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USACE / NAVFAC / AFCEA UFGS-16375A (April 2005)  
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Preparing Activity: USACE Superseding  
UFGS-16375A (February 2002)

## UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UML dated 22 December 2004

Latest change indicated by CHG tags

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### SECTION TABLE OF CONTENTS

#### DIVISION 16 - ELECTRICAL

##### SECTION 16375A

##### ELECTRICAL DISTRIBUTION SYSTEM, UNDERGROUND

04/05

#### PART 1 GENERAL

- 1.1 REFERENCES
- 1.2 GENERAL REQUIREMENTS
  - 1.2.1 Terminology
  - 1.2.2 Service Conditions
- 1.3 SUBMITTALS
- 1.4 DELIVERY, STORAGE, AND HANDLING
- 1.5 EXTRA MATERIALS
- 1.6 DRAWINGS
  - 1.6.1 Detail Drawings
  - 1.6.2 As-Built Drawings

#### PART 2 PRODUCTS

- 2.1 STANDARD PRODUCT
- 2.2 NAMEPLATES
  - 2.2.1 General
  - 2.2.2 Liquid-Filled Transformer Nameplates
- 2.3 CORROSION PROTECTION
  - 2.3.1 Aluminum Materials
  - 2.3.2 Ferrous Metal Materials
    - 2.3.2.1 Hardware
    - 2.3.2.2 Equipment
  - 2.3.3 Finishing
- 2.4 CABLES
  - 2.4.1 Medium-Voltage Cables
    - 2.4.1.1 General
    - 2.4.1.2 Ratings
    - 2.4.1.3 Conductor Material
    - 2.4.1.4 Insulation
    - 2.4.1.5 Shielding
    - 2.4.1.6 Neutrals
    - 2.4.1.7 Jackets

- 2.4.2 Low-Voltage Cables
  - 2.4.2.1 Conductor Material
  - 2.4.2.2 Insulation
  - 2.4.2.3 Jackets
  - 2.4.2.4 Direct Buried
  - 2.4.2.5 In Duct
- 2.5 CABLE JOINTS, TERMINATIONS, AND CONNECTORS
  - 2.5.1 Medium-Voltage Cable Joints
  - 2.5.2 Medium-Voltage Separable Insulated Connectors
  - 2.5.3 Low-Voltage Cable Splices
  - 2.5.4 Terminations
    - 2.5.4.1 Factory Preformed Type
    - 2.5.4.2 Taped Terminations
- 2.6 CONDUIT AND DUCTS
  - 2.6.1 Metallic Conduit
  - 2.6.2 Nonmetallic Ducts
    - 2.6.2.1 Bituminized Fiber Duct
    - 2.6.2.2 Concrete Encased Ducts
    - 2.6.2.3 Direct Burial
  - 2.6.3 Conduit Sealing Compound
- 2.7 MANHOLES, HANDHOLES, AND PULLBOXES
- 2.8 POLES AND HARDWARE
- 2.9 TRANSFORMERS, SUBSTATIONS, AND SWITCHGEAR
  - 2.9.1 Secondary Unit Substation
    - 2.9.1.1 Incoming Section
    - 2.9.1.2 Transformer Section
    - 2.9.1.3 Integral Outgoing Section
    - 2.9.1.4 Nonintegral (Cable Compartment) Outgoing Section
  - 2.9.2 Pad-Mounted Transformers
    - 2.9.2.1 High-Voltage Compartments
    - 2.9.2.2 Load-Break Switch
    - 2.9.2.3 Transformer Tank Sections
    - 2.9.2.4 Low-Voltage Cable Compartments
    - 2.9.2.5 Accessories
  - 2.9.3 Busways
  - 2.9.4 Pad-Mounted, Metal-Enclosed, Switchgear
    - 2.9.4.1 Ratings at 60 Hz shall be:
    - 2.9.4.2 Operators, Devices, and Controls
    - 2.9.4.3 Enclosures
  - 2.9.5 Pad-Mounted Sectionalizers
    - 2.9.5.1 Ratings
    - 2.9.5.2 Enclosures
  - 2.9.6 Cable Terminating Cabinets
- 2.10 METERING AND PROTECTIVE DEVICES
  - 2.10.1 Circuit Breakers, Low-Voltage
    - 2.10.1.1 Low-Voltage Power Circuit Breakers
    - 2.10.1.2 Molded-Case Circuit Breakers
  - 2.10.2 Fuses, Medium-Voltage, Including Current-Limiting
    - 2.10.2.1 Construction
    - 2.10.2.2 Ratings
    - 2.10.2.3 E-Rated, Current-Limiting Power Fuses
    - 2.10.2.4 C-Rated, Current-Limiting Power Fuses
  - 2.10.3 Fuses, Low-Voltage, Including Current-Limiting
    - 2.10.3.1 Cartridge Fuses
    - 2.10.3.2 Transformer Circuit Fuses
  - 2.10.4 Instrument Transformers
    - 2.10.4.1 General
    - 2.10.4.2 Current Transformers
    - 2.10.4.3 Current Transformers for Power Transformers

