Layer and Lay Direction (Left or Right)

Core 6 wire layer (inner)		
- Preferred	66	
Core 12 wire layer (outer)		
- Preferred	66	
Aluminum Inner		Right-Hand Lay
- min	10	
- preferred	13.5	
- max	17	
Aluminum Middle		Left-Hand Lay
- min	10	
- preferred	13	
- max	16	
Aluminum Outer		Right-Hand Lay
- min	10	
- preferred	11.5	
- max	13	

TABLE C

The rod and drawn wires shall meet the specifications listed in TABLE C.

	Diameter	Minimum UTS (2)	Minimum Elongation(2)	Minimum Conductivity	Maximum Resistivity	Minimum Thermal resistance(1)
	Inch (mm)	Ksi (MPa)	%	at 20°C %IACS	At 20°C Ohm-mm²/km	280°C/1h
Redraw rod	0.374 (9.50)	17.4 (120)	8	60.5	Max. 28.50	
Drawn wire	<0.128 (3.25)	24.0 (165)	2	60.0	Max.. 28.73	90%
Drawn wire	<0.154 (3.91)	23.5 (162)	2	60.0	Max. 28.73	90%
Drawn wire	<0.185 (4.70)	23.0 (159)	2	60.0	Max. 28.73	90%
Drawn wire	>0.185 (4.70)	TBD	2	60.0	Max. 28.73	90%

(1) % Strength retention at room temperature (20°C) after exposure at 280C for 1 hour

(2) From a tension test per ASTM 557 or by procedure agreed upon between manufacturer and customer

For 1033 – T13:

Diameter of Al Wire 0.1385 inches (±1%)

Composition: Confidential from supplier

TABLE D

The aluminum matrix core strands shall conform to the properties listed in TABLE D.

Minimum Conductivity 24.0 %IACS

Diameter 0.0831 inches (±0.0025 inches)

Attachment 2 – Project Summary and ACCR Review

Via a request for information about the possible use of 3M ACCR on a TNHC transmission upgrade we respectfully asks the California Public Utility Commission (CPUC) to include 3M's approach for the upgrade detailed below, of the 51 mile Talega-Escondido (TE) 230 kV Transmission Line. The TE upgrade features 3M™ Aluminum Conductor Composite Reinforced (ACCR), as part of the primary transmission option presented for the Talega-Escondido/Valley-Serrano (TE/VS) 500 kV Interconnect Project . Benefits include:

- Potential economic savings by avoiding significant permitting, easement and structure costs because 3M ACCR's light weight and low thermal expansion allow for installation on existing structures without any structure modifications or relocations;
- Increased power flow up to approximately 2000 amps per circuit while meeting the clearances and tensions of the existing line on the existing towers;
- Less disruption to both the community and the environment compared to other alternatives because 3M ACCR can be installed on the existing structures and can be used with common installation techniques or alternate installation techniques which may minimize the number of locations required for pulling site set ups;
- A more robust power delivery system as part of TNHC's long-term vision of an interconnection that allows for access to new economical and renewable energy sources beyond the capacity of the LEAPS project, to potentially include wind power and other renewables;
- Potentially increased power system reliability because the additional capacity of 3M ACCR would provide N-1 and G-1 contingencies;
- A quick solution to provide more immediate capacity. The 3M ACCR capacity upgrade could be completed by late spring of 2009 (a January start date may be possible due to reduced time for permitting, environmental study, construction, and the availability of 3M ACCR);
- Experience indicates installation costs comparable to traditional conductors;
- A proven, reliable solution that has successfully undergone stringent and extensive testing and has been installed in commercial applications with conditions similar to those affecting TE/VS;
- A solution backed by a local 3M presence that can offer the CPUC and the electricity customers of Southern California the benefits of 3M's global technological resources, which have been proven in the world's most demanding marketplaces;

3M has developed a high-performance conductor that can provide transmission capacity up to 2 to 3 times greater than those of conventional transmission lines. The high-performance 3M ACCR relies on a core of aluminum matrix composite wires surrounded by temperature-resistant aluminum-zirconium wires. This conductor operates at elevated temperatures with reduced sag and with higher ampacity than comparably sized traditional conductors. It can be installed quickly and easily as a replacement conductor on transmission lines, with little or no modifications to towers or foundations and minimal environmental impact.

