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September 2014
SUPERSEDING
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May 2012

DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION SPECIFICATION

INSTALLATION, TERMINATION, SPLICING, AND TRANSIENT/SURGE PROTECTION OF UNDERGROUND ELECTRICAL DISTRIBUTION SYSTEM POWER CABLES

This specification is approved for use by all Departments of the Federal Aviation Administration (FAA)

FOREWORD

1. This specification provides requirements for the installation of FAA-owned and maintained underground electrical line distribution (ELD) systems in support of FAA facilities. The ELD systems include power cable and associated components on the exterior, commercial power supply side of the circuit at the airfield or remote site through to the service entrance power panels of FAA facilities.

2. This specification applies only to FAA medium-voltage (MV) and low-voltage (LV) underground power cables, and to a limited extent to overhead lines that may form a part of an FAA-owned circuit. It does not apply to control, telecommunication, or facility service entrance (load side) wiring. For standards pertaining to these non-power cable and electrical systems, consult the appropriate office of primary responsibility for applicable standards.

3. Power for airfield lighting cables has a separate set of standards and procedures. Refer to the appropriate FAA Advisory Circular (AC) 150/5340 and associated governing standards.

4. This is an update to an existing specification. It assimilates recent utility industry knowledge concerning ELD systems, with the aim of providing safer, more reliable FAA underground MV and LV ELD systems.

5. Changes in this version of the document include (see change history, page iv):

   a. Revised from "c" version to "d" version.
   b. Miscellaneous updates collected from field comments.
   c. Submittals section updated; submittals matrix added as an appendix.
   d. Duct joining processes added, with special consideration of joining HDPE sections (see also appendix for sample bonding adhesives data sheet).
   e. Product section updated (added power cable, transformers, switchgear/sectionalizers, service disconnects, terminations/splices, overcurrent devices, underground duct systems, and ducts and fittings, etc).

6. This specification is intended to ensure that minimum FAA requirements are met based on current commercial practices relating to safety, reliability, and restorability of FAA electrical line distribution systems. Contractors are encouraged to provide innovative, best-value solutions wherever possible within the bounds of these requirements.

> Comments, suggestions, or questions on this document should be addressed to: Federal Aviation Administration, AJW-22, Power Services Group, Power Cable Program, 800 Independence Ave., S.W., Washington, DC 20591, https://employees.faa.gov/org/linebusiness/ato/operations/technical_operations/atc_facilities/power_services/power_cable/

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10/30/14
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Change History

1. Originator Name and Address AJW-22, Power Services Group	2. [] Proposed	3. Code Identification	4. Document No. FAA-C-1391c
Washington, DC	[X] Approved	5. Code Identification	6. DCN No.
7. System Designation	8. Related ECR/NCP No. ATO0W-CABLE-1023	9. Contract No.	10. Contractual Activity N/A
11. Product Integration Plan		12. Effectivity	

This notice informs recipients that the standard identified by the number (and revision letter) shown in block 4 has been changed. The pages changed by this DCN (being those furnished herewith) carry the same date as the DCN. The page numbers and dates listed below in the summary of changed pages, combined with non-listed pages of the original issue of the revision shown in block 4, constitute the current version of this specification.

13. DCN No.	14. Pages changed	S*	A/D*	15. Date
	Summary - general: a. Deletion of requirements for non-electrical-line-distribution (non-ELD) systems, including communications and telecommunications cables (both copper and FOTS), control cables, and constant-current-regulated runway approach and edge lighting power cables. Basic separation requirements between ELD and non-ELD cables have been retained. Installation standards and specifications for the non ELD systems may be found by consulting the appropriate office of primary responsibility. b. Emphasis on product changes in FAA ELD systems from the older 2.4 kV to 4.16 kV distribution circuits to the newer industry standard medium voltage systems, e.g., 3-phase/7200 V (phase to neutral). The Power Cable Program favors 15 kV rated cables and equipment to bring FAA ELD systems up to compatibility with the utility industry and to meet future FAA needs. c. Increased attention to the protection of sensitive internal constituent parts of MV cable systems during installation, by (1) the imposition of stringent tests meeting IEEE criteria, and (2) using proper cable pulling, splicing, and terminating techniques. d. Addition of power cable acceptance testing process for newly installed cables (text main body and Appendix C). Acceptance tests classified as destructive by the IEEE, such as the DC high potential (HIPOT) test, shall no longer be performed on in-service power cables. e. Treatment of the qualifications of MV "qualified persons" during installations.			1/24/2012
	Details – changes: a. Non ELD systems, deletions from FAA-C-1391b version: pp. 1-4, 7-15, 17-19. Sections/paragraphs affected: 2.1.2, 2.1.3, 3.1.2, 3.2.1, 3.2.2, 3.4, 3.4.1.1, 3.4.1.2, 3.4.2.2, Table I, 3.4.3, 3.4.3.1, 3.4.4, 3.4.5, 3.5.1, 3.5.2, 3.6, 4.2, 4.3, 4.5, 4.5.1, 4.5.2, 4.6, 4.6.1, 4.6.2, 4.6.3, App A.			1/24/2012
	Details – changes: b. Product changes, additions in FAA-C-1391c: cable 3.3.6.2; 15 kV surge protection 5.8.2; 15 kV splice kits 5.9.			1/24/2012
	Details – changes: c. Installation of cables, additions in FAA-C-1391c: splice procedures 5.9; cable pulling 5.5.12 and App B; cable end sealing 5.5.11; installer qualifications 3.3.3.2; 50/60 Hz offline partial discharge test 3.3.6.3, 3.3.6.4.			1/24/2012
	Details – changes: d. Acceptance testing procedures, additions in FAA-C-1391c: 3.3.6; Appendix C.			1/24/2012
	Details – changes: e. Qualified persons and contractors, change in FAA-C-1391c: 3.3.3 (all), 3.3.6.4, 5.9.			1/24/2012
	Updated document from "c" version to "d" version.			4/4/2014
	Miscellaneous updates collected from field comments.			4/4/2014
	Submittals updated, products updated (added power cable, transformers, switchgear/sectionalizers, service disconnects, terminations/splices, overcurrent devices, underground duct systems, and ducts and fittings).			4/4/2014
	Manhole cover wheel loading and guard wire grounding upgraded.			8/15/14

CONTENTS

1. SCOPE

This specification defines the minimum requirements for the installation of medium voltage and low voltage (600 V) electrical line distribution (ELD) power cables buried directly in the earth or installed in underground duct or conduit. The industry definition of medium voltage is between 600 V and 34,500 V nominal voltage line to ground. The work includes surveying, trenching, and backfilling, installation of cables, conduits, concrete-encased ducts, hand holes, manholes, duct markers, joints and splicing, terminating, providing surge protection, and testing of cables for acceptability of the finished ELD. In addition, this specification defines the responsibilities of the contractor with respect to safety, quality assurance, and quality control during the installation and testing of ELD systems.

This specification covers installation and acceptance testing of FAA ELD systems only. For FAA power cable maintenance directives, refer to FAA Order 6950.22.

This specification applies to installation of medium and low voltage facility electrical supply power cables and associated equipment only. These systems provide facility power from the power supplier's primary service to the service entrance power panels of FAA facilities. For detailed information on the installation of non-ELD cable systems such as control cables, fiber optics telecommunication (FOTS) cables, communication cables, etc., consult with the office of primary responsibility (OPR) for guidance. The 2400-V shielded constant current power cables serving runway edge lighting fixtures have their own standards and are not the subject of this specification. Consult the appropriate office of primary responsibility and the airport circulars for guidance. For basic separation requirements of FAA utility power cable systems from non-electrical-power cable systems, consult the section of this specification entitled, "Separation of Cables" (5.5.10). When physically integrating non-ELD cables with power cables, do not assume all of the provisions of FAA-C-1391 apply without first coordinating with the appropriate OPR and the FAA onsite project engineer responsible for integration of multiple cable assets.

Non-ELD OPRs consist of:

- **a. AJW-45 Ground-Based Navaids Group,**
- **b. AJW-46 Lighting Systems Group,**
- **c. AJW-52 Communications Systems Engineering Group,**
- **d. AJW-53 Telecommunication Services Group,**
- **e. AJW-55 Air-Ground Data Communications Group,**
- **f. AJW-56 Air-Ground Voice Communications Group,**
- **g. Others (as applicable).**

2. APPLICABLE DOCUMENTS

2.1 General

Due to the continuous updating of Government documents, the FAA Contracting Officer and/or the FAA Project Engineer must specify the document version and publication date current at the time of contract award or project design. The documents below form a part of this specification. Some of the FAA documents listed are out of date but are still applicable; reference the notations next to each reference provided. FAA tailoring organizations should consult with the offices of primary responsibility to obtain the most recent applicable documentation.

2.2 Order of precedence

In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.3 Government documents

The following citations are government documents that are used as references in this specification.

2.3.1 FAA orders, standards, specifications, and handbooks

The following FAA orders, standards, specifications, and handbooks form a part of this document to the extent specified herein. Unless otherwise stated, requirements contained in these documents are as cited in the project solicitation or contract. (Copies of FAA orders, standards, specifications, handbooks, drawings, and other applicable FAA documents may be obtained from the Contracting Officer issuing the invitation-for-bids or request-for-proposals. Requests should fully identify the material desired; for example: specification, standard, amendment, drawing numbers [drawings possessing standard FAA signature block], and dates. Requests should cite the invitation for bids, request for proposals, the contract involved, or other source of the requested material.)

2.3.1.1. ORDERS

JO 3900.XX	Air Traffic Organization Electrical Safety Program [Future]
JO 6750.16	Siting Criteria for Instrument Landing Systems
JO 6950.27	Short Circuit Analysis and Protective Device Coordination Study [contact PSG Systems Engineering for arc flash calculations]

2.3.1.2 STANDARDS

FAA-STD-XXX	Underground Electric Line Distribution (ELD) Systems [Future]
FAA-STD-019	Lightning Protection, Grounding, Bonding and Shielding Requirements for Facilities

2.3.1.3 ADVISORY CIRCULARS AND SPECIFICATIONS

150/5300-13	Airport Design
150/5320	Surface Drainage Design
150/5370	FAA Standards for Specifying Construction of Airports
FAA-E-113	Poles, Wood, Treated
FAA-E-2793	Cable, Electrical Power, 2,000 to 35,000 Volts
FAA-E-2013	Cable, Electrical Power, Exterior 600 Volts

2.3.1.4 HANDBOOKS

FAA-HDBK-XXX	Underground Electric Line Distribution (ELD) Systems [Future]

2.3.2 Other Government documents, drawings, and publications

The following Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

American Association of State Highway & Transportation Officials Specifications

AASHTO HB-17	Standard Specifications for Highway Bridges.
AASHTO HS-20	Standard Specifications for Highway Bridges

Occupational Safety and Health Administration Codes

Part 1926	Safety and Health Regulations for Construction.

Military Specifications

MIL-I-3825	Insulating Tape, Self-Fusing
DLA A-A-50563	Conduit Outlet Boxes, Bodies, and Entrance Caps, Electrical: Cast Metal
DLA A-A-59213	Splice Connectors
DLA A-A-59214	Junction Box: Extension, Junction Box; Cover, Junction Box (Steel, Coated with Corrosion-Resistant Finish)
DLA A-A-59544	Cable and Wire, Electrical (Power, Fixed Installation)
DLA A-A-59551	Wire, Electrical, Copper (Uninsulated)
Navy A-A-59827	Topside Conduit (Flexible) and Conduit fittings, Electrical: Composite Based (Non-metallic)
UFC 3-350-03FA	Electrical Power Supply and Distribution
UFC 3-600-01	Fire Protection Engineering for Facilities
UFGS 26 12 19.20	Single-Phase Transformers
UFGS 26 12 19.10	Three-Phase Transformers
UFGS 33 70 02.00 10	Electrical Distribution System, Underground

Federal Specifications

W-C-375/3	Circuit Breakers, Molded Case; Branch Circuit and Service
W-S-865	Switch, Box (Enclosed), Surface Mounted
WW-C-566	Conduit, Metal, Flexible
WW-C-581	Class 1 Type A with Standard for Electrical Rigid Metal Conduit - Steel, UL 6

2.4 Non-Government publications

The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

American National Standards Institute (ANSI) Standards

ANSI 6	Standard for Rigid Metal Conduit. (Same as UL 6)
ANSI 467	Standard for Grounding and Bonding Equipment. (Same as UL 467)
ANSI 514	Fittings for Cable and Conduit. (Same as UL 514)
ANSI 651	Schedule 40 and 80 Rigid PVC Conduit. (Same as UL 651)
ANSI A14.3	Safety Code for Fixed Ladders
ANSI C2	National Electrical Safety Code (NESC). (Same as IEEE C2)
ANSI C62.11	IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits (>1 kV). (Same as IEEE C62.11)
ANSI C62.22	IEEE Guide for the Application of Metal Oxide Surge Arrester for Alternating Current Power Circuits. (Same as IEEE C62.22)
ANSI C62.22.1	Guide for the Connection of Surge Arresters to Protect Insulated, Shielded Electric Power Cable Systems (Same as IEEE 1299/C62.22.1)
ANSI C62.41	Recommended Practice on Characterization of Surges in Low-Voltage (1000V and Less) AC Power Circuits. (Same as IEEE C62.41)
ANSI C80	Rigid Steel Conduit – Zinc Coated. (Same as NEMA C80)
ANSI C119.1	Sealed Insulated Underground Connector System Rated 600 Volts. (Same as NEMA C119.1)
ANSI FB 1	Fittings, Cast Metal Boxes, and Conduit Bodies for Conduit and Cable Assemblies. (Same as NEMA FB1)
ANSI RN 1	Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Steel Conduit. (Same as NEMA RN 1)
ANSI S-97-682-2007	Standard for Utility Shielded Power Cables Rated 5 through 46 kV (Same as ICEA S-97-682-2007)

ANSI TC 6 & 8	PVC Plastic Utilities Duct for Underground Installation. (Same as NEMA TC 6 & 8)
ANSI Z535	Safety Alerting Standards. (Same as NEMA Z535)

American Society of Civil Engineers Standards

CI/ASCE 38-02	Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data.

American Society for Testing & Materials (ASTM) Standards

ASTM A48	Standard Specification for Gray Iron Castings.
ASTM B8	Standard Specification for Concentric-Lay-Stranded Copper Conductors
ASTM C267-97	Standard Test Methods for Chemical Resistance of Mortars, Grouts, Monolithic Surfacings and Polymer Concretes
ASTM C478	Standard specification for Precast Concrete Manhole Section (AASHTO No. M199)
ASTM C579-96	Standard Test Methods for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings and Polymer Concretes
ASTM C580-93	Standard Test Method for Flexural Strength and Modulus of Elasticity of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings and Polymer Concretes
ASTM C858	Standard Specification for Underground Precast Concrete Utility Structures
ASTM C990	Standard Specification for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants.
ASTM D422	Standard Test Method for Particle-Size Analysis of Soils
ASTM D698	Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort
ASTM D1056	Standard Specification for Flexible Cellular Materials - Sponge or Expanded Rubber

ASTM D2444-93	Standard Test Method for Determination of the Impact Resistance of Thermoplastic Pipe and Fittings by Means of a Tup (Falling Weight)
ASTM F512	Standard Specification for Smooth-wall PVC Conduit and Fittings for Underground Installation
ASTM 1962	Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit under Obstacles
ASTM F2160	Standard Specification for Solid Wall High Density Polyethylene (HDPE) Conduit

Institute of Electrical and Electronics Engineers (IEEE) Standards

IEEE C2	National Electrical Safety Code (NESC)
IEEE-48	Test Procedures and Requirements for Alternating-Current Cable Terminations Used on Shielded Cables Having Laminated Insulation Rated 2.5 kV through 765 kV or Extruded Insulation Rated 2.5 kV through 500 kV
IEEE 80	IEEE Guide for Safety in AC Substation Grounding
IEEE-100	The Authoritative Dictionary of IEEE Standards Terms
IEEE-386	Standard for Separable Insulated Connector Systems for Power Distribution Systems above 600V
IEEE-400.2	IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF)
IEEE-400.3	Guide for Partial Discharge Testing of Shielded Power Cables in a Field Environment
IEEE-404	Standard for Power Cable Joints
IEEE-525	Cable Systems in Substations
IEEE-835	Power Cable Ampacity Tables
IEEE C62.11	IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits (>1 kV).

IEEE C62.22	IEEE Guide for the Application of Metal Oxide Surge Arrester for Alternating Current Power Circuits
IEEE 1299/C62.22.1	Guide for the Connection of Surge Arresters to Protect Insulated, Shielded Electric Power Cable Systems
IEEE C62.41 (Formerly IEEE 587)	Recommended Practice on Characterization of Surges in Low-Voltage (1000V and Less) AC Power Circuits

Insulated Cable Engineers Association (IECA) Standards

ICEA S-94-964	Concentric Neutral Cables Rated 5-46 kV
ICEA S-97-682-2007	Standard for Utility Shielded Power Cables Rated 5 through 46 kV

International Electrotechnical Commission (IEC) Standards

IEC 60071-2	Insulation coordination Part 2: application guide.

National Electric Manufacturers Association (NEMA) Standards

RN 1	Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Steel Conduit
FB1	Fittings, Cast Metal Boxes, and Conduit Bodies for Conduit and Cable Assemblies
TC 2	Electrical Polyvinyl Chloride (PVC) Tubing (EPT) and Conduit (EPC-40 AND EPC-80)
TC 3	PVC Fittings for Use with Rigid PVC Conduit and Tubing
TC 6 & 8	PVC Plastic Utilities Duct for Underground Installation
TC 7	Smooth-Wall Coilable Electrical Polyethylene Conduit
TC 9	Fittings for PVC Plastic Utilities Duct for Underground Installation
TC 14	Filament-Wound Reinforced Thermosetting Resin Conduit and Fittings
NECA/NEMA 605	Recommended Practice for Installing Underground Nonmetallic Utility Duct

Underwriters' Laboratories (UL) Inc. Standards

UL 6	Standard for Rigid Metal Conduit
UL 467	Standard for Grounding and Bonding Equipment
UL 514	Fittings for Cable and Conduit
UL 651	Schedule 40 and 80 Rigid PVC Conduit

National Fire Protection Association (NFPA) Standards

NFPA-70	National Electric Code (NEC)
NFPA-70E	Electrical Safety in the Workplace
NFPA-780	Standard for the Installation of Lightning Protection Systems
NEC Hdbk	Art. 110.16, Flash Protection
NEC Hdbk	Art. 344.10, Rigid Metal Conduit: Type RMC
NEC Hdbk	Art. 280, Surge Arrestors, Over 1 kV

3. GENERAL

3.1 Definitions

Unless otherwise specified, electrical and electronics terms used in this specification, and on the drawings, shall be as defined in IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms*.

In the text of this specification, the words “conduit” and “duct” are sometimes used interchangeably and have the same meaning.

In the text of this specification, "medium voltage cable splices" and "medium voltage cable joints" are used interchangeably and have the same meaning.

For the purposes of this specification, “FAA electrical line distribution systems (ELD)” shall be defined as:

FAA owned and operated electrical power distribution systems (underground or overhead) running from a power source to FAA facility load(s). An ELD may include some or all of the following: power cable; transformers; sectionalizers; switchpads; disconnect switches; manholes; hand-holes; utility poles; direct earth buried (DEB) cables; and underground duct banks. Intra-facility wiring, runway edge lighting cables, and FOTS and system cables, such as MALSR or ALSF loop cables are not included as part of ELD.

The demarcation point between an FAA ELD system and FAA facility premises wiring on an airport can be ambiguous. When in doubt, consult AJW-22, Power Services Group, Power Cable Program.

3.2 Submittals

Submittals are limited to those necessary for quality control (see Appendix E). Submittals marked A are required. For submittals marked B or C, the FAA task or contract specifier shall evaluate the contract for each kind, voltage, or type of submittal used on the project and make a determination as to whether the submittal is required. Examples given are not limited to those shown in parentheses:

“A” indicates that the submittal is required.

“B” indicates that the submittal is required, unless specifically deleted by the contract specifier.

