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Introduction

The purpose of the ACCC® Conductor Maintenance and Repair Manual is to provide experienced personnel with guidelines, recommendations, and the requirements necessary to successfully Maintain and Repair ACCC® Conductor and associated accessories.

This document is an overview and guideline covering what to do but not necessarily how to do it. It is not intended to serve as a more intensive training manual or act as a substitute for proper training required, personal skill sets, or industry experience.

These Guidelines should be used in conjunction with the ACCC® Installation Guidelines, where advice on the correct tools and equipment and installation methods can be found. A copy of the installation Guidelines can be downloaded via CTC Global Website.

Safety practices applicable to other conductors are identical for ACCC® Conductor installations. Proper grounding is a critical aspect for the safe installation of any high voltage conductor particularly when nearby line circuits may remain energized during installation. Refer to Subject Matter Experts for directions on working in areas where high induction currents may be present.

ACCC® Conductor is maintained and repaired using industry standards, installation equipment, methods, and standards such as IEEE-524, National Grid Linesmens Manual M1 (UK), and others. Many standards exist world-wide and applicable standards should be observed. For ACCC® Conductor, where standards conflict with this manual, please contact CTC Global (fieldservice@ctcglobal.com).

I. Scope

These guidelines apply to all sizes and types of ACCC® Conductor and associated hardware, including Ultra-Low Sag (ULS), Ultra-High Strength (AZR™) (Ice Load), and ACCC InfoCore®.

II. Supporting Documentation

- ACCC® Installation Guidelines.
- IEEE Std. 524-2016
- CIGRÉ WG B2.47 TB 708-2017

III. Inspection

After successful installation, maintenance of ACCC® Conductor consists simply of periodic inspection for environmental damage, structure degradation, broken insulators, hardware failure, phase-to-phase and phase-to-ground clearances, vegetation encroachment, underbuild, or other issues, and then the rectification of such, exactly as for any other bare overhead conductor and in accordance with this manual.

A. Conductor Trolleys

There are no special requirements for the use of conductor trolleys on undamaged conductor. However, if aluminum strand damage is observed and the condition of the core is suspected to have been compromised, then a conductor trolley MUST NOT be used for access. An alternative source of access should be used to allow further inspection.

Devices supporting personnel (spacer carts or buggies, baker boards, ladders, or working platforms) must never create a conductor angle greater than 8° (6° for ULS) where the device contacts the ACCC Conductor.

B. Conductor Inspection.

Visual patrols from a helicopter, drone, ground vehicle, or foot patrol can detect damage that might have occurred on insulators, broken or damaged conductor strands, leaning structures and vegetation. Thermal imaging cameras can quickly and reliably find "hot spots" in conductors and hardware, indicating a potential issue.

C. Discoloration

The surface of new ACCC Conductor will normally appear shiny, bright, and reflective. ACCC Conductor may be ordered with a non-specular finish to reduce reflectivity and the appearance is then silver or light grey.

When conductor reels are stored outdoors, moisture can be trapped in wrapping material next to the conductor, this is often found at the bottom of the reel where water has pooled. The moisture can combine with chemicals from the surrounding atmosphere, and a black stain can appear on the conductor. This has been found to be more prevalent in non-specular conductor as the drawing oils have been removed.

Water stains are a cosmetic issue; they have no adverse effect on the performance or service life of the conductor. In many environments, the conductor will darken in the first few months the line is energized, and water stains will no longer be noticeable.

Figure 1 - Water Stain

New conductor may darken in service, sometimes rapidly and dramatically, due to contaminants in the atmosphere such as near fertilized agricultural fields or in heavily polluted environments.

D. Abrasion damage

Abrasion damage is a chafing, impact wear that accompanies relative movement between conductor hardware and the conductor or armor rods. Abrasion damage can be identified by black deposits on the conductor. Abrasion eventually results in the failure of the conductor strands. If the damage is detected early, it can be repaired. Always ensure the cause of the abrasion is identified and corrected.

