CHAPTER 12 UNDERGROUND ELECTRICAL SYSTEMS

Additional information on underground electrical systems can be found in IEC 61820 and the FAA advisories AC 150/5340-30.

Dimensions shown herein are typical and based upon existing practice. Different dimensions may be stipulated by local authorities having jurisdiction.

12.1 General

12.1.1 The installation of underground electrical systems can be envisaged as the provision of 4 fundamental components:

1. **Primary cable.** The installation of primary cable from the CCR to and between the light stations. The installation can be done through means of direct burial or placement within conduit. The latter is preferred for reason that it provides relative protection against soil movements and facilitates future need for cable replacement. If the conduit is of sufficient size, it can serve for later installation of additional cable.

2. **Light station equipment.** The equipment at the light station consisting of a stake or housing, the AGL transformer and appropriate connectors. The tendency is to use housings which enable later maintenance of the AGL transformer rather than to do direct burial of this transformer. The light fixture may be installed either: on a stake with the transformer in a nearby housing, on the housing itself, or separately as in the case of inpavement lights provided in a shallow base receptacle. If an elevated light is to be installed on a housing, then the latter should in a concrete pad to obviate movement. For approach lighting systems, at some airports the housing has been in the form of a cabinet attached to the lower portion of the light tower. This eliminates the problem of water in the housing.

3. **Secondary wiring.** The secondary wiring from the AGL transformer to the light fixture. If the light unit is located remote from the housing, the loading represented by this secondary wiring should be taken into account [refer chapter 8]. For inpavement lighting of the shallow base type, the secondary wiring may be installed directly in sawcuts or in conduit.

4. **Counterpoise Wire.** The counterpoise wire is for purpose of lightning protection. It is normally installed over direct buried cables and over conduit. Depending upon local practice, the manner of installation at light stations varies for which the counterpoise may be bonded to the metal housing or may bypass the housing. At least one State, for edge lighting in non-paved areas, locates the counterpoise at a mid-point distance between the pavement edge and the line of light units. The counterpoise wire may be further earthed by installation of ground rods at intervals of at least 150m. At runway or taxiway crossings, the counterpoise may be terminated with a ground rod at each side of the crossing.

The counterpoise wire is typically of solid copper in sizes from 16mm² [#6AWG]. Other materials have been used such as galvanized steel. Refer to EN 62305 regarding the suitability of wire material against corrosion in soils.

5. **Equipment Grounding.** An equipment grounding system may be installed for personnel safety protection in case of a shorted power cable or AGL transformer. In some practices, the equipment ground is provided by means of an insulated conductor that is bonded internally at the transformer housing or within the shallow base receptacle and then through the conduit to the building ground of the electrical vault. Alternatively this equipment grounding may be installed by means of a ground rod at each light station. In the case of inpavement lights, it is advisable to provide a bonding jumper between the ground lug of the base and the fixture or cover of the
housing. This jumper is of particular benefit in the case of inpavement lights should the optical assembly be lifted free of the base. Equipment grounding may also include the use of AGL transformers having means for grounding one side of the secondary winding.

Although equipment (safety) grounding and lightning protection can be seen as distinct design functions, for some practices these are combined within the single component of counterpoise wiring. For such practice there is the risk of equipment damage from lightning, especially where AGL transformer secondary grounding is used.

12.1.2 Initial considerations

12.1.2.1 Installation of electrical cables underground is expensive and techniques to assure long and effective service with a minimum of maintenance should be used. All work should be done by experienced personnel regularly engaged in their type of work. Most underground cables will be located on, or very close to, the manoeuvring area of the aerodrome. Hence, at active aerodromes great care must be exercised to ensure that the installation does not present a hazard to aircraft or to the installers.

12.1.3 Preconstruction arrangements

12.1.3.1 Obtain prior approval of the engineer in charge for the materials, workmen, time of day or night for the work, method and procedures for the installation, and procedure for any temporary or permanent repairs to be made. Arrange for coordinating the effort with Air Traffic Control if it may be involved. Carefully determine and mark the route for the cables. Take all reasonable precautions to protect existing underground utilities such as fuel tanks, water lines, buried control and power cables, etc. All known utilities and power and control cables leading to and from any operating facility should be marked in the field before any work in the general vicinity is started. Thereafter and throughout the entire time of construction they should be protected from any possible damage. Any underground cables which are damaged during installation should be immediately repaired with equal quality material.

12.1.3.2 Tape the ends of the cables to prevent the entry of moisture until connections are made.

12.1.3.3 Splices in ducts, conduits, or in the primary cables between light base and transformer housings should not be permitted.

12.1.3 Methods of installation. There are three methods of installing underground electrical cables: by direct burial, by installation in direct buried conduit, and by installation in concrete enclosed duct [duct bank]. These methods are discussed below.

Note: Although direct burial of cable is described herein, the preferred practice is to install cable in conduit or duct.

12.2 Direct Burial of Cable

12.2.1 The major steps of installing electrical cables by direct burial are;

(1) TRENCHING,
(2) PLACEMENT OF CABLE, and
(3) BACKFILLING.

12.2.2 Trenching

12.2.2.1 Basic requirements. Unless required otherwise, all cables in the same location and running in the same general direction should be installed in the same trench. Walls of trenches should be essentially vertical so that a minimum of shoulder surface is disturbed. The bottom surface of trenches should be
essentially smooth and free from coarse aggregate. If possible, trenches should be opened only to the extent that cables can be installed and the trench closed in the same working day. Where turf is well established and the sod can be removed, it should be carefully stripped and properly stored.

