Section III  Covered and Insulated Aluminum Wire and Cable

Chapter 11

Installation Practices*

Aluminum was first used on an overhead transmission line more than 85 years ago. Today virtually all overhead transmission lines have conductors of aluminum or aluminum reinforced with steel (ACSR).

The performance record of aluminum on overhead transmission lines led to its use in conductors of other types so that today most overhead distribution, service drop, and service entrance cables are aluminum. More recently, insulated aluminum cable has come into widespread use in underground distribution and building wire applications.

Aluminum building wire installation procedures are basically the same as those for copper. However, because aluminum is a different metal with different properties, several differences in installation practices must be followed. Connectors tested and approved for aluminum conductors must be employed and equipment to which aluminum conductors are to be connected must have terminals intended for use with aluminum conductors.

Aluminum wire and cable are available in sizes to meet all needs and with the same types of insulation as copper (See Table 11-1). Connectors for all types and sizes of aluminum conductors and equipment with suitable terminals are available. Such equipment, UL-listed and designated for use with aluminum or copper conductor (AL/CU), and connectors designated "AL7CU" or "AL9CU" are available as stock merchandise in leading supply houses.

The types and electrical properties of wires and cables used in secondary distribution and interior wiring circuits are listed in previous chapters. However, the dimensions for a wide range of sizes and various types of insulation are listed, for convenience, in Table 11-1. The method of connecting** a single wire or cable (or the individual conductors of a multi-conductor cable) to other conductors or to switch-gear depends on the size of the conductor, the type of connector, and whether the components to be joined are both aluminum or one is of another metal such as copper.

Aluminum Conductor Connections

The electrical conductor has no functional value until it has been properly connected to complete the electrical circuit. Experience indicates that, apart from damage due to faulty installation or operation, most of the problems encountered in the field are at connections. Therefore, it is apparent that care taken in making a proper termination or splice is time well spent.

A similar record can be attained with insulated aluminum conductors if there is proper attention to the connecting methods. The basic function of extending the conducting path is the same whether the conductor is bare or insulated, overhead or underground, inside building walls, or in cable trays or conduit.

In the joining process, the oxide film on the contact surface of the aluminum must be ruptured to expose base metal. This fissured contact surface must be entrapped and collapsed against the adjoining contact member to establish metal-to-metal conducting areas. In addition, the joining process must protect these conducting areas against the degrading effects of service. In this respect the use of joint compound is most important. Its main function is to prevent the entry of moisture. Electrical connections are particularly vulnerable to this when the

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* For further information on the installation of aluminum building wire see the AA booklet "Aluminum Building Wire Installation Manual and Design Guide."

** For purposes of this discussion, splicing and terminating will refer to conductors in circuits above 1000 volts which require not only connecting the separate conductor elements, but also the restoration of sometimes complex installation systems over the splice or terminal and, under some circumstances, application of added protection. Splicing and terminating are described separately, page 11-11 et. seq.
covered and insulated aluminum wire and cable

TABLE 11-1
Nominal Dimensions* and Areas, Aluminum Building Wire (Taken From 1987 NEC)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<td>.0510</td>
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<td>.865</td>
<td>.5876</td>
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<td>.7542</td>
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<td>.6939</td>
<td>1.285</td>
<td>1.0386</td>
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<td>.8659</td>
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<td>1.0386</td>
<td>1.525</td>
<td>1.3968</td>
<td>1.230</td>
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<td>1.230</td>
<td>1.230</td>
<td>0-750</td>
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<tr>
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<td>61</td>
<td>1.060</td>
<td>1.285</td>
<td>1.2968</td>
<td>1.625</td>
<td>1.5270</td>
<td>1.382</td>
<td>1.382</td>
<td>1.382</td>
<td>1.382</td>
<td>0-1000</td>
</tr>
</tbody>
</table>

*Dimensions are from industry sources.
**Compact conductor per ASTM B 400: Article 310-14 of the 1967 NEC calls for AA 8000 series electrical grade aluminum alloy conductor material.

power is off and the conductors are cool. To the extent these are accomplished, the connection will have low and stable contact resistance during its service life. (For more information on electrical contact theory, the reader is referred to the bibliography at the end of Chapter 13.)

In this, as in preceding chapters, we will first consider conductors for secondary circuits (0 to 1000 volts) and the installation practices associates with them.

Building Wire Connectors

Only pressure-type connectors marked AL7CU or AL9CU to indicate they have been tested and are listed by UL for aluminum, copper, or aluminum to copper connections interchangeably should be used. The connectors are usually plated to avoid the formation of oxide and to resist corrosion.

Pressure connectors are of two basic types—mechanical screw type and compression type applied with a tool and die.

Both types are designed to apply sufficient pressure to shatter the brittle aluminum oxide from the strand surfaces and provide low resistance metal to metal contact.

Both basic types are suitable for use with aluminum, although many contractors believe that compression connectors are less susceptible to installation error.

UL Standard 486, covering connectors for use with aluminum wire, has been revised. A number of connectors have already been tested under the more stringent requirements of the new standard, UL 486B, and are currently available.

Installers are cautioned to avoid mechanical pressure connectors with too wide a range of wire sizes because the screw may not adequately engage the strands of the smaller conductors. Installers are also advised to contact conductor manufacturers for recommendations concerning specific connectors for use with their products.

Connectors for every conceivable need are available. Some typical connectors are shown in Fig. 11-1. Whichever type you use, follow the manufacturer’s instructions carefully.

Compression Connectors

Aluminum conductors are particularly suitable for connecting to each other or to an equipment terminal by use of solderless compression type sleeves because the conductor strands tend to weld together as a result of high compression pressure.

Compression connectors similar to those used for bare conductors (see Chapter 5) are widely used for connecting insulated conductors (Fig. 11-1). Various styles are available, along with special tools, representing the “system” of a particular manufacturer. Depending on
the size of the conductors, compression is obtained by use of hand tools or from hydraulic pressure.

**Mechanical Connectors**

Pressure connectors of the setscrew or bolted mechanical type, Fig. 11-2, also provide a rapid means of making connections particularly where space is limited and where many taps are taken from a main as in panel boards or junction boxes. Aluminum connector bodies are machined from extruded high-strength aluminum, such as 6061-T6. The setscrews are of the Allen head type and tightening of screws or bolts by wrench compresses the aluminum conductor strands against the side wall of the recess, causing the strands to intermingle. Fig. 11-1. Mechanical connectors should be tightened to manufacturer’s recommended torque levels. In the absence of manufacturer’s recommended torque levels, values in Table 11-2 should be followed.

**Connector Plating**

UL standards require that connectors for use with aluminum conductors be plated with tin or some other suitable contact metal and the face of any pad or lug that is plated should not be scratch-brushed but merely cleaned with a suitable solvent cleaner. Scratching the plated surface is likely to remove the plating. It should be noted that zinc plated connectors have an adverse effect on aluminum and should never be used on systems where aluminum wire is used.

**Building Wire Terminations**

UL-listed terminal lugs marked AL7CU or AL9CU are used to connect aluminum conductors to transformers, switches, bus bar, motors and other equipment. Aluminum terminals are usually plated and plated connectors should not be scratch-brushed or abraded.

Like connectors, they are of two basic types—mechanical screw type and compression type applied by tool and die. Some typical terminal lugs are shown in Fig. 11-2. They are applied to the conductor ends in the same manner as described under “Connectors.”

All equipment should be furnished with UL-listed, all aluminum terminals. Mechanical terminal lugs that are copper bodied and tin plated should not be used with aluminum conductors larger than #6 unless they have passed the 500-cycle requirements of new UL Standard 486B.

Care should be taken that the conductor temperature and ampacity ratings are compatible with the terminals and equipment to which they are to be connected.

When all components are aluminum (bus, slugs, lugs) only aluminum bolts should be used to make the connections.

