FAA-C-1391a
December 4, 1973
SUPERSEDING
FAA 1391, 11/30/62

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION SPECIFICATION

INSTALLATION AND SPLICING OF UNDERGROUND CABLES

1. SCOPE

1.1 Scope.- This specification covers minimum requirements for installation of electrical cables buried directly in the earth or installed in underground duct or conduit. It includes trenching, installation and splicing or other joining of cables, and testing of cables for acceptability.

2. APPLICABLE DOCUMENTS

2.1 Applicable documents.- The following publications, of the issues in effect on the date of the invitation for bids or request for proposals, form a part of this specification and are applicable to the extent specified herein.

2.1.1 Federal specification

WW-C-581 Galvanized Steel Conduit

2.1.2 Military specifications

MIL-I-3825 Insulating Tape, Self Fusing

MIL-C-38359 Cable, Power, Electrical, Airport Lighting

2.1.3 FAA specifications

Specification for L-823 Plug and Receptacles, Cable Connectors

Specification for L-824 Underground Electrical Cables for Airport Lighting Circuits

2.1.4 National Electrical Manufacturers Association (NEMA) publications

Publication TC 6, Plastic Utilities Duct for Underground Installation

2.1.5 Underwriters' Laboratories, Inc.

Publication UL 651, Rigid Non-metallic Conduit

(Copies of this specification may be obtained from the Contracting Officer in the Federal Aviation Administration Office issuing the invitation for bids or request for proposals. Requests should fully identify material desired, i.e., specification, standard, amendment, and drawing numbers and dates. Requests should cite the invitation for bids, request for proposals, or the contract involved or other use to be made of the requested material.)

(Information on obtaining copies of Federal specifications may be obtained from General Services Administration offices in Washington, D.C.; Seattle; San Francisco; Denver; Kansas City, Mo.; Chicago; Atlanta; New York; Boston; Dallas; and Los Angeles.)

(Single copies of Military specifications may be requested by mail or telephone from U. S. Naval Supply Depot, 5801 Tabor Avenue, Philadelphia, Pa. 19120 (for telephone requests call 215 697-3321, 8 a.m. to 4:30 p.m., Monday through Friday). Not more than five items may be ordered on a single request, and the invitation for bid or contract number should be cited where applicable.)

(Information on obtaining copies of NEMA Standards may be obtained from National Electrical Manufacturers Association, 155 East 44th Street, New York, New York 10017.)

(Copies of UL publications may be obtained from Underwriters' Laboratories, Inc., Publications Department, 207 E. Ohio Street, Chicago, Illinois 60611.)

3. REQUIREMENTS

3.1 Materials and workmanship.- The requirements of this specification shall be considered as minimum requirements and shall not relieve the contractor from furnishing and installing higher grades of material and workmanship than specified herein when so required by the contract drawings and specifications.

3.1.1 Government furnished cable.- Government furnished cable will be delivered to the contractor in accordance with the provisions of the contract. The contractor will be required to test the cable in accordance with paragraph 4.1 of this specification and report electrically or physically defective cable within two weeks after receipt. If inadequate lengths of cable are accessible for testing on the reel, a visual inspection shall be made and any damage reported. The required tests shall then be made immediately after unreeling. Hidden defects discovered when the cable is being installed shall be reported to the resident engineer in accordance with the contract provisions.

3.1.2 Contractor furnished cable.- Multi-conductor power, control and telephone type cables furnished by the contractor shall, as a minimum, meet the following specifics:

(a) Copper conductors.

(b) Thermoplastic or thermosetting insulation.

(c) Neoprene, polyethylene or vinyl jacket.

(d) Shielding of multi-conductor power cables rated 5 KV shall be an over-the-core aluminum shield, unless armored where shielding is not required, or shielding as required by IPCEA.

(e) The standard product of major cable manufacturers such as Okonite, Anaconda, Brand-Rex, etc.

(f) The specific type required for the job.

Airport series lighting type single conductor cable shall be manufactured in accordance with either FAA Specification L-824, Class C, 5 KV or MIL-C-38359, Class II.

Telephone cable manufactured under Rural Electrification Administration Specification PE-22 for duct installation, or PE-23 or PE-39 for direct earth burial, is acceptable.

Single conductor cables, except series lighting type, shall comply with a, b, e, and f above.

Coaxial cables and connectors shall comply with the appropriate Military specification.

3.1.3 Workmanship.- All work shall be done by experienced personnel regularly engaged in this type of work. All cable splices shall be performed only by experienced and qualified cable splicers. Before any cable splices are made, the resident engineer may request a sample splice be made for his approval. When required by the local government, the workman shall be properly licensed.

3.2 Trenching

3.2.1 Precautions.- The contractor shall take all reasonable precautions to protect existing underground utilities such as fuel tanks, water lines, and buried control and power cables, etc. All known utilities and power and control cables leading to and from any operating facility will be marked in the field by the resident engineer for the information of the contractor before any work in the general vicinity is started. Thereafter and through the entire time of construction they shall be protected from any possible damage. The contractor shall immediately repair, with equal material by skilled workmen, any underground cables which are damaged by his workmen, equipment or work. Prior approval of the resident engineer must be obtained for the materials, workmen, time of day or night, method or repairs, and for any temporary or permanent repairs the contractor proposes to make.

