UFC 3-550-01
February 3, 2010

UNIFIED FACILITIES CRITERIA (UFC)

EXTERIOR ELECTRICAL POWER DISTRIBUTION

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

EXTERIOR ELECTRICAL POWER DISTRIBUTION

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

U.S. ARMY CORPS OF ENGINEERS

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

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 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 more 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 Support Agency (AFCESA) 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 (CCR). 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://www.wbdg.org/.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

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UNIFIED FACILITIES CRITERIA (UFC)
NEW DOCUMENT SUMMARY SHEET

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

Superseding:

- UFC 3-501-03N, *Electrical Engineering Preliminary Considerations*
- UFC 3-550-03FA, *Design: Electrical Power Supply and Distribution*
- UFC 3-550-03N, *Design: Power Distribution Systems*

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.

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FIGURES

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.

Onsite generation is not addressed by this UFC.

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.

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

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.

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.

1-3 **REFERENCES**.

Appendix A contains a list of references used in this UFC. References applicable to a specific topic are also listed and described in the appropriate sections of this UFC.

1-4 **AUTHORITY HAVING JURISDICTION**.

The Authority Having Jurisdiction (AHJ) for each service has the authority to interpret the applicability of the requirements in this UFC, and the codes and standards referenced herein.

- For the Air Force, the AHJ is the Chief Electrical Engineer, Headquarters AFCESA/CEOA.
- For the Army, the AHJ is the Headquarters, U.S. Army Corps of Engineers (HQUSACE), Engineering and Construction (CECW-CE).
- For the Navy, the AHJ is Chief Engineer, Naval Facilities Engineering Command (NAVFAC).

1-5 **TECHNICAL POINTS OF CONTACT**.

For the Air Force, contact the Air Force Civil Engineer Support Agency (AFCESA) at daryl.hammond@tyndall.af.mil.

For the Army, contact the US Army Corps of Engineers (USACE) at robert.b.billmyre@usace.army.mil.

For the Navy, contact Code CIEE, NAVFAC Atlantic Office at john.peltz@navy.mil.

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 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 UFC3-501-01.

CHAPTER 3 DESIGN CRITERIA

3-1 MAIN ELECTRICAL SUPPLY STATION/SUBSTATION.

The main electric supply station/substation 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. Electrical power will be supplied by the utility over one or more incoming power lines. 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.

Refer to Appendix C for general electrical system criteria.

3-2 GENERAL ELECTRICAL INSTALLATION REQUIREMENTS.

Design 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. When project is limited to connecting to an existing system and the primary electrical characteristics are established and defined, continuation of the existing system shall be considered.

On the primary service to all pad-mounted or substation type transformers, provide a 600-volt insulated neutral conductor to the transformer and bond it to the transformer ground system.

Equipment intended to interrupt current at fault levels must have interrupting ratings sufficient for the nominal circuit voltage and the current that is available at the line terminals of the equipment.

Provide 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. Primary unit substations shall 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. Secondary unit substations shall 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**.

Pad-mounted transformers shall 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.

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 480/277 volt service if the required 208/120 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.

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 1.5 m (5 ft) out from the transformer pad.

3-5.3 **Transformer Connections**.

Connections shall be delta-wye for three phase systems.

3-5.4 **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.

3-5.5 **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 AHJ. 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. Consider remote racking device designs (robots) to rack breakers in and out.

Metal clad switchgear shall 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*.

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

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 an upstream pad-mounted switchgear.

3-7 **PAD-MOUNTED SWITCHGEAR (SWITCHES)**.

For the Navy, apply pad-mounted switchgear when switching, isolation, or electrical protection for the downstream circuit is required or anticipated. Provide SF6 or oil insulated, vacuum break, dead-front switches. Specify switches that have operating handles located on the opposite side of the tank from the cable entrance bushings such that switch operating personnel will not be exposed to the switch cable entrance bushings, terminations and cable. When over current protection is needed, use re-settable circuit breakers with electronic trip circuits. Do not use air-insulated or fused switches. Pad-mounted switchgear shall comply with the following industry standards:

- IEEEC57.12.28, *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, comply with the above, except that there are no limitations regarding the operating handle location, and air-insulated and fused switches can be used in either a live-front or dead-front configuration. Do not use air-insulated switches in coastal 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.

3-9 CAPACITORS.

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.

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

3-10 OVERHEAD POWER DISTRIBUTION.

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.

Connect underground extensions to pad-mounted transformers, secondary unit substations, and other primary devices to the overhead system neutral with a 600 volt insulated system neutral. This system must extend to all transformers, substations, and other primary devices and be connected to the grounding system of the load or other device.

Use NAVFAC pole details OH-1.1 through OH-41 whenever applicable. 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. Designer developed details shall contain a level of detail equivalent to NAVFAC pole details and include material requirements. Refer to UFC 3-501-01 for additional pole detail requirements.

3-10.1 **Pole Types**.

Use solid wood poles for electric distribution lines; concrete and steel poles can be used for roadway or area lighting circuits carried underground or separately from 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.

3-10.2 **Conductors**.

Use aluminum conductor steel reinforced (ACSR), aluminum alloys, or hard-drawn copper (CU) for medium-voltage lines. Use aluminum alloys with ACSR messengers or copper for low voltage lines. Do not use ACSR conductors in coastal areas as defined by UFC 3-501-01.

Limit conductor to a maximum of 4/0 awg copper or equivalent aluminum. Justify conductor sizes above 4/0 awg copper or equivalent aluminum by an economic analysis of the alternatives (such as additional circuits or a higher distribution or sub-transmission voltage). The economical minimum conductor size for circuits serving administrative, support and housing areas is 2 awg hard drawn copper or equivalent aluminum. For small, isolated loads use a minimum size of 6 awg copper or equivalent aluminum.

3-10.3 **Pole-Mounted Transformers**.

Provide pad-mounted transformers rather than pole-mounted transformers for new installations.

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 mount transformers, either singly or in banks, having an individual unit or combined capacity greater than 300 kVA on single wood poles. Do not use pole-platform mounting (two-pole structure or H-frame), except where other mounting methods are not satisfactory. Cluster mounting for transformer banks is preferred over crossarm mounting as less visually objectionable. Similarly, the cluster or three-phase bracket mountings is permitted for mounting of surge arresters and cutouts.

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

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.

3-10.4 **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.

3-10.5 **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.

3-10.6 **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.

3-10.7 **Automatic Circuit Reclosing**.

Do not provide automatic circuit reclosing on underground distribution circuits.

3-10.8 **Grounding 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**.