12.2.2.2 Duct bank or conduit markers temporarily removed for trench excavations should be replaced as required. Where existing active cable(s) cross proposed installations, the installer should insure that these cable(s) are adequately protected. Where crossings are unavoidable, no splices will be allowed in the existing cables, except as specified on the plans. Existing cables should be located manually. Unearthed cables should be inspected to assure no damage has occurred.

12.2.2.3 **Cable depth.** Cables should be a minimum of 450mm below the finished grade when on the aerodrome property and at a minimum of 600mm for under runways, taxiways, aprons, and roads, with a minimum mechanical protection of rigid conduit or a system of concrete encased underground raceways. When installed off airport property the cable should be installed in accordance with local electrical code requirements. The minimum cable depth when crossing under a railroad track, should be 1200mm unless otherwise specified.

12.2.2.4 **Trench depth.** The depth of the trench into which cables are to be installed should be sufficient for the required cable depth plus a minimum 75mm bedding (e.g. sand) layer below the level of the lowest cable as shown in Figure 12-1.

12.2.2.5 **Placing of cables.** Wherever possible, cable should be run in one piece, without splices, from light station to light station. Use the longest practicable lengths of feeder cable in order to minimize splicing requirements. When cable cutting is required, cable ends should be effectively sealed against moisture immediately after cutting. Cables should not be bent at a radius of less than eight times the diameter for rubber or plastic covered cable and twelve times the diameter for metallic armoured cable. Cable that has been kinked should not be installed. Someone should be stationed at the reel to observe and report any irregularities in the cable when the cable is being unreeled. Cable for direct earth burial should be unreeled in place in the open trench or unreeled by the side of the trench and carefully placed in the trench bottom. The cable(s) should not be unreeled and pulled into the trench from one end. Where cables must cross over each other, a minimum of 75mm vertical displacement should be provided with the topmost cable depth at or below the minimum required depth below finished grade. Slack cable sufficient to provide strain relief should be placed in the trench in a series of S curves.
12.2.2.6 Placement of Counterpoise Wire. The counterpoise wire provides a 90 degree "zone of protection" [45 degrees on each side of the vertical]. The counterpoise wire is installed continuously 75 to 150mm above the cable, conduit or duct bank, or as shown on the plans if greater. Based upon the zone of protection a counterpoise at 75mm is suitable for 1 to 2 cables and at 150mm for 3 to 4 cables after which additional counterpoise wires are required, as shown in Figure 12-2.

12.2.2.7 Additionally, counterpoise wire should be installed at least 200mm below the top of the subgrade in paved areas or 250mm below finished grade in un-paved areas. This dimension may be less than 100mm where conduit is to be embedded in existing pavement. Counterpoise wire should not be
installed in conduit except for runway or taxiway crossings where the counterpoise may be installed within an existing duct. When installed in duct, the counterpoise should be insulated.

12.2.2.8 **Warning Tape.** Underground electrical warning (caution) tape should be installed in the trench and located 150mm above the direct buried cable or the counterpoise wire if present or approximately half way between the surface and upper level of direct buried cables or counterpoise wire if present and 200mm minimum below finished grade. The tape should be a 100 to 150mm wide polyethylene film detectable tape, with a metalized foil core. It should have a color and continuous legend as indicated on the plans.

12.2.2.9 **Heavy traffic areas.** Cables should not be direct buried under paved areas, roadways, railroad tracks, or ditches. In these areas the cable should be installed in concrete-encased ducts or in rigid steel conduit.

12.2.2.10 **Areas of rock.** When solid rock is encountered and cannot be avoided, the rock should be excavated, the cables put in tubing or duct, and backfilled with concrete. As shown in Figure 12-3, the tubing should be not less than 150mm below the surface and 75mm above the bottom of the excavation. The counterpoise is installed above the duct. A nylon pull rope may be included in the duct.

![Figure 12-3. Installation in Rock Area](image)

12.2.2.11 **Trench width.** Trench width for a single cable should be not less than 150mm. Where more than one cable is located in a trench, the trench width is adjusted so that the separations given below can be maintained.

12.2.3 **Lateral separation between cables**

(a) Series lighting cables of different series lighting circuits should have a lateral separation of 75mm. Series lighting cables of the same circuit may be placed without separation.
(b) Power cables of the same or different circuits of less than 600 volts, may be laid together in the same trench without horizontal separation.
(c) Power cables of different circuits with voltages between 600 and 5000 volts should be separated a minimum of 300mm.
(d) All power cables, 5000 volts and below, should be separated from all control, telephone, and coaxial type cables by a minimum of 300mm.
(e) Power cables, of more than 5000 volts, should be separated from all other cables by a minimum of 300mm.
(f) Control, telephone, and coaxial cables may be laid in the trench without horizontal separation from each other.

**Figure 12-4. Cable/counterpoise lateral spacing**

12.2.4 Vertical separation between cables

(a) No cable should directly overlap another cable because compacting may damage the cable.
(b) Vertical separation between cables should be similar to those given for horizontal separation except that cables which do not require horizontal separation should be separated vertically by a minimum of 60mm.

12.2.2.4 Crossovers. Although vertical separations are indicated above it is not suggested that there be a layering of direct buried cables within a trench. Such layer may render repair of lower cables difficult. For the most part, vertical separations are intended for instances where cables crossover another at an angle. It is preferable that such crossovers occur as close to 90 degrees as possible. The trench depth is increased as shown in Figure 12-4 to enable the vertical separation indicated in paragraph 12.2.4.

