HIGH-PERFORMANCE CONDUCTOR MEANS MUCH GREATER CAPACITY

By Doug Johnson, Product Development Specialist, 3M

A high-performance conductor that can provide transmission capacity up to two to three times greater than that of existing transmission lines is finding its way onto the nation's power grids.

Relying on a core of aluminum matrix composite wires surrounded by temperature-resistant aluminum-zirconium wires, 3M's Aluminum Conductor Composite Reinforced (ACCR) can operate at elevated temperatures with reduced sag. Since sag due to thermal expansion is a major factor limiting capacity, reducing sag increases the amount of current the line can carry while maintaining required clearances. 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, saving time and cost.

The tremendous advantages of ACCR are due to innovations in the core material (see Figure 1). Compared to steel, the core has:

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

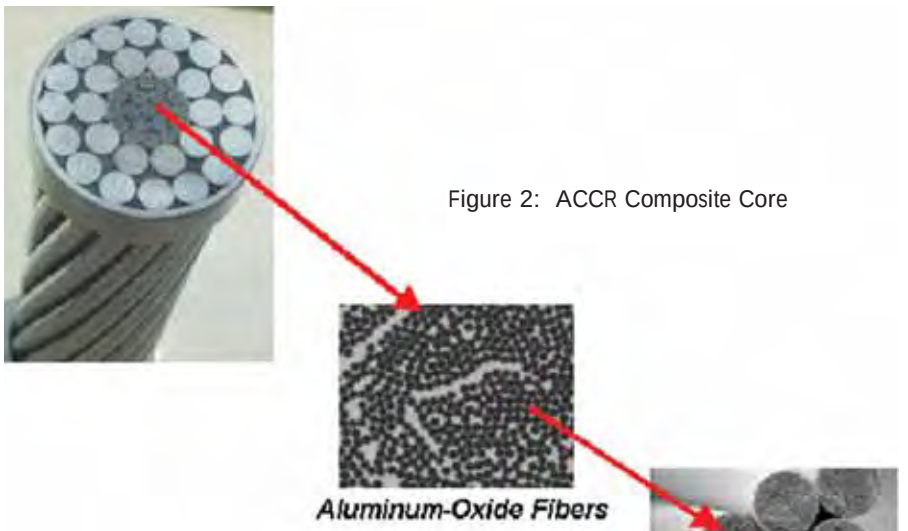

Figure 2: ACCR Composite Core

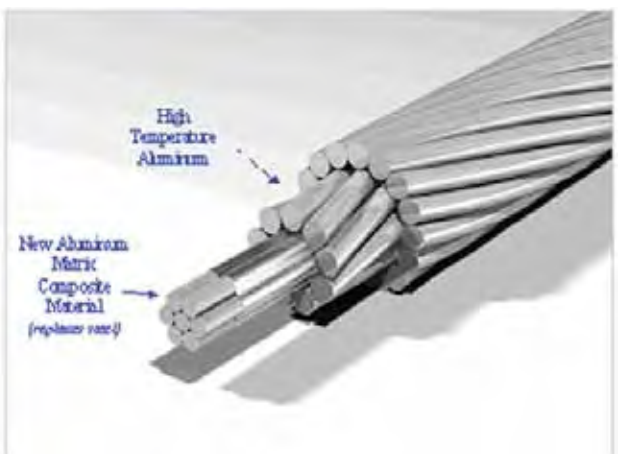

Figure 1: ACCR Core and Outer Strands

MATERIAL PROPERTIES AND ADVANTAGES

Metal Matrix Core

The core contains metal matrix composite wires infused with pure aluminum. The core wires have the strength and stiffness of steel, but with much lower weight, higher conductivity, and half the thermal expansion. Each core wire contains many thousands of small-diameter, ultra-high-strength aluminum oxide fibers, as shown in Figure 2. The core wires look like traditional aluminum wires, but exhibit superior mechanical and physical properties.

