THE OKONITE COMPANY

SELF-SUPPORTING AERIAL CABLES

Setting the Standard
Introduction

Okonite’s factory assembled aerial cables have been successfully used for over 75 years on distribution systems from 600V to 46kV. Okonite’s aerial cables are a product of closely coordinated efforts in research, engineering and manufacturing to bring to the market the lowest cost and most reliable Self-Supporting Aerial Cables that can be made today.

Okonite’s aerial cable designs combine over 40 years of reliable service, using an all EPR Okoguard insulation system, together with engineered installation technology.

The following two constructions are typical of EPR Self-Supporting Aerial Cable designs.

Self-Supporting 15kV Unjacketed Aerial Cable with Bare Copper Binder Strap.

Self-Supporting 15kV Jacketed Aerial Cable with Thermoplastic Coated Binder Strap.
Important Features of the Okoguard System Used in Factory Assembled Aerial Cables

- Okoguard Cables are manufactured on a continuous vulcanization machine (CV) with three tandem extruders.
- A closed system that applies all three EPR components in one process.
- Damage of critical interfaces and contamination are eliminated.
- Employs laser micrometers to measure and control dimensions.
- Triple Tandem is superior to the common head process which is limited to the measurement of the combined insulation and insulation shields.

**Triple Tandem All EPR Insulation System**
Okonite manufactures the exclusive Okoguard all EPR insulation system. The insulation system is applied using a triple tandem extrusion process that assures compatibility between the extruded layers. Laser measurements are utilized between the layers to verify diameters of the insulation and semiconducting screens.

**Deformation Resistance**
Okoguard insulation exhibits excellent deformation resistance over the entire spectrum of its temperature operating range and is unaffected by pressure that may be applied by the aerial cable binder strap and messenger.

**Thermal Stability Shrink-Back**
Good thermal stability and minimum shrink-back are other important features provided by the Okoguard insulation system, especially since cables are exposed to direct sunlight. Thermal stability with minimum shrink-back eliminates concerns on moisture ingress into splices and terminations.
Important Features

Moisture Resistance
Long term water immersion tests have verified Okoguard’s moisture resistance and assures its suitability when exposed to rain, snow and sleet that are common to an aerial cable environment.

AEIC Qualification-Impulse Test
The AEIC Qualification-Impulse Test data illustrates the Okoguard insulation system’s ability to withstand lightning strikes and switching surges or "spikes" that can damage aerial cables.

Corona Testing
Partial discharge testing of all Okoguard cables verifies the absence of voids in the insulation and in the interface between semiconductor shields and the insulation.
Important Features

Flexibility
The flexibility of Okoguard over extreme temperature ranges facilitates installation under harsh climatic conditions.

Strippability
Good strippability, by controlled adhesion of the EPR semiconducting insulation shield, simplifies splicing and terminations, minimizing the possibility of damage to the insulation.

The Okoguard service record of over 45 years is a testimonial to its reliability in a broad spectrum of applications.
Design Features of Okonite’s Preassembled Aerial Cable

- Messenger design provides a safety factor of 4 times the allowable messenger stress to allow ample safety margin for wind and ice loading.

- Messengers are copper clad steel, galvanized steel or stainless steel to prevent corrosion damage.

- Binder straps have rounded edges and are protected with a thermoplastic covering to prevent damage of the jacket.

- Engineered factory packaging helps to prevent installation problems.

- The use of an all EPR insulation system provides flexibility for easier installation.

- Jackets are designed to withstand cold flexure damage and are UV light resistant.

- Okoguard 105°C Medium Voltage and 90°C Low Voltage insulations are moisture resistant EPR compounds, designed and tested for long-term stability.

- Messengers, when properly grounded, provide protection against lightning and surge currents.
Aerial Cable Construction

600 volt — Three 1/C Class B stranded copper or aluminum conductors, tandem extruded Okoguard EPR insulation, and Okolon jacket. Three single conductors are cabled together and laid parallel to a copper clad steel, galvanized steel or stainless steel messenger. The messenger and triplexed assembly are bound together with a PE coated copper or stainless steel strap.