In this submission, with the information given, we describe an option for achieving the increased transmission capacity required on TE. New permitting, environmental study and easements are potentially required for new transmission lines whether through rebuilding the existing line with interset structures and tower replacements or the building of a new line, which could be eliminated by the use of the existing structures via reconductoring. The proposal is to upgrade TE by the removal of the existing ACSR Ortolan AW 1033 conductor, replacing it with a single

3M ACCR 1033-T13 conductor and adding a single 3M ACCR 1033-T13 conductor to the existing unused circuit on the same structures. The reduced weight and improved performance of 3M ACCR conductors, compared to standard ACSR, would enable a potential 4000 amp transfer capability on the path without major structure modifications, extensive environmental study and/or permitting, or disruption to both the environment and constituents. Because 3M's ACCR features superior ampacity, the circuits could be up-rated in one step, significantly increasing the existing capacity at the continuous operating temperature based on current information. With the installation of the ACCR conductor, using the existing sags, tensions and conductor strength safety factors as known to us, an approximate continuous line rating can be achieved that would supply 764 MVA (1919 amps) of transfer capability and an approximate emergency line rating of 823 MVA (2068 amps). Compared to the existing conductor under the same design conditions, these ratings represent an increase of 134% and 47% respectively.

Comparison of 3M ACCR product performance to other potential solutions

Applications of standard techniques for transmission upgrades are well known and have been incorporated into utility standards for many years, giving those techniques an advantage over new technologies for the expressed purpose of transmission upgrades. For that reason alone adoption of a new technologies is slow and often delayed for reasons of reliance on prior experience rather than the evaluation of new techniques and materials. This industry culture may also be one of the drivers behind the FERC's adoption of an incentive rate for new technologies, a rate which we believe would apply to the use of 3M ACCR. For that reason and with the input from 6 utilities, the Department of Energy (DOE) and other industry leaders, 3M ACCR has been developed with rigorous testing to industry standards and constant validation through open testing with various industry groups such as EPRI, IEEE, ANSI, Cigre and others. These efforts should be taken into context while evaluating alternatives:

a. *The type and nature of the technology involved*—3M ACCR has an extensive history of testing and commercial installations that demonstrate its effectiveness in transmission applications similar to the TE/VS. Current installations have been completed for the purpose of relieving congestion, providing greater path transfer capability on existing structures and providing significant capacity increase for serving peak loads at high temperatures.

b. *The availability of the alternative* —3M ACCR is commercially available now, and the Project could be operational as early as June 2009, well ahead of other traditional alternatives.

c. *The likelihood that the alternative rebuilds would proceed*—3M will provide support and assistance throughout all phases of the project. A thorough review of the operational, installation and design requirements and the line itself would be the next step.

3M's ACCR conductor has successfully undergone stringent and extensive testing, detailed in Appendix C: 3M Aluminum Conductor Composite Reinforced Testing and Applications. In addition, ACCR has been installed in commercial applications similar to those that are the subject of this information request and under a number of environmental and loading conditions, including Southwest regions experiencing desert conditions with high ambient and operating temperatures, and corrosive coastal environments. It has been installed as the primary path to serve major growing and constrained urban areas, including downtowns and airports, and, due to its high strength and low weight, it is installed in long span and environmentally sensitive applications, such as river crossings (longest single span currently installed is over 5700 feet).

Operational Considerations

The unique combination of an aluminum matrix composite core and heat resistant aluminum-zirconium (Al-Zr) outer strands provides many advantages over other conductors for increased capacity at high temperature.

- The use of aluminum matrix composite reinforcement, with it's light weight and low thermal elongation, reduces conductor sag allowing higher operating temperatures and greater power transfer than traditional conductors, without additional structural loads.
- The use of full strength aluminum results in a partition of load between the core and the outer aluminum, which offers redundancy in design.