**Figure 12-5. Crossover of cables**

12.2.5 Counterpoise Interconnections. Where cables or conduits cross, the counterpoise conductors should be interconnected. Where a number of counterpoise wires are installed over cables, conduit or duct, they should be interconnected at intervals of not more than 150m. Figure 12-6 illustrates a means of interconnection which lessens the stress produced by the transient surge of a lightning strike.
12.2.6 Slack cable. Slack cable of approximately 1m length should be left on each end of cable runs, on each side of all connections, isolating transformers, light units, and at all points where cable connections are brought above ground. The slack loop should be installed at the same minimum depth as the cable run. Loops should have bends with an inner radius not less than twelve times the outside diameter of the cable. Where cable is brought above ground, additional slack should be left above ground. At all cable splices, provide slack loops free of bends at the splice or within 30cm of the ends of the splice. Where provisions must be made for testing or for future above grade connections, provide enough slack to allow the cable to be extended at least one foot vertically above the top of the access structure. This requirement also applies where primary cable passes through empty base cans, junction and access structures to allow for future connections, or as designated.

12.2.7 Final backfilling. After the cable has been installed, the trench should be backfilled as follows:

(a) Trenches should not contain pools of water during backfilling operations.
(b) Backfill separating cables should be firmly tamped in place. The cable separations given in 12.2.3 and 12.2.4 should be maintained. These separations may be either horizontal, vertical, or a combination of the two.
(c) The first layer of backfilling should be not less than 75mm deep, loose measurement, and should be either earth or sand containing no material aggregate particles larger than 8mm diameter. This layer should not be compacted, except for tamping to maintain separation of cables. The counterpoise wires are laid on top of this layer.
(d) The second layer should be not less than 120mm deep, of loose measurement, and should contain no particles larger than 25mm diameter. The warning tape may be laid on top of this layer.
(e) The second and subsequent layers should be thoroughly tamped and compacted to at least the density of the adjacent undisturbed soil. If necessary to obtain the desired compaction, the backfill material may be moistened or aerated as required.
(f) The third and subsequent layers of backfill should not exceed 200mm and may be of excavated or imported material and should not contain stones or aggregate larger than 100mm in diameter.
(g) The trench should be completely backfilled and tamped level with the adjacent surface, except that when turf is to be established over the trench, the backfilling should be stopped at an appropriate depth consistent with the type of turfing operation to be accommodated. A proper allowance for settlement should also be provided. Any excess excavated material should be removed and disposed of in accordance with the plans and specifications.
(h) Restoration. Where sod has been removed it should be replaced as soon as possible after the backfilling is completed. All areas disturbed by the trenching, storing of dirt, cable laying, pad
construction, and other work should be restored to its original condition. The restoration should include any necessary topsoiling, fertilizing, liming, seeding, sodding, sprigging, or mulching. If trenching cuts are made through paved areas, the cuts, after proper backfilling, should be resurfaced with paving similar to the original paving. Resurfaced cuts should be level with the original paving, free from cracks, and capable of withstanding traffic loads imposed without settling or cracking.

12.2.8 **Electromagnetic Interference (EMI).** Airfield lighting circuits can generate excessive EMI that can degrade the performance of some of the airport’s critical air navigational systems, such as RVR equipment, glide slopes, localizers, etc. Some CCRs are likely sources of EMI due to their inherent operating characteristics. The following cautionary steps may help decrease EMI and/or its adverse effects in the airport environment:

(a) Do not install cables for airfield lighting circuits in the same conduit, cable duct, or duct bank as control and communications cables.
(b) Do not install cables for airfield lighting systems so that they cross control and/or communications cables.
(c) In some cases, you can install harmonic filters at the regulator output to reduce EMI emitted by the regulator. These filters are available from some regulator manufacturers.
(d) Ground spare control and communication cables.
(e) Notify manufacturers, designers, engineers, etc. about existing navigational equipment and the potential for interference.
(f) Require electromagnetic compatibility between new equipment and existing equipment in project contracts. Operational acceptance tests may be required to verify compliance.

12.2.9 **Cable plowing.** Under certain conditions, it may be possible to install cables by cable plowing. This type of installation method should only be specified where sandy soils are prevalent and with no rocks or other debris that would nick or cut the cable insulation. The equipment is such that cables are placed at a minimum depth of 450mm below the finished grade. The cable should be manually unreeled off the spool as the machine travels, such that the earth is not unreeling the spool.

12.2.10 **Splicing**

12.2.10.1 Connections of the type shown on the plans should be made by experienced personnel regularly engaged in this type of work and should be made as follows:

(a) Cast Splices. These should be made by using crimp connectors for jointing conductors. Molds should be assembled, and the compound should be mixed and poured in accordance with manufacturer's instructions and to the satisfaction of the Engineer.
(b) Field-attached Plug-in Splices. These should be assembled in accordance with manufacturer's instructions. These splices should be made by plugging directly into mating connectors. In all cases the joint where the connectors come together should be wrapped with at least one layer of rubber or synthetic rubber tape and one layer of plastic tape, one-half lapped, extending at least 1-1/2 inches (37 mm) on each side of the joint.
(c) Factory-Molded Plug-in Splices. These should be made by plugging directly into mating connectors. In all cases, the joint where the connectors come together should be wrapped with at least one layer of rubber or synthetic rubber tape and one layer of plastic tape, one-half lapped, extending at least 37mm (1-1/2 inches) on each side of the joint.
(d) Taped or Heat-Shrink Splices. Application of taped splices is discussed in chapter 13, Cables and Connectors:

12.3 **Installation of ducts (conduit)**

12.3.1 Installation techniques and procedures
12.3.1.1 Selection of routes. Duct-line routes should be selected to balance maximum flexibility with minimum cost and to avoid foundations for future buildings and other structures. Where it may be necessary to run communication lines along with electric power distribution lines, two isolated systems in separate manhole compartments should be provided. Where possible, ducts should be installed in the same concrete envelope. Electric and communication ducts should be kept clear of all other underground utilities, especially high temperature water or steam pipes.