E. Line Hardware

When inspecting the many aspects that make up line hardware, look for:

- Missing cotter pins, bolts, or nuts.
- Rust, as this is a telltale sign the hardware is in a weakened state and could ultimately cause the line to fall.

F. Strand Loosening / Birdcage

It is likely that any strand loosening or birdcage observed would have been caused and not rectified correctly during installation, as birdcage does not normally occur during service. However, anomalies in the conductor strands can also be a telltale sign of a broken core and therefore further examination must be undertaken.

Figure 2 - Strand Loosening Due to Core Damage

If the loosening is not too severe and the cross-sectional area of aluminum remains intact, then the electrical performance will not be affected. Where strand loosening is observed there is a possibility that debris could build up between the open strands. This has the potential to cause corona or noise.

Extremely high current such as short-circuit events can cause birdcage or significant localized loosening of the aluminum strands. Where birdcage has occurred, this could cause localized corona or noise. Therefore, where the core is visible the aluminum must be repaired, or the section replaced.

Where strand loosening is observed always carry out further checks to ensure the core has not been damaged.

G. Conductor Damage Mid Span

If there is damage to the conductor mid-span due to contact with trees or from some other incident, it is important to look at the structures on both sides of the damaged conductor. Check both ends of the armor rod at each adjacent structure and ensure that there are no sharp bends in the conductor or strand opening as this could signify a possible broken core.

IV. Types and Causes of Conductor Damage

A. Aeolian Vibration

Aeolian Vibration is a high frequency motion (10 to 250 Hz) which can occur under smooth wind conditions (5 to 15 mph or 8 to 24 km/h) across the conductor surface, resulting in cyclic bending at the supporting hardware (i.e., dead-ends, splices, suspension clamps,) and causing damaging stress fatigue and strand breakage.

Figure 3 - Aeolian Vibration

B. Galloping

Galloping is a low frequency, high amplitude oscillation due to high winds (15 to 40 mph or 24 to 65 km/h) blowing over the ice-covered conductor. Ice accretion takes place on the conductor, changing the shape leading to aerodynamic lift and rotational moment which results in negative aerodynamic damping and leads to galloping. Conductors can move up to 30 feet (10 meters) resulting in cyclic bending at the supporting hardware (i.e. dead-ends, splices, suspension clamps) and causes damaging stress fatigue and strand breakage.

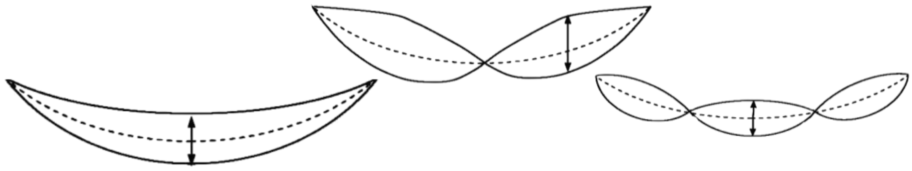
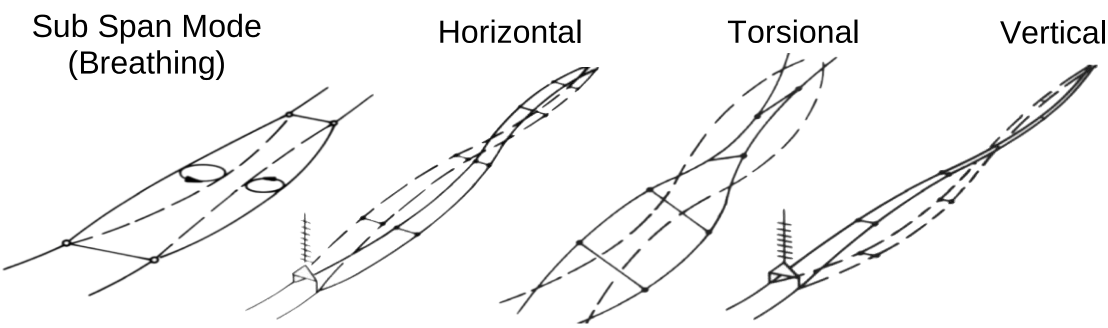


Figure 4 - One, Two, and Three-Loop Galloping

C. Wake-Induced Oscillation

Wake-induced oscillations, (winds of 10 to 40 mph) appear only in bundled conductors. They are due to the shielded conductor lying in the wake of the windward conductor. The oscillations may be vertical, horizontal, or torsional in motion. Cyclic stress fatigue can break strands at spacers, dead-ends, etc.



