PREFORMED LINE PRODUCTS
The connection you can count on.

A Guide Book for the Inspection, Classification and Restoration of Damaged or Worn Conductors

OVERHEAD DISTRIBUTION LINE REPAIR MANUAL

COMMUNICATIONS ENERGY SPECIAL INDUSTRIES SOLAR

INTRODUCTION

For almost 70 years, Preformed Line Products Company (PLP) has been concentrating on the development and manufacture of helical accessories for conductor. PLP's pioneering spirit and devotion to perfecting this highly specialized technology has put it in the position of a consultant to utilities concentrating on the solution of conductor motion-related problems. In this role, PLP has made thousands upon thousands of line repair recommendations to utilities that have sought help.

As in the past, PLP will continue to provide this type of service to the utility industry. However, a great majority of problems that occur in the field can be identified, isolated and solved expeditiously by the utility itself if an inspection and repair program is employed. This Overhead Power Line Repair Manual is published for those individuals seeking a better understanding of the specifics involved in establishing such programs.

Almost all distribution conductor damage occurs at support points. The need to detect the damage early and repair it properly has led PLP to publish this Repair Manual.

CONTENTS

HISTORY OF TIED SUPPORTS

Overhead distribution involves the securing of conductors to pin, post and spool insulators. There is a trend toward larger conductors, higher voltages, longer spans and greater ground clearances. These requirements demand improved mechanical and electrical performance.

Starting with the first overhead power lines in 1882, hand ties of many different configurations have been used (Figure 1). These were originally based on early communications line construction practices. However, hand ties are vulnerable to loosening from various forces and types of motion: differential ice buildup, ice dropping, violent wind buffeting, sway oscillation, galloping and aeolian vibration. Once a hand tie has loosened, it constitutes a potential source of abrasion during any subsequent motion.

In the late 1950's and early 1960's, factory-formed ties were developed to tie power conductors into the top grooves of pin and post insulators. Five years of highly successful field testing in severe vibration environments preceded their commercialization. Since then, factory-formed ties have been providing security for conductor at the insulator points (Figure 2).

Since the introduction of the first factory-formed tie, additional designs for both top and side grooves have been developed for use with most ANSI C29 Compliant tie top type insulators. Factory-formed ties with the characteristics of secure fit, low stress concentration and uniformity of installation reduce mechanical difficulties and radio interference problems associated with loosened hand tie wires.

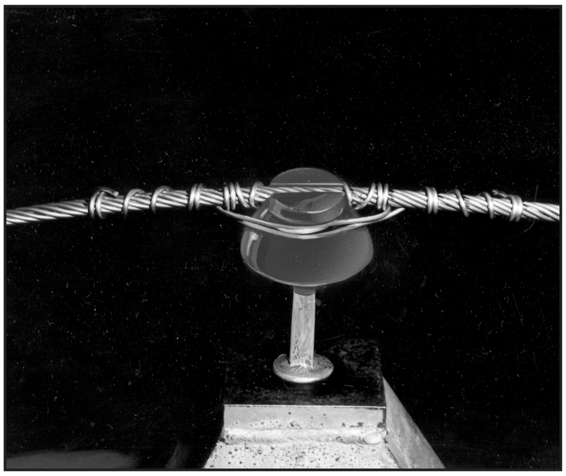

Figure 1

Hand tie: Consistency varies based on lineman training and skill. However, the longevity of the tie is a function of the soft malleable wire from which the tie is made.

Figure 2

Factory-formed tie: Consistency dependent on quality controls in the factory. Provides uniformity of installation and long term, unchanging performance due to use of high strength materials.

CAUSES OF CONDUCTOR DAMAGE

The cost of conductors is one of the major expenses in any overhead power line construction. It is the primary component in the flow of revenue for a utility and also the component most exposed to hazards. With the introduction of aluminum conductor, the vulnerability to damage increased due to its easily abraded surface. The four types of motion occurring on overhead power lines are (1) aeolian vibration, (2) galloping, (3) sway oscillation and (4) unbalanced loading. Each is independent in cause and effect.

A. Aeolian Vibration

Aeolian vibration is characterized by low amplitude and high frequency. It becomes most devastating to overhead lines in flat, wide-open areas with 5- to 15-mph laminar winds, generally perpendicular to the span. Up until the early 1930's, aeolian vibration was not a major concern to utilities. Since then, and primarily through the 1960's and 1970's, aeolian vibration has emerged as a significant source of trouble. The rapidly increasing incidence of vibration is related to the following construction practices:

1. Longer spans;
2. Higher tensions;
3. Extended rural service and more lines across open country;
4. Widespread use of aluminum and ACSR cable; and
5. Taller structures.

The most common types of aeolian vibration damage are:

1. Fatigue breakage of conductor strands at:
   a. Support points where the conductor movement is restricted;
   b. Rigid splices and dead-ends; and
   c. Broken-down wire leads from taps or stirrups;
2. Severe abrasion of conductors at:
   a. Loose ties; and
   b. Loose hardware;
3. Severe abrasion and breakage of tie wires;
4. Fatigue breakage under clamps of trunion-mounted post insulators; and
5. Loosening of associated hardware, such as nuts or bolts in structures, pins of pin-type insulators, and clamps of various line fittings;

B. Galloping

Galloping is a violent, low frequency, high amplitude vertical conductor motion. The frequency is usually below two cycles per second, but can be up to 40 feet. It usually occurs as a result of ice forming on the conductor; however, this is not the only cause. Galloping has been observed resulting from wind alone – usually in excess of 15 mph (24 km/h). Failures due to galloping occur in a short duration of time, and damage can be extensive. The most common types of damage that result from galloping are:

1. Broken crossarms and, in severe cases, toppled structures;
2. Sheared-through bolts, bent pins and other deformed or distorted fittings;
3. Electrical trip-outs and conductor burning from phase-to-phase contact;
4. Excessive sag from overstressing conductors;
5. Bird-caging of conductors; and
6. Complete conductor failure.

C. Sway Oscillation

Sway oscillation is the most common type of motion on power line conductors. It is caused by gusting wind forces, which cause the conductor to sway back and forth in a horizontal plane. Both sway oscillation and unbalanced loading can cause abrasion, the most common type of damage found on distribution lines.