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 exposed overhead distribution.

Do not route primary underground utilities under buildings. Systems greater than 600 volts shall also not be routed under buildings except as a direct service entrance to a single interior transformer.

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. Refer to paragraph entitled Directional Boring for criteria applicable to directional boring.

3-11.2.1 **Conduit Size**.

Minimum conduit sizes must be as follows:

- Primary Distribution Conduits (along main run between underground structures) – 6 in (155 mm).

  Note: For the Army and Air Force, this conduit size can be 5 in (127 mm) if the conductor size is 500 kcmil or smaller for 15 kV and below.

  Note: For the Navy and Air Force, provide concrete encasement for these ductbanks.

  Note: For the Army, concrete encasement is not required.

- Primary Distribution Conduits (on laterals) and Secondary Distribution Conduits – 4 in (103 mm).

- Telecommunication Conduits – 4 in (103 mm).

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.

- 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.

- Provide spare conduits such that at least 1/3 of the ductbank contains empty conduits.

- 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.

Direct buried wiring for medium voltage systems is not allowed.

Direct buried wiring for low voltage systems from the distribution transformer to the facility service entrance is not allowed.

Direct buried wiring for low voltage systems is acceptable in large open areas only.

Sleeve all direct buried conductors under existing roads, paved areas and railroad tracks. Use galvanized rigid steel conduit.

Sleeve all direct buried conductors under new roads and use concrete encased conduits extending 5 ft (1.5 m) beyond the edge of the pavement. Use galvanized rigid steel or minimum Schedule 40 PVC conduit.

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**.

DB methods shall not be chosen 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).
- 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.

3-11.4.2 **Limitations**.

DB is applicable to medium-voltage (HV) 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 C 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)**.

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.

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

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 medium voltage systems rated for less than 15 kV.
- Power distribution equipment, including transformers and switches.

Individually fireproof medium voltage cables in all underground structures.

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 feet from the edge of paving, 50 feet from any hydrant lateral control pit, and 200 feet from a fueling point for all manholes.

Determine the size of power manholes by the number of circuits, voltage ratings and splicing requirements of the cables within. Manholes shall be a minimum 2 m (6.5 ft) deep. 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.

For circuits rated above 15 kV, manholes shall be a minimum of 9 ft by 12 ft (2.8 m by 3.7 m) in interior size.

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.

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 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**.

Medium voltage cables shall comply with NEMA WC 74, be type MV, have copper conductors, and meet the following criteria:

- 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 – The insulation level must be 133 percent based on the system voltage level and grounding configuration. Typically, a 4-wire system will be effectively grounded and a 100 percent insulation rating on the cable will achieve 133 percent insulation level for the system. Whereas a 3-wire system will not be effectively grounded and will require 133 percent insulation level for the cable.
- Cable Shields – Use tape shielded cables and ensure minimum bending radii of 12 times the overall cable diameter. Use 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**.

The following requirements shall be met 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 quadraplexes per transformer.
- Minimum conductor size from the transformer to the service entrance equipment should be 3/0 copper in underground conduit.

- Maximum length of service lateral conductors from the distribution transformer to the service entrance device (or meter base) shall be 220 ft (67 m).

- 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**.

Ground rods must be copper clad steel with diameter adequate to permit driving to full length of the rod, but not less than 3/4 in (19 mm) diameter and 10 ft (3.05 m) long.

Driven electrodes must consist of one or more stacked and bonded rods or a system of rods at a single location bonded together. All connections to ground rods below ground level must be by exothermic weld; connections above ground level can be accomplished by clamping. When multiple driven electrodes are required, they must be driven in-line with the overhead pole line. Spacing for driving additional grounds must be a minimum of 10 ft (3.05 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). If soil conditions are poor, an electrolytic grounding system may be used.

Ensure non-current-carrying metallic parts associated with electrical equipment have a maximum resistance to solid earth ground not exceeding the following values:

Secondary unit substations	
500 kVA or less	5 ohms
500 kVA to 1000 kVA	5 ohms
1000 kVA or over	3 ohms
Pad-mounted transformers without protective fences	5 ohms
Ground in manholes, handholes, and vaults	5 ohms
Grounding other metal enclosures of primary voltage electrical and electrically-operated equipment	5 ohms
Pole grounds	25 ohms
Grounded secondary distribution system neutral and non-current-carrying metal parts associated with distribution systems and grounds not otherwise covered	5 ohms

3-15 METERING.

Supply housing units with meter sockets only. Sockets must be single phase, four terminal, and ring-less with manual bypass device and polycarbonate blank cover plate.

For all other services, provide electronic programmable watt-hour meters with solid-state demand registers. Include necessary KYZ initiation hardware for Energy Management and Control System (EMCS) coordinated with the mechanical Direct Digital Control System (DDC). Locate watt-hour meters directly on pad mounted transformers or integral to unit substations.

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 transformers may be used either outdoors or indoors; these liquids shall have a fire point of not less than 300 degrees Celsius.

GLOSSARY

Acronyms and Abbreviations

AC	Alternating Current
ACSR	Aluminum Conductor Steel-Reinforced
A/E	Architect/Engineer
AFCESA	Air Force Civil Engineer Support Agency
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
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
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

Terms

Activity – The end user of a facility.

Coastal Area – Any area within 8 km (5 miles) of the coast, a bay or a harbor.

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

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

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.

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

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.

APPENDIX A REFERENCES

Note: *The most recent edition of referenced publications applies, unless otherwise specified.* [1]

Military Publications

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 3-600-01, *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*.

IEEE (formerly Institute of Electrical and Electronics Engineers)

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*.

[1] Addresses for standards:
1. Institute of Electrical and Electronics Engineers, 3 Park Avenue, 17th Floor, New York, NY 10016
2. International Electrical Testing Association,
3. National Electrical Manufacturers' Association, 1300 North 17th Street, Suite 1752, Rosslyn, VA 22209National Fire Protection Association, One Batterymarch Park, P.O. Box 9101, Quincy, MA 02269.

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 Fire Protection Association

NFPA 70, *National Electrical Code.*
NFPA 70B, *Electrical Equipment Maintenance.*

National Electrical Manufacturers' Association

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

Miscellaneous Documents

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

APPENDIX B DIRECTIONAL BORING

B-1 **CONDUIT TYPE**.

HDPE conduit shall be smoothwall, 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: HDPE conduit shall always be installed below freeze lines and in no case shall the conduit be installed less than the minimum depths noted below.

B.1.1. Minimum size HDPE conduit shall be 5 inches for distribution voltages greater than 1,000 V and less than 34.5 kV (nominal).