“C” indicates that a submittal is not generally required because it is expensive and/or time consuming (i.e., a special case). If the submittal is required, the contract specifier shall show the required submittal on the submittals matrix (Appendix E) and in the contract documents (as a CLIN item).

a. Contractor-generated design data (ANSI C2 and FAA-STD-032, Para 3.1.13)
   1. Code analysis (e.g., voltage drops, clearance calculations, design arc flash study, etc) (ANSI C2) [A]
   2. Design assumptions and parameters (FAA-STD-032) [B]
   3. Test reports and findings (e.g., soil resistivity, load bearing, frost analysis, etc) [C]
   4. Design calculations (FAA-STD-032) [A]
   5. Contractor-generated design drawings or sketches. [A]
b. Cost estimates [A]
c. Medium voltage cable [A]
d. Medium voltage cable splices and joints* [A]
e. Medium voltage cable terminations* [A]
f. Conduits [A]
g. Duct construction materials (e.g., concrete, alternatives to concrete where approved, fills and layers, etc) [A]
h. Switch pads and sectionalizers [A]
i. Transfer switches (automatic and manual) [A]
j. Transformers [A]
k. Surge arresters [A]
l. Live end caps or protective caps [A]
m. Precast concrete structures [A]
n. Sealing Material [B]
o. Manhole frames and covers [A]
p. Hand hole frames and covers [A]
q. Cable supports (racks, arms and insulators) [A]
r. Protective devices and coordination study [A]
s. As-built arc flash hazard study. Required when an existing study is not available, or if modifications are being made to the existing ELD system. [A]
t. Electrical equipment factory test reports [A]
   1. Medium voltage cable factory certified test result report as per FAA-E-2793, Section 4.2 (includes meeting ICEA S-94-649, Sections 4.3.2.1 and 9.13). [A]
   2. Transformers [A]
   3. Switchgear, sectionalizers [A]
   4. Disconnects [A]
   5. Other applicable components [B]
u. Field acceptance checks and tests (see Appendix C) [A]
v. Arc-proofing test for cable fireproofing tape [C]
w. Cable installation plan and procedure (use cable installation plan only when pulling cable between manholes; do not use for pulling from pole riser to manhole only):
   1. Site layout drawing with cable pulls numerically identified [B]
   2. A list of equipment used, with calibration certifications [A]
   3. The manufacturer, type, and quantity of lubricant used on pull [B]
   4. The cable manufacturer and type of cable [A]
   5. The dates of cable pulls, time of day, and ambient temperature [C]
   6. The length of cable pull and calculated cable pulling tension (calculated value, not maximum value). A single generic table cable pulls may be submitted. [A]

7. The actual cable pulling tensions encountered during pull [A]
8. Certificates (tensiometer calibration, VLF tester calibration, etc) [A]

x. Cable splicer/terminator qualifications* [A]
y. Cable installer qualifications* [A]
z. Project design drawings [A]

*Note: The contractor shall provide the product drawings showing details of the connecting methods to be used, and a statement of the experience of the contractor in making connections on underground systems with the proposed product. Cable splicing/terminating personnel shall have a minimum of three (3) years continuous experience in terminating/splicing medium voltage cable. Products shall meet the latest editions of applicable standards as follows:

APPLICATION STANDARD (USE LATEST ISSUED)	LEVEL OF ACCEPTANCE
IEEE-404 Standard for Power Cable Joints	Meet or Exceed
IEEE-48 Standard for Cable Terminations	Meet or Exceed
ANSI C119.1 Sealed Insulated Underground Connector System Rated 600 Volts	Meet or Exceed
IEEE – 386 Standard for Separable Insulated Connectors	Meet or Exceed

3.3 Quality assurance

All work shall comply with the National Electrical Code (NEC) and IEEE C2/National Electrical Safety Code (NESC) for components and installation. To the maximum extent practicable, furnish products that are listed and labeled by a nationally recognized testing laboratory (NRTL) for the application, installation condition, and the environment in which the products are installed. Use of nonlisted components will not be allowed unless (1) it is demonstrated that listed components are not available, and (2) the FAA preapproves such components before installation. Approval shall be at the discretion of the FAA.

3.3.1 Quality plan

The contractor shall submit a Quality Plan in compliance with ISO 9001, *Quality Management Systems Requirements*. This plan will allow the FAA to identify the stages at which the FAA requires carrying out an inspection or witnessing a test. The plan shall cover all relevant stages of personnel qualification, design, coordination, supplier selection, manufacturers' acceptance testing, site inspection, site quality control testing, and commissioning. The plan shall identify relevant suppliers by name, components supplied, country of origin, and whether suppliers and supplied components are quality assurance certified.

3.3.2 Quality control

The quality of the equipment installed shall be controlled at the manufacturers' plants and at the project site to ensure that it meets the required specifications. The quality of civil engineering work, such as trenching, ducting, and other operations, shall be inspected by the FAA and approved after each major construction step. The contractor shall inform the FAA of manufacturing/shipping schedules and shall offer representatives of the FAA the opportunity to witness acceptance tests. These tests shall be performed on a statistically meaningful number of samples, as specified by FAA engineers. After receipt of equipment shipment and prior to installation, the contractor shall subject equipment to a thorough visual inspection. An FAA representative shall be notified in advance and afforded the opportunity to be present and witness this step. Nameplates and markers shall be checked against the required specifications, and deviations brought to the FAA's attention. At the FAA's request, quality control checks, including acceptable electrical measurements (such as cable insulation resistance tests and surge protection leakage current measurements) shall be performed and reported. After the installation of cable systems is completed, acceptance/commissioning tests shall be performed.

All equipment and materials shall be subject to acceptance through the manufacturers' certification of compliance with applicable requirements when so requested. The requirements of this standard shall be considered as minimum requirements and shall not relieve the contractor of the responsibility to furnish and install higher grades of materials than specified when so required by the contract drawings and specifications. The installation shall conform to the most stringent requirements of the National Electrical Code (NEC), the local electrical codes, NFPA-70E, and applicable ANSI and IEEE standards, e.g., the National Electrical Safety Code (NESC), as well as other relevant guides and standards as listed in Section 2.

3.3.3 Qualifications of personnel

3.3.3.1 Designers

The design team shall have at least one engineer with significant experience in medium voltage design, review, and construction management. The engineer shall have worked with electrical power systems, and shall have designed electrical distribution systems whose reliability, maintainability, availability, and fault tolerance are of a similarly high level to those found in campus environments such as hospitals, life safety systems, and/or large computer and telecommunication facilities. The design engineer shall have the ultimate responsibility for the construction set (specifications, drawings, and cost estimates) and installation quality control. Drawings and engineering documents published by a non-FAA entity shall be signed by a registered professional engineer with knowledge and qualifications tailored to underground medium-voltage and low-voltage electrical distribution systems. Drawings and engineering documents published by a non-FAA entity shall be signed as approved by FAA Engineering Services or a representative of the PSG ELD/Power Cable Program upon design acceptance. Drawings ready for release for construction shall incorporate the project's design acceptance drawings by reference.

3.3.3.2 Installation Crew

Experienced personnel regularly engaged in underground electrical distribution system work shall perform the installation. Personnel exclusively or mainly trained in overhead line work, or low voltage facility wiring work, are not sufficiently qualified to install FAA medium-voltage underground electrical distribution systems. Workers shall be properly licensed where required by law. Only qualified personnel may work on electric circuit parts or equipment being installed.

A qualified person is one who has skills and knowledge related to the construction and operation of the FAA's electrical equipment and installations, and has received safety training to recognize and avoid the hazards involved. Management personnel shall be responsible for authorizing the qualified personnel to perform a task. Besides completion of Occupational and Safety and Health

Administration (OSHA)/FAA required electrical safety training for qualified personnel, those persons authorized to work on FAA ELD systems shall meet the requirements of a Qualified Person as mandated by OSHA and as discussed in NFPA 70E.

Along with training, personnel performing medium voltage work on FAA ELDs shall have: (1) the skills and techniques necessary to distinguish exposed live parts from other parts of electric equipment, including wire and cables, (2) the skills and techniques necessary to determine the nominal voltage of exposed energized electrical conductors or parts, (3) knowledge of the safe approach boundaries, work clearances, and voltages involved, (4) familiarity with construction and operation of equipment and the hazards involved, (5) familiarity with electrical safety related work practices and precautionary techniques, (6) familiarity with proper use of personal protective equipment (PPE), arc flash, insulating and shielding materials, (7) familiarity with the proper use of insulated tools and test equipment, (8) ability to make good decisions in determining the degree and extent of the hazard and the PPE and job planning necessary to perform the task safely, (9) familiarity with safety precautions associated with confined spaces, (10) knowledge of skills and techniques regarding how to select and use a voltage detector and phase meter, (11) familiarity with mechanical aspects of ELD installation work such as trenching, boring, excavation around existing utilities and structures, manhole rigging, and pulling cable, and (12) CPR training and basic training for emergency dispatch if an electrocution or confined spaces injury occurs.

Cable termination and splicing shall be performed only by experienced and qualified medium/high voltage electricians experienced in underground distribution systems. Before cable splices/terminations are made, the FAA may request an example splice and/or termination be made to demonstrate the electricians' qualifications. In order to qualify the splicer, this example splice and/or termination shall comply with the requirements of accessory manufacturers, and pass the requirements of IEEE standards 48, 386, and 404 with respect to partial discharge.

3.3.3.3 Inspectors and Testing Personnel

Inspectors of the FAA ELD distribution systems shall have knowledge and experience in quality control activities related to the inspection of cables laid in trenches such as are found at large campus environments such as hospitals, life safety systems, and/or large computer and telecommunication facilities; shall perform quality control activities during installation and preacceptance of medium and low-voltage switchgear and sectionalizers, protective devices, power distribution transformers, surge arrestor equipment, and motor control centers; shall review functional tests of electrical equipment and conduct inspection and preacceptance of electrical drawings, termination drawings, and cable schedules; and shall interpret the various drawings used in the projects for executing and recording the work.

Test personnel shall be qualified persons meeting the requirements stipulated in Appendix C.

3.3.4 Receiving, storing, and protecting

The contractor shall receive, store, protect, and handle products according to National Electrical Contractors Association NECA 1, *Standard Practices for Good Workmanship in Electrical*

Construction, and NECA/NEMA 605, *Recommended Practice for Installing Underground Nonmetallic Utility Duct.*

3.3.5 Sequencing and scheduling

The contractor shall:

1) Notify the FAA resident engineer to schedule inspection of each duct bank or duct bank segment before concrete is placed.

2) Provide the FAA resident engineer with reasonable notification before the anticipated date of acceptance testing of the newly installed replacement ELD system so that arrangements can be coordinated with the testing contractor.

3.3.6 Cable testing

3.3.6.1 Government-furnished cable

If government-furnished power cable is delivered to the contractor, the contractor shall test the cable on the reel and report electrical or physical cable defects within two weeks of cable receipt. If adequate cable lengths are unavailable for testing on the reel, a visual inspection shall be made and damage reported to the FAA. The required tests shall then be made immediately after unreeling. Defects discovered when installing the cable shall be reported to the FAA in accordance with the contract provisions.

3.3.6.2 Contractor-furnished cable

Single and multi-conductor power cables furnished by the contractor shall conform to the FAA specifications given in the Products section of this specification.

Cable shall meet the following minimum requirements:

a. Copper conductors.

b. Thermoplastic, thermosetting, or silicon rubber insulation.

c. Neoprene, polyethylene, or vinyl jacket for normal areas, and polytetrafluoroethylene (PTFE) (Teflon®) jacket in areas exposed to fuel, oil, solvent or chemical leakage, excessive groundwater, or extremely acidic soil.

d. For cables with rated voltages to 8 kV, cable insulation shall have a minimum continuous voltage withstanding capability of four times rated voltage (but not less than 150 volts). For rated voltages above 8 kV, insulation shall have a minimum continuous voltage withstanding capability of three times rated voltage. Cable voltage surge capabilities shall be 15 times rated voltage for voltages to 8 kV, nine times rated voltage for voltages above 8 kV through 15 kV, and seven times rated voltage for voltages above 15 kV through 25 kV. Whenever a cable is covered by applicable ICEA/NEMA specifications, the cable shall pass the test requirements for such cable. In addition, the installed cable shall satisfy after-installation acceptance tests as specified below, and in Appendix C.

e. The pull strength of the completed cable(s) shall exceed the expected installation forces by a minimum of 50 percent.

3.3.6.3 Acceptance testing of new cable

Following installation, the contractor shall perform cable testing in the presence of the FAA. The contractor shall furnish necessary test instruments except where otherwise indicated in the project plans. Only currently calibrated instruments shall be used for cable testing. A laboratory approved by the measurement instrument manufacturer shall have performed instrument calibration. When conducting FAA-authorized third-party testing, offline partial discharge testing shall constitute the final acceptance test after completion of the installation.

Testing shall be completed on contractor-installed cable before connection is made to existing cables. If warranted, the FAA will test existing cables and provide the results to the contractor through the contracting officer prior to the contractor splicing or connecting cables he has installed to existing cables.

Certain acceptance tests classified as "destructive" by the IEEE shall only be conducted on newly installed cables. Such tests shall only be conducted within the test constraints given in Appendix C. Destructive tests shall not be performed on in-service (five years or older) power cables.

3.3.6.4 Acceptance testing of new power cables above 2000 volts

CAUTION
Zero-energy verification shall be accomplished before doing any work on de-energized medium-voltage equipment. In preparing for, and conducting, power cable tests, follow electrical safety procedures as outlined in FAA Order 6950.22.

New FAA underground, shielded, medium-voltage power cables rated 2000 volts and above shall be subjected, after installation but before connection to terminal equipment, to the following acceptance tests:

a. Continuity test for cable conductor, shield, and armor, using an ohmmeter type instrument. See FAA Order 6950.22 for parameters and test equipment.

b. Limited-voltage DC insulation resistance test using a Megger ™ type instrument. This test is formulated to apply and hold a DC voltage on the cable for a specified time, while measuring insulation resistance. See Appendix C for test description and processes.

c. One of the following tests:

a. Very low frequency (VLF, 0.1 Hz) AC high-potential withstand "pass/fail" test. The purpose of this type of test is not to ensure cable system future performance but simply to reassure the construction team that the line is not grounded/shorted before energization. The test shall be performed after cable system installation, including terminations and joints, but before the cable system is placed in normal service. See Appendix C for test description and procedures.

b. If third-party partial discharge acceptance testing is authorized, a diagnostic 50/60 Hz, off-line partial discharge test. This test can localize and determine the severity of any defects in the new installation. Due to its requirements for specialized test equipment, signal processing software, and diagnostic skills, the test must be conducted by a third-party testing firm. The testing firm shall be a qualified contractor preauthorized by the FAA. See Appendix C for test description and procedures.

3.3.6.5 Acceptance testing of new power cables 600 volts and below

CAUTION
Zero-energy verification shall be accomplished before doing any work on de-energized medium-voltage equipment. In preparing for, and conducting, power cable tests, follow electrical safety procedures as outlined in FAA Order 6950.22.

All low-voltage (≤ 600 V) power cables shall measure not less than 50 megohms resistance between conductors, and between conductors and ground (see FAA Order 6950.22, *Maintenance of Electrical Power Cables*, Chapter 3, *Standards and Tolerances*, Paragraph 301, Table (see column heading labeled "NEW CABLE"). Measurements shall be taken at not less than 500 volts DC and not more than 1000 volts DC. This test does not constitute proof that the system is free from insulation defects but rather supplies evidence that the insulation was not damaged during the installation process.

3.3.6.6 Failure of cable under test

If the contractor-furnished cable fails to meet test requirements after installation, the contractor shall repair or replace, at his expense, the sections of cable proven defective.

If the government-furnished cable fails to meet test requirements after installation due to contractor's faulty installation practices, the contractor shall repair or replace the defective sections of cable at contractor's expense.

The installation contractor shall be responsible for retest costs if components are found to be substandard during acceptance test(s) as a result of contractor faulty installation practices.

4. PRODUCTS

4.1 Product options and substitutions

Alternative products may be substituted for product types that do not apply to the project. Consult with the airport authority and the local FAA project engineer.

4.2 Power cable

Single and multi-conductor power cables shall conform to the following FAA specifications:

a. FAA-E-2013 for single-and multi-conductor power cables used in exterior 600 volt applications.

b. FAA-E-2793 for single and multi-conductor power cables used in exterior 2,000 to 35,000 volt applications. Reference Section 4.2 for product factory certified test result reporting requirement.

4.3 Transformers

4.3.1 High voltage transformers (>600 volts)

4.3.1.1 Transformer design

ELD transformers are normally installed outdoors with proper clearance from structures. Transformers shall be "enviro-friendly" mineral-oil-filled or biodegradable electrical insulating and cooling-liquid filled. Choose less-flammable transformer liquids unless there is a specific requirement to do otherwise.

If the local site stipulates less flammable transformer liquids, the following section shall apply, use NFPA 70 for liquids having a fire point not less than 300 degrees C tested per ASTM D92 and a dielectric strength not less than 33 kV tested per ASTM D 877. Provide identification of transformer as "non-PCB" and "manufacturer's name and type of fluid" on the nameplate. The fluid shall be a biodegradable electrical insulating and cooling liquid classified by UL and approved by FM Approvals® as "less flammable" fluids. The fluid shall meet the following properties:

- Pour point: ASTM D 97, less than -15 degree C,
- Aquatic biodegradation: EPA 712-C-98-075, 100%,
- Trout toxicity: OECD Test 203, zero mortality of EPA 600/4-90/027F, pass.

Silicon-filled and R-temp filled transformers shall not be used for less-flammable applications.

Transformers shall be pad mounted and of dead front design. If two-compartment transformers are required, obtain preapproval from the lead Engineering Services engineer or the Power Services Group, AJW-22. Aluminum core construction is acceptable. Due to associated safety hazards, transformers of the pole-mounted style shall not be used for ground-level FAA ELD applications.

4.3.1.2 Transformer bases and cabinets

Use stainless steel bases and cabinets in most applications, unless otherwise specified. The manufacturer's standard construction material is acceptable only in noncoastal and noncorrosive environments. For coastal/corrosive environments, ensure that front sill, hood, and tank base of single compartment transformers are corrosion resistant and constructed of stainless steel of not less than No. 13 U.S. gage, conforming to ASTM A167, Type 304 or 304L, unless otherwise indicated on the drawings. Base shall include any part of the pad-mounted transformer that is within 1.5 inches of the concrete pad.

In highly corrosive environments, the addition of totally stainless steel tanks and metering is required.

4.3.1.3 Warning signs and arc flash/shock hazard labels

For the enclosures of pad-mounted transformers having a nominal rating exceeding 600 volts, provide warning signs. After completion of arc flash hazard and shock analyses, label transformers with arc flash hazard and shock hazard warning information suitable to the particular installation.

4.3.1.4 Transformer losses

Transformers should meet the efficiency standards set forth in DOD's Unified Facility Guide Specification (UFGS) 26 12 19.20, *Single Phase Transformers,* Section 2.2.3.

4.3.2 Low-voltage transformers (<600 volts)

In FAA ELD systems, dry-type distribution transformers are used for buck boost applications or for short point-to-point distances for small loads of 600 volts or less. When used indoors, refer to FAA Specification FAA-C-1217, *Electrical Work*, *Interior.*

Transformers shall be mounted to allow for adequate ventilation (suitable for the local ambient temperatures).

4.4 Switchgear and sectionalizers

FAA ELD systems contain two types of switchgear: switch pads and sectionalizers. Both are fused devices used to de-energize equipment to allow work to be done and to clear faults downstream. More importantly, they isolate faulted line segments from a distribution system. These units shall be dead front-type units.

- Low-profile switch pads are typically used for single-phase applications.
- Sectionalizers are typically used for three-phase applications.

- Enclosures shall be outdoor rated or stainless steel, depending on location, meeting the requirements of ANSI C57.12.28. Use steel construction for typical installations. Use stainless steel construction for corrosive/salt environments.
- Pads or vaults shall be constructed of concrete or composite concrete-glass material. Concrete is preferred, but the latter may be used if approved by the FAA Resident Engineer and included on the drawings.
- Bases and cabinets shall be constructed of materials based on geographic location. Applications in dry locations shall employ steel; in wet locations, stainless steel.
  - Use stainless steel bases and cabinets in most applications. The manufacturer's standard construction material is acceptable only in noncoastal and noncorrosive environments. For coastal/corrosive environments, ensure that front sill, hood, and tank base of single compartment transformers are corrosion resistant and constructed of stainless steel of not less than No. 13 U.S. gage, conforming to ASTM A167, Type 304 or 304L, unless otherwise indicated on the drawings. Base shall include any part of the pad-mounted transformer that is within 1.5 inches of the concrete pad.
  - In highly corrosive environments, the addition of totally stainless steel tanks and metering is required.

4.5 Service disconnecting means

A main disconnect switch (MDS) ensures that electrical service to a facility can be completely de-energized for service or maintenance.

- MDSs shall be outdoor rated or stainless steel. Enclosures shall be NEMA 3R for typical applications, NEMA 4X for corrosive/salt environments.
- Pads shall be constructed of concrete or polymer concrete composite material. Concrete pads shall be no less than 6 in. thick. Concrete pads shall be brushed, chamfered, and graded for drainage. Expansion couplers should be considered in areas prone to frost heaving or ground settling.

4.6 Terminations and splices

4.6.1 Terminations

All power cable terminations rated above 4000 volts or with an outer shield shall be made with an authorized stress-relief device. Cable terminations shall be of a prefabricated design. Special care shall be exercised to provide the proper ratings and physical dimensions.

4.6.2 Splices

For medium voltage power cables (600 volts and above), use cold-shrink splice kits meeting ANSI/IEEE Std. 404 (for a 15 kV rating). For power cables 600 volts and below, use heavy-wall self-sealing heat-shrinkable tubing meeting ANSI-C119.1-2006. Alternatively, use a poured epoxy splice, or any other splicing means approved by ANSI standards.

4.7 Overcurrent protective devices

- For FAA ELD systems, the preferred protective devices are fuses. In transformers, fuses shall be immersion-type, current-limiting fuses, accessible from the exterior of the equipment.
- The specific type and size of protective device shall be selected based on a protective device coordination study and short circuit analysis, and as provided in the drawings.

4.8 Underground duct systems

The configuration of an underground duct system shall depend on the specific application. Conduit types used within FAA duct systems shall be of the size, material, and type indicated on the contract documents. Size of conduit shall always be indicated on the drawings. All conduit material shall be UL listed and installed in accordance with UL listings.

4.8.1 Concrete-encased rigid nonmetallic conduit

Rigid nonmetallic conduit consists of two types:

1) Concrete-encased Schedule 40 PVC conduit is preferred for ELD duct systems. To reduce costs or for special applications, direct-buried Schedule 80 PVC conduit may be used in lieu of concrete encasement.

2) High-density polyethylene (HDPE) is a rigid nonmetallic conduit commonly used for boring.

4.8.1.1 PVC conduit

PVC conduit shall meet the requirements of UL651 – *Schedule 40 and 80 Rigid PVC Conduit,* NEMA TC 2 – *Electrical Polyvinyl Chloride (PVC) Conduit.* Solvent-welded socket fittings shall meet the requirements of UL514C – *Non-Metallic Fittings for Conduit and Outlet Boxes,* and NEMA TC 3 – *PVC Fittings for Use with Rigid PVC Conduit and Tubing*.

4.8.1.2 HDPE conduit

HDPE conduit shall meet the requirements of ASTM F2160-10/ASTM 1962-11/NEMA TC7.

4.8.2 Plastic-coated steel conduit

4.8.2.1 PVC coated RGS

Where situations warrant, such as when runway and equipment shutdown impacts are a consideration, PVC coated RGS may be used in lieu of concrete encased PVC duct. This substitution must be annotated on the drawings. Direct-buried rigid galvanized steel shall be plastic coated. An acceptable alternative is RMC wrapped in half-lap fashion with pressure-sensitive 10-mil PVC-based corrosion protection tape.

