UFC 3-550-01
1 September, 2016

UNIFIED FACILITIES CRITERIA (UFC)

EXTERIOR ELECTRICAL POWER DISTRIBUTION

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UNIFIED FACILITIES CRITERIA (UFC)

EXTERIOR ELECTRICAL POWER DISTRIBUTION

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by **1**\ ... /**1**/)

Change No.	**Date**	**Location**

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with USD (AT&L) Memorandum dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: Criteria Change Request. The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site http://dod.wbdg.org/.

Refer to UFC 1-200-01, *General Building Requirements*, for implementation of new issuances on projects.

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UNIFIED FACILITIES CRITERIA (UFC)
REVISION SUMMARY SHEET

Document: 3-550-01, *Exterior Electrical Power Distribution*

Superseding: UFC 3-550-01, *Exterior Electrical Power Distribution*, dated Feb 3, 2010, including Change 1, dated Jul 1, 2012.

Description: This UFC 3-550-01 provides design guidance for the design of exterior distribution systems.

Reasons for Document:

- Provide technical requirements.
- Incorporate new and revised industry standards.

Impact: There are negligible cost impacts associated with this UFC. However, the following benefits should be realized.

- Standardized guidance has been prepared to assist engineers with unique installation requirements.
- Exterior electrical equipment design criteria are specified to ensure that a reliable installation is realized.

Unification Issues:

The Air Force has the following noted exceptions:

- Paragraph 3-11.5.1 Permits use of pad-mounted sectionalizing cabinets instead of manholes.
- Paragraph 3-11.5.2 Prohibits T splices and Y splices on any MV system.
- Paragraph 3-11.5.5 Does not permit manholes in aircraft aprons.

The Navy has the following noted exceptions:

- Paragraph 3-2.3 Requires 600V insulated neutral conductor in pole riser and ductbanks.
- Paragraph 3-7 Requires switchgear to be SF-6 gas or high fire point liquid insulated.
- Paragraph 3-11.8 Does not permit concentric neutral conductors in ductbanks.
- Paragraph 3-11.8 Requires EPR insulation for MV cables.

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CHAPTER 1 GENERAL

1-1 PURPOSE.

This UFC provides policy and guidance for design criteria and standards for electrical power and distribution systems. The information provided here must be utilized by electrical engineers in the development of the plans, specifications, calculations, and Design/Build Request for Proposals (RFP) and must serve as the minimum electrical design requirements. It is applicable to the traditional electrical services customary for Design-Bid-Build construction contracts and for Design-Build construction contracts. Project conditions may dictate the need for a design that exceeds these minimum requirements.

UFC 3-501-01 provides the governing criteria for electrical systems, explains the delineation between the different electrical-related UFCs, and refers to UFC 3-550-01 for exterior electrical system requirements. Refer to UFC 3-501-01 for design analysis, calculation, and drawing requirements.

1-2 APPLICABILITY.

The design criteria and standards contained within are the minimum requirements acceptable for military installations for efficiency, economy, durability, maintainability, and reliability of electrical power supply and distribution systems. The criteria and standards herein are not intended to be retroactively mandatory.

1-2.1 NFPA 70 and IEEE C2.

Comply with the requirements of NFPA 70 and IEEE C2. Generally, IEEE C2 is the basis for UFC 3-550-01 and NFPA 70 is the basis for UFC 3-520-01. However, there are exceptions to which standard applies to each UFC, including:

- Systems covered by other UFCs, such as airfield lighting and shore power systems.
- Exterior circuits such as lighting and service entrance (overhead and underground), which are covered by NFPA 70.

For medium voltage applications, feeder conductor sizing is permitted to be determined by qualified persons under engineering supervision as defined by NFPA 70 Article 215.2 (B) (3), *Supervised Installations*.

1-2.2 Additional References.

Comply with UFC 3-560-01 for electrical safety requirements applicable to the installation and operation of electrical systems.

Comply with UFC 4-010-01 and UFC 4-020-01 for security requirements related to exterior electrical distribution systems.

1-2.3 Exclusions.

Onsite generation is not addressed by this UFC.

1-3 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, DoD Building Code (General Building Requirements). UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance and sustainability requirements, and safety. Use this UFC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein.

1-4 CRITERIA WAIVER PROCESS.

The criteria waiver process is provided in MIL-STD 3007.

1-5 REFERENCES.

Codes and standards are referenced throughout this UFC. The publication date of the code or standard is not routinely included with the document identification throughout the text of the document. In general, the latest issuance of a code or standard has been assumed for use. Refer to Appendix A to determine the publication date of the codes and standards referenced in this UFC.

1-6 UTILITY-OWNED AND OPERATED DISTRIBUTION SYSTEMS ON FEDERAL PROPERTY.

This UFC does not apply to:

- Utility-owned and operated distribution systems with right-of-way or easements on Federal property.
- Military installations that have privatized their electrical distribution system.

CHAPTER 2 ELECTRICAL POWER REQUIREMENTS

2-1 ELECTRICAL POWER REQUIREMENTS: GENERAL.

Virtually all military bases have an existing overhead and underground distribution system that has been in service for many years. As part of any new design project, review the existing design with base personnel to determine which existing features should not be duplicated in future designs. Address design preferences with responsible engineering and operations personnel as part of the system design analysis.

2-2 SELECTION OF PRIMARY VOLTAGE.

NEMA C84.1 establishes typical voltages and voltage ranges for 60 Hz systems.

Facilities located outside of the United States must also comply with the applicable host nation standards; refer to UFC 3-510-01 and UFC 1-202-01 for additional information.

2-3 DESIGN FOR MAINTENANCE.

Design primary distribution system equipment installations with future periodic maintenance as a principal consideration. Equipment must be capable of removal from service while minimizing the outage time of affected facilities and missions. Looped and alternate feed designs are essential to allow periodic maintenance.

Provide maintenance criteria with the design analysis as part of the basis for the design as specified in UFC 3-501-01.

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CHAPTER 3 DESIGN CRITERIA

3-1 MAIN AND UTILIZATION ELECTRIC SUPPLY STATIONS.

For all main and electric supply stations/substations, comply with the requirements of IEEE C2 Part 1, *Rules for the Installation and Maintenance of Electric Supply Stations and Equipment*, as follows:

- Electric Supply Stations are defined as stations that transform the energy level (voltage) for further bulk distribution at medium voltage levels.
- Comply with the requirements of NFPA 70 for the low voltage equipment in a main or electric supply station (equipment that is being served from a Utilization Electric Supply Station).

3-1.1 Main Electric Supply Stations.

The main electric supply station is the installation/utility interface point where further transmission, distribution and utilization of electrical power, the monitoring and control of such power or equipment and the protection of electrical equipment or systems usually becomes the sole responsibility of the Government or their contracted representatives. Coordinate the design of new stations, or modifications to existing stations with the supplying utility and with any other suppliers or users of power supplied through the station.

3-1.2 Utilization Electric Supply Stations.

Utilization Electric Supply Stations are defined as equipment such as pole or pad-mounted transformers, secondary unit substations, or primary unit substations that transforms the energy level (voltage) to a utilization voltage for consumer use. Some examples of Utilization Electric Supply Stations are station service transformers (serving low voltage equipment in a Main Electric Supply Station), a lighting transformer (serving equipment for a roadway lighting system), a pole or pad-mounted transformer (serving a building), or a secondary unit substation (serving piers and wharfs electrical systems).

3-2 GENERAL ELECTRICAL REQUIREMENTS.

Refer to Appendix C for Best Practices-General Electrical Power Requirements.

3-2.1 Industry Standards.

Overhead systems – comply with the requirements of IEEE C2 Part 2, *Safety Rules for the Installation and Maintenance of Overhead Electric Supply and Communication Lines*.

Underground systems – comply with the requirements of IEEE C2 Part 3*, Safety Rules for the Installation and Maintenance of Underground Electric Supply and Communication Lines*.

3-2.2 Arc Flash Analysis Criteria.

Refer to UFC 3-560-01 Section 1-4.1.1 for arc-flash criteria and the delineation points between IEEE C2 and NFPA 70E conformance requirements.

3-2.3 System Design.

Design new primary distribution systems as four wire, multi-grounded systems that are wye connected at the source transformer. Provide a system grounded neutral conductor throughout the system. Provide a bare conductor for the neutral on overhead systems.

Note: For the Navy, provide a neutral that is a 600 volt insulated conductor for pole riser and underground systems.

When a project is limited to connecting to an existing three wire system and the primary electrical characteristics are established and defined, continuation of the existing system is permitted with the following requirements:

- For extensions from underground structures, provide a four wire extension. Bond the grounded neutral conductor at each end of the extension to the applicable grounding electrode systems.
- For extensions from overhead pole lines, provide a four wire extension. Bond the grounded neutral conductor at each end of the extension to the applicable grounding electrode systems.

Note: Design of the extensions as four wire systems does not change any circuit classifications. It provides an extended grounding electrode system to facilitate any future circuit conversions to four wire systems.

3-2.4 Pad-Mounted Equipment.

Provide pad-mounted equipment foundation pads and ensure a minimum of 10 ft (3 m) clear workspace in front of pad-mounted equipment for hot stick work. Orient equipment so that adjacent equipment will not interfere with the clear workspace. Provide bollards in areas where equipment is subject to vehicular damage.

3-3 PRIMARY UNIT SUBSTATIONS.

Provide primary unit substations to distribute underground medium voltage circuits. Comply with the following industry standards as applicable for the specified configuration:

- IEEE C37.06, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Basis – Preferred Ratings and Related Required Capabilities*.
- IEEE C37.46, *High Voltage Expulsion and Current-Limiting Type Power Class Fuses and Fuse Disconnection Switches*.

- IEEE C37.121, *Switchgear – Unit Substations Requirements*.
- IEEE C57.12.28, *Pad-Mounted Equipment – Enclosure Integrity*.
- IEEE C57.12.00, *General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- IEEE C57.12.80, *Terminology for Power and Distribution Transformers*.
- IEEE C57.12.90, *Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- IEEE C57.96, *Loading Dry-Type Distribution and Power Transformers*.
- IEEE C57.98, *Guide for Transformer Impulse Tests*.
- IEEE C37.74, *IEEE Standard Requirements for Subsurface, Vault, and Padmounted Load- Interrupter Switchgear and Fused Load-Interrupter Switchgear for Alternating Current Systems up to 38 kV*.

3-4 SECONDARY UNIT SUBSTATIONS.

Provide secondary unit substations when secondary currents exceed 3,000 amperes at 1,000 volts and below. Comply with the following industry standards as applicable for the specified configuration:

- IEEE C57.12.28, *Pad-Mounted Equipment – Enclosure Integrity*.
- IEEE 57.12.50, *Ventilated Dry-Type Distribution Transformers, 1 to 500 kVA, Single-Phase, and 15 to 500 kVA Three-Phase, with High-Voltage 601 to 34,500 Volts, Low-Voltage 120-600 Volts*.
- IEEE 57.12.51, *Ventilated Dry-Type Power Transformers, 501 kVA and larger, Three-Phase, with High-Voltage 601 to 34,500 Volts, Low-Voltage 208Y/120 to 4160 Volts*.
- IEEE C57.12.00, *General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- IEEE C57.12.01, *General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid-Cast and/or Resin-Encapsulated Windings*.
- IEEE C57.12.80, *Terminology for Power and Distribution Transformers*.
- IEEE C57.12.90, *Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- IEEE C57.12.91, *Test Code for Dry-Type Distribution and Power Transformers*.
- IEEE C57.96, *Loading Dry-Type Distribution and Power Transformers*.
- IEEE C57.98, *Guide for Transformer Impulse Tests*.

- IEEE C57.124, *Detection of Partial Discharge and the Measurement of Apparent Charge in Dry-Type Transformers*.

3-5 PAD-MOUNTED DISTRIBUTION TRANSFORMERS.

3-5.1 Reference Criteria.

Comply with the following industry standards:

- IEEE C57.12.28, *Pad-Mounted Equipment – Enclosure Integrity*.
- IEEE C57.12.00, *General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- IEEE C57.12.34, *Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers (2500 kVA and Smaller) – High-Voltage, 34,500 GrdY/19,200 Volts and Below; Low-Voltage: 480 Volts and Below*.
- IEEE C57.12.80, *Terminology for Power and Distribution Transformers*.
- IEEE C57.12.90, *Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*.
- IEEE C57.98, *Guide for Transformer Impulse Tests*.
- IEEE C57.12.22, *Transformers – Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers with High-Voltage Bushings, 2500 kVA and Smaller: High Voltage, 34,500 Grd Y/19,920 Volts and Below; Low Voltage, 480 Volts and Below*.

3-5.2 Configuration.