B.1.1.1. Conduit fill shall not exceed 30 percent.

B.1.1.2. Installed HDPE conduit shall have a minimum ground cover of:

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

B.1.2. Minimum size HDPE conduit shall be 4 inches for distribution voltages less than 1,000 V.

B.1.2.1. Conduit fill shall not exceed 35 percent.

B.1.2.2. Installed HDPE conduit shall have a minimum ground cover of 48 inches in pavement- or non-pavement-covered areas.

B.1.3. Minimum size HDPE conduit for branch circuit wiring less than 600 V shall be determined by calculation, addressing, as a minimum, branch circuit conductor size, maximum allowable pulling tension, and maximum 5 percent voltage drop.

B.1.3.1. Conduit fill shall not exceed 40 percent.

B.1.3.2. Installed HDPE conduit shall have a minimum 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. 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. Water-jetting is not permitted.

B.2.3. Pre-installed cable-in-conduit is not permitted.

B.2.4. Drilling fluids used for DB methods shall be approved by federal, state, and local codes and authorized for use by the BCE.

B.2.5. The conduit(s) shall be installed immediately after the conduit hole is completed.

B.2.6. 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.2.6.1. A registered Professional Engineer (PE) shall 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.

B.2.6.2. The electrical contractor shall provide certification of compliance with the PE‘s design requirements.

B.2.6.3. 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.

B.2.6.4. Allowable tensile forces must be determined by a PE. The PE certifying the installation shall account for the conduit's allowable bend radius to prevent ovalization and kinking from installation. Ovalization of the conduit shall not exceed 5 percent.

B.2.7. HDPE conduits shall terminate into concrete-pad-mounted electrical equipment from either a pavement or non-pavement transitional area as indicated in Figures B-1 through B-5. HDPE or rigid conduit shall be routed and terminated within the concrete pad such that no conductor exiting the conduit shall be bent past the vertical plane formed with the equipment pad when routed to conductor terminations and with approved insulated bushings (Figure B-1).

