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Reinforcing Aluminum Conductors with High Tensile Strength Bezinal® Coated Steel

WHITE PAPER

Reinforcing Aluminum Conductors with High Tensile Strength Bezinal®[1] Coated Steel

Dr. Dale A. Douglass

Over 80% of all the self-supporting, bare overhead, concentric-stranded aluminum conductors used in transmission lines around the world, have a stranded steel reinforcing core. Adding a relatively inexpensive steel core to a stranded aluminum conductor has several advantages including:

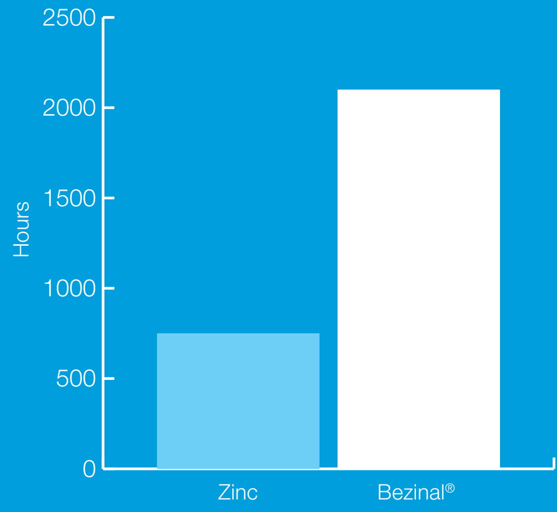
- Increased conductor breaking strength with minimal increase in weight per unit length
- Smaller sag increase under high ice loading or at high temperature
- Less blowout and reduced right-of-way width
- Reduced plastic elongation over time
- Less reduction in conductor strength at temperatures above 100 °C (212 °F)

1 Zn95/Al5 Alloy

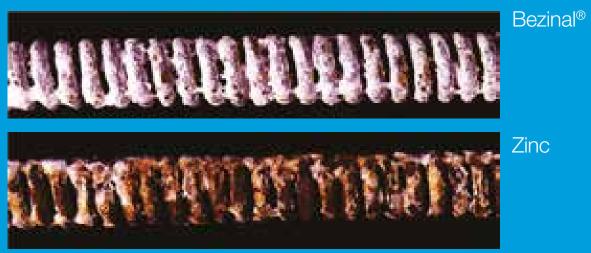
CORROSION PERFORMANCE IN SALTSPRAY

(according to DIN SS 50021, ASTM B117, ISO 9227)

SALT-SPRAY RESISTANCE - HOURS UNTIL 5% DBR



COATED SPRING AFTER SALT SPRAY TEST



To these generic advantages for stranded steel core, Bekaert's High Tensile-Strength Bezinal® coated steel cores add 2 to 3 times greater galvanic corrosion protection than conventional hot-dipped galvanized steel core wire (without resorting to the use of grease). Also, with the additional design flexibility that higher strength conductors (using Ultra, Mega and Giga strength) provide, line designers have more freedom to design with less sag and shorter towers to meet the demands from challenging situations of cost control or aesthetics.

Conductors stranded entirely with wires of aluminum, aluminum alloys, or a combination of the two, have been used in overhead lines where ice and wind loading is "light", where spans are relatively short, and where high-post-contingency N-1 emergency power flows remain moderate over the life of the line. Also, in comparison to ordinary galvanized steel core wires, all aluminum has been an attractive choice where the environment causes unusual levels of corrosion (e.g. seacoast and industrial area). For a bare stranded aluminum conductor, the resistance is primarily determined by the cross-sectional area of the aluminum wires. For a given aluminum area such as 483 mm^2 (954 kcmil), reinforcing the conductor with a stranded steel core increases the conductor breaking strength dramatically as shown in Tables 1A (metric units) and 1B (imperial units). Assuming an initial installed tension equal to 20% of the conductor strength, the initial sag of 54/7 Cardinal at 15 °C (59 °F) (row 3) is 3.9 m (12.7 ft) less than Magnolia AAC (row 1), in a 305 m (1000 ft) span. At 100 °C (212 °F), the sag advantage of Cardinal ACSR is the same.