- 2.10.4.4 Current Transformers for Metal-Enclosed Switchgear
- 2.10.4.5 Current Transformers for Kwh and Demand Metering (Low-Voltage)
- 2.10.4.6 Voltage Transformers
- 2.10.5 Watthour Meters
- 2.10.6 Protective Relaying
  - 2.10.6.1 General
  - 2.10.6.2 Construction
  - 2.10.6.3 Ratings
- 2.11 SURGE ARRESTERS
- 2.12 GROUNDING AND BONDING
  - 2.12.1 Driven Ground Rods
  - 2.12.2 Grounding Conductors
- 2.13 CONCRETE AND REINFORCEMENT
- 2.14 PADLOCKS
- 2.15 CABLE FIREPROOFING SYSTEMS
  - 2.15.1 Fireproof Coating
  - 2.15.2 Fireproofing Tape
  - 2.15.3 Plastic Tape
- 2.16 LIQUID DIELECTRICS
- 2.17 FACTORY TESTS
- 2.18 FENCING
- 2.19 COORDINATED POWER SYSTEM PROTECTION
  - 2.19.1 Scope of Analyses
  - 2.19.2 Determination of Facts
  - 2.19.3 Single Line Diagram
  - 2.19.4 Fault Current Analysis
    - 2.19.4.1 Method
    - 2.19.4.2 Data
  - 2.19.5 Coordination Study
  - 2.19.6 Study Report

### PART 3 EXECUTION

- 3.1 INSTALLATION REQUIREMENTS
  - 3.1.1 Conformance to Codes
  - 3.1.2 Verification of Dimensions
  - 3.1.3 Disposal of Liquid Dielectrics
- 3.2 CABLE AND BUSWAY INSTALLATION
  - 3.2.1 Cable Installation Plan and Procedure
    - 3.2.1.1 Cable Inspection
    - 3.2.1.2 Duct Cleaning
    - 3.2.1.3 Duct Lubrication
    - 3.2.1.4 Cable Installation
    - 3.2.1.5 Cable Installation Plan
  - 3.2.2 Duct Line
  - 3.2.3 Direct-Burial
    - 3.2.3.1 Trenching
    - 3.2.3.2 Cable Burial
    - 3.2.3.3 Other Requirements
    - 3.2.3.4 Cable Joints or Splices
    - 3.2.3.5 Cable Markers
  - 3.2.4 Insect and Rodent Damage
  - 3.2.5 Electric Manholes
  - 3.2.6 Busway Installation
- 3.3 CABLE JOINTS
- 3.4 FIREPROOFING
  - 3.4.1 Tape Method
  - 3.4.2 Sprayable Method

- 3.5 DUCT LINES
  - 3.5.1 Requirements
  - 3.5.2 Treatment
  - 3.5.3 Concrete Encasement
  - 3.5.4 Nonencased Direct-Burial
  - 3.5.5 Installation of Couplings
    - 3.5.5.1 Bituminized-Fiber Ducts
    - 3.5.5.2 Plastic Duct
  - 3.5.6 Duct Line Markers
- 3.6 MANHOLES, HANDHOLES, AND PULLBOXES
  - 3.6.1 General
  - 3.6.2 Electric Manholes
  - 3.6.3 Communications Manholes
  - 3.6.4 Handholes
  - 3.6.5 Pullboxes
  - 3.6.6 Ground Rods
- 3.7 PAD-MOUNTED EQUIPMENT INSTALLATION
  - 3.7.1 Concrete Pads
    - 3.7.1.1 Construction
    - 3.7.1.2 Concrete and Reinforcement
    - 3.7.1.3 Sealing
  - 3.7.2 Padlocks
  - 3.7.3 Fencing
- 3.8 CONNECTIONS BETWEEN AERIAL AND UNDERGROUND SYSTEMS
- 3.9 CONNECTIONS TO BUILDINGS
- 3.10 GROUNDING
  - 3.10.1 Grounding Electrodes
  - 3.10.2 Grounding and Bonding Connections
  - 3.10.3 Grounding and Bonding Conductors
  - 3.10.4 Surge Arrester Grounding
  - 3.10.5 Manhole, Handhole, or Concrete Pullbox Grounding
  - 3.10.6 Metal Splice Case Grounding
  - 3.10.7 Riser Pole Grounding
- 3.11 FIELD TESTING
  - 3.11.1 General
  - 3.11.2 Safety
  - 3.11.3 Ground-Resistance Tests
  - 3.11.4 Ground-Mat Connection Inspection
  - 3.11.5 Medium-Voltage Cable Test
  - 3.11.6 Low-Voltage Cable Test
  - 3.11.7 Liquid-Filled Transformer Tests
  - 3.11.8 Dry-Type Transformer Tests
  - 3.11.9 Circuit Breaker Tests
  - 3.11.10 Power Circuit Breaker Tests
  - 3.11.11 Protective Relays
  - 3.11.12 Pre-Energization Services
  - 3.11.13 Operating Tests
- 3.12 MANUFACTURER'S FIELD SERVICE
  - 3.12.1 Onsite Training
  - 3.12.2 Installation Engineer
- 3.13 ACCEPTANCE

