CHAPTER 13 - CABLES FOR UNDERGROUND SERVICE AT AERODROMES

13.1 Characteristics of cables for underground service

13.1.1 Insulation. The following insulation materials are commonly specified because they provide the maximum rated conductor temperatures for operating, overload, and short-circuit conditions for cables rated up to a maximum of 35 kilovolts:

(a) Cross-linked polyethylene (XLP). This thermo-setting compound has excellent electrical properties, good chemical resistance, good physical strength characteristics.
(b) Ethylene-propylene rubber (EPR). This compound has electrical properties which are considered equal to cross-linked polyethylene; therefore, the contractor should be given the option to provide either type.
(c) Thermo-plastic elastomer (TPE). This cable material provides effective electrical insulation and toughness in thin layers as well as good flexibility over a range of temperatures.
(d) Polyurethane (PUR) jacketed. This cable jacket is halogen free and resistant to de-icing products.

13.1.2 The following insulation materials may be used where special circumstances warrant their lower rated conductor temperatures or their lower rated maximum voltage class.

(a) Rubber. Rubber insulated conductors provide ease of splicing, good moisture resistance, and low dielectric losses.

(b) Paper insulated. Use paper insulated cable for low ionization, long life, high dielectric strength, low dielectric losses, and good stable characteristics under temperature variations. As with varnished-cambric insulation, paper insulation requires a suitable protective metallic sheath. It may be specified as an option when existing cables are paper insulated, or as a requirement when the extra cost is justified because neither cross-linked polyethylene or ethylene-propylene rubber provide the required qualities.
(c) Butyl rubber. This thermosetting insulation has high dielectric strength and is highly resistant to moisture, heat, and ozone. It can be used up to 35000 volts, but has lower rated conductor temperatures than either cross-linked polyethylene or ethylene-propylene rubber.
(d) Silicone rubber. This thermosetting insulation is highly resistant to heat, ozone, and corona. It can be used in wet or dry locations, exposed, or in conduit. It has the highest rated conductor temperature but can be used only for applications up to 5000 volts.

13.1.3 The following Table 1 provides a conversion from AWG to metric sizes. The equivalents are rounded upwards [e.g. for AWG #10 with area of 5.26mm² the metric equivalent is 6mm²].
### Table 1

<table>
<thead>
<tr>
<th>AWG</th>
<th>Diameter (inch)</th>
<th>Area (inch²)</th>
<th>Diameter (mm)</th>
<th>Area (mm²)</th>
<th>Resistance (Ω/km)</th>
<th>Metric equivalent (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0.2043</td>
<td>0.0327</td>
<td>5.189</td>
<td>21.149</td>
<td>0.82</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>0.1620</td>
<td>0.0206</td>
<td>4.115</td>
<td>13.298</td>
<td>1.30</td>
<td>16</td>
</tr>
<tr>
<td>8</td>
<td>0.1285</td>
<td>0.0129</td>
<td>3.264</td>
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<td>2.06</td>
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<td>10</td>
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<td>0.0081</td>
<td>2.588</td>
<td>5.261</td>
<td>3.28</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>0.0808</td>
<td>0.0051</td>
<td>2.053</td>
<td>3.309</td>
<td>5.21</td>
<td>4</td>
</tr>
<tr>
<td>14</td>
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<td>1.628</td>
<td>2.081</td>
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<td>0.0020</td>
<td>1.291</td>
<td>1.309</td>
<td>13.17</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Based on $\rho = 0.1724 \times 10^{-8}$ ohms - m

### 13.2 Cable Sheaths

(a) Nonmetallic. Nonmetallic sheaths should be flexible, moisture repellent, and long lasting. Neoprene, which is often used as nonmetallic cable sheaths, is unsuitable in many locations. This material frequently absorbs excessive amounts of water which may penetrate through to the insulation. Some non-metallic-sheath materials, especially in some tropical areas, are reported to be damaged by micro-organisms, insects, and plant life. Some sheath materials, which perform well where installed underground or in conduits, deteriorate rapidly if installed where it is exposed to sunlight. Materials which become brittle at low temperatures should not be used in cold regions. In some locations, rodents frequently damage non-metallic-sheathed cable. In these areas the cable should be installed in ducts or metallic-sheathed cable should be used.