PVC exterior coated, urethane interior coated, galvanized rigid steel conduit shall meet the requirements of NEMA RN 1 – *PVC Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit.*

4.8.2.2 Fittings and conduit bodies

Use 40 mil PVC exterior coated, urethane interior coated, zinc-plated, threaded, malleable iron meeting the requirements of UL514B – *Fittings for Conduit and Outlet Boxes*, and NEMA RN 1 – *PVC Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit*.

4.8.3 Direct buried rigid nonmetallic conduit

Direct-buried conduit shall be Schedule 80 PVC.

Solvent-welded socket fittings shall meet the requirements of UL514C – *Non-Metallic Fittings for Conduit and Outlet Boxes*, and NEMA TC 3 – *PVC Fittings for Use with Rigid PVC Conduit and Tubing*.

4.8.4 Rigid metal conduit (RMC)

Above-ground exterior conduit shall be rigid steel conduit.

Conduit used in exterior applications such as in an equipment rack shall meet the RGS requirements of UL6 – *Rigid Metal Electrical Conduit*, and ANSI C80.1 – *Rigid Steel Conduit, Zinc Coated*.

RMC fittings and conduit bodies shall meet the requirements of UL514B and ANSI/NEMA FB1.

Fittings: Follow NEMA TC 9, NEMA TC 14, and ASTM F-512.

4.9 Corrosion protection tape

Use pressure-sensitive, 10-mil-thick, PVC-based tape for corrosion protection of metal conduit and fittings.

4.10 Insulating bushings

Use NRTL-listed insulating bushings with 105º C rated insulation. Apply insulated protective caps to any unoccupied bushings. Dust caps shall not be used as substitutes for protective caps.

4.11 Grounding bushings

NRTL-listed, galvanized malleable iron, 150º C rated insulated throat grounding bushings with lay-in type ground cable lugs.

4.12 Sweeps

All sweeps shall be PVC-coated or tape-wrapped rigid galvanized steel (RGS).

Do not provide sweeps into a manhole. Vaults shall be considered for all transformer and switchgear applications wherever possible, eliminating the need for sweeps.

4.13 Duct spacers

Standard precast spacers ("chairs") shall be used for duct support and alignment. Duct spacers shall provide a 3-inch separation between the conduit and the ground. There shall be a minimum of 3 inches of concrete on bottom, sides, and top of duct.

4.14 Duct plugs

In unused ducts, use soft, expansible gasket material compressed with non-metallic plates and bolts to produce a positive seal against water and gas.

4.15 Duct sealant and joint filler

Use expandable foam duct sealant kits to prevent water and gas from entering manholes, vaults, or structures.

Use premolded joint filler to fill holes in and around conduit to keep rodents out of the ELD system. Use closed-cell expanded neoprene joint filler conforming to ASTM D1056 – *Standard Specification for Flexible Cellular Materials - Sponge or Expanded Rubber*.

4.16 Underground duct and cable warning tape

Furnish detectable underground warning tape for underground duct banks. Use aluminum-backed, 0.005 inch thick, underground warning tape with a red background color. Lettering shall be black and indicate the type service buried below:

"CAUTION BURIED ELECTRIC LINE BELOW"

Use tape width appropriate for the burial depth:

A. Three-inch wide tape for up to 18 inches depth.
B. Six-inch wide tape for up to 24 inches depth.

All direct buried cable shall be marked with extrusion-laminated underground marking tape. Tape shall be a minimum of six inches (6”) wide and shall run continuously in the cable trench six inches (6”) below the surface or as indicated on the project plans. Tape shall be bright red, and constructed of solid 100% pigmented plastic, and not an ink-coated plastic.

4.17 Pull wires and tape

For spare ducts, specify ¼ inch pull tape having a minimum tensile strength of 400 pounds for non-metallic conduit. The FAA project engineer may specify a larger or more specialized pull tape (impregnated lubricant, distance marking, etc).

For ELD circuits that include raceways within vaults or other locations, raceway measuring/pulling tape may be used. Tape shall have permanently printed measurements in one-foot increments and minimum 1200 lb average breaking strength.

4.18 Precast electrical manholes and hand holes, accessories

4.18.1 Manholes and hand holes

Precast reinforced concrete electrical utility structures shall be of the size and shape as detailed on the drawings in conformance with ASTM C-858 – *Standard Specification for Underground Precast Concrete Utility Structures*. Electrical manholes are typically 4’ long, 4’ wide, and 4’ high, or as shown on the drawings. Electrical manhole sections shall conform to ASTM C-478.

4.18.1.1 Manholes/hand hole structures, frames, and lids

4.18.1.1.1 Airports handling aircraft with maximum departure/takeoff weight of 30,000 lb and above--For airports with a design aircraft maximum departure weight of 30,000 lb and above,* manholes/hand holes, frames, and lids located within the airport runway/taxiway safety areas (RSA/TSA) shall be of the aircraft-rated type, designed and certified for 100,000 lb (45,000 kg) wheel loads with 250 psi (1.72 MPa) tire pressure. (Refer to FAA Advisory Circular 150/5320-6, Appendix 3, *Design of Structures for Heavy Airplanes*). Clearly indicate on the drawings underground utility structures that will be subject to aircraft loading. For planned future-expansion projects where manholes and hand holes are projected to fall within RSA and TSA boundaries, those structures shall be aircraft rated.

Outside the RSA/TSA, H-20 highway-rated manhole and hand hole components are permitted, provided an adequate proof load safety margin for the casting is met. First, live loading shall meet basic H-20 loading requirements per A.A.S.H.T.O. HB-17, *Standard Specifications for Highway Bridges*. The live load shall be that loading which produces the maximum bending and shear moments in the structure. H-20 design wheel load is a minimum of 16,000 pounds, or 80 psi. For the safety margin, the casting must meet AASHTO M306, which requires that it pass a proof load test of 40,000 lb applied on a 9x9-in. pad in the center of the casting. H-20 rated utility structures that do not meet the above requirements shall not be used.

Manholes that consist of two sections shall be joined at the site to provide a watertight joint using a preformed flexible sealant as specified in ASTM C-990. A twelve inch (12 in.) diameter sump, four inches (4 in.) deep, shall be cast in the center of the manhole floor and supplied with a cast iron cover.

Manhole floor shall be cast integral with walls to form the bottom ring. Furnish a keyed joint between the bottom ring and top ring. Manhole roof shall be a one-piece concrete cap.

*Airports handling dual-wheel-landing-gear aircraft up to 60,000 lb maximum departure weight are permitted to use highway-rated manholes/hand holes and components in the RSA/TSA because the wheel load is distributed over four tires (60,000 ÷ 4 = 15,000 lb). Adequate safety margins must be met through proof loading. Refer to the H-20 loading requirements specified above.

4.18.1.1.2 Airports handling aircraft maximum departure/takeoff weight of 30,000 lb or below-- For airports with a design aircraft maximum departure weight of 30,000 lb or below (60,000 lb if dual-wheel landing gear), manholes/hand holes, frames, and lids located both within and outside the airport runway/taxiway safety areas (RSA/TSA) shall be of the highway-rated type, provided a safety margin for the manhole casting is added. Live loading shall be for H-20 loading with adequate safety margin as described in Section 4.18.1.1.1 above. Clearly indicate on the drawings underground structures that will be subject to aircraft loading.

For planned future-expansion projects where manholes and hand holes are projected to fall within RSA and TSA boundaries, and the expansion is expected to accommodate heavier aircraft with maximum departure/takeoff weight of 30,000 lb and above (60,000 lb if dual-wheel landing gear aircraft), those structures shall be aircraft rated. Concurrently, existing non-aircraft-rated manhole/hand hole structures throughout the airport's RSA/TSA areas shall be retrofitted with aircraft-rated structures and components.

Outside the RSA/TSA in non-vehicular traffic areas, other types of enclosure structures (e.g., polymer concrete, nonreinforced concrete, or other) may be used provided (1) they meet ANSI Tier 22 (design/ test = 22,500/33,750 lb) specifications, and (2) have been approved by the FAA resident engineer.

Manholes that consist of two sections shall be joined at the site to provide a watertight joint using a preformed flexible sealant as specified in ASTM C-990. A twelve inch (12 in.) diameter sump, four inches (4 in.) deep, shall be cast in the center of the manhole floor and supplied with a cast iron cover.

Manhole floor shall be cast integral with walls to form the bottom ring. Furnish a keyed joint between the bottom ring and top ring. Manhole roof shall be a one-piece concrete cap.

Manhole markings--Identify electrical power manholes and hand holes by "FAA Power" markings cast in the steel cover, or so identified with a die stamped, nominal one sixteenth inch (1/16") minimum thickness copper plate, brazed or fastened to the cover with a minimum of two 10-32 brass machine screws.

4.18.2 Manholes accessories

Frame and lids--Use heavy duty cast iron manhole frame with solid lid. Lid may be spring loaded. Alternatively, lid may consist of partitioned aircraft-rated lid segments, each segment capable of being lifted separately, facilitating easier and safer access.

Racks--Cable racks and cable support arms shall be furnished in the quantities and locations indicated by the drawings for each manhole. Racks shall be made of nonmetallic material (for example, PVC, plastic, or UL-rated glass-reinforced nylon). Saddle arms shall be as per the approved project drawings. Splices and cables shall be attached to cable racks.

4.19 Grounding cables

Depending on the application, ELD exterior grounding conductors shall be of the type and size required by applicable sections of FAA-STD-019.

a. For equipment grounding conductors, use 4/0 AWG bare stranded, soft temper copper cable per ASTM B 8, *Standard Specification for Concentric-Lay Stranded Copper Conductors.*

b. For guard wire, use 1/0 AWG bare copper, stranded.

c. For bonding conductors, use No. 2 AWG bare copper, stranded.

4.20 Ground rods

Ground rods (“grounding electrodes”) shall be three quarter inch (3/4”) by ten foot (10’) long copper or copper-clad steel.

4.21 Weather heads on risers, drip loops

Risers feeding FAA owned underground distribution systems shall have weather heads installed. Each weather head shall have drip loops that loop no less than 6” below the weather head.

4.22 Electrical equipment enclosures

Bases and cabinets of electrical equipment shall be constructed of materials suitable to their geographic location.

Typical, dry environments--For typical dry conditions, mild steel bases and enclosures may be used. These provide protection against rain, sleet, and snow in outdoor applications.

Corrosive or wet environments—For typical wet (or wet and salt-corrosive) conditions, use stainless steel bases and enclosures.

Use stainless steel bases and cabinets in most applications. The manufacturer's standard construction material is acceptable only in noncoastal and noncorrosive environments. For coastal/corrosive environments, ensure that front sill, hood, and tank base of single compartment transformers are corrosion resistant and constructed of stainless steel of not less than No. 13 U.S. gage, conforming to ASTM A167, Type 304 or 304L, unless otherwise indicated on the drawings. Base shall include any part of the pad-mounted transformer that is within 1.5 inches of the concrete pad.

In highly corrosive environments, the addition of totally stainless steel tanks and metering is required.

4.23 Equipment vaults and pads

Follow the drawings for specification and construction details of equipment foundation support structures. Specific applications are as follows:

4.23.1 Concrete vaults

For low-profile single phase transformers, use precast concrete vaults to facilitate ease of transition from duct bank system to transformer termination points. Concrete shall meet or exceed a 28-day compressive strength of 3,000 psi.

4.23.2 Concrete pads for transformers

Foundations of poured concrete pads for larger size transformers (>50 kVA) shall have a minimum thickness of 6 inches, unless otherwise specified on the drawings. Thicker pads than 6 in. may be considered in areas subject to frost heave. Concrete shall meet or exceed a 28-day compressive strength of 3,000 psi.

4.23.3 Concrete pads for equipment racks

Foundations of poured concrete pads shall have a minimum thickness of 6 inches, unless otherwise specified on the drawings. Thicker pads than 6 in. may be considered in areas subject to frost heave. Concrete shall be chamfered, brushed, and graded for drainage. Expansion couplers on protruding conduits should be considered in areas prone to frost heaving or ground settling. Concrete shall meet or exceed a 28-day compressive strength of 3,000 psi.

Prefabricated concrete pads with cutouts for cables can be used where frost heave is prevalent. Arrange for lift equipment to place the pads. Install cables in conduit and leave a slack length of cable in case the pad is displaced upward by ground frost.

4.23.4 Composite polymer concrete equipment pads

If approved by the FAA Resident Engineer and included on the drawings, lightweight polymer concrete flat pads and box bases that provide sufficient strength-to-weight ratios may be used. These units have cutouts and preinstalled mounting hardware. No extra equipment is required to lift the pads into position.

Composite pads/boxes shall be composed of cement mortar reinforced by alkali resistant glass fibers. The material shall incorporate a minimum of 4 percent by volume of alkali resistant glass fibers.

Composite pads/boxes shall meet or exceed a compressive strength of 11,000 psi per ASTM C579-96, a flexural strength of 1,800 psi per ASTM C580-93, and a modus of elasticity of 2,900,000 psi per ASTM C580-93. Composite pads/boxes shall also pass chemical resistance and impact resistance tests in accordance with ASTM C267-97 and D2444-93.

Composite pads/boxes shall not warp, support flame, rust, or be UV degradable. They shall have a waffle bottom design to permit loose earth to fill bottom voids to level and stabilize the pad. The pad/box shall not be affected by asphalt, road salts, fertilizers, transformer oil, other common chemicals, weather, sunlight or other normal service conditions to which they may be exposed. Composite pads/boxes shall be capable, with equipment installed, of withstanding temperature variations of -40 degrees C (-40 degrees F) to +65 degrees C (149 degrees F) without cracking, splitting, or deforming. They shall not be designed and constructed so as to trap or hold water and shall be able to withstand repeated freeze-thaw cycles.

4.24 Bollards

Bollards shall be used only where it is necessary and/or as required by the airport authority to protect electrical equipment and enclosures from field vehicle damage or other mechanical damage. Bollard use and placement shall be as specified on the drawings or as determined by final location of equipment. Unless otherwise specified, use 4-in. diameter steel pipe filled with concrete. Bollards shall be placed 3 ft deep and extend 4 ft above ground level. Premanufactured plastic jackets shall cover each bollard.

5. EXECUTION

5.1 Scheduling of work

Airport runways must remain in operation during certain periods. Contractors shall proceed in a manner that produces minimum disruption to the FAA and airport operations. During construction activity, contractors shall coordinate work through the FAA Resident Engineer, the airport authority, air traffic control tower, airport security, and other contractors as defined by the contract documents. Work performed within the RSA/TSA of an active runway may require runway/taxiway closing. Advance notice of proposed work near an active runway shall be required to be given by contractors to the FAA.

5.2 Existing FAA buried cable and ducts

5.2.1 FAA documentation

The contract documents define the drawing format used by the FAA to record the location of buried cable and ducts. The contractor shall use the FAA format during the course of work to ensure the accurate location of the new installations as described on the FAA drawings. The contract documents shall include copies of FAA drawings for the area of work. Contract drawings and engineering documents published by a non-FAA entity shall be approved by the FAA project engineer.

5.2.2 FAA marking of known buried cables and ducts

All known FAA power and control cables leading to and from an operating facility will be marked in the area of work by the FAA for the information of the contractor before starting work. The FAA will mark these cables once for the contractor. It shall be the contractor's responsibility to maintain these markings throughout the course of the project. Airport mowers may be expected to be in use by airport personnel throughout the duration of the work, keeping markers visible. FAA is responsible for marking FAA cables ONLY. The contractor shall be responsible for marking other cables and utilities in the work areas through a third party location service.

5.2.3 Other buried cables, ducts, piping and items

Locating utilities--The contractor shall be responsible for contacting the utilities prior to starting work and for confirming the location of existing utilities and other items that may be buried in the area of work. Along an area suspected of having utilities of any sort, the contractor shall hand dig or use other authorized low-impact digging system. The airport authority shall be contacted to locate those items owned or known by the airport to exist.

Avoiding buried structures--The contractor shall take precautions to protect existing underground (buried) items including but not limited to; fuel tanks, water lines, cables, ducts, and structures.

Buried items shall be protected from damage for the duration of work. The contractor shall immediately repair, with equal material by skilled workmen, those items damaged by the contractor or subcontractor.

Procedure for making repairs during installation--Prior authorization from the FAA shall be obtained for the materials, workers, time of day or night for making repairs, method of repairs, and permanent repairs the contractor proposes to make. In the event of inadvertent damage, the contractor shall immediately stop work and notify the FAA and utility when appropriate. Repair work shall be inspected and authorized by the FAA with the concurrence of the affected utility company, airport, or other owner(s) of the damaged item(s).

Cables to be abandoned—When a DEB cable is identified to be abandoned, where possible it shall be disconnected and left in place. Unless otherwise directed, cut the cable, armor, and ground wires back 10 feet at each end. Where possible, exothermically weld the cable ends to ¾" by 10' ground rods 12 in. below grade. Document the section that was cut back as "abandoned" on as-built drawings.

When a cable in duct is identified to be abandoned, ground the cable, armor, and ground wires at both ends. Where possible, exothermically weld the cable ends to ground rods 12 in. below grade. Document the section that was cut back as "abandoned" on as-built drawings.

Replaced cables—Replaced cables shall trace the same routing path as previously employed. Should there be a need to divert from the previous route, careful planning shall be exercised, especially in areas where utilities, communications, control, and NAVAIDS systems such as Glide Slope and Localizer facilities are installed or planned to be installed in the future. Approval from the office of primary interest is required.

5.3 Safety during construction and testing

All necessary site work included in the overall scope of work, from delivery to site to final authorization, shall undergo a safety risk assessment. A detailed, site-specific, Safety Risk Assessment shall be submitted by the contractor to FAA for final authorization no fewer than 3 weeks prior to commencement of on-site work. During construction, installation, and testing, the contractor shall comply with the safety rules of FAA (FAA Order JO 3900.XX, FAA Advisory Circular AC 150/5370-2) and those dictated by OSHA (Part 1926), NEC, ANSI/IEEE, and ANSI C2 (the NESC). The contractor shall be responsible for the implementation of FAA-authorized items in the Safety Risk Assessment document.

5.4 Excavation and trenching

The following are general excavation and trenching requirements. Note paragraphs that follow for particular requirements for either (1) direct earth buried cables, or (2) underground duct cables.

5.4.1 Depth requirements

IEEE ANSI C2 (part of the National Electric Safety Code) specifies the minimum legal depth requirements for medium-voltage power cable during installation. Tailoring organizations shall evaluate site-specific requirements and follow the following standards in order of precedence: (1) IEEE ANSI C2, then (2) paragraphs below, then (3) local standards if applicable.

Conduits shall meet the following minimum standards:

a. Unless otherwise specified due to soil conditions or other circumstances, cables, conduits, and ducts shall be buried to the minimum depth to their top as specified by the following paragraphs b through g. In the event that achieving the minimum depth is not feasible, follow the direction of the FAA Resident Engineer.

b. Top of direct-earth buried (DEB) conduit or cables under 600V shall be a minimum of twenty four inches (24") below finished grade, per ANSI C2 (see Table I), unless local conditions and regulations require deeper burial, in which case the contractor shall advise FAA about these conditions and regulations before proceeding with the construction.

TABLE I. Burial depths (source: ANSI C2)

Voltage (phase to phase)	Depth of burial	
	(mm)	(in.)
0 to 600	600	24
601 to 50,000	750	30

c. Top of direct-earth-buried conduit or cables over 600V shall be a minimum of thirty inches (30") below finished grade, per ANSI C2 (see Table I), unless local conditions and regulations require deeper burial, in which case the contractor shall advise FAA about these conditions and regulations before proceeding with the construction.

d. If finished grade has not been established before the cable trenches are excavated, it is the contractor's responsibility to determine what the final finished grade elevation will be and excavate the trench deep enough to meet the depth requirements at the end of the project.

e. Underground concrete-encased duct, and duct consisting of PVC Schedule 80, HDPE, or RGS conduit, shall be installed so that the top of the conduit is buried at not less than twenty-four inches (24") below finished grade.

f. Additional requirements for all ducts: concrete-encased duct, rigid steel conduit, or PVC conduit shall be installed so that the top of the conduit is buried as follows:

1. When installed under runways, not less than four feet (4') below the bottom of paving, or as specified by the airport authority,

2. When installed under taxiways, not less than four feet (4') below the bottom of paving, or as specified by the airport authority,

3. When installed under other paved areas, in accordance with Table I or as required by the local jurisdiction.

4. For railroads and state-owned highways, at the minimum depth below grade as specified by those entities.

5. Where local conditions require unusually deep burial of ducts, contractor shall discuss the situation with the FAA project engineer and obtain preauthorization.

g. In northern climates where deep trenching is cost prohibitive, use a standard depth of not less than 24 inches (24") from top of duct, cable, or conduit to finished grade.

h. Cables shall not be direct buried under paved areas, runways, taxiways, roadways, railroad tracks, or ditches. Where cables cross under roads or other paving exceeding 5 feet in width, such cables shall be installed in rigid steel conduit, concrete-encased PVC, steel conduit, or high-density polyethylene (HDPE) conduit, as defined by the contract documents. Where cables cross under railroad tracks, such cables shall be installed in accordance with the requirements of the railroad authority. Cables under railroad grades may be installed in reinforced concrete-encased ducts, rigid galvanized steel sleeves, or HDPE conduit, subject to the requirements of the railroad authority. HDPE must be of sufficient crush strength to withstand expected static and dynamic loads over the expected lifetime of the cable without deformation. For directional boring under railroad and roadway grades, standard dimension ratio (SDR) 11 or 9 shall be used depending on conditions and conduit diameter. The SDR of a conduit is defined as the ratio of the average conduit diameter divided by the minimum wall thickness. Damage to conduit coatings shall be prevented by providing ferrous pipe jackets or by predrilling. Ducts shall extend at least 1 foot beyond each edge of paving and at least 5 feet beyond each side of railroad tracks.

i. Where direct burial cable transitions to duct-enclosed cable, direct-burial cables shall be centered in duct entrances, and a waterproof nonhardening mastic compound shall be used to facilitate such centering. Cables may be pulled into duct from a fixed reel where properly sized rollers are provided in the trench. Where cuts are made in paving, the paving and subbase shall be restored to their original condition. Where cable is placed in duct (for example, under paved areas, roads, or railroads), ducts shall be made to slope in order to drain.