2.4 kV or 5 kV non-shielded — Three 1/C Class B stranded copper or aluminum conductors, triple tandem extruded, EPR strand screen Okoguard EPR insulation and Okolon jacket. Three single conductors are cabled together and laid parallel to a copper clad steel, galvanized steel or stainless steel messenger. The messenger and triplexed assembly are bound together with a PE coated copper or stainless steel strap.

Medium voltage 5-46kV shielded — Three 1/C Class B stranded copper or aluminum conductors, triple tandem extruded, semiconducting EPR strand screen — Okoguard EPR insulation — extruded semiconducting EPR insulation screen, shielding tape and an overall jacket. This construction is also available in unjacketed form and with alternate type shielding tapes. Three single conductors are cabled together and laid parallel to a copper clad steel, galvanized steel or stainless steel messenger. The messenger and triplexed assembly are bound together with a PE coated copper or stainless steel strap.

*Alternate aerial cable constructions are available upon request.
Typical Self-Supporting Aerial Cable Designs

Design and assembly of Okonite aerial cables are a product of dedicated engineering efforts to provide cables which install without twisting or snagging and withstand the hostile environmental conditions of wind, rain and ice.

Many assembly parameters must be considered and optimized in the manufacture of these cables. These include:

- Balancing torsional characteristics of the components
- Quality control and assurance
- Proper spacing of the components
- Precise messenger tension
- Controlled binder tension
- Cable length of lay
- Preparation of cable ends
- Packaging for shipment

Jacketed Shielded Construction 5-46kV

Unjacketed Shielded Construction 5-46kV
## Aerial Cable Constructions

Typical triplexed Self-Supporting Aerial Cable Designs (150 ft. spans)

<table>
<thead>
<tr>
<th>Conductor</th>
<th>Strands</th>
<th>Insulation Thickness Mils</th>
<th>Jacket Thickness Mils</th>
<th>Copper Clad Steel Messenger Size</th>
<th>Approx. O.D. Inches</th>
<th>Approx. NWM Lbs.</th>
<th>Ampacity Amps</th>
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The Economics of Self-Supporting Aerial Cable

Installed Costs are Surprisingly Low

Okonite Self-Supporting Aerial Cable is an economical solution, and may actually cost less than other overhead constructions, where annual tree trimming, taller poles, extra labor or additional hardware may be required.

Here are the various types of construction available when primary power distribution lines are to be installed overhead.

1. Ordinary bare conductor strung through or above trimmed trees on insulators and crossarms on conventional length poles.

2. Tree wire with rubber insulation, strung through trees on insulators and crossarms on conventional length poles.

3. Ordinary weatherproof wires strung above trees on insulators and crossarms on extra length poles.

4. Aerial cable pre-assembles with a messenger (self-supporting) and strung through trees on conventional length poles.

5. Aerial cables spun to the messenger in the field and strung on conventional length poles in open areas or below tree limbs.

6. Aerial cable pulled into rings on a messenger on conventional length poles with comparatively little or no tree trimming necessary.

7. Spacer cable. Three single conductors, partially insulated, suspended from a messenger and held by a spacer.

Reliability Improvements

Okoguard Insulated Self-Supporting Aerial Cables typically provide higher reliability, which translates into lower Total Owning Costs when evaluating against other overhead construction methods.

System reliability has been the focus of Distribution System owners and continues to be the key component for capital investment and customer satisfaction.

Reduced Need for Tree Trimming

Since the SSAC system is completely insulated, the requirements for tree trimming are reduced. This not only saves operating costs, but alleviates problems with customers sensitive to aesthetics.
Where to use Okonite Self-Supporting Aerial Cable

*In Utility and Industrial Distribution Applications*

- Where tree conditions prohibit the use of open wires or require constant trimming.
- Where taller poles would be needed to clear trees.
- Where improved aesthetics are needed.
- Where an existing pole line is incapable of carrying any additional open wire circuits but can accommodate one or more aerial cables below the open wire construction.
- Where narrow clearances from structures and other lines prohibit the use of open bare wire.
- Where overhead line approaches to power stations and substations are already congested and space for additional pole lines is limited.
- Where the voltage to be used makes it impractical to have open wire circuits.
- Where right-of-way for open bare wire is unobtainable.
- Where cable circuits are urgently required and aerial cable can be installed much more quickly than underground cable.
- Where joint construction in connection with other utilities is best provided for by the use of Self-Supporting Aerial Cable.
Where to use Okonite Self-Supporting Aerial Cable

- Where additional safety is needed for crossing private properties, freight yards, bridges, trestles, and in other public areas.