D. Unbalanced Loading

Unbalanced loading causes longitudinal movement of the conductor at the support. This motion may be induced through ice unloading, objects striking the conductor, wind-induced motion of the conductor, or thermal changes in unequal spans.

CLASSIFICATION OF INSULATOR AND CONDUCTOR DAMAGE

Where lines are seldom inspected, the first indication of damage may not be detected until the conductor fails and falls to the ground, which may be too late to apply simple corrective measures. In order to avoid the consequences of broken conductors, a visual inspection of conductor and hardware should be made as often as the severity of the conditions suggests.

The following is a classification of the most common types of damage and the corresponding clues to watch for in making line inspections:

A. Abrasion

Abrasion to outside surfaces is highly visible and therefore easy to detect (Figure 3). Abrasion damage is a chafing and impact wear that accompanies relative movement between a loose tie and the conductor or armor rods. Even well-made hand ties can loosen if subjected to prolonged or severe motion. Abrasion can be identified by black deposits on the conductor or tie. It can also be identified by aluminum deposit build-up on the insulator and/or scoring of the insulator glaze.

Figure 3

B. Fretting

Fretting of aluminum wires is a deterioration process created by a rubbing action between two wires (or between a wire and another object). The action wipes away the oxide film normally on the surface of the wires so that the underlying metal is exposed to further oxidation. Since aluminum is a chemically active metal, oxidation occurs at a rapid rate. The back-and-forth motion re-exposes the metal to oxidation and repeatedly makes and breaks the microscopic welds. During this process, oxide fragments accumulate and the fretted surfaces become rough. The fragments look like black dust, and the fretted surfaces are usually black. Fretting is often hidden, especially when it takes place on the inner strands of the conductor. On multi-layer conductor, breaks from fretting may sometimes be detected by spreading the outer strands in order to view the inner layers (Figure 4). CAUTION! Do not use a screwdriver or other sharp objects that could cause additional damage to the conductor. A nylon-covered tool or nylon fid is best for this purpose.

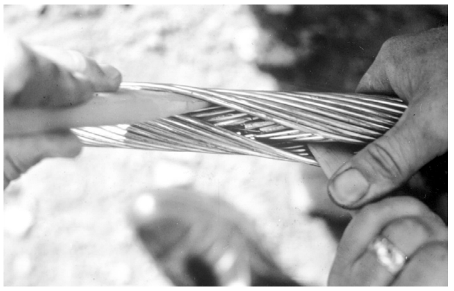

Figure 4

C. Fatigue Breaks

Fatigue breaks are the ultimate failures of the conductor strands or tie wire. They are caused by any one, or a combination of (1) aeolian vibration, (2) galloping, (3) sway oscillation, and (4) unbalanced loading. Typical fatigue breaks are shown in Figure 5.

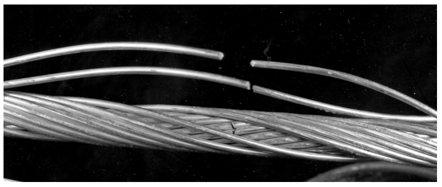

Figure 5

D. Tensile Breaks

These breaks are the result of a load exceeding the strength of the material broken and can usually be identified by the cup-cone nature of the break. (Figure 6).

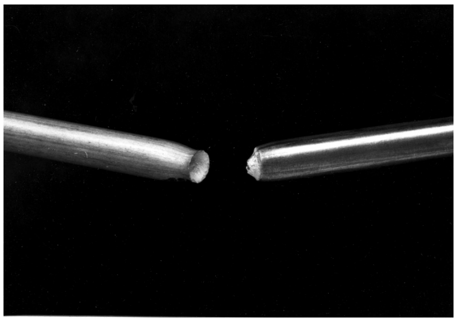

Figure 6

PROTECTIVE MEASURES AGAINST DAMAGE FROM CONDUCTOR MOTION

A number of precautionary measures to counteract conductor motion and its effects are currently available to the line designer and construction personnel. These methods vary in expense, complexity and effectiveness. A brief description and qualitative estimate of the feasibility of each protective measure are contained in the following paragraphs.

Gentle Handling of Cable

Careful handling in the field to avoid scratches, cuts or kinks in the conductor is desirable during the field operations of paying out, stringing, and tying or clipping in. Additionally, to minimize the possibility of conductor damage occurring in the sheaves, tying should be carried out as soon as possible after sagging. These procedures will help to reduce the number of stress concentrations due to surface discontinuities.

Follow Sag-Tension Charts

Sagging conductors at tensions higher than recommended increases susceptibility to aeolian vibration. Sagging in at tensions lower than recommended reduces the probability of aeolian vibration but increases susceptibility to galloping. Proper choice of sag tensions is preferable at the original design stage since resagging is costly and sometimes impossible due to lack of ground clearance or scheduled outage time.

Regarding line tensions, it is advisable that the designer study the recommendations of the conductor manufacturers.

The Use of Armor Rods on Conductors

Armor Rods are intended for clamp supports, but they can also be used at tied supports. Armor rods are effective in sacrificing their surface to abrasion instead of the conductor’s outside surface. In addition, they provide protection against electrical burning of the conductor from flashovers. Armor rods distribute the bending stresses imposed on the conductor at line angles. Armor rods also distribute compression forces under clamps. Armor rods do not suppress line motion but merely shield against its effect. Armor-rodded conductors have many times the life expectancy of bare conductors. But where experience indicates that prolonged periods of aeolian vibration might lead to fatigue of the conductor, cause inner fretting, or score the insulator glaze, it is recommended that armor rods be supplemented by dampers.

Generally, dampers are recommended in all repair cases involving damage from aeolian vibration, and in some cases, anti-galloping devices maybe advisable to counter-act galloping.

Should the conductor become partially damaged, armor rods offer restorative repair capabilities. The maximum repair depends upon the conductor size and stranding, as described in Tables I and II on page 25.

Line guards are a shortened, smaller rod version of armor rods intended for tied supports. They protect against abrasion and arc-over but do not shield against the effects of aeolian vibration. Line guards provide restorative repair capabilities to a lesser degree than armor rods, as described on page 26.