12.3.1.2 Duct materials. Acceptable standard materials for ducts include fiber, tile, and plastic. Plastic ducts and conduit should be made of polyethylene for reason that it is free of halogens and thus more environmentally suitable. Rigid steel conduit may also be installed below grade and should be provided with field or factory applied coatings where required.

12.3.1.3 Size of ducts. Size of conduits in a duct bank should be not less than 10cm inside diameter except that ducts for communication lines with a minimum diameter of 7.5cm are acceptable.

12.3.1.4 Installation of ducts without concrete encasement. Trenches for single-duct lines should be not less than 150mm nor more than 300mm wide, and the trench for two or more ducts installed at the same level should be proportionately wider. Trench bottoms for ducts without concrete encasement should be made to conform accurately to grade so as to provide uniform support for the duct along its entire length. A layer of fine earth material at least 75mm thick (loose measurement) should be placed in the bottom of the trench as bedding for the duct. The bedding material should consist of soft dirt, sand, or other fine fill, and it should contain no particles larger than 6mm diameter. The bedding material should be tamped until firm. When two or more ducts are installed in the same trench without concrete encasement, they should be spaced not less than 75mm apart (measured from outside wall to outside wall) in a horizontal direction or not less than 75mm apart in a vertical direction. Rigid steel and heavy-wall conduit may be direct earth buried. All other conduits should be encased.

Figure 12-7. Duct/conduit without concrete encasement
12.3.1.5 **Installation of ducts encased in concrete.** All ducts installed in concrete encasement should be placed on a layer of concrete not less than 75mm thick. Where two or more ducts are encased in concrete, they should be spaced not less than 75mm (measured from outside wall to outside wall). As the duct laying progresses, concrete not less than 75mm thick should be placed around the sides and top of the duct bank. Flared ends of ducts or couplings should be installed flush with the concrete encasement or inside walls of manholes or handholes. Interlock spacers should be used at not more than 1.5m spacing to ensure uniform spacing between ducts. Joints in adjacent ducts should be staggered a minimum of 600mm apart and should be made waterproof prior to concreting. No duct having a defective joint should be installed. Concrete-encased duct or rigid steel conduit should be installed so that the top of the concrete envelope or conduit is not less than 450 below the stabilized base course where it is installed under roadways, railroads, runways, taxiways, other paved areas, and ditches and not less than 450mm below the finished grade elsewhere.

![Concrete encased duct bank](image)

**Figure 12-8. Concrete encased duct bank**

12.3.1.6 **Ducts and flexible tubing.** When doing installation of cable in a duct system, the cables should be grouped as shown in Figure 12-7. Flexible duct [tubing] is placed in trench as shown in Figure 12-6.

12.3.1.7 **Grounding bushings.** Where rigid steel conduit enters or leaves a manhole or handhole a grounding bushing should be provided for all conduits.

12.3.1.8 **Arrangement of duct banks.** An arrangement of two ducts wide or high should be used for best heat dissipation. Correspondingly, the duct banks may be several ducts high or wide. (This may be impossible where a large number of ducts are involved.) The vertical two conduit-wide arrangement
enables the cables to be more easily racked on manhole walls but may not be as economical as the horizontal two conduit-high arrangement.

12.3.1.9 **Drainage.** All duct lines should be laid so as to slope toward handholes, manholes and duct ends for drainage. Grades should be at least 2.5mm per meter. Where it is not practicable to maintain the slope all one way, the duct lines may be sloped from the center in both directions toward manholes, handholes, or duct ends. Pockets or traps where moisture may accumulate should be avoided.

12.3.1.10 **Pull wire.** Each spare duct installed should be provided with a copper-clad steel pull wire of not less than 5mm² in area. Alternatively, a polypropylene pull rope which will not rot or support mold in the wet duct/base can/manholes may be used. The open ends of the spare ducts should be plugged with removable tapered plugs. The plug should secure the pull wire firmly.

12.3.1.11 **Spare capacity.** Sufficient ducts for planned installations, future expansion, plus a minimum of 25 percent of spare ducts, should be included for all new underground systems.

12.3.1.12 **Flexible tubing.** Use of flexible tubing should be limited to direct burial and short cable runs. Rigid conduit should be used for concrete encased duct banks for reason that it is difficult to avoid displacement of flexible tubing during the stage of concrete pouring or general backfilling. In addition, flexible tubing can be problematic for cable pulling for reason that the pull wire may cut into the relatively soft sides of the tubing. A suitable pulling compound should be used.

12.3.1.13 **Counterpoise installation above multiple conduits and duct banks**

Counterpoise wires should be installed above multiple conduits/duct banks for airfield lighting cables, with the intent being to provide a complete cone of protection over the airfield lighting cables. When multiple conduits and/or duct banks for airfield cable are installed in the same trench, the number and location of counterpoise wires above the conduits should be adequate to provide a complete zone of protection measured 45 degrees each side of vertical.