Use dead-front construction for pad-mounted transformers unless not available within system parameters. Use pad-mounted transformers, separately protected with vacuum fault interrupter equipped switches for 34.5 kV systems.

Three-phase pad-mounted transformers must be loop-feed capable with 6 bushings. Provide two-position, oil-immersed, load break switches that are appropriate for the application. If the transformer might be used as part of a loop-feed design, provide three switches to permit closed transition loop feed and sectionalizing. If the transformer will be installed at the end of a radial supply with no intention of future loop feed capability, provide a single on-off switch. Provide a spare conduit in the high voltage section extending 5 ft (1.5 m) out from the transformer pad.

3-5.3 Size and Secondary Voltage.

Do not use pad-mounted transformers with secondary currents exceeding 3,000 amperes because of the size and quantity of secondary conductors. Transformers rated above 1,000 kVA serving 208Y/120 volt loads and above 2,500 kVA serving 480Y/277 volt loads must be in a secondary unit substation configuration.

Minimize double transformations to reduce energy consumption and to minimize items of equipment. Provide two oil-filled pad-mounted transformers in lieu of one 480Y/277 volt service if the required 208Y/120 volt load using dry-type transformers exceeds 40 percent of the 480 volt service transformer capability. Connect equipment at the highest available voltage to minimize the capital cost and energy losses of transformation equipment.

3-5.4 Winding Configuration.

Provide delta-wye connections for three phase systems.

3-5.5 Surge Protection.

Provide bushing-mounted elbow type arresters at the ends of all radials and in normally open locations in loops. Provide arresters for all voltage levels above 5 kV.

3-5.6 Drawing Details.

When using a pad-mounted transformer, select the applicable pad-mounted transformer detail in AutoCAD format from: http://www.wbdg.org/ccb/browse_cat.php?o=78&c=232, supply the missing data, and incorporate that detail onto the contract drawings. These details are also provided in a PDF format at http://www.wbdg.org/ccb/browse_cat.php?o=29&c=248. These drawing details represent typical situations but may not meet all requirements. Modify transformer details as required to indicate the actual requirements for each particular installation.

In rare cases when “live front construction” is required due to equipment ratings (available system fault current values), obtain approval from the Authority Having Jurisdiction (AHJ), as defined in UFC 1-200-01. Do not use the pad-mounted transformer details to show secondary unit substations.

3-6 MEDIUM VOLTAGE SWITCHGEAR.

3-6.1 Metal-Clad Switchgear.

Metal-clad switchgear can include either SF6 or vacuum style breakers and must consist of a single section or multiple section line-up of NEMA 1 or NEMA 3R enclosures. Either walk-in or non-walk-in construction can be provided. Medium voltage metal-clad switchgear can be provided as unit substation construction or as stand-alone switchgear. The sections must contain the breakers and the necessary accessory components. The equipment must be factory-assembled (except for necessary shipping splits) and be operationally checked before shipment. As an electrical safety consideration, provide a remote racking mechanism to rack breakers in and out. As an electrical safety consideration, provide ground ball studs on the load side of each circuit breaker to allow for connection of temporary grounding sets.

Comply with the following industry standards:

- IEEE C37.06, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis – Preferred Ratings and Related Required Capabilities*.
- IEEE C37.121, *Switchgear – Unit Substations Requirements*.
- IEEE C37.04, *Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*.
- IEEE C37.20.2, *Metal-Clad Switchgear*.
- IEEE C37.90, *Relays and Relay Systems Associated with Electric Power Apparatus*.

3-6.2 Metal-Enclosed Switchgear.

Do not use metal-enclosed switchgear. Instead, use either a vacuum fault interrupter (VFI) in a unit substation configuration or pad-mounted switchgear.

3-6.3 Circuit Breaker Operation Design.

Provide batteries with battery charger for dc opening and closing of circuit breakers. Do not use ac or capacitor control methods.

3-7 PAD-MOUNTED SWITCHGEAR (SWITCHES).

For the Navy, utilize multi-way pad-mounted switchgear when switching, isolation, or electrical protection is required. Specify SF6 gas or high fire point liquid (non-temperature dependent) insulation technology and vacuum bottle interruption technology. Specify dead front construction with stainless steel tanks and operator full size viewing windows for each switching way. Specify three position (On/Off/Ground) switch ways for all new construction. For switch replacements when existing switching arrangement is On/Off/Tie, a similar arrangement without ground position is permissible. Specify switch design which incorporates operating handles on the opposite side of the tank from the cable entrance bushings, terminations and cables. Specify 600 ampere dead break connectors with 200 ampere interface bushings for each switch way. Coordinate with the Activity and include ground fault circuit indicators in accordance with the base design standard. Air-insulated (fused or non-fused) technology is not permitted. Comply with the following industry standards:

- IEEE C57.12.28, *Pad-Mounted Equipment – Enclosure Integrity*.
- IEEE C37.60, *Requirements for Overhead, Pad-Mounted, Dry Vault, and Submersible Automatic Circuit Reclosers and Fault Interrupters for Alternating Current Systems Up to 38 kV*.
- IEEE C37.74, *IEEE Standard Requirements for Subsurface, Vault, and Padmounted Load- Interrupter Switchgear and Fused Load-Interrupter Switchgear for Alternating Current Systems up to 38 kV*.

For the Army and Air Force, air-insulated and fused switches can be used in either a live-front or dead-front configuration. Do not use air-insulated switches in corrosive and high humidity areas as defined in UFC 3-501-01 unless the installation experience for the installed location confirms that switch corrosion and tracking is not a problem.

3-8 PAD-MOUNTED SECTIONALIZING TERMINATION CABINETS.

Apply pad-mounted sectionalizing termination cabinets only when switching, isolation, or electrical protection for the downstream circuit is not required or anticipated. Sectionalizing termination cabinets can be used instead of in-line splices in manholes or for minor loads that do not warrant the expense of pad-mounted switchgear. Sectionalizing cabinets are available up to 35 kV. Provide low profile sectionalizing termination cabinets when the conductor size is 4/0 awg or smaller. Coordinate with the Activity and include ground fault circuit indicators in accordance with the base design standard.

3-9 CAPACITORS.

3-9.1 Application.

Do not use capacitors unless they are needed for power factor correction or to minimize line losses. Verify the need by a system analysis; the analysis must consider the potential adverse effects of transients caused by capacitor switching. Refer to TSEWG TP-2: *Capacitors for Power Factor Correction*, at http://www.wbdg.org/ccb/browse_cat.php?o=29&c=248 for additional information if power factor correction is considered.

Underground distribution has more capacitance than equivalent overhead distribution. When converting from overhead distribution to underground distribution, provide pad-mounted capacitors on a distribution system only if supported by the design analysis. Do not automatically replace existing pole-mounted capacitors with equivalent pad-mounted capacitors.

3-9.2 Disconnect Design.

For safety purposes, include an oil switch disconnect with pole-mounted capacitors.

3-10 OVERHEAD POWER DISTRIBUTION.

Design overhead lines to IEEE C2 Grade B construction complying with the following:

a. Limit the initial loaded conductor tension to a maximum of 50% of the conductor rated breaking strength. Lesser tensions are usually applicable and generally more preferred. Utility distribution line design is generally in the range of 25% to 35% of the rated breaking strength.

b. Provide clearance requirements using final sag values in conformance with IEEE C2 Part 2.

c. Limit the maximum design tensions for any conductors to 4,750 pounds (2,154 kg). Base all clearance values on the following maximum conductor temperatures.

- Copper phase conductors – 167 degrees F (75 degrees C).
- Aluminum/aluminum alloy phase conductors – 194 degrees F (90 degrees C).
- Neutral conductors for multi-phase circuits – 120 degrees F (49 degrees C).
- The maximum conductor temperature for single-phase neutral conductors is identical to the phase conductors.

Match the existing base construction methods. Match those construction methods used by the local utility when directed. Where new overhead distribution is required, route the overhead distribution along roadways and other major topographical features; the poles must be accessible for future maintenance or work. Coordinate pole locations with land-use planning to ensure that new poles do not interfere with future facility plans.

3-10.1 Drawing Details.

Use NAVFAC pole details OH-1.1 through OH-41. NAVFAC pole details are available in Adobe PDF format and in AutoCAD format http://www.wbdg.org/ccb/NAVGRAPH/graphtoc.pdf. In situations where an applicable pole detail has not been developed, provide new detail drawings as required. For designer developed details, provide a level of detail equivalent to NAVFAC pole details and include material requirements. Refer to UFC 3-501-01 for additional pole detail requirements.

3-10.2 Pole Types.

Use solid wood poles for electric distribution lines. Concrete or steel poles may be justified for medium-voltage distribution circuits where wood poles do not provide adequate strength, or where climatic conditions cause wood poles to deteriorate rapidly. Do not use laminated wood poles for electric distribution lines.

3-10.3 Conductors.

Due to the increasing technology improvements with aluminum conductors and connectors, and the economic disadvantage of providing copper conductors, provide aluminum conductor steel reinforced (ACSR) or aluminum alloys for new overhead lines and extensions of existing lines. Do not use ACSR conductors in corrosive and high humidity areas. For corrosive and high humidity areas, provide Type ACSS conductors. Except for grounding systems, the use of copper conductors is prohibited without specific approval and documentation by the applicable local engineering authority. The local engineering authority is defined by the following:

- For the Navy, the Facilities Engineering Command (FEC) organization's chief engineer has the authority to use copper product for their applicable jurisdiction.

- For the Army, the Installation Department of Public Works Chief Engineer has the authority to use copper product for their applicable jurisdiction if documented in the planning process and the design analysis.

- For the Air Force, the Base Civil Engineer has the authority to exercise the criteria option of copper product for their applicable jurisdiction if documented in the planning process and the design analysis.

3-10.4 Pole-Mounted Transformers.

3-10.4.1 Maximum kVA Rating.

Provide pad-mounted transformers rather than pole-mounted transformers for new three-phase installations larger than 75 kVA.

Limit pole-mounted transformer sizes (except for projects involving system conversions to a different operating voltage) as follows:

- Three-phase installations – limited to three 25 kVA transformers or smaller.
- Single-phase installations – limited to one 75 kVA transformer or smaller.

3-10.4.2 Configuration.

Use only single phase transformers for pole-mounted installations. For single phase installations and when banking single phase transformers for three phase applications, apply phase-to-neutral primary connections unless installed on three wire distribution systems.

Do not use self-protected transformers. Self-protected transformers have internal primary fuses that must be replaced by experienced personnel.

3-10.4.3 Mounting and Location.

Do not use pole-platform mounting (two-pole structure or H-frame).

Aerially mounted installations might supply several buildings. When that is the case, install the transformers at the pole location closest to the building with the greatest load. Secondary wiring should drop directly to the buildings served, if the span does not exceed 125 feet; otherwise, intermediate poles are required.

3-10.5 Pole-Top Switches.

Pole top switches are installed at important system locations to allow either isolation of the downstream circuit or cross-connection to a different circuit. Where ground operated, gang type, three phase, air break switches are used with non-insulated operator handles, provide a metal plate or grate at ground level for the operator to stand on when operating the switch. Connect the metal plate or grate to the pole ground conductor as well as through a braided conductor connection to the switch handle mechanism. Include a provision for locking ground accessible switch handles in the open and closed position.

Single-pole knife blade switches and copper barrels inside distribution cutouts are only acceptable for use in locations where frequent switching is not expected.

3-10.6 Surge Arresters.

Provide surge arresters on the line side of:

- Pole mounted transformers.
- Overhead to underground terminal poles.
- All “normally open” switch ways of pad-mounted sectionalizing switches connected to and served from overhead lines.
- Underground primary metering installations connected to and served from overhead lines.

Provide surge arresters on the line and load sides of:

- Gang operated airbreak switches on overhead lines.
- Primary metering applications on overhead lines.
- Recloser/sectionalizer applications on overhead lines.

3-10.7 Fuse Protection.

Provide IEEE C37.41 rated backup current limiting fuses in series with Type K expulsion fuses on systems that are:

- Greater than 15 kV.
- 15 kV and lower that have available fault currents equal to or greater than 7,000 asymmetrical amperes.

Note: Existing systems should continue to use the expulsion fuse link type that represents the standard for that system.

3-10.8 Automatic Circuit Reclosing.

Do not provide automatic circuit reclosing on underground distribution circuits.

3-10.9 Ground Connections.

Keep ground wires straight and short. Minimize bends in all ground connections.

3-11 UNDERGROUND ELECTRICAL SYSTEMS.

3-11.1 Underground Distribution General Criteria.

3-11.1.1 Locations.