3.2.2 Excavations.- Where turf is well established and the sod can be removed, it shall be carefully stripped and properly stored. The contractor shall excavate all trenches for direct earth burial cable as follows:

(a) At the depth specified in paragraph 3.2.2.1 below.

(b) To a width of not less than six inches for single or multiple runs of power or telephone, control and coaxial cables.

(c) To a width and depth which will provide a minimum of six inches of horizontal or vertical separation of power cables from other power cables of different voltage ratings, or from any power cable and telephone, control and coaxial types. Backfill shall be firmly tamped in the separation area. Note: Telephone, control and coaxial cables may be installed without separation from each other.

Unless specified otherwise in the plans, all cables in the same location and running in the same general direction shall be installed in the same trench. Trenches for cables may be excavated manually or with mechanical trenching equipment. Walls of trenches shall be essentially vertical so that a minimum of shoulder surface is disturbed. The bottom surface of trenches shall be essentially smooth and free from coarse aggregate. Unless otherwise specified, trenches shall be opened only to the extent that cables can be installed and the trench closed in the same working day.

Where rock excavation is encountered the rock shall be removed to a depth of at least three inches below the required cable depth and it shall be replaced with bedding material of earth or sand containing no mineral aggregate particles that would be retained on a 1/4-inch sieve. When solid rock is encountered the resident engineer shall be consulted as to alternatives such as rerouting the trench, transition to overhead lines, or installation in rigid steel conduit.

3.2.2.1 Cable location and depth requirements.- Unless otherwise specified, all cables, ducts and conduits shall be installed as follows:

(a) Direct earth burial cables shall be a minimum of 24 inches below the finished grade when on airport or government controlled property and 36 inches below the finished grade when off airport or government controlled property. Cables shall not be direct buried under paved areas, roadways, railroad tracks or ditches.

(b) Direct earth burial ducts shall be installed so that the top of all ducts are at least 18 inches below the finished grade. Direct earth burial ducts, except rigid steel conduit, will not be allowed under paved areas, roadways, railroad tracks or ditches.

(c) Concrete encased duct or rigid steel conduit shall be installed so that the top of the concrete envelope or conduit is not less than 18 inches below the bottom of the paving where installed under runways, taxiways and other paved areas and not less than 18 inches below the finished grade when installed in unpaved areas.

(d) When the cable routing is under railroad tracks, the cable shall be in rigid steel conduit or concrete encased duct with the top of the duct at a minimum depth of 42 inches below the base of the rail.

3.2.3 Backfilling.- After the cable has been installed the trench shall be backfilled. The first layer of backfill shall be three inches deep, loose measurement, and shall be either earth or sand containing no material aggregate particles that would be retained on a 1/4-inch sieve. This layer shall not be compacted, except as noted in paragraph 3.4.1.1. The second layer shall be five inches deep, loose measurement, and shall contain no particles that would be retained on a 1-inch sieve. The remainder of the backfill shall be excavated or imported material and shall not contain stone or aggregate larger than four inches maximum diameter. The third and subsequent layers of the backfill shall not exceed eight inches in maximum depth, loose measurement.

The second and subsequent layers shall be thoroughly tamped and compacted to at least the density of the adjacent undisturbed soil and to the satisfaction of the resident engineer. If necessary to obtain the desired compaction, the backfill material shall be moistened or aerated as required.

Trenches shall not be excessively wet and shall not contain pools of water during backfilling operations. The trench shall be completely backfilled and tamped level with the adjacent surface. When sod is to be placed over the trench the backfilling shall be stopped at a depth equal to the thickness of the sod to be used. Any excess excavated material shall be removed and disposed of in accordance with instructions issued by the resident engineer.

3.2.4 Restoration.- Where sod has been removed it shall 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 shall be restored to its original condition. The restoration shall include any necessary topsoiling, fertilizing, liming, seeding, sodding, sprigging or mulching.

Where trenching cuts through paved areas the surface, after properly backfilling, shall be resurfaced with paving similar to the original paving. Resurfaced trench shall be level with original paving, free from cracks and capable of withstanding traffic loads imposed without settling or cracking. The contractor shall be held responsible for maintaining all restored, disturbed surfaces until final acceptance.

3.3 Installation of underground conduits

3.3.1 General.- All underground conduits shall be:

(a) Rigid steel conduit conforming to Federal Specification WW-C-581, or

(b) Rigid non-metallic conduit (duct) conforming to UL 651 and/or NEMA T-C-6. Heavy wall conduit may be direct earth buried. All other conduits, except rigid steel, shall be concrete encased.

Ducts shall be of the size, material, and type indicated in the plans or specifications. Standard precast spacers shall be used for duct support and alignment. Where no size is indicated in the plans or specifications, the ducts shall not be less than four inches inside diameter. All duct lines shall be laid so as to slope toward handholes, manholes and duct ends for drainage. Grades shall be at least three inches per 100 feet. On runs where it is not practicable to maintain the slope all one way, the duct lines shall be sloped from the center in both directions toward manholes, handholes or duct ends. Pockets or traps where moisture may accumulate shall be avoided.