D. Other Damage Considerations.

To avoid a possible recurrence, it is important that the cause of the damage is established and repaired prior to the line being put back in service. Other possible causes of damage that should be considered but not limited to when inspecting conductors include:

1) Lightning Strike
2) Gun Shot
3) Short Circuit
4) Impact from Debris
5) Incorrect Fittings or Badly Installed Fittings
6) Poor Installation

V. Repair Fittings and Criteria Guidelines

A. Factory-Formed Helical Repair Fitting

Factory-Formed Helical (FFH) fittings consists of helically formed wires which provide the compressive force necessary to grip the conductor.

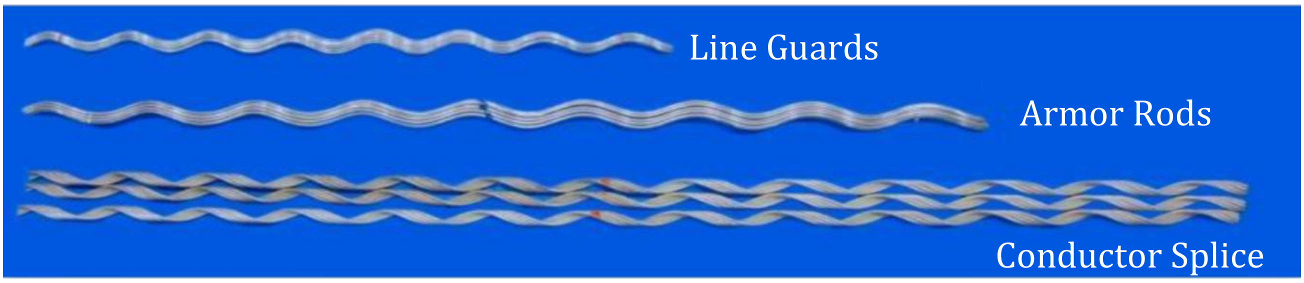


Figure 5 - Factory-Formed Helical fittings.

Line Guards

Also known as Patch Rods.

Line guards are used to protect against abrasion and for limited repair. They can be used at support points or in-span and will restore the conductance and strength of the aluminum for damage up to 25 percent of outer layer strands.

Armor Rods

Also known as Helical Repair Sleeve, Helical Rods, Preformed Repair Rods.

Armor rods are intended to protect an undamaged conductor at a support point or with ancillary fittings such as Armor Grip Suspension (AGS) and vibration dampers, respectively. They protect against bending, compression, abrasion, and arc-over. Armor rods will restore the electrical conductance and strength of the conductor for damage up to half of the outer layer strands.

Conductor Splice

Also known as Line Splice, Armor Splice.

A Conductor Splice is used to repair conductor when the damage level exceeds half of the outer layer strands. They are designed as a single-component outer-layer assembly. A Conductor Splice will provide better electrical conductance than an equivalent length of unspliced conductor and only restore the strength of an ACCC® conductor's aluminum strength.

B. Hydraulic Compression Repair Fitting

Hydraulic Compression (HC) are made of a round aluminum tube, installed on the conductor by radial compression, using a die and hydraulic pressure system.

IMPORTANT For ACCC® conductors, implosive type HC repair fittings are NOT permitted.

The compression of the tube creates a permanent, strong electrical and mechanical bond with the conductor.

Certain HC fittings requires cutting the conductor at the damage location. This procedure will reduce the conductor length, which needs to be addressed either by using a fitting with the appropriate length to compensate for the shortening of the conductor or splicing in a new length of conductor between two HC fittings.

Compression Repair Sleeve

Also known as Compression Sleeve, Repair Sleeve.