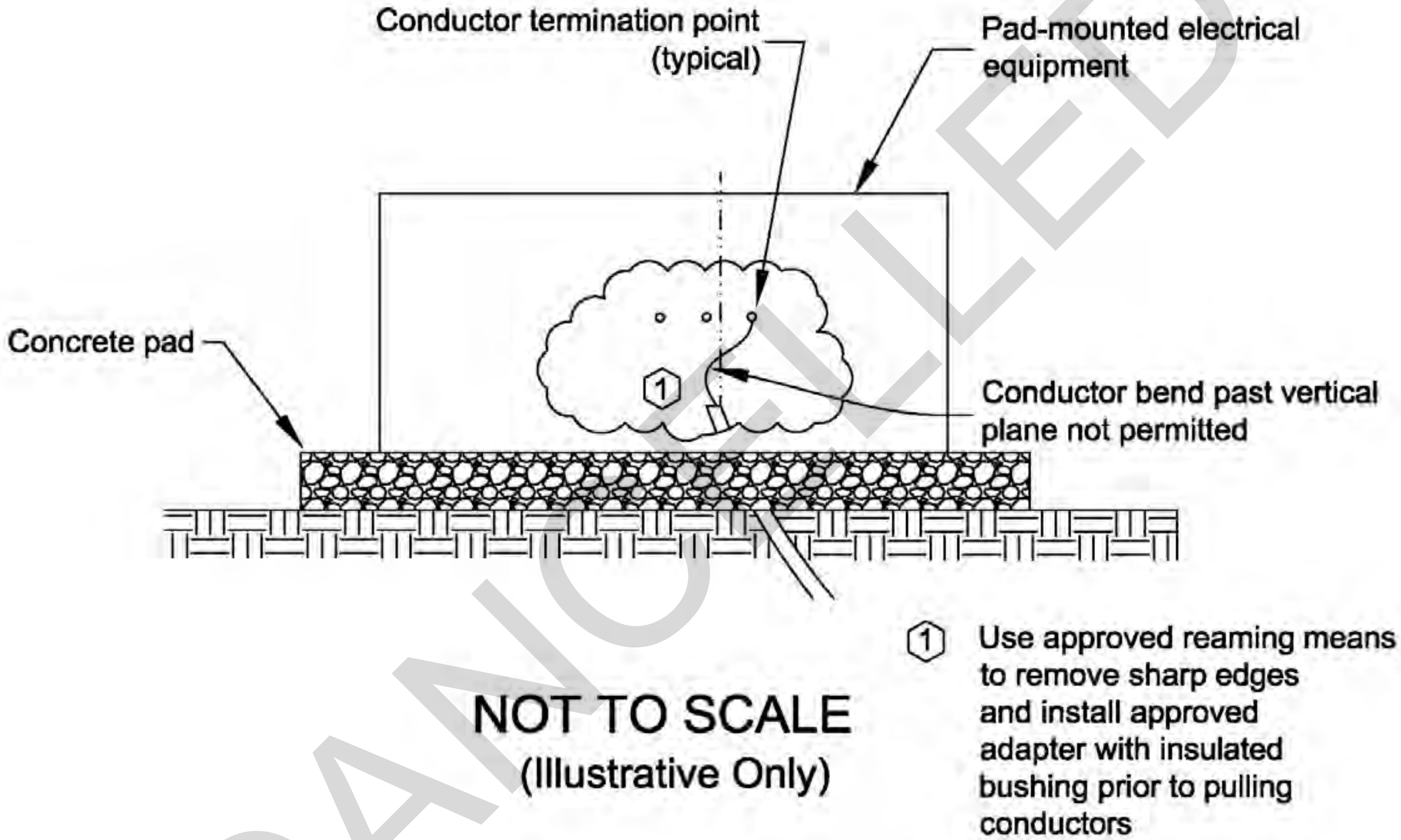

Figure B-1. HDPE or Rigid Conduit Electrical Equipment Transition

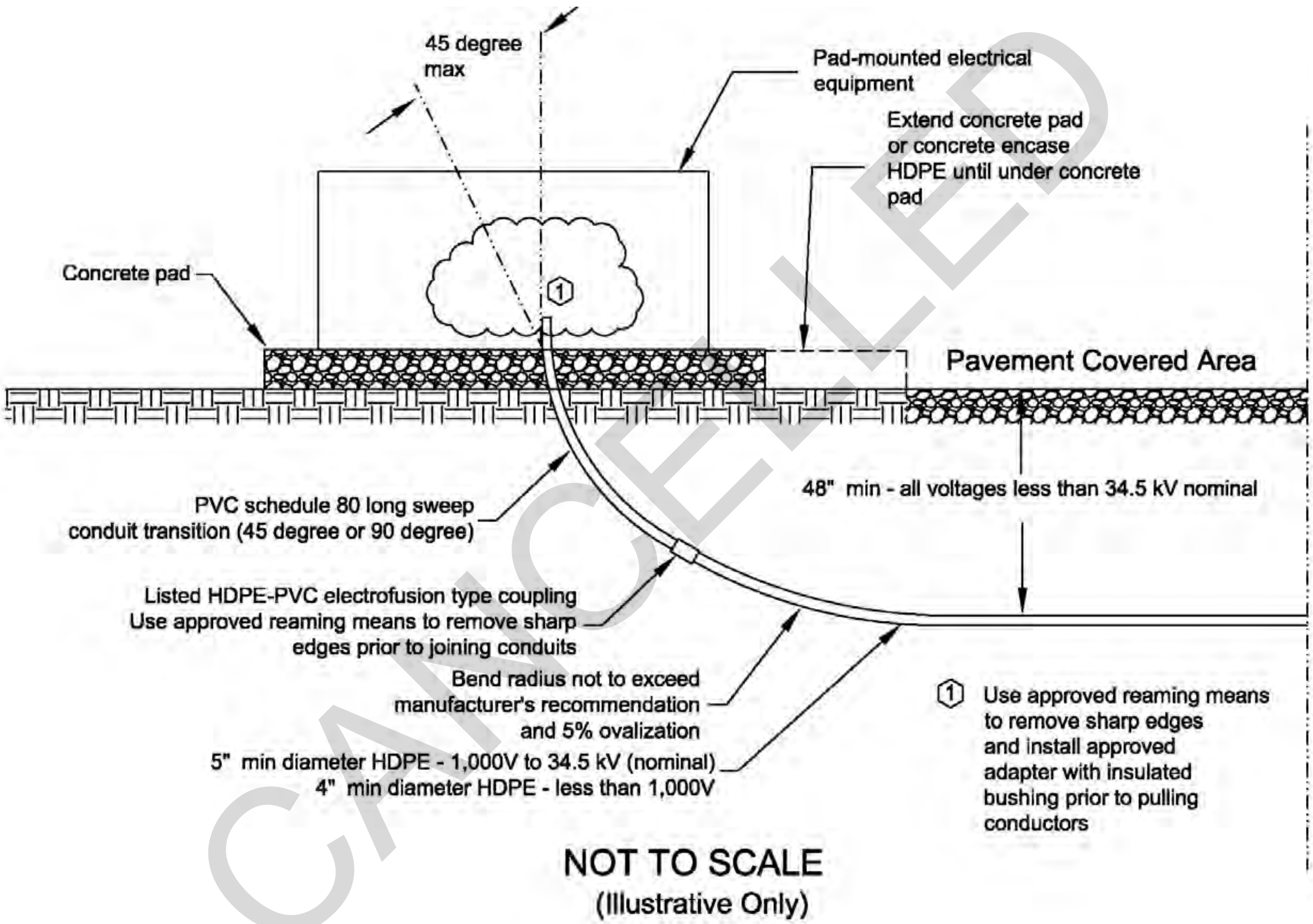

Figure B-2. Pavement Covered Area to Electrical Equipment Transition – Rigid Conduit (45˚–90˚)

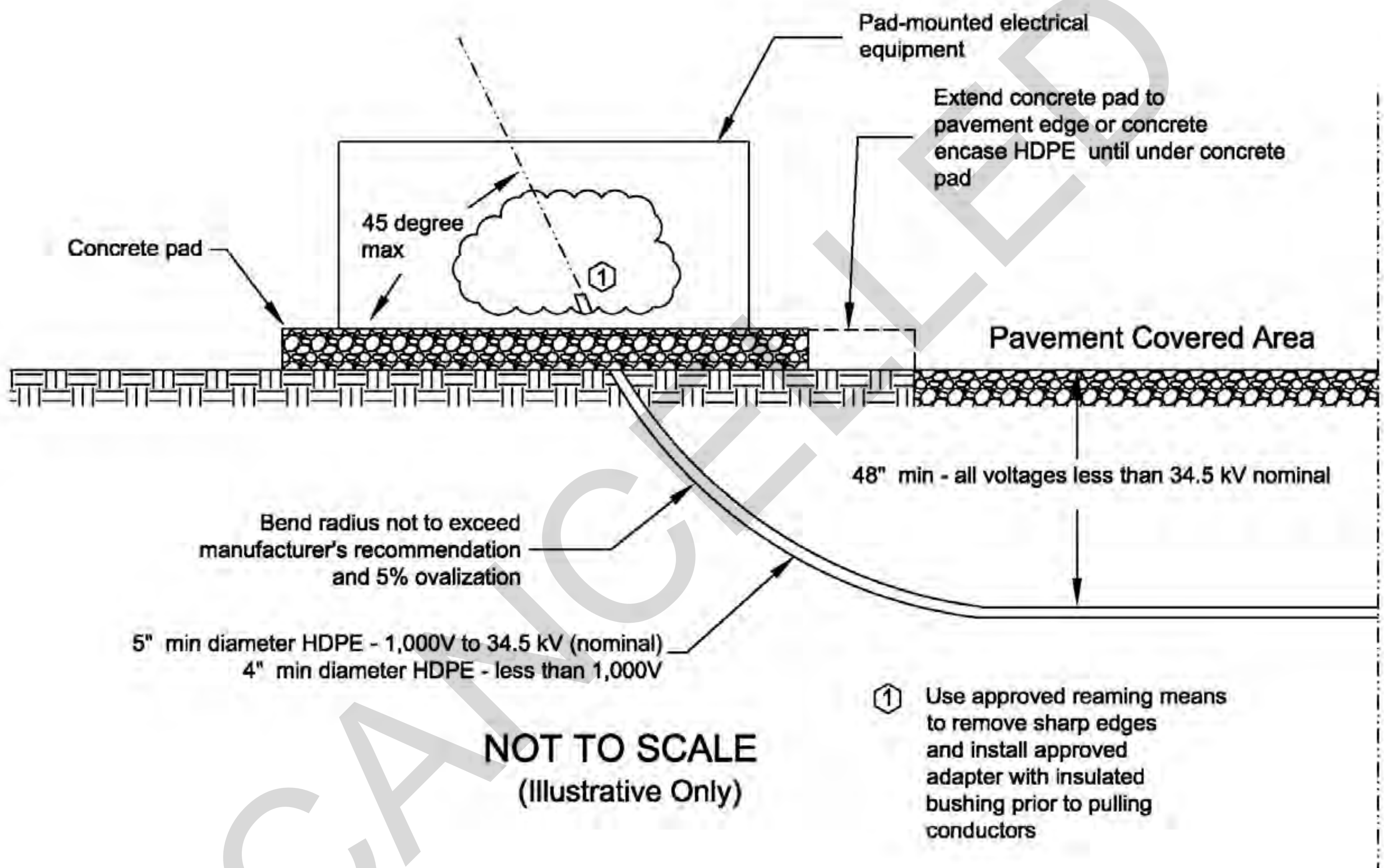

Figure B-3. Pavement Covered Area to Electrical Equipment Transition – HDPE Conduit (20˚–45˚)