-- End of Section Table of Contents --

\*\*\*\*\*  
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-----  
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### SECTION 16375A

#### ELECTRICAL DISTRIBUTION SYSTEM, UNDERGROUND 04/05

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NOTE: This guide specification covers the requirements for underground electrical distribution systems.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.

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## PART 1 GENERAL

### 1.1 REFERENCES

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NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest guide specification. Use of SpecsIntact automated reference checking is recommended for projects based on older guide specifications.

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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ALLIANCE FOR TELECOMMUNICATIONS INDUSTRY SOLUTIONS (ATIS)

ATIS O5.1 (2002; R 2003) Specifications and  
Dimensions (for Wood Poles)

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C119.1 (2002) Sealed Insulated Underground  
Connector Systems Rated 600 Volts

ANSI C12.10 (1997) Watthour Meters

ANSI C12.11 (1987) Instrument Transformers for Revenue  
Metering, 10 kV BIL through 350 kV BIL  
(0.6 kV NSV through 69 kV NSV)

ANSI C12.4 (1984; R 1990) Mechanical Demand Registers

ANSI C135.30 (1988) Zinc-Coated Ferrous Ground Rods for  
Overhead or Underground Line Construction

ANSI C29.1 (1988; R 2002) Test Methods for Electrical  
Power Insulators

ANSI C37.121 (1989) Switchgear Unit Substations  
Requirements

ANSI C37.16 (2000) Low-Voltage Power Circuit Breakers  
and AC Power Circuit Protectors -  
Preferred Ratings, Related Requirements,  
and Application Recommendations

ANSI C37.46 (2000) For High Voltage Expulsion and  
Current-Limiting Type Power Class Fuses  
and Fuse Disconnecting Switches

ANSI C37.50 (1989; R 2000) Low-Voltage AC Power  
Circuit Breakers Used in Enclosures - Test  
Procedures

ANSI C37.72 (1987) Manually-Operated, Dead-Front  
Padmounted Switchgear with Load  
Interrupting Switches and Separable  
Connectors for Alternating-Current Systems

ANSI C42.100 (2000) Standard Dictionary of Electrical  
and Electronics Terms

ANSI C57.12.21 (1992) Requirements for Pad-Mounted,  
Compartmental-Type, Self-Cooled,  
Single-Phase Distribution Transformers  
with High-Voltage Bushings; High Voltage,  
34 500 Grd Y/199200 Volts and Below; Low  
Voltage, 2400/120 Volts; 167 kVA and  
Smaller

ANSI C57.12.26 (1993) Pad-Mounted Compartmental-Type,  
Self-Cooled, Three-Phase Distribution  
Transformers for Use with Separable

Insulated High-Voltage Connectors,  
High-Voltage, 34 500 Grd Y/19 920 Volts  
and Below; 2500 kVA and Smaller

- ANSI C57.12.28 (1999) Padmounted Equipment - Enclosure Integrity
- ANSI C62.2 (1987; R 1994) Guide for the Application of Gapped Silicon-Carbide Surge Arresters for Alternating Current Systems
- ANSI C80.1 (1994) Rigid Steel Conduit - Zinc Coated

ASSOCIATION OF EDISON ILLUMINATING COMPANIES (AEIC)

- AEIC C8 (2000) Extruded Dielectric Shielded Power Cables Rated 5 Through 46 kV
- AEIC CS6 (1996) Ethylene Propylene Rubber Insulated Shielded Power Cables Rated 69 kV

ASTM INTERNATIONAL (ASTM)