- The rated design temperature of 3M ACCR is 210ºC continuous, 240ºC emergency. The composite core of the conductor is a metal-based composite, an inorganic material. The core is thermo chemically stable at temperatures that are significantly higher than the operating temperature of the conductor.
- The aluminum in the outer strands is heat resistant and hardened, also retaining its strength while operating at high temperatures.
- A high strength to weight ratio enables the conductor to maintain mechanical load, tension, and clearances – even across long spans and within ice and wind loading specifications.
- The composition of the core, which consists of aluminum oxide fibers that are embedded in a matrix of pure aluminum, is corrosion resistant. No protective coatings are required for the core, unlike steel cores, which require galvanized coatings. Further, there is no galvanic coupling between the core and the stranded aluminum wires, which would also be subject to corrosion.
- The composition is unaffected by UV or humidity and the conductor retains strength after long-term exposure to both.
- No failures of the conductor or accessories have occurred during installation or in any commercial operation.
- Life expectancy of 40 years or more, even when operated at high temperatures (210^{o}C).

As with conventional conductors, a variety of accessories are needed for the successful operation of ACCR. However, the equipment and installation process with 3M ACCR is similar to those required for conventional ACSR conductor. Installation costs for ACCR are approximately equivalent to traditional conductor installation costs. Additionally, 3M provides experienced personnel to train installers and to oversee the installation process.

3M, in partnership with industry-recognized accessory suppliers, has undertaken a thorough series of tests on a variety of accessories. Proven, tested, terminations (also called dead-ends) and joints (also called mid-span splices or full-tension splices/joints) are commercially available from Preformed Line Products (PLP) and from ACA Conductor Accessories (ACA). Both companies furnish splices and terminations; the former provides helical rod type, and the latter compression type hardware. All hardware is rated for high-temperature operation.

3M ACCR is a proven, reliable technology, used successfully in a variety of sites, representing a broad range of operating and environmental challenges.

Environmental Benefits

Replacing existing conductors with 3M ACCR results in less environmental impact compared to building a new transmission line on a new or expanded right of way. Reconductoring with 3M ACCR does not change the visual impact of the line, unlike new larger towers or the addition of interest structures. The construction footprint is significantly smaller when compared to the building of new towers, including foundations and the potential need to build service roads and other access requirements. Installation is expedient, community disruption for tower construction is significantly reduced or eliminated, and the increased capacity of the ACCR could be available almost immediately with potentially less cost per megawatt of capacity.

A major uncertainty when building new transmission lines is obtaining the easements to facilitate the use of taller towers. An advantage of 3M ACCR is that it can often be installed on existing structures, eliminating the need to expand existing easements for clearance requirements. In the scenario developed for this information request, reconductoring one circuit and using 3M ACCR on the unused circuit could potentially defer the need for new lines beyond the planning horizon, eliminating the need to obtain easements for a new corridor.

Conclusions

The reliable delivery of the best available power, by a cost effective means, is a goal that many organizations work towards everyday. 3M acknowledges that ACCR, a new technology that has the benefit of addressing many problems associated with transmission upgrades, will be subject to a type of scrutiny, on many different levels, to evaluate its worthiness and suitability for the TE upgrade. With that in mind, it is important to remember that many of the benefits of the conductor are also the answers to many of the potential objections for the use of the conductor. The important features to remember about this project are:

- The solution of reconductoring with ACCR is cost effective when compared to the overall cost of alternatives at the system level.
- Reconductoring does not require an extensive use of time for permits, environmental study or construction outages.
- Costs to install ACCR are similar to standard conductors like ACSR.
- ACCR has been installed in several high temperature applications similar to the proposed TE line and has operated without failures.
- The additional ampacity provided by the 3M ACCR solution potentially increases system reliability and robustness by supporting N-1 and G-1 contingencies.
- ACCR reconductoring can be accomplished by the end of Spring 2009 if the go ahead is given in the next 30 days – compared with the many years it would take for conventional methods.
- The tower profile of the line will not change.

3M ACCR is an extensively tested, commercially available, proven technology well suited for the demands of a growing transmission system serving a major urban hub such as the Los Angeles/San Diego area. The product is supported by design assistance, accessories, and installation expertise of 3M and its partners, offering the electric utility sector the benefits of the corporation's global technological resources, which have been proven in the world's most demanding marketplaces. The CPUC can also rely upon 3M's well-established reputation and credibility as one of the most innovative corporations in the world across its numerous business lines.