(b) Metallic. Cables exposed to mechanical damage or high internal pressure require a metallic sheath, such as lead, aluminum, or steel. Certain insulations, such as paper and varnished cambric, require such protection in all cases.

### 13.3 Cable coverings

A suitable covering or jacket may be required for corrosion protection of metallic sheaths.

### 13.4 Shielded cables

Shielding of a medium-voltage distribution cable is required to confine the electric field to the insulation itself and to prevent leakage currents from reaching the outside of the cable. Insulation shielding is required on all nonmetallic-shielded cable rated to kilovolts and above, except for aerodrome-lighting series-circuit cables, and all metallic-sheathed cable rated five kilovolts and above. Shields should be grounded to reduce the hazards of shock. Grounding is required at each termination, otherwise dangerous induced shield voltages may occur.

### 13.5 Cable fireproofing

Cables in manholes, handholes, and transformer vaults operating at 1400 volts or over, or exposed to the failure of other cables operating at these voltages, should be fireproofed with a suitable spray coating. Exceptions may be made where physical separation, isolation by barriers, or other considerations permit.
13.6 **Protection against corona damage**

Insulation of high-voltage cables which may be damaged by ozone should be protected against this damage by controlling corona, which produces ozone, by placing a thin semi-conducting film between the conductor and its insulation. This film fills the voids between the conductor and the insulation thus preventing the generation of corona and hence ozone. (See 5.1.3.6)

13.7 **Cable conductors**

Annealed copper is used in most forms of insulated conductors because of its high conductivity, flexibility, and ease of handling. Medium-hard-drawn copper has greater tensile strength than annealed copper. Conductors may be permitted as a conductor’s option except where corrosive conditions limit their usage.

13.8 **Health and Environmental Issues**

Health and environmental issues should be taken into account when selecting cables. One should avoid products that contain halogens and are problematic for recycling such as Polyvinyl chloride (PVC) and Lead (Pb). Such cables preferably should be replaced by more environmental friendly cables as those indicated in the following standards.

- Flame and Fire retardant (IEC 332 - 3 Cat C),
- Halogen free cable (IEC 754 - 1),
- Non corrosive and non toxic cable (IEC 754 - 2),
- Low smoke emission and opacity (IEC 1034).

Designers and those procuring cable should be aware of the Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment; referred to as the Restriction of Hazardous Substances Directive (RoHS) ... 2002/95/EC ... restricting the use of hazardous materials for electrical equipment. It is related to the Waste Electrical and Electronic Equipment Directive (WEEE) ... 2002/96/EC ... pertaining to collection, recycling and recovery targets for electrical products and is part of a legislative initiative to solve the problem of huge amounts of toxic e-waste.

13.9 **Classes of service**

13.9.1 Low-voltage cables. Low-voltage cables - - insulation rated at 600 volts or less - - are used to connect the secondaries of series/series isolating transformers to the lamps in the fixtures, for low-voltage distribution circuits, as low-voltage feeder circuits to single units and the shorter circuits. The conductors are usually copper but may be aluminum, and either single- or multi-conductor cables are used. Both solid and stranded conductors are used but stranded is preferred if frequent flexing of the cable is expected. The cross-sectional area of the conductor may vary from 2.5mm² to 4mm² (#14 to #12 AWG) or larger if necessary to decrease the voltage drop.
13.9.2 High-voltage cables. For aerodrome lighting, high-voltage cables are used mostly for source power distribution and feeder cables. The criteria and materials are the same as for power distribution cables discussed in articles 4.5 to 4.7. The voltages used usually range from 1000 to 5000 volts. Conductor sizes usually are in the range of 4 to 25mm² (#12 to #4) in cross-section but larger sizes are occasionally used. These cables may be either single-conductor or two- or three-conductor cables. Consider the soil, environment, method of installation, subjection to chemicals, and any special problems in selecting the insulation, jackets, sheathing, and shielding for these cables.