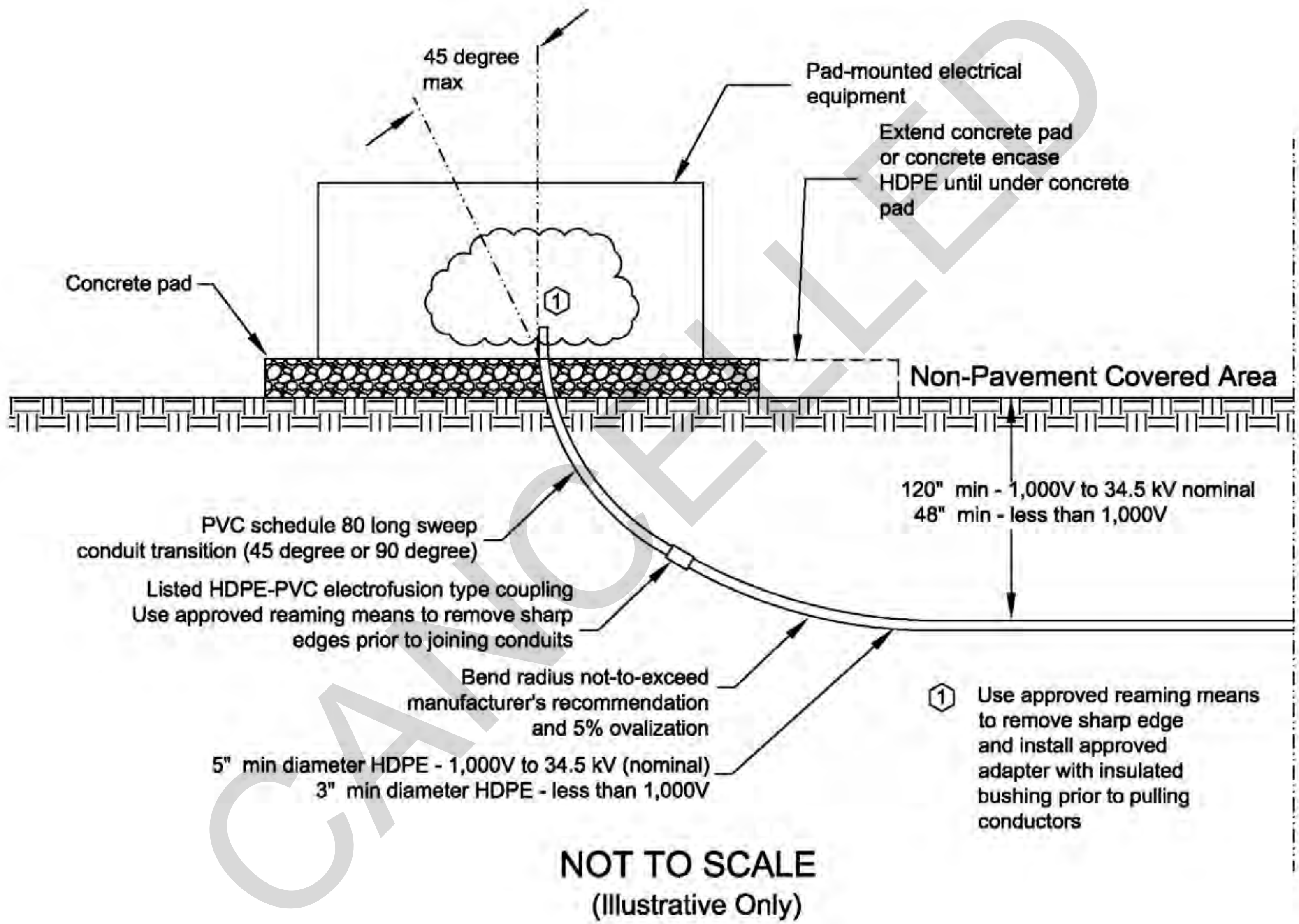

Figure B-4. Non-Pavement Covered Area to Electrical Equipment Transition – Rigid Conduit (45˚–90˚)