The following procedures should be used:

1. Aluminum bolts should be anodized alloy 2024-T4 and conform to ANSI B18.2.1 specifications and to ASTM B 211 or B 221 chemical and mechanical property limits.
2. Nuts should be aluminum alloy 6061-T6 or 6262-T9 and conform to ANSI B18.2.2.
3. Washers should be flat aluminum alloy Alclad 2024-T4, Type A plain, standard wide series conforming to ANSI B27.2 SAE or narrow series washers should not be used.
4. Hardware should be assembled as shown in Fig. 11-3.
covered and insulated aluminum wire and cable

Fig. 11-2. Typical plated aluminum terminal lugs come in variety of styles.

TABLE 11-2
STANDARD PRESSURE-CONNECTOR TORQUE TABLES

<table>
<thead>
<tr>
<th>Wire Size</th>
<th>Torque Pounds-Inches</th>
<th>Hexagonal Head-External Drive Socket Wrench</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tightening Torque For Screws</td>
<td>Split-Bolt Connectors</td>
</tr>
<tr>
<td>Slot Width-Inches</td>
<td>To 3/8</td>
<td>Over 3/8</td>
</tr>
<tr>
<td>18-10 AWG</td>
<td>80</td>
<td>75</td>
</tr>
<tr>
<td>6</td>
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<td>165</td>
</tr>
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<td>325</td>
</tr>
<tr>
<td>1</td>
<td>825</td>
<td>325</td>
</tr>
<tr>
<td>1/2</td>
<td>1000</td>
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<tr>
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<td>500</td>
</tr>
<tr>
<td>5/8</td>
<td>1100</td>
<td>500</td>
</tr>
</tbody>
</table>

Note: The torque tables presented here are taken from UL Standard 486B, but are representative of those published in other UL Standards, in NEMA equipment installation instruction publications, and in the Canadian Electrical Code. The same values apply to pressure connectors for both copper (UL Standard 486A) and aluminum conductors.

Torque For Slotted Head Screws

<table>
<thead>
<tr>
<th>Screw-Slot Length-Inches</th>
<th>Torque-Lb-Inches</th>
<th>Screw-Slot Width-Inches</th>
<th>Torque-Size Across Flats-Inches</th>
<th>Screw-Head Screws</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8</td>
<td>45</td>
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<td>45</td>
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<td></td>
</tr>
<tr>
<td>7/32</td>
<td>150</td>
<td>7/32</td>
<td>150</td>
<td></td>
</tr>
<tr>
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<td>200</td>
<td>1/4</td>
<td>200</td>
<td></td>
</tr>
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<td></td>
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<td>1/2</td>
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<td>500</td>
<td></td>
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<tr>
<td>9/16</td>
<td>600</td>
<td>9/16</td>
<td>600</td>
<td></td>
</tr>
</tbody>
</table>

a. Clamping screws with multiple tightening means: for example, for a slotted hexagonal head screw, use the highest torque value associated with the different tightening means.
b. For values of slot width or length other than those specified, select the largest torque value associated with conductor size.
c. For slot lengths of intermediate values, select torques pertaining to next shorter slot length.

11-4
5. All hardware should be suitably lubricated before tightening.

6. Bolts securing lugs should be tightened to the manufacturer’s recommended torque. In the absence of such recommendations, torque values listed in UL 486 Standards should be used. (See Table 11-3)

If adding to an existing installation containing copper bus or studs or if it is impossible to obtain the required equipment with aluminum terminations, then a steel bolt should be used with a Belleville spring washer to allow for the differing rates of thermal expansion of the materials. The following procedures should be used:

1. The steel bolt should be plated or galvanized, medium carbon steel heat treated, quenched and tempered equal to ASTM A 325 or SAE grade 5.

2. Nuts should be heavy semi-finished hexagon, conforming to ANSI B18.2.2, threads to be unified coarse series (UNC), class 28.

3. Flat washers should be steel, Type A plain standard wide series, conforming to ANSI B27.2. SAE or narrow series washers should not be used.

4. Belleville conical spring washers come in sizes for use with bolts ranging in sizes indicated in Table 11-4.

5. Hardware should be assembled as shown in Fig. 11-5.

6. All hardware should be suitably lubricated before tightening.

7. In the absence of specific manufacturer’s instructions, bolts should be tightened sufficiently to flatten the spring washer and left in that position.

---

### TABLE 11-3

<table>
<thead>
<tr>
<th>Lug Bolting Torques*</th>
<th>Bolt Diameter Inch</th>
<th>Tightening Torque Pound-Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 or less</td>
<td>6</td>
<td></td>
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<tr>
<td>5/16</td>
<td>11</td>
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<tr>
<td>3/8</td>
<td>19</td>
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<td>40</td>
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</tr>
<tr>
<td>5/8 or more</td>
<td>55</td>
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</tbody>
</table>

*From UL 486 Standards

NOTE: If bolts are not lubricated with silicon spray or other suitable lubricant, torque may vary widely and result in high contact resistance at joints.

---

### TABLE 11-4

**BELLEVILLE SPRING WASHERS**

<table>
<thead>
<tr>
<th>Bolt size</th>
<th>O.D.</th>
<th>Thickness</th>
<th>Lb. nom. load to flat</th>
<th>In-lbs. torque to flat</th>
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<tr>
<td>1/4</td>
<td>11/16</td>
<td>050</td>
<td>800</td>
<td>50-75</td>
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<td>5/16</td>
<td>13/16</td>
<td>060</td>
<td>1000</td>
<td>125-150</td>
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<td>3/8</td>
<td>15/16</td>
<td>070</td>
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<td>1/2</td>
<td>1-3/16</td>
<td>085</td>
<td>2700</td>
<td>175-200</td>
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<tr>
<td>5/8</td>
<td>1-1/2</td>
<td>100</td>
<td>4000</td>
<td>222-250</td>
</tr>
</tbody>
</table>

Note: Torque values to be used as guides only. Actual installation conditions will vary considerably. Bolt should be tightened until a sudden increase in torque is felt. In this manner, no torque wrench is required and washer will be flattened.

Material: Hardened Steel  Table Courtesy of Thomas & Betts Co.
covered and insulated aluminum wire and cable

Fig. 11-4. Gutter splice is used when terminal lugs are not removable and are approved for copper cable connection only.

Fig. 11-5. Belleville washer is used to make an aluminum-to-copper or steel joint. Note: Crown of Belleville washer should be under the nut.

Fig. 11-6. There are a number of UL-listed adaptor fittings available for use with terminals not suitable for direct connection of aluminum conductors.

With equipment having terminals that will accommodate only copper conductors, a "gutter splice" may be used to connect the aluminum conductor. The aluminum conductor is spliced to a short length of copper conductor, and the copper conductor stub is then connected to the equipment terminal (Fig. 11-4). An AL7CU or AL9CU compression type connector is used to make the splice.

Instead of a gutter splice, one of the many UL-listed AL7CU or AL9CU adaptor fittings specifically designed for this purpose may be used (Fig. 11-6).

For connecting large aluminum conductors (500 kcmil and up) to heavy equipment having copper terminal studs and/or pads, large compression type lugs, preferably with two holes, should be used in making such a connection (Fig. 5-2). With other than aluminum bolts, Belleville spring washers and heavy flat washers in consecutive arrangement as shown in Fig. 11-5 must be used. If aluminum bolts and nuts are used, only the heavy washer, bearing on the aluminum lug, is necessary.

Figures 11-7 to 11-12 show some typical connections of aluminum conductors to equipment terminals.

Because of the differing rates of thermal expansion of aluminum and other conducting or support metals, it is preferable to have all parts of the circuit, including studs and clamp bolts, of aluminum. The aluminum bolts should be of alloy 2024-T4 and the nuts compatible, though preferably not of identical alloy and temper. Bolts and nuts should be of heavy series design to reduce stress beneath the head. NC (coarse) threads are preferred for the 2024-T4 aluminum bolts. Components should be assembled as shown in Fig. 11-9. More information about aluminum bolted connections will be found in Chapter 13.