For these reasons, 3M presents the scenarios in this submission as economically, environmentally, and technically attractive alternatives, and respectfully requests that the CPUC include them as part of its short list of options for further consideration in the CEQA review of the TE/VS 500 kV Interconnect Project submitted by TNHC.

Appendix A: Technical Information

3M has developed a high-performance conductor that can provide transmission capacities up to two to three times greater than those of existing transmission lines. The high-performance 3M ACCR represents the first major breakthrough in overhead conductor technology since the conventional aluminum-steel reinforced conductor (ACSR) was introduced in the early 20th century. Relying on a core of aluminum matrix composite wires surrounded by temperature-resistant aluminum-zirconium wires, 3M ACCR can operate at elevated temperatures with reduced sag to increase transmission capacity. It can be installed quickly and easily as a replacement conductor on existing transmission lines, with little or no modifications to towers or foundations and minimal environmental impact.

Material Properties

The tremendous advantages of 3M ACCR are due to innovations in the materials used. Compared to a conventional steel core, the composite core has:

- equivalent strength ,
- less weight
- better corrosion resistance,
- lower thermal expansion, and
- higher electrical conductivity.

This permits the use of higher operating temperatures, which in turn leads to higher ampacities. Both the composite core and the outer aluminum-zirconium (Al-Zr) strands contribute to the overall conductor strength and conductivity.

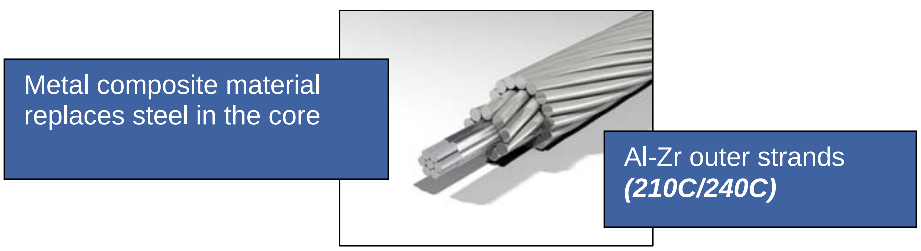

Figure 1: 3M™ Aluminum Conductor Composite Reinforced

Composite Core

The composite core contains 3M metal matrix composite wires. Depending on the conductor size, the wire diameters range from 0.073” (1.9 mm) to 0.114” (2.9 mm). The core wires have the strength and stiffness of steel, but with much lower weight and higher conductivity. Each core wire contains many thousands of small diameter, ultra-high-strength aluminum oxide fibers. The ceramic fibers are continuous, oriented in the direction of the wire, and fully embedded within high-purity aluminum. The composite wires look like traditional aluminum wires, but exhibit mechanical and physical properties far superior to those of aluminum and steel. For example, the composite wire provides nearly 8 times the strength of aluminum and 3 times the stiffness. It weighs less than half of an equivalent segment of steel, with greater conductivity and less than half the thermal expansion of steel.

Outer Strands

The outer strands are composed of a temperature-resistant aluminum-zirconium alloy that permits operation at high temperatures (210ºC continuous, 240ºC emergency). The Al-Zr alloy has properties and hardness similar to standard 1350-H19 aluminum. However, its microstructure is designed to maintain strength after operating at high temperatures - that is, it resists annealing. In contrast, 1350-H19 wire rapidly anneals and loses strength with temperature excursions above 100ºC. The temperature-resistant Al-Zr alloy wire has tensile strengths and stress-strain behaviors equivalent to standard 1350-H19 aluminum wire.

Benefits

The unique combination of an aluminum matrix composite core and heat resistant Al-Zr outer strands provides many advantages over other conductors.

- First, the use of full strength aluminum results in a partition of load between the core and the outer aluminum, which offers redundancy in design; generally both the outer strands and the core can each carry the full design load of the conductor.
- Second, the rated design temperature of 3M ACCR is 210ºC continuous, 240ºC emergency. The composite core of the conductor is a metal-based composite, an inorganic material. The core is thermo chemically stable at temperatures that are significantly higher than the operating temperature of the conductor.
- Third, the composition of the core, which consists of aluminum oxide fibers that are embedded in a matrix of pure aluminum, is corrosion resistant. No protective coatings are required for the core, unlike steel cores that require galvanized coatings. Further, there is no galvanic coupling between the core and the stranded aluminum wires, which would result in corrosion.
- Fourth, the composition is unaffected by UV or humidity and retains strength after long-term exposure to both.
- Fifth, the aluminum in the outer strands is heat resistant, retaining its strength while operating at high temperatures.