Where rigid steel conduit enters or leaves a manhole or handhole a grounding bushing shall be provided for all power cable and spare conduits.

The contractor shall mandrel each duct installed by him, or when he installs or replaces cable in an existing duct. An iron-shod mandrel, not more than 1/4-inch smaller than the bore of the duct, shall be pushed through each duct by means of jointed conduit rods. The mandrel shall have a leather or rubber gasket slightly larger than the duct hole.

All spare ducts installed by the contractor shall be provided with a No. 10 copper-clad steel pull wire. The open ends of the spare ducts shall be plugged with removable tapered plugs, of a type recommended by the duct manufacturers. The plug shall be adapted to firmly secure the pull wire.

All ducts shall be securely fastened in place during construction and progress of the work and shall be plugged to prevent seepage of grout, water, or dirt. Any duct section having a defective joint shall not be installed. Trenching for ducts shall be in accordance with Section 3.2 of this specification.

3.3.2 Ducts encased in concrete.- All ducts for concrete encasements shall be placed on a layer of concrete not less than three inches thick prior to its initial set. Where two or more ducts are encased in concrete the contractor shall space them not less than 1-1/2 inches apart (measured from outside wall to outside wall) using spacers applicable to the type of duct. As the duct laying progresses concrete not less than three inches thick shall be placed around the sides and top of the duct bank. End bells or couplings shall be installed flush with the concrete encasement where required.

Interlock spacers shall be used every five feet minimum to insure a uniform spacing between ducts. All bottom spacers shall be secured to one inch by three-inch boards to prevent sinking and overturning. All joints in adjacent ducts shall be staggered a minimum of 24 inches apart and shall be made completely waterproof prior to concreting.

3.3.3 Ducts without concrete encasement.- Trenches for single-duct lines shall be not less than six inches nor more than 12 inches wide, and the trench for 2 or more ducts installed at the same level shall be proportionately wider. Trench bottoms for ducts without concrete encasement shall 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 four inches thick (loose measurement) shall be placed in the bottom of the trench as bedding for the duct. The bedding material shall consist of soft dirt, sand or other fine fill, and it shall contain no particles that would be retained on a 1/4-inch sieve. The bedding material shall be tamped until firm.

When two or more ducts are installed in the same trench without concrete encasement, they shall be spaced not less than two inches apart (measured from outside wall to outside wall) in a horizontal direction or not less than six inches apart in a vertical direction.

3.4 Installation of cables.- Wherever possible, cable shall be run in one piece, without splices, from connection to connection. The number of splices shall be kept to a minimum. If the job plans do not include a schedule for laying each reel of cable the contractor shall provide such a plan for the approval of the resident engineer prior to installing any of the cable. The plan shall be predicated to the use of longest practicable lengths of cable in order to minimize splicing requirements.

When cable cutting is required cable ends shall be effectively sealed against moisture immediately after cutting. The method of sealing shall be approved by the resident engineer. Bends of a radius less than eight times the diameter for rubber or plastic covered cable and twelve times

the diameter for metallic armored cable shall not be made. Cable that has been kinked shall not be installed.

When unreeling, a man shall be stationed at the reel to observe and report any irregularities in the cable. Unless otherwise specifically stated in the plans nonarmored type cable will be used in duct and armored type will be used for direct earth burial. Nonarmored coaxial and series lighting cable may be direct earth buried when not otherwise specified. Grounding conductors, where required in the job plans, shall be bare copper wire, minimum size AWG No. 6.

3.4.1 Direct earth burial.- Cable for direct earth burial shall be unreeled in place in the open trench or unreeled near the trench and carefully placed in the trench bottom. Pulling the cable into the trench by dragging over the ground will not be permitted.

3.4.1.1 Separation between direct earth burial cables

(a) Power cables, of the same circuit, may be laid together in the trench without separation, except as noted below. Series lighting cables may be considered of the same circuit.

(b) Power cables, of the same or different circuits of less than 600 volts, may be laid together in the same trench without separation.

(c) All power cables, 5,000 volts and below, shall be separated from all control, telephone and coaxial type cables by a minimum of 6 inches.