13.9.3 Series aerodrome lighting cables. The requirements of the cables for this purpose have been standardized more than have the cable requirements for most power circuits. The series current used in these circuits is between 6 and 20 amperes. The conductor size commonly used is 6mm² in cross-section (#8 AWG). These cables are single conductor. The conductor is usually stranded but solid conductor can also be used. The insulation is usually 5000 volt rated. A non-metallic jacket over the insulation is commonly used. Metallic-tape shielding between the insulation and jacket or between the jacket and non-metallic covering is often used but may not be required for some installations. The preferred series-lighting cables are stranded, copper, cross-linked polyethylene, ethylene-propylene-rubber, or butyl-neoprene rubber insulation; chlorosulfonated polyethylene, polyvinyl chloride, polyethylene, or heavy duty neoprene jacketed; metal-tape shielded types.
13.9.4 Control cables. Control cables are low-voltage cables usually in pairs or multi-conductor. A group of single-conductor cables may be used for some simple control circuits. Some control cables have one or two larger conductors for the line voltage and/or neutral and several smaller conductors for the individual controls. Other installations may use a pair of larger wires for the line and neutral and other cables with many smaller conductor wires for the individual controls. Multi-conductor control cables have 7, 12, 16, or many more conductors used. Most control cables have stranded copper conductors. The size of the conductor is selected to keep the line voltage drop within an acceptable range. The cross-sectional size of the conductors is usually between 2.5mm² and 0.5mm² (#12 to #22). The insulation resistance rating must be suitable for the control voltage which is usually 250 volt or less. Rubber, polyethylene, polyvinyl chloride, varnished cambric, and paper are some of the types of insulation for control cables. Thin insulation is desirable to reduce the diameter of the cable. Twisted pairs or spiralling of the conductors is desirable for alternating-current control circuits to reduce induced voltage between circuits. Multi-conductor cables must have an outside jacket and may be shielded with metal tape.

13.9.5 Communications cable. Special intercommunications or telephone circuits should be installed to provide communications between control tower, lighting vaults, and offices or stations. The circuits are usually one or more twisted-pair telephone type cables. These cables should be suitable for underground installation. Although the control cables may be used for communications at some installations, separate cables in separate conduits or well separated in the trench, if direct burial, are preferred.

13.10 Ground wires. A ground wire or counterpoise wire should be installed to protect underground power and control cables from high ground current surges in areas where damage from lightning strikes may be expected. The ground wire should be installed between the earth's surface and the underground cables. It is usually an uninsulated, stranded copper conductor although in some States, steel banding has been used. The size of this ground wire should be not less than the largest size conductors which it protects. Cross-section area of the conductor may range from 6mm² to 25mm² (#8 to #4AWG) or larger. It should be a continuous conductor and connected to each fixture, light base, and ground rod or connection along its route.
13.11 Causes of cable damage

13.11.1 Cable faults are frequent reasons for aerodrome lighting circuit failures and often require considerable time and effort to locate and repair. Effective methods of reducing cable faults improve reliability of the system. Better knowledge of the causes of damage to cable should aid in choosing types of cable and installation procedures. Some of these causes are discussed below.