The Use of Ties

PLP factory-formed ties with pads are recommended as a superior replacement for a hand tie wire, with or without protective rods. One reason is that the tie surrounds the conductor with a resilient cushion that eliminates abrasion at the conductor insulator interface. By comparison, protective rods sacrifice their outside surfaces to abrasion but do not eliminate abrasion. Ties not only replace protective rods, but also replace hand tie wire or clamp top insulators as a means of securing conductors to insulators. The PLP Tie offers a superior method of attachment because it permits controlled movement of the conductor under unbalanced loads, and then restores itself. This elastic feature of controlled movement and recovery is called "resiliency". Hand tie wire permits movement but has no recovery because it permanently deforms. Clamp top insulators do not permit resilient movement in the conductor when load imbalances occur. Since the clamp does not yield to tension changes, cantilever loading occurs at the base of the insulator.

Protective rods are usually not required under ties with pads on new construction except for some lines that may experience excessive or severe conditions. However, PLP recommends armor rods to restore a partially damaged conductor to its original strength and conductivity before ties are installed, thereby eliminating the recurrence of abrasion by hand tie wire. Recommendations regarding dampers with ties on original construction are on page 11. Dampers are recommended in all repair cases where fatigue damage is found.

Use of Dampers

For distribution lines where experience indicates that prolonged periods of aeolian vibration may lead to fatigue of the conductor, cause inner wire fretting, or score the insulator’s glaze, it is recommended that dampers be installed.

Because all of the conditions conductive to aeolian vibration cannot be continuously monitored in the field, emphasis is on a utility’s own experience in recognizing damage caused by aeolian vibration.

The following are guideline definitions for vibration activity, with damper recommendations for each. Field examples of “excessive”, “severe” and “moderate” also appear in this manual.

Vibration	Definition	Damper Requirements
Excessive	Where abrasion damage has required replacement of both hand tie wire and protective rods, or where fatigue has been found under clamps. Protective rods should be replaced when visual inspection shows approximately one-half of the rod’s diameter has been worn away.	**Supplemental use of dampers is recommended with any formed wire tie product.**
Severe	Where abrasion damage has required replacement of hand tie wire, but less than one-half of the protective rod’s diameter has been worn away.	**Supplemental use of dampers is recommended with any formed wire tie product.**
Moderate	Where replacement of hand tie wires has not been required, and damage is minor.	**Supplemental use of dampers is recommended with armor rods.**

Because dampers represent an additional expense, a number of utilities install dampers in selected areas on troublesome spans or sections of line. PLP’s damper recommendations apply this same experience to new lines of similar construction in these same selected areas.

Spiral Vibration Damper

PLP's Spiral Vibration Damper (SVD) is designed to be effective in responding to predictable vibration frequencies on small diameter conductors or strand typically up to .760" (19.3mm) outside diameter. For applications above .760" (19.3mm) up to 1.0" (25.4mm), contact PLP as special large SVD's may be suitable.

On spans less than 800ft (253.8m), two SVD's per span, or one on each side of the support point, are recommended. On spans 800ft (253.8m) or greater, four SVD's per span, two on each side of the support point, are recommended. Where two SVD's are required, they can be installed end to end, or can be subset and installed as one "subset length" (Figure 34).

It is not necessary to make engineering calculations as to the placement of SVD's relative to the support point or conductor accessories.

VORTX™ Dampers

For applications on cables greater than .760" (19.3mm), 1.0" (25.4mm), or where frequency response type aeolian vibration dampers are desired, PLP offers the multi response VORTX Damper.

Placement of the VORTX Dampers, as with all frequency responsive type dampers, requires an engineering analysis of the line to which they will be installed.

Contact your PLP representative for specific recommendations for application of VORTX Dampers (Figure 35).

RECOMMENDED LINE INSPECTION AND REPAIR PROCEDURES

Detection of incipient conductor damage in the early stages saves not only unsuspected outages but also considerable time and money devoted to extensive line repair. A slightly abraded conductor costs less to repair than a broken conductor; therefore, early detection of line wear can prevent high-cost repairs. PLP recommends that a plan for periodic line inspections be established, including follow-through inspections. A good routine to follow in making inspections and repairs follows.

Pertinent line data is important and helpful in determining the cause of the problems and consequently the remedial repairs. The following information should be obtained and recorded, if possible (Figure 7):

1. Name of the line, installation date and type of construction.
2. Conductor size of phase wires, neutral wire and stranding.
3. Line direction, prevailing winds and type of terrain.
4. Type and size of insulator (by catalog number if possible) used to support phase wires, and diameter of secondary spool.
5. Loose hardware (nuts, pins, braces, insulators, etc.).
6. Type of tie (size and hardness) and armor rod.
7. Condition of tie wire (broken or worn) and where the damage is located with respect to the insulator.
8. Condition of armor rods with wear related in percent through its diameter.
9. Condition of insulator (wear in depth through glaze).
10. Relate data by phase (road, center, field or neutral).
11. Record any unusual observations (e.g., broken ground wires, chipped insulators, etc.).
12. Remove at least one set of old rods to determine the condition of the conductor under the rods.
13. Determine sag, tension, temperature and span length.
14. Check one double arm pole and at least one dead-end structure (the latter for fatigue breaks outside the dead-end clamps).

It is good practice to make specific notations on the above points to be certain that no stage is overlooked. The form shown in Figure 7, page 14 is ideal as a guide to recording all necessary information. The form may be copied or modified for use by individual utilities. Contact PLP for additional copies.

LINE INSPECTION LOG

Representative ______________________ Inspection Date ______________________

Customer ______________________ Inspector(s) ______________________

Address ______________________ ______________________

Name of Line ______________________ Installation Date ______________________

Voltage ____________ Phase Wire Size ________ Neutral Size ______________________

Line Direction ________ Prevailing Winds ________ Terrain ______________________

Insulator (Cat. No.) ______________________ Spool Insulator Size ______________________

<u>Pole No. 1 Remarks:</u>

Road ø ______________________

C ø ______________________

Field ø ______________________

<u>Pole No. 2 Remarks:</u>

Road ø ______________________

C ø ______________________

Field ø ______________________

<u>Pole No. 3 Remarks:</u>

Road ø ______________________

C ø ______________________

Field ø ______________________

Sag Check 3 Returns Road ø ________ C ø ____________ Field ø ______________

Temperature ________ Span Length ________ ft. Conductor Weight ______________

Tension ____________ lbs. Conductor RBS __________ lbs. Tension % ________

Send Recommendations to: ______________________

____

____

General Remarks: ______________________

____

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____

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Figure 7

The utility may also record the information and submit it to PLP for analysis and repair recommendations.