Provide underground distribution as follows:

- In areas where the primary distribution is already underground.
- In locations where overhead distribution is operationally hazardous, such as within airfield clearance zones.
- As required to supply pad-mounted equipment and transformers.
- Near electronics or munitions facilities that have clearance requirements for overhead power lines.
- Near piers and loading areas where overhead cranes operate.
- In congested industrial areas.
- In areas where storm and hurricane damage can damage overhead distribution.

3-11.1.2 Conductor Type.

Due to the increasing technology improvements with aluminum conductors and connectors and the economic disadvantage of providing copper conductors, provide aluminum conductors for new underground lines and extensions of existing circuits. This includes all new medium voltage system designs that do not require interface (splicing copper to aluminum in underground structures) with existing copper infrastructure. Provide only copper grounding electrode systems. The use of copper conductors is authorized for extensions of existing systems in which the use of aluminum results in technical limitations, such as:

- Maintaining required circuit ampacity, including derating associated with number of circuits in a common ductbank or burial depth.
- Maintaining base infrastructure capacity, including feeder cross-tie capability.
- Conduit size. All phases are required to be installed in the same conduit.
- Undersized or congested structures necessitating tape splices of aluminum cable to existing copper cable. *Note: If adequate space exists for the use of improved technology "heat shrink or cold shrink" splices, or if proper aluminum to copper compression connectors designed for the natural offset of size difference between the conductor materials is available as a standard manufactured product, provide the copper to aluminum cable extension*.

Approval of copper conductors is authorized as follows:

- For the Navy, the Facilities Engineering Command (FEC) organization's chief engineer has the authority to use copper product for applications within their applicable jurisdiction, in addition to the above authorized use for extensions.

- For the Army, the Installation Department of Public Works Chief Engineer has the authority to use copper product, in addition to the above authorized use for extensions, within their applicable jurisdiction if documented in the planning process and the design analysis.

- For the Air Force, the Base Civil Engineer has the authority to exercise the criteria option of copper product, in addition to the above authorized use for extensions, within their applicable jurisdiction if documented in the planning process and the design analysis.

3-11.1.3 Routing.

Do not route primary underground utilities under buildings. Do not route systems greater than 600 volts under buildings except as a direct service entrance to a single interior transformer.

3-11.1.4 Marking and Labeling.

Tag all underground cables in all accessible locations such as in manholes, transformers, switches and switchgear. Install a detectable locator tape above all buried underground circuits. Marking must meet the base utility standards.

3-11.2 Ductbanks.

The definition of the terms ductbank, conduit, and duct are often confused. Within this UFC, a ductbank consists of two or more conduits (or ducts) routed together in a common excavation with or without concrete encasement

3-11.2.1 Conduit Size.

Minimum conduit sizes must be as follows:

- Provide concrete encasement for primary distribution conduits between underground structures, and between underground structures and associated equipment, except in locations where soil conditions prohibit a stable environment. With approval of the Activity, utilize directional boring where conditions are not conducive to concrete-encased ductbanks.

  Primary Distribution Conduits (along main run and on laterals between underground structures and associated equipment) – size as needed to satisfy conduit fill and jam ratio criteria for the selected conductor size and voltage class, with 5 in (127 mm) minimum. For primary distribution conduits serving Navy dockside utilities, provide 6 in (155 mm) minimum.

Secondary Distribution Conduits (Low Voltage) – size as needed to satisfy conduit fill and jam ratio criteria for the selected conductor size, with 4 in (103 mm) minimum for conductor sizes 500 kcmil and larger. In this case, secondary distribution conduits refer to the low voltage conduit routing from the distribution transformer to the service entrance equipment. This requirement does not apply to street lighting circuits, secondary supplies to housing, or secondary circuits originating from an interior panel.

- Telecommunication Conduits – 4 in (103 mm) for main telecommunications circuits.

  Specialty telecommunications circuits, such as cable television or alarm circuits, can select conduit sizes as needed for the application.

  Example: a cable television circuit might only require a 2 in (52 mm) conduit stubbed out to a fiberglass composite handhole.

3-11.2.2 Installation.

- Use Type EB Schedule 20 PVC conduits (minimum thickness) for conduits installed in concrete encasement. Provide at least 3 in (75 mm) of concrete encasement.
- Use Schedule 40 PVC conduit (minimum thickness) for conduits that are not installed in concrete encasement.
- Install all phase conductors and neutral conductor, if applicable, in the same conduit for three-phase circuits and delta-connected single-phase circuits. *Note: some utilities install each phase conductor in a separate conduit. This practice is not authorized*.
- Bury conduit at a minimum depth of 18 in (450 mm) below grade. Conduits must be 24 in (600 mm) minimum depth under roads and pavement, and for voltages between 22 kV and 40 kV. Apply conductor ampacity derating when exceeding the NFPA 70 maximum burial depths.
- Provide 3 in (75 mm) clearance between conduits utilizing interlocking plastic spacers.
- For primary distribution circuits, provide spare conduits such that at least 1/3 of the ductbank contains empty conduits with a minimum of at least one spare conduit.
- For secondary distribution circuits on the secondary side of distribution transformers, provide one spare conduit.
- Include pull wires (pull string or pull rope) in all spare ducts.
- Provide a transition from Type EB conduit to Schedule 40 PVC conduit before emerging from underground.

- Use directional boring or jack-and-bore techniques for routing conduit(s) under existing pavement for roadways, aircraft aprons, runways and taxiways. Directional boring can be used for other locations where excavation can adversely affect daily operations.

  Note: Comply with Appendix B for the use of directional boring for conduit installations.

- For permafrost locations, use ductbank installation methods that are the standard for the base, post, or local utility.

3-11.3 Direct Buried Wiring Methods.

The term direct buried wiring refers to the direct burial of conductors without any conduit or concrete encasement. Comply with IEEE C2 for all direct burial systems.

3-11.3.1 Authorized Locations.

With approval of the Activity, direct buried wiring methods for low or medium voltage systems may be allowed for specific applications such as:

- Special applications in remote or extremely controlled areas. Examples of such applications could be ranges or range facilities, renewable energy projects such as wind farms or bulk photovoltaic (PV) facilities provided for the purpose of supplementing system demand loading.
- Housing projects utilizing residential type distribution principles of single-phase, pad-mounted transformer designs and single-phase distribution principles for balanced three phase system loading.
- Bulk power transfer (feeder) from point to point crossing remote or controlled real estate which will revert to public utility ownership and maintenance upon completion.

Direct buried wiring methods are not authorized for any application which constitutes a part of the base utility core distribution infrastructure.

3-11.3.2 Conductor Type.

All approved direct burial medium voltage systems can utilize concentric neutral underground distribution cable design instead of the typical Type MV tape-shielded conductor design utilizing a separate 600 volt insulated neutral conductor.

3-11.3.3 Crossing of Paved Areas.

Provide a spare conduit system with associated enclosures for direct buried systems under all streets, roads, and parking areas to provide for future maintenance capability without having to disrupt pavements. Provide minimum Schedule 40 PVC extending 5 feet on each side and capped for future use.

For crossing existing paved areas, the directional boring technology referenced in the paragraph titled Directional Boring, also applies for installation of the direct buried system.

3-11.4 Directional Boring.

Directional boring (DB) is a trenchless technology method to install high density polyethylene electrical (HDPE) conduit used for underground electrical distribution systems.

3-11.4.1 Authorized Locations.

Do not select DB methods as an installation means in lieu of concrete encasement or other approved jack-and-sleeve techniques, based solely on cost. Concrete encasement and jack-and-sleeve techniques always provide the best means to protect conduit and conductors; therefore, DB is authorized only for crossing under the following:

- Roads.
- Parking lots.
- Airfield aprons, taxiways, or runways (not airfield lighting circuits due to counterpoise requirements).
- Bodies of water.
- Environmentally sensitive areas with appropriate federal, state, and local government approval.
- Historical preservation areas with appropriate federal, state, and local government approval.

DB is also authorized for locations where earth setting has caused shearing of conduits. Document this basis for selection of DB as part of the design analysis.

3-11.4.2 Limitations.

DB is applicable to medium-voltage (MV) underground distribution systems between 1000 volts (V) and 34.5 kilovolts (kV) (nominal) and all low-voltage distribution systems (less than 1000 V). It is not applicable to airfield lighting circuits. Use of DB techniques to install electrical conduit distribution for voltages greater than 34.5 kV (nominal) is prohibited.

Refer to Appendix B regarding depth of DB. The depth can be less if a detailed survey is performed and documented before starting boring.

3-11.5 Underground Structures (Manholes and Handholes).

3-11.5.1 General Requirements.

Provide separate power and communication manholes. When power and communication duct lines follow the same route, use a common trench and locate power and communication manholes in close proximity to one another and staggered. Use manholes for main duct runs and wherever shielded medium voltage cable is installed. For the Air Force, pad-mounted sectionalizing termination cabinets can be used instead of manholes for locations that do not have multiple feeders.

Handholes can only be used for airfield lighting circuits, for other non-shielded medium voltage circuits, and for low-voltage and communication lines.

3-11.5.2 Equipment Prohibited Inside Manholes.

The following equipment is prohibited inside underground structures:

- Load junctions.
- Separable splices (bolt-T connections).
- T-splices and Y-splices on systems rated for greater than 15 kV.
- For the Air Force, T-splices and Y-splices on all medium voltage systems.
- Power distribution equipment, including transformers and switches.

3-11.5.3 Splice Locations.

All in-line splices must be in underground structures. Do not use handholes for splicing shielded power cables.

3-11.5.4 Fireproofing.

Individually fireproof medium voltage cables in all underground structures.

3-11.5.5 Design Loading.

Specify H20 highway loading for most locations. Structures subject to aircraft loading must be indicated to the Contractor. Design decks and covers subject to aircraft loadings per FAA AC-150/5320-6D except as follows:

- Design covers for 100,000 lb (45,000 kg) wheel loads with 250 psi (1.72 MPa) tire pressure.
- For spans of less than 2 ft (0.6 m) in the least direction, use a uniform live load of 325 psi (2.24 MPa).
- For spans of 2 ft (0.6 m) or greater in the least direction, the design must be based on the number of wheels which will fit the span. Use wheel loads of 75,000 lb (34,000 kg) each.

Note: For the Air Force, do not install electrical manholes in aprons. Maintain a distance of 50 ft (15 m) from the edge of paving, 50 ft (15 m) from any hydrant lateral control pit, and 200 ft (60 m) from a fueling point for all manholes.

3-11.5.6 Manhole Size.

Determine the size of power manholes by the number of circuits, voltage ratings and splicing requirements of the cables within. Provide manholes that are a minimum 2 m (6.5 ft) deep. For circuits rated above 15 kV, provide manholes that are a minimum of 9 ft by 12 ft (2.8 m by 3.7 m) in interior size. Provide cable racks in all new manholes. When reworking cables in existing manholes, provide racks for new cables. Route cable installations inside manholes along those walls providing the longest route and the maximum spare cable lengths.

Size communications manholes for equipment and splices contained, including future projections. Manholes must accommodate racking of splice closure of largest multi-pair cable while keeping cable bending radii greater than 10 times cable diameter.

3-11.5.7 Manhole Drawing Details.

Provide manhole foldout details or exploded views for all multiple-circuit primary systems and all primary systems requiring splices. Indicate the entrance of all conduits and the routing of all conductors in the manholes. Manhole details are available in Adobe PDF format at http://www.wbdg.org/ccb/NAVGRAPH/graphtoc.pdf and in AutoCAD format at http://www.wbdg.org/ccb/browse_cat.php?o=78&c=232.

3-11.6 Locating Underground Structures.

Provide where splices are required, where duct lines change direction, and within 100 ft (30 m) of every riser pole, pad mounted transformer, or unit substation unless a calculation is provided to justify a greater distance. The distance must not exceed 200 ft (60 m).

Separation on straight runs must not exceed 400 ft (120 m). In situations where greater separation is desired and this greater separation is not prohibited by either excessive pulling tension or site requirements, separation of up to 600 ft (180 m) is permitted.

3-11.7 Pull Boxes.

Pull boxes are used for electric circuits supplying low-voltage electric loads which require conductors no larger than 1/0 AWG and no more than one 2-inch (52 mm) conduit entrance at each side. Wherever larger conduits are installed, use handholes or manholes. Do not use pull boxes in areas subject to vehicular traffic.

3-11.8 Medium Voltage Cable.

Comply with NEMA WC 74 and select type MV (105°C) aluminum or copper based on the specific applications as defined in Para. 3-11.1. Provide a 600 volt insulated neutral when required. For the Army and Air Force, concentric neutral conductors are also authorized.