13.11.2 Mechanical damage. Probably most cable faults are caused by mechanical damage. Poor installation techniques and procedures are probably the most common cause of mechanical damage, but frost heaves, vibration from aircraft or vehicle traffic, rodents, ground shifting or settling, and many other reasons may physically damage the cable. Some types of mechanical damage are:

(a) Nicks and scrapes of the insulation.
(b) Over stressing of the cable when pulling into ducts or unrolling the cable for direct burial.
(c) Stones or foreign objects in the beds or backfills of trenches.
(d) Inadequate slack at entrances to or inside of handholes, manholes, light bases, conduits, fixtures, connections to equipment, connectors, splices, along trenches or conduit, or other locations where settling, maintenance, installations, or weather may increase stresses.
(e) Nicking of the conductor at splices or connector joints may later break the conductor.
(f) Inadequate separation of cables in trenches, either vertically or horizontally, at slack loops of cable, or places where earth compaction or freezing action may force two sections of cable into direct contact.
(g) Freezing or frost heaves forcing the cable against ice, frozen earth, or any other solid object or material. Proper cushioning and slack to reduce stress at these points is necessary.
(h) Improperly supported cables in manholes or other areas where sagging or exposure may result in objects or persons putting pressure on the cable.
(i) Vibration from traffic passing over the cable or from equipment operation attached to or near the cable may cause fatigue of the conductor or of the jacket and insulation. Where such conditions may exist or be developed, install the cables in ducts which extend well beyond the area of vibration.
(j) Breaking or separation of conduits or ducts may break the cable. The installation of the ducts and conduit must be properly joined and suitably backfilled and tamped.

13.11.3 Water penetration.

(a) A ground fault is formed when water is able to penetrate through the cable sheath and insulation to the conductor. Water penetration or leakage may occur at splices, connections, cable terminations, physical damage areas, unsatisfactory insulation, pinholes from lightning or over voltage, or other defects.

(i) Improperly made splices and improperly installed connector kits are a frequent source of water penetration. See Section 13.12 for instructions for making splices and installing connectors.
(ii) In order to avoid water penetration at the ends of cable, these ends should be kept clean and free from moisture before as well as after connecting to the equipment. The ends of spare cables should be similarly protected. Some types of insulation, especially paper and mineral filled, may attract moisture from the atmosphere during periods of high humidity. The ends of the cables of these types should be kept sealed at all times even after connecting to the equipment.

(iii) Same insulations, either from defects or composition, may permit excessive water penetration. Quality tests of insulation resistance should detect such defects. There are reports that some neoprene-jacketed cable is not adequately water resistant, although other reports state that cable of this type performs well. Before cable is purchased, the performance of the type of cable at other installations, preferably from the same manufacturer, should be investigated.

(iv) Lightning strikes may severely damage cables or the induced voltages may be enough to damage the insulation by creating pinholes. These pinholes are more likely to occur at points of crossing cables or where the cable is near or in contact with metal conductors. Properly installed ground wire or counterpoises should reduce the damage from lightning strikes.

(v) Excessive voltage may be applied to a cable, either accidentally or from faulty operation. Damage to the cable may not be noticeable immediately.

(b) The installation design should incorporate means for drainage of ducts and manholes in order to avoid lengthy immersion of cables and connectors.

13.11.4 Chemical damage. Often aerodrome lighting cables are located in areas where fuel, oil, acids, or other chemicals may be present regularly or occasionally. These chemicals affect the insulation resistance of some types of cables. If it is known, or suspected, that cables may be exposed to such chemicals, select a type of cable which is resistant to these chemicals. Neoprene and rubber insulation may not be suitable in the presence of some de-icing fluids.

13.11.5 Rodent damage. In some areas, direct burial cable is damaged by rodents, especially gophers, gnawing the insulation. There is some evidence that the rodents may be attracted to the cable either by the heat emitted from it or by its taste. Where rodent damage is a serious problem, it may be desirable to install the cable in ducts or to use metal-sheathed cable.

13.11.6 Micro-organism or plant damage. Micro-organisms and plants are reported to have damaged some types of cables in tropical or subtropical areas. Other types of cable are not seriously affected. If it is anticipated that such problems may occur, select a type of cable which is known to be resistant to such micro-organisms and plants.