5.4.2 Survey requirements

5.4.2.1 Recording of data

The ELD project record shall consist of (a) information entered in computer-aided design and drafting (CADD) systems, (b) manual plotting onto the FAA drawing set, (c) Global Positioning System (GPS) data, (d) Geographic Information System (GIS) information or databases, and/or (e) other appropriate documentation as set forth in the contract documents.

Placement of markers--Drawings shall record positions of markers placed in or on top of direct earth buried (DEB) power cable trenches, and at duct bank manholes and hand holes. The markers shall be identified on the drawings by a small circle with a "P" in the center for power cable, "C" for control/fiber cable, "R" for coaxial cable, "S" for special purpose points, and "T" for telecommunications.

DEB cable--DEB cable trenches shall be identified on the drawings with text boxes pointing to the trench indicating what is in the trench. If there are several cables in the trench, each cable shall be called out. Power cables shall be identified by the actual working voltage of the cable and not by the cable insulation rating. Anything unusual, peculiar, or unique about the cable runs shall also be called out in the drawings.

Duct banks--Duct banks shall be plotted on the drawings. Duct banks that are installed for future use shall have text boxes pointing to them indicating that they are future-use duct banks. In the case of a duct bank where the duct bank is not a straight line between the manholes or hand holes, enough markers of the type specified herein shall be installed to accurately depict the routing of the duct bank.

Manholes, hand holes, and splices--Manholes shall be identified on drawings by a small square with an "MH" in the center. Hand holes shall be identified by a small square with an "HH" in the center. Where manhole and hand hole numbers are provided on the contract drawings, they shall also be called out on the completed cable drawing. Splices made in manholes and hand holes shall be shown on the cable drawings.

Abandoned cables--The contractor shall provide data on the types and locations of abandoned cables in places where they affect the excavation of new trenching, such as at points of intersection with other structures, including runways, taxiways, concrete pads, utility pathways, roads, etc. This information shall be included on the drawings.

5.4.2.2 Survey points

The contractor shall record the survey point of each manhole using GPS coordinates. At each major change of direction of the cable circuit, a manhole shall be present and its location surveyed and recorded. Surveying and data gathering for this purpose shall be completed before a trench or structure is backfilled.

If for some reason the cable path deviates from a straight line between manholes and is not capable of being traced using tracing equipment, the deviation should be recorded as a survey point on the drawings for future reference. Where the cable terminates to a building, a transformer, an antenna, a light bar, an outside demarcation cabinet, switch rack, or other similar device, the survey shall include the four corners of the device or facility where it terminates. A tolerance of plus or minus five inches (± 5") will be acceptable for describing the cable path.

Special-purpose points--Special-purpose points may be used to indicate points such as splices or entrances to duct banks in records and on the drawings. Special-purpose points shall be accompanied by a text box to describe the function of the specific point.

5.5 Underground duct systems

Power distribution cables at FAA installations shall be installed in underground duct systems. Unless preauthorized per the drawing set and construction specifications, direct earth burial (DEB) of power distribution cables is prohibited. If preauthorized, any DEB construction shall meet the requirements in Section 5.6.

5.5.1 Preparation and excavation for underground ducts

In preparing to install underground ELD ducts, contractor shall meet the industry standards given in this section. Contractor shall also work with FAA to contact the owner for their requirements, coordinating underground ELD duct work to avoid interference with other airport projects and existing utilities. The contract specifier shall work with the Power Cable (ELD) Program Office to ensure coordination of work with other FAA programs that may have an interest in using the same duct system or trench.

The contractor shall excavate trenches for underground ducts as follows:

a. To the depth specified in paragraph 5.4.1c.

b. Install underground duct bank systems according to the NEC, the NESC, NECA/NEMA 605 (*Recommended Practice for installing Underground Nonmetallic Utility Duct)*, ANSI/IEEE C2, and other requirements in this section.

c. Verify routing and termination locations of duct banks before excavation for rough-in.

d. Verify that field measurements are as shown on the drawings.

e. Position trench so concrete envelope of duct banks shall have the following minimum horizontal and vertical separations from parallel or perpendicular runs of other utility pipes or conduits (Table II). Note: Measurements are guides only; check with local authorities and the owner for their specific requirements.

f. Make trenches of sufficient width to receive work to be installed and provide specified concrete coverage on sides.

g. Conduit or castings required under roadways or railroads shall be installed by boring. Jacking of conduit is not allowed. Conduits bored under roads off airport property shall be a minimum of thirty inches (30”) below finished grade, or as required by the local jurisdiction.

h. Backfill excavations for duct banks and manholes in 6-inch layers using excavated soil. Remove roots, rocks and sharp objects. Furnish coarse sand as required for additional backfill material.

i. Moisture condition backfill soil and compact to 95% of maximum density under paved areas and 90% of maximum density under unpaved areas.

j. Overfill excavations to allow for settling.

k. Firmly tamp backfill in the separation area.

l. Restore area.

TABLE II. Spacing of power cable ducts from other utilities.

UTILITY TYPE	PARALLEL LINES	PERPENDICULAR CROSSINGS
Water	36 inches horizontal separation	24 inches
Gravity Sewer	36 inches horizontal separation	24 inches
Force Main Sewer	36 inches horizontal separation	24 inches
Storm Drain	36 inches horizontal separation	24 inches
Natural Gas	60 inches horizontal separation	24 inches
Steam or Hot Water	60 inches horizontal separation	24 inches
Open Communications	24 inches horizontal separation of tamped soil or 3 inches of concrete	12 inches vertical separation of tamped soil or 3 inches of concrete
Secure Communications	36 inches horizontal separation of tamped soil or 6 inches of concrete; verify case-by-case with FAA office of primary responsibility.	24 inches vertical separation of tamped soil or 6 inches of concrete; verify case-by-case with FAA office of primary responsibility.
Electrical	12 inches horizontal separation of tamped soil or 3 inches of concrete	12 inches vertical separation of tamped soil or 3 inches of concrete

5.5.1.1 Connecting requirements for HDPE conduit running through and emerging from a bore

When placing HDPE conduit underground through a bore, use one continuous length of flexible HDPE conduit. In instances where a continuous run of conduit is not possible, individual sections shall be joined using heat-welded (fused) connections. After emerging from a bore, the HDPE will typically terminate in a manhole at both ends.

To join lengths of conduit together after emergence from a bore, follow these procedures:

a. If the emerging HDPE conduit is to be joined to PVC conduit, the HDPE conduit section shall be run into the bell end of the PVC conduit and cemented using a special bonding agent (Table III) (see Appendix F for a sample two-part bonding product). Adhesives typically used for connecting PVC segments are not of sufficient strength for HDPE-to-PVC transitions and shall not be used. Alternatively, the HDPE conduit may be connected to a PVC coupling on the end of a length of PVC conduit. The point of transition shall then either be (1) encased in concrete together with the remaining run of PVC, or (2) direct earth buried, depending on the type of burial method used for the rest of the run.

b. Connection details involving HDPE conduit shall be shown on the drawings.

TABLE III. Adhesive minimum pullout-force requirements for bonding HDPE to HDPE and HDPE to PVC conduit materials.

Conduit Diameter	Polyethylene Conduit to PVC Standard Coupling	
	Coupling length	Pullout Force
1 inch	2 ⅛ inch	760 lb
1 ½ inch	2 ⅜ inch	1,140 lb
2 inch	2 ½ inch	1,520 lb
4 inch	3 ¾ inch	4,560 lb

5.5.2 Backfilling

Backfilling material and procedures depend on the design used, whether concrete-encased duct or direct buried conduit. Consult FAA Advisory Circular AC 150/5370-10 for construction details.

Trenches shall be completely backfilled and tamped level with the adjacent surface. When necessary to obtain the desired compaction, backfill material shall be moistened or aerated. When sod is to be placed over a trench, backfill shall be stopped at a depth equal to the thickness of the sod to be used. Excess excavated material shall be removed in accordance with the contract documents.

5.5.3 Restoration

Restoration shall be in accordance with local airport authority requirements, or as otherwise stated in the contract statement of work. Where it has been removed, soil 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 the original condition.

Restoration shall include the necessary grading, seeding, sodding, sprigging, or hydroseeding as required to restore the disturbed area to match the adjacent area. Where trenching cuts through paved areas, the surface shall be properly backfilled and resurfaced with paving similar to the original paving or concrete as the drawings specify.

Resurfaced areas shall be level with original paving, free from cracks, and capable of withstanding full traffic loads without settling or cracking. The contractor shall be held responsible for maintaining all disturbed and restored surfaces until final acceptance by the FAA.

5.5.4 Duct installation

Cable duct banks shall be installed outside of the airport runway/taxiway service areas (RSA/TSA), as well as ILS critical areas, to the greatest extent possible. Where trenching is required through an RSA or TSA area, place the manholes to the farthest extent possible outside the RSA and TSA while still maintaining standard spacing and directional change requirements as noted elsewhere in this specification. For locations of RSA/TSA/ILS areas, consult with the FAA Resident Engineer. (See also FAA Order JO 6750.16, *Siting Criteria for Instrument Landing Systems*, and FAA Advisory Circular 150/5300-13, *Airport Design*, particularly Chapter 6, *Navigation Aids [NAVAIDs] and On-Airport Air Traffic Control Facilities [ATC-F]*).

When there is an immediate change in direction of a duct system, a manhole or hand hole shall be installed. Any gradual change in direction (e.g., a gradual arc of the duct) shall require the approval of the resident engineer prior to installation.

5.5.5 Manhole and hand hole installation

5.5.5.1 Manhole installation

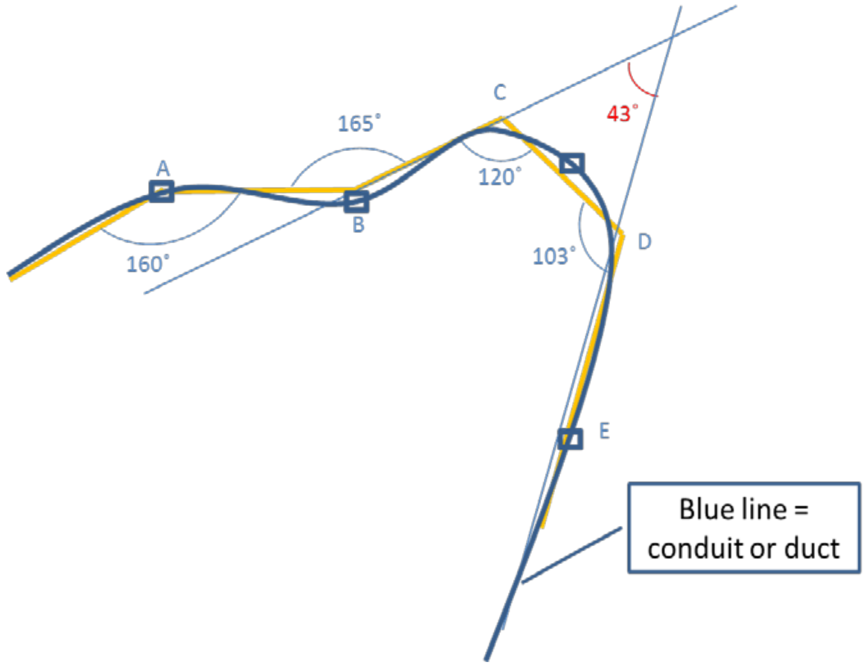
Install manholes every 600 feet. Where there are long continuous, straight runs, manholes may be placed up to 1200 feet apart with preapproval of the project engineer. When there is a planned change in direction of the conduit between manholes of greater than 45 degrees (cumulatively within a run), an additional manhole shall be installed in place of the directional change (Figure 5.5.5.1-1).

The top of the completed manhole shall be set above finish grade in unpaved areas to prevent water from ponding on the manhole. Place the top of the manhole 2 inches (2") above grade, plus or minus 1 inch (1"). Grade the backfill material downward and away from the manhole. A one-eighth-inch (1/8") per foot fall from the manhole top to finish grade, ten feet (10') from each edge of the manhole is recommended.

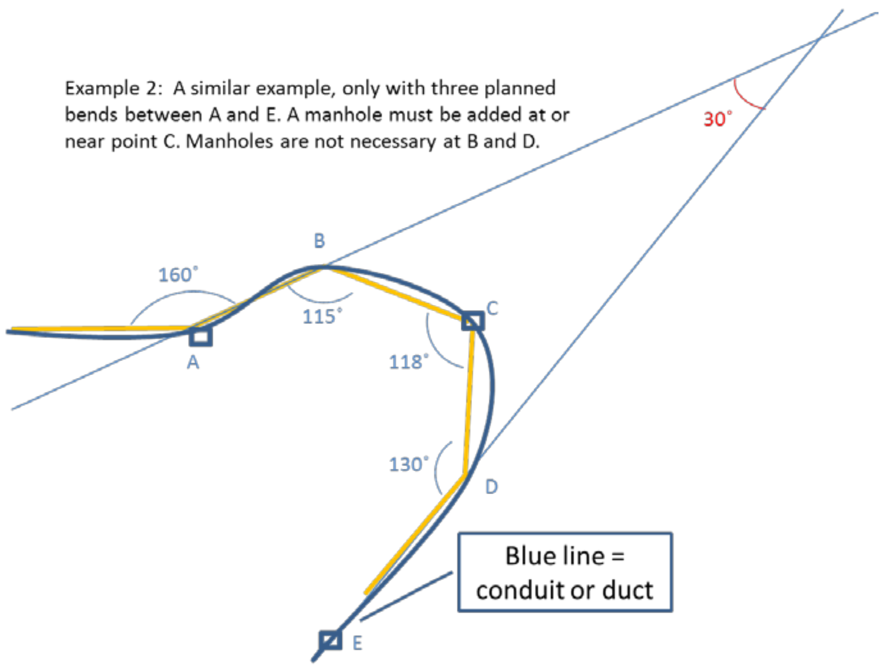
The manhole lower half shall be set on a four-inch (4") bed of crushed stone on undisturbed earth. Add a layer of geotextile fabric between the gravel and earth to enhance soil stability and prevent settling of the manhole. The contract drawings will define any additional requirements where soil bearing capacities are an issue or concern.

Backfill around the manhole in lifts commensurate with the soil and compact each backfill lift to the density of the surrounding earth.

Example 1: Bends at points A and B are greater than 45 degrees and are proper. Bends at planned manholes C and D each individually are greater than 45 degrees and are nominally proper, but in combination, they form a virtual angle of less than 45 degrees. Therefore, a manhole is required between points C or D. Measured angles shall take into account entrance and exit angles of the duct if entering or leaving a manhole or hand hole.



(A)



(B)

FIGURE 5.5.5.1-1. Adding a manhole at points of tight radius of a duct or conduit.

5.5.5.2 Hand hole installation

The top of the hand hole shall be set above finish grade in unpaved areas to prevent water from ponding on the hand hole. A one eighth inch (1/8") per foot fall from the manhole top to finish grade, ten feet (10') from each edge of the hand hole is recommended.

The hand hole shall be set on a four-inch (4") bed of crushed stone on undisturbed earth. Add a layer of geotextile fabric between the gravel and earth to enhance soil stability and prevent settling of the manhole. The contract drawings will define any additional requirements where soil bearing capacities are an issue/concern.

Backfill around the hand hole in lifts commensurate with the soil and compact each backfill lift to the density of the surrounding earth.

5.5.5.3 Manhole and hand hole penetrations

Where a steel conduit penetrates a wall of a manhole or hand hole, a grounding bushing shall be installed. These grounding bushings shall be connected to each other and to the earth ground system with 6 AWG tinned bare copper conductors.

Conduits entering a junction box or other electrical cabinets from underground shall be sealed with duct sealing compound**.** Expanding foam sealants are not allowed for this purpose.

Conduit connections to exterior boxes, electrical cabinets, or switches shall be made with weatherproof hub fittings.

5.5.6 Mandrel requirements

The contractor shall mandrel each duct or conduit installed and each existing duct or conduit in which cable is installed or replaced. As each conduit run is completed, proceed according to the following steps:

a. For conduit sizes 3 inches (3") and larger, draw a flexible testing mandrel approximately 12 inches (12") long with a diameter less than the inside diameter of the conduit through the conduit. Next, draw a stiff bristle brush through until conduit is clear of particles of earth, sand, and gravel; then immediately install conduit plugs.

b. For conduit sizes less than 3 inches, draw a stiff bristle brush through until conduit is clear of particles of earth, sand, and gravel; then immediately install conduit plugs (see UFGS 33 71 02.00 20).

c. If the mandrel fails to pass through the duct being tested, either the duct is obstructed, misaligned, or the curve has too small a radius. If obstructed, use a high-pressure water jet to clear the conduit. Defective duct(s) shall be exposed and the defect corrected. After the duct(s) are repaired, repeat the mandrel test in that section of duct.

5.5.7 Spare ducts, preparation

Prepare spare ducts in the following manner. Install ¼ inch pull tape having a minimum tensile strength of 400 pounds for non-metallic conduit. The FAA project engineer may specify a larger or more specialized pull tape (impregnated lubricant, distance marking, etc) unless cost prohibitive. Seal the open ends of spare ducts with removable tapered plugs of a type recommended by the duct manufacturers. Adapt the plug to firmly secure the pull tape.

5.5.8 Duct protection

All power cable ducts shall be securely fastened in place during construction and progress of the work, and shall be plugged daily at the end of work to prevent entrance of foreign material. A duct section having a defective joint shall not be installed.

All concrete-encased power cable ducts shall be raised at least 3 inches off the bottom of the trench using spacers ("chairs"). Bottom spacers may be secured to nominal one inch (1") boards to prevent sinking and overturning. This step shall be followed by a monolithic pour of concrete. Where two or more ducts are encased in concrete the contractor shall space them at not less than one and a half inches (1-1/2") (measured from outside wall to outside wall) using spacers applicable to the type of duct. As the concrete pour progresses, concrete not less than three inches (3") 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 (5') to ensure a uniform spacing between ducts.

Joints in adjacent ducts shall be staggered a minimum of twenty four inches (24") apart and shall be made completely waterproof prior to covering with concrete.

5.5.8.1 Concrete mix specification

Concrete used in FAA ELD projects shall meet the cement, fine and coarse aggregate, and water specifications; mix design; compressive strength; and curing and protection requirements of FAA Advisory Circular AC-150/5370-10. Concrete for ELD structures such as pads and vaults shall have a minimum 28-day compressive strength of 3,000 psi when tested per ASTM C39. Concrete for concrete-encased ducts shall also meet the minimum strength requirement of 3,000 psi, unless otherwise directed by the FAA Resident Engineer.

5.5.9 Ducts without concrete encasement

Trenches for single-duct power cable runs shall be no less than six inches (6") or more than twelve inches (12") wide, and the trench for two or more ducts installed at the same level shall be proportionally wider. Trench bottoms for ducts without concrete encasement shall be made to conform accurately to grade to provide uniform support for the duct along its entire length. A three inch (3") layer of bedding material shall be placed around the ducts. The bedding material shall contain no particles that would be retained on a half inch (1/2") 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 (2”) apart (outside wall to outside wall) in a horizontal direction, or not less than six inches (6”) apart (outside wall to outside wall) in a vertical direction.

5.5.10 Separation of cables

For non-distribution power cable installations in the vicinity of power cables, consult first with the FAA office of primary responsibility for guidance.

Subject to the approval of the FAA project engineer, separation of cables installed in conduit or duct shall be as follows:

a. Power cables of the same circuit shall be installed in the same conduit.
b. Conductors of circuits rated 600 volts, nominal, or less, ac circuits, and dc circuits shall be permitted to occupy the same equipment wiring enclosure, cable, or raceway. Conductors shall have an insulation rating equal to at least the maximum circuit voltage applied to a conductor within the enclosure, cable, or raceway. (NEC 300.3 C 1)
c. Conductors of circuits rated over 600 volts, nominal, shall not occupy the same equipment, wiring enclosure, cable, or raceway with conductors of circuits rated 600 volts, nominal, or less unless preauthorized by the FAA project engineer and permitted in NEC 300.3 (C)(2)(a-e).
d. Except in circumstances authorized by the FAA project engineer, power cables shall not be installed in the same duct systems with communication, control, and signal cables.
e. If joint-use applications apply and are authorized, power cable shall be installed in its own separate conduit. This conduit shall be separated a minimum of three inches (3”) outside wall to outside wall, from conduits that contain communications, control, and signal cables. The actual separation for each specific case shall be stipulated by the FAA project engineer.
f. Fiber optic, communications, and control cables shall have completely separate and clearly identified and marked hand holes, pull boxes, and junction boxes.

5.5.11 Installation of cables

To minimize splicing, the longest practicable lengths of cable shall be pulled into the ducts at one time. Unless otherwise specified, electrical power manholes and hand holes shall be as far apart as practicable based on the pulling specification of the cable installed. Typically, manholes and hand holes are installed 600 ft apart and at all points where directional change of the duct system is greater than 45 degrees. For long, straight, continuous runs, spacing may be increased, not to exceed 1,200 ft, provided cable manufacturer’s specifications for pulling tension has been met, and subject to the project engineer’s oversight. To meet grounding requirements of underground multigrounded neutral cable systems over 1000 V, under no condition shall the distance between manholes or hand holes exceed 1,200 ft in accordance with NFPA 70 (NEC) Rule 96C, and ANSI C2 (NESC) standards.

Splicing lengths of cables of different construction types together is not allowed. For example, do not connect shielded cable to concentric cable, or shielded cable to old unshielded cable. Exceptions to this rule will require written PSG approval before installation.