Compression Repair Sleeves may be used to repair and restore conductivity and strength of the aluminum strands when damage does not exceed 25% of the outer layer strands or as specified by the manufacturer. The two-piece sleeves are fitted over a damaged area, and then compressed in a similar way to dead-ends. They are 14 to 24 in (350 to 600 mm) long, depending on manufacturer and conductor size.

Figure 6 – Compression Repair Sleeve.

ACCC® Compression Splice

Also known as Compression Joint, Midspan Joint, Midspan Splice, Full Tension Joint.

ACCC® Compression Splice, like ACCC® Compression Dead-Ends, are specially designed for ACCC® conductors. They utilize a collet and housing interface that effectively transfers load from composite core to another. The fitting is then compressed, ensuring electrical continuity and mechanical design strength.

An ACCC® Compression Splice replaces approximately 9 to 11 in (230 -280 mm) of core and represents the only way to restore the line to 95% of its original rated tensile strength (RTS). This is the best technical solution for repairing damaged transmission lines for the following reasons:

1) ACCC® Compression Dead-Ends and Splices have a guaranteed ultimate tensile strength that's equivalent to 95% of the rated tensile strength of the conductor.
2) The electrical resistance of the assembly when properly compressed on conductor is less than 75% of the resistance of the equivalent length of conductor.

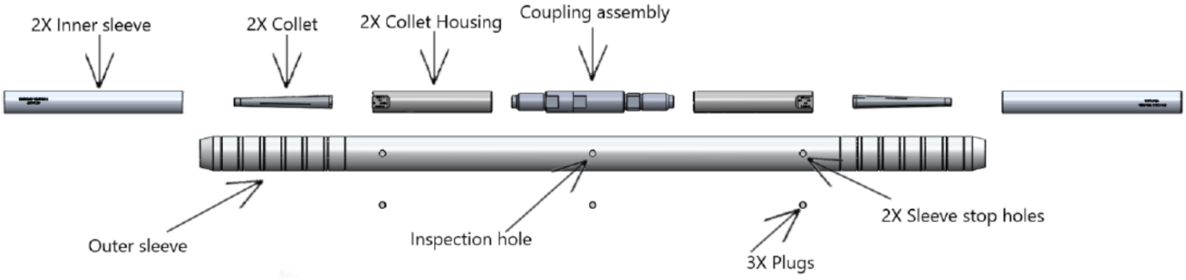


Figure 7 - ACCC® Compression Splice.

C. Repair Fitting Criteria.

The following table is a general guideline and must ONLY be used when it is certain that there is **no core damage**. Any amount of core damage must be repaired using an ACCC® Compression Splice.

Many utilities have developed their own guidelines for conductor repair criterion which can be more or less conservative guidelines than the table below. Consult appropriate authorities and manufacturers for guidelines and recommendation.

Percentage of Damaged Aluminum Strands	Location of Damage	Factory-Formed Helical (FFH) Repair	Hydraulic Compression (HC) Repair
Up to 25% of outer strands.	In span	- Line guards* - Armor Rods* - Conductor Splice	Compression Repair Sleeve*
	Support point, Dead-end		
25% to 50% of outer strands.	In span	- Armor Rods* - Conductor Splice	ACCC® Compression Splice to dead-end/structure or Compression Splice (2) and suitable length of conductor.
	Support point, Dead-end		ACCC® Compression Splice and suitable length of conductor from dead-end/structure.
Up to 100% of outer strands.	In span	- Conductor Splice	ACCC® Compression Splice to dead-end/structure or Compression Splice (2) and suitable length of conductor.
	Support point, Dead-end		ACCC® Compression Splice and suitable length of conductor from dead-end/structure.
Any number of inner strands or Any core damage	In span		ACCC® Compression Splice to dead-end/structure or ACCC® Compression Splice (2) and suitable length of conductor.
	Support point, Dead-end		ACCC® Compression Splice and suitable length of conductor from dead-end/structure.

Table 1 – Recommended ACCC® Repair Methods for Transmission.