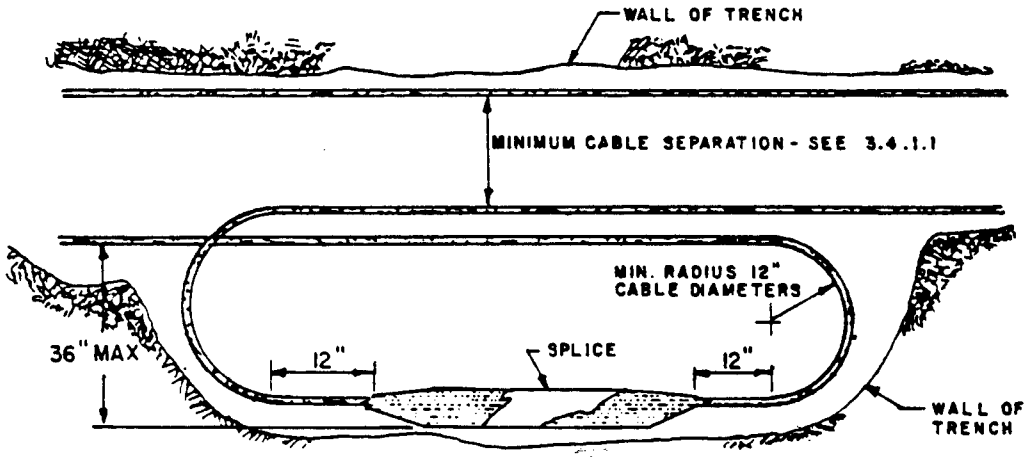
(d) Power cable, of more than 5,000 volts, shall be separated from all other cables by a minimum of 12 inches.

(e) Control, telephone and coaxial cables may be laid in the trench without separation from each other.

Backfill separating cables shall be firmly tamped in place. All the above cable separations shall be measured either horizontally or vertically after tamping.

3.4.1.2 Cable slack loops, direct earth burial.- A cable slack loop of three feet plus or minus six inches shall be left on each end of cable runs, and at all points where cable connections are brought above ground. The slack loop shall be installed at the same minimum depth as the cable run. Loops shall have no bends with an inner radius less than twelve times the outside diameter of the cable. Where cable is brought above ground additional slack left above ground shall be as shown by the drawings or as directed by the resident engineer.

Cable loops shall not be installed on coaxial type cable. At all other cable splices a slack loop shall be installed as shown in Figure 1. Joints in coaxial cables shall be made in accordance with the contract project specification.'



CABLE LOOP @ SPLICES
(PLAN VIEW)

FIGURE 1

3.4.2 Cable installation in duct or conduit.- The contractor shall make sure that the duct or conduit is open, continuous, and clear of debris before installing cable. The cable shall 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 shall be sealed with moisture-seal tape before pulling, and it shall be left sealed until connections are made. Where more than one cable is to be installed in one duct or conduit all cable shall be pulled at the same time. In no case shall a splice be pulled into a duct or conduit.

3.4.2.1 Cable pulling.- The apparatus used for pulling cable at the entrance to the manhole shall be a pulling tube or consist of a framework and two sheaves, with the diameter of the sheaves being at least ten times that of the diameter of the largest cable. The cable to be installed in the duct may be pulled by a power winch or by hand. An adequate amount of cable pulling compound shall be used on all pulls. The type of pulling compound shall be approved by the resident engineer. Petroleum grease shall not be used. The surface of any cable sheath or jacket shall not be damaged to a depth greater than 1/10th the original thickness or be flattened out of round more than 1/10th the outside diameter.

Maximum pulling tensions for commonly installed cables are listed in Table 1.

TABLE NO. I

MAXIMUM ALLOWABLE NON-ARMORED CABLE PULL USING DYNAMOMETER OR ROPE

CABLE	LBS TENSION	ROPE DIAMETER			
2 - 1c #8 Sol	275 Lbs	3/16" C			
3 - 1c #8 Sol	367	1/4" C	3/16" M		
4 - 1c #8 Sol	550		1/4" M		
2 - 1c #6 Str	420	1/4" C	3/16" M		
3 - 1c #6 Str	630	5/16" C	1/4" M		
4 - 1c #6 Str	840	3/8" C		3/16"D	
1 - 2C #8 Str	305	1/4" C			
1 - 3c #8 Str	395	1/4" C			
1 - 4c #8 Str	585		1/4" M		
1 - 2c #6 Str	455	1/4" C	3/16" M		
1 - 3c #6 Str	685	5/16" C			
1 - 4c #6 Str	880	3/8" C	5/16" M	3/16" D	
1 - 6c #12 Str	315	1/4" C			
1 - 12c #12 Str	630	5/16" C	1/4" M		
1 - 12PR #19	230	3/16" C			
1 - 25PR #19	541		1/4" M		
1 - 50PR #19	1061	7/16" C			3/16" N
1 - 100PR #19	2000		15/32" M	5/16" D	
RG - 11/U	85	3/16" C			
RG - 213/U	125	3/16" C		Formerly RG - 8/U	
RG - 214/U	145	3/16" C		Formerly RG - 9/U	
RG - 216/U	135	3/16" C		Formerly RG -13/U	
RG - 217/U	250		1/4" M	Formerly RG -14/U	
RG - 218/U	800	7/16" C		Formerly RG -17/U	

C-Cotton M-Manila D-Dacron N-Nylon

Maximum pulling tensions for cables not listed in Table I shall be obtained from the manufacturer of the cable.

The limitations in Table No. I are not intended to preclude the use of steel or wire rope as a means of pulling. However, unless a dynamometer graduated to actually indicate the proper tension for the cable being pulled is used, the contractor shall adapt a harness of the proper size rope that will limit the tension of the pull to pounds indicated in Table I.