Where a power cable duct or conduit crosses a runway or taxiway, manholes and hand holes shall be placed just outside the RSA/TSA boundaries on opposite sides of the crossing. This will allow for adequate working space to avoid penetrating the safety areas during installation and maintenance activities.

The contractor shall verify that the duct is open, continuous, and clear of debris or blockage (use mandrel) before installing cable. Cable shall be installed in a manner to prevent harmful stretching of the conductor or damage to the outer protective covering or conductor insulation. Until connections are made, cable ends shall be sealed using adhesive-lined, heat-shrink end caps. Where more than one cable is to be installed in one duct, cable shall be pulled at the same time. In no case shall a splice be pulled into a duct or conduit.

When cable cutting is required, cable ends shall be effectively sealed against moisture immediately after cutting, using end caps as above. Bends of a radius less than eight (8) times the diameter for rubber-covered or plastic-covered cable, or twelve (12) times the diameter for metallic armored cable, shall not be made. Cable that has been kinked shall not be installed.

When unreeling, an observer shall be stationed at the reel to report cable irregularities. Unless specifically stated in the drawings, cables for installation in ducts or for direct burial shall comply with FAA-E-2013D and FAA-E-2793A. Specifically excluded are bare concentric neutral wire cable types. Grounding conductors, where required, shall be a minimum size of 6 AWG bare copper wire. Fire wrap medium voltage cables in all manholes and hand holes.

5.5.12 Cable pulling

The below provisions on cable pulling shall be followed unless otherwise specified on the submittals matrix (Appendix E).

The contractor shall obtain from the manufacturer an installation manual or set of instructions that address such aspects as cable construction, insulation type, cable diameter, bending radius, cable temperature limits for installation, lubricants, coefficient of friction, conduit cleaning, storage procedures, moisture seals, testing for and purging moisture, maximum allowable pulling tension, and maximum allowable sidewall bearing pressure.

The contractor shall then perform pulling calculations and prepare a pulling plan, which shall be submitted along with the manufacturer's instructions. Cable shall be installed strictly in accordance with the cable manufacturer's recommendations, ANSI/IEEE C2 standards, and the authorized installation plan.

The pulling plan shall include:

a. Site layout drawing(s) with cable pulls identified in numeric order of expected pulling sequence and direction of cable pull.

b. List of cable installation equipment.

c. Lubricant manufacturer's application instructions. Corrosive lubricant is prohibited.

d. Procedure for resealing cable ends to prevent moisture from entering cable.

e. Cable pulling tension calculations of all cable pulls (calculated values, not maximum values).

f. Cable percentage conduit fill.

g. Cable sidewall bearing pressure.

h. Cable minimum bend radius and minimum diameter of pulling wheels used.

i. Cable jam ratio. Refer to Appendix B, item 4).

j. Maximum allowable pulling tension on each different type and size of conductor.

k. Maximum allowable pulling tension on pulling device (see UFGS-33 71 02.00 20).

Prior to pulling cable, pump the water out of the manholes and pull a mandrel/swab 1/4 inch smaller than the duct diameter through duct run to ensure adequate opening of duct run. Thoroughly swab conduits to remove foreign material before pulling cables.

Cables shall not be pulled from an outdoor (exterior) location when the outdoor (exterior) air temperature is below the cable manufacturer’s minimum recommended pulling temperature.

Contractor shall furnish required installation tools to facilitate cable pulling without damage to the cable jacket. Such equipment is to include, but be not limited to, framework, sheaves, winches, cable reels and/or cable reel jacks, duct entrance funnels, pulling tension gauge, and similar devices.

The diameter of the sheaves shall be at least 10 times that of the diameter of the largest cable. Equipment shall be of substantial construction to allow steady progress once pulling has begun. Makeshift devices which may move or wear in a manner to pose a hazard to the cable shall not be used. Cable installation may be accomplished using a power winch or by hand.

Cable pulling lubricant shall be used to ease pulling tensions. The lubricant shall be compatible with the jacket material. The FAA project engineer will authorize the pulling compound. Lubricant shall be water or silicone based so as not to injure the cable material used. Wax-based lubricants are not allowed. Lubricant shall not harden or become adhesive with age. Petroleum grease shall not be used.

Cable ends shall be sealed and firmly held in the pulling device during the pulling operation.

Use of a tensiometer is required for cable-pulling operations. Actual pulling tensions shall be continuously monitored and compared to both (1) calculated pulling tensions as in item "e" above, and (2) maximum allowable pulling tensions as in item "j" above. If actual pulling tension exceeds calculated pulling tension by 30% or more, the pulling operation shall be suspended and the project engineer consulted for investigation of a possible pulling obstruction or other anomaly. The cable pulling operation shall not exceed maximum allowable pulling tension. See Figure 5.5.12-1.

During pulling operations, several personnel shall be stationed at key points to ensure safety to cable and personnel: at duct entry, duct exit, cable feed, and at the pulling machinery.

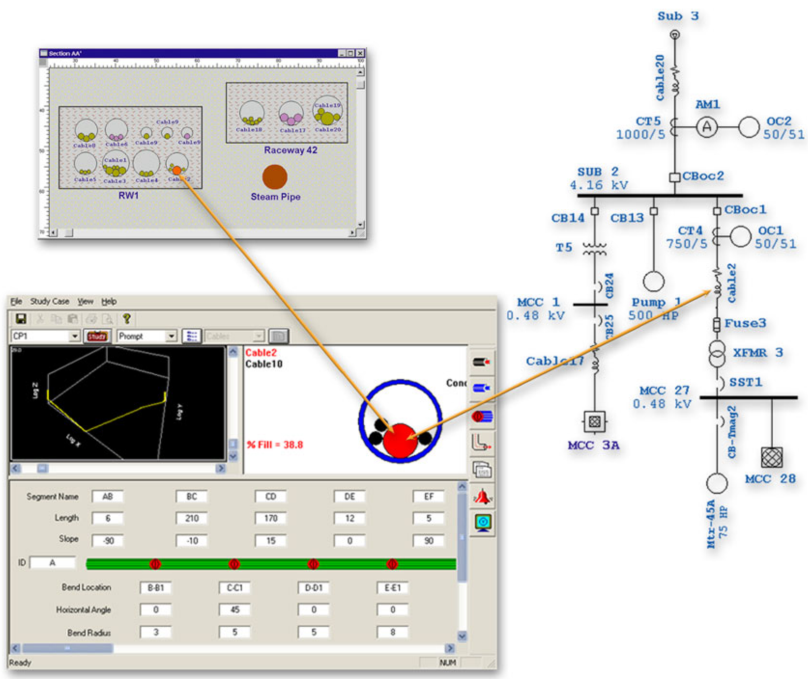


Diagram courtesy of ETAP Cable Systems Software

FIGURE 5.5.12-1. Industry software is readily available to assist with pulling calculations.

Avoid abrasion and other damage to cables during installation. The surface of a cable sheath or jacket shall not be damaged to a depth greater than one tenth (1/10th) the original thickness or be flattened out-of- round more than one tenth (1/10th) of the outside diameter.

Where cables are left in manhole or switchgear overnight or more than 8 hours prior to termination, the cable ends shall be sealed with paraffin or shrink wrap caps and supported in a manner which will prevent entrance of moisture into the cable. Cable shall be terminated and energized as soon as possible.

Table IV lists example maximum pulling tensions for commonly installed cables (see also Appendix B for a pocket guide on calculation method).

The table is for illustration purposes only; it is the designer's and/or installer's responsibility to obtain the manufacturer's data for the cable chosen for installation. The manufacturer's data shall be used in conjunction with the pull-configuration(s) proposed, cable type and ampacity, size of conduit, distance, grade, degree of sweeps/bends, proper lubricant, etc, to calculate the maximum tension for each cable pull. The resulting value shall not exceed cable maximum tension and maximum sidewall pressure values.

5.6 Medium-voltage direct earth buried cables

Direct earth buried (DEB) cables are to be avoided. However, if preauthorized per the FAA-approved drawing set and construction specifications, DEB cable construction shall meet the following requirements. Coordinate underground power cable installation work to avoid interference with other airport projects and with existing utilities.

General--The contractor shall excavate trenches for direct-earth burial cable as follows:

a. To the depth specified in paragraph 5.4.1b.

b. To a width of not less than four inches (4”) for single or six to eight inches (6-8”) for multiple runs of power cable.

c. To a width and depth that will provide horizontal or vertical separation of power cables from other power cables of different voltage ratings, or from power cable and a control or signal cable.

d. Where soil is known to be rocky, select backfill for cable protection. Backfill shall be firmly tamped in the separation area.

e. Restoration shall be in accordance with paragraph 5.5.3.

Unless otherwise specified, power cables in the same location and routed in the same general direction shall be installed in the same trench. Trenches for cables may be excavated manually or with powered trenching equipment. Cable plows shall not be used unless express permission is granted by the FAA project engineer. When rock is encountered, remove to a depth of at least 3 inches (3”) below the cable and fill the space with sand or clean earth free from particles larger than 1/4 inch. Bottoms of trenches shall be smooth and free of stones and sharp objects. Where materials in bottoms of trenches are other than sand, a 3-inch layer of sand shall be laid first and

TABLE IV. Maximum allowable non-armored cable pull tensions using dynamometer or rope.

CABLE	TENSION (Pounds)	ROPE DIAMETER (INCHES) Cotton	Manila	Dacron	Nylon
2 - 1c #8 Solid	264	3/16			
3 - 1c #8 Solid	264	1/4	3/16		
4 - 1c #8 Solid	422		1/4		
2 - 1c #6 Stranded	420	1/4	3/16		
3 - 1c #6 Stranded	420	5/16	1/4		
4 - 1c #6 Stranded	672	3/8		3/16	
1 - 2c #8 Stranded	264	1/4			
1 - 3c #8 Stranded	396	1/4			
1 - 4c #8 Stranded	528		1/4		
1 - 2c #6 Stranded	420	1/4	3/16		
1 - 3c #6 Stranded	630	5/16			
1 - 4c #6 Stranded	840	3/8	5/16	3/16	
1 – 1c #4 Stranded, Conc Neut (CN)	334	For pull rope sizes, consult manufacturer			
2 – 1c #4 Stranded, CN	668	(etc)			
3 – 1c #4 Stranded, CN	1,002	|			
4 – 1c #4 Stranded, CN	1,069	V			
3 – 1c #2 Stranded	1,593				
4 – 1c #2 Stranded	1,699				
3 – 1c #2 Stranded, CN	1,856				
4 – 1c #2 Stranded, CN	1,962				
3 – 1c #1/0 Stranded	2,534				
4 – 1c #1/0 Stranded	2,703				
3 – 1c #1/0 Stranded, 600 V	2,955				
4 – 1c #1/0 Stranded, 600 V	3,124				

Legend: No. of cables - No. of conductors (c)/ Gauge (AWG)
Note: The above figures are to be used as a guide only. Consult with the manufacturer for exact maximum pull tensions for a given cable type. Ensure conformance with the ANSI/IEEE C2 standards.

compacted to approximate densities of surrounding firm soil. Trenches shall be in straight lines between cable markers. Bends in trenches shall have a radius of not less than 36 inches (36”) consistent with the cable manufacturer's published minimum cable bending radius for the cable installed. Walls of trenches shall be essentially vertical so that a minimum of shoulder surface is disturbed.

Trenches shall be opened only for the time required to install, inspect and survey the cables in accordance with FAA Advisory Circular 150/5370. The trench shall be closed in the same working day or marked, barricaded and/or lighted according to current airport specifications and requirements.

Installation in trench--Direct earth burial cable shall be unreeled in place along the sides of or in trenches and carefully placed on sand or earth bottoms. Pulling cables into direct-burial trenches from a fixed reel position shall not be permitted, except as required to pull cables through conduits under paving or railroad tracks. Dragging cables over the ground shall not be permitted.

Separation of cables--Separation between direct earth burial cables shall be as follows:

a. Power cables may be laid together in the trench. In these instances, there shall be a minimum of 3 inches (3”) of separation between cables.

b. Non-power cables (fiber optic, communications, and control cables) shall be installed in a separate trench from power cables (exception: DEB power cable crossing a control cable at the perpendicular and with 12 inches [12”] vertical separation). A concrete marker indicating the presence of power cables shall be installed along the route of the trench.

c. Where cables of different types (power and control or signal) or of different voltages are installed together as stated in (a) and (b) above, the individual cables or groups of the same type cables shall be clearly and unambiguously identified by installing metal or approved plastic tags indicating the type (power, control or signal) and voltages for power cables. These tags should be installed in accordance with Section 5.11.

d. Backfill that serves to separate cables shall be firmly tamped.

Bends--Bends in cables shall have an inner radius not less than those specified in NFPA 70 for the type of cable, or manufacturer's recommendation.

Splicing--Where splices are required, provide splices designed and rated for direct burial. See splicing Section 5.9 for instructions. All splices shall have their neutrals/shield solidly grounded.

Slack loop--A slack loop shall be provided at each end termination point of a cable to facilitate any future repairs. Slack 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 shall be as shown by the drawings or as directed by the FAA.

Backfilling--After underground medium-voltage DEB cable has been installed and inspected, the trench shall be backfilled. The first layer of backfill shall be 3 inches (3") deep, loose measurement, and shall be either earth or natural sand containing no material aggregate particles that would be retained on a one quarter inch (1/4") sieve. This layer shall not be compacted. The second layer shall be 9 inches (9") deep, loose measurement, and shall contain no particles that would remain on a one inch (1") sieve.

The remainder of the backfill shall be excavated or imported material (if necessary) and shall not contain stone aggregate larger than 4 inches (4") maximum diameter. The second and subsequent layers shall be thoroughly tamped and compacted to the density of the adjacent undisturbed soil.

Thermal resistivity--Trench backfill shall have a soil thermal rho of 90°C-cm/W or less.

Screening/sieving-- Compacted trench backfills shall meet ASTM D422 and ASTM D698, shall be sufficiently compacted, and shall not have backfill lifts that are too thick. Failure to prepare backfill properly will result in degraded thermal capability of the cable system.

5.7 Cable installation in manholes

Cables shall be carefully formed on nonmetallic racks around the interior of manholes or hand holes, avoiding sharp bends or kinks. Ensure that enough cable is coiled in the manhole so that a number of splice repairs can be made without having to fully enter the manhole. Tie splices and cables to cable racks using one eighth inch (1/8") nylon line. Splices shall be a minimum of two feet (2') from the mouth of the duct opening into the manhole or hand hole. Where this is not possible, splices shall be located as advised in the manhole/hand hole specification or drawing. Splices in different cables shall be staggered.

5.8 Cable terminations, connections, surge protection, and fault protection

5.8.1 Cable terminations and connections

Installation of prefabricated cable terminations shall strictly conform to manufacturer's installation recommendations using proper specialized tools. A cable manufacturer's representative shall be present at least in the initial phase to provide guidance to the installation team. Special care shall be exercised to use the proper ratings and physical dimensions.

5.8.2 Connections to a three-phase engine generator

When providing backup power to other facilities, connect the two new single-phase legs to the lowest loaded phases of the generator. The lowest loaded phases shall be determined by performing a load reading. This reading shall be confirmed by referring to the history of the technical performance record (TPR).

5.8.3 Surge protection

Apply surge protection in accordance with the following standards:

a. For FAA-owned low voltage power systems (600 V or less) at or after the facility service entrance, surge protection devices (SPD) shall be applied in accordance with FAA-STD-019.

b. In ELD installations, a fused disconnect switch may be installed before the TVSS and connected to the line side of the service. The TVSS must be a UL 1449 (third edition) Type 1 device, which allows for protected line-side connection.

c. Surge protection for the 1000 V to 15 kV medium voltage range shall be implemented in accordance with ANSI/IEEE C62.11 and NEC Article 280.

d. Limit nominal voltage of ELD systems to 34.5 kV. For any other voltages, consult with the office of primary responsibility.

The following guidelines apply to locating and installing surge protection devices (SPD) (see Appendix A for product operating parameters).

a. If an FAA-owned distribution transformer is fed from an overhead line by means of a medium voltage cable, surge arresters of the metal-oxide varistor (MOV) type shall be installed at the pole top and at the transformer between each phase and ground. The pole type arrester shall be of the intermediate class, while the transformer surge arrester shall be of the distribution type. The continuous voltage rating of the arresters shall be determined in a protection and insulation coordination study. As a further protection against direct lightning, intermediate arresters shall be installed one span before and after the interconnection of transformer. Surge arrester leads connecting to cable conductor and grounded metal shield must be as short as possible to minimize the protective voltage level. This recommended surge protection scheme is illustrated in Figure 5.8.3-1.

b. If an FAA-owned distribution transformer is fed from a station transformer directly by means of a medium voltage underground cable, a distribution arrester shall be installed at both ends of the cable in accordance to the guidelines provided in paragraph (a) above.

c. Install surge arrestors of the proper class on transformers.

d. Unless otherwise shown on the drawings, surge arresters are not required on medium-voltage switchgear and sectionalizers.

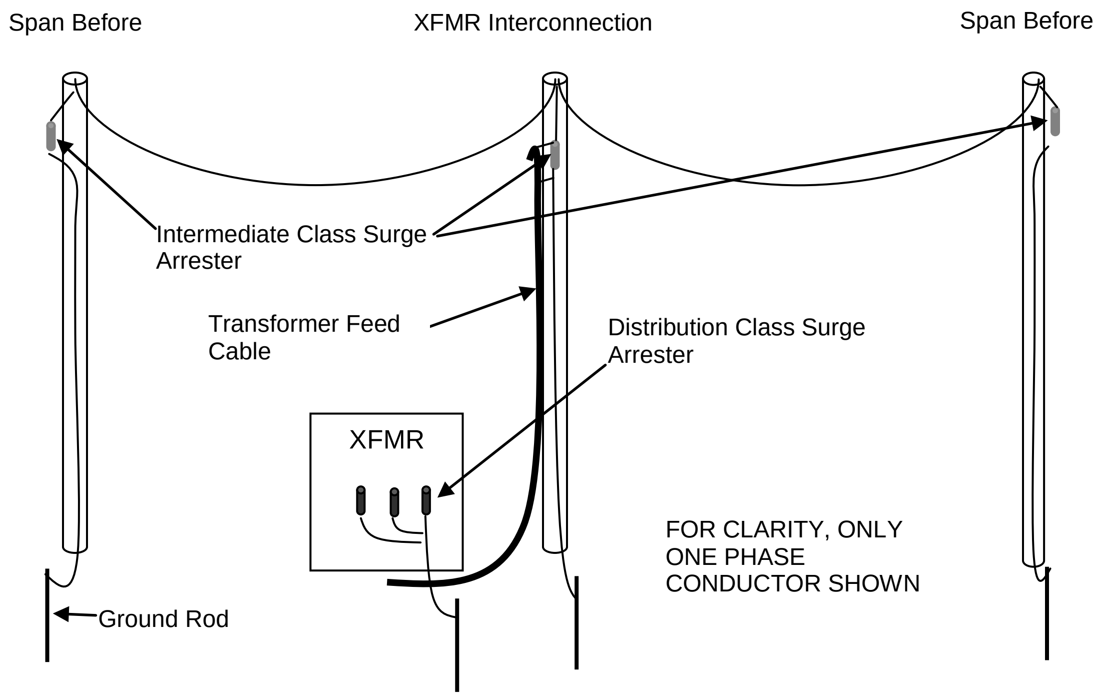


FIGURE 5.8.3-1. Schematic representation of recommended surge protection system.

5.8.4 Fault isolation

Use sectionalizers to protect the underground electrical line distribution circuit as a whole from electrical faults. This shall be accomplished by isolating faults to single National Airspace System (NAS) facilities versus multiple facilities ("daisy chained"). Where existing power cable layouts do not permit the isolation of individual facilities, add a sectionalizer.

Similarly, do not connect transformer primaries in a given electrical line distribution (ELD) service together in parallel such that a single power cable or transformer fault upstream will be allowed to deenergize downstream loads in the ELD circuit, thereby disabling multiple NAS facilities.

5.9 Splices

Whenever possible and while still meeting required cable grounding standards, splices are to be avoided. Splices on multiple cables in a trench shall be staggered. Cable ends to be spliced shall be kept free from moisture by using tape or caps. Cable runs shall be given continuity and insulation resistance tests per this specification at the completion of each splice. When conducting FAA-authorized third-party testing, at the completion of the installation of each cable section (from termination to termination), subject the cable section to a 50/60 Hz partial discharge test in accordance with IEEE 400.3 at up to 2.5 times operating voltage level for a duration not to exceed 30 seconds, while the cable section is disconnected from the rest of the system. Any partial discharge within a splice shall comply with the requirements of IEEE 404. Splices are not to be drawn inside of any conduit or duct.

Buried and nonseparable T and Y joints shall not be used. These joints are inherently unreliable and cannot be properly commissioned with partial discharge diagnostics. Finding a fault becomes more difficult and harmful to existing cable assets. In addition, faults due to these types of unreliable joints can cause failures in multiple facilities due to a lack of sectionalizing.

Each cable splicer shall be qualified in making cable splices and in the use of specified cable splicing kits and specialized tools. The contractor shall obtain FAA authorization of the splice and cable splicer prior to making field splices. Cable splicing methods and materials shall be of a type recommended by the splicing materials manufacturer for the cable to be spliced, and a cable manufacturer's representative shall be present at least in the initial phase to provide guidance to the installation team. Splices shall be as follows.

a. Medium voltage power cables (600 volts and above). Use cold-shrink splice kits. The contractor shall make sure that the proper kit and tools are used for each application. The cold shrink product shall meet ANSI/IEEE Std. 404 (for a 15 kV rating).

b. Power cables 600 volts and below. Use heavy-wall self-sealing heat-shrinkable tubing meeting ANSI-C119.1-2006, poured epoxy splice, or any other splicing means approved by ANSI standards.

c. Cable armor and shields. Armor and shield may be folded back prior to splicing, then reinstalled across the splice and bonded by the use of authorized bonding clips, or soldering when copper material is used. If the armor is galvanized material, it shall be bolted. Excess threads should be cut from bolts and wrapped with butyl tape so there are no sharp projections prior to using heat-shrink tubing.

d. Evaluation of products. As a submittal to FAA, the contractor shall provide the product drawings showing details of the splicing methods to be used, and a statement documenting the 3-year experience qualification of the contractor in making splices on underground systems with the proposed product (reference FAA Advisory Circular 150/5370-10). In addition, products shall meet the latest editions of standards in Table V.