**Figure 12-9. Counterpoise above multiple ducts**

12.4 **Manholes and handholes**

12.4.1 **Factors bearing on the choice of manholes and handholes are number, direction, and location of duct runs; cable rack arrangements; method of drainage; adequacy of work space (especially if equipment is to be installed in the manhole); and the size of the opening required to install and remove equipment.**

12.4.2 **Location.** Manholes or handholes should be placed where required for connections or splices and where conflict with other utilities will be avoided. Manhole separation should not exceed 200m on straight runs and 100m on curved duct runs. Spacing should be decreased where necessary to prevent installation damage during pulling of cables. Strain should be limited during installation to a point that will not damage cable insulation or deform the cable. (see Table 12-1)
12.4.3 **Stubs.** It is good practice to provide a set of two or more spare stubs (short lengths of ducts leading out from the manhole) so that the manhole wall need not be disturbed when a future extension is made. The stubs should be plugged on both ends.

12.4.4 **Hardware.** Hardware applicable to the installation should be chosen. Where flared ends of ducts are provided, cable-duct shields are necessary only for protection of metallic-sheathed cables.

12.4.5 **Pulling Irons.** Pulling irons [also referred to as "draw irons"] are loops or formed bars inset in the walls of the manhole to serve as an anchor point for the pulling in of cable. The pulling irons should be of a strength to withstand twice the expected load that may be applied.

12.4.6 **Two-section manholes.** Two-section manholes should be used to maintain separation of the circuits where electric power and communication lines are installed in the same duct or use the same manhole.

![Manhole Diagram](image)

**Figure 12-10. Manhole**

### 12.5 Installation of Underground Cables

12.5.1 **Preparation of ducts**

12.5.1.1 After the duct installation is completed, the cables are installed by drawing or pulling into the ducts. The duct should be open, continuous, and clear of debris before the cable is installed. The cable should be installed in a manner to prevent harmful stretching of the conductor, injury to the insulation, or damage to the outer protective covering. The ends of all cables should be sealed with moisture-seal tape before installing, and they should be kept sealed until connections are made. Where more than one cable
is to be installed in a duct or conduit, all cable should be installed at the same time. In no case should a splice or connection be placed in a duct or conduit.

12.5.2 Cable pulling in ducts

12.5.2.1 Method of pulling. The cable to be installed in the duct be pulled by a power winch or by hand. An adequate amount of cable pulling compound should be used on all pulls. Petroleum grease should not be used. The surface of any cable sheath or jacket should not be damaged to a depth greater than 1/10th its original thickness. The cable should not be flattened out of round more than 1/10th its outside diameter. Maximum pulling tensions for commonly installed cables are listed in Table 12-1. The limitations in Table 12-1 are not intended to preclude the use of steel or wire rope as a means of pulling. However, unless a dynamometer is used to indicate the proper tension for the cable being pulled, a harness of the proper size rope that will limit tension of the pull to forces indicated in Table 12-1 should be used. Any combination of a group of cables to be pulled into a duct should not exceed the sum of individual allowable tension of each cable plus 15 percent.

Table 12-1: Maximum Allowable Non-armoured Cable Pull Using Dynamometer or Rope

<table>
<thead>
<tr>
<th>Cable</th>
<th>Tension (kg)</th>
<th>Rope diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 - 1c 8.4mm² Sol</td>
<td>125</td>
<td>4.8 C</td>
</tr>
<tr>
<td>3 - 1c 8.4mm² Sol</td>
<td>165</td>
<td>6.4 C</td>
</tr>
<tr>
<td>4 - 1c 8.4mm² Sol</td>
<td>250</td>
<td>4.8 M</td>
</tr>
<tr>
<td>2 - 1c 13.3 mm² Str</td>
<td>190</td>
<td>6.4 C</td>
</tr>
<tr>
<td>3 - 1c 13.3 mm² Str</td>
<td>285</td>
<td>8.0 C</td>
</tr>
<tr>
<td>4 - 1c 13.3 mm² Str</td>
<td>380</td>
<td>9.6 C</td>
</tr>
<tr>
<td>1 - 2c 8.4 mm² Str</td>
<td>140</td>
<td>6.4 C</td>
</tr>
<tr>
<td>1 - 3c 8.4 mm² Str</td>
<td>180</td>
<td>6.4 C</td>
</tr>
<tr>
<td>1 - 4c 8.4 mm² Str</td>
<td>265</td>
<td>6.4 M</td>
</tr>
<tr>
<td>1 - 2c 13.3 mm² Str</td>
<td>220</td>
<td>6.4 C</td>
</tr>
<tr>
<td>1 - 3c 13.3 mm² Str</td>
<td>310</td>
<td>8.0 C</td>
</tr>
<tr>
<td>1 - 4c 13.3 mm² Str</td>
<td>400</td>
<td>9.6 C</td>
</tr>
<tr>
<td>1 - 6c 3.3 mm² Str</td>
<td>140</td>
<td>6.4 C</td>
</tr>
<tr>
<td>1 - 12c 3.3 mm² Str</td>
<td>285</td>
<td>8.0 C</td>
</tr>
<tr>
<td>1 - 12PR 0.6mm²</td>
<td>105</td>
<td>4.8 C</td>
</tr>
<tr>
<td>1 - 25PR 0.6mm²</td>
<td>245</td>
<td>4.8 C</td>
</tr>
<tr>
<td>1 - 50PR 0.6mm²</td>
<td>480</td>
<td>11.5 C</td>
</tr>
<tr>
<td>1 - 100PR 0.6 mm²</td>
<td>120</td>
<td>12.0 M</td>
</tr>
<tr>
<td>c - Conductor</td>
<td>Sol - Solid</td>
<td>Str - Stranded</td>
</tr>
<tr>
<td>C - Cotton</td>
<td>M - Manila</td>
<td>D - Dacron</td>
</tr>
<tr>
<td>PR -Pair</td>
<td>N -Nylon</td>
<td></td>
</tr>
</tbody>
</table>

Maximum pulling tensions for cables not listed should be obtained from the manufacturer of the cable.