Fig. 11-7. Where possible, current transformer terminals should be replaced with compression type (B). If not possible to remove, section of copper cable should be spliced to aluminum (A).

Fig. 11-8. Power transformer terminals, if copper, must employ short copper stub spliced to aluminum cable.
Basic Installation Techniques

1. Stripping Insulation

Never use a knife or pliers to ring a conductor when stripping insulation. One way to avoid this is to pencil or whittle the insulation (Fig. 11-13).

Another method is to skin the insulation back from the cut end of the conductor and then cut outward (Fig. 11-14).

Several types of insulation stripper are available for quick, easy removal of insulation. One of these, useful for small size conductors, is shown in Fig. 11-15.

2. Making Connections

Preparation of aluminum conductors for connection to an equipment terminal or another conductor requires stripping of the insulation and rupture and dispersal of the nonconducting oxide film that appears quickly on a fresh aluminum surface exposed to air. Care must be taken not to nick the wires when removing insulation in order to avoid broken strands in installation or service. Several types of insulation stripper are available for quick, easy penciling or square-cut removal of insulation. One type is shown in Fig. 11-16.

Abrading the conductor strands with a wire brush or other appropriate tool will serve to clean the conductor and disperse the oxide coating prior to application of joint compound.

The conductor end is then inserted into a compression sleeve of adequate thickness or a suitable mechanical type pressure connector. If the connector does not come factory-filled with an acceptable joint compound, such paste should be applied to the conductor end before insertion into the connector. (Some manufacturers' connectors may not require the use of compound but it should be used in the absence of specific instructions to the contrary.) The compression sleeve should then be compressed with a hydraulic compression device, or the setscrew of a mechanical connector tightened, in a manner prescribed by the connector manufacturer. Excess compound should be removed from the conductor insulation, but not from the joint itself where it will serve to prevent air from entering.

Solid aluminum wires are prepared in a similar manner, and the smaller sizes may be fastened under a binding-head screw* (without joint compound) after looping in a clockwise direction.

* Note: The AL7CU or AL9CU marking is not required on equipment connectors. However the equipment in which they are installed must indicate suitability for use with aluminum and connector tightening torques.
covered and insulated aluminum wire and cable

Fig. 11-13. Never ring a cable—it may lead to a break. Insulation should be removed as one would sharpen a pencil.

Fig. 11-14. Another safe way of removing insulation from conductor is to peel the insulation back and then cut outward.

Fig. 11-15. Use wire stripper for removing insulation from smaller wire sizes. Match stripper notch to wire size.

Fig. 11-16. Penciling tool for removal of insulation in bevel configuration by rotation. Several sizes are available, which by proper selection of bushing are applicable to all usual sizes of cables. This tool is particularly suitable for primary cables, which have comparatively thick insulation.

In making connections, first strip the insulation as instructed heretofore. Then apply joint compound if it is not already contained in the connector.

If the connector is a mechanical screw type, apply the manufacturer's recommended torque (Fig. 11-17). In absence of specific torque recommendations, use UL 468B torque values shown in Table 11-1. If a compression type, crimp it as recommended by the manufacturer (Fig. 11-18). Be sure to select the correct size die and close the tool completely for full compression. Wipe off any excess compound. Then tape the joint as instructed under Section B2 or apply the insulating enclosure that comes with some types of connectors.

3. Pulling Conductors in Conduit or Electrical Tubing

The following procedures are applicable to conduit of all types including aluminum:

a. Run a “fish” line through the conduit. This may be done by attaching the line to a piston-type device which is propelled through the conduit by compressed air. Another method is to push a round flexible speedometer type steel wire through the conduit. Polyethylene fish tapes may be used for shorter runs—up to about 100 feet.

b. Attach a clean-out brush to the fish line and behind it attach the pull line, then pull both through the conduit by means of the fish line.

c. Attach the pull line to the conductor or conductors. A basket grip over the insulation may be used for this purpose (Fig. 11-19).
d. Where conductors are pulled with a rope, stagger the conductor ends and anchor in position with tape, to provide maximum flexibility around bends (Fig. 11-20).

c. Try to feed conductors into conduit end closest to the sharpest bend, to reduce pulling tension.

f. Have pulling equipment with adequate power available to make a steady pull on the cables without "jerks" during the pulling operations.

g. Use pulling compound compatible with the conductor insulation as the conductors are fed into the conduit, to reduce coefficient of friction and required pulling tension.

h. For single conductors on a reel, stagger reels, one behind the other, while feeding in conduit, to maintain equal pulling tensions and prevent conductors from "crossing over" and jamming in the conduit.

i. Wherever possible, pull conductors in a downward direction, to allow gravity to assist in pulling with reduced tension.

j. When conductor ends are prepared for pulling, be sure not to nick the stranded aluminum conductor during insulation removal. Damaged strands can reduce the pulling tension capabilities of the conductor. To avoid this, pencil the insulation for removal, as described above; do not ring cut the insulation.

k. Follow all NEC requirements.

For a detailed description of calculating pulling tensions, see the example given on page 11-11 on underground installations. See Chapter 17 for a complete treatment of aluminum conductors in conduit.

4. Installation of Cables in Trays

Where aluminum cable is to be pulled in trays or cable racks, take the following precautions, plus those applicable to conduit:

a. Where pulling attachments are used on the conductors, cover them with rubber-like or plastic tapes to prevent scoring of the trays and installation sheaves during a conductor pull.

b. Use large-radius sheaves around bends and smaller sheaves on the straight sections of cable support trays to facilitate cable installations, to reduce the required pulling tensions and to prevent damage to stranded conductors or insulations.

c. Where cables are anchored on trays, be sure straps or other cable anchoring devices do not cut into the insulation.

d. Cables installed in trays should follow the requirements of NEC Article 318 for the allowable number of cables permitted in trays and their respective amperages.
covered and insulated aluminum wire and cable

c. Straight cable tray runs may often be installed by simply laying the lightweight aluminum cables in place.

e. Be sure tray supports are capable of handling maximum weight of conductors and planned conductor additions in the future.

5. Minimum Training Radii

Where permanent bends are made at terminations using aluminum building wire, Table 11-5 indicates the minimum bending radius as a multiple of the overall cable diameter. Such bends should be made before the terminal is applied to minimize electrical contact distortion.

6. Conductors in Vertical Raceways

The NEC under section 300-19 stipulates that conductors in vertical raceways shall be supported. As a general rule one cable support shall be provided at the top of the vertical raceway or as close to the top as is practical plus an additional support for each interval of spacing as shown in Table 11-6. An exception to this rule is that if the vertical riser is less than 25% of the spacing listed in the Table, no cable support shall be required.

Installing Cable in Conduit or Duct

The procedures for inserting a “fish” line or tape through a conduit or duct, followed by a pull line and/or cable as required for the pull, are well known and established as field practice and do not need extensive description here. Aluminum conductors may be attached to pull line or cable by means of a factory-installed pulling eye, by placing a basket grip around the conductors’ insulation (Fig. 11-21), or by tying the line to a loop in the uninsulated part of the conductor (Fig. 11-20). Steel pull cables used to pull conductors around bends in aluminum conduit runs may damage the conduit at the bend. This is often avoided by using steel elbows with aluminum conduit or by use of a pull line that will not damage aluminum elbows.

Pulls should be accomplished with steady tension and pulling speeds not exceeding 50 feet per minute. Hard pulls can be eased if the reel if hand controlled and slack cable is guided into the conduit.

Pulling tensions may be reduced by lubricating the cable surface. However, some lubricating materials have been found to adversely affect cable insulations or outer jackets. In addition to cable pulling compounds, this

| TABLE 11-5 |
| TRAINING RADII |
| For 600 V Cable Not in Conduit, on Sheaves or While Under Tension |

**POWER CABLES WITHOUT METALLIC SHIELDING ON ARMOR.**

The minimum recommended bending radii as multiples of the overall cable diameter given in the following tabulation are for both single and multi-conductor cable with or without lead sheath and without metallic shielding or armor.