*Certain manufacturers such as Burndy limit repairs up to 2 damaged outer aluminum strands for certain fittings. Consult and verify with the manufacturer for repair limits.

Percentage of Damaged Aluminum Strands	Location of Damage	Factory-Formed Helical (FFH) Repair	Hydraulic Compression (HC) Repair
Up to 40% of strands.	In span	- Conductor Splice* **	Compression Repair Sleeve* **
	Support point, Dead-end		Armor Splice Rods* **
Over 40% of strands, Any number of inner strands, or Any core damage	In span		ACCC® Compression Splice to dead-end/structure or Compression Splice (2) and suitable length of conductor.
	Support point, Dead-end		ACCC® Compression Splice and suitable length of conductor from dead-end/structure.

Table 2 - Recommended ACCC® Repair Methods for Distribution.

*See Section VI – Repair Fitting Location Guidelines for more in-depth details regarding Distribution repairs.

**Certain manufacturers such as Burndy limit repairs up to 2 damaged outer aluminum strands for certain fittings. Consult and verify with the manufacturer for repair limits.

VI. Repair Guidelines

When planning to make repairs on ACCC® conductors, the following must be taken into consideration for **both** Transmission and Distribution:

1) Many utilities do not allow the installation of repair fittings on spans depending on its surroundings (i.e. river crossings, railroads, and highways) as well as the number of fittings in a single span. Consult the appropriate authorities for what is permitted.
2) Repairs fittings must be made with materials (Aluminum) and components which are rated for ACCC® operating temperatures (200° C).
3) A spacer damper of the appropriate size should be fitted 4 m from the repair sleeve to prevent sub-conductor clashing in the vicinity of the repair.
4) When replacing conductors or a section of sub-conductors, the creep of the existing conductors must be taken into consideration. For further advice contact fieldservice@ctcglobal.com.
5) In all cases, carefully follow the installation instructions provided by the manufacturer such as the crimping dies used and the direction of compression.

Repair Fitting Location Guidelines

Some utilities prescribe a larger minimum distance between repair fittings and ancillary hardware. Consult the appropriate authorities for guidelines and recommendations.

For Transmission Circuit:

1) The minimum distance from a HC fitting to another or to a dead-end/structure shall be 50 ft (15 m).
2) The minimum distance from a HC fitting to FFH fitting or ancillary hardware such as spacers or vibration dampers shall be 13 ft (4 m).
3) The minimum distance from a FFH fitting rod ends to another (including ancillary hardware) shall be 4 ft (1.2 m).

For Distribution Circuit:

1) The minimum distance from a HC fitting to the conductor support shall be 2 ft (0.6 m).
2) The minimum distance from the end of a FFH fitting to the end of existing Armor Rods, Line Guards, or another FFH fitting shall be 6 inches (16.24 cm).
3) Armor Splice Rods are required when damage is located near the conductor support that removal and replacement of the existing armor rods or line guards is required.
4) Armor Splice Rods must be ordered with sufficient length so that a distance equal to ½ of the length of the splice covers the conductor beyond the damaged point on the conductor.
5) Where the use of those conductor repair methods conflicts with vibration damper position, a section of the conductor should be replaced.

When the minimum spacing condition cannot be respected, an alternative solution must be tailored to the unique conditions of the line. Contact the line engineer and hardware manufacturer.

VII. Repair Examples

A. Aluminum Strand Damage Only

Use appropriate repair method from Table 1.

B. Conductor and Core Damage, Small Area (under 9 to 11 in)

If beyond 50 ft (15m) from a structure/dead-end, cut the small area of conductor with damaged core and install an ACCC® Compression Splice.

If within 50 ft (15 m) of a structure/dead-end, replace 50 to 100 ft (15 to 30 m) of conductor and install an ACCC® Compression Splice. This involves installing a new ACCC® Dead-end at the structure.