Comply with the following:

- Cable Jacket – PVC or polyethylene jacket suitable for wet conditions.
- Insulation Type – Provide ethylene propylene rubber (EPR). For the Army and Air Force, cross-linked polyethylene is also authorized. Do not use paper insulated lead covered (PILC) for new installations.
- Insulation Level – Provide a 100% minimum insulation level for all circuits classified as multi-grounded (4 wire systems throughout the entire circuit). Provide a 133% insulation level for all other classification of circuits.
- Cable Shields – Use copper-tape shielded cables and ensure minimum bending radii of 12 times the overall cable diameter. Use copper-wire shielded cables only where existing manholes are utilized and the minimum cable bending radii of tape shielded cables cannot be realized. Refer to NEMA WC 74 for cable bending radii.
- Number of Conductors – Use single conductor cable as a general rule. Three conductor cable may be used only when splicing to existing three conductor cable.

3-12 CONCRETE FOR UNDERGROUND ELECTRICAL SYSTEMS.

Concrete for encasement of underground ducts must be 3000 psi (20 MPa), minimum 28-day compressive strength. Concrete associated with electrical work for other than encasement of underground ducts must be 4000 psi (30 MPa), minimum 28-day compressive strength unless specified otherwise.

3-13 HOUSING DISTRIBUTION.

Comply with the following requirements for electrical distribution to housing units:

- Serve single dwelling units, duplexes and quadra-plexes in housing areas by single-phase, 240/120V transformers.
- Serve no more than 6 dwelling units; 4 duplexes; or 2 quadra-plexes per transformer.
- Minimum conductor size from the transformer to the service entrance equipment should be 3/0 copper in underground conduit.
- Provide a maximum length of 220 ft (67 m) for the service lateral conductors from the distribution transformer to the service entrance device (or meter base).
- Design the distribution system such that the available fault current at the service equipment is less than 10,000 amperes.

Where an underground 3-phase circuit is used to feed single-phase transformers, provide a separate 3-phase pad-mounted switch or sectionalizing cabinet with a radial supply to the single-phase transformers.

3-14 DISTRIBUTION SYSTEM GROUNDING.

Comply with the requirements of IEEE C2 Section 9, *Grounding Methods for Electric Supply and Communication Facilities*, for distribution system grounding (medium voltage systems classified as multi-grounded, single point grounded at source transformer either solidly or with grounding resistors, and ungrounded).

Design in accordance with IEEE Std 80 main electric supply stations and all supply stations consisting of equipment for the purpose of transforming the voltage level for further bulk distribution. Complete measurements of the station grounding system prior to inter-connection with other systems and prior to station energization to assure the limits of step and touch potentials as required by IEEE Std 80 have been attained.

3-14.1 Separation of Grounding Conductors.

Comply with the requirement for separation of grounding conductors between classes of equipment operating in excess of 750 volts and below 750 volts for the design of all facilities. The exception for connecting the different classes of equipment “to a sufficiently heavy ground bus or system ground cable that is well connected to ground at more than one place” is the Government’s engineering basis for interconnecting the different classes of equipment connected to existing systems.

Note: The predominant classification of existing Government medium voltage systems is a classification of something other than multi-grounded. For designs on new systems or existing systems classified as multi-grounded, the standard grounding detail of a 4/0 ground ring and interconnecting ground rods on utilization electric supply stations may be omitted and replaced with a simpler system complying with the requirements of IEEE C2 Section 9.

3-14.2 Materials and Special Requirements.

3-14.2.1 Ground Rods.

Comply with IEEE C2 Section 9 for ground rod composition, minimum spacing requirements and connections except provide ground rods with minimum dimensions of 10 ft (3.0 m) in length and ¾ inch (19 mm) in diameter. Provide copper-clad steel, solid copper, or stainless steel ground rods. Sectional ground rods are permitted. All connections to ground rods below ground level must be by exothermic weld connection or with a high compression connection using a hydraulic or electric compression tool to provide the correct circumferential pressure. Accessible connections above ground level and in test wells can be accomplished by clamping. Pole–butt plates and wire wraps recognized by IEEE C2 Section 9 are not authorized as grounding electrodes.

Spacing for driving additional grounds must be a minimum of 10 ft (3.0 m). Bond these driven electrodes together with a minimum of 4 AWG soft drawn bare copper wire buried to a depth of at least 12 in (300 mm).

3-14.2.2 Ground Rings.

Comply with the requirements of NFPA 70 Section 250 for ground rings. If the system is not classified as multi-grounded, utilization electric supply stations, switchgear, and sectionalizing cabinets require a 4/0 bare copper ground ring with a minimum of four ground rods for three phase service. Single phase service installations can be modified to minimum 1/0 copper and two ground rods for the ground ring. Test wells are permitted on specific applications as required.

If metal bollards are installed and are within 8 feet of the pad-mounted equipment, bond each bollard to the ground ring.

3-14.3 Low Voltage Grounding Interface With Utilization Electric Supply Stations.

For design purposes, the secondary terminals of the utilization electric supply station is the demarcation point between IEEE C2 and NFPA 70. The transition between the grounded neutral conductor (functioning as a neutral and a grounding conductor per IEEE C2) and the grounded conductor (functioning as a neutral conductor only per NFPA 70) must be at the “service point” as defined by UFC 3-501-01 Chapter 2.

- The service point for low-voltage conductors from utilization electric supply stations containing no secondary overcurrent protection device is defined as the line side terminals for the facility service equipment.
- The service point for utilization electric supply stations containing an overcurrent protection device is at the main breaker on the secondary side of the utilization electric supply station. This is the transition point from IEEE C2 to NFPA 70 grounding where the service main bonding jumper is located.

3-14.4 Grounding Requirements – Fences.

Ground metal fences for electrical equipment in accordance with IEEE C2 Section 9.

Other metal fences that are electrically continuous with metal posts extending at least 24 inches (610 mm) into the ground require no additional grounding unless specifically required by other criteria.

3-14.4.1 Ordnance Facilities.

Ordnance facilities or locations where ordnance and explosives are handled and stored require special protective measures. Refer to the following service-specific criteria for grounding of metal fences near these facilities:

- NAVSEA OP-5, *Volume 1, Ammunition and Explosives Ashore*.
- AFMAN 91-201, *Explosive Safety Standards*.
- AFMAN 91-118, *Safety Design and Evaluation Criteria for Nuclear Weapon Systems*.
- Department of the Army Pamphlet 385-64, *Ammunition and Explosives Safety Standards*.

3-14.4.2 Plastic Coated Fencing.

Plastic coated fencing is prohibited for fences that require grounding.

3-15 METERING.

Provide metering in accordance with UFC 3-520-01.

3-16 EXTERIOR SITE LIGHTING.

Provide exterior lighting in accordance with UFC 3-530-01.

3-17 CATHODIC PROTECTION SYSTEMS.

Provide cathodic protection in accordance with UFC 3-570-02N for the Navy and UFC 3-570-02A for the Army.

3-18 ENVIRONMENTAL CONSIDERATIONS.

Consider oil spill containment for substation transformers. Containment is not authorized for pad-mounted oil-filled distribution transformers and switches.

Do not use askarel-insulated and nonflammable, fluid-insulated transformers because of environmental concerns as to their insulation liquid.

3-19 FIRE PROTECTION CONSIDERATIONS.

Provide fire protection and specify installation location for oil-filled equipment in accordance with UFC 3-600-01.

Oil-filled transformers using mineral oil can only be used outdoors. Less-flammable liquid (fire point of not less than 300 degrees C (575 degrees F)) transformers may be used either outdoors or indoors.

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APPENDIX A REFERENCES

Note: The most recent edition of referenced publications applies, unless otherwise specified.

DEPARTMENT OF DEFENSE

AFMAN 91-118, *Safety Design and Evaluation Criteria for Nuclear Weapon Systems*.

AFMAN 91-201, *Explosive Safety Standards*.

Department of the Army Pamphlet 385-64, *Ammunition and Explosives Safety Standards*.

NAVSEA OP-5, Volume 1, *Ammunition and Explosives Ashore*.

IEEE

www.ieee.org

IEEE C2, *National Electrical Safety Code*.

IEEE C37.04, *Rating Structure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis*.

IEEE C37.06, *AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis – Preferred Ratings and Related Required Capabilities*.

IEEE C37.20.2, *Metal-Clad Switchgear*.

IEEE C37.41, *Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Accessories*.

IEEE C37.46, *High Voltage Expulsion and Current-Limiting Type Power Class Fuses and Fuse Disconnection Switches*.

IEEE C37.60, *Requirements for Overhead, Pad-Mounted, Dry Vault, and Submersible Automatic Circuit Reclosers and Fault Interrupters for Alternating Current Systems Up to 38 kV*.

IEEE C37.74, *IEEE Standard Requirements for Subsurface, Vault, and Padmounted Load- Interrupter Switchgear and Fused Load-Interrupter Switchgear for Alternating Current Systems up to 38 kV*.

IEEE C37.90, *Relays and Relay Systems Associated with Electric Power Apparatus*.

IEEE C37.121, *Switchgear – Unit Substations Requirements*.

IEEE C57.12.00, *General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*.

IEEE C57.12.01, *General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid-Cast and/or Resin-Encapsulated Windings*.

IEEE C57.12.22, *Transformers – Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers with High-Voltage Bushings, 2500 kVA and Smaller: High Voltage, 34,500 Grd Y/19,920 Volts and Below; Low Voltage, 480 Volts and Below*.

IEEE C57.12.28, *Pad-Mounted Equipment – Enclosure Integrity*.

IEEE C57.12.34, *Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers (2500 kVA and Smaller) – High-Voltage, 34,500 GrdY/19,200 Volts and Below; Low-Voltage: 480 Volts and Below*.

IEEE C57.12.50, *Ventilated Dry-Type Distribution Transformers, 1 to 500 kVA, Single-Phase, and 15 to 500 kVA Three-Phase, with High-Voltage 601 to 34,500 Volts, Low-Voltage 120-600 Volts*.

IEEE C57.12.51, *Ventilated Dry-Type Power Transformers, 501 kVA and larger, Three-Phase, with High-Voltage 601 to 34,500 Volts, Low-Voltage 208Y/120 to 4160 Volts*.

IEEE C57.12.80, *Terminology for Power and Distribution Transformers*.

IEEE C57.12.90, *Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*.

IEEE C57.12.91, *Test Code for Dry-Type Distribution and Power Transformers*.

IEEE C57.96, *Loading Dry-Type Distribution and Power Transformers*.

IEEE C57.98, *Guide for Transformer Impulse Tests*.

IEEE C57.124, *Detection of Partial Discharge and the Measurement of Apparent Charge in Dry-Type Transformers*.

IEEE 80, *IEEE Guide for Safety in AC Substation Grounding*.

NATIONAL ELECTRICAL MANUFACTURERS' ASSOCIATION

www.nema.org

NEMA C84.1, *Electric Power Systems and Equipment-Voltage Ratings (60 Hz)*.

NEMA WC 74, 5-*46 KV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy*.

NEMA TC7, *Smooth-Wall Coilable Polyethylene Electrical Plastic Conduit*.

NETA MTS, *Maintenance Testing Specifications*.

NFPA NATIONAL FIRE PROTECTION ASSOCIATION

www.nfpa.org

NFPA 70, *National Electrical Code*.

NFPA 70B, *Electrical Equipment Maintenance*.

NFPA 70E, *Standard for Electrical Safety in the Workplace*. The 2012 edition has been published and is under review by the Tri-Services Electrical Working Group. Additional applicable changes in the 2012 edition will be incorporated into criteria in the next revision.

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 3-260-01, *Airfield and Heliport Planning and Design*.

UFC3-501-01, *Electrical Engineering*.

UFC 3-510-01, *Foreign Voltages and Frequencies Guide*.

UFC 3-530-01, *Design: Interior and Exterior Lighting and Controls*.

UFC 3-560-01, *Electrical Safety, O&M*.

UFC 3-570-02A, *Cathodic Protection*.

UFC 3-570-02N, *Electrical Engineering Cathodic Protection*.

UFC 3-575-01, *Lightning and Static Electricity Protection Systems*.

UFC 3-600-01, *Fire Protection Engineering for Facilities*.

UFC 4-010-01, *DoD Minimum Anti-Terrorism Standards for Buildings*.

UFC 4-020-01, *DoD Security Engineering Facilities Planning Manual*.

UFC 4-211-01N, *Aircraft Maintenance Hangars: Type I, Type II and Type III*.

UFC 4-211-02NF, *Corrosion Control and Paint Finishing Hangars*.

MISCELLANEOUS REFERENCES

ASTM D2447, Standard Specification for Polyethylene (PE) Plastic Pipe, Schedules 40 and 80, Based on Outside Diameter.