<table>
<thead>
<tr>
<th>Thickness of Conductor Insulation</th>
<th>Minimum Training Radius as multiple of cable diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.000 and Less</td>
<td>1.001 to 2.000</td>
</tr>
<tr>
<td>2.001 and over</td>
<td></td>
</tr>
<tr>
<td>155 and less</td>
<td>4</td>
</tr>
<tr>
<td>170 to 310</td>
<td>5</td>
</tr>
<tr>
<td>325 and over</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

**POWER CABLES WITH METALLIC SHIELDING OR ARMOR.**

(a) Interlocked Armored Cables

The minimum recommended bending radius for all interlocked armored cables is in accordance with table above but not less than 7 times the overall diameter of the cable, except as noted below (c) for tape shielded cable.

(b) Flat Tape and Wire Armored Cables

The minimum recommended bending radius for all flat tape armored and all wire armored cables is 12 times the overall diameter of cable.

(c) Tape Shielded Cables

For all cables having metallic shielding tapes the minimum recommended bending radius is 12 times the overall diameter of the completed cable.

(d) Wire Shielded Cables

Wire Shielded Cables should have the same bending radius as power cables without metallic shielding tape.

Reprinted from IEC 5-66-524, NEWA WC-7
TABLE 11-6
SUPPORTING CONDUCTORS IN VERTICAL RACEWAYS
From 1987 NEC Table 300-19 (a)

<table>
<thead>
<tr>
<th>No.</th>
<th>Conductors</th>
<th>Aluminum</th>
<th>Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 to 8</td>
<td>Not greater than</td>
<td>100 feet</td>
<td>100 feet</td>
</tr>
<tr>
<td>6 to 0</td>
<td>Not greater than</td>
<td>200 feet</td>
<td>100 feet</td>
</tr>
<tr>
<td>00 to 0000</td>
<td>Not greater than</td>
<td>180 feet</td>
<td>80 feet</td>
</tr>
<tr>
<td>211.6 kcmil to 350 kcmil</td>
<td>Not greater than</td>
<td>135 feet</td>
<td>60 feet</td>
</tr>
<tr>
<td>350 kcmil to 500 kcmil</td>
<td>Not greater than</td>
<td>120 feet</td>
<td>50 feet</td>
</tr>
<tr>
<td>500 kcmil to 750 kcmil</td>
<td>Not greater than</td>
<td>95 feet</td>
<td>40 feet</td>
</tr>
<tr>
<td>Above 750 kcmil</td>
<td>Not greater than</td>
<td>85 feet</td>
<td>35 feet</td>
</tr>
</tbody>
</table>

applies to potting and joint compounds, adhesives, tapes, etc. If in doubt, compatibility of materials foreign to the insulation should be cleared through the cable manufacturer.

A number of proprietary wire pulling lubricants and compounds are UL-listed and labeled to indicate the compound’s compatibility with conductor coverings. In all cases, the manufacturers’ instructions should be observed.

Allowable Pulling Tension

The following formulas can be used to calculate the maximum allowable tension that should be applied to the cables. Note that these allowable tensions assume the pulling eye is attached to the conductor. Where the pulling line is attached to a basket grip that surrounds the insulation, the pulling tension should not exceed 1000 lbs. It should be kept in mind that tension developed for straight runs per unit length is less than that for the portion of the cable in bends.

1. The maximum allowable pulling tension, if the pulling eye is attached to the conductor

   \[ P_m = KN A \]  \hspace{1cm} (Eq. 11-1)

   where \( P_m \) = Maximum allowable tension, lb
   \( N \) = Number of conductors being pulled simultaneously
   \( A \) = Circular mil area of each conductor
   (If conductors are of various sizes, add the individual NA values)
   \( K \) = Conductor stress factor

2. The maximum allowable pulling tension \((P_m)\) cannot exceed 1000 lb where cables are pulled with a basket grip; however, the tension per Eqs. 11-1 or 11-2 should not be exceeded.

3. The maximum allowable pulling tension for cable in conduit or duct bends (to prevent cable damage because of rubbing on sides of bend) must not exceed the following:

   \[ P_b = 100r \]  \hspace{1cm} (Eq. 11-2)

   where \( P_b \) = Maximum allowable bend tension, lb
   \( r \) = Radius of curvature of the conduit or duct bend, ft

   Note: The maximum allowable tension determined from Eqs. 11-1 or 11-2 should not be exceeded.

4. For straight section of conduit or duct, the pulling tension (lb) likely to be developed can be determined as follows:

   \[ P_c = Lwf \]  \hspace{1cm} (Eq. 11-3)

   where \( P_c \) = Pulling tension in straight section, lb
   \( L \) = Length of conduit or duct straight section, ft
   \( w \) = Weight of cable (or cables), lb per ft
   \( f \) = Coefficient of friction

   Note: For a well constructed conduit or duct with a lubricated cable, “f” approximates 0.5. For less favorable conditions or with considerable curvature, “f” may approximate 0.75.

5. For curved sections of conduit or duct, the pulling tension (lb) likely to be developed can be determined as follows:

   \[ P_c = P_s + P_s e^{i} \]  \hspace{1cm} (Eq. 11-4)

   where \( P_c \) = Total pulling tension, lb
   \( P_s \) = Tension for straight section at pulling end, lb
   \( P_f \) = Tension for straight section at feeding end, lb
   \( \alpha \) = Angle of bend in radians (1 radian = 57.3 deg)
   \( e \) = Base of Napierian logarithms (2.718)
   \( f \) = Coefficient of friction

Example: Determine the maximum pulling tension required to install three single-conductor cables in a duct, according to the arrangement in Fig. 11-22. The cable specifications are:

Three single conductor #4/0 AWG 600-volt aluminum cables with cross-linked PE insulation

Weight, 3 @ 290 lb/M ft = 0.87 lb per ft
Cable diameter, each 0.690 in.
Coefficient of friction=0.5; K value=0.008*

\*K = 0.008 for ¼ hard aluminum conductors, or 0.004 for ½ or ¾-hard aluminum.

11-11
Using a single pulling eye attached to the three conductors and applying Eq. 11-1, the maximum allowable pulling tension is

\[ P_m = 0.008 \times 3 \times 211,600 = 5078 \text{ lb} \]

For the entire run from pull-box (1) to pull-box (6), the tension increments are as follows:

Eq. 11-4: At box (5) \( P_5 = P_6 \times e = 43.5 \times e \)

Eq. 11-5: At box (6) \( P_6 = 95.4 + (L_{6a} \times w \times f) = 95.4 + (50 \times 0.87 \times 0.5) = 117.2 \text{ lb} \)

The total pulling tension of 254 lb is far below the 5080 lb limitation, and the tension at each bend is far below the recommendation per Eq. 11-2 of 100 \( \times 10 \), or 1000 lb. Study of such examples shows that there is an advantage in pulling cables from the pull box or manhole closest to the first bend. This aids in reducing tension on the installed cable. In this instance, if the pull started at box (6), the final tension would be about half the above-found value.

For a more complete treatment of cable pulling in conduit, the reader is referred to R.C. Rifenberg, AIEE Transactions, Dec. 1953.

**Installing Directly Buried Power Cables**

If cable placement can be started before sidewalks and other obstructions are installed, the plowing-in method usually is the most economical method of burying power cable. If soil conditions are unsuitable for plowing, the

*See also Aluminum Underground Distribution Reference Book.*
use of trenchers, back hoes, or manual digging is customary. If the soil is rocky, it should be screened to prevent cable damage. If it is not sufficiently fine to closely cover the cable surface, a four-inch thickness of sandy loam placed under and over the cable will improve the heat radiating quality of the soil.

Duct or conduit also should be used under streets or where access by digging to a buried cable is not practicable.

Sufficient cable slack should be provided at risers and terminals to permit earth movement that may occur because of conductor thermal expansion, frost, and also as an allowance for future repair.