The inspection starts by spot-checking typical support points with binoculars. Where damage is noted from the ground, climb the pole to check the severity of the problem at closer range. The following are illustrated examples of damage, along with recommended products for line repair:

Example #1 – Moderate Damage

In Figures 8 and 9, note that the hand tie is removed from the right side, revealing moderate abrasion of both tie wire and armor rods. The wear at the end of the tie wire on the right (Figure 9) reveals that it became loose in operation, but did not release the conductor (sometimes called a "floater"). Since the wear on the armor rods has progressed to only about 25% of their diameter – a moderate amount – it is not necessary to replace them. Simply remove the old tie, scrap it, and apply a factory-formed tie. Either a PLP Distribution Tie or a WRAPLOCK® Tie may be used. To be sure of correct size and fit, check PLP's Distribution Product Catalog or contact your PLP representative.

Figure 8

Figure 9

Example #2 – Excessive Damage

In Figures 10 and 11, the tie wire has been broken off completely, and the deep gouges in the armor rods indicate more than 50% wear-through of the rod diameter. In removing the armor rods to determine whether or not conductor damage had resulted, some of the rods broke off, indicating the rods were ineffective in protecting the conductor. Recommendation: If no conductor strands are damaged, remove old tie wires and armor rods and retie with a PLP Distribution Tie or WRAPLOCK® Tie. Because protective rods need replacement, it will be necessary to add PLP Spiral Vibration Dampers.

If conductor strands are broken, repair with new PLP Armor Rods or a Line Splice, then retie with a Distribution Tie or WRAPLOCK Tie, adding dampers.

During such inspections it is a good practice to look at the pole pin conductor first. Historically, the center phase may suffer more damage than the outside phases since it is more rigid, and the effects of the conductor motion are concentrated at the conductor-insulator point.

Figure 10

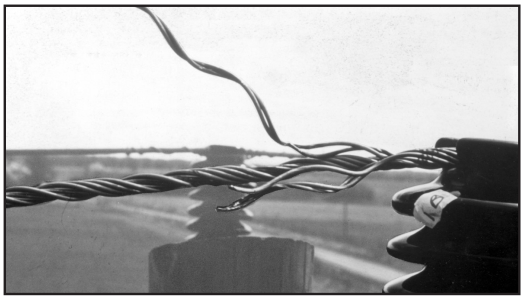


Figure 11

Example #3 – Severe Damage

Figure 12 illustrates severe vibration on double-arm construction. However, in this case, the damage took place on the field phase to the same extent as on the center phase of single-arm construction. The tie wire has been completely severed and the armor rod wear is less than 50% of the diameter of several rods.

Because the tie wire was severed, it will be necessary to use PLP Spiral Vibration Dampers in conjunction with a PLP Double Support or Double Side Tie depending upon which groove the conductor is applied in.

Figure 12

Example #4 – Excessive Damage

Figures 13 and 14 reveal broken tie wires at the insulator and armor rods that are more than 50% worn through. Excessive dynamic conditions on this line were evidenced by the numbers of buttons that were broken off and floating into midspan; on one span a button was found 525' (160m) from its original support assembly and it was lodged against the armor rod of the adjacent support assembly. Radio interference was severe.

Repair procedure is to remove old tie wires and armor rods and carefully check conductor for breaks. If any conductor elements are broken, repair with PLP Armor Rods or a Line Splice and retie with a PLP Distribution Tie or WRAPLOCK® Tie, then apply Spiral Vibration Dampers. If no conductor strands are broken, use one of the factory-formed ties mentioned above, with dampers.

Figure 13

Figure 14

Example #5 – Severe Motion

Figure 15

Figure 15 illustrates that hand ties are inadequate for highly active lines. Three weeks prior to the inspection of this line, linemen found the field phase floating free of the insulator at this support point. Note the dark marks of abrasion caused by the old tie wires. After only three weeks, the new tie wire was broken. Note the loose loop of the tie. Although motion was severe enough to have broken the tie wire, the three-week period was not of sufficient duration to have caused extensive wear of the armor rods. Removal of the old tie wires and replacement with the PLP Distribution Tie or WRAPLOCK Tie with Spiral Vibration Dampers is designed to provide sufficient protection since the armor rods are practically undamaged.

Example #6 – Excessive Damage

Figures 16 and 17 reveal excessive damage typical of every ridge pin support point throughout this system. The tie wire is broken at several places and abrasion has worn the armor rods almost completely through to the conductor. Maximum protection is required here. The procedure is to remove old wires and rods to determine if there is conductor damage. If so, repair with new PLP Armor Rods, Line Splice, or Armor Splice (if steel core damage is suspected, it may be necessary to use a full tension splice) then retie with Distribution Ties or WRAPLOCK® Ties and add Spiral Vibration Dampers.

Figure 16

Figure 17

Example #7 – Severe Damage

In this case, severe vibration has caused abrasion wear to break through the glaze in the saddle of the insulator (Figure 18). Wear, caused by the hand tie wire, can also be seen in the side groove. A WRAPLOCK Tie by itself may prevent porcelain abrasion both in the saddle and the side groove of the insulator. A PLP Distribution Tie will prevent porcelain abrasion in the saddle. But in this case, where vibration was severe enough to cause abrasion in the side groove, supplemental use of Spiral Vibration Dampers is recommended.

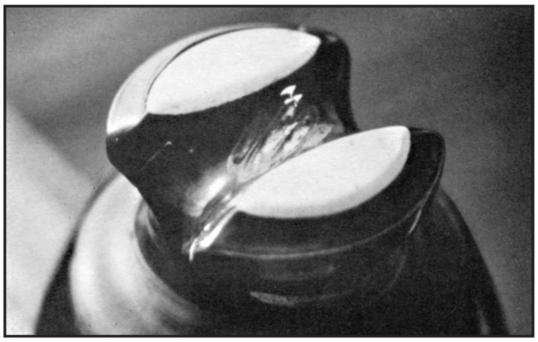


Figure 18

Example #8 – Severe Damage

Severed tie wire and mildly abraded armor rods (indicated by black marks) call for removal of tie wires and the application of a PLP Spool Tie and Spiral Vibration Dampers (Figure 19).