TABLE V. Cable splicing specification equivalents.

APPLICATION STANDARD	LEVEL OF ACCEPTANCE
IEEE-404 Standard for Power Cable Joints	Meet or Exceed
IEEE-48 Standard for Cable Terminations	Meet or Exceed
ANSI C119.1 Sealed Insulated Underground Connector System Rated 600 Volts	Meet or Exceed
IEEE – 386 Standard for Separable Insulated Connectors	Meet or Exceed

5.10 Equipment racks and disconnect switches

Equipment racks - If vertical supports for equipment racks supporting disconnect switches are separated by more than 6 feet, add a middle (third) vertical support.

Main disconnect switches – Ensure that installed MDSs meet NEMA 3R for typical applications, NEMA 4X for corrosive environments. If required by the designer, use bollards to protect the installation from vehicle impacts. Construct pads of concrete, or use prefabricated composite pads.

Lightning protection of equipment racks – Air terminals shall be installed on each end of an equipment rack, regardless of rack width or proximity to a zone of protection of other nearby facilities. Air terminal selection and grounding shall conform to FAA-STD-019.

5.11 Grounding of ELD systems

Local published standards may take precedence over the national standard. In the case of ambiguity or significant deviation, contact Power Services Group, Power Cable Program Office, to provide a technical evaluation. ELD system grounding shall comply with FAA-STD-019, NFPA 70, IEEE C2, and in accordance with the specific guidance provided herein.

Typical FAA medium-voltage ELD elements to be grounded include:

a. Power Cables – ground the multigrounded neutral wires and shields,
b. Guard wires,
c. Manholes and hand holes,
d. Equipment and equipment enclosures,
e. Surge arresters,
f. Steel conduits and fittings based on application,
g. Direct earth buried power cables – multigrounded shields,
h. Abandoned power cables--ground the conductor(s) and the multigrounded neutral wires and shields (if present).

Typical FAA low-voltage ELD elements to be grounded include:

a. Low-voltage cable segment between a facility transformer and the service entrance,
b. Service entrance disconnects, meter bases, and associated equipment,
c. Service entrance equipment racks.

5.11.1 Power cables, multigrounded neutral wires and shields

The FAA ELD systems follow the same practice as multigrounded (solidly grounded, reactance grounded) medium voltage neutral systems in common use by the electric utility companies.

FAA power cables (both in conduit and DEB) shall be effectively grounded by ground connections of sufficiently low impedance levels (< 7 ohms), and have sufficient current carrying capacity to limit the buildup of voltages to levels below those that may result in undue hazards to persons or connected equipment.

Multigrounded system—FAA medium voltage cables typically use metallic shields that require grounding (NEC requirement above 5 kV). The shields confine electric fields within the cable to obtain uniform radial distribution of the electric field, protect against induced voltages, and reduce the shock hazard risk to personnel. To effectively ground the shield, install multiple grounds to the cable neutral conductor to limit the voltage rise to 25 volts maximum (measured from neutral to earth ground) per IEEE Std 525. This shall be accomplished by connecting the neutral of the multigrounded system to electrodes at each transformer location and at a sufficient number of additional points totaling not less than four ground points in each mile of the entire line (every 1300 ft / 400 m [¼ mile], or less), not including grounds at individual services. This rule applies to underground jacketed shielded cable and to jacketed concentric neutral cable. (Ref NESC Section 9, Rule 096, *Ground Resistance Requirements – Multigrounded System)*. The same practice applies to different kinds of cables; for example, concentric wire, tape shield, etc.

Bonding across joints--Apply a shield bonding jumper wire across cable splices.

DEB cable shield and separate neutral conductor grounding – Ground direct earth buried cable shields and shields of separate neutral conductor cables at least eight times per mile (not to exceed 660 ft spacing), not including grounds at individual services, in accordance with NESC C2, Rule 354.D.3c).

Service Laterals--For service laterals, when two disconnects are separated by 200 feet or more, neutral-to-ground bonds are required at both locations in accordance with the national electrical safety code (NESC). When the distance is less than 200 feet, the disconnect closest to the transformer shall have the neutral to ground bonded. Typically, this is the first disconnecting means in accordance with the National Electrical Code (NEC).

5.11.2 Cable guard wires

Guard wires protect the power cable from lightning surges. The contractor shall install cable guard wires for all buried cables and conductors not routed in ferrous conduit to protect underground conductors from the effects of lightning discharges. A 1/0 AWG bare copper stranded guard wire shall be used. The guard wire shall be embedded in the soil a minimum of 10 inches (25 cm) directly above, centered and parallel to the cable and/or duct to be protected.

When the width of the cable run or duct does not exceed 3 ft (90 cm), one guard wire centered over the cable run or duct shall be installed. When the cable run or duct is more than 3 feet (90 cm) in width, two guard wires shall be installed. The guard wires shall be spaced at least 12 inches (30 cm) apart and not be less than 12 inches (30 cm) or more than 18 inches (45 cm) inside the outermost wires or the edges of the duct.

The guard wire shall run continuously along the cable/duct run with no deviations from the run of the duct, and with no gaps. The guard wire shall be bonded to the earth electrode system (EES) at each end and to ground rods at approximately 90-foot intervals using exothermic welds. The spacing between ground rods shall vary by 10% to 20% to prevent resonance. Install the ground rods approximately 6 feet (2 m) on either side of the trench and connect them via jumper wire to the continuously running guard wire as shown in Figure 5.11.2-1. The jumper wires shall be swept away from the guard wire in a repeatable pattern such that a lightning impulse will always be able to follow a curved path to ground within 180 ft. of any point along the run. Maintain a minimum 9-in. radius bend in the jumper sweeps.

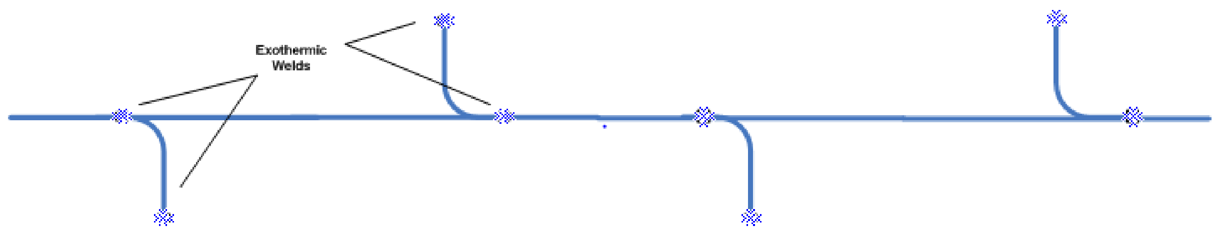


Figure 5.11.2-1 Grounding of cable guard wire. Note the alternating direction of the sweeps of the jumper wires. This pattern is required for the proper protection of the power cable.

For difficult excavations, such as rock formations or permafrost, the ground rods may be driven 3 feet on either side of the trench.

5.11.3 Manholes and hand holes

Power and control cables shall be installed in separate manholes and hand holes.

Until ready for acceptance testing, no installation work shall involve energized systems. Install power cables, ground wires, grounding loops, and manhole racks and furniture in such a way as to give maximum safe clearance space for personnel to enter the manhole when conducting subsequent operation and maintenance tasks. Conductors shall be placed well out of the way of human ingress/egress pathways through the manhole or vault. During acceptance inspection, manhole installation configurations that are found to be untidy and/or lacking in clearance for later maintenance tasks shall be required to be redone at the contractor’s expense.

If space is available, cable slack sufficient for one splice for each cable shall be left in each manhole. Elimination or shortening of slack lengths shall require authorization by the FAA.

All new and existing cable in manholes shall be secured to nonmetallic racks on the manhole walls. Cables shall be secured to racks or mounted on a heavy duty nonmetallic multi-mount cable support arm.

Jumper cables shall be routed in such a manner that through-air clearance between adjacent conductors, and between conductors and any metallic or grounded surface, is maintained.

Physical dimensions of manholes may be altered to fit requirements. The following procedure covers the minimum grounding requirements (Figure II):

a. Install a solid, bare copper bus bar inside the manhole, or alternatively, run a 4/0 bare copper conductor along the inside of the manhole, creating a grounding surface about 12 inches (12") above the finished floor. Arrange bus bar or conductor so as to avoid interference with duct entrances into the manhole, and construct of sufficient length to facilitate repair and future installation operations.
b. Bond all cable shields (or steel interlocked armor if used) to the bus bar in accordance with the manufacturer's directions. Bond other metallic bodies to the bus bar with a minimum 6 AWG bare copper conductor using mechanical connections and two-hole lugs.
c. Connect and exothermically weld the 1/0 AWG guard wires to the outside ground rods on each side of the manhole, ensuring 10 feet (10') distance from the outside of the manhole to the ground rod.
d. If feasible, all connections, sweeps, or curves in the grounding system shall be smooth and shall be of at least 8 inch (8") radius no matter what the orientation (vertical or horizontal).
e. All splices inside a manhole shall be solidly grounded, with jumpers running across the joints to connect the cable shields.
f. Mechanically connect and bond the manhole frame to the bus bar using two-hole lugs and a 6 AWG solid copper ground conductor.
g. Apply expandable foam duct sealant at openings to prevent water and gas from entering manholes.
h. Hand holes follow the same basic principles as above, with appropriate modifications.

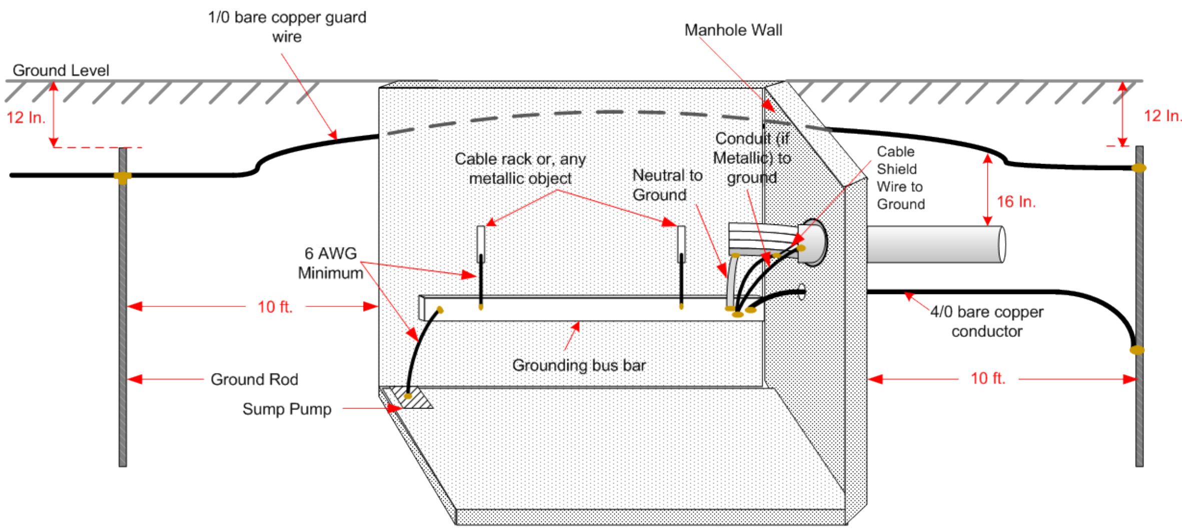


FIGURE 5.11.3-1. Grounding and guard wire installation detail at a manhole.

Where multiple conduits enter manholes, the following schemes illustrate guard wire grounding methods (all sharp corners to be rounded out) (Figure III).

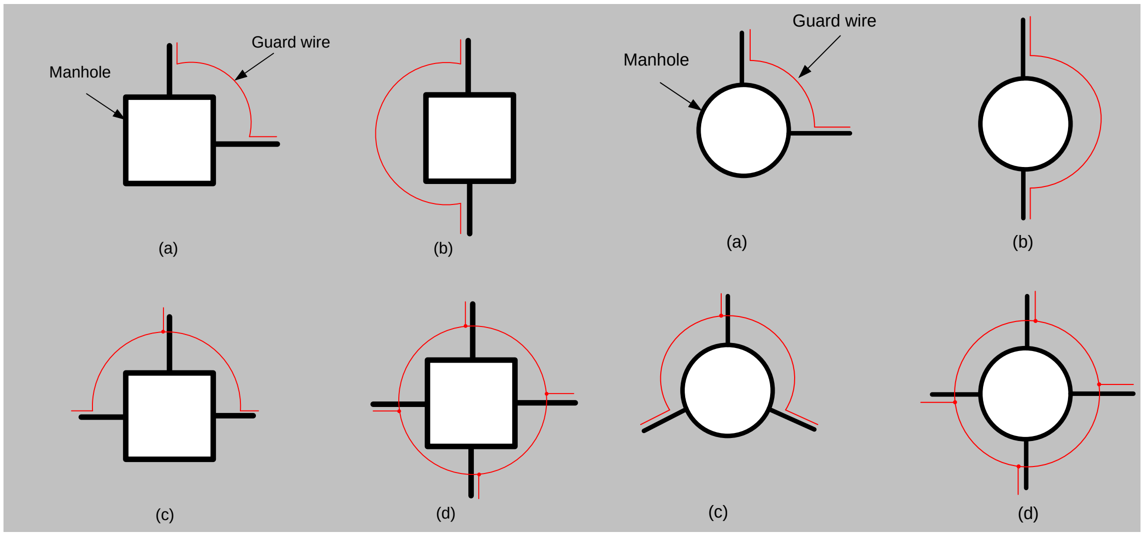


Figure 5.11.3-2. Guard wire grounding schemes.

5.11.4 Equipment and equipment enclosures

Where feasible, ground ELD equipment and equipment enclosures in accordance with NESC ANSI C2 Section 38, Rule 384 (for medium voltage equipment), FAA-STD-019 (for low voltage equipment), and IEEE 80 (when bonding grounding conductors to FAA NAS earth electrode systems).

For FAA ELD systems, ground rods shall be interconnected by a buried, bare, 4/0 AWG copper conductor (ground loop or counterpoise). Connections to the ground rods shall be exothermically welded. The interconnecting conductor shall close on itself forming a complete loop ("ground ring" or "counterpoise") with the ends exothermically welded.

Pad-mounted transformers and other pad-mounted equipment—At a minimum, install a single ground rod. Bond the transformer equipment frame and other non-current-carrying metal parts, such as cable shields, cable sheaths and armor, metallic conduit, and other non-current-carrying metal parts to the equipment counterpoise using exothermic welds. Ground the secondary neutral.

Equipment racks—Install a counterpoise 2' to 6' from equipment racks. Counterpoise shall consist of bare 4/0 copper conductors and driven ground rods around the rack. Ground the equipment rack and equipment and other non-current-carrying metal parts to the counterpoise using exothermic welds. If equipment rack is within 15 feet of a shelter having an existing FAA NAS EES, a connection between both counterpoises shall be made.

Connect metallic conduits that terminate without mechanical connection to the enclosure by grounding bushings and grounding conductor to the equipment ground bus.

Route cables within switchgear and enclosures in a manner which will allow room for bending and terminating of cables. Cables shall be secured in a manner that will not result in cable weight being placed on the termination electrical joint. Cable support shall be made in a manner that does not force cable against grounded metal or that compresses cable diameter. Cable training bend radius shall be at least 12 times cable diameter or shall not be installed.

Route jumper cables in a manner that maintains through-air clearance between adjacent conductors and between conductors and any metallic or grounded surface.

5.11.5 Surge arresters

Follow detail drawings in the drawing set for surge arrester grounding. For ungrounded and single-grounded systems, modify the requirement in accordance with IEEE C2 and UFC 3-550-03FA.

Bond surge arresters and neutrals directly to a transformer enclosure and then to the grounding electrode system using a bare copper conductor. Keep lead lengths as short as possible with no kinks or sharp bends.

5.11.6 Conduit and fittings

Conduit joints and fittings shall be electrically continuous between joined parts. Ferrous conduit enclosing power conductors to FAA facilities shall be terminated using conductive fittings to their respective junction boxes, equipment cabinets, enclosures, or other grounded metal structures.

5.11.7 Low-voltage cable runs to facility service entrances

The ELD low-voltage (≤ 600 V) cable runs coming from a commercial utility power meter and feeding power to FAA facility service entrances are considered to be FAA owned and operated utility distribution systems and shall follow the grounding and safety requirements of IEEE C2/NESC. Wiring after the distribution service delivery point (usually at the terminals of the service equipment but always as close to the FAA facility as possible) is generally considered premises wiring and shall follow NEC/NFPA 70 Section 250, *Alternating Current Systems between 50 V and 1000 V.*

For the grounding requirements of service laterals, consult the grounding section of this specification.

There are gray areas in determining which electrical safety and grounding codes apply (NESC or NEC); consult the office of primary interest to determine whether a segment is distribution or premises wiring.

5.11.8 Installation details

5.11.8.1 Installation of equipment counterpoise and ground rods

To meet site grounding requirements, install equipment counterpoise and ground rods according to the design drawings to ensure that the desired grounding values are achieved at all points of the ELD system.

Equipment counterpoise (pad mount loop) – Where not on or within 15 feet of an FAA NAS earth electrode system (EES), install bare 4/0 AWG copper conductors in a loop not less than 12 inches (12”) below finished top of soil grade, or consistent with IEEE 80. Connect the counterpoise to ground rods using 4/0 AWG copper conductors and exothermic bonds.

When installing the pad mount loop on or within 15 feet of a NAS EES, a deeper burial depth may be required. Consult FAA-STD-019 or the project drawings.

Ground rods - Drive cone-pointed ground rods to full depth plus another 12 inches below grade. Ensure that the installation provides an earth ground of the appropriate value for the particular equipment being grounded. Neatly and firmly attach and exothermically weld ground rods to the counterpoise and keep the amount of exposed bare wire to a minimum.

5.11.8.2 Grounding and bonding connections at or within equipment enclosures

When feasible, where grounding connections are buried, external to equipment enclosures, or otherwise normally inaccessible and/or uninspectable, use exothermic welds. Make exothermic welds strictly in accordance with the weld manufacturer's written recommendations. Welds that are "puffed up" or that show convex surfaces indicating improper cleaning are not acceptable. No mechanical connectors shall be made below grade.

Mechanical connections within equipment enclosures above grade shall employ bolted solderless connectors, in compliance with UL 467.

5.11.8.3 Routing grounding and bonding conductors

Connect and bond transformer enclosures and equipment frames to the grounding counterpoise system. Size grounding and bonding conductors in accordance with the drawings. Bends less than 90 degrees are not permitted. Avoid routing ground conductors through concrete. When concrete penetration is necessary, cast nonmetallic conduit flush with the points of concrete entrance and exit so as to provide an opening for the ground conductor. Seal the opening with a sealing compound after installation.

5.11.8.4 Grounding cable across expansion joints

For grounding cables that cross expansion joints or similar separations in structures and pavements, use approved devices or methods of installation to provide the necessary slack in the cable across the joint to permit movement. Use stranded or other approved flexible copper cable across such separations.

5.11.8.5 Grounding of armored cable and metallic conduit
Apply the following requirement during initial cable installation. For medium voltage systems, bond cable armor and/or metallic conduit to the earth electrode grounding systems of the connected equipment at both ends with a 2 AWG conductor, including at splices in manholes and hand holes. An armored bonding jumper shall be installed across each splice. For low voltage systems, bond the cable armor to the ground bus of the service disconnecting means at the electrical service entry point. Bonds shall be electrically continuous between joined parts (see FAA-STD-019).

5.11.8.6 Grounding metal splice cases
Ground metal splice cases for medium-voltage direct-burial cable by connection to a driven ground rod located within 2 feet of each splice box using a grounding electrode conductor having a current-carrying capacity of at least 20 percent of the individual phase conductors in the associated splice box, but not less than No. 6 AWG.

5.11.8.7 Grounding Riser poles
Directly connect equipment, neutrals, surge arresters, and items required to be grounded to the single continuous vertical ground rod conductor (No. 2 AWG minimum) on each riser pole. Ensure that ground rod conductors are stapled to wood poles at intervals not exceeding 2 feet.

5.12 Cable tagging, equipment markers and labels, and safety signs

5.12.1 Cable tags

Individual cables or groups of the same type of cable shall be clearly and unambiguously identified in accessible locations such as manholes, hand holes, junction boxes, and pull boxes by means of a minimum of two tags per cable, one near each duct entrance hole. Unless otherwise specified in the contract documents, cable tags shall be constructed of metal, or of rigid laminated plastic of at least 1/16” total thickness.

Plastic tags shall be exterior classified and consist of two plies: a plastic base and a 0.005” surface of impact acrylic plastic for front engraving. The tag shall be ultraviolet (UV) light stable. Engraving shall be done with 1/4-inch minimum lettering (white background and black letters). Tags shall be attached to the both terminated ends of the cable with two UV-rated nylon or stainless steel cable ties.

Cable terminations and potheads shall be tagged as to function, including facility which they serve, and any pertinent data. Tags shall be marked with an abbreviation of the name of the facility or facilities served by the cable plus the letter “P” (Power). Where more than one identical cable is used to serve the same facility, cables may be bundled under one tag unless job plans state otherwise.

5.12.2 Equipment markers and labels

Design and select equipment markers and labels for exterior use.

5.12.2.1 Exterior equipment identification tags, labels, and plaques
Aluminum tags, or any other tags or labels approved by the project engineer, shall be printed with numbers to identify ELD equipment. Attachment options include wires and ties, or screw mounts, nails, or bolts. Contrasting colors shall be considered when ordering tags and labels. Plaques may be made of laminated plastic.