Boards or slabs placed over the cable for mechanical protection should not be directly in contact with the cable but should be laid on an earth fill over the cable.

Depth of burial ranges from about 30 to 48 inches for primary cable and from about 24 to 42 inches for secondary cable when buried separately. On many systems, both primary and secondary cables are buried in the same trench with no separation. In many areas, the trenches are shared jointly with other utilities, notably communications—both telephone and television cables. Joint use of trenches requires close collaboration on installation schedules but offers substantial economies to the sharing utilities.

Initially, a separation of one foot was required between primary power and communication cables and many companies still require this separation. An amendment to the NESC, however, permits random-lay (no deliberate separation) installation of communication and power cables in the same trenches with grounded wye power systems operating at voltages not in excess of 22 kV to ground or delta systems operating at voltages not in excess of 5.3 kV phase to phase, under certain conditions described in NESC Section 35, Article 354. However, joint use with very long single-phase primary circuits is not recommended because of the inductive pickup of harmonics by the communication cables from the power cables.

Care exercised in handling the cable during installation will help to avoid trouble later, for damage sustained by the cable during installation has proved to be a major cause of subsequent cable failure.

Many of these precautions have to do with making sure there is no insulation damage. The cable is not susceptible to corrosion failure when insulation is unbroken, even where moisture has gained entry into the conductor is some manner; this fact has been determined in cable manufacturer laboratory tests and from research by utilities. Migration of moisture through damaged insulation in the presence of ac potential concentrates ions and promotes ac electrolysis.

Cable transitions between overhead and underground usually employ the conventional factory-molded pothead, of which special types are available for use in URD systems. A termination is not required, however, if the insulated aerial cable is also suitable for direct burial. Such a cable can be carried directly down the pole. Riser shields or conduit should be used to protect the cable on the riser pole to a point at least eight feet above ground level, and should extend at least 12 inches below ground. The riser shield must be solidly grounded to the system neutral, and bonded to the lightning arrester to avoid transient potentials.

Many other practices relating to buried cables and their connection to transformers, to service entrances, and tap connections in junction boxes and vaults are described in industry manuals. Practice is gradually becoming standardized in the direction of increasing reliability and lowering installation and maintenance costs in this most important segment of power distribution.

The following suggestions will help to avoid failures from this cause; they apply equally to cable and cable in pipe:

1. Make sure that end seals are intact both while the cable is stored and installed to avoid entrance of water into the strands.
2. If plowing is not used, cables, if at all possible, should be payed out along the side of the trench from moving reels, or carefully laid in the trench from stationary reels.
3. The trench should not be dug before final grading is determined, so cable will not be exposed or be too close to the surface.

* See also IEEE Conference Record 31C35 Special Technical Conference on Underground Distribution, Sept. 27-29, 1966.

11-13
covered and insulated aluminum wire and cable

<table>
<thead>
<tr>
<th>Thickness of Insulation, Inch</th>
<th>1,000 and less</th>
<th>1,001 to 2,000</th>
<th>2,001 and over</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.156 and less</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>0.157 to 0.312</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>0.313 and over</td>
<td>—</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>

* Only applicable for cable training; bearing pressure limitation may require larger bending radii for cable tension.

** Data apply to single and multiple conductor cable; also to wire-shielded cable. Minimum bending radius for cables with metallic shielding type is 12 times the completed cable OD. The National Electrical Code Section 300—34 requires 8 times for non-shielded and 12 times for shielded medium voltage cable bending radii.

4. In rocky soil areas, use screened backfill or sand to protect direct buried cable. A 2-inch bedding is sufficient below; but there should be a minimum cover of about 4 inches. (The bedding and cover can be omitted when duct in conduit is used).

5. If boards, concrete slabs, etc., are used above the cable for mechanical protection, they should not be in direct contact, to avoid shearing action when the soil settles. Make sure boards are treated with preservatives that will not harm the cable’s insulation.

6. Check the cable visually for damage before burial or installation in duct.

7. When primaries are pulled into ducts or open trenches, the use of a pulling grip over the cable is common rather than a pulling eye or other attachment connected directly to the conductor. Duct should be carefully cleaned by pulling a plug through it to remove all burrs and obstructions. To keep the cable-pulling tension within safe limits, a lubricant approved for use with the specific insulation and insulation shield should be used.

8. When doing permanent training make sure that the minimum bending radii are observed (see Table 11-7). Make every effort to provide more radius than these values at reel payout, risers, plow guides, duct bend, etc.

9. Make sure splices and other connections are made in accordance with manufacturers’ recommendations.

10. Double check to make sure proper backfilling is done. Rock fill should be kept away from the cables to prevent damage. Compacting should be carefully done, and air spaces minimized.

11. Proof test the cable after installation to insure integrity of insulation and splices. (See Table 11-8).

12. Don’t overfuse the cable. Because of the paucity of failures, many utilities prefer to use one-shot fuses as an added protective measure for the cable.

Many of these precautions have to do with making sure there is no insulation damage. The conductor in 600 volt cables is not susceptible to corrosion failure when insulation is unbroken and moisture has not gained entry into the conductor. When moisture enters a break in insulation, however, ac electrolysis begins.

Splicing and Terminating in Underground Systems

The revolution in underground distribution system design has included the devices and methods used for making splices, connections, and terminations. The objective here has been to reduce the amount of skill and time required in the field so as to reduce the installation costs. More prefabrication is being done under factory-controlled conditions, and the need for heating and pouring of insulating compounds or extensive taping in the field has been greatly reduced.

Aluminum connectors and terminating devices should be used with aluminum conductors so as to avoid differential thermal expansion and contraction upon heating and cooling that could result from the use of connectors of dissimilar metals. Compression type connectors and lugs applied with a tool and die are widely used. It is
TABLE 11-8

ICEA RECOMMENDED dc PROOF-TEST VOLTAGES
(15 Minute Test)

<table>
<thead>
<tr>
<th>Polyethylene or Cross-Linked Polyethylene Insulated Cables</th>
<th>Insulation Thickness (Mils)</th>
<th>Proof-Test Voltage (KV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Circuit Voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001 - 5000</td>
<td>90</td>
<td>25</td>
</tr>
<tr>
<td>5001 - 8000</td>
<td>115</td>
<td>35</td>
</tr>
<tr>
<td>8001 - 15000</td>
<td>175</td>
<td>55</td>
</tr>
<tr>
<td>15001 - 25000</td>
<td>260</td>
<td>80</td>
</tr>
<tr>
<td>25001 - 28000</td>
<td>280</td>
<td>85</td>
</tr>
<tr>
<td>28001 - 35000</td>
<td>345</td>
<td>100</td>
</tr>
</tbody>
</table>

important in installing these devices that a die of the correct size be used and full pressure be applied in order to obtain permanently sound connections.

600 Volt Secondary Circuits

In this regard connector manufacturers have made important advances in the design of connection devices for secondary circuits. There are far too many types to describe them all in this handbook. However, a couple of examples are given below to indicate the types of pre-molded splices and terminations that are currently available for this type of service.

(a) Underground Direct Burial Splice 600 volt insulated cable splices are available for conductor sizes #6 AWG stranded through 1000 kcmil and can be completely installed and sealed without taping or compound filling. Typical installation procedure is (Fig. 11-23) as follows:

Step A
Lubricate both uninsulating splice caps by applying a small amount of the supplied lubricant to the inside diameter of the cap at both the housing end and also to the inside diameter at the conductor hole end. For easier assembly of the insulating caps to the conductor, it is recommended that the insulation at the end of the conductor be penciled before stripping. Then place the proper caps over each conductor end.

Step B
Strip correct length of conductor insulation for the splice connector being used. Place splice housing over end of conductor and assemble one cap to housing. Large end of cap should cover the knurled line of the housing body.

Step C
Wire brush exposed cable ends and then immediately insert cables into connector. Start crimping splice onto conductor as per manufacturer’s instructions. Continue crimping to ends of splice, overlapping crimps 1/8 inch minimum. Wipe away all excess oxide inhibitor.