- ASTM A 123/A 123M (2002) Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
- ASTM A 153/A 153M (2004) Zinc Coating (Hot-Dip) on Iron and Steel Hardware
- ASTM A 48/A 48M (2003) Gray Iron Castings
- ASTM B 117 (2002) Operating Salt Spray (Fog) Apparatus
- ASTM B 231/B 231M (2004) Concentric-Lay-Stranded Aluminum 1350 Conductors
- ASTM B 3 (2001) Soft or Annealed Copper Wire
- ASTM B 400 (2004) Compact Round Concentric-Lay-Stranded Aluminum 1350 Conductor
- ASTM B 496 (2004) Compact Round Concentric-Lay-Stranded Copper Conductors
- ASTM B 609/B 609M (1999; R 2004) Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical purposes
- ASTM B 8 (2004) Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
- ASTM B 800 (2000) 8000 Series Aluminum Alloy Wire for Electrical Purposes-Annealed and Intermediate Tempers
- ASTM B 801 (1999) Concentric-Lay-Stranded Conductors of 8000 Series Aluminum Alloy for Subsequent Covering or Insulation

ASTM C 478	(2003a) Precast Reinforced Concrete Manhole Sections
ASTM C 478M	(2003a) Precast Reinforced Concrete Manhole Sections (Metric)
ASTM D 1654	(1992; R 2000) Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments
ASTM D 2472	(2000) Sulfur Hexafluoride
ASTM D 4059	(2000) Analysis of Polychlorinated Biphenyls in Insulating Liquids by Gas Chromatography
ASTM D 923	(1997) Sampling Electrical Insulating Liquids
FM GLOBAL (FM)	
FM P7825a	(2003) Approval Guide Fire Protection
INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)	
IEEE C2	(2002) National Electrical Safety Code
IEEE C37.1	(1994) Definition, Specification, and Analysis of Systems Used for Supervisory Control, Data Acquisition, and Automatic Control
IEEE C37.13	(1990; R 1995) Low-Voltage AC Power Circuit Breakers Used in Enclosures
IEEE C37.2	(1996) Electrical Power System Device Function Numbers and Contact Designations
IEEE C37.20.1	(2002) Metal-Enclosed Low-Voltage Power Circuit-Breaker Switchgear
IEEE C37.20.2	(1999) Metal-Clad Switchgear
IEEE C37.20.3	(2001) Metal-Enclosed Interrupter Switchgear
IEEE C37.23	(1987) Guide for Metal-Enclosed Bus and Calculating Losses in Isolated-Phase Bus
IEEE C37.30	(1997) Requirements for High-Voltage Switches
IEEE C37.34	(1994) Test Code for High-Voltage Air Switches
IEEE C37.41	(2000) Design Tests for High-Voltage Fuses, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches,



and Accessories

IEEE C37.63	(1997) Requirements for Overhead, Pad-Mounted, Dry-Vault, and Submersible Automatic Line Sectionalizers for AC Systems
IEEE C37.90	(1989) Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C37.90.1	(2002) Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C37.98	(1987) Seismic Testing of Relays
IEEE C57.12.00	(2000) General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
IEEE C57.13	(1993) Requirements for Instrument Transformers
IEEE C57.98	(1994) Guide for Transformer Impulse Tests
IEEE C62.1	(1989; R 1994) Gapped Silicon-Carbide Surge Arresters for AC Power Circuits
IEEE C62.11	(1999) Metal-Oxide Surge Arresters for Alternating Current Power Circuits (>1KV)
IEEE Std 242	(2001) Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems - Buff Book
IEEE Std 386	(1995) Separable Insulated Connector Systems for Power Distribution Systems Above 600V
IEEE Std 399	(1997) Recommended Practice for Power Systems Analysis - Brown Book
IEEE Std 404	(2000) Extruded and Laminated Dielectric Shielded Cable Joints Rated 2500 V Through 500 000 V
IEEE Std 48	(1996; R 2003) Test Procedures and Requirements for Alternating-Current Cable Terminations 2.5 kV through 765 kV
IEEE Std 81	(1983) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System (Part 1) Normal Measurements

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA AB 1	(2002) Molded-Case Circuit Breakers, Molded Case Switches, and Circuit-Breaker
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## Enclosures

NEMA BU 1	(1999) Busways
NEMA FB 1	(2001) Fittings, Cast Metal Boxes, and Conduit Bodies for Conduit, Electrical Metallic Tubing and Cable
NEMA FU 1	(2002) Low Voltage Cartridge Fuses
NEMA LA 1	(1992; R 1999) Surge Arresters
NEMA PB 1	(2000) Panelboards
NEMA PB 2	(2001) Deadfront Distribution Switchboards
NEMA SG 2	(1993) High Voltage Fuses
NEMA SG 6	(2000) Power Switching Equipment
NEMA TC 6 & 8	(2003) Polyvinyl Chloride PVC Plastic Utilities Duct for Underground Installation
NEMA TC 7	(2000) Smooth-Wall Coilable Polyethylene Electrical Plastic Duct

## NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2005) National Electrical Code
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## UNDERWRITERS LABORATORIES (UL)

UL 1072	(2001; Rev thru Apr 2003) Medium-Voltage Power Cables
UL 1242	(2000; Rev thru May 2003) Electrical Intermediate Metal Conduit -- Steel
UL 1684	(2000) Reinforced Thermosetting Resin Conduit (RTRC) and Fittings
UL 198C	(1986; Rev thru Feb 1998) High-Interrupting-Capacity Fuses, Current-Limiting Types
UL 198D	(1995) Class K Fuses
UL 198E	(1988; Rev Jul 1988) Class R Fuses
UL 198H	(1988; Rev thru Nov 1993) Class T Fuses
UL 467	(1993; Rev thru Feb 2001) Grounding and Bonding Equipment
UL 486A-486B	(2003; Rev thru Apr 2004) Wire Connectors
UL 489	(2002; Rev thru May 2003) Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures

UL 510	(1994; Rev thru Apr 1998) Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape
UL 514A	(2004) Metallic Outlet Boxes
UL 6	(2000; Rev thru May 2003) Rigid Metal Conduit
UL 651	(1995; Rev thru Oct 2002) Schedule 40 and 80 Rigid PVC Conduit
UL 854	(1999; Rev thru Nov 2002) Service-Entrance Cables
UL 857	(2001; Rev thru Nov 2002) Busways

## 1.2 GENERAL REQUIREMENTS

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**NOTE: Select the features and fill in blanks with selections appropriate for the design condition and in accordance with guidance contained in TM 5-811-1/AF AFJMAN 32-1080.**  
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### 1.2.1 Terminology

Terminology used in this specification is as defined in ANSI C42.100.

### 1.2.2 Service Conditions

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**NOTE: See TM 5-811-1/AF AFJMAN 32-1080 for guidance regarding service conditions. Retain or add the required conditions.**  
  
**Provide seismic requirements, if a Government designer is the Engineer of Record, and show on the drawings. Delete the inappropriate bracketed phrase. Sections 13080 and 16070A, properly edited, must be included in the contract documents.**  
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Items provided under this section shall be specifically suitable for the following service conditions. Seismic details shall [conform to Sections 13080 SEISMIC PROTECTION FOR MISCELLANEOUS EQUIPMENT and 16070A SEISMIC PROTECTION FOR ELECTRICAL EQUIPMENT] [be as indicated].

- a. Fungus Control [\_\_\_\_\_]
- b. Altitude [\_\_\_\_\_] m feet.
- c. Ambient Temperature [\_\_\_\_\_] degrees C degrees F.
- d. Frequency [\_\_\_\_\_]
- e. Ventilation [\_\_\_\_\_]

- f. Seismic Parameters [\_\_\_\_\_]
- g. Humidity Control [\_\_\_\_\_]
- h. Corrosive Areas [\_\_\_\_\_]
- i. [\_\_\_\_\_]

### 1.3 SUBMITTALS

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NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy projects.

Submittal items not designated with a "G" are considered as being for information only for Army projects and for Contractor Quality Control approval for Navy projects.

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Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Detail Drawings  
As-Built Drawings

Drawings, as specified.

#### SD-03 Product Data

Fault Current Analysis[; G][; G, [\_\_\_\_]]  
Protective Device[; G][; G, [\_\_\_\_]]  
Coordination Study[; G][; G, [\_\_\_\_]]

The study shall be submitted with protective device equipment submittals. No time extension or similar contract modifications will be granted for work arising out of the requirements for this study. Approval of protective devices proposed shall be based on recommendations of this study. The Government shall not be held responsible for any changes to equipment, device ratings, settings, or additional labor for installation of equipment or devices ordered and/or procured prior to approval of the study.

Nameplates[; G][; G, [\_\_\_\_]]

Catalog cuts, brochures, circulars, specifications, product data, and printed information in sufficient detail and scope to verify compliance with the requirements of the contract documents.

Material and Equipment[; G][; G, [\_\_\_\_]]

A complete itemized listing of equipment and materials proposed for incorporation into the work. Each entry shall include an item number, the quantity of items proposed, and the name of the manufacturer of each such item.