FAA Advisory Circular 150/5320-6D, Airport Pavement Design and Evaluation.

APPENDIX B DIRECTIONAL BORING

B-1 CONDUIT TYPE.

Provide smoothwall HDPE conduit, approved/listed for directional boring, approved/listed for electrical system installations, and minimum Schedule 80 meeting ASTM D2447/F2160/NEMA TC-7 (latest editions).

Note: Install HDPE conduit below freeze lines and in no case can the conduit be installed less than the minimum depths noted below.

B-1.1 Conduit Design – 1,000 Volts to 34,500 Volts.

Provide a minimum size HDPE conduit of 5 inches for distribution voltages greater than 1,000 V and less than 34.5 kV (nominal). Do not exceed 30 percent conduit fill.

Install HDPE conduit with a minimum ground cover of:

- 120 inches in non-pavement-covered areas.
- 48 inches in pavement-covered areas.

B-1.2 Conduit Design – Less Than 1,000 Volts.

Provide a minimum size HDPE conduit of 4 inches for distribution voltages less than 1,000 V. Do not exceed 35 percent conduit fill.

Install HDPE conduit with a minimum ground cover of 48 inches in pavement- or non-pavement-covered areas.

B-1.3 Conduit Design – Branch Circuit Wiring Less Than 600 Volts.

Provide a minimum size HDPE conduit for branch circuit wiring less than 600 V that is determined by calculation, addressing, as a minimum, branch circuit conductor size, maximum allowable pulling tension, and maximum 5 percent voltage drop. Do not exceed 40 percent conduit fill.

Install HDPE conduit with a minimum ground cover of 24 inches in pavement- or non-pavement-covered areas.

B-2 INSTALLATION METHODS.

The use of specific conductor or insulation types for either high- or low-voltage installations is not mandated here. However, the combination of a chosen conductor and insulation type may not meet the requirements for the installation methods required in the following paragraphs where length, depth, and routing of the directional bore conduit may require an alternative conductor material and/or insulation type (i.e., maximum pulling tensions are different for aluminum and copper conductors).

B-2.1 Ampacity.

If the directional bored portion of the cable run is more than 25 percent of the total run length, evaluate and document the conductor derated ampacity in accordance with NFPA 70 Article 310.60 (C) (2).

B-2.2 Installation.

Water-jetting is not permitted. Use drilling fluids for DB methods that are approved by federal, state, and local codes and authorized for use by the BCE.

Pre-installed cable-in-conduit is not permitted. Install the conduit(s) immediately after the conduit hole is completed.

B-2.3 Allowable Pulling Tension.

B-2.3.1 Distance.

There is no restriction on DB distances provided the allowable pulling tension of the conduit and installed conductors are not exceeded, conductor splices are not within the conduit, and maximum ampacity of conductors due to depth derating is not exceeded.

B-2.3.2 Calculation Requirements.

A registered Professional Engineer (PE) must calculate pulling tension requirements for each directional bore, taking into consideration the HDPE conduit(s) size and type, bend radius, elevation changes, vertical and horizontal path deviations, installed electrical conductor size and type, and any conductor ampacity derating due to depth of HDPE conduit. The electrical contractor must provide certification of compliance with the PE‘s design requirements.

The professional engineering design process must include consideration of tensile forces and bend radii created during the installation so that allowable limits are not exceeded. Allowable tensile forces must be determined by a PE, including accounting for the conduit’s allowable bend radius to prevent ovalization and kinking from installation. Do not exceed 5 percent ovalization of the conduit.

B-2.4 Termination into Equipment Pads.

Terminate HDPE conduits into concrete-pad-mounted electrical equipment from either a pavement or non-pavement transitional area as indicated in Figures B-1 through B-5. Route and terminate HDPE or rigid conduit within the concrete pad such that no conductor exiting the conduit is bent past the vertical plane formed with the equipment pad when routed to conductor terminations and with approved insulated bushings (Figure B-1).

Figure B-1 HDPE or Rigid Conduit Electrical Equipment Transition

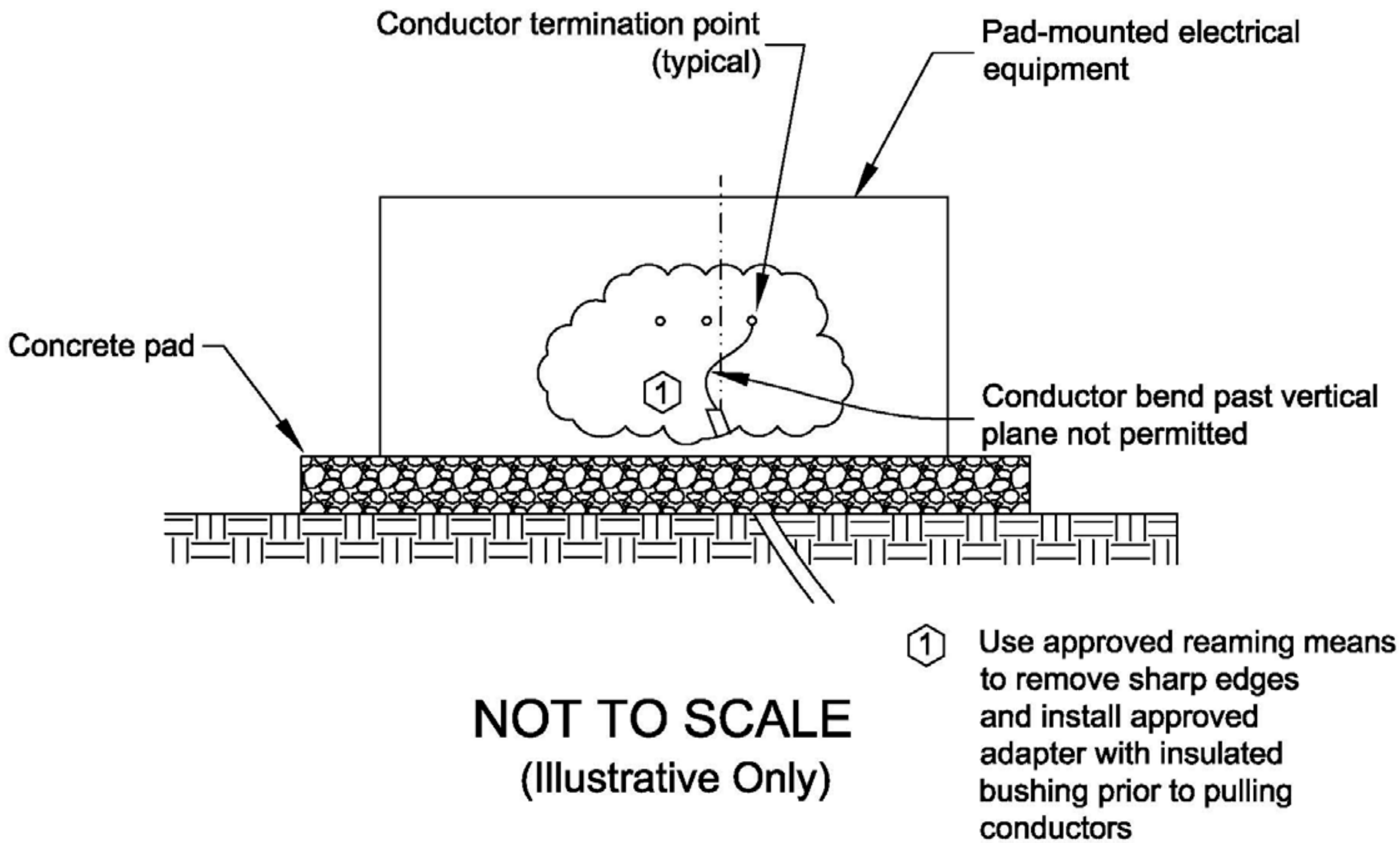


Figure B-2 Pavement Covered Area to Electrical Equipment Transition – Rigid Conduit (45˚–90˚)

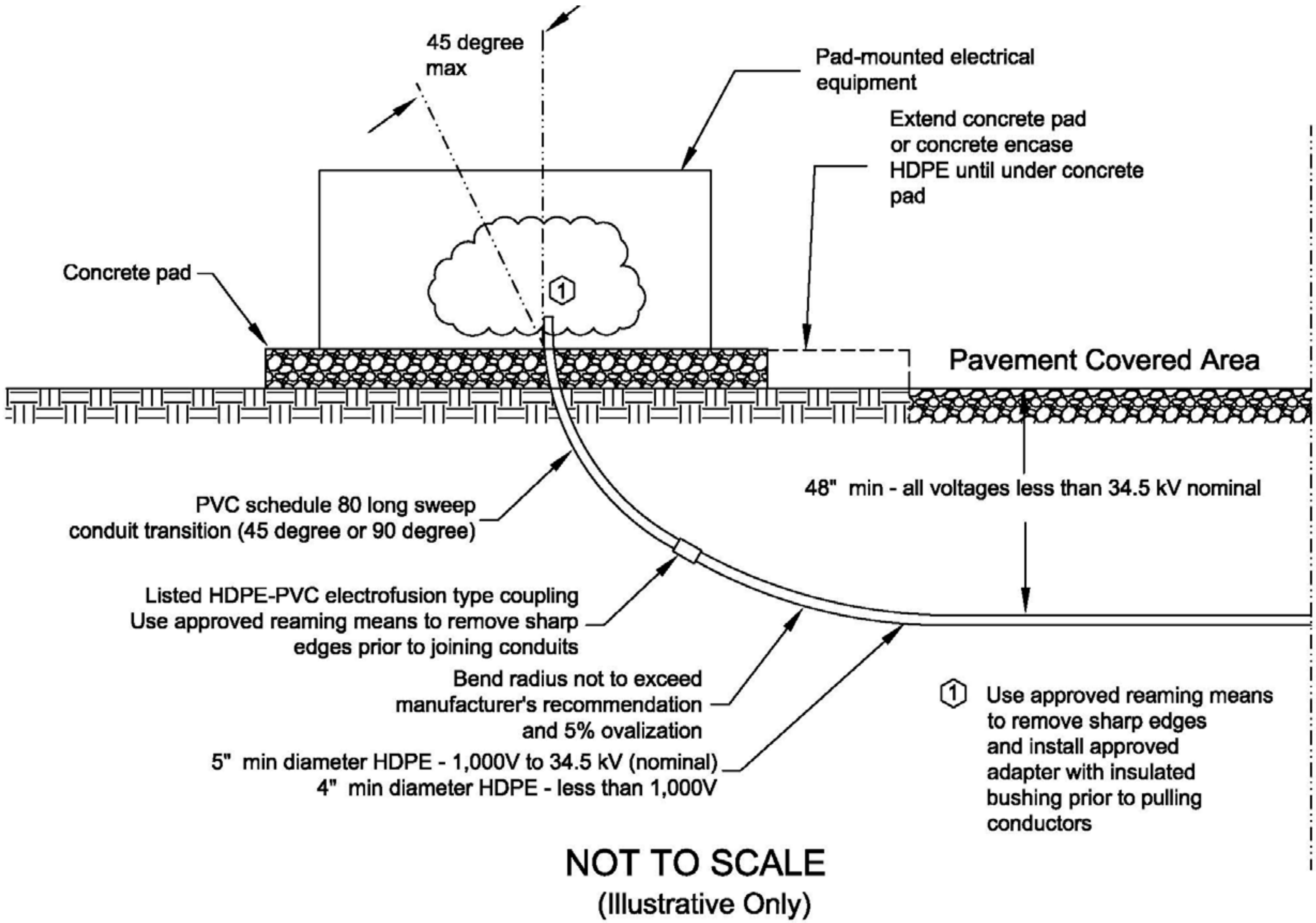


Figure B-3 Pavement Covered Area to Electrical Equipment Transition – HDPE Conduit (20˚–45˚)