The steel core in Cardinal also increases the conductor's elastic modulus, E, which limits mechanical elongation under high ice and wind loading, limits the total conductor thermal elongation of the conductor at high temperature, and reduces the loss of conductor Rated Breaking Strength (RBS) due to operation above 100 °C (212 °F), as shown in Column 8.

The use of Bezinal® high tensile strength steel core wire (UHS, MHS, and GHS) in place of ordinary High Strenght (HS) steel wires, further increases the conductor rated breaking strength and reduces the loss of strength due to operation above 100 °C (212 °F). The conductor weight and diameter are unchanged but special connectors may be required.

COMPARISON OF 954 KCMIL CONDUCTORS

1A - METRIC UNITS

Code Name[2]	Alum/St Weight [kg/km]	Cond OD [mm]	RBS[3] [kN]	Sag in 1000 ft span @20% RBS1 [m]	Final[4] Sag @100 °C [m]	E [MPa]	%RBS after 100hr @ 150 °C [%]
37 strand Magnolia AAC	1330/0	28.5	72.9	10.4	14.3	59	84%
45/7 Rail ACSR	1330/262	29.6	115	7.6	12.0	68	92%
54/7 Cardinal ACSR	1330/490	30.4	150	6.6	10.5	74	95%
Cardinal with EHS	1330/490	30.4	159	6.2	10.2	74	95%
Cardinal with UHS	1330/490	30.4	165	6.0	9.9	74	100%
Cardinal with MHS	1330/490	30.4	179	5.5	9.4	74	105%
Cardinal with GHS	1330/490	30.4	193	5.1	9.1	74	110%
30/19 Canvasback ACSR	1340/863	31.7	205	5.7	8.9	83	100%

1B - IMPERIAL UNITS

Code Name[2]	Alum/St Weight [lb/kft]	Cond OD [in]	RBS[3] [klb]	Sag in 1000 ft span @20% RBS1 [ft]	Final[4] Sag @100 °C (212 °F) [ft]	E [msi]	%RBS after 100hr @ 150 °C (302 °F) [%]
37 strand Magnolia AAC	895/0	1.124	16.4	34.2	47.0	8.6	84%
45/7 Rail ACSR	899/176	1.165	25.9	25.0	39.4	9.8	92%
54/7 Cardinal ACSR	899/329	1.196	33.8	21.5	34.5	10.8	95%
Cardinal with EHS	899/329	1.196	35.7	20.4	33.4	10.8	95%
Cardinal with UHS	899/329	1.196	37.1	19.6	32.6	10.8	100%
Cardinal with MHS	899/329	1.196	40.3	18.0	31.0	10.8	105%
Cardinal with GHS	899/329	1.196	43.4	16.8	29.8	10.8	110%
30/19 Canvasback ACSR	900/580	1.248	46.1	18.8	29.3	12.0	100%

2 The Aluminum Association, 1997, Code Words for Overhead Aluminum Electrical Conductors, 7th edition
3 RBS: Rated Breaking Strength
4 After 10 years of creep at 15 °C (60 °F)

Q&A

Q – How does a steel reinforcing core improve all aluminum conductor?

A – Adding a steel core increases the aluminum conductor's breaking strength by a factor of 2 to 3, reduces sag increase under unexpected heavy ice load or at high temperature by up to 50%, reduces horizontal blowout distances and thus the probability of horizontal clearance violations, and greatly reduces loss of tensile strength at sustained conductor temperatures above 100 °C (212 °F). As a result, the risk of needing to constrain future power flows and replace phase conductors over the life of the transmission line is reduced.

Q – Can't I reduce the cost of new lines by using all aluminum conductors (AAC, ACAR, or AAAC)?