Figure 19

Example #9 – Moderate Abrasion

Inspection revealed considerable Armor Rod wear due to repeated unbalanced loading. The progression of abrasion was arrested by the installation of PLP factory-formed ties (Figure 20).

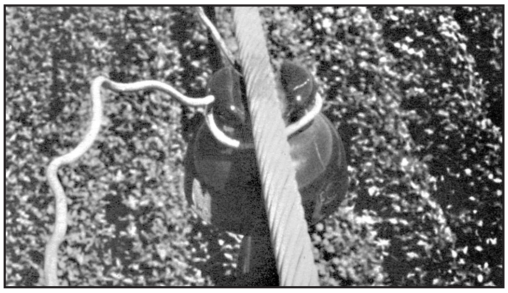


Figure 20

Example #10 – Moderate Abrasion

Abrasion of tie wire and armor rods in this case is the result of misalignment of the insulator (Figure 21). A factory-formed tie with a pad would have prevented this abrasion. Correction is to install either a WRAPLOCK® Tie or a Distribution Tie with pads that compensate for misalignment.

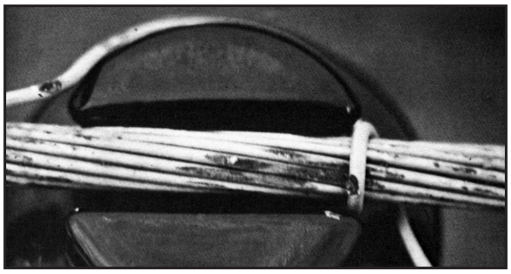


Figure 21

Note: PLP product cartons contain Application Procedures which uprovide correct installation for long-life performance. Extra copies of Application Procedures for all PLP products are available on request. Lineman training is also available through videos and on-site schools, which can be scheduled through your PLP representative.

DEFINITION AND RECOMMENDED USE OF PLP PRODUCTS FOR RESTORATIVE REPAIR OF DAMAGED CONDUCTORS

The following are two common areas which require repair of overhead electric power lines.

(1) Repair at the point of support: most of the repair products are used including splices, armoring devices, and factory-formed ties.

(2) In-span repair typically requires splicing and armoring products.

The following PLP products are illustrated and defined with respect to their use in line repair. Laboratory and field tests (see Tables I and II, page 25) demonstrate that in all cases where the proper product was selected, (1) greater than 95% of the rated breaking strength was developed, and (2) resistance measurements across a length of repaired conductor were consistently less than across the equivalent of uncut conductor.

(All of the products reviewed are used widely in new construction, as well as repair. Specifications, sizes and other details are available in the PLP Distribution Product Catalog.)

PREFORMED® Line Guards

Figure 22 is a product illustrated without a tie. Line Guards are designed to protect the conductor against abrasion and arc-over at tied supports. This product is designed to restore conductance and strength to ACSR and aluminum conductors where damage is located outside the point of support, provided the restoration characteristics in Table III, page 26, are observed.

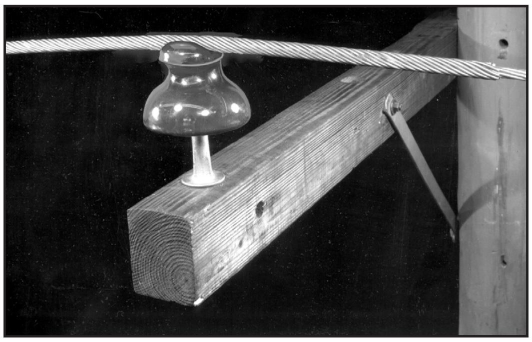


Figure 22

PREFORMED Armor Rods

Figure 23 is a product illustrated without a tie. Armor rods are designed to protect the conductor against bending, compression, abrasion and arc-over. This product is designed to restore conductance and strength to ACRS and aluminum conductors where damage is located outside the point of support, provided the restoration characteristics in Table III, page 26, are observed.

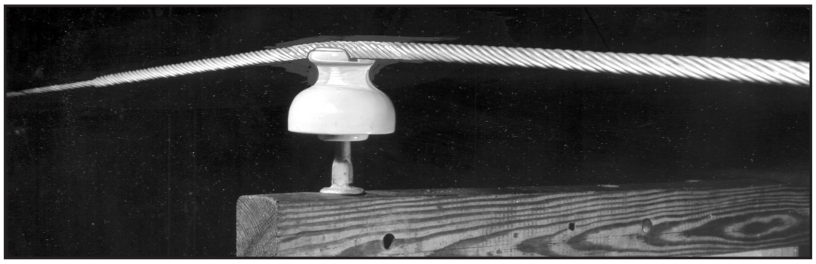


Figure 23

PREFORMED Splices (Conductor)

Conductor splices are designed as a single component, outer layer assembly, and are intended for use on all-aluminum, aluminum alloy, ACSR, and copper conductors. This product is designed to restore original conductivity to all-aluminum, aluminum alloy, copper, and ACSR conductors. The rated breaking strength is designed to be restored to all-aluminum, aluminum alloy and copper conductors of homogeneous stranding. On ACSR conductors, strength is designed to be restored to the aluminum and core wires as indicated in Table III, page 26. When core damage on ACSR conductor is suspected, consult the information shown in the paragraph below on ACSR full-tension splices (Figure 24).

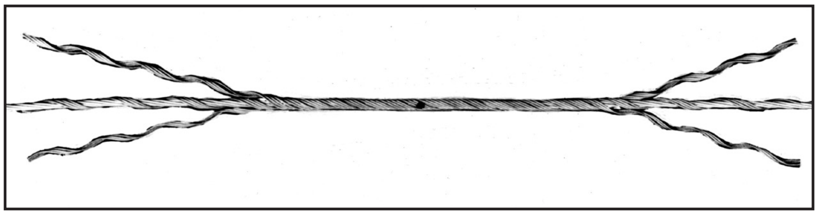


Figure 24

PREFORMED Splices (ACSR Full-Tension)

ACSR full tension splices (FTS) are comprised of three basic components: core splice, filler rods and outer splice (Figure 25). Unlike conductor splices, these are designed specifically for ACSR conductors sustaining core wire damage. The same comments for Conductor Splices apply, with the addition that the FTS splice will develop the rated breaking strength of the ACSR conductor on which it is used. This splice is recommended when core wire damage is suspected. Refer to Table III, page 26, for restorative characteristics.