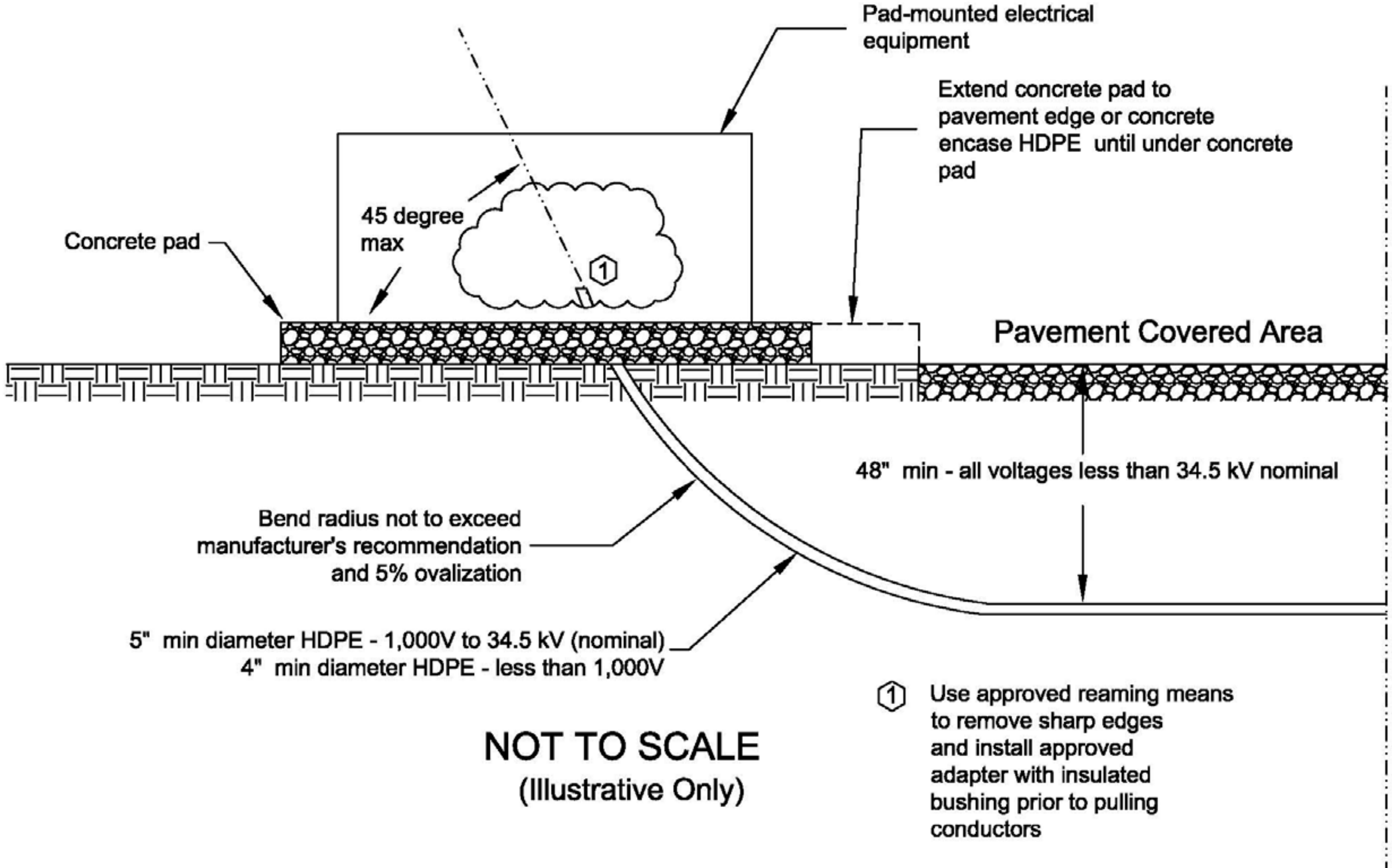


Figure B-4 Non-Pavement Covered Area to Electrical Equipment Transition – Rigid Conduit (45˚–90˚)

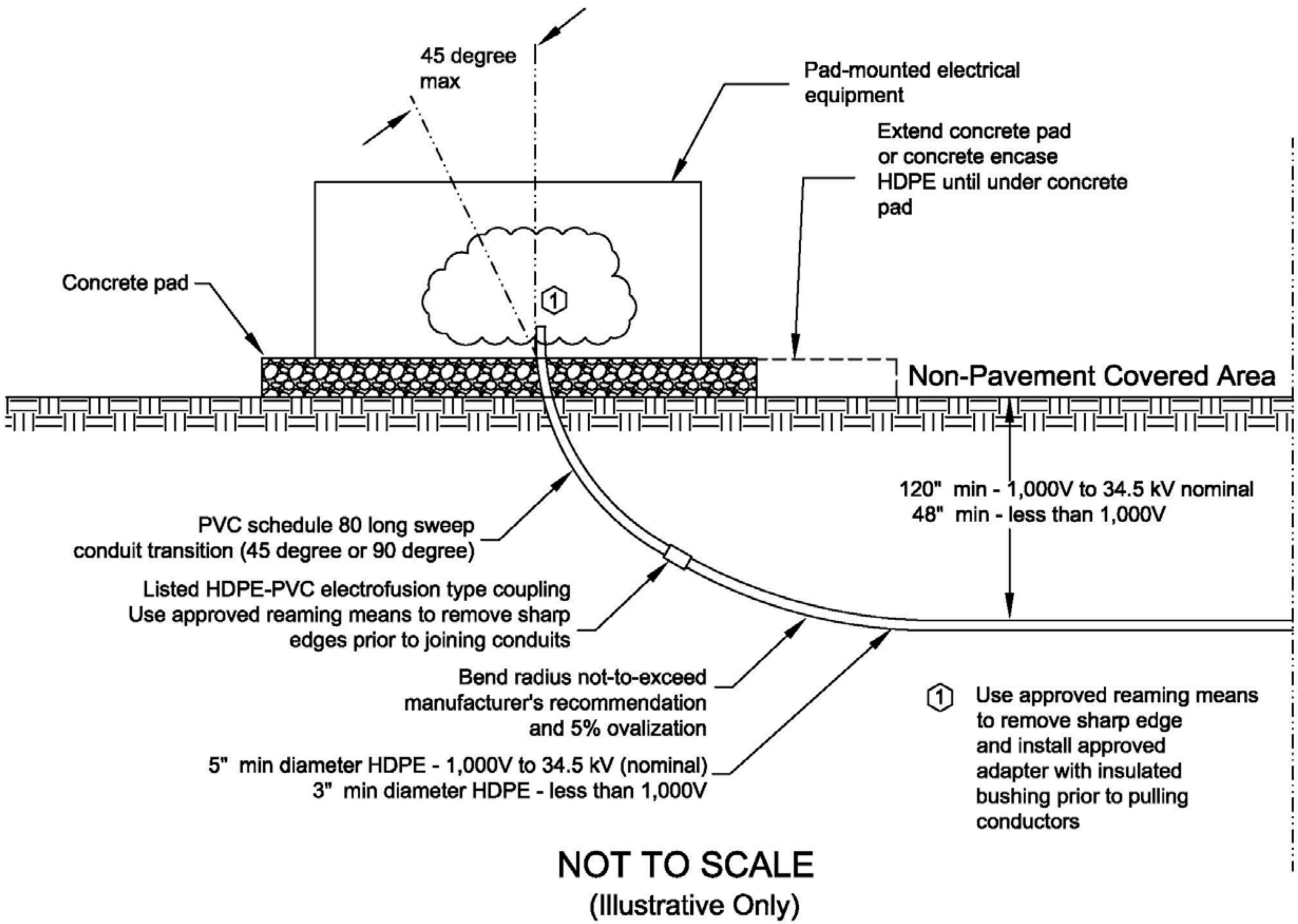
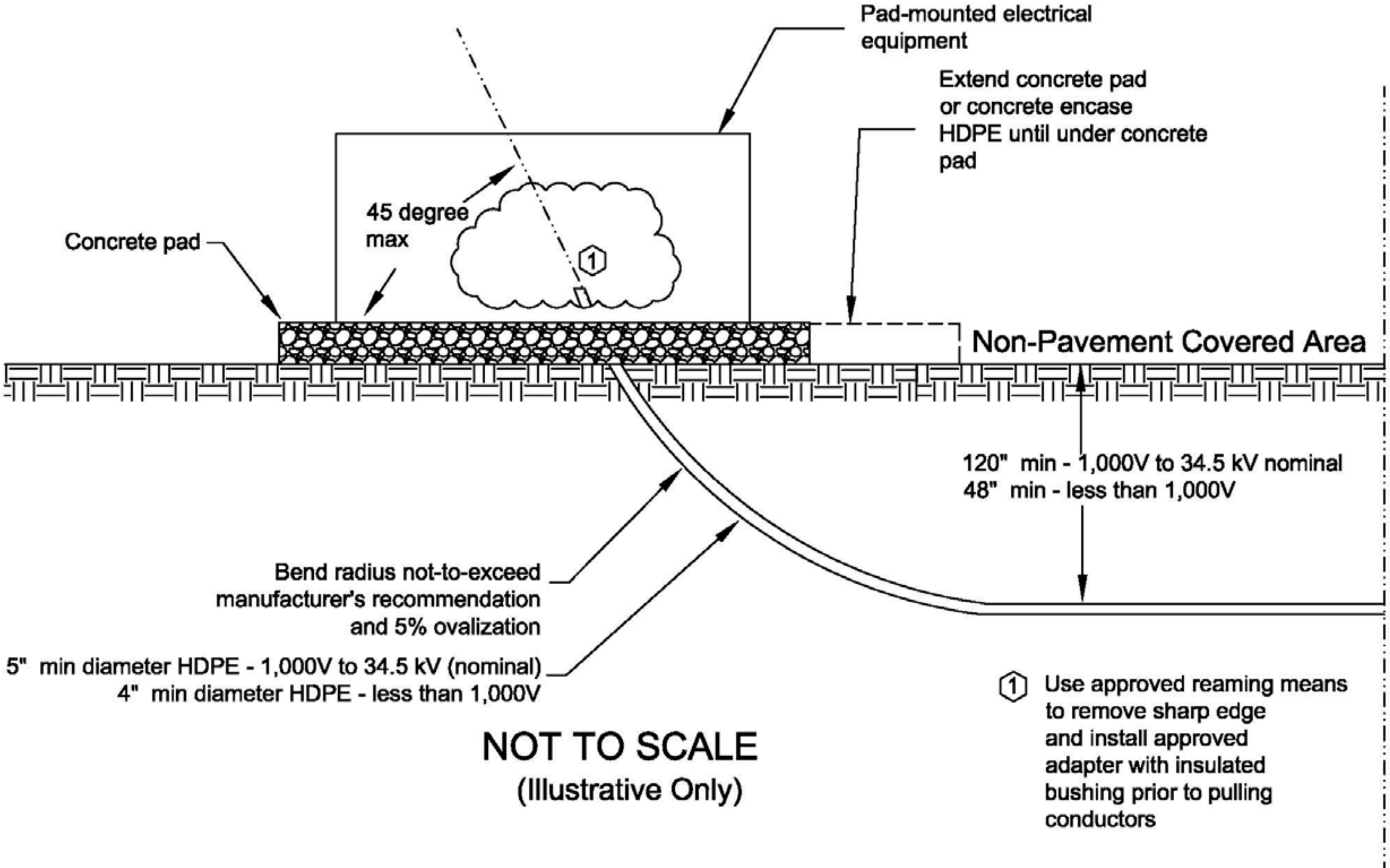


Figure B-5 Non-Pavement Covered Area to Electrical Equipment Transition – HDPE Conduit (20˚–45˚)



B-2.5 Multiple Conduits and Wiring Methods.

B-2.5.1 Installation.

Multiple HDPE conduits are permitted to be pulled through each bore. Designs requiring multiple conduits to accommodate parallel conductor installations must comply with NFPA 70 grounding and wiring methods requirements. As an example, one set of paralleled conductor requirements is illustrated in the following excerpt from NFPA 70, Article 310.4, which states:

> *“The paralleled conductors in each phase, polarity, neutral, or grounded circuit conductor shall comply with all of the following:*
> *(1) Be the same length*
> *(2) Have the same conductor material*
> *(3) Be the same size in circular mil area*
> *(4) Have the same insulation type*
> *(5) Be terminated in the same manner*”

Thus, using DB methods to comply with (1) from the NFPA 70 excerpt, as well as other requirements, may not be possible, especially for long boring distances. NFPA 70 has other requirements for paralleled conductor installations that must also be considered when designing for these types of installations.

Note: Any deviations from NFPA 70 requirements must be approved by the AHJ.

B-2.5.2 Ampacity.

If the directional bored portion of the cable run is more than 25 percent of the total run length, evaluate and document the conductor derated ampacity in accordance with NFPA 70 Article 310.60 (C) (2).

B-2.6 Joining Methods.

Butt and electrofusion joining means are the only joining methods approved for HDPE conduit installations. Complete installations by persons certified in the process and in accordance with the manufacturer’s procedures.

B-2.7 Transition from HDPE to PVC.

Make the transition from HDPE to PVC using only electrofusion coupling means with approved and listed materials. Perform coupling installation by persons certified on the equipment and process.

Complete coupling between HDPE and concrete-encased duct banks from pavement or non-pavement transitional areas as indicated in Figures B-6 and B-7. Perform the transition from HDPE to concrete manholes from pavement or non-pavement transitional areas as indicated in Figures B-8 and B-9.