Appendix B: Accessories

As with conventional conductors, a variety of accessories are needed for the successful operation of ACCR. However, the equipment and installation process is similar to those required for conventional ACSR conductor. Also, 3M provides experienced personnel to train installers and to oversee the installation process.

3M, in partnership with industry-recognized accessory suppliers, undertook a thorough series of tests on a variety of accessories. Terminations (also called dead-ends) and joints (also called mid-span splices or full-tension splices/joints) are commercially available from Preformed Line Products (PLP) and from ACA Conductor Accessories. Both companies furnish splices and terminations; the former provides helical rod type and the latter compression type hardware. All hardware is rated for high-temperature operation.

Compression-Type Hardware

The compression-type hardware from ACA uses a modified two-part approach for separate gripping of the core and then an outer sleeve to grip the aluminum strands, as shown in Figure 2. This approach is similar to the approach used in ACSS, although modified to prevent crushing, notching, or bending of the core wires. The gripping method ensures the core remains straight, to evenly load the wires, and also ensures that the outer aluminum strands suffer no lag in loading relative to the core.

Figure 2: ACA Compression-Type Hardware

Helical Rod-Type Hardware

Helical rod-type hardware has been developed by PLP for use with the 3M ACCR at high operating temperatures. It uses the helical rod design, which places minimal compression loading on the conductor. A multi-layer design maximizes both the holding strength and heat dissipation, and has the advantage of easy installation.

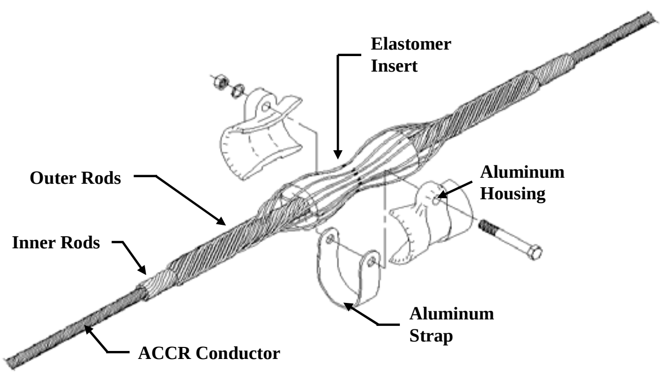

Figure 3: PLP Helical Rod-Type Hardware

PLP also provides suspension assemblies for 3M ACCR. These accessories are based on field-proven ARMOR-GRIP® Suspensions. The multi-layer design maximizes the mechanical protection and heat dissipation, while minimizing heat transfer to mating hardware and insulators. A cushioned insert provides protection against wind and ice loads. The helical rods also provide local stiffening to the conductor, which reduces the bending strains on the conductor.

Appendix C: 3M Aluminum Conductor Composite Reinforced Testing and Applications

Laboratory Testing

3M, in partnership with various industry leaders, has tested 3M ACCR in both laboratory and field conditions to verify theoretical properties and behavior. Testing to date has been performed on a variety of conductor constructions using a wide variety of tests. Testing includes:

- tensile strength;
- stress strain behavior;
- creep;
- axial impact;
- strength;
- crush strength;
- torsion behavior;
- DC resistance;
- lightning strike behavior; and
- fault current behavior.

Testing of the core includes:

- high temperature creep;
- strength retention after exposure to high temperatures;
- corrosion resistance;
- stability of composition after high-temperature exposure; and
- no visual signs of cracking or discoloration after high-temperature exposure.

Suspension tests include:

- turning angle;
- unbalanced load;
- elevated temperature profiles;
- galloping behavior;
- Aeolian vibration behavior; and
- corona RIV testing.

Deadend and splice tests include:

- tensile strength (e.g. accessory's ability to support tensile strength of the conductor);
- sustained load tests at room temperature,
- load tests at elevated temperature of 240^{o}C; and
- current cycle testing.

Jumper tests include current cycle testing, and damper tests include damper efficiency tests.