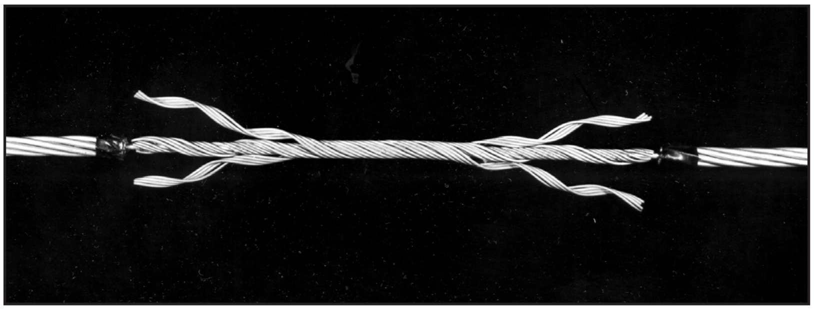


Figure 25

PREFORMED Armor-Splices

The Armor-Splice combines the features of both armor rods and conductor splices and should be considered when damage occurs in close proximity to an existing support of armor rods or line guards, making a conductor splice application impossible (Figure 26). In this instance, an armor-splice is recommended and is designed to replace existing support armor rods or line guards with a continuous length product extended beyond the insulator for proper armor rod protection and beyond the damaged portion for adequate splicing properties.

Whenever protective rods are used for restorative repair purposes, an inhibitor should be used.

Figure 26

PREFORMED Splice Shunt

For repair of faulty automatic or compression splices, PLP offers the custom designed Splice Shunt (Figure 27). This formed wire product applies on "good" conductor on either side of and over a faulty splice. It can provide mechanical and electrical repair properties similar to single layer line splices.

It permits rehabilitation of a faulty splice location without the need to cut out the faulty splice and replace it with 2 new splices and a section of new conductor. It can also be applied with hot sticks so the line does not have to be de-energized during installation.

Consult your PLP representative for specific recommendations for application of custom designed splice shunts.

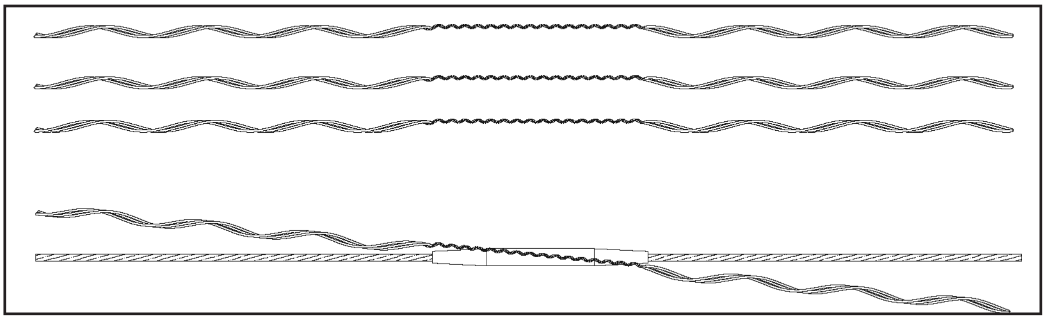


Figure 27

AFTER RESTORATIVE REPAIRS – PRODUCTS FOR RE-TYING AND VIBRATION DAMPING

After the strength and conductivity of the conductor have been determined and any necessary restorative repairs completed, it is recommended that factory-formed ties by PLP be applied where necessary. Follow these steps in selecting ties:

1. Determine overall diameter of the conductor (including protective rods when used) in the area of the insulator so that the proper size tie is selected. (Refer to example of O.D. calculations, Armor Rod section of PLP Distribution Product Catalog.)
2. Compare total applied length of conductor repair rod product with the total applied length of the tie to insure that the tie is not longer than the rods. (If the tie is longer than the rods, consult PLP directly.)
3. Verify that the overall diameter of the repaired conductor will still fit in the insulator's top or side groove when compared to the tie products General Information section of the PLP Distribution Product Catalog, which indicates maximum diameter acceptable for use of PLP ties on most insulators. If your insulator is not listed, or if overall O.D. is too large, consult PLP directly.

Distribution Tie with Pad

The Distribution Tie should repair damage that has occurred to tie wire and/or protective rods at the support point (Figure 28). The Distribution Tie offers protection against future abrasion damage.

Broken or damaged tie wire should be replaced with the Distribution Tie and the supplemental use of Spiral Vibration Dampers is recommended. (See page 12 for details on Spiral Vibration Dampers.)

Figure 28

WRAPLOCK® Tie

The WRAPLOCK Tie should repair excessive tie wire damage that has occurred on armor rodded support points (Figure 29). The WRAPLOCK Tie offers a superior method of securing conductors to insulators because the conductor and insulator are completely surrounded by a resilient elastomer.

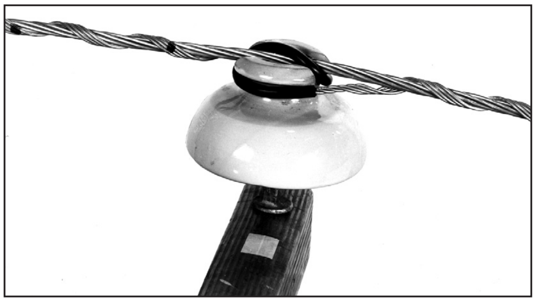


Figure 29

Side Tie and Spool Tie with Pad

PLP Side Tie and Spool Tie's should replace worn or fatigued ties occurring on spool type insulators or when conductors are "side" mounted on pin or post type insulator (Figures 30 and 31 respectively).

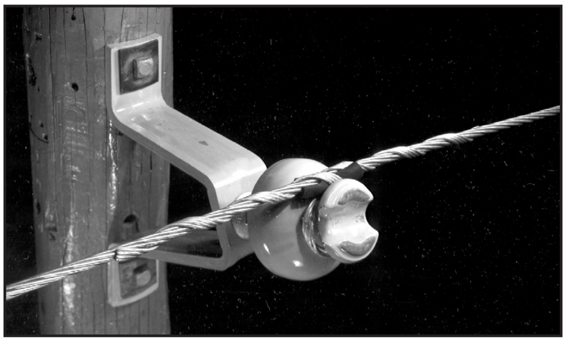


Figure 30

Figure 31

Double-Support Tie

The Double-Support Tie should be used on double crossarm construction for repair when damage has occurred to tie wire and/or protective rods at the support point (Figure 32).