Figure B-6 HDPE-to-PVC Pavement Covered Area Concrete Ductbank Transition

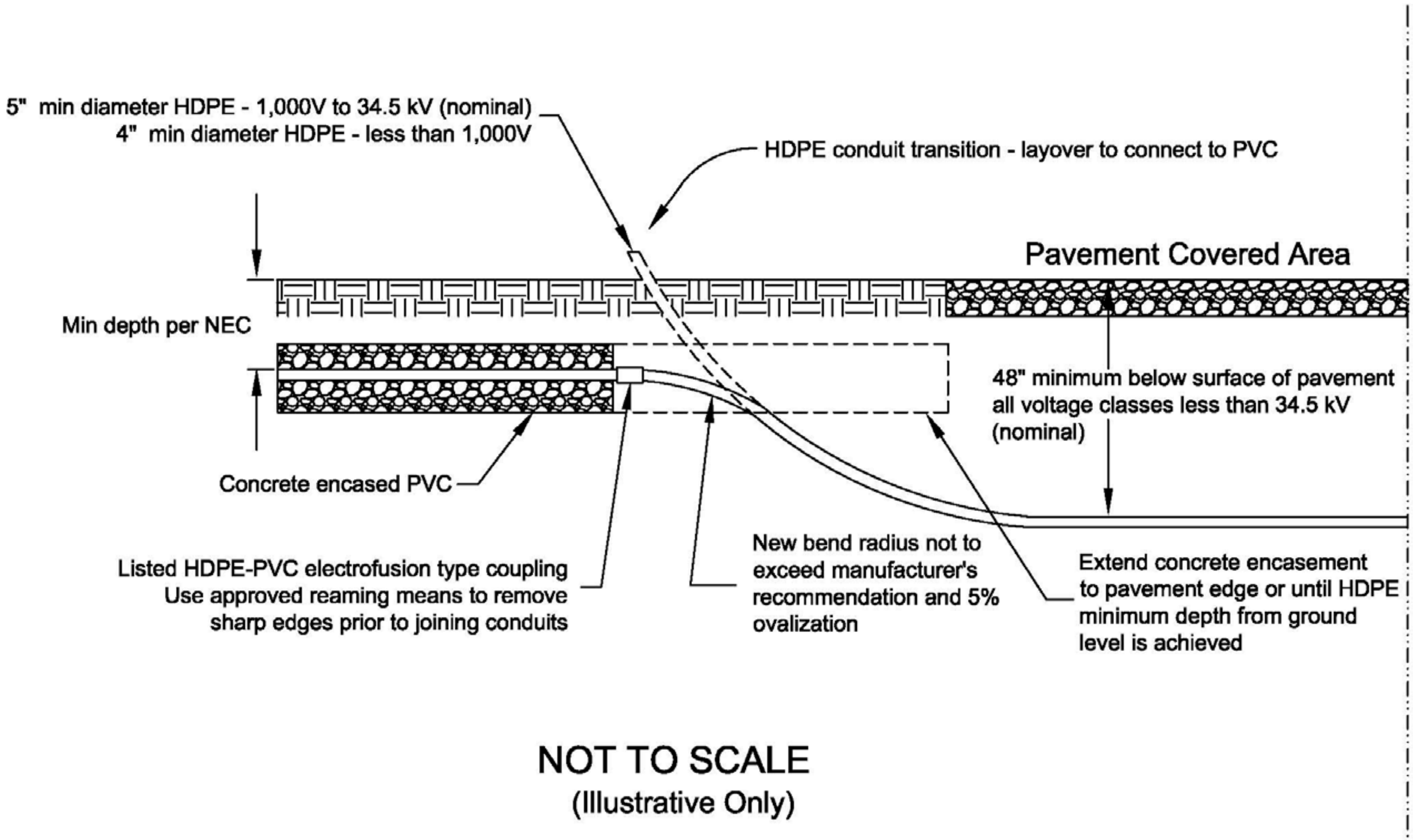


Figure B-7 HDPE-to-PVC Non-Pavement Covered Area Concrete Ductbank Transition

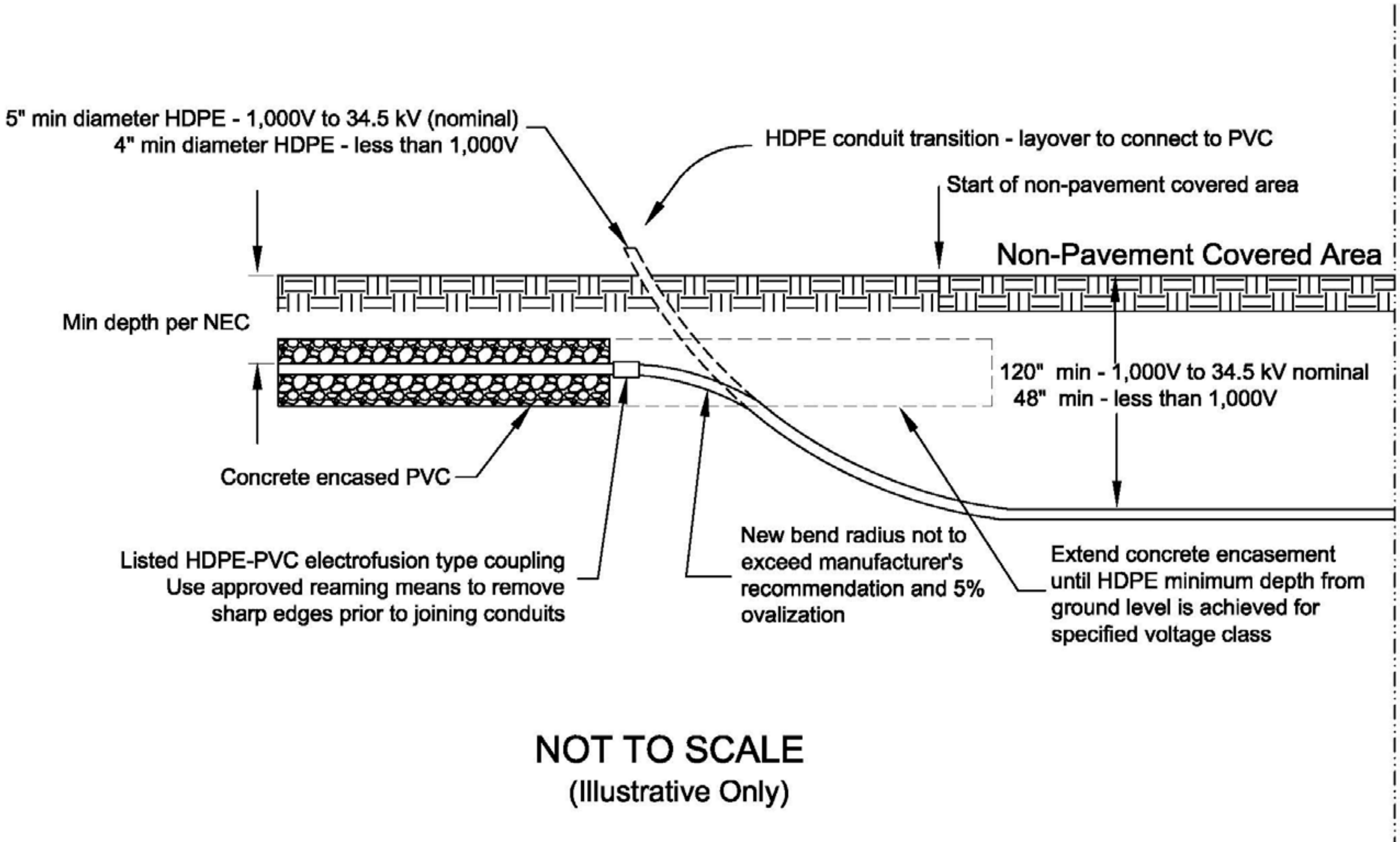


Figure B-8 HDPE-to-Manhole Pavement Covered Area Transition

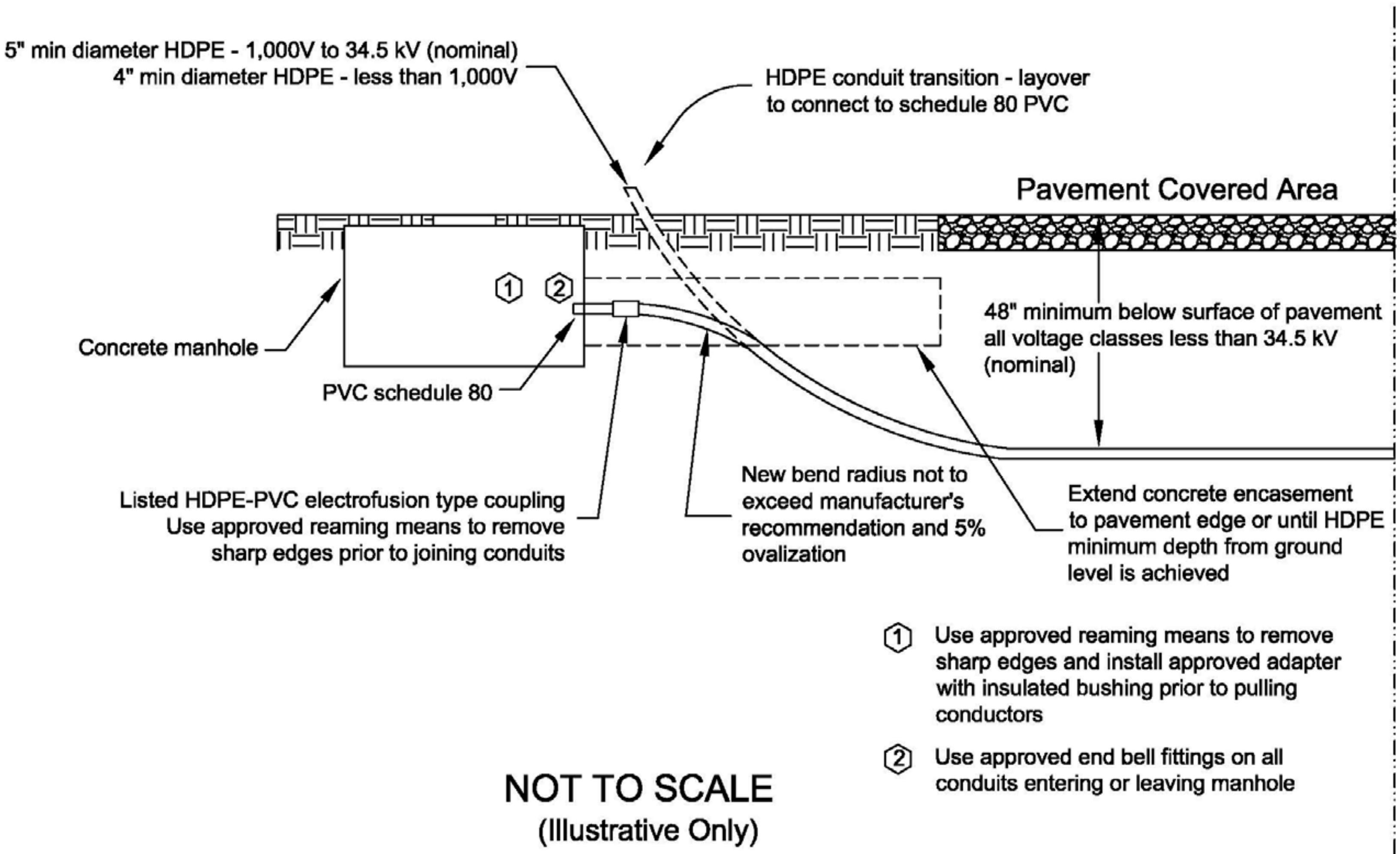
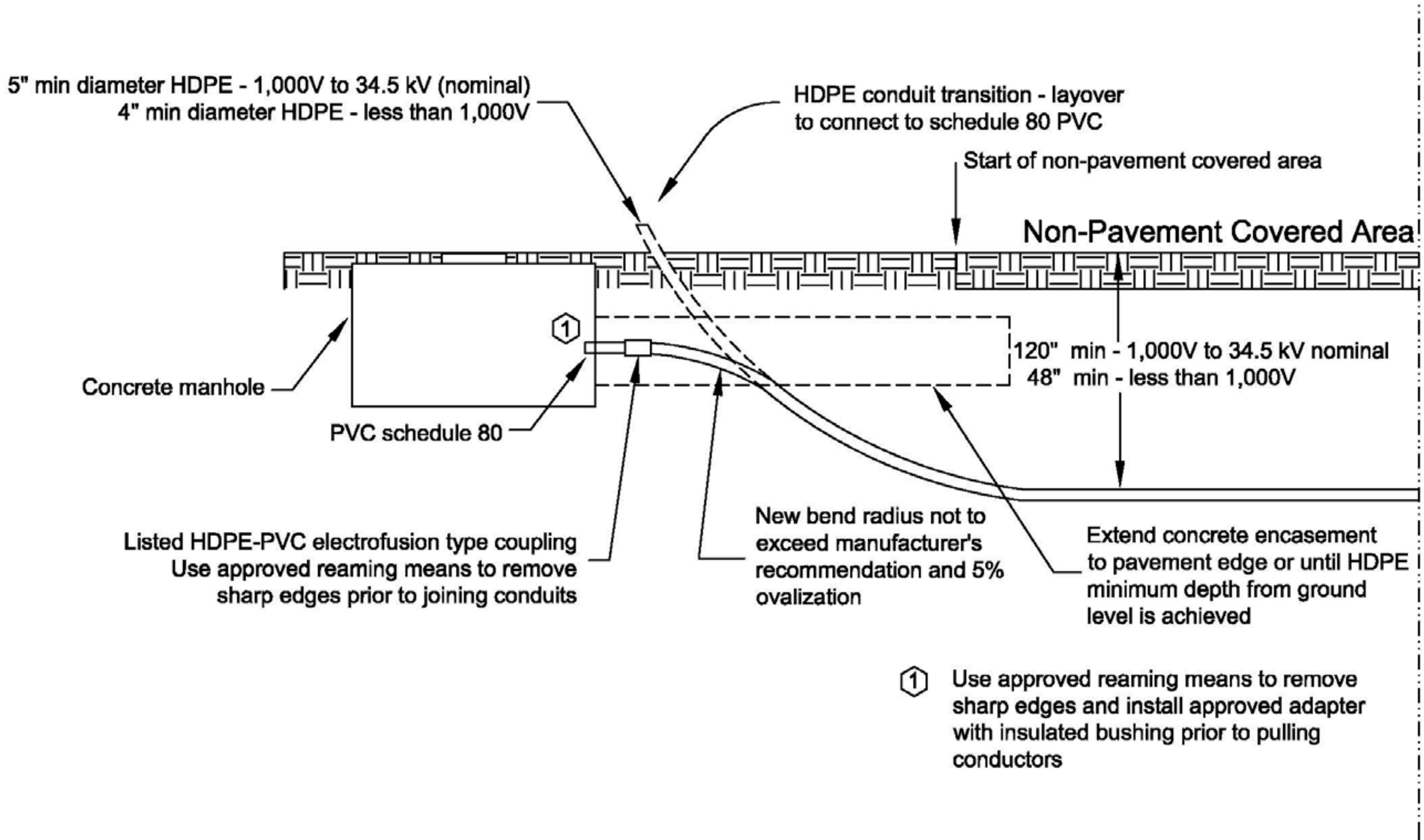