13.11.7 Ozone and corona damage. Some cable insulations are damaged by ozone and thus by the corona produced by the circuit or by nearby circuits. Cable insulations are available which satisfactorily resist these effects. Select cables with these qualities if the cable is carrying high voltages or may be exposed to other sources of ozone or corona. In the past some States have used cables which were not protected against corona damage for runway and approach light series systems reasoning that these systems are operated at full intensity for only a relatively small number of hours per year. Consequently, these cables are subjected to high-voltage stress during only a small fraction of the time in service. This practice has been found to be undesirable since the reduction in cost is small and because some of this cable invariably is inserted into the power distribution circuits and are subjected to continuous high-voltage stress.
13.11.8 Ultraviolet damage. Some cable insulation, which performs satisfactorily in underground installations, may become brittle and deteriorate rapidly where exposed to sunlight if used on elevated supports such as approach light towers. If the cable will receive this sort of exposure, select cable with insulation which resists ultraviolet or install the cable in metal conduit.

13.11.9 Cable deterioration. Most cable insulation deteriorates slowly. The service life of underground cables should be 10 to 20 years.

13.12 Cable Connections

Note: Cable splices should not be located with ducts - it is tolerated only in manholes and handholes.

13.12.1 Cable splices

13.12.1.1 All cable splices should be performed by experienced and qualified cable splicers using high standards of workmanship. Splicing methods and materials should be of types recommended by the manufacturer of the splicing material for the particular type of cable being spliced. All cable splices should meet the following requirements.

13.12.1.2 Power cables insulated for more than 5000 volts. Splice kits designed for the type of cable being spliced should be used. When such kits are not available, taped splices made in accordance with paragraph 13.12.2 may be used. Epoxy or resin splices should not be used.

13.12.1.3 Power cables with 610 to 5000 volt insulation. Pressure epoxy-resin splice envelopes and cast splice kits designed for the cable should be used in strict conformance with the manufacturer's instructions. Taped splices should be used only if necessary.

13.12.1.4 Power cables insulated for 600 volts or less. Cast splice kits or pressure epoxy-resin splice envelopes suitable for all direct earth-burial cable may be used. Taped splices using prestretched or heat-shrinkable tubing as a covering may also be used.

13.12.1.5 Control and telephone cables. A type of re-enterable filled splice envelope is available for use on thermoplastic-insulated non-pressurized cables. Splices to existing pressurized, lead-covered, or paper-insulated cables should be in accordance with the requirements of the authority involved.

13.12.2 Taped splices

13.12.2.1 Taped splices are usually used only when satisfactory connectors and splice kits cannot be obtained. If taped splices are to be made, the correct technique must be used in order to obtain satisfactory service. The technique described below is intended for single-conductor cable but applies with suitable adaption to multi-conductor cable splice.

13.12.2.2 Keep the ends of the cables to be joined clean and protected from moisture at all times.
13.12.2.3 As illustrated in Figure 13-3, carefully taper and remove the covering, jacket, metallic shield, sheath, and insulation from the ends of the cables to be joined. Remove all traces of insulation from the conductors for a length of approximately 3mm plus half the length of the crimp connector being very careful not to nick the conductor. Smoothly taper the insulation back from the conductor for at least 40mm. Remove the sheath, metal tape, jacket, etc. back along the outer surface of the insulation layer for an additional 20mm. This offset of the tapering should block paths of water penetrating along the tapering. Keep intact the metal tape for shielding, if involved, over the entire length of the splice. Similarly, taper the non-metallic sheath for 20mm or more. Remove any steel or metal armour or outer metal covering but leave stubs or ends for reconnecting across the splice.

13.12.2.4 Use a crimp-type connector to join the ends of the conductor. Crimp the connector onto the ends of the conductors using a tool designed to make a complete crimp before the tool can be removed. The conductor connector may also be soldered if desired.