Installation Requirements[; G][; G, [\_\_\_\_]]

As a minimum, installation procedures for transformers, substations, switchgear, and splices. Procedures shall include cable pulling plans, diagrams, instructions, and precautions required to install, adjust, calibrate, and test the devices and equipment.

#### SD-06 Test Reports

##### Factory Tests

Certified factory test reports shall be submitted when the manufacturer performs routine factory tests, including tests required by standards listed in paragraph REFERENCES. Results of factory tests performed shall be certified by the manufacturer, or an approved testing laboratory, and submitted within 7 days following successful completion of the tests. The manufacturer's pass-fail criteria for tests specified in paragraph FIELD TESTING shall be included.

##### Field Testing

A proposed field test plan, [20] [30] [\_\_\_\_] days prior to testing the installed system. No field test shall be performed until the test plan is approved. The test plan shall consist of complete field test procedures including tests to be performed, test equipment required, and tolerance limits.

##### Operating Tests

[Six] [\_\_\_\_\_] copies of the tests report in 215.9 by 279.4 mm (8-1/2 by 11 inch) 8-1/2 by 11 inch binders having a minimum of three rings, including a separate section for each test. Sections shall be separated by heavy plastic dividers with tabs.

#### Cable Installation

[Six] [\_\_\_\_\_] copies of the information described below in 215.9 by 279.4 mm (8-1/2 by 11 inch) 8-1/2 by 11 inch binders having a minimum of three rings from which material may readily be removed and replaced, including a separate section for each cable pull. Sections shall be separated by heavy plastic dividers with tabs, with all data sheets signed and dated by the person supervising the pull.

- a. Site layout drawing with cable pulls numerically identified.
- b. A list of equipment used, with calibration certifications. The manufacturer and quantity of lubricant used on pull.
- c. The cable manufacturer and type of cable.
- d. The dates of cable pulls, time of day, and ambient temperature.
- e. The length of cable pull and calculated cable pulling tensions.
- f. The actual cable pulling tensions encountered during pull.

#### SD-07 Certificates

##### Material and Equipment

Where materials or equipment are specified to conform to the standards of the Underwriters Laboratories (UL) or to be constructed or tested, or both, in accordance with the standards of the American National Standards Institute (ANSI), the Institute of Electrical and Electronics Engineers (IEEE), or the National Electrical Manufacturers Association (NEMA), the Contractor shall submit proof that the items provided conform to such requirements. The label of, or listing by, UL will be acceptable as evidence that the items conform. Either a certification or a published catalog specification data statement, to the effect that the item is in accordance with the referenced ANSI or IEEE standard, will be acceptable as evidence that the item conforms. A similar certification or published catalog specification data statement to the effect that the item is in accordance with the referenced NEMA standard, by a company listed as a member company of NEMA, will be acceptable as evidence that the item conforms. In lieu of such certification or published data, the Contractor may submit a certificate from a recognized testing agency equipped and competent to perform such services, stating that the items have been tested and that they conform to the requirements listed, including methods of testing of the specified agencies. Compliance with above-named requirements does not relieve the Contractor from compliance with any other requirements of the specifications.

## Cable Joints

A certification that contains the names and the qualifications of people recommended to perform the splicing and termination of medium-voltage cables approved for installation under this contract. The certification shall indicate that any person recommended to perform actual splicing and terminations has been adequately trained in the proper techniques and have had at least three recent years of experience in splicing and terminating the same or similar types of cables approved for installation. In addition, any person recommended by the Contractor may be required to perform a practice splice and termination, in the presence of the Contracting Officer, before being approved as a qualified installer of medium-voltage cables. If that additional requirement is imposed, the Contractor shall provide short sections of the approved types of cables along with the approved type of splice and termination kits, and detailed manufacturer's instruction for the proper splicing and termination of the approved cable types.

## Installation Engineer

The Contractor shall provide at least one onsite person in a supervisory position with a documentable level of competency and experience to supervise all cable pulling operations. A resume shall be provided showing the cable installers' experience in the last three years, including a list of references complete with points of contact, addresses and telephone numbers.

## SD-10 Operation and Maintenance Data

### Operation and Maintenance Manuals

[Six] [\_\_\_\_\_] copies of operation and maintenance manuals, within [7] [\_\_\_\_\_] calendar days following the completion of tests and including assembly, installation, operation and maintenance instructions, spare parts data which provides supplier name, current cost, catalog order number, and a recommended list of spare parts to be stocked. Manuals shall also include data outlining detailed procedures for system startup and operation, and a troubleshooting guide which lists possible operational problems and corrective action to be taken. A brief description of all equipment, basic operating features, and routine maintenance requirements shall also be included. Documents shall be bound in a binder marked or identified on the spine and front cover. A table of contents page shall be included and marked with pertinent contract information and contents of the manual. Tabs shall be provided to separate different types of documents, such as catalog ordering information, drawings, instructions, and spare parts data. Index sheets shall be provided for each section of the manual when warranted by the quantity of documents included under separate tabs or dividers. Three additional copies of the instructions manual shall be provided within 30 calendar days following the manuals.