- Where cable has to be continued across marshy ground that would otherwise necessitate costly pile foundations for underground conduit.

In Mines
- To carry power circuits along haulage ways and drifts within the mine.

- Where power lines are carried overhead through trees to distant shafts and bore holes in outdoor locations.

In Industrial Plants
- Where power circuits can be carried overhead supported by beams or trusses rather than by hazardous open wire on insulators, or with cable in conduit.

- Outdoors, on brackets attached to buildings or on poles in the open.
Installation of Self-Supporting Aerial Cable

Pulleys are mounted on each pole and a pulling line threaded using the pulleys, through any trees which the cable will pass. In some cases additional pulleys may be necessary to prevent the cable catching in limbs or at road crossings to prevent sagging which could block traffic. These additional pulleys are sometimes mounted from a temporary messenger or a bucket truck. All pulleys should be large enough to allow ample clearance around the cable so that there will be no danger of the binder tape catching against the frame of the pulley. A minimum diameter of ten inches for the inside of the pulley and a minimum clearance of 1 inch on both sides of the cable is recommended. Figure 1 shows a typical straight line pulley. The top is hinged and fastened with a loose pin so the cable can be readily removed and the messenger can be placed in the messenger clamp.

When the cable must make a change in direction, a multisheave radius roller assembly is necessary. Figure 2 shows a corner pulley. This is hung by a bracket pinned to the center top of the pulley frame. It can be mounted on the pole slightly above or connected to the messenger clamp. The side of the frame next to the pole is hinged so the cable may be pulled out and placed in the clamp. For large diameter or heavy cables a large radius (4 or 5 ft.) multisheave roller is recommended.

The following instructions and sketches are intended to suggest methods for installing Self-Supporting Aerial Cables. In general, operating companies can use fittings and practices that are most convenient and in line with their normal usage and needs.

Self-Supporting Aerial Cable can be supplied in long lengths, which result in minimizing the number of splices. The practical limit is usually the reel size, which can be handled by the power drive reel trailer or cable truck.

The cable is normally transported to the installation site on a power drive reel trailer or cable truck and set up 50-75 feet from the terminal pole.
Installation of Self-Supporting Aerial Cable

The pulling line is fastened to the overlength of messenger with a swivel connection. A ball bearing or roller bearing swivel is recommended. The end of the cable should be tapered and tightly bound to the messenger to prevent slippage of the messenger and to facilitate passing through the pulleys.

The speed of the reel must be controlled so as to maintain a reasonable sag between the poles. This sag should be controlled to prevent dragging the cable on the ground between spans or rubbing on tree limbs and other cables. Using the greatest sag possible results in lower pulling tension and helps prevent twisting of the cable. The tension on the cable leaving the reel should be kept to a minimum.

A cable will sometimes rotate or twist as it goes through a pulley. This twist can usually be removed by temporarily halting the pull and having line-personnel untwist the cable. Once the cable passes through the pulley there should be no further tendency for the cable in that span to twist.

After the entire reel has been pulled, the end should be dead-ended at the pole leaving ample cable for making connections to fuse cutouts, splices, or other devices. Sometimes an additional 100-150 feet of messenger is coiled on the reel drum, so that the trailing cable end can be pulled up to the desired location. This method eliminates the previous procedure of temporarily tying off the cable at the first pole, unreeling the last couple of cable coils still on the reel, and attaching a winch to the trailing end of the messenger.

The cable should be pulled to a tension 25% higher than the final tension, and then loosened to facilitate the placement of holding clamps. A come-along is then applied to the cable at the last pole to maintain the tension. This tensioning is not intended to prestretch the messenger but rather to equalize the tension in the various spans. It is impossible to prestress unidirectional cable completely as the messenger will not slide for the entire distance. Some strain will always be taken by the conductors in the center of the section but this will gradually relax with time.
Installation of Self-Supporting Aerial Cable

Figure 3 shows a typical arrangement of a dynamometer being used for tensioning and a come-along for holding tension. Temporary guys may be required.

The binder strap is then removed for about a foot on each side of the pulley and clamped to the messenger.