Any combination of a group of cables to be pulled into a duct shall not exceed the sum of individual allowable tension of each cable plus 15 percent.

To minimize splicing, the longest practicable lengths of cable shall be pulled into the ducts at one time. Unless otherwise specified, 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 600 feet. If possible, the maximum cable length to be pulled shall be obtained from the cable manufacturer. An estimate of the absolute maximum length of pull in a straight duct may be calculated from the following equation:

$$L = \frac{T}{KW} \qquad \text{where}$$

L = length of cable pull in feet

T = total tension in pounds

W = weight of all cables being pulled in pounds per foot

K = Coefficient of Friction
(0.3 for single cables)
(0.4 for multiple cables)

This formula is based on new, level, straight plastic duct and the use of adequate cable pulling compound.

3.4.2.2 Separation of cables installed in conduit or duct.

(a) Power cables of the same voltage may be installed in the same duct.

(b) Power cables of less than 600 volts may be installed in the same duct.

(c) Power cables of less than 600 volts shall not be installed in the same duct with control, telephone or coaxial type cables.

(d) Power cables of more than 600 volts shall not be installed in the same duct with control, telephone, coaxial, or power cables of less than 600 volts.

(e) Control, telephone and coaxial cables may be installed in the same duct.

(f) Power, control and telephone cables may be installed in the same duct system, subject to provisions of paragraph 3.4.3.

3.4.3 Cable installation in manholes or handholes.- Power and control cables shall be installed in separate manholes and handholes unless otherwise specified on the job plans. If space is available cable slack sufficient for one splice for each cable shall be left in each manhole.

3.4.3.1 Separation of cables in manholes and handholes.- When it is not possible to install power and other type cables in separate manholes or handholes, they shall be installed on opposite sides. In addition, the entire exposed length of all control, telephone, and coaxial cables shall be fireproofed by applying a 1/4 inch minimum thickness of arc-proofing 3M No. 7700 or equal, in accordance with the manufacturer's instructions.

3.4.3.2 Cable racking.- Cables shall be carefully formed around the interior of manholes or handholes avoiding sharp bends or kinks. All splices and cables shall be tied to cable racks using 1/8-inch nylon line. Handhole and manhole racks shall be the plastic type or provided with porcelain insulators. Splices shall be a minimum of two feet from the mouth of the duct opening into the manhole or handhole. Where feasible, splices in different cables are to be staggered.

3.4.4 Cable terminations.- Termination of all control, telephone, and coaxial cables shall be as specified. Termination of all power cables rated above 5000 volts shall be made with a stress relief device. Where potheads are used strict conformance to manufacturer's recommendations shall be followed. Where terminations are made at transformer bushings exposed conducting surfaces on both high and low voltage sides shall be taped for full voltage and coated with Glyptal red enamel or equal.

3.4.5 Cable grounding

(a) All shielded power cables shall have the shield grounded at each end. The grounding conductor shall be connected to a ground rod by means of a U.L. approved grounding connector specifically designed for this purpose. The shields or armor on direct earth buried power cables shall be grounded on each end, but not at each splice.

(b) All shielded control cables shall have the shield grounded at each end. The shield shall be insulated from ground equal to that of the original cable at each splice.

(c) Telephone cables shall have the shields grounded at one end only and the shield shall be insulated from ground equal to that of the original cable at each splice.

(d) Coaxial cable shields shall be insulated from ground throughout the length of the cable run. The shields will only be grounded at the coaxial connector terminating into the equipment on each end of the cable run.

3.4.6 Pressurized type coaxial cables.- Special precautions must be observed during the installation of Heliax and Styroflex type coaxial cables. These cables will be furnished and installed in one piece under nitrogen gas pressure with cable and seals kept securely in place at all times during cable handling, shipping and installation. The installation contractor shall not cut or splice this cable at any time.

Styroflex coaxial cable of 1-7/8 inch diameter shall not be subjected to a bending radius of less than 42 inches during installation or less than a 25 inch radius when secured in place. The maximum allowable pulling tension for this size of cable is 1,850 pounds. Heliax coaxial cable shall not be subjected to a bending radius of less than 30 inches during installation nor less than a 20 inch radius when secured in place. The maximum allowable pulling tensionsfor this size of cable is 750 pounds.

As the cable is unwound from the reel a supplementary straightening device such as shown in Figure 2 is recommended and may be rigged on the let-off side of the reel. Utmost care should be exercised at all times to prevent kinking any part of the cable during installation.