## 1.4 DELIVERY, STORAGE, AND HANDLING

Devices and equipment shall be visually inspected by the Contractor when

received and prior to acceptance from conveyance. Stored items shall be protected from the environment in accordance with the manufacturer's published instructions. Damaged items shall be replaced. Oil filled transformers and switches shall be stored in accordance with the manufacturer's requirements. Wood poles held in storage for more than 2 weeks shall be stored in accordance with ATIS 05.1. Handling of wood poles shall be in accordance with ATIS 05.1, except that pointed tools capable of producing indentations more than 25 mm 1 inch in depth shall not be used. Metal poles shall be handled and stored in accordance with the manufacturer's instructions.

#### 1.5 EXTRA MATERIALS

One additional spare fuse or fuse element for each furnished fuse or fuse element shall be delivered to the contracting officer when the electrical system is accepted. Two complete sets of all special tools required for maintenance shall be provided, complete with a suitable tool box. Special tools are those that only the manufacturer provides, for special purposes (to access compartments, or operate, adjust, or maintain special parts).

#### 1.6 DRAWINGS

##### 1.6.1 Detail Drawings

The Contractor shall submit detail drawings consisting of equipment drawings, illustrations, schedules, instructions, diagrams manufacturers standard installation drawings and other information necessary to define the installation and enable the Government to check conformity with the requirements of the contract drawings.

- a. If departures from the contract drawings are deemed necessary by the Contractor, complete details of such departures shall be included with the detail drawings. Approved departures shall be made at no additional cost to the Government.
- b. Detail drawings shall show how components are assembled, function together and how they will be installed on the project. Data and drawings for component parts of an item or system shall be coordinated and submitted as a unit. Data and drawings shall be coordinated and included in a single submission. Multiple submissions for the same equipment or system are not acceptable except where prior approval has been obtained from the Contracting Officer. In such cases, a list of data to be submitted later shall be included with the first submission. Detail drawings shall consist of the following:

- 1). Detail drawings showing physical arrangement, construction details, connections, finishes, materials used in fabrication, provisions for conduit or busway entrance, access requirements for installation and maintenance, physical size, electrical characteristics, foundation and support details, and equipment weight. Drawings shall be drawn to scale and/or dimensioned. All optional items shall be clearly identified as included or excluded.
- 2). Internal wiring diagrams of equipment showing wiring as actually provided for this project. External wiring connections shall be clearly identified.
- 3). Detail drawings shall as a minimum depict the installation of the following items:



(a). Medium-voltage cables and accessories including cable installation plan.

(b). Transformers.

(c). Substations.

(d). Switchgear.

(e). Pad-mounted loadbreak switches.

(f). Busways.

(g). Surge arresters.

#### 1.6.2 As-Built Drawings

The as-built drawings shall be a record of the construction as installed. The drawings shall include the information shown on the contract drawings as well as deviations, modifications, and changes from the contract drawings, however minor. The as-built drawings shall be a full sized set of prints marked to reflect deviations, modifications, and changes. The as-built drawings shall be complete and show the location, size, dimensions, part identification, and other information. Additional sheets may be added. The as-built drawings shall be jointly inspected for accuracy and completeness by the Contractor's quality control representative and by the Contracting Officer prior to the submission of each monthly pay estimate. Upon completion of the work, the Contractor shall provide three full sized sets of the marked prints to the Contracting Officer for approval. If upon review, the as-built drawings are found to contain errors and/or omissions, they will be returned to the Contractor for correction. The Contractor shall correct and return the as-built drawings to the Contracting Officer for approval within 10 calendar days from the time the drawings are returned to the Contractor.

### PART 2 PRODUCTS

#### 2.1 STANDARD PRODUCT

Material and equipment shall be the standard product of a manufacturer regularly engaged in the manufacture of the product and shall essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening. Items of the same classification shall be identical including equipment, assemblies, parts, and components.

#### 2.2 NAMEPLATES

##### 2.2.1 General

Each major component of this specification shall have the manufacturer's name, address, type or style, model or serial number, and catalog number on a nameplate securely attached to the equipment. Nameplates shall be made of noncorrosive metal. Equipment containing liquid dielectrics shall have the type of dielectric on the nameplate. Sectionalizer switch nameplates shall have a schematic with all switch positions shown and labeled. As a minimum, nameplates shall be provided for transformers, circuit breakers, meters, switches, and switchgear.