![Figure 3 — Tensioning Self-Supporting Cable](image)

The pulleys are then removed, as the messenger is placed in position in permanent supporting clamps at each pole. The messenger should be placed in corner clamps before final tensioning. A block and fall is usually required to pull the messenger over the clamp. The clamp is left loose and the messenger allowed to slide during tensioning. The cable is not removed from straight pulleys until after tensioning, as the cable can be readily removed and placed in the messenger clamps under final tension. The pulleys are then moved along to the next section and the pulling line threaded.

Figure 4 shows a typical straight line support. Figure 5 shows a typical angle support.

![Figure 4 — Permanent tangent messenger hanger](image)

![Figure 5 — Permanent angle messenger hanger](image)

Figure 6 shows a typical corner pole. Note that the messenger has been spliced to obtain additional length for passing through thimbles. In this case the cable must be tensioned at this intermediate pole. The entire length is pulled in but not tensioned. Then the section back from this corner pole is tensioned with a come-along and dead-ended. The messenger is spliced and the cable trained at the corner. The rest of the cable is then tensioned as for a straight pull.

![Figure 6 — Corner pole](image)

The next section is pulled similar to the first section, except that instead of dead-ending the last end off the reel it is spliced to the first section, leaving an overlap of insulated cable. This section is then pulled, tensioned and fastened at the last pole. The temporary fastening at the last pole of the first section is then removed.

It is recommended that the cable be left at least a day before splicing so any uneven tension may equalize throughout the length.

Lightning arresters should be provided at junctions to open wire lines, being sure the arrester grounds are interconnected with the messenger to minimize surges across the insulation. Frequent grounding of the messenger is desirable for protection of the cable.
Sag and tension calculations for aerial cables

The sag and tension are based on the formulas for a parabola which are approximately the same as for a true catenary for small deflections. This well-known formula is:

\[
t = \frac{s^2 W}{8d}
\]

where

- \( t \) = horizontal tension in messenger (lbs.)
- \( s \) = span length (ft.)
- \( w \) = weight of complete cable including messenger (lbs. per foot)
- \( d \) = sag (ft.)

*Use 50% of messenger breaking strength for Heavy Loading and 25% of breaking strength for Normal Loading.

The total tension in the messenger at the support is the horizontal tension plus the vertical component due to the dead load. The vertical component has been neglected.

Some typical messenger breaking strengths are given below.

For more information see ICEA Publication P-79-561 “Guide for Selecting Aerial Cable Messengers and Lashing Wires”. Also, see IEEE Std C2 (NESC) Section 250 for extreme wind loading on wind and ice loading for the installation load.

Determination of ice and wind loading

Ice and wind loading are determined by geographical location. The United States is divided into three districts for which standard loading conditions are specified in the National Electric Safety Code. The loadings for the various districts are as follows:

<table>
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<th>Loading District</th>
<th>Heavy</th>
<th>Medium</th>
<th>Light</th>
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</table>

The resultant weight of loaded cables is calculated as follows:

\[ i = \text{Weight of ice loading (lbs./ft.)} = 1.24 (D + t) \]
\[ t = \text{Thickness of ice (inches)} \]
\[ D = \text{Diameter of cable (inches)} \]
\[ P = \text{Force due to wind (lbs./sq. ft.)} \]

\[ h = \text{Force due to wind (lbs./ft.)} = \frac{P(D + 2t)}{12} \]

\[ w' = \text{Weight of unloaded cable} \]
\[ w'' = \text{Vertical weight of loaded cable} \]
\[ w'' = w' + i \]

The loaded weight of the cable is the resultant of the vertical and horizontal weights plus the proper constant.

\[ w''' = \text{Resultant weight of loaded cable} \]
\[ w''' = \sqrt{(w' + i)^2 + h^2 + k} \]

### Messenger Characteristics

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<td>Area x Modulus (ae)</td>
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Coefficient of Linear Expansion .0000072, Except Stainless Steel = .0000092 per degree F.
Installation Practices

**Typical example of sag and tension calculations**

Cable: 3 conductor 2/0 Self-Supporting Cable rated at 5 kV.

Messenger: 3/8" Extra High Strength (30% Conductivity) Copperweld

Ruling Span: 125 ft.