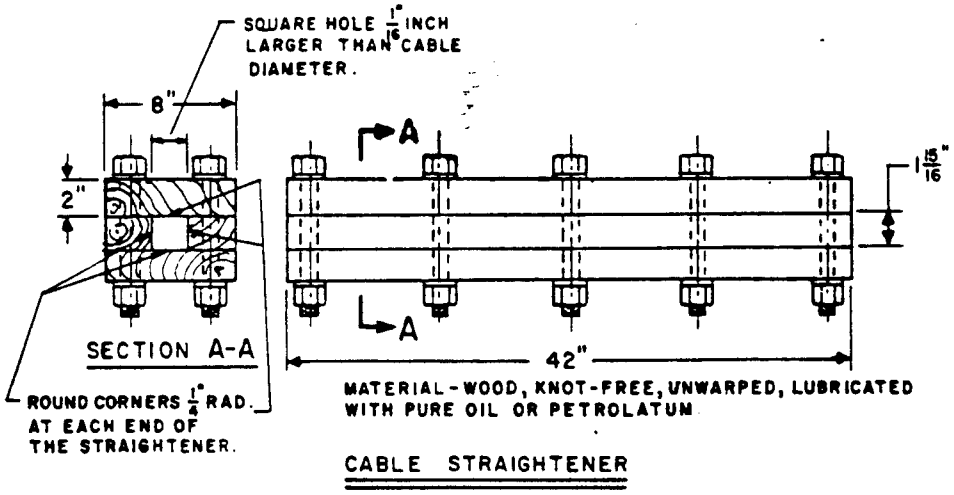


FIGURE 2

In order to determine that the cable has not been damaged or punctured prior to installation and before attempting to install the cable, the contractor shall determine if the nitrogen gas shipping pressure is

still retained in the cable. If this gas pressure reading varies more than minus one pound and the loss is not due to temperature change, a nitrogen gas test shall be conducted. See paragraph 4.6.4.

Slack coil cable loop will not be permitted in the installation. The cable end shall be fed through the opening provided at the building from the reel located outside the building. The cable between the structure entrance and the respective cable end shall continue into the building on relatively the same horizontal plane. No bends shall be less than the minimum prescribed herein. The installation contractor shall provide a temporary support for the cable end so that the cable will not "droop" or "hang," pending final connection to the electronic apparatus.

3.5 Cable marking

3.5.1 Cable tagging.- All cables shall be tagged in each manhole or handhole with not less than two tags per cable, one near each duct entrance hole. Tags shall be attached to cable immediately after installation. Cable terminations and potheads shall be tagged as to function, i.e., facility which it serves or other pertinent data. Tags shall be circular in shape, two inch minimum in diameter and of not less than .020 inch thick copper or .0625 inch minimum thickness of lead. Steel lettering dies, one-fourth inch minimum size or the equivalent engraving process, shall be used to mark the tag. It shall be securely attached to the cable using 1/8 inch nylon cord. Marking of tags shall consist of an abbreviation of the name of facility or facilities served by the cable plus the letter "P", "T", "C", or "R" (Power, Telephone, Control and Radio Frequency, (coax) respectively), whichever is applicable. Where telephone type cable is used for control functions it shall be marked "T" instead of "C." Where more than one identical cable is used to serve the same facility, they may be bundled under one tag unless job plans state otherwise. The following illustration will serve as a guide for tagging:

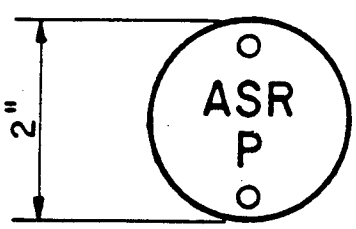


FIGURE 3

3.5.2 Cable markers.- Direct earth burial cables shall be marked every 200 feet along a cable run, at each change of direction of the cable and at each cable splice with a two feet square and six inch thick concrete slab marker. These markers shall be installed within 24 hours of the final backfill of the cable trench. The markers shall be installed flat in the ground with the top approximately one inch above the finished grade.

After the concrete marker has set a minimum of 24 hours, the top surface shall be painted bright orange with paint manufactured specifically for uncured exterior concrete.

Each cable marker shall have the following information impressed upon its top surface:

(a) The word "CABLE" or "SPLICE." The letter designating the type of cable spliced shall precede the word "SPLICE."

(b) The name of the facility served, such as "ASR", "VORTAC","ALS", etc.

(c) The type of cable installed shall be marked with the following abbreviations "P" for Power, "C" for Control, "T" for Telephone, and "R" for Coaxial (Radio Frequency). The designation of all type cables installed shall be shown on the marker.

(d) An arrow to indicate the direction or change of direction of the cable run.

(e) Any additional information, as directed by the resident engineer.

The contractor shall obtain approval from the resident engineer of the information to be impressed on the cable marker and for the method of impression. The letters shall be four inches high, three inches wide and one-half inch deep. A typical example is shown in Figure 4.

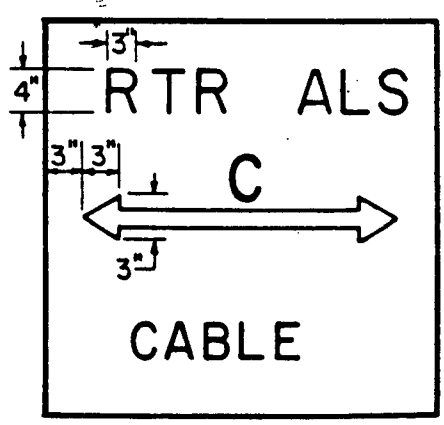


FIGURE 4

Cables installed in duct or conduit shall have cable markers installed every 200 feet and at every change in direction of the cable, except markers shall not be installed in concrete or asphalt surfaces.

anholes and handholes shall be identified by "FAA-Power" or "FAA-Control" markings cast in the steel manhole or handhole cover, or so identified with a die stamped, nominal 1/16 inch minimum thickness copper plate, brazed or fastened to the cover with a minimum of two 10-32 brass screws.