Step D
Place housing with the assembled cap over splice connection and snap remaining cap in place on housing to complete the sealed splice. When caps are correctly installed, the large ends should cover the knurled lines on both ends of the housing body.

(b) Secondary 600 V Underground Terminations. There are several different designs of connector products which are approved for use in underground 600 V electric power systems. They supply the needs of connectors required for residential or commercial use; direct burial, below grade vaults; pedestal or pad mounted equipment; bolted or compression fittings, and in any combination.

Fig. 11-24 shows a representative group of these fittings which are designed to accommodate a wide range of conductors. Their installation is straightforward and requires no field cutting or hand taping for insulation or environmental sealing. The threaded stud connector for transformers is such that the connector can be detached from the transformer without disconnecting the conductors.

Primary Circuits

Termination of primary underground cables requires some type of stress relief. Initially, these were made up by taping a stress cone, which proved to be one of the most tedious and time-consuming jobs for the field man. Today most utilities use some form of preshaped or prefabricated stress cone, which can be installed in a fraction of the time.
Typical terminations for primary cables indicate that molded, precut tape, and porcelain types are used indoors while porcelain units are most often used outdoors. One of the most significant developments in primary cable terminations has been the introduction of plug-in connectors for joining the cables to equipment or other cables. With these devices it is almost as easy to connect a primary cable as to plug in or remove an appliance cord from a convenience outlet.

The concept of premolded stress relief takes the fabrication of a stress relief core away from the field and into the factory with its controlled environment, leaving just the assembly to the field installer. Elastomeric connections form a very convenient, inexpensive, and reliable method of connecting or terminating high voltage cables. Power cable loadbreak elbows in the 35 kV class were introduced to the industry in 1983, with designs for 15 kV and 25 kV following in 1985.
Fig. 11-24. Some typical 600 V underground termination fittings.

Through the combined efforts of the connector and apparatus manufacturers and the utilities, there is available today an array of premolded products that exhibit a high degree of safety, reliability, and flexibility.*

*See James W. Fitzhugh's paper, "Exploring the Application of Premolded Products for High Voltage Power Systems."

Some typical applications of premolded products are at pulling or junction boxes, cable to equipment connectors, and cable to cable connections. All of these components are designed and tested to be in compliance with ANSI/IEEE Standard 386—1985 Separable Insulated Connectors for Power Distribution Systems above 600 Volts.
Primary Voltage Circuits

A cutaway view of an up-to-date power cable joint is shown in Fig. 11-25. The cloverleaf design allows the joint to operate at lower temperatures.

While installation of premolded devices are similar, conditions may vary depending on the device, the cable, and the manufacturer of the splice or termination. In all cases, full instructions will be provided and should be followed. Additional typical designs are shown in Fig. 11-26.

Development work in splicing, connecting, and terminating devices is still proceeding. Users thus are advised to keep posted on the latest designs being offered by the connector manufacturers in order to achieve greatest economies in making cable splices, connections, and terminations.

Though recent trends have been toward the use of premolded splicing and terminating devices, it is still necessary or desirable in some circumstances to make hand-taped joints by traditional methods. Because of this the details of making a hand-taped, concentric neutral, straight splice are given below. Details of the joint are shown in Fig. 11-27.

The following are the instructions to be generally based in making the joint illustrated in Fig. 11-27. They are for a typical hand-taped primary cable splice. All splices and terminations should be made by a qualified cable splicer in accordance with the manufacturer’s instructions and recommendations.

1. Study splice drawing and instructions:
2. Train cables into final position and overlap for 18 inches to afford enough excess concentric wire for final jointing.
3. Temporarily wrap a number of turns of tape over the outer concentric wires at least 18 inches from the centerline of the splice.
4. Carefully unwrap outer concentric wires and temporarily remove them out of the splice area, being sure not to damage or kink them.

<table>
<thead>
<tr>
<th>TABLE 11-9: Recommending Taping Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation Thickness</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>15KV</td>
</tr>
<tr>
<td>.175&quot; or .220&quot;</td>
</tr>
<tr>
<td>25KV</td>
</tr>
<tr>
<td>.280&quot; One-half Connector Length</td>
</tr>
<tr>
<td>35KV</td>
</tr>
</tbody>
</table>
| .345" One-half Connector Length | 3" | 7" | 2A + 22" | 9/16"

5. Cut off excess cable at splice centerline.
6. Remove outer semiconducting jacket for a distance of (A + 1 + B + C) inches from each cable, making sure that the insulation is not damaged during the removal operation. All traces of the semiconducting jacket must be removed by a nonconductive abrasive or rasp.
7. Remove the insulation from each conductor for a distance of (A + 1) inches, making sure that the conductor is not nicked during the removal operation.
Fig. 11-26. Some typical primary voltage premolded splicing and terminating devices.
covered and insulated aluminum wire and cable

**Splicing*—15kV—25kV—35kV Primary Cables—Hand Taped Splice**

Single conductor with concentric neutral, straight splice (conventional or cross-linked polyethylene insulated, solid or stranded) for grounded neutral service.

**Fig. 11-27. Details of a taped primary cable joint.**

Penciling tools will remove the insulation, as well as provide smooth penciled surface.

8. Apply the required compression connector on each cable, following the connector manufacturer’s recommended procedure. Note: It is recommended that a smooth surface type connector be used—not an indented type. If an indented type is used, fill the indents with a pliable insulation putty.

9. Remove all sharp edges from compressed connector, using a file or heavy abrasive cloth.

10. Pencil the ends of the polyethylene insulation for a distance of (B) inches. Be sure not to cut into the insulation or damage the conductor during the penciling procedure. Buff the insulation pencils if they are not smooth with a nonconductive abrasive or rasp. This step would be completed with a penciling tool. (See Step 7 above.)

11. Clean all exposed surfaces with a nontoxic and nonflammable solvent and allow to dry. Care must be taken in wiping the black conducting jackets, since this may smear over the insulation surface.

12. Apply one half-lapped layer of semiconducting tape (Bishop Tape No. 17 or equivalent) over the exposed conductor and connector. Tape should just contact the edge of the cable insulation and be applied with enough tension to conform to the connector.

13. Apply half-lapped layer of high voltage, self-fusing tape with manufacturer’s recommended tension, starting at connector centerline and building up to the level of the connector in areas between insulation pencil and connector by evenly wrapping tape back and forth across the connector. Apply splice tape buildup to a thickness of “K” inches over the connector and for a longitudinal distance of “D” inches, tapering at the ends.

14. Apply one half-lapped layer of self-fusing semiconducting tape over insulating tape buildup, extending 1 inch beyond insulating tape onto the semiconducting jacket on each side of splice. The semiconducting tape should be applied with adequate tension.

15. Apply one half-lapped layer of tinned copper mesh braid over the semiconducting tape and extend 1 inch at each end of splice. The tinned copper mesh braid
should be wrapped as tight as possible, and taping should be started at the centerline of the splice, using two portions of tinned copper mesh braid.

16. Apply two solder lines 180 degrees apart for the full length of the mesh braid, making sure that the heat does not remain in one spot too long to damage the cable insulation or tapes.

17. Tie the concentric outer wires in place using wraps of No. 14 AWG tinned or bare copper wire and tack solder in place.

18. Apply two half-lapped layers of a self-fusing high voltage tape over the outer braid with minimum tension.

19. Apply one half-lapped layer of jacket tape over the mesh braid to the edge of the concentric wires at each end of the splice.

20. Twist the concentric wires together and cut off excess length. Place the formed wires into the proper sized mechanical (or compression) connector and splice in place to form low resistance joint, following the connector manufacturer’s recommended procedure.

**Terminating Detail**

The construction details of secondary or primary cable terminations depend on whether the termination is outdoor, indoor, or from underground and whether it is horizontal for connection to an equipment terminal or vertical for connection to another conductor. Trifurcating assemblies are also used for terminating a three-conductor cable so the uninsulated terminals are well separated (Fig. 11-28).