13.12.2.5 Using rubber or synthetic rubber tape of good quality, carefully wrap the joint one layer at a time maintaining enough tension on the tape for approximately 25 percent elongation and overlapping the tape approximately 50 percent of its width. Each layer will extend further up the taper along the insulation. Continue this build-up of layers of rubber tape to the full size of the insulation layer.

13.12.2.6 If shielding tape is used over the insulation, connect the metal tape, which should have been kept intact, across the splice by soldering or using suitable connectors. Wrap with extra metal tape of similar type if needed.

13.12.2.7 Continue to wrap the rubber tape as in 13.12.2.5 to not less than 1.5 times the diameter of the cable. Carefully apply tension on the tape to prevent any voids and obtain good adhesion to the cable surfaces and each inside layer of tape.

13.12.2.8 Over the rubber tape, add several layers of high-insulation-resistance, flame-retardant, weather-resistant and cold-resistant tape. Apply the plastic tape with appreciable tension and overlapping each turn by approximately 50 per cent of its width. The plastic tape should extend for 30mm or more along the surface of the insulation of sheath on each side of the splice.
13.12.2.9 If the cable has a steel-armour or other metallic cover, connect a length of grounding braid across the splice and fasten to the armour on the cable with suitable clamp connectors and/or solder on each side of the splices. Refer Figure 13-4(a). If the cable is lead encased, make a suitable wiped-lead joint over the splice to provide a waterproof seal to the lead covering on the cable. If the metal covering is protected from corrosion by a coating, apply a coating of similar material over the entire surface of the cable and splice in the area of this work.

13.12.2.10 Cable splicing is best done using commercially available splicing kits containing butt splice connectors and epoxy potting compounds. These help provide a waterproof and mechanically strong splice. Armored cables are difficult to splice if the mechanical strength is to be maintained; special mechanical connections need to be fabricated which will grip the armor firmly.
13.13 Connector kits for aerodrome lighting

13.13.1 Use of connector kits. In recent years most series-circuit connections have been made using connector kits. Although the cost of connector kits is significant, the time saved in installation and the ease with which circuits can be opened and reclosed when locating faults have made their use desirable. Since the leads of most isolating transformers are now manufactured with connectors, cable connectors are required and provide an easy means of connecting or disconnecting the transformer into the series circuit and to the light. Single-conductor primary connectors and two conductor secondary connectors are shown in Figures 13-5 and 13-6.
Figure 13-5. Primary Connectors

Figure 13-6. Secondary Connectors
13.13.2 Installation of connectors. The cable ends should be prepared carefully in accordance with the instructions, keeping both the cable ends and the connector surfaces free of dirt and moisture. Make certain that any cavities between the cable and interior of the connector are filled with the gel provided to prevent voids. After joining the connectors ensure that air is not trapped which may tend to force the connection apart. Taping over the joint with vinyl electric tape to keep the area clean and from separating is suggested.

13.13.3 Figure 13-7 illustrates the use of primary connectors and field splices. Although the method (b) to an extent increases the labour for installation, it is recommended for reason of later reduction of maintenance costs. The use of factory moulded connector is preferred over that of field assembled connectors as shown in (a).

![Figure 13-7. Primary connections with field splices](image)

13.15 Connection of conductors

13.15.1 Power conductors. Connections of cable conductors should be made using crimp connectors utilizing a crimping tool designed to make a complete crimp before the tool can be removed. Split-bolt connectors may be used for low-voltage circuits of 600 volts or less.

13.15.2 Control and telephone cables. Joining of telephone or control conductors should be done with a twisted and soldered splice or an appropriate self-stripping, preinsulated connector installed with the specific tool designed to crimp the connector. Color coding of the conductors should be followed throughout the installation.

13.15.3 Cable armour and shields. Armour shields should be electrically bonded across the splice by cleaning and soldering. Use sections of metal braid and conducting tape, if needed. Armour and shielding should be completely insulated from each and from ground, except as noted in paragraph 12.5.3.3.