A – The relatively small cost savings from not using a steel reinforcing core may have expensive long-term consequences, requiring conductor replacement and/or structure reinforcement. This is especially true at voltages of 400 kV and below where over the 40 to 80-year life of an overhead line, infrequent but severe N-1 and N-2, post-contingency power flows may occur. All aluminum conductors can experience severe annealing (loss of tensile strength) from operation at even 10 to 1000 cumulative hours above 100 °C (212 °F). Without a steel core, all aluminum conductors can also experience permanent plastic elongation due to extended operation at 50 °C to 70 °C (122 °F to 158 °F). You can save money upfront but risk big repair costs, including the need for structure reinforcement and replacement in the future.

Q – Isn't stranded steel wire "old" technology

A – Steel core is a proven technology for 100 years. In designing and building overhead transmission lines which are expected to last 40 years or more, the inclusion of technical innovations such as Ultra, Mega, and Giga-strength steel wire and Bezinal® anti-corrosion coatings increase the value and effectiveness of new lines without causing unnecessary disruptions in proven design, construction methods (e.g. tension-stringing, clipping, sagging). Used with conventional strandings, Bekaert's advanced-technology Ultra, Mega, and Giga strength steel cores combined with Bezinal® anti-corrosion coating, constitute a major improvement over existing conventional tensile strength, galvanized steel cores.

Q – What if I underestimate future emergency power flow with ACSR?

A – Power flow limits on overhead lines are typically limited by the line's thermal rating. All-Aluminum conductors cannot be used above 100 °C (212 °F) without risking permanent loss-of-strength, creep, and increased sag. Adding a steel reinforcing core is excellent insurance against higher than anticipated loads because the steel core can often allow operation of an existing line at higher temperature (i.e. increased thermal uprating) with minor loss of tensile strength and modest increase of sag at higher temperature.

Q – Can I easily adjust the amount of steel reinforcement for the same aluminum area?

A – Yes. As shown in Table 1, the steel core area can easily be adjusted to provide just the right conductor for new lines, and the availability of Ultra, Mega, and Giga-High Strength Bezinal® steel wires allow the line designer to adjust conductor properties without changing conductor core area. The availability of Ultra, Mega, and Giga-High Strength Bezinal® steel wires with above conventional tensile strengths provide an increase of up to 36%-63% in nominal rating. This plus the design flexibility mentioned above allow the line designer to adjust conductor properties without changing conductor weight per unit length or diameter.

Dr. Dale A. Douglass
is Principal of Douglass Power Consulting, LLC. He lives in Niskayuna, New York, USA, and has over 40 years of experience in transmission power delivery, having worked previously with Power Delivery Consultants, Power Technologies, Inc., Kaiser Aluminum, and Bell Laboratories.

He has been involved in many manufacturing, laboratory and field studies of bare overhead transmission conductors including conductor design, sag at high temperature, real-time monitoring and risk analysis of lines and line failure analysis.

He was elected a Fellow of the Institute of Electrical and Electronic Engineers for his work related to transmission conductors in 1996, was chairman of the Overhead Lines Subcommittee (15.11) from 2004 to 2009, and Secretary from 2009 to 2013.

He has been the U.S. Representative to CIGRE Study Committee B2 (overhead lines), chairman of Technical Advisory Group B2.04 on Electrical Effects, and Working Groups on Uprating of Existing Lines and Predicting Dynamic Thermal Line Ratings.

Dr. Douglass has authored and co-authored over 60 technical papers, IEEE tutorials, and CIGRE Technical Brochures on the electrical, mechanical and thermal behavior of overhead transmission lines. He recently chaired the IEEE working group which modified IEEE 738-2014 on line thermal ratings.

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Bekaert is a world market and technology leader in steel wire transformation and coating technologies. To be the preferred supplier of steel wire products and solutions, we consistently deliver superior value to our customers worldwide.
Bekaert (Euronext Brussels: BEKB) was established in 1880 and is a global company with approximately 30 000 employees worldwide.

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