12.5.2.2 Length of pull. To minimize splicing, the longest practicable lengths of cable should be pulled into the ducts at one time. Unless otherwise required, manholes and handholes should be as far apart as practicable for the type of cable being installed, but under no condition should the distance between handholes or manholes exceed 200 metres.

12.5.2.3 Installation of Cables in Duct.

(a) The following are applicable to the installation of two or more cables in the same duct.

(i) Power cables of the same voltage may be installed in the same duct.
(ii) Power cables of less than 600 volts may be installed in the same duct.
(iii) Power cables of less than 600 volts should not be installed in the same duct with control, telephone, or coaxial type cables.
(iv) Power cables of more than 600 volts should not be installed in the same duct with control, telephone, coaxial or power cables of less than 600 volts.
(v) Control, telephone, and coaxial cables may be installed in the same duct.
(vi) Power, control, and telephone cables may be installed in the same duct system, subject to provisions of sub-paragraphs g) and h).
(vii) Cable installation in manholes or handholes. Power and control cables should be installed in separate manholes and handholes unless required otherwise. If space is available, cable slack sufficient for one splice for each cable should be left in each manhole.
(viii) Separation of cables in manholes and handholes. When it is not possible to install power and other type cables in separate manholes or hand-holes, they should be installed in separate compartments or on opposite sides of the manhole or handhole.

(b) Further,

(i) Cables of different class of voltages should not be installed in the same duct.
(ii) Cables of different areas, as for example that of runway side and taxiway side should also not be mixed in the same duct.
(iii) Interleaved circuits are generally installed in a same duct and may be necessitated for common routing in the deep base systems.

12.5.3 Installation of cables in manholes and handholes

12.5.3.1 Cable racks. Cables should be carefully formed around the interior of manholes or handholes avoiding sharp bends or kinks. All splices and cables should be tied to cable racks using 3.2mm diameter nylon line. Handhole and manhole racks should be the plastic type or provided with porcelain insulators. Splices or connectors should be a minimum of 0.6m from the mouth of the duct opening into the manhole or handhole. Where feasible, splices in different cables should be staggered.

12.5.3.2 Cable terminations. Termination of all control, telephone, and coaxial cables should be as required. Termination of all power cables rated above 5000 volts should be made with a stress relief device. Where potheads are used, strict conformance to manufacturer's recommendations should be followed. Where terminations are made at transformer bushings, exposed conducting surfaces on both high- and low-voltage sides should be taped for full voltage and painted with a high insulation water-resistant coating.

12.5.3.3 Cable grounding. The following conditions apply to the grounding of cables.

(a) All shielded power cables should have the shield grounded at each end. The grounding conductor should be connected to a ground rod by means of a grounding connector specifically designed for this purpose. The shields or armor on direct earth-buried power cables should be grounded on each end, but not at the splices.
(b) All shielded control cables should have the shield grounded at each end. The shield at each splice should have insulation resistance from ground equal to that of the original cable.
(c) Telephone cables should have the shields grounded at one end only. The shield at each splice should have insulation resistance from ground equal to that of the original cable.
(d) Coaxial cable shields should be insulated from ground throughout the length of the cable run. The shields should be grounded only at the coaxial connector terminating into the equipment on each end of the cable run.

12.5.4 Cable installation in saw cuts [secondary wiring]

12.5.4.1 Use of saw cuts.
(a) When new lights are installed in existing pavements, for example, runway centre line and
touchdown zone lights and taxiway centre line lights, cable installation in saw cuts or kerfs may
be required. Only secondary circuits of isolating transformers should be installed in saw cuts.
This technique should not be used in new pavement as it weakens the pavement.

(b) Saw cuts are used primarily for concrete pavements and are generally limited to repairs or
temporary works on asphalt pavements.

12.5.4.2 Cutting the pavement. Saw cuts are made with diamond blade saws. The saw cut or kerf should
be not less than 10mm wide and not less than 20mm deep. The width and depth should be increased if
several cables are to be installed in the same saw cut and at entrances to light fixtures, transformer
enclosures, and splice chambers. The depth of the kerf should be increased sufficiently to allow slack
wire under the pavement joint where a saw cut crosses a construction joint in the pavement. All saw cuts
should be in straight lines with vertical sides. The intersecting edges should be chamfered where saw cuts
intersect to reduce damage to the cable insulation. It may be desirable to collect the debris from saw
cutting and process it to recover the diamond grit.

12.5.4.3 Cleaning the saw cut. The saw cut should be sandblasted to remove all foreign and loose
material. Sand for blasting should be of the proper size and quality for this work and applied with proper
size nozzles and air pressure. Immediately prior to installing the cables or wires, the saw cut should be
flushed with a high-speed jet of water or steam and dried with a high speed jet of air. Keep this area clean
until completion of the work.