Outer Strands

The outer strands of ACCR are composed of a hardened, 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.

ACCR BENEFITS AND APPLICATIONS

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

- First, the rated design temperature of 3M ACCR is 210ºC continuous, 240ºC emergency. In contrast, Aluminum Conductor Steel Reinforced, or ACSR, is rated to 100ºC continuous, 150ºC emergency.
- Second, both the outer strands and the core can each carry the full design load of the conductor. The use of hardened aluminum results in a partition of load between the core and the outer aluminum, which offers redundancy in design.
- Third, the composition of the core is corrosion resistant. Further, there is no galvanic coupling between the core and the stranded aluminum wires. No protective coatings are required for the core, unlike steel cores, which require galva-

Continued on page 32

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continued from Page 30

nized coatings, or carbon composite core, which requires a glass barrier between the core and outer strands.

• Fourth, the composition is unaffected by ultraviolet light 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.

Benefits of 3M ACCR are summarized in Table 1.

Utilities and Sites where 3M ACCR is Being Used...		Operating Since
Xcel Energy	Minneapolis/St. Paul, Minnesota	2001
Hawaiian Electric Company	Oahu, Hawaii	2002
Western Area Power Administration	Fargo, North Dakota	2002
Bonneville Power Administration	Washington State	2004
National Grid	New York	2004
WAPA	Phoenix, Arizona	2004
Salt River Project	Phoenix, Arizona	2004
Pacific Gas & Electri	Santa Clara, California	2005
San Diego Gas & Electric	San Diego, California	2005
Xcel Energy	Minneapolis/St. Paul, Minnesota	2005
Arizona Power Service	Phoenix, Arizona	2006
Western Area Power Administration	Arizona/California Border	Winter 2006-2007
Alabama Power	Alabama State	TBD

Table 1: Advantages of 3M ACCR

ACCR CAN RELIABLY INCREASE AMPACITY BY TWO TO THREE TIMES WITHOUT INCREASING SAG OR REQUIRING STRONGER TOWERS AND FOUNDATIONS

3M's ACCR can substantially increase the capacity of existing lines simply by replacing existing conductors on the existing towers, often avoiding the need for new easements and rights-of-way, simplifying what can be lengthy and costly proceedings.

A primary application of the ACCR is for thermal upgrades of existing transmission lines. As an upgrade conductor, ACCR with the same diameter as the existing conductor can generally be installed to increase capacity without increasing sag or requiring new or larger structures (see Figure 3).

The improved sag and strength performance may also allow further design options such as use of a larger ACCR conductor with existing structures and rights-of-way, higher ice loads, long span crossings with shorter or fewer towers, and reduced tower heights in new construction.