Normal Tension: 3470 lbs. (25% of ultimate strength)

To find the sag at 60°F and the sag and tension under heavy loading conditions:

Weight of complete cable \( w = \frac{2.712 \text{ lbs./ft.}}{2712 \text{ lbs./1000'}} \)

Diameter of cable (circumscribed circle) \( D = 2.50' \)

Normal Tension \( T = 3470 \text{ lbs.} \)

Area x Modulus, \( ae = 2,088,000 \)

Calculate normal sag at 60°F.

\[
S = \frac{125 \times 2.712}{3470} = 0.0976
\]

From Table on page 19 note that sag factor corresponding to \( S = 0.0976 \) is 0.01221

Sag = 0.01221 x 125 = 1.530 ft.

= 18.3 inches

To find sag and tension under heavy loaded conditions:

Heavy loading — 1/2" radial ice and 4 lb. sq. ft. horizontal wind force at 0°F.

Constant \( k = 0.31 \)

Weight of ice loading, \( i = 1.24 x \frac{7(0.30 + .5)}{1.860} \)

= 1.24 x 0.5 (2.50 + .5)

= 1.860 lbs.

Horizontal force, \( h = \frac{P(D + 2t)}{12} \)

= 1.167

Vertical weight of loaded cable, \( w^* = w^* + i \)

= \( 2.712 + 1.860 \)

= 4.572 lbs

Resultant force, \( w^* = \sqrt{h^2 + (w^* + i)^2} + k \)

= \sqrt{1.167^2 + 4.572^2} + 0.31

= 4.72 + 0.31 = 5.03

The procedure for calculating the sag and tension under loaded conditions consists of finding the unstrained length of the cable, changing its length for the change in temperature and then stressing the cable for the new loaded conditions and determining the new sag and tension.

In the above calculations of normal sag we calculated

\[
S = \frac{D x 2.712}{T} = 0.0976
\]

Calculate Elongation factor

\[
S = \frac{125 \times 2.712}{2,088,000} = 0.000162
\]

From the curves on pages 20 and 21 determine the unstrained length factor for the abscissa \( \frac{Sw'}{ae} = 0.000162 \)

and the curve \( \frac{Sw'}{T} = 0.0976 \)

This is found to be 0.99873 = unstrained length factor

Correct this from 60°F to 0°F.

Temperature correction factor of linear expansion

\[
-0.000072/F.
\]

Correction of length factor = -0.000432

Unstressed length at 0°F = 0.99873-0.000432

= 0.99830

Calculate elongation factor for loaded weight \( w^* = \frac{5.03 \text{ lbs./ft.}}{2,088,000} = 0.000300 \)

From the curves on pages 20 and 21 determine \( \frac{Sw^*}{T} \) for the ordnance of 0.99830 and the abscissa of 0.000300.

This is found to be 0.126.

Calculate T' under loaded conditions from \( \frac{Sw^*}{T'} = 0.126 \)

\[
T' = \frac{125 \times 5.03}{0.126} = 4990 \text{ lbs}
\]

This is seen to be 35.9% of the ultimate strength of the messenger.

The sag factor is determined from Table on page 19 corresponding to \( \frac{Sw^*}{T'} = 0.126 \) and is found to be 0.01578

Sag = 0.01578 x 125 = 1.970 ft. = 23.6 inches

For stringing the cable it is usual practice to calculate the stringing tension (unloaded) for various temperatures and plot a curve for ready reference. The procedure is the same as in the above example using the unloaded cable weight. The work can be speeded by tabulating the calculations.

Stringing Temp. F 0 30 60 90

Correction for length -0.000043 -0.000022 0 +0.000022

Unstressed length factor 0.99830 0.99851 0.99873 0.99895

For these values find \( \frac{Sw'}{ae} = 0.000162 \)

Solving for

Stringing Tension T 4140 3760 3460 3200

The sags may also be calculated if desired, but the spans usually vary so it is more convenient to pull the entire length of cable up to the desired tension rather than measuring the sag.

The above calculations are based on final stretch values. The messenger is usually over-stressed during installation so the final stretch values are more accurate than initial values.

*Additional information can be found in ANSI/CEA P-79-561

"Guide for Selecting Aerial Cable Messengers and Lashing Wires".
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