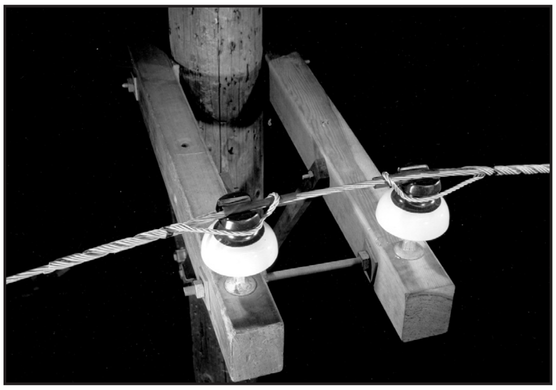


Figure 32

SEVERE WEATHER TIE KITS

For lines that may experience severe or excessive conditions caused by activity such as aeolian vibration, galloping, heavy ice loads, etc, PLP offers the custom designed Severe Weather Tie Kit (Figure 33). This kit combines the benefits of a factory formed Storm Tie (distribution, spool or double ties) with special length Storm Guards for the best possible tied support. The components of each kit are pre-engineered to provide the correct size Storm Guard and Storm Tie for the conductor and insulator to be used on the line. The Storm Guard component of the kit may also provide conductor repair properties comparable to line guards depending upon the specifics of the conductor damage.

Figure 33

Consult your PLP representative for recommendations on the use and repair properties of the Severe Weather Tie Kit.

Vibration Dampers

On selected lines where prolonged periods of vibration might approach the fatigue life of the conductor, or cause inner wire fretting or scoring of the insulator’s glaze, it will be necessary to supplement with dampers. (Figure 34 & 35)

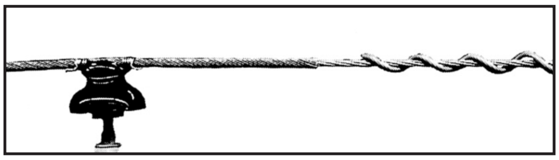


Figure 34
Spiral Vibration Damper

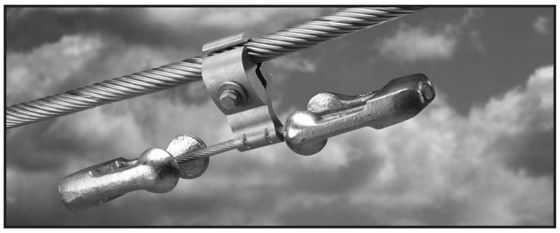


Figure 35
VORTX Damper

Table I - Conductance and Strength Restoration Test Data: Armor Rods

Size and Type	Conductor Diameter (In)	Conductor RBS (lb)	Actual Breaking Load (lb)	Resistance Across Conductor Load (lb)	Fraction Cut*	Resistance Across Break at 25% RBS	Product Applied	Resistance Across Product at 25% RBS	Maximum Developed Load (lb)	% RBS
#2 ACSR 6/1	0.316	2,790	2,940	0.00093	3/6	0.00112	AR-0114	0.00057	2,890	103.6
1/0 ACSR 6/1	0.398	4,280	4,500	0.00075	3/6	0.00088	AR-0118	0.00037	4,610	107.7
4/0 ACSR 6/1	0.563	8,420	8,650	0.00047	3/6	0.00052	AR-0124	0.00033	8,175	97.1
336.4 ACSR 26/7	0.721	14,050	14,500	0.00041	8/16	0.00044	AR-0130	0.00029	14,700	104.6
336.4 ACSR 18/1	0.684	8,625	9,250	0.00036	6/12	0.00039	AR-0129	0.00025	9,100	105.5
336.4 ACSR 30/7	0.741	17,040	18,600	0.00037	9/18	0.00040	AR-0131	0.00028	18,150	106.5
795 ACSR 26/7	1.108	31,200	30,000	0.00019	8/16	0.00020	AR-0141	0.00009	30,700	99.0
954 ACSR 45/7	1.196	26,900	29,500	0.00016	10/21	0.00017	AR-0143	0.00012	26,500	98.5
477 ACSR 30/7	0.833	23,300	25,500	0.00024	9/18	0.00027	AR-0134	0.00015	25,400	109.0
#2 AAC 7-w	0.292	1,265	1,300	0.00131	2/6	0.00136	AR-0113	0.00074	1,290	102.0
2/0 AAC 7-w	0.414	2,480	2,620	0.00065	2/6	0.00073	AR-0119	0.00039	2,670	107.7
4/0 AAC 7-w	0.521	3,790	3,950	0.00041	2/6	0.00042	AR-0123	0.00026	3,710	97.9
336.4 AAC 19-w	0.666	5,940	6,000	0.00037	5/12	0.00044	AR-0128	0.00031	6,200	104.4
556.5 AAC 37-w	0.858	9,830	9,650	0.00024	9/18	0.00025	AR-0134	0.00014	9,650	98.2
#2 AAAC 7-w	0.316	2,655	2,760	0.00125	2/6	0.00129	AR-0114	0.00071	2,590	97.6
336.4 AAAC 19-w	0.721	12,830	14.500	0.00035	6/12	0.00036	AR-0130	0.00028	12,550	97.8