5.12.2.2 Warning and safety signs and labels
To minimize accidents, manufacturers of electrical products use ANSI Z535, *Safety Alerting Standards*, to make their products and manuals safer. Contractors shall ensure that colors, safety signs and labels, safety symbols, barricade tapes, and information on product manuals, instructions, and collateral materials applying to FAA ELD equipment meet ANSI Z535.1 thru .6 standards.

5.12.2.3 Arc flash hazard labeling
In instances where an arc flash analysis has been completed and updated with any as-built changes, the results of the study shall be labeled on all corresponding equipment, as well as the drawings. Follow NEC Article 110.16 for guidance on warning labels.

Electrical equipment shall be field marked to warn qualified persons of potential electric arc flash hazards. The marking shall be located so as to be clearly visible to qualified persons before installation of the equipment.

Following the completion of arc flash hazard and shock analyses, the electrical equipment evaluated shall be labeled to include the findings of the analyses. At a minimum, the label shall include the following information: flash hazard boundary; incident energy (calories/cm^2) at appropriate working distances; personal protective equipment (PPE) level - including what fire-retardant clothing is required; shock hazard level (kV); limited approach boundary (feet/inches); restricted approach boundary (feet/inches); class of voltage-rated gloves for restricted approach boundary; prohibited approach boundary (feet/inches); class of voltage-rated gloves for prohibited approach boundary; equipment name; additional PPE required (ear, eye, face, and/or head protection); and date of survey.

5.13 Cable markers

5.13.1 Concrete markers for DEB cable

Concrete markers are required only for direct earth buried (DEB) cables. Install a concrete slab marker at each change of direction of DEB cable, over the ends of ducts or conduits which are installed under paved areas and roadways, and over each splice. Markers shall be two feet (2’) square and six inches (6”) thick, and 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 (1”) above the finished grade. Install slabs so that the side nearest the inscription on top includes an arrow indicating the side nearest the cable. Provide color, type, and depth of warning tape.

Concrete shall have a compressive strength of not less than 20 MPa (3000 psi) and have a smooth, troweled finish on the exposed surface. 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. Markers shall not be installed in concrete or asphalt surfaces.

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

a. The word “CABLE”.

b. Name of facility served; for example, “ASR,” “VORTAC,” “ALS,” etc.

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

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

e. Any additional information as defined by the contract drawings.

f. The contractor shall obtain authorization from the FAA for the information to be impressed on the cable marker and for the method of impression. The letters shall be four inches (4”) high, three inches (3”) wide and one half inch (1/2”) deep.

All cable and cable markers shall be coded with applicable color coding standards, as applicable to the locality. If no standard applies, use the American Public Works Association (APWA) color codes shown in Table VI.

TABLE VI. APWA color codes.

COLOR CODE	TYPE OF UNDERGROUND UTILITY
RED	Electric power lines, cables or conduits, and lighting cables
YELLOW	Gas, oil, steam, petroleum or other hazardous liquid or gaseous materials
ORANGE	Communications, cable TV, alarm or signal lines, cables, or conduits
BLUE	Potable water lines
GREEN	Sewers, storm sewer facilities and utilities, or their drains lines
PURPLE	Reclaimed water, irrigation, or slurry lines
WHITE	Proposed excavation
PINK	Temporary survey marking

The location of the ends of ducts shall be marked with concrete markers 2 feet (2') square and 6 inches (6") thick. The duct markers are to be installed in the same manner as cable markers, except the following shall be impressed upon their top surface:

a. The word, "DUCT".

b. Name of facility served; for example, "ASR," "VORTAC," "ALS," etc.

c. An arrow to indicate the direction or the change in direction of the cable route.

d. The number of conduits and the type of conduits: for example, 4-P/2-C.

e. Any additional information as directed by the FAA project engineer.

DEB cables shall be marked every two hundred feet (200') along a cable run, at each change of direction of the cable, and at each cable splice. Markers shall be either concrete or other type, or a combination of both as specified in the contract documents.

The markers used for DEB cables shall be impressed with a "P" for power cable.

5.13.2 Special-purpose and near-surface markers

Special-purpose and near-surface markers are used to indicate points of additional information. At a minimum, markers shall indicate the location of splices and the entrances of separate duct banks and/or bores. Other significant points may be required as field-determined. Appropriate-colored surface markers shall also be placed where crossing other utilities (for example, blue for water, orange for telephone, yellow for gas). Markers shall be either drilled into existing surfaces (for example, concrete edge of manhole or pavement) or set in a concrete slab square as above.

5.14 Acceptance and inspection procedures

After the installation of cable systems is completed, the FAA and/or its contractor shall perform acceptance/commissioning testing (refer to Appendix C). All safety procedures for energizing the systems following installation shall follow OSHA confined spaces regulations and NFPA 70E. Tests shall be conducted in the operational environment to confirm operational readiness of the ELD and to identify safety hazards involving any component of the ELD system that will support a system in the NAS.

If applicable, participants shall include the FAA project manager, project engineer(s), contract technical representatives, environmental, safety, real estate, power company contracts representative, airport authority representative, and airport staff.

Once acceptance tests are completed and the results accepted, the FAA shall take beneficial occupancy of the ELD system. This may occur in stages.

APPENDIX A—Surge Arrester Performance Data

1. SCOPE

This appendix provides surge arrester performance data for FAA medium-voltage (MV) electrical line distribution (ELD) systems. Surge arresters protect the following ELD system elements:

a. Overhead lines and distribution transformers (utility responsibility),
b. MV transformers and cable installations,
c. MV cables,
d. Internal switchgear and sectionalizers in MV networks,
e. Other ELD-related special-purpose applications as required.

2. APPLICABLE DOCUMENTS

2.1 Non-government publications

Institute of Electrical and Electronics Engineers (IEEE)

IEEE C62.11 (2005; And 1 2008)
Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits (>1kV)

Guide Information for Electrical Equipment, The White Book 2011, and UL Product Categories Correlated to the 2008 and 2011 National Electrical Code®. Surge Arresters 1000 Volts and Higher (VZQK)

National Electrical Manufacturers Association (NEMA)

NEMA LA 1 (1992; R 1999) Standard for Surge Arresters

National Fire Protection Association (NFPA)

NFPA 70 (2008; TIA 08-1) National Electrical Code

NEC article 280: Introduces surge arresters, general requirements, installation requirements, and connection requirements.

3. REQUIREMENTS

3.1 Performance Requirements

3.1.1 General

The requirement is for high-quality metal-oxide surge arresters for use in FAA-owned distribution networks to ensure the protection of underground power cables, low-level distribution transformers, generators, sectionalizing switches, and other electrical equipment. Surge arresters limit dangerous voltage surges caused by lightning strikes or switching anomalies occurring in the ELD network. Arresters also increase the availability of power by reducing outages. Voltage surges can result in personnel injuries from electrical shock, insulation damage to equipment, and possibly fire. Surge arresters provide safe dissipation of these surges.

The standard root-mean-square (rms) maximum continuous operating voltage (MCOV) and rms duty-cycle voltage ratings for typical nominal voltage values and configurations used in FAA underground electrical distribution systems (except note 1) are shown in the table below. Light-duty surge arresters in common use in FAA ELD systems correspond to these configurations.

Nominal Voltage (KVrms)	MCOV (KVrms)	Duty-Cycle (KVrms)
4,160Y (3φ) 2,400 (1φ)	5.1 KV 2.55 kV	6 KV 3 kV
13,200Y(3φ) 7,620 (1φ)	15.3 KV 7.65 kV	18 KV 9 kV
4,160Δ (3φ)(see note 1)	5.1	6 kV
13,800	15.3 kV	18 kV

Note (1): The delta configuration is not a typical FAA ELD configuration. If you encounter this configuration or any configuration not shown above, call the Power Cable Program Office, AJW-22, for guidance.

3.1.2 Placement

Surge arresters shall be provided on the line side of:

1. Pole-mounted transformers (utility responsibility in most cases),

2. Overhead to underground terminal poles (utility),

3. All “normally open” switchways of pad-mounted sectionalizing switches connected to and served from overhead lines, THERE ARE NONE. ELIMINATE? ASK MATT M. AT IMCORP

4. Underground primary metering installations connected to and served from overhead lines.

5. On the line side of any location where a voltage/facility transition occurs.

3.1.3 IEEE Standard C62.11

The design, fabrication, testing, and performance requirement to which a medium voltage surge arrester shall comply is IEEE C62.11 (reference provided above). The definition provided in IEEE C62.11 for metal-oxide surge arresters for ac power circuits greater than 1 kV is:

> **Arrester, distribution, light duty class:** An arrester normally installed on and used to protect underground distribution systems where the major portion of the lightning stroke current is discharged by an arrester located at the overhead line/cable junction.

This class of surge arrester conforms to the minimum recommended level to provide protection against switching and other transient voltages in the underground ELD infrastructure. Light duty class arresters are constrained by the prescribed test requirements of standard IEEE C62.11 (see table below).

Surge arrester test requirements

Class	Rated voltage (kV)		Lightning impulse classifying current (kA)	Minimum High current Short duration withstand (kA)	Minimum Low current Long duration withstand (A, µs)
	Duty cycle	MCOV			
Distribution, light duty	3–36	2.55–29	5	40	75, 2000

3.1.4 Service conditions

An arrester installed in the FAA ELD system shall be capable of successful operations under the service conditions given in the paragraphs below.

3.1.4.1 Usual service conditions

Physical conditions

a) Ambient air temperature in the general vicinity of the arrester shall be between –40°C and +40°C except that: (1) Ambient air temperature in the general vicinity of dead front arresters shall be between –40 °C and +65 °C, and (2) Ambient liquid temperature in the general vicinity of liquid-immersed arresters shall be between –40°C and +95°C.
b) Maximum temperature of the arrester, due to external heat sources in the general vicinity of the arrester, shall not exceed 60°C, except that (1) Maximum temperature of the dead front arrester shall not exceed 85°C, and (2) Maximum temperature of the liquid-immersed arresters shall not exceed 120°C.
c) Altitude shall not exceed 1800 m (6000 ft), except for liquid-immersed arresters.

System conditions

a) Nominal power system frequency of 48 Hz to 62 Hz.
b) System line-to-ground voltage within the ratings of the arrester under all system operating conditions.

3.1.4.2 Unusual service conditions. Exposure to any of the service conditions described in the sections below may require special consideration in the design or application of arresters.

Physical conditions

a) Ambient temperatures in the general vicinity of the arrester exceeding the values given in Section 3.1.4.1 above, Physical Conditions.
b) Maximum arrester temperatures exceeding the values given in Section 3.1.4.1 above, Physical Conditions.
c) Altitude exceeding 1800 m (6000 ft). Arresters for service at higher altitudes shall be suitable for operation at either of the following altitude ranges:
   i) 1801–3600 m (6,001–12,000 ft).
   ii) 3601–5400 m (12,001–18,000 ft).
d) Exposure to any of the following:
   i) Damaging fumes or vapors
   ii) Excessive dirt, salt spray, or other current-conducting deposits.
   iii) Steam.
   iv) Explosive atmospheres, abnormal vibrations, or shocks
e) Limitation on clearances to nearby conducting objects, particularly at altitudes exceeding 1800 m (6000 ft)
f) Unusual transportation or storage.

System conditions

a) Nominal power frequency other than 48 Hz to 62 Hz
b) System operating conditions whereby the ratings of the arrester may be temporarily exceeded. Some examples are as follows:
   i) Loss of neutral ground on normally grounded circuit
   ii) Generator overspeed
   iii) Resonance during faults upon loss of major generation
   iv) System instability
   v) Persistent single line-to-ground fault on ungrounded three-phase systems
c) Any other unusual conditions known to the user.

APPENDIX B—Cable Pulling Calculations

This appendix provides basic information on how to calculate maximum pull force during cable pull operations. For detailed information and more elaborate tables, consult the cable manufacturer. Industry software is readily available to assist with these calculations.

1. To calculate cable pulling force for a cable consisting of several segments, and/or where a cable bends around a curve or a number of curves, calculations are done in incremental segments/steps using formulas and tables, with the segments/steps added together to arrive at the cumulative maximum pull tension. Add an additional 15% margin for safety. To illustrate the cumulative method, an example is given: the pull force calculated for a cable segment A is added to a "bend multiplier" AB, a pull force for straight cable segment B, a pull force for cable segment C, a bend multiplier CD, and a cable segment D, etc., plus 15%.

The basic formula for calculating maximum pulling tension in a single cable section is:

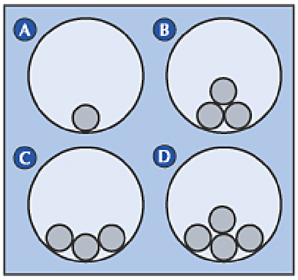
$$T = L \times w \times f \times W,$$

where
T is the total pulling tension (lb),
L is the length (ft) of cable being pulled,
w is the total weight (lb/ft) of the conductors,
f is the coefficient of friction (usually 0.5 for well-lubricated conditions),
W is the weight correction factor.

2. The process for calculating pull force for a segment of a cable run is as follows:

a. Enter the length of the cable segment in the formula above.
b. Enter the weight of the cable segment.
c. Enter the coefficient of friction.
d. Enter the weight correction factor W, derived as follows:
  i. Determine the geometric position of how the cables will lay in the conduit.
  ii. Calculate W using the table below.
e. Check for jamming hazard of the cables in the conduit.
f. Check sidewall bearing pressure (SWBP).
g. Check headroom.

3. The weight correction factor (W) calculation is based on the cable geometry in the duct:



A = Single; B = Triangular; C = Cradled; D = Diamond

To determine cable geometry, use the ratio of the conduit's inside diameter (D) to the cable's outside diameter (d) to find how the single conductors will sit in the conduit:

Triangular (Fig. B): This occurs when pulling three individual conductors from three separate reels, and their D/d ratio is less than 2.5. If pulling individual triplexed conductors from a single reel, the cables will also sit in this position.

Cradle (Fig. C): This position may occur when pulling three individual conductors from three separate reels, and their D/d ratio is between 2.5 and 3.0. This position is the least favorable because it yields the worst-case scenario of drag during the pull.

Diamond (Fig. D): This position occurs when pulling four individual conductors from four separate reels, and their D/d ratio is less than 3.0. If pulling quadruplexed individual conductors from a single reel, the multiconductor cable will also sit in this position.

No. of Conductors	Position	Weight Factor Equation
1	Single	$W = 1$
3	Triangular	$W = 1 / \{1-[d/(D-d)]^2\}^{1/2}$
3	Cradled	$W = 1 + \{(4/3) \times [d/(D-d)]^2\}$
4	Diamond	$W = 1 + \{2 \times [d/(D-d)]^2\}$
W = Weight correction factor D = Inside diameter of conduit d = Outside diameter of individual conductor		

For the most conservative calculation, use the cradle configuration.

4. Jamming ratio. When sizing the conduit system, installers must consider the possibility of cables jamming or wedging. This usually occurs when three or more individual conductors lie side by side in a single plane. As the conductors are pulled through a bend, the curvature of the bend tends to squeeze the conductors together. Use the following formula to determine the likelihood of jamming. Use the inside diameter of the conduit and the outside diameter of the individual conductor. Avoid jam ratios of 2.8 to 3.2 for Type MV extruded dielectric power cables:

$$1.05 \times (D \div d)$$

Where
D = the inside diameter of the conduit
d = the outside diameter of an individual conductor.
Constant factor 1.05 = correction for oval shape of bends in the sectional view.

- If the value is less than 2.5, the cable will jam,
- If the value is less than 3.0 but greater than 2.8, jamming is very possible,
- If the value is greater than 3.0, jamming will not occur.
- For medium-voltage extruded dielectric power cables, avoid values between 2.8 to 3.2.

5. Sidewall bearing pressure (SWBP). Sidewall bearing pressure (in pounds per foot) is the tension on the cable coming out of a bend (in pounds) divided by the inside radius of the bend (in feet). When pulling at a bend, the recommended maximum sidewall pressures for 15kV class and less is 500 lb/ft (or less, if recommended by the manufacturer).

No. of Conductors	**Position**	**SWBP Equation**
1	Single	SWBP = T ÷ R
3	Cradled	SWBP = [(3W – 2) x T] ÷ 3R
3	Triangular	SWBP = (W x T) ÷ 2R
4	Diamond	SWBP = (W – 1) x (T ÷ R)
W = weight correction factor; T = calculated tension; R = radius of bend (inside radius).		

6. Headroom. To ensure a safe and easy pull, provide clearance between the uppermost conductor and the top of the conduit. For straight pulls, a clearance as small as ¼ in. is considered safe. For more complex pulls, between ½ in. and 1 in. is required. Use the equations below to derive the clearance for a given conduit and cable sitting position. Note that allowance is made for variations in cable and conduit diameters, and the oval shape of the raceway sections at bends.

Configuration	**Clearance**
Single	$C = D' - d'$
Triangular	$C = \left[\sqrt{D' - 1.366\,d'} + \sqrt{(D' - d')}\right] \times$ $\times \sqrt{[1 - (d' \div D' - d)^2]}$
Diamond	$C = \left[(D' - d') - 2d'^2\right] \div (D' - d')$
C = Clearance, D´ = 1.05 x nominal conduit inside diameter; d´ = 1.05 x nominal overall diameter of individual conductor.	

7. Limit pulling tension to 0.008 lb/cmil for copper conductors pulled by pulling eyes or pulling bolts (pulling tension applied directly to the conductor).

8. Limit pulling tension to 1000 lb for jacketed cables pulled by cable grips.

9. Angle of bend. Every time there is a bend in the cable, a bend multiplier factor must be introduced:

Bend Angle	Multiplier
15	1.14
30	1.30
45	1.48
60	1.70
75	1.94
90	2.20
105	2.50
120	2.86

10. For steel, wire, rope, or tape used for cable pulling, a dynamometer graduated to indicate the tension on the cable being pulled can be used, or the contractor shall adapt a rope harness properly sized to limit pull tension to the value indicated. 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.

APPENDIX C—Acceptance testing of newly installed FAA medium voltage underground power cables

This appendix specifies *acceptance testing* of newly installed FAA insulated underground medium voltage power cables rated 2 kV to 15 kV, shielded, non-shielded, and armored. It does not cover *installation testing* or *maintenance testing* as defined in IEEE 400.2. Nor does it cover testing of older, in-service cables. For comprehensive treatment of the maintenance testing of FAA power cables, refer to FAA Order 6950.22, *Maintenance of Electrical Power Cables*.

The testing guidance below applies to both direct burial cables and cables installed in nonmetallic and metal conduit. This appendix covers four types of tests used for validating acceptance of FAA medium voltage cables and accessories: (1) a continuity test, (2) an insulation resistance test; (3) an AC VLF field test; and (4) an offline 50/60 Hz partial discharge test. At a minimum, tests one through three (continuity, insulation resistance, and VLF withstand tests) shall be employed as acceptance tests of new FAA cable installations. Test four (offline PD test) is a state-of-the art test that provides the most thorough and exacting test data of all the choices. It can be substituted for the VLF withstand test if funding is available. The test must be conducted by a qualified third-party testing firm that is preapproved by the FAA, and requires extra lead time in planning the test activity (3 months).

Any newly installed cable that fails as a result of cable acceptance testing shall be replaced by the installation contractor at the installation contractor's expense.

The paragraphs that follow detail each test's theory of operation, parameters and tolerances, test schedules, and safety and test procedures. If any conflicts arise relating to power cable testing parameters, procedures, or safety as presented in this appendix, the guidance of FAA Order 6950.22 shall take precedence.

SAFETY REQUIREMENTS, GENERAL

The following are general safety requirements for all electrical power cable acceptance tests. Safety requirements particular to each test are provided in the tests' respective sections that follow.

Before testing is performed, ensure that cables and associated terminations are isolated from electrical apparatus such as power transformers, potential transformers, surge arresters, capacitors, etc. Cables are allowed to be connected to switches and fused cutouts as long as the switch isolates the cable and terminations from electrical apparatus mentioned above. Maintain at least a 6-inch clearance between cable ends and any grounded surface. If modular "load break" elbow terminations are used on the cable, ensure that the load break elbows are inserted in the associated isolated parking bushings.

Ensure that all cables and terminations are disconnected and isolated from all sources of power. Using proper high-voltage test instruments, verify that the conductors are not energized and there is no back-feed from some unknown source.

Ensure that all cable shields, equipment grounding conductors, armor, and metallic conduits are properly grounded to the earth electrode system at both ends of the cable to be tested. If present, check to ensure that the cable shield, armor, and equipment grounding conductors are electrically continuous from one end of the cable to the other.

Refer to FAA Order 6950.22, Chapters 1 (Para. 105), 2 (Para. 220, 221, 222), and 5 (Para. 504), as well as applicable IEEE standards for more safety guidance.

1. INSULATION RESISTANCE TEST

1.1 Theory of Operation

After cable system installation and before the cable system is placed in normal service, a “limited voltage” DC insulation resistance test shall be performed and documented, including the testing of terminations and joints.

The insulation resistance test is classified by the IEEE as a diagnostic test. The purpose of the test is not to ensure the cable systems’ future performance but simply to assure the construction team that the line is not grounded/shorted before energization. Insulation or dielectric resistance is the resistance to the flow of direct current through or over the surface of the insulating material. Cables are tested by measuring the resistance between conductors, and the resistance between each conductor and ground. For a new cable, or one that is believed to be in very good condition, all of these resistances should measure in megohms (for tolerances, see Section 1.2 of this appendix below).

Any insulation resistance values less than 50 megohms shall be investigated. Note that the insulation resistance values may be affected by temperature, cable geometry, cable length, and leakage along cable terminations.

The installation contractor shall be responsible for repair/replacement of any failed components and retest costs.

1.2 Parameters and Tolerance limits

For test parameters and tolerance limits, refer to FAA Order 6950.22, *Maintenance of Electrical Power Cables*, Chapter 3, *Standards and Tolerances*, Paragraph 301, Table (see column heading labeled “NEW CABLE”).

1.3 Test Schedules

Test after installation and just before energizing the new system.