Terminations usually are either of the pothead type or the built-up stress-relief type. Both types provide extra insulation close to the actual termination of the conductor to provide protection against the extra voltage at these locations.

Primarily, potheads of plastic insulating materials are used with primary and secondary URD systems, although porcelain potheads and semi-assembled, built-up stress relief cones (or kits that facilitate their quick assembl.) are still used for this application. (Fig. 11-16)

Stress-relief cones are also required in cable splices

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![Diagram of cable termination](image)

**A. Single conductor outdoor termination**  
**B. 3-Conductor outdoor termination**

Fig. 11-28. Typical terminations 5-15kV.
covered and insulated aluminum wire and cable

where there is a change of conductor size; the variation of current density in the adjacent conductors creates dielectric stress variations that occur when a cable is terminated.

The detailed methods of terminating shielded and non-shielded cables closely resemble those used for splicing, except that the termination process requires the inclusion of a stress-relief cone or a pothead, and if the installation is outdoor and vertical the addition of a rain shield to shed water from the cable insulation is customary. Descriptive details are supplied by cable and accessory manufacturers with dimensions for various sizes and voltages. The accompanying illustrations list the successive operations. The precautionary recommendations mentioned in relation to cable splicing also apply to terminating procedure, subject to such changes as appear in manufacturer’s instructional manuals.

The cross-section of a molded terminal connector is shown in Fig. 11-29, illustrating the component part of a connector designed for conductors up to 25 kV. It is suitable for use on solid dielectric cables and can be applied directly on cables with extruded semi-conductive shields including full neutral concentric. It will accommodate aluminum conductors in the range of No. 6 to 4/0 AWG with an insulation thickness of 0.495 to 1.115”. After proper cable preparation, the terminal connector is slid down over the bared cable insulation until it bottoms on the cable shield. No special tools or potting compounds are required for the assembly of this type of fitting.

1. TERMINAL CONNECTOR
   The universal rod connector attaches to the power source.

2. MOLDED RUBBER CAP
   Presses over top of terminator with an interference fit to provide complete water seal integrity.

3. RETAINING WASHER
   Mechanically prevents any cable slippage within terminator.

4. TERMINATOR HOUSING
   Molded of special EPDM compounds for functional reliability and long life. Actual creep distance is 18” (45.7 cm).

5. CABLE INSULATION
   Primary insulation is provided since cable insulation carries through the terminator.

6. INTERFERENCE FIT
   Molded insulating EPDM exerts uniform concentric pressure on insulation of cable to provide required creep-path length and water seal.

7. MOLDED STRESS RELIEF

8. GROUND STRAP
   Provides a convenient point to connect a ground wire to the molded conductive shield and places the molded shield at ground potential.

Courtesy Amerace Corp., Elastimold Div.

Fig. 11-29. Typical single conductor molded pothead for cable termination.
Installing Aerial Insulated Cables

Single insulated or covered overhead primary aluminum conductors suspended from insulators sometimes are used in tree areas or similar locations. Their installation is similar to that of bare conductors, as described in Chapter 5. The span lengths usually are moderate so that sag and tension values generally are obtained from tables. However, for unusual spans, sag-tension charts can be computed or are available from conductor suppliers. For aluminum 1350 conductors or less than hard tempers, adjustment must be made for reduction of strength.

For economic reasons, however, most overhead spans of insulated power conductors are in the form of preassembled or field-assembled multi-conductor cables suspended from a bare messenger. Insulator support is not required and space is saved by using a single-multi-conductor cable. The conductors may be spiraled around the messenger or arranged parallel to it, as described in Chapter 7. Messenger supported cables are in two groups:

Preassembled aerial cables (to 35 kV)
Aerial cable assemblies (0 to 600 volts).

Primary Aerial Cables

The messenger size for primary cables is determined by the required strength, except that for single-phase primary circuits (No. 2 AWG or smaller) where the messenger also serves as a neutral conductor, the conductance of the messenger must equal that of the insulated conductor. Bare messengers not used as neutral conductors are often used also as a part of relaying circuits, as a part of the grounding circuit for the insulation shielding, and as an auxiliary to a common-neutral. For these reasons specifications for multi-conductor primary cables with bare messengers usually specify the ohmic resistance of the messenger. The combination of strength and electrical resistance requirements of such non-neutral messengers has led to wide acceptance of composites of aluminum and of steel (Alumoweld) for the make-up of the messenger.

Messenger sizes are such that the normal initial sagging tension at 60°F will not exceed 30% of its rated strength, and its maximum tension will not exceed 50% of its rated strength at the fully loaded condition. Physical details of the cables used for the messengers listed in Tables 11-10 and 11-11 can be found in Tables 4-5 (1350-H19), 4-12 (6201-T81) and 4-14 (ACSR). These messenger sizes conform to the ICEA recommendation that the initial sag be such that the final sag be not less than 1.667% of the span length.

Stringing sag and tension charts are supplied by cable manufacturers as an aid to circuit design for light, medium, or heavy loading conditions (NESC, see Table 5-1) for use as described in Chapter 5. However, in most instances the spans are of moderate length so suitable sag-tension values may be obtained directly or interpolated from manufacturer-supplied tables that list initial and final values for 100, 125, and 150 ft spans.

For the installer of the cable the most useful tabular values are those for initial sag and tension, usually for 60°F, but a correction factor is applied if the installation temperature differs from 60°F. The final sag and tension values for the various NESC loading districts then will meet requirements as to the percent that messenger tension bears to its ultimate breaking strength, and the manufacturer’s table will confirm this if required. The messengers for preassembled primary cables are not neutral conductors, but high conductance is useful for grounding or signal purposes, hence the equivalent conductor rating is usually listed for the messenger. For this reason various combinations of steel, 1350 aluminum, and high-strength alloy aluminum are often used for primary aerial messengers.

Table 11-10 is extracted from more complete tables in order to show the form in which such tables are supplied. Although this table shows use of a combination messenger made of 1350 aluminum strands assembled with strands of aluminum-clad steel, other messengers are similarly used of high strength ACSR, as well as combinations of 6201 aluminum with steel reinforcement (AACSR).

Fig. 11-30 depicts several kinds of fittings and accessories used when installing messengers and preassembled aerial cables, some of which also apply to preassembled secondary and service-drop cables.

Neutral-Supported Secondary and Service-Drop Cables

Preassembled aluminum insulated multi-conductor cables supported by bare neutral messenger conductors have practically become standard for secondary aerial circuits and service drops. Subject to the NEC limitation of 300 volts to ground for bare neutrals, the triplex form (two insulated conductors preassembled with a bare neutral) supplies the usual single-phase three-wire circuits. Similar quadruplex cables (three insulated conductors) if connected to a three-phase Y source supplies low-voltage three-phase loads.

The neutral messengers of such cables are selected on basis of strength and conductivity; either with conductivity equal to that of a phase conductor or as a “reduced” neutral having conductivity not less than one-half that of a phase conductor, depending on service requirements. Tables in Chapter 4 show, as mentioned above, data regarding bare neutral messengers for such cables. Chapter 10 describes various types of cables. Fig. 11-31 depicts installation details for usual conditions of installation of the secondary cable and the service-drop taps extending from it. Initial sag-and-tension data for preassembled triplex aluminum cables with full- and reduced-size neutrals are in Table 11-11 for the various NESC loadings for 125 ft spans.

11-23


covered and insulated aluminum wire and cable

The notation on Table 11-11 with regard to initial sag values for other spans than 125 ft is based on Eq. 5-2, but it is only approximate; hence it is available to obtain correct values from the cable manufacturer.