C. Conductor and Core Damage, Larger Area (over 9 to 11 in)

If core damage extends greater than 9 to 11 in (230 to 280 mm) or exists in multiple places, use multiple ACCC® Compression Splices and replace 50 to 100 ft (15 to 30 m) of conductor. Locate splices at least 50 ft (15 m) away from any structure or from another splice. Ensure the accumulated creep of the existing sub-conductors is considered when re-sagging.

D. Conductor Damage Mid Span and One Structure

If mid span core damage is accompanied by damage at suspension clamp armor rod, use ACCC® Compression Splices, replace all damaged conductor, keeping splices at least 50 ft (15 m) from any structure. Ensure the accumulated creep of the existing sub-conductors is considered when re-sagging.

E. Conductor and Core Damage, Dead-end Span:

Add 50 to 100 ft (15 to 30 m) of conductor with an ACCC® Compression Splice and add a new dead-end. Ensure the accumulated creep of the existing sub-conductors is considered when re-sagging.

F. Conductor Strands Open, Core Exposed:

Cover the affected area using a suitable repair sleeve (See Table 1), where the area is too large to cover with a single repair sleeve the section must be replaced with ACCC® Compression Splices and the appropriate length of conductor.

VIII. Live or Energized Maintenance

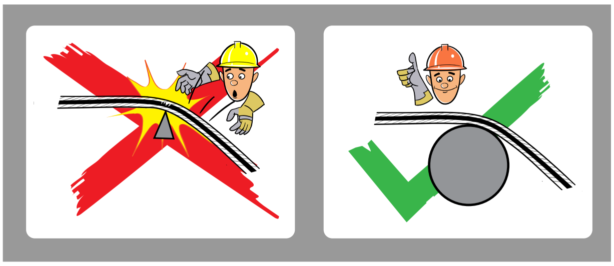
Live or energized maintenance can be utilized to work on ACCC® Conductor, however it is important that the following points are considered prior to starting work:

Equipment for working with live lines (hot-sticks, gloves, Faraday suits, etc.) are temperature rated, but typically lower than 180°C ACCC Conductor rating. Thus, the maximum conductor temperature that can be worked will be determined by your equipment.

IX. Dos & Don’ts

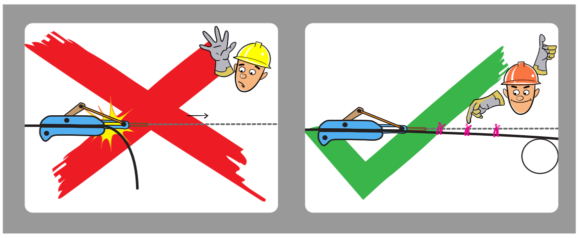
A. DON’T OVER-BEND!

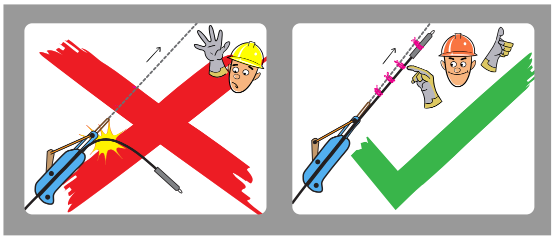
Don’t allow tensioned conductor to contact surfaces that present sharp angles or small diameters.



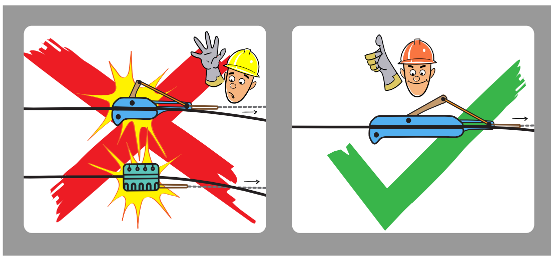
B. Tension Grip DON’Ts:

Don't allow the conductor tail or the dead-end to fall or droop unsupported while handling the conductor. If the tail is not controlled, it will damage the core at the back of the grip.