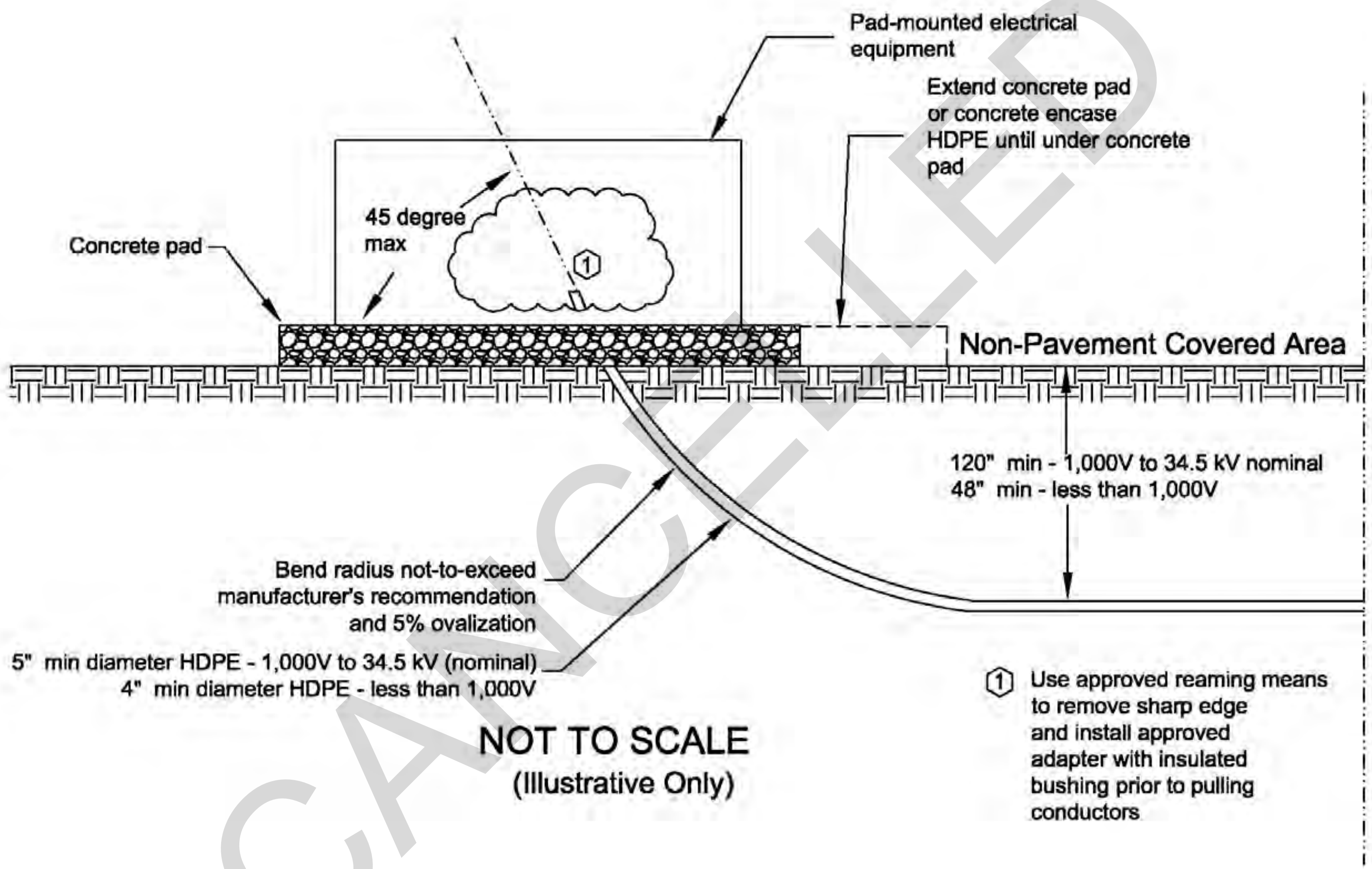

Figure B-5. Non-Pavement Covered Area to Electrical Equipment Transition – HDPE Conduit (20˚–45˚)

B.2.8. Multiple Conduits and Wiring Methods.

B.2.8.1. 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.2.8.2. 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.2.9. Joining Methods. Butt and electrofusion joining means are the only joining methods approved for HDPE conduit installations and shall be accomplished by persons certified in the process and in accordance with the manufacturer's procedures.

B.2.10. Transition from HDPE to PVC. Transition from HDPE to PVC shall be made using only electrofusion coupling means with approved and listed materials. Coupling means shall be accomplished by persons certified on the equipment and process.

B.2.10.1. Coupling between HDPE and concrete-encased duct banks from pavement or non-pavement transitional areas shall be accomplished as indicated in Figures B-6 and B-7.

B.2.10.2. Transition from HDPE to concrete manholes from pavement or non-pavement transitional areas shall be accomplished as indicated in Figures B-8 and B-9.