The sag-tension values of Table 11-11 are for initial unloaded conditions at 60°F. The sag eventually will increase to the final value and the tension correspondingly will decrease as a result of long-time creep. When fully loaded according to NESC values the sag and tension both will increase, and as temperature drops to 0°F under Heavy-Loading conditions the sag decreases and tension increases. Thus, for 2/0—2/0 cable with aluminum-alloy messenger, the initial stringing sag-tension of 13 in.—865 lb becomes 24 in.—1955 lb (see Chapter 5).

The sag-tension values under conditions of maximum NESC loading are useful for circuit design because they indicate minimum clearances under the cable, and also verify that there is the specified margin between actual tension and the rated breaking strength of the messenger. However, tables similar to Table 11-11 for initial stringing conditions are used as a basis for installation, which is the subject considered in this chapter.

Fig. 11-30. Typical details for supporting and dead-ending cables, messengers, and guy wires on poles.
Fig. 11-31. Typical installation details for secondary triplex cables, neutral-messenger-supported, showing service-drop taps and other details.

A—Dead-end at pole, showing also application of service-drop span clamp.

B—Double service-drop taps at service-drop span clamp, and messenger suspension clamp at pole.

C—Service-drop “T” tap near pole.

D—Clevis support at pole for directional change of less than 45°.

E—Dead-end support at pole for directional change of more than 45°.

Notes: Compression connections are to be taped, even though not so shown. Poles are to be suitably guyed to resist unbalanced forces. Armor rods are used where abrasion is likely. See Chapter 5 for additional details of armor rods and the like.
covered and insulated aluminum wire and cable

TABLE 11-10

Representative Values Extracted from Tables Supplied by Cable Manufacturer for Initial Sag-and-Tension Values at 60°F, suitable for Light or Heavy NESC Districts

For Preassembled Primary Aerial 3-1/C Cables with AWAC Messenger

<table>
<thead>
<tr>
<th>Conductor Size</th>
<th>Messenger</th>
<th>Cable Assembly (2)</th>
<th>Span Length in Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Size</td>
<td>Rated Strength</td>
<td>Diam. in.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AWG or Kcmil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>#3-3/4</td>
<td>7700</td>
<td>1.251</td>
</tr>
<tr>
<td></td>
<td>&quot;</td>
<td>&quot;</td>
<td>1.575</td>
</tr>
<tr>
<td>1</td>
<td>&quot;</td>
<td>&quot;</td>
<td>1.770</td>
</tr>
<tr>
<td>2/0</td>
<td>&quot;</td>
<td>&quot;</td>
<td>2.007</td>
</tr>
<tr>
<td>4/0</td>
<td>&quot;</td>
<td>&quot;</td>
<td>2.374</td>
</tr>
<tr>
<td>350</td>
<td>&quot;</td>
<td>&quot;</td>
<td>2.693</td>
</tr>
<tr>
<td>500</td>
<td>#3-2/5</td>
<td>11300</td>
<td>2.815</td>
</tr>
<tr>
<td>750</td>
<td>#2-2/5</td>
<td>13500</td>
<td>3.215</td>
</tr>
<tr>
<td>1000</td>
<td>#1/0-2/5</td>
<td>19500</td>
<td>3.695</td>
</tr>
</tbody>
</table>

5000 Volt Unshielded (Class B concentric stranded aluminum, cross-linked polyethylene insulation)

15,000 Volt Shielded, Grounded Neutral (Class B concentric stranded aluminum; semi-con tape; strand shield; 0.175 in. XLPE insulation; extruded semi-con PE, No. 22 AWG copper concentric; Mylar tape; PVC jacket)

|               |           |                    |          |              |     |     |     |     |     |     |
|               |           |                    |          |              |     |     |     |     |     |     |
| 2             | #3-3/4    | 7700               | 2.459    | 1.379        | 19  | 23  | 27  | 1122 | 1418 | 1739 |
| 1/0           | "         | "                  | 2.618    | 1.606        | "   | "   | "   | 1306 | 1645 | 2024 |
| 4/0           | #3-2/5    | 11300              | 3.006    | 2.215        | "   | "   | "   | 1801 | 2269 | 2679 |
| 350           | #1/0-2/5  | 19500              | 3.504    | 3.075        | "   | "   | "   | 2500 | 3151 | 3720 |
| 500           | "         | "                  | 3.789    | 3.696        | "   | "   | "   | 3005 | 3787 | 4659 |
| 750           | #556,500(30/7) | 26900             | 4.575    | 5.039        | "   | "   | "   | 4032 | 5040 | 6048 |
| 1000          | "         | "                  | 5.079    | 6.390        | "   | "   | "   | 5031 | 6400 | 7051 |

1. Initial tension is such that the final tension will not exceed 25 percent of rated strength at 60°F, for Light or Heavy NESC loading districts.
2. Includes weight of messenger and binder tape.
3. Initial sag is such that final sag approximately conforms to ICEA recommendation of 1.667 percent of span length.
**TABLE 11-11**

Typical Initial Stringing Sag and Tension Values for
Three-Conductor Self-Supported Polyethylene Service-Drop and
Secondary Cable (Triplex), for 125 ft span at 60°F
for Various NESC Loading Districts (see Table 5-1)*

Note: For roughly approximate values for spans of 100 ft and 150 ft, multiply the initial sag values for 125 ft span by 0.64 for 100-ft span and by 1.45 for 150-ft span, retaining the initial tension values for 125 ft span. These approximations are less accurate for the Heavy Loading District. More accurate values for spans other than for 125 ft, are obtainable from cable manufacturers.

<table>
<thead>
<tr>
<th>Conductor Size</th>
<th>Neutral Messenger</th>
<th>NESC Light-Loading District</th>
<th>NESC Medium-Loading District</th>
<th>NESC Heavy-Loading District</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Size AWG (or Equiv.)</td>
<td>Rated Strength lb</td>
<td>Initial Sag</td>
<td>Initial Tension</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>1760</td>
<td>8</td>
<td>467</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2800</td>
<td>8</td>
<td>750</td>
</tr>
<tr>
<td>1/0</td>
<td>1/0</td>
<td>4460</td>
<td>8</td>
<td>1195</td>
</tr>
<tr>
<td>2/0</td>
<td>2/0</td>
<td>5390</td>
<td>8</td>
<td>1415</td>
</tr>
</tbody>
</table>

**ALUMINUM ALLOY 6201 NEUTRAL MESSENGER**

| 6            | 6                 | 1190                       | 10           | 290            | 10          | 305            | 29          | 98             |
| 4            | 4                 | 1880                       | 10           | 445            | 8           | 415            | 11          | 375            |
| 2            | 2                 | 2850                       | 10           | 660            | 11          | 575            | 11          | 600            |
| 1/0          | 1/0               | 4380                       | 10           | 1005           | 12          | 865            | 12          | 840            |
| 2/0          | 2/0               | 5310                       | 10           | 1255           | 12          | 1070           | 13          | 975            |

**ACSR NEUTRAL MESSENGER**

| 4            | 6                 | 1190                       | 12           | 295            | 12          | 350            | 34          | 105            |
| 2            | 4                 | 1860                       | 13           | 445            | 13          | 435            | 17          | 330            |
| 1/0          | 2                 | 2850                       | 13           | 670            | 14          | 600            | 13          | 655            |
| 2/0          | 1                 | 3550                       | 13           | 835            | 16          | 730            | 14          | 755            |

**REDUCED ACSR NEUTRAL MESSENGER**

| 6            | 6                 | 560                        | 26           | 91             | 54          | 44             | 104         | 23             |
| 4            | 4                 | 881                        | 19           | 195            | 19          | 195            | 72          | 53             |
| 2            | 2                 | 1350                       | 17           | 385            | 19          | 295            | 49          | 115            |
| 1/0          | 1/0               | 1990                       | 19           | 485            | 23          | 410            | 40          | 230            |

* These initial sag-tension values are based on NESC loading limits for REA systems; that is, loaded tension is not to exceed 50% of messenger rated strength; final stringing tension is not to exceed 25% of rated strength; and initial stringing tension is not to exceed 33 1/3% of rated strength.