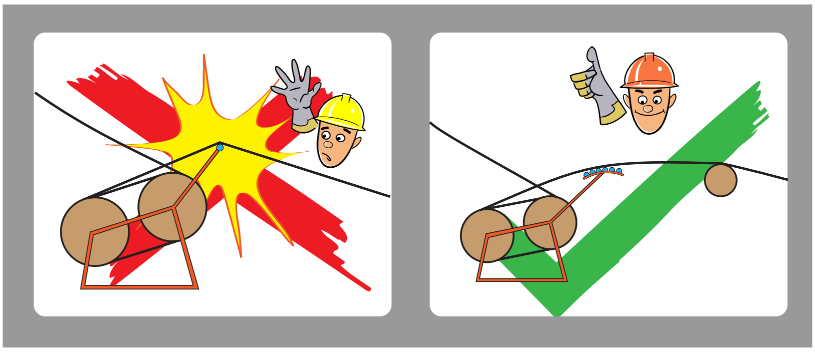


Don't allow the conductor tail or the dead-end to fall or droop unsupported while handling the conductor. If the tail is not controlled, it will damage the core at the back of the grip. Don’t use pocketbook grips or short-jaw parallel jaw grips.



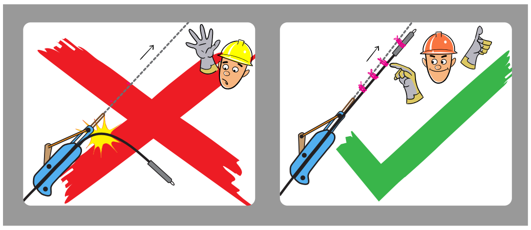
C. Fairlead DON'T:

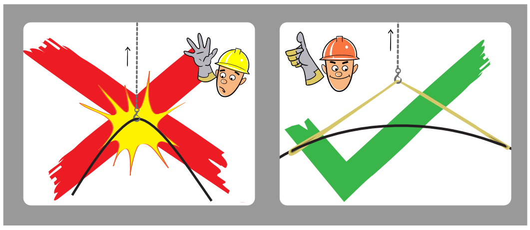
Don't let ACCC Conductor run hard against any roller of the fairlead. Always use a tensioner feed sheave (meeting minimum sheave diameter requirements) between the payout reel and tensioner to guide the conductor into the middle of the tensioner fairlead opening.



D. Handling DON'T:

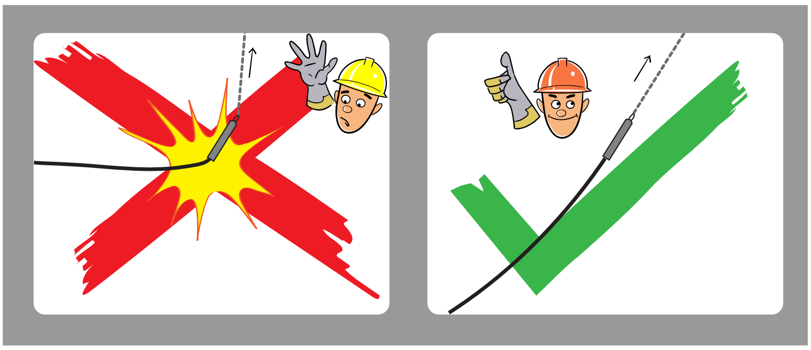
Don't hoist or handle the conductor in any manner which causes a sharp bend in the conductor.





E. Termination DON'T:

Don't allow a sharp bend where the conductor exits the termination hardware. Hoisting conductors or dead-end without paying attention to this area can damage the core at that point.



Revision History

Revision	Change Reason and Description Change	Release Date
A	Initial Release replaced Chapter 9 of WI-750-019 (obsolete)	30 July 2020
B	Introduction: Added grounding sentences Section III A: Added maximum angle for line carts Section III F: Added short-circuit bird cage sentence Section III F: Removed risk of UV damage to core Section V D: Added minimum distance between splices Section VIII: Removed restriction against energized maintenance Minor language and formatting changes	July 2023
C	Section V: Repair Criteria Section VI: Repair Guidelines Section VII: Repair Examples	April 2024
D	Section V: Repair Criteria – Table 2 for Distribution. Section VI: Repair Fitting Location Guidelines - Distribution	October 2024