12.5.4.4 Installation of cables in saw cuts. Since these cables are for the secondary current of isolating
transformers, 600 volt insulation suitable for wet or damp locations should be used. Polyvinyl-chloride,
polyethylene, rubber, and ethylene-propylene-rubber are suitable types of insulation. A jacket over the
insulation is not required. The conductor should be stranded copper not less than 1.5mm² in cross-
sectional area. If the total length of the conductor will exceed 350m, the conductor size should be not less
than 6.0mm². Usually single-conductor wire is used, but two-conductor cable is acceptable. Do not
splice the cable in the saw cuts; use only full length runs of cable. The cables should be placed at the
bottom of the saw cuts and anchored with rubber or plastic wedges or with non-corrosive metal clips.
There is no need for separation of cables when more than one cable is placed in the same cut. The
wedges or clips should be spaced approximately 1m apart except that closer spacing may be desired at
pavement joints, saw cut intersections, and entrances to splice chambers or lights. Cables should be
encased in flexible tubing of polyethylene or other suitable material of not less than 0.3m in length at
joints in the pavements. The size of the tubing should be sufficient to allow movement of the cables. The
tubing should be centered on the joint and the ends of the tubing wrapped with tape to prevent the
entrance of sealing materials.
12.5.4.5 Alternatively, the secondary wires may be protected by inclusion of "backer rods" which are tubular flexible foam rods (ropes) that are cut to length and put into the saw kerf. The backer rod on top prevents the cables from being encapsulated by the liquid sealer and makes it easier to later remove the cables in case of a fault etc. The backer rod on the bottom provides a cushion for the cables to help protect against abrasion. Nylon rope could also be used.

12.5.4.6 Sealing the sawcut. The saw cut should be sealed with suitable adhesive compounds along the entire length after the cables are installed. The compounds are usually two-component liquid types suitable for the cable insulation and the type of concrete. Test samples of the sealant should have a minimum elongation of 45 percent. The adhesive components should not be older than recommended by the manufacturer and should not be stored where the temperature exceeds 30ºC or the manufacturer's recommendations. The manufacturer's instructions should be followed in mixing and installing. Usually if the adhesive components are pre-warmed to 25ºC before and during mixing, the compound may be satisfactorily installed and cured without the application of external heat if the ambient temperature is 7ºC or greater. The joints of pavement in the areas of saw cuts should be packed with roving material such as hemp, jute, cotton, flax or other suitable material to prevent the sealing material from flowing into the open joint. All surplus and spilled material should be removed.

12.5.4.7 Cable terminations. Cables should be properly terminated in fixtures, transformer enclosures, and splice chambers. The entrances to these termination units should be sealed. The termination ends of the cables should be suitably connected and the cable protected from moisture entering the cable between the conductor and the end of the insulation.
12.5.4.8 **Secondary cable installation in duct.** Alternatively, the secondary wiring may be installed in conduit. Care is necessary to select a duct type whose thermal expansion is compatible with that of the pavement.

12.5.5 **Cable marking**

12.5.5.1 **Colour coded tape.** All cables and cable routes should be marked for easy identification.

12.5.5.2 **Cable tagging.** Installed primary airfield lighting cables should have cable circuit identification markers attached on both sides of each connector and on each airport lighting cable entering or leaving cable access points, such as manholes, handholes, pullboxes, junction boxes, etc. Tags should be attached to the cable immediately after installation. Cable terminations and potheads should be tagged as to function, facility which it serves, and other pertinent data. Tags should be of suitable size and thickness, using letters not less than 6mm in size and of non-corrosive material. They should be securely attached to the cable using nylon cord. Marking of tags should consist of an abbreviation of the name of facility or facilities served by the cable, the letter indicating the type of service (power, telephone, control and radio frequency (coax)) provided by the cable. Where telephone type cable is used for control functions, it should be marked as a control cable, not a telephone cable. Where two or more identical cables are used to serve the same facility, they may be bundled under one tag.

12.5.5.3 **Markers should be of sufficient length for imprinting the cable circuit identification legend on one line.** The cable circuit identification should match the circuits noted on the construction plans.

12.5.6 **Light Station Identification Numbers.**

12.5.6.1 **Identification numbers should be assigned to each station (transformer housing installation) per the plans.** Place the numbers to identify the station by one of the following methods:

- (a) Stencil numbers of a 50mm minimum height using black paint on the pavement side of the transformer housing base plate.
- (b) Attach a non-corrosive metal disc of 50mm minimum diameter with numbers permanently stamped or cut out under the head of a transformer housing base plate bolt.
- (c) Stamp numbers of a 75mm minimum height on a visible portion of the concrete backfill surrounding the transformer light base.

![35](image)

**Figure 12-14  Identification Tag**

12.5.7 **Cable route markers**

12.5.7.1 **Direct earth-burial cable routes should be marked every 60m along the cable run, with an additional marker at each change of direction of the cable run, and at each cable splice with a concrete slab marker of suitable size and thickness.** These markers should be installed shortly after the final
backfill of the cable trench. The markers should be installed flat in the ground with the top approximately 25mm above the finished grade. After the concrete marker has set a minimum of 24 hours, the top surface should be painted bright orange (or alternate conspicuous colour) with paint suitable for uncured exterior concrete. Each cable marker should have the following information impressed upon its top surface:

(a) the word "CABLE" or "SPLICE". The letter designating the type of cable spliced should precede the word "SPLICE";
(b) the name of the facility served;
(c) the type of cable installed should be marked with "POWER", "CONTROL", "TELEPHONE", or "COAXIAL", or with suitable abbreviations for these terms. The designation of all type cables installed should be shown on the marker;
(d) arrows to indicate the direction or change of direction of the cable run;
(e) the letters should not be less than 100mm high, 70mm wide and 10mm deep;
(f) cables installed in duct or conduit should have cable markers installed every 60m and at every change in direction of cable, except markers should not be installed in concrete or asphalt surfaces; and
(g) manholes and handholes should be identified by purpose.