1.4 Safety and Test Procedure

1.4.1 Safety

Follow safety practices as set forth in Chapter 2 (Para. 221e[2][c]) and 5 (Para. 502, 503) of FAA Order 6950.22, *Maintenance of Electrical Power Cables.* Refer also to the paragraphs that follow, and IEEE standards, for additional safety and grounding procedures.

Before testing begins, ensure that all associated cable shields, armor, equipment grounding conductors, and metallic conduit are properly grounded at both ends to an approved earth grounding systems or electrode. Verify that the conductors are not energized.

Ensure that cable shields and/or armor are electrically continuous by performing a simple resistance measurement using a reliable and calibrated digital multimeter. Ensure that all insulated conductors in the cable assembly that are not to be tested, as well as adjacent cables, are properly grounded at both ends to prevent capacitive voltage build-up.

When testing, one or more cable ends will need to be remote from the testing site. Therefore, before testing is begun, cables ends under test must be cleared and guarded. Switches and fused cutouts and circuit breakers used for isolating the cable under test shall be identified, locked, and tagged out of service. If possible, remote ends of cable being tested should be enclosed in a locked enclosure, vault, room, or other location accessible to qualified personnel only. All testing shall be performed between earth/ground and each insulated conductor, and between each insulated conductor.

Insulation testing must comply with OSHA regulations, Standard for Electrical Safety in the Work Place (NFPA-70E), and the National Electrical Safety Code (ANSI C2). ***All medium/high voltage testing must be performed by TWO individuals.*** Before, during, and after testing, ensure that all applicable safety rules are followed, including the use of proper personal protection equipment (PPE), lockout/tagout of all associated electrical energy sources, testing cables for possible "backfeed" from unknown electrical sources, and discharge of residual capacitive charges on cables to be tested.

Use only the approved high-voltage power test instruments to check for AC and DC voltages on all cables. ***DO NOT use hand-held test instruments which are only rated (or used in electrical/electronic applications) at 1,000 volts or less.***

1.4.2 Test Procedure

Refer to FAA Order 6950.22, Chapter 5, Para. 503 for detailed test procedures. The test procedures cover new cables having either 100% or 133% cable insulation ratings. In instances where the new cable to be tested is joined to an older cable, consult with the FAA project engineer to adjust the testing parameters as needed.

CAUTION: After all tests are complete and before the cables and terminations are placed back into normal operation, ENSURE that all temporary safety grounding connections are removed from all insulated conductors that will be energized.

1.4.2.1 New 2,000 to 5,000 Volt Cables, Terminations, and Joints

Insulation resistance baseline measurements shall be taken and documented after cable system installation, including terminations and joints, but before the cable system is placed in normal service. Test with a 5,000 volt insulation resistance test set (AEMC Instruments Type 5070 or approved equal) applied incrementally up to the voltage rating of the cable for a duration of not to exceed 5 minutes. Do not exceed the rms line-to-ground voltage across the conductor and metallic shield. Record the resistance at each voltage level as well as the ambient temperatures and relative humidity. Perform insulation resistance testing from each insulated conductor to ground and between each insulated conductor (ref FAA Order 6950.22). Because of possible power capacity limitations of the test set, the maximum length of the cable to be tested shall be based on the manufacturer's testing data and the capability of the test equipment. Any insulation resistance values less than 50 Megohms shall be investigated. Note that the insulation resistance values may be affected by temperature, cable geometry, cable length, and leakage along cable terminations. Terminations shall be thoroughly cleaned and, if required, a guard circuit shall be used at the termination. The installation contractor shall be responsible for repair/replacement of any failed components and retest costs.

1.4.2.2 New 15,000 Volt Cables, Terminations, and Joints

Insulation resistance baseline measurements shall be taken and documented after cable system installation, including terminations and joints, but before the cable system is placed in normal service. Test with a 5,000 volt insulation resistance test set (AEMC type 5070 or approved equal) applied incrementally up to 5,000 volts for a duration not to exceed 5 minutes. Record the resistance at each voltage level as well as the ambient temperatures and relative humidity. Perform insulation resistance testing from each insulated conductor to ground and between each insulated conductor (ref FAA Order 6950.22). Because of possible power capacity limitations of the test set, the maximum length of the cable to be tested shall be based on the manufacturer's testing data and the capability of the test equipment. Any insulation resistance values less than 50 Megohms shall be investigated. Note that the insulation resistance values may be affected by temperature, cable geometry, cable length, and leakage along cable terminations. Terminations shall be thoroughly cleaned and, if required, a guard circuit shall be used at the termination. The installation contractor shall be responsible for repair/replacement of any failed components and retest costs.

2. AC VLF FIELD TEST

2.1 Theory of Operation

The AC Very Low Frequency (VLF) (0.1 Hz sinusoidal) field test is essentially a DC Hipot test with a slow voltage oscillation to prevent the buildup of space charge in the cable insulation. The purpose of the test is not to ensure cable system future performance but simply to reassure the construction team that the line is not grounded/shorted before energization. The test is classified by the IEEE as a destructive test because it is designed to bring a cable and/or accessory to failure where severe defects are present. Thus, the VLF withstand test is a pass/fail test and provides no localization or severity data other than the obvious outward sign of a defect upon failure. Only properly qualified persons who are VLF test-certified may perform this test on FAA ELD systems.

VLF withstand testing is performed after insulation resistance testing. Even if prior insulation resistance testing has indicated that the cable is in good condition, the VLF test may provide a further indication of cable reliability.

Because VLF testing can cause a severe defect in a cable, joints, and/or terminations to fail, provisions should be made to have personnel on-site to find the defective/faulted cable or termination and make the required repairs. Retest the cable after the repairs. Repeat this procedure until cable and terminations pass the VLF test. The installation contractor shall be responsible for repair or replacement of any failed components and retest costs.

2.2 Parameters and Tolerance Limits

For test parameters and tolerance limits, refer to FAA Order 6950.22, *Maintenance of Electrical Power Cables*, Chapter 3, *Standards and Tolerances*, Paragraph 301, Table (see column heading labeled “NEW CABLE”). Also consult IEEE 400.2, *IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF).*

2.3 Test Schedules

Test after installation and just before energizing the new system.

2.4 Safety and Test Procedure

2.4.1 Safety

Follow general safety practices as set forth in Chapters 1, 2, and 5 of FAA Order 6950.22, *Maintenance of Electrical Power Cables.* Refer also to IEEE 400.2 for safety and grounding procedures, and to the paragraphs below.

VLF testing must comply with OSHA regulations, Standard for Electrical Safety in the Work Place (NFPA-70E), and the National Electrical Safety Code (ANSI C2). ***All medium/high voltage testing must be performed by TWO individuals.*** Before, during, and after testing, ensure that all applicable safety rules are followed, including the use of proper personal protection equipment (PPE), lockout/tagout of all associated electrical energy sources, testing cables for possible "backfeed" from unknown electrical sources, and discharge of residual capacitive charges on cables to be tested.

Before testing is performed, ensure that all cables and associated terminations are disconnected and isolated from all sources of power, including electrical apparatus such as power transformers, potential transformers, surge arresters, capacitors, etc. Cables are allowed to be connected to switches and fused cutouts as long as the switch isolates the cable and terminations from the electrical apparatus mentioned above. Maintain at least a 6-inch clearance between cable ends and any grounded surface. If modular load-break elbow terminations are used on the cable, ensure the load-break elbows are inserted in the associated isolated parking bushings. Verify that the conductors are not energized and there is no back-feed from some unknown source.

Properly ground all associated cable shields, armor, equipment grounding conductors, and metallic conduit at both ends to an approved earth grounding systems or electrode. Ensure that cable shields and/or armor are electrically continuous from one end of the cable to the other by performing a simple resistance measurement using a reliable and calibrated digital multimeter. Ensure that all insulated conductors in the cable assembly that are not to be tested, as well as adjacent cables, are properly grounded at both ends to prevent capacitive voltage build-up.

When testing, one or more cable ends will need to be remote from the testing site. Therefore, before testing is begun, cables ends under test must be cleared and guarded. Switches and fused cutouts and circuit breakers used for isolating the cable under test shall be identified, locked, and tagged out of service. If possible, remote ends of cable being tested should be enclosed in a locked enclosure, vault, room, or other location accessible to qualified personnel only.

All testing shall be performed between earth/ground and each insulated conductor, and between each insulated conductor. Use only the approved high-voltage power test instruments to check for AC and DC voltages on all cables. ***DO NOT use hand-held test instruments which are only rated (or used in electrical/electronic applications) at 1,000 volts or less!!!***

2.4.2 Test Procedure

If the new cable to be tested is joined to an older, in-service cable segment, consult with the FAA project engineer for guidance. The test voltage or other parameters may need to be adjusted for in-service cables because they are more sensitive to the high voltage levels attained during the test. Likewise, consult the FAA project engineer if two cable segments of different voltage ratings are being tested simultaneously, as the lower rated cable could be damaged by high voltage levels used to test the higher rated segment.

VLF testing is not required for cables with rated voltages less than 5,000 volts.

2.4.2.1 5,000 Volt Cables

For new 5,000 volt cables and terminations, the AC VLF field acceptance test shall be applied at not to exceed 14,000 volts (peak) for a duration of 15 minutes. This covers cables with both 100% and 133% cable insulation ratings. Record the pass or fail condition at the end of the test along with the ambient temperature and relative humidity. ***Because of possible power capacity limitations of the test set, the maximum length of the cable to be tested shall be based on the manufacturer's testing data and the capability of the test equipment.***

2.4.2.2 15,000 Volt Cables
For new 15,000 volt cables and terminations, the AC VLF field acceptance test shall be applied at 28,000 volts (peak) using a VLF test set (High Voltage Inc., type VLF-28CM or approved equal) for a duration of 15 minutes. This covers cables with both 100% and 133% cable insulation ratings. Record the pass or fail condition at the end of the test along with the ambient temperature and relative humidity. ***Because of possible power capacity limitations of the test set, the maximum length of the cable to be tested shall be based on the manufacturer's testing data and the capability of the test equipment.***

CAUTION: After all tests are complete and before the cables and terminations are placed back into normal operation, ENSURE that all temporary safety grounding connections are removed from all insulated conductors that will be energized.

3. OFFLINE 50/60 Hz PARTIAL DISCHARGE TEST

3.1 Theory of Operation

The offline 50/60 Hz partial discharge (PD) test can identify the location and severity of a defect within the new cable or its accessories, including a latent defect missed by hipot tests.
The test uses a 50/60 Hz high-voltage power source and sophisticated signal processing/analysis to detect minute partial discharges (PD) in cable insulation, pinpointing manufacturing weaknesses and workmanship errors. It is a reliable method for detecting defects inadvertently missed during factory tests, defects introduced during transportation and installation, and flaws introduced while handling and splicing the cables. These defects frequently do not appear in normal voltage withstand tests but can eventually cause undesirable service failures weeks, months, or years into the future.

The test is classified by the IEEE as a diagnostic test and not a destructive test (i.e., it is not designed to cause cable and accessories to fail). Due to its requirements for specialized test equipment, signal processing software, and diagnostic skills, the test must be conducted by a third-party testing firm. The testing firm must be a qualified contractor preauthorized by the FAA.

3.2 Parameters and Tolerance Limits

The test is conducted in accordance with IEEE 400.3 using a maximum test voltage of 2.0 to 2.5 times operating voltage level (Uo) for a duration not to exceed 30 seconds.

For test parameters and tolerance limits, refer to FAA Order 6950.22, Maintenance of Electrical Power Cables, Chapter 3, Standards and Tolerances, Paragraph 301, Table (see column heading labeled "NEW CABLE").

3.3 Test Schedules

Test after installation and just before energizing the new system. Allow adequate lead time for test planning with the third party testing firm: about 3 months before project completion for the initial notice, followed by 8 weeks' advance notice for setting up the information-gathering and detailed planning sessions.

3.4 Safety and Test Procedure

3.4.1 Safety

The third-party testing firm shall provide safety briefings at the beginning of each test session. See FAA Order 6950.22, Chapter 5, paragraph 504e(1) and applicable IEEE safety standards.

3.4.2 Test Procedure

For test procedure details, refer to FAA Order 6950.22, Maintenance of Electrical Power Cables, Chapter 5, Paragraph 504.

CAUTION: After all tests are complete and before the cables and terminations are placed back into normal operation, ENSURE that all temporary safety grounding connections are removed from all insulated conductors that will be energized.

APPENDIX D—Acronyms/glossary

AASHTO American Association of State Highway and Transportation Officials
AC Alternating Current
Advisory Circular
AJW-22 FAA Power Services Group
ALS Approach Lighting Systems
ANSI American National Standards Institute
APWA American Public Works Association
ASCE American Society of Civil Engineers
ASR Air Surveillance Radar
ASTM American Society for Testing and Materials
AWG American Wire Gauge. A standard for expressing wire diameter. As the AWG number gets smaller, the wire diameter gets larger.
C Clearance (cable pulling)
°C Degrees Centigrade
CADD Computer-Aided Design and Drafting
cmil Circular Mil(s). Area of a wire that is one-thousandth of an inch (.001 inch, one mil) in diameter.
CN Concentric Neutral
CONUS Continental United States
CT Current Transformer
d Cable Outside Diameter (cable pulling)
D Conduit Inside Diameter (cable pulling)
D' D x 1.05 (cable pulling)
DC Direct Current
DEB Direct Earth Buried
DLA Defense Logistics Agency
DOD Department of Defense
Duct Bank A set of parallel conduits made of steel, PVC covered, steel, heavy-walled PVC, or thin-walled PVC in reinforced concrete. Duct banks terminate in utility access holes or vaults. If not enclosed in concrete, duct banks must be of thicker material than thin-walled PVC.
EES Earth Electrode System
ELD Electrical Line Distribution (System). An underground or overhead electrical distribution system running from a power source to FAA facility load(s). An ELD may include some or all of the following: power cable; transformers; sectionalizers; switchpads; disconnect switches; manholes; hand-holes; utility poles; direct earth buried (DEB) cables; and underground duct banks. Intra-facility wiring, runway edge lighting cables, and FOTS and system cables, such as MALSR or ALSF loop cables are not included as part of ELD.
Electrical Trees Tree-like growths consisting of non-solid or carbonized microchannels, which can occur at electric field enhancements such as protrusions, contaminants, voids, or water trees subjected to electrical stress for extended time periods. Partial discharges are responsible for electrical tree growth.
EPT Electrical PVC Tubing

EPC	Electrical PVC Conduit
f	Coefficient of Friction (cable pulling)
FAA	Federal Aviation Administration
FOTS	Fiber Optic Telecommunications System(s)
ft	Feet
GIS	Geographic Information Systems
GPS	Global Positioning System
Grounding Conductor	A conductor used to connect equipment or the grounded circuit of a wiring system to the grounding electrode system.
Grounding Electrode	Copper rod, plate, or wire embedded in the ground for the specific purpose of dissipating electrical energy to the earth.
HAZMAT	Hazardous Materials
HDBK	FAA Handbook
HDPE	High-Density Polyethylene
HH	Hand Hole
HIPOT	High Potential (Test)
Hz	Hertz
ICEA	Insulated Cable Engineers Association
IEC	International Electrotechnical Commission
IECA	Insulated Cable Engineers Association
IEEE	Institute of Electrical and Electronics Engineers
in.	Inch(es)
ISO	International Standards Organization
JO	FAA Order
kg	Kilogram(s)
kV	Kilovolt(s)
L	Length of Cable (cable pulling)
lb	Pound(s)
LV	Low Voltage (Typically 600V and Below for ELD Systems)
m	Meter(s)
MCOV	Maximum Continuous Operating Voltage
MH	Manhole
mH	Millihenry(s)
MIL-STD	Military Standard
MIL-I	Military Specification
mil	Unit of Length, Equal to One Thousandth (10^{-3}) of an Inch (0.0254 millimeter)
mm	Millimeter
MOV	Metal Oxide Varistor
MV	Medium Voltage (600 V to 37.5 kV)
NAS	National Airspace System
NEC	National Electrical Code
NECA	National Electrical Contractors Association
NEMA	National Electrical Manufacturers Association
NESC	National Electrical Safety Code

NFPA	National Fire Protection Association
NRTL	Nationally Recognized Testing Laboratory
OPR	Office of Primary Responsibility
OSHA	Occupational Safety and Health Administration
Pa	Pascal(s)
pC	Picocoulomb(s)
PD	Partial Discharge
PPE	Personal Protective Equipment
psi	Pounds per Square Inch
PSG	Power Services Group
PTFE	Polytetrafluoroethylene (Teflon™)
PVC	Polyvinyl Chloride
PWRFRQ	Power Frequency (Test)
Qualified Person (Electrical)	A person knowledgeable in the construction and operation of electric power generation, transmission, and/or distribution equipment, along with associated hazards. Also known as “qualified worker.”
R	Radius of Bend (cable pulling)
rms	Root Mean Square
RMC	Rigid Metal Conduit
RSA	Runway Safety Area. Areas of a runway established to enhance safety in the event of an aircraft undershoot, overrun, or excursion from the side of the runway.
SDR	Standard Dimensional Ratio
SPD	Surge Protection Device
STD	FAA Standard
SWBP	Sidewall Bearing Pressure (cable pulling)
T	Total Pulling Tension (cable pulling)
TR-XLPE	Tree-retardant XLPE
TSA	Taxiway Service Area
U_o	Operating Voltage, Line to Ground
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification (DOD). The UFGS was founded by the Secretary of Defense and mandated by the Department of Defense for all Military Services to unify their specifications into one database.
UL	Underwriters’ Laboratory
UV	Ultraviolet
V	Volt(s)
VLF	Very Low Frequency
VORTAC	VOR/Tactical Air Navigation
w	Weight of Conductors (cable pulling)
W	Weight correction factor (cable pulling)
Xfmr	Transformer
XLPE	Cross-Linked Polyethylene

APPENDIX E--Submittals Matrix

Contractor-generated design data	
• Code analysis (e.g., voltage drops, clearance calculations, design arc flash study, etc) (ANSI C2)	A Required.
• Design assumptions and parameters (FAA-STD-032)	B ☐ Required for this project (check block).
• Test reports and findings (e.g., soil resistivity, load bearing, frost analysis, etc)	C ☐ Required for this project.
• Design calculations (FAA-STD-032)	A Required.
• Contractor-generated design drawings or sketches.	A Required.
Cost estimates	A Required.
Medium voltage cable	A Required.
Medium voltage cable splices and joints*	A Required.
Medium voltage cable terminations*	A Required.
Conduits	A Required.
Duct construction materials (e.g., concrete, alternatives to concrete where approved, fills and layers, etc)	A Required.
Switch pads and sectionalizers	A Required.
Transfer switches (automatic and manual)	A Required.
Transformers	A Required.
Surge arresters	A Required.
Live end caps or protective caps	A Required.
Precast concrete structures	A Required.
Sealing Material	B ☐ Required for this project.
Manhole frames and covers	A Required.
Hand hole frames and covers	A Required.
Cable supports (racks, arms and insulators)	A Required.
Protective devices and coordination study	A Required.
As-built arc flash hazard study. Required when an existing study is not available, or if modifications are being made to the existing ELD system.	A Required.

Electrical equipment factory test reports			
Medium voltage cable factory certified test result report as per FAA-E-2793, Section 4.2 (includes meeting ICEA S-94-649, Sections 4.3.2.1 and 9.13).	A		Required.
Transformers	A		Required.
Switchgear, sectionalizers	A		Required.
Disconnects	A		Required.
Other components	B	☐	Required for this project.
Field acceptance checks and tests (see Appendix C)	A		Required.
Arc-proofing test for cable fireproofing tape	C	☐	Required for this project.
Cable installation plan and procedure			
• Site layout drawing with cable pulls numerically identified	B	☐	Required for this project.
• list of equipment used, with calibration certifications	A		Required.
• The manufacturer, type, and quantity of lubricant used on pull	B	☐	Required for this project.
• The cable manufacturer and type of cable	A		Required.
• The dates of cable pulls, time of day, and ambient temperature	C	☐	Required for this project.
• The length of cable pull and calculated cable pulling tension (calculated value, not maximum value). A single generic table of cable pulls may be submitted.	A		Required.
• The actual cable pulling tensions encountered during pull	A		Required.
• Certificates (tensiometer calibration, VLF tester calibration, etc) [A]	A		Required.
Cable splicer/terminator qualifications* [A]	A		Required.
Cable installer qualifications* [A]	A		Required.
Project design drawings [A]	A		Required.

APPENDIX F—HDPE-to-HDPE and HDPE-to-PVC Conduit Adhesive - Sample Product

BonDuit®

Conduit Adhesive

American Polywater's

BONDS to Polyethylene, PVC, Fiberglass, Metals and more

BonDuit® Conduit Adhesive is a unique two-part adhesive system used to transition-splice conduits (innerducts) of different types. BonDuit® Adhesive in 5 minutes makes a strong, durable splice that is air/water tight. Requires no expensive equipment.

Estimated Load Capacity and Usage

Conduit Diameter	Polyethylene Conduit to PVC Standard Coupling	
	Coupling length	Pullout Force
1 inch	2 ¼ inch	760 lbs
1 ½ inch	2 ⅜ inch	1,140 lbs
2 inch	2 ½ inch	1,520 lbs
4 inch	3 ¾ inch	4,560 lbs

Results are based on careful surface preparation and a 24-hour cure at 70° F. Under these cure conditions; the load will reach 50% capacity after one hour and fully cured in 24 hours. To create air-tight joints for air-assisted cable installation, a cure time of 2 hours at 70°F is recommended. BonDuit® Conduit Adhesive is not designed for high stress pulls, such as those in HDD installations.

Numbers of Applications

BonDuit® Conduit Adhesive kit contain the materials necessary to prepare plastic and metal surfaces for bonding. By following the instructions, a strong joint takes just minutes. Each cartridge contains enough material for numerous applications, depending on the size of each coupling or joint.

Conduit Size	Applications per Cartridge
1 inch	20-30
1 ½ inch	12-18
2 inch	10-15
4 inch	4-6