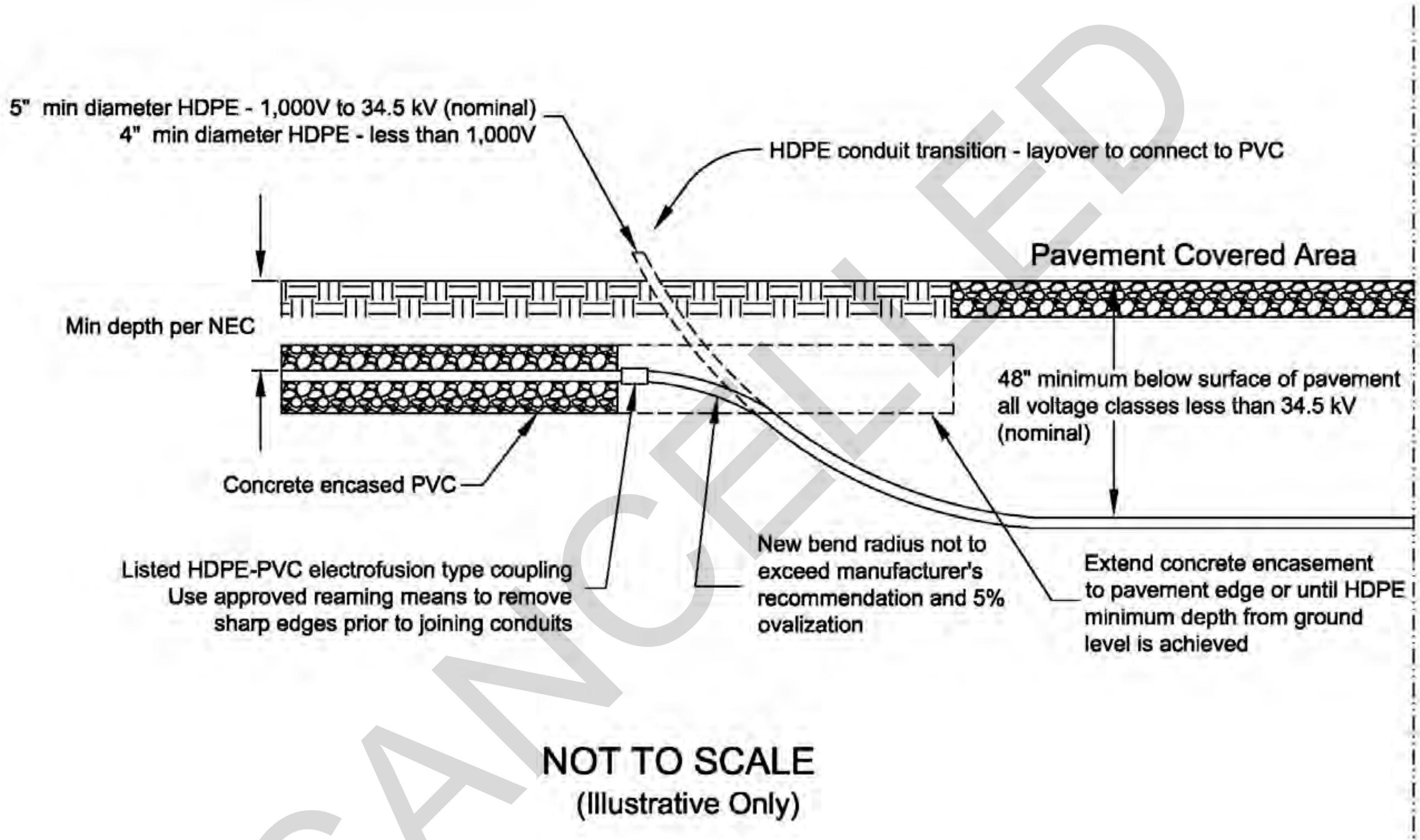

Figure B-6. HDPE-to-PVC Pavement Covered Area Concrete Ductbank Transition

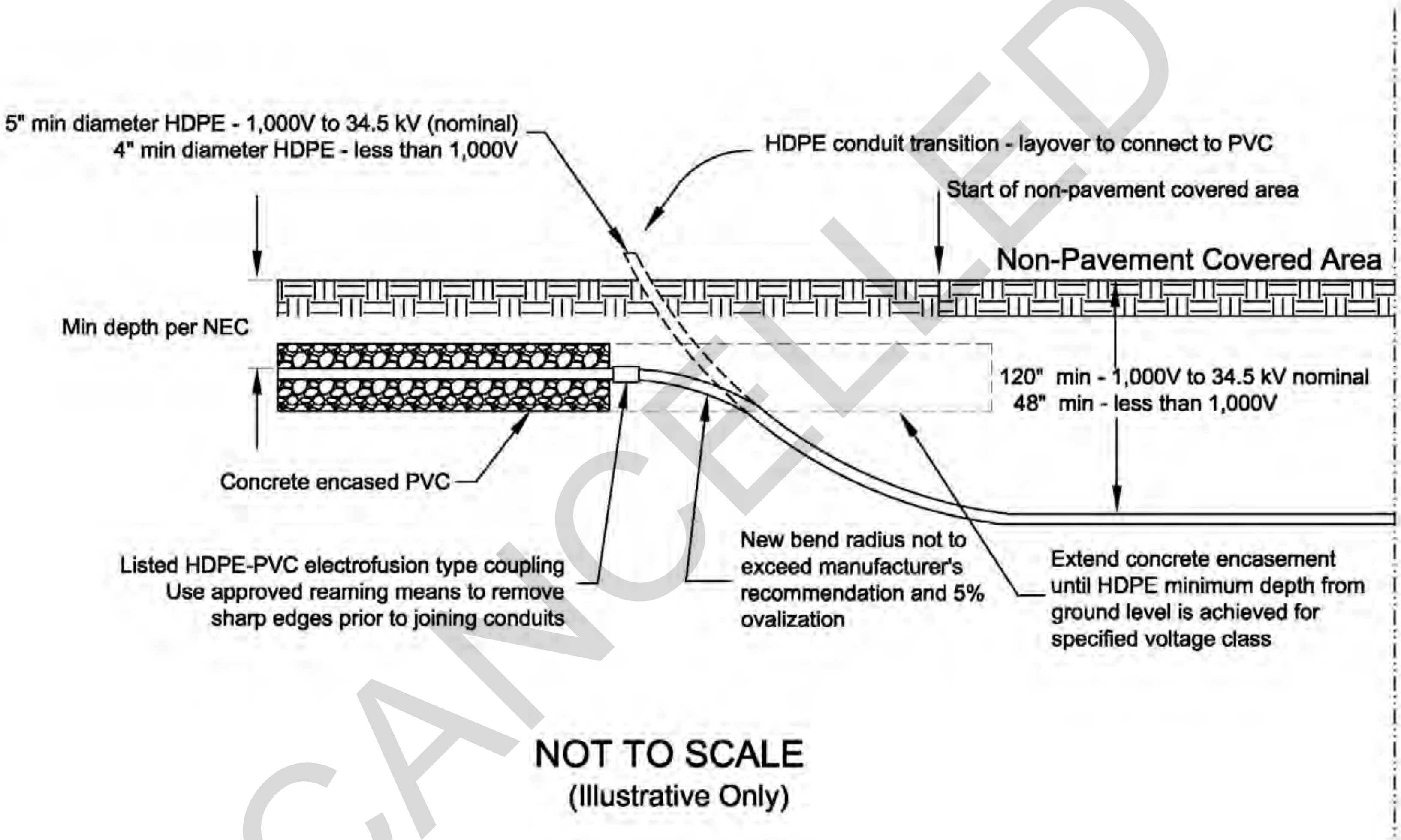

Figure B-7. HDPE-to-PVC Non-Pavement Covered Area Concrete Ductbank Transition

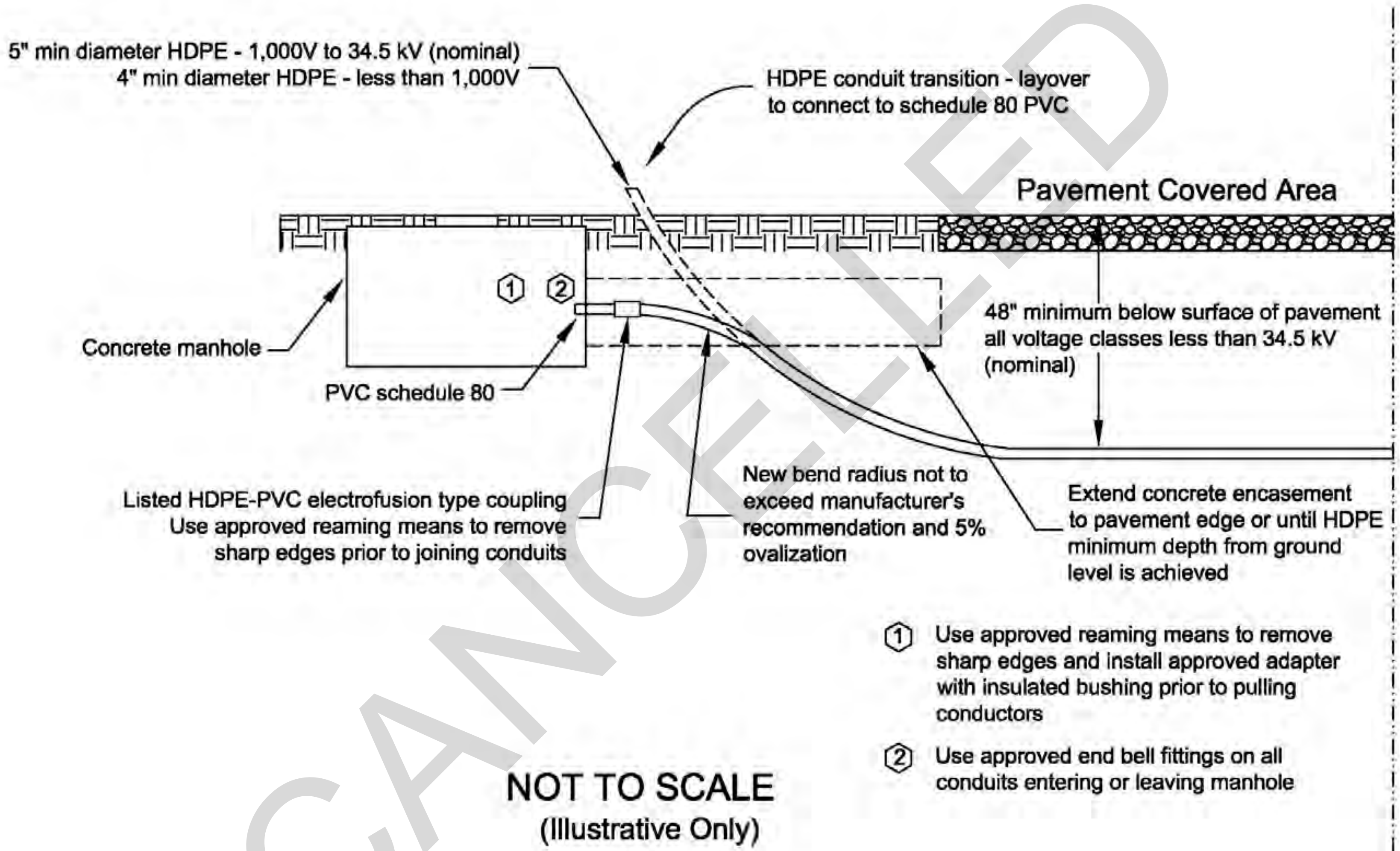

Figure B-8. HDPE-to-Manhole Pavement Covered Area Transition

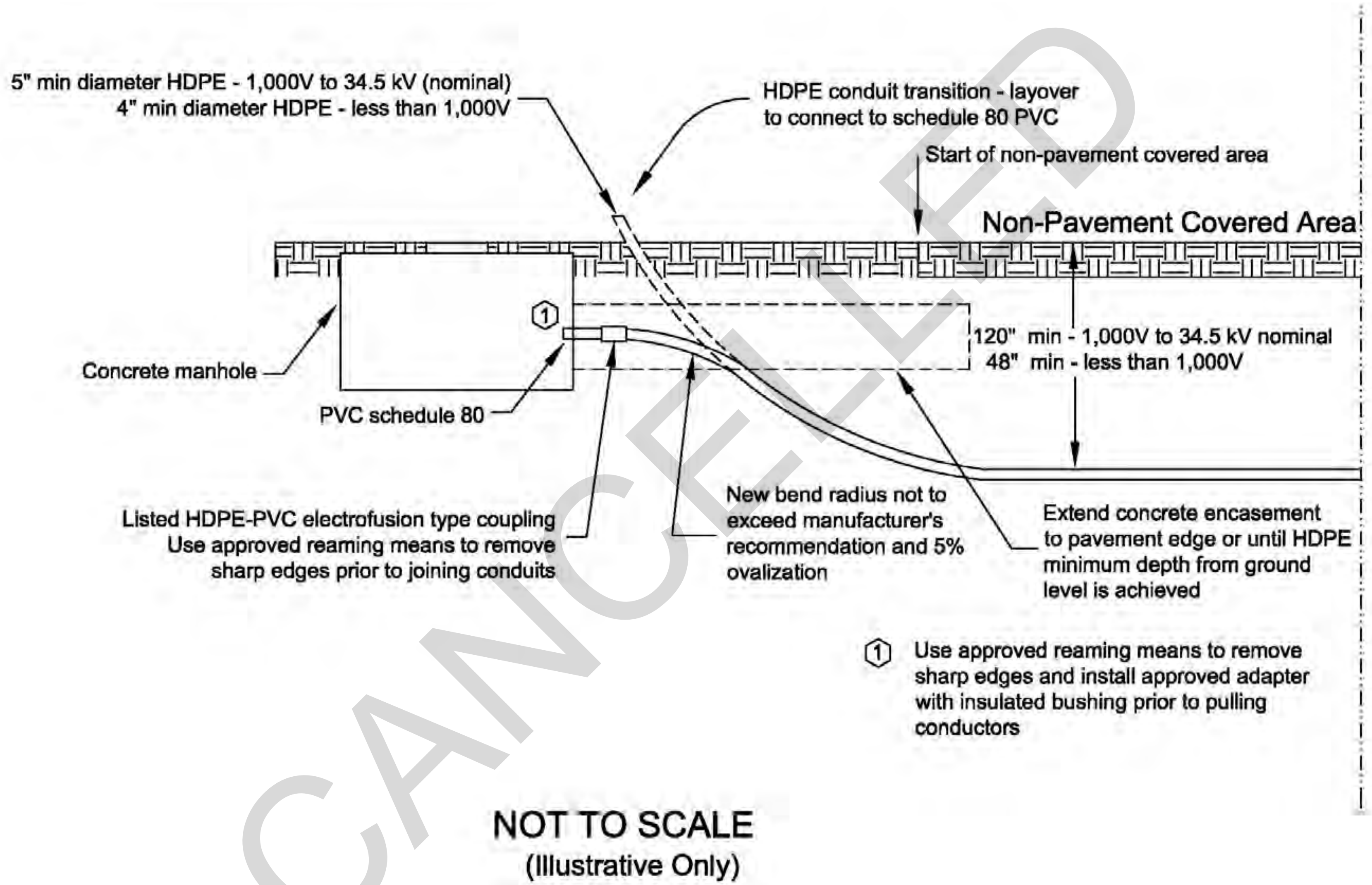

Figure B-9. HDPE-to-Manhole Pavement Covered Area Transition

B-3 **DOCUMENTATION**.

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

APPENDIX C GENERAL ELECTRICAL POWER REQUIREMENTS

C.1 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 Use or modify existing substations unless a new substation is required for capacity or unique requirements. Aging substations will often require complete replacement.

C.3 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.

C.4 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.5 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.6 Design a main electric supply station/substation for reliability of service and maintenance. The design analysis for the supply station/substation shall address the following:

- 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.

- Physical security. Provide a station fence and grounding in accordance with IEEE 80 and IEEE C2. For personnel safety, use metal or fiberglass enclosures around all live parts. Provide locks on all gates.