Table II - Conductance and Strength Restoration Test Data: Line Guards

Size and Type	Conductor Diameter (In)	Conductor RBS (lb)	Actual Breaking Load (lb)	Resistance Across Conductor at 25% RBS	Fraction Cut*	Resistance Across Break at 25% RBS	Product Applied	Resistance Across Product at 25% RBS	Maximum Developed Load (lb)	% RBS
#2 ACSR 6/1	0.316	2,790	2,940	0.00069	1/6	0.00071	MG-0131	0.00057	2,750	98.6
1/0 ACSR 6/1	0.398	4,280	4,500	0.00083	1/6	0.00095	MG-0135	0.00064	4,415	103.2
4/0 ACSR 6/1	0.563	8,420	8,650	0.00027	1/6	0.00027	MG-0141	0.00022	8,600	102.1
336.4 ACSR 26/7	0.721	14,050	14,500	0.00022	4/16	0.00025	MG-0147	0.00019	15,150	107.8
336.4 ACSR 18/1	0.684	8,625	9,250	0.00026	4/12	0.00029	MG-0146	0.00017	8,700	100.9
336.4 ACSR 30/7	0.741	17,040	18,600	0.00030	5/18	0.00036	MG-0148	0.00028	17,100	100.4
795 ACSR 26/7	1.108	31,200	30,000	0.00011	4/16	0.00011	MG-0156	0.00007	33,500	107.4
954 ACSR 45/7	1.196	26,900	29,500	0.00011	15/21	0.00011	MG-0157	0.00008	27,200	101.1
477 ACSR 30/7	0.833	23,300	25,500	0.00017	5/18	0.00019	MG-0150	0.00013	22,900	98.3
#2 AAC 7-w	0.292	1,265	1,300	0.00086	1/6	0.00089	MG-0130	0.00064	1,285	101.6
2/0 AAC 7-w	0.414	2,480	2,620	0.00042	1/6	0.00043	MG-0136	0.00036	2,450	98.6
4/0 AAC 7-w	0.521	3,790	3,950	0.00031	1/6	0.00032	MG-0140	0.00027	3,760	99.2
336.4 AAC 19-w	0.666	5,940	6,000	0.00024	3/12	0.00032	MG-0145	0.00022	5,720	96.3
556.5 AAC 37-w	0.858	9,830	9,650	0.00015	4/18	0.00015	MG-0150	0.00012	9,350	96.9
715.5 AAC 37-w	0.974	12,640	12,100	0.00014	4/18	0.00016	MG-0152	0.00009	12,500	98.9
1113 AAC 61-w	1.216	19,660	19,250	0.00010	6/24	0.00010	MG-0158	0.00009	19,000	98.7
#2 AAAC 7-w	0.316	2,655	2,760	0.00056	1/6	0.00078	MG-0131	0.00053	2,540	95.7
336.4 AAAC 19-w	0.721	12,830	14.500	0.00020	2/12	0.00021	MG-0147	0.00016	12,900	100.5

*No. of Strands Cut/Total Strands in Outer Layer

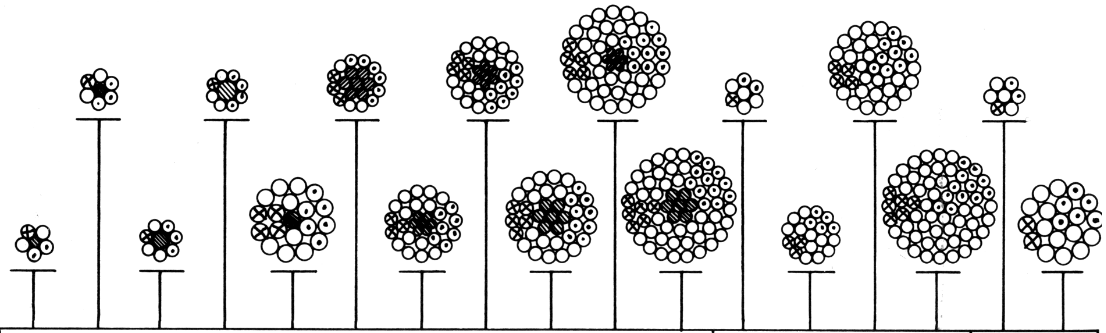
Conductance and Strength Restoration Tables

TABLE III

STRENGTH RESTORATION OF ACSR, ALL-ALUMINUM AND ALUMINUM ALLOY CONDUCTOR

Total Reparable Number of Broken or Damaged Conductor Wires

LEGEND ⊙ Armor Rods
⊗ Line Guard



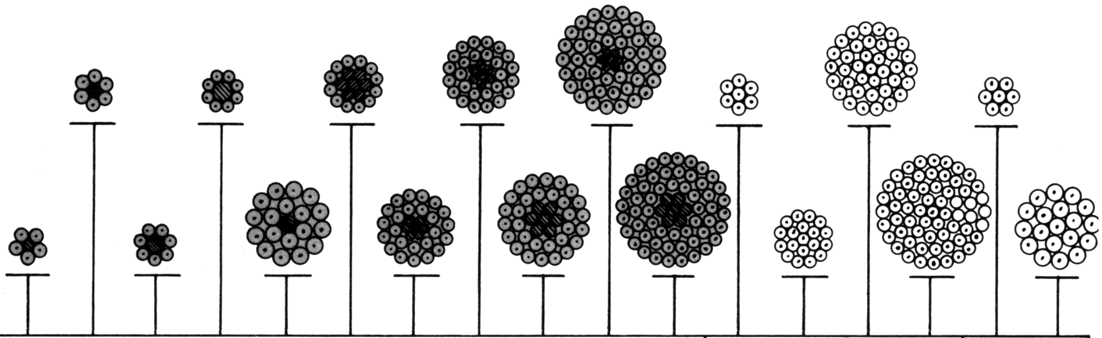
MATERIAL		ACSR											AAC				AAAC	
CONSTRUCTION		5/1	6/1	7/1	8/1	18/1	12/7	24/7	26/7	30/7	45/7	54/7	7w	19w	37w	61w	7w	19w
Product	Armor-Rods	2	3	3	4	6	6	7	8	9	10	12	2	5	9	12	2	6
	Line Guards	1	1	1	1	4	3	3	4	5	5	6	1	3	4	6	1	2

TABLE IV

STRENGTH RESTORATION OF ACSR, ALL-ALUMINUM AND ALUMINUM ALLOY CONDUCTOR

Total Reparable Number of Broken or Damaged Conductor Wires

LEGEND ⊙ Conductor Splice
● ACSR Full Tension Splice



MATERIAL		ACSR											AAC				AAAC	
CONSTRUCTION		5/1	6/1	7/1	8/1	18/1	12/7	24/7	26/7	30/7	45/7	54/7	7w	19w	37w	61w	7w	19w
Product	Conductor Splice	5	6	7	8	18	12	24	26	30	45	54	7	19	37	54	7	19
	ACSR Full Tension Splice	5	6	7	8	18	12	24	26	30	45	54	–	–	–	–	–	–

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