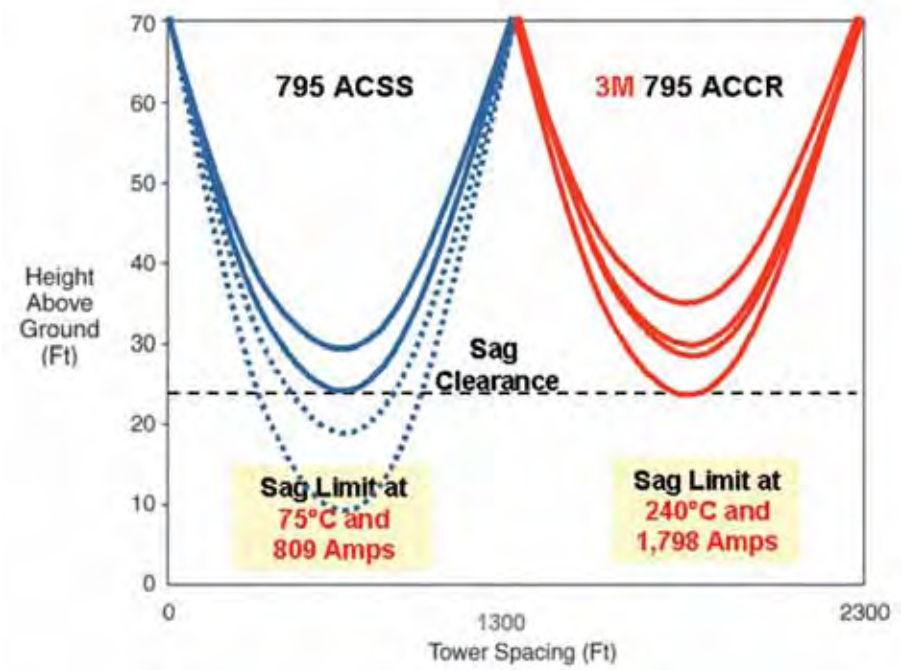

Figure 3: Increase in Ampacity without Increased Sag Using ACCR

ACCR Saves Time and Money

Because using ACCR avoids the cost of new tower construction and the delay and expense of permitting and siting new lines and rights-of-way, shortens the time to increase capacity (allowing power to be available sooner) and reduces bottlenecks (permitting utilities to reach more markets with available capacity), 3M's ACCR saves time and money on the total cost of a line upgrade. In actual customer installations, 3M ACCR has saved cus-

tomers from 4 to 16 months' installation time, avoiding long outages and FERC penalties.

Permitting and Land Acquisition

Upgrading a system and building new structures often require lengthy permitting processes involving various government agencies and public hearings, outages, land acquisition and many other activities that create uncertainty and cost. ACCR can be used to simply replace existing conductors and towers, minimizing the need to acquire additional rights-of-way and involvement in lengthy proceedings.

Installation

The industry is built on standard constructions of ACSR that have been used for decades. 3M's ACCR does not deviate from this basic and proven approach. Therefore, the installation of the ACCR is similar to conventional conductors, as shown in Figure 4.

There are similar accessories to ACCR, like that of ACSR. Terminations (also called dead-ends) and joints (also called mid-span splices or full-tension splices/joints) helical-rod hardware are available, and are rated for high-temperature operation.

Figure 4: ACCR Larger Outer Sleeve, Which Is Similar to Conventional Conductor Accessories

ACCR Mitigates Environmental Impact

In many areas of the world, building or upgrading transmission lines means building towers in environmentally sensitive, protected or densely populated areas. ACCR can substantially increase the capacity of existing lines simply by replacing existing conductors on the existing towers, often avoiding the need for new easements and rights-of-way. Installation is quick, the ampacity gains are large, and the outstanding strength-to-weight ratio and low thermal expansion enables long spans and fewer structures across rivers, canyons and other sensitive areas with no change to the look of the existing line.

ACCR OFFERS RELIABLE PERFORMANCE

Product Testing

ACCR was developed and tested over a number of years by a 3M-led team of industrial companies, the Department of Energy, independent test laboratories, and utilities with a focus on reliability. This includes key laboratory measurements of high temperature creep and other key conductor properties, validated at an outdoor test facility at Oak Ridge National Laboratory, as well as various field installations. The complete set of test results is available at www.3M.com/accr.

Installations and Commercial Applications

ACCR is installed and operational on a number of critical utility sites. These include installation sites where ACCR has been used to interconnect different types of generation, such as combined cycle generators and hydro-electric dams, to the transmission network, as well as installations in which ACCR is the primary path to serve rapidly growing urban areas, including downtown businesses and large commercial airports. Figure 5 lists some of these installations.

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Xcel Energy	Minneapolis/St. Paul, Minnesota	2001
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Western Area Power Administration	Fargo, North Dakota	2002
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National Grid	New York	2004
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San Diego Gas & Electric	San Diego, California	2005
Xcel Energy	Minneapolis/St. Paul, Minnesota	2005
Arizona Power Service	Phoenix, Arizona	2006
Western Area Power Administration	Arizona/California Border	Winter 2006-2007
Alabama Power	Alabama State	TBD

Figure 5: Locations of the ACCR Installations