Figure 12-15. Cable Markers

12.6 Transformer Housings

12.6.1 Installation of transformer housings. Most cable connections to the isolating transformers are in special housings, in the bases for lighting fixtures that are below the surface at the edge of paved runways or taxiways, or in the pavement. Preferably, these housings are installed at the designated locations in a poured concrete foundation which encases the enclosure container by not less than 10 to 15cm of concrete around the bottom and sides. Metal conduits connected to entrances of the container for admitting the cables of the circuit should extend through the concrete walls. These conduits should be provided with clamps for connecting the ground wires or counterpoises. The top of the container must be level and at the proper depth below the top surface of the concrete for mounting the light fixture or cover plate. A holding device or jig should be used to maintain level, alignment, and proper depth of the top of the enclosure container during installation and curing of the concrete. The ends of cables are pulled into the enclosure container and the end of the conduit outside the concrete foundation is sealed around the cable with a suitable compound to keep the enclosure free of water. The elevated lights, semi-flush lights, or blank covers mounted on these containers should include a gasket or other means of sealing to prevent water from entering the container.
12.6.2 **Installation in existing pavement.** If lights are to be installed in existing pavements, installing the transformer housing in a concrete foundation may not be practical. Usually the transformer housing is located at the edge of the pavement and the secondary cables to the light are installed in saw cuts. A transformer housing, junction box, or the light fixture may be installed at the location for the light for making the connections to the light by boring a hole of the proper size and depth in the pavement. The light fixture may be mounted on a housing or be of a type suitable for installing directly in the hole. Holes of proper diameter for the fixtures or housings should be bored in the pavement with diamond-edged bits. The bottom of the hole for junction boxes and light fixtures should be flat or slightly concave except that an area 2.5 cm wide around the perimeter should be flat. If the holes are drilled too deep, they should be filled with sealant compound to the desired depth and the compound permitted to cure before proceeding with the installation.

12.6.3 **Installing the enclosure.** The sides and bottom of the transformer housing, junction box, or fixture should be sandblasted immediately prior to installation. Also sandblast the inside faces of the bored hole. The bottom and sides of the enclosure or fixture and the faces and bottom of the bored hole should be covered with a coating of a suitable sealant with a minimum amount that will completely fill the space between the concrete and the fixture or enclosure. The sealant compound is usually a two-part paste compound which is mixed and installed in accordance with the manufacturer's instructions. A holding device or jig should be used for installing each light or enclosure to assure its proper elevation and alignment. The holding device should be left in place until the sealant has set. The cables should be pulled in and brought into position for connecting or splicing as required and the entrance should be sealed. All surplus sealant or embedding compound should be removed.

12.6.4 **Direct burial of isolating transformers.** Direct-burial AGL transformers should usually be installed at the same depth as the cables connected to the transformers. Transformers and cables should be arranged so that there will be no bends or stresses on the connectors, and the cables and leads should be provided with slack to accommodate earth settling and frost heaves. Use proper connectors and tape the outside joint with 2 or 3 turns of electrical tape. Do not make splices for connecting the cables to the transformers.
12.6.5 Installing AGL transformers. When isolating transformers are installed in transformer enclosures, the transformers should be positioned with a flat side on the bottoms of the enclosures, if possible. Connect the cables to the leads of the transformers using suitable connectors, not splices, and tape the joints. Connectors should lie flat on the bottoms of the enclosures without bending or tension if possible. Ground connections on isolating transformers should be connected to the ground wire if such connections are provided. If the internal temperatures in the enclosures will be more than 120°C, a section of foil between the light fixtures and the transformers will reduce the effects of the heat on the transformer. It is the practice of some states to place the AGL transformer on a brick or to hang the transformer on the wall of the housing so as to keep it elevated from water that may accumulate in the bottom of the housing.

12.7 Shallow Light Base Installation

For existing pavements, a shallow base or receptacle is used for installation of the inpavement light fixture, as shown in Figure 12-18. The base is placed into a cored hole in the pavement and held in position by means of a special jig to ensure proper azimuth, elevation and level. The secondary wiring to the optical assembly is brought to the fixture through means of conduit installed in a sawcut. Alternatively the secondary wiring may be placed directly in a sawcut as shown above in Figure 12-13. A grounding wire may also be brought to the light base. It is recommended that this grounding be extended to the optical assembly by means of a jumper so as to enable equal potential should this assembly be lifted clear of the base during maintenance. A liquid sealer is used to fill the remaining space between the base and sides of the cored hole.
12.8 Bonding of counterpoise wire

12.8.1 Bonding of counterpoise wire should be by the exothermic welding process. Only personnel experienced in and regularly engaged in this type of work should make these connections. The installations should comply with the manufacturer's recommendations and the following:

(a) All slag should be removed from welds.
(b) For welds at light fixture base cans, all galvanized coated surface areas and "melt" areas, both inside and outside of base cans, damaged by exothermic bond process should be restored by coating with a liquid cold-galvanizing compound. Surfaces to be coated should be prepared and compound applied in accordance with manufacturer's recommendations.
(c) All buried copper and weld material at weld connections should be thoroughly coated with coal tar bitumastic material or equivalent means to prevent surface exposure to corrosive soil or moisture."