3.6 Cable splicing.- All cable splices shall be performed by experienced and qualified cable splicers in accordance with the trade's highest standards of workmanship. All splicing methods and materiel shall be of a type recommended by the manufacturer of the splicing material for the particular type of cable being spliced and shall be approved by the resident engineer prior to installation. All cable splice envelopes shall also meet the following requirements:

(a) Power cables above 5,000 volts.

Tape splice kits designed for the type of cable used employing field applied rubber or synthetic rubber tape covered with plastic tape are approved. The rubber tape shall be 30 mils in thickness and meet MIL-I-3825. The plastic tape shall meet HH-I-595 and be flame retardant and weather and cold resistant.

Epoxy or resin splices will not be allowed.

(b) Power cables 601 to 5,000 volts.

Pressure epoxy resin splice envelopes as manufactured by the Minnesota Mining and Manufacturing Company or equal, and installed in strict conformance with the manufacturer's instructions, are approved. Taped or cast splice kits designed for the cable are also approved. For unshielded series lighting power cables a field installed plug-in splice in accordance with FAA Specification L-823, "Plug and Receptacle Cable Connectors" shall be used.

(c) Power cables 600 volts and below.

Cast or pressure epoxy resin splice envelopes or equal, as manufactured by the Minnesota Mining and Manufacturing Company, are approved for all direct earth burial cable. A taped splice using a prestretched or heat-shrinkable tubing covering is also approved. Splices in manholes, handholes, or above ground may be taped.

(d) Control and telephone cables.

A "Scotch" brand 3925 reenterable filled splice envelope, or equal, is approved for use on thermoplastic insulated nonpressurized cables. Splices to existing FAA pressurized, lead covered, or paper insulated cables shall be in accordance with the contract specifications.

(e) Coaxial cables (nonpressurized).

Coaxial cable shall be joined using coaxial connectors as specified in the plans. Each connector will be covered with a six-inch minimum length of heat shrinkable tubing having a 3:1 or higher shrink ration as manufactured by American Pamcor catalog No. 603025 or equal. A spray cable adhesive as manufactured by American Pamcor catalog No. 602416 or equal shall be sprayed on the cable but not the connector prior to shrinking. A flameless heat gun shall be used for shrinking the heat shrinkable tubing. An alternate covering may be prestretched, mechanically shrinkable tubing applied as recommended by the manufacturer.

(f) Coaxial cables (pressurized).

No field installed splices will be allowed in pressurized coaxial cable unless otherwise specified.

(g) Connectors, power cable.

Connections of cable conductors shall ~~be~~ made using crimp connectors utilizing a crimping tool designed to make a complete crimp before the tool can be removed. Low voltage, 600 volts and below, may use split bolt connectors.

(h) Connectors, control and telephone cable.

Joining of AWG 19 telephone or control conductors shall be a twisted and soldered splice, or the 3M Company Moisture Proof self-stripping, preinsulated connector, or Burndy No. PS-M-18 or equal, installed with the specific tool designed to crimp the connector. Color coding of the conductors shall be followed throughout the installation.

(i) Cable armor and shields.

Armor and shields shall be electrically bonded across the splice by cleaning and soldering. Armor and shielding shall be completely insulated from each other and from ground, except as noted in paragraph 3.4.5.

4. QUALITY ASSURANCE PROVISIONS

4.1 Cable testing.- All cable testing shall be performed by the contractor in the presence of the resident engineer. The contractor shall furnish all necessary test instruments, except where otherwise indicated. All instruments shall have been calibrated within a period of two years preceding the cable testing.

All cables shall be tested prior to installation, after each splice, and again upon completion of the installation. All testing shall be done on the contractor installed cable before connection is made to any existing cables. The FAA will test existing cables prior to connecting to contractor installed cables.

4.2 Power cables, 5,000 volts.- Conductors, splices, etc., will be tested at 10,000 volts. The test will be made between conductors and from conductors to ground with cable shield and armor grounded and for a period of not less than one minute after instrument readings have stabilized. Minimum acceptable resistance values will be 50 megohms. Original insulation values of the cable have been substantially reduced to the specified 50 megohms in order to compensate for cable length, aging of conductor insulation and other factors which may affect test results both before and during installation. Unless cable length should appreciably exceed ten thousand feet, no reduction in the specified insulation resistance should be considered. Note: Until the cable has been completely charged by the measuring instrument insulation readings may be erroneous.

A test will be made for continuity of the cable's shield or armor. An ohmmeter type instrument may be used. The contractor shall demonstrate that circuits are properly connected, including operation of each lighting and power circuit for not less than one-half hour.

4.2.1 Power cables, above 5,000 volts.- Power cables above 5,000 volts shall be tested as in paragraph 4.2, except the test voltage shall be twice the cable voltage rating plus 1,000 volts.