Figure B-9 HDPE-to-Manhole Pavement Covered Area Transition



NOT TO SCALE
(Illustrative Only)

B-3 DOCUMENTATION.

Record the location and depth of DB-installed HDPE electrical conduit on applicable as-built drawings. Use Global Positioning System (GPS) recording means with “resource grade” accuracy to record HDPE conduit bore path. Record GPS coordinates at intervals not to exceed 50 feet along the bore path. Provide this information, along with the size of conduit, number of conductors, conductor size, and insulation type, to the appropriate base civil engineering office for incorporation into the GeoBase database.

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APPENDIX C BEST PRACTICES – GENERAL ELECTRICAL POWER REQUIREMENTS

C-1 EXTERIOR SYSTEM DESIGN.

Consider the following general criteria as part of any exterior electrical system design:

- Looped versus radial primary distribution. The alternate supply capability of a looped system for primary distribution system feeders can enable the system to continue operation even with a failed conductor. Evaluate design changes to the existing system to ensure that the potential impact of conductor failure is minimized.
- Cross-tie (alternate supply) capability. The ability to remove a feeder supply from service while ensuring continuity of power is essential for a reliable and maintainable design. Feeder cross-tie capability should be provided near the beginning of the feeder (to reduce voltage drop) and at key points downstream (to provide alternate supply capability for a portion of the feeder). Address cross-tie capability and how it is improved in the design analysis.
- Mission essential facilities. These facilities require additional consideration for the exterior electrical system design. Even if the facility is equipped with standby generation, minimize single points of failure in the exterior electrical system design. Provide redundant power supplies to the facility fed from different feeders, if multiple feeders are available.
- Communication. Determine communication requirements for the system, including SCADA, security, access, metering, and breaker control. Include security requirements as an input to the electrical system design criteria.
- Safety. Include electrical safety as a design consideration. Equipment selection, redundancy, installation approach, and how the equipment can be removed from service can all affect equipment and personnel safety.
- Reliability and maintenance. NFPA 70B, NETA MTS, and the manufacturers' documents provide periodic maintenance criteria applicable to exterior electrical equipment. Consider maintenance requirements in the specification of equipment and in the installation design of the equipment. As an example, a single manhole located near a substation should not contain the cables for all base feeders; in this example, the design should install multiple manholes with fewer distribution feeders located inside each manhole.

C-2 METERING.

Coordinate metering, system design, protection, electrical coordination, load requirements, and short circuit limitations with the local utility. If the supply station/substation is owned by the utility, obtain sufficient design information for the utility-owned equipment to help establish design requirements for downstream equipment.

Coordinate revenue metering requirements with the local utility. Provide a government-owned revenue meter for the supply station/substation even when the local utility meters the incoming supply.

C-3 DEMARCATION.

Clearly define the point of demarcation between the utility-owned system and the government owned equipment. Define ownership for the incoming utility supply lines if there are any shared equipment, such as overhead distribution with utility and government-owned lines sharing the same power poles.

C-4 SUBSTATIONS AND SWITCHING STATIONS.

Use or modify existing substations unless a new substation is required for capacity or unique requirements. Aging substations will often require complete replacement.

Design a main electric supply station/substation for reliability of service and maintenance. Address the following in the design analysis for the supply station/substation:

- Formal design. Substations require a formal design. Address the structure and foundation design, lightning protection, manholes and vaults, grounding, lighting, protective relaying, and the other electrical items listed below.
- Dual substation transformers. Coordinate with the utility to provide separate utility feeders, if available. The transformers should be sized so that either transformer and incoming supply line can carry the entire substation peak demand, including load increase projections for the next 10 years.
- Voltage regulation. Either transformer load-tap changing (LTC) transformers or separate voltage regulators are acceptable. Separate voltage regulators, wherever installed, must be provided with bypass and disconnect switches.
- Circuit breaker or circuit switcher on each substation transformer primary side for local isolation of the incoming supply. For substations with overhead bus structure, include a load-break or non-load break switch as an additional isolation device.
- Circuit breaker on each substation transformer secondary side. This is typically the main breaker to the substation switchgear. For substations with overhead bus structure, include a load-break or non-load break switch as an additional isolation device.

- Separate switchgear for each transformer with cross-tie capability between switchgear. Provide spare breakers and evaluate the need for additional distribution system feeders.
- Electronic protective relays to allow circuit protection, monitoring, and event recording.
- Station class surge arresters.
- SCADA controls. If remote SCADA control is included, provide dedicated fiber-optic lines between the facility and the desired control location. Obtain approval from the AHJ for communication systems that enable remote access.
- Connections between the transformer secondary and the main circuit breaker. Preferred connection methods include cables in conduit or cable trays. Busway transitions are discouraged, but if they are used, it must be labeled for the application by Underwriter's Laboratories, or equivalent; designed for outdoor service, including a stainless steel housing and hardware for corrosion control; rated and braced for the maximum expected continuous current and short circuit current; designed to control condensation and its effects; and designed to allow access for periodic inspection following the NETA MTS guidance.

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APPENDIX D GLOSSARY

D-1 ACRONYMS

AC	Alternating Current
ACSR	Aluminum Conductor Steel-Reinforced
ACSS	Aluminum Conductor Steel Supported
A/E	Architect/Engineer
AFCEC	Air Force Civil Engineer Center
AHJ	Authority Having Jurisdiction
AL	Aluminum
ASTM	American Society for Testing and Materials
AWG	American Wire Gauge
UFC	Unified Facilities Criteria
BCE	Base Civil Engineer
BIL	Basic Insulation Level
CT	Current Transformer
CU	Copper
DB	Directional Boring
DDC	Direct Digital Control
DIA	Diameter
DoD	Department of Defense
EMCS	Energy Management and Control System
ESS	Electric Supply Station
Degrees F	Degrees Fahrenheit
fc	Footcandles
ft	Feet (or Foot)

ft^2	Foot Squared
GPS	Global Positioning System
HDPE	High Density Polyethylene Electrical
HQUSACE	Headquarters, US Army Corps of Engineers
HV	High Voltage
HVAC	Heating Ventilation and Air Conditioning
Hz	Hertz
IEEE	formerly Institute of Electrical and Electronic Engineers
in	Inch
kcmil	Thousand circular mils
kg	Kilograms
kV	Kilovolts
kVA	Kilo-Volt-Ampere
kVAR	Kilo-Volt-Ampere-Reactive
lb	Pound
LTC	Load-Tap Changing
m	Meter
m^2	Meter Squared
Max	Maximum
Min	Minimum
mm	Millimeter
MPa	Mega-Pascals
MTS	Maintenance Testing Specifications
MVA	Mega-Volt-Ampere
NAVFAC	Naval Facilities Engineering Command

NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NETA	InterNational Electrical Testing Association
NFPA	National Fire Protection Association
OH	Overhead
O&M	Operation and Maintenance
PE	Professional Engineer
psi	Pounds per square inch
PILC	Paper Insulated Lead Covered
PPE	Personal Protective Clothing
PT	Potential Transformer
PVC	Polyvinyl Chloride
RFP	Request for Proposal
SCADA	System Control and Data Acquisition
SF6	Sodium Hexafluoride
TSEWG	Tri-Service Electrical Working Group
UESS	Utilization Electric Supply Station
UL	Underwriters Laboratories
UFC	Unified Facilities Criteria
V	Volt
VA	Volt-Amp
VFI	Vacuum Fault Interrupter
W/ft^2	Watts per Foot Squared
W/m^2	Watts per Meter Squared

D-2 DEFINITION OF TERMS

Activity: With respect to this UFC, approval is provided by the following:

- For the Air Force, this is the Base Civil Engineer.
- For the Navy, this is the Public Works Officer.
- For the Army, this is the Installation Director of Public Works.

Contractor: Person(s) doing actual construction portion of a project.

Corrosive Area: An area identified by the Technical Reviewing Authority as requiring special equipment corrosion mitigation methods.

Designer of Record: The engineer responsible for the actual preparation of the construction documents.

Main Electric Supply Station: A main electric supply station is also referred to as a "switching station" and does not have power transformers to transform from the utility transmission voltage to a lower distribution voltage. The main electric supply station is the installation/utility interface point where further transmission, distribution and utilization of electrical power, the monitoring and control of such power or equipment and the protection of electrical equipment or systems usually becomes the sole responsibility of the Government or their contracted representatives. **Main Electric Supply Substation**: A main electric supply station that also transforms the energy level (voltage) for further bulk distribution at medium voltage levels. A main electric supply substation includes power (substation) transformers.

Facility Core Distribution Infrastructure: System components that constitute a part of the base infrastructure system that are required to provide electrical service to multiple users.

Low Voltage System: An electrical system having a maximum root-mean-square (rms) voltage of less than 1,000 volts.

Medium Voltage System: An electrical system having a maximum RMS ac voltage of 1,000 volts to 34.5 kV. Some documents such as NEMA C84.1 define the medium voltage upper limit as 100 kV, but this definition is inappropriate for facility applications.

Primary Distribution: A system of alternating-current distribution for supplying the primary of distribution transformers from the generating station or substation distribution buses. Primary distribution can be supplied either overhead or underground and includes all associated equipment.

Project Manager: Engineer charged with the administration of the project.

Secondary Distribution: An alternating-current system that connects the secondaries of distribution transformers to the consumers' services. A secondary distribution is typically operating at low voltage, but could be operating at medium voltage.

Service: The conductors and equipment for delivering electrical energy from the serving utility or Government-owned system to the wiring system of the premises served.

Site Electrical Utilities: Site Electrical Utilities are the primary electric power distribution to the facilities and other electrical loads, all exterior lighting not attached to the building; and all telecommunication services (fiber optic, copper cable, CATV, etc.) required by the Facilities.

Switching Station: refer to Main Electric Supply Station.

Utilization Electric Supply Station: Equipment such as pole or pad-mounted transformers or secondary unit substations that transforms the energy level (voltage) to a utilization voltage for consumer use.