4.3 Cables, 5,000 volts, series lighting.- After installation is completed, each series loop with its connectors and lighting transformers shall be tested for insulation resistance in accordance with paragraph 4.2. Both ends of each series loop shall be disconnected from the series cutouts at the substation prior to making tests. Each series loop will also be tested for series loop resistance with the lighting transformers installed. The DC circuit resistance of each series loop shall be calculated by the use of the following formula:

Where: $R\ total = (Rx \times Lm) + (Rt \times Tn)$

R total = Loop resistance

Rx = Resistance of the cable conductor per 1,000 feet (.64 ohms @ 68°F)
Rt = Resistance of the transformer primary as measured with a Wheatstone bridge.
Tn = No. of series transformers in loop.
Lm = Length of loop in K feet.

The loop resistance shall be measured with a Wheatstone bridge or equivalent type instrument and recorded. The value of the measured resistance shall not exceed the calculated resistance by more than 20 percent.

4.4 Power cables, 600 volts and below.- Secondary power cables and lighting and power wiring shall measure not less than 50 megohms resistance between conductors and between conductors and ground. Measurements shall be taken at not less than 500 volts DC.

4.5 Control and telephone cables.- After installation these cables shall comply with the following requirements:

Size Cable	Minimum No. of Acceptable Conductors
(a) 12 pair or less	All
(b) Over 12 pair to 25 pair. incl.	All, except one pair
(c) Over 25 pair	All, except 2 pair

Acceptable conductors include satisfactory test as to (a) continuity, (b) freedom from short circuits, and (c) a minimum of 50 megohms resistance between conductors and from each conductor to grounded shield when tested at not less than 500 volts DC.

The contractor shall test the cable prior to installation and notify the FAA representative of any unusable conductors found. These may be subtracted from the allowable number of excepted conductors tabulated above, if the cable is government furnished. Conductor pairs or test between unpaired conductors showing an insulation resistance below infinity on a 500 volt, 100 megohm or equivalent insulation measuring instrument shall be tabulated by the contractor and furnished to the FAA representative. This record shall indicate actual resistance values. Note: Some telephone cables may include an extra pair and if so, in some instances may have one pair tagged as defective by the manufacturer. This extra pair shall not be included in the minimum number of acceptable pairs listed above.

4.6 Coaxial cables.- Radio frequency cables shall be tested for insulation and loop resistance prior to installation and the results recorded and a copy furnished to the FAA representative. The insulation test shall be made between the center conductor and shield with a 500 volt DC instrument. The loop resistance test shall be also made as above, but with the center conductors shorted to the shield at the far end of the cable. This test shall be made with a bridge, ohmmeter or other suitable instrument.

After installation, the conductor to shield and conductor to ground resistance shall exceed 50 megohms when measured at 500 volts DC. Loop resistance shall be within plus or minus 10 percent of the measured values prior to installation, e.g., measured resistance per 1,000 feet of cable on reel, multiplied by each 1,000 feet and fraction thereof of installed cable. Shield to ground insulation shall be measured and the results furnished to the FAA representative.

4.6.1 Pulse reflection test.- Coaxial cable to be used for carrying video or trigger information will be tested by an FAA representative for discontinuities prior to and after installation. Results of the test will be recorded and a copy furnished to the contractor. This test will be performed with a synchroscope with time calibrated sweep speeds and a pulse generator producing a pulse amplitude of 60 to 100 volts at 0.5 microseconds, or less, pulse duration. The pulse reflection test will determine if discontinuities were introduced in the cable during installation. These could occur from improper installation of connectors or mechanical damage of cable.

4.6.2 Coaxial cable, pressurized.- Upon completion of the cable installation, the contractor shall perform the following tests under the supervision of the government representative.

4.6.3 Electrical test.- A hipot tester with microammeter current leakage meter or an equivalent tester will be used and 3,000 volts DC applied between the inner and outer conductors for a minimum period of three minutes. While this voltage is applied no noticeable current shall flow between the conductors after charging current has stabilized.

4.6.4 Nitrogen gas test.- Nitrogen gas at 15 pounds per square inch regulator gas pressure shall be applied to the cable, the gas valve closed, and ambient temperature recorded. Six successive, hourly readings will be taken and recorded. After the sixth reading is taken and after a time interval of about 24 hours, a seventh reading shall be made of the pressure gauge. If variations in gas pressure are due only to changes in ambient temperature, the length of cable is acceptable. A temperature correction factor of .0094 pounds per degree F shall be used.

4.7 Failure of cable under test.- If the contractor furnished cable fails to meet test requirement after installation, the contractor shall repair or replace, at his expense, the sections of cable proven defective. If the cable is government furnished and the failure results from a manufacturing defect or from a cause undetectable prior to installation, the government will repair or replace the cable. If the government furnished cable fails to meet test requirements after installation from causes due to faulty installation practices, the contractor shall repair or replace the sections of cable proven defective.

5. PREPARATION FOR DELIVERY - Not applicable.

6. NOTES - None.

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