## 2.2.2 Liquid-Filled Transformer Nameplates

\*\*\*\*\*  
**NOTE: Coordinate nameplate information with the manufacturer. Select 50 ppm for Army projects and 2 ppm for Air Force projects.**  
\*\*\*\*\*

Power transformers shall be provided with nameplate information in accordance with IEEE C57.12.00. Nameplates shall indicate the number of liters gallons and composition of liquid-dielectric, and shall be permanently marked with a statement that the transformer dielectric to be supplied is non-polychlorinated biphenyl. If transformer nameplate is not so marked, the Contractor shall furnish manufacturer's certification for each transformer that the dielectric is non-PCB classified, with less than [50] [2] ppm PCB content in accordance with paragraph LIQUID DIELECTRICS. Certifications shall be related to serial numbers on transformer nameplates. Transformer dielectric exceeding the [50] [2] ppm PCB content or transformers without certification will be considered as PCB insulated and will not be accepted.

## 2.3 CORROSION PROTECTION

### 2.3.1 Aluminum Materials

[Aluminum shall not be used in contact with earth or concrete. Where aluminum conductors are connected to dissimilar metal, fittings conforming to UL 486A-486B shall be used.] [Aluminum shall not be used.]

### 2.3.2 Ferrous Metal Materials

#### 2.3.2.1 Hardware

Ferrous metal hardware shall be hot-dip galvanized in accordance with ASTM A 153/A 153M and ASTM A 123/A 123M.

#### 2.3.2.2 Equipment

\*\*\*\*\*  
**NOTE: A 120-hour test will be specified in a noncorrosive environment and a 480-hour test will be specified in a corrosive environment.**  
\*\*\*\*\*

Equipment and component items, including but not limited to transformer stations and ferrous metal luminaries not hot-dip galvanized or porcelain enamel finished, shall be provided with corrosion-resistant finishes which shall withstand [120] [480] [\_\_\_\_\_] hours of exposure to the salt spray test specified in ASTM B 117 without loss of paint or release of adhesion of the paint primer coat to the metal surface in excess of 1.6 mm 1/16 inch from the test mark. The scribed test mark and test evaluation shall be in accordance with ASTM D 1654 with a rating of not less than 7 in accordance with TABLE 1, (procedure A). Cut edges or otherwise damaged surfaces of hot-dip galvanized sheet steel or mill galvanized sheet steel shall be coated with a zinc rich paint conforming to the manufacturer's standard.

### 2.3.3 Finishing

Painting required for surfaces not otherwise specified and finish painting

of items only primed at the factory shall be as specified in Section 09900  
PAINTS AND COATINGS.

## 2.4 CABLES

\*\*\*\*\*  
NOTE: Justify selection of copper or aluminum,  
based upon an analysis using life-cycle,  
environmental, and cost factors. Refer to TM  
5-811-1/AF AFJMAN 32-1080 for guidance regarding  
cables.  
\*\*\*\*\*

Cables shall be single conductor type unless otherwise indicated.

### 2.4.1 Medium-Voltage Cables

\*\*\*\*\*  
NOTE: Medium voltage cables are complex and  
sophisticated products that can be manufactured to  
have very specific properties for the installed  
environment. The two most commonly  
produced/specified medium voltage cables are Type MV  
(as described in UL 1072) and underground  
distribution ("UD/URD"), commonly used by electrical  
utilities. Type MV is a type designation recognized  
by NFPA 70 because it is UL listed. "UD/URD" is not  
a recognized type designation because it is utilized  
primarily by electrical utilities, who are not  
governed by NFPA 70 and for whom a UL listed cable  
adds unnecessary expense. Both type MV and "UD/URD"  
can be specified for use in duct or direct buried.  
Type MV cable are typically manufactured with copper  
or aluminum conductors; an extruded semi-conductor  
conductor shield; ethylene-propylene rubber (EPR) or  
cross-linked polyethylene (XLP) insulation; an  
insulation shield consisting of extruded  
semi-conductor and metal tape; and a polyvinyl  
chloride (PVC) jacket. "UD/URD" cables are  
typically manufactured with copper or aluminum  
conductors; an extruded semi-conductor conductor  
shield; an insulation shield consisting of extruded  
semi-conductor and metal tape, or extruded  
semi-conductor with concentric-wound copper drain  
wires; cross-linked polyethylene (XLP) insulation; a  
concentric neutral; and a polyethylene jacket. A  
cable can be made from almost any combination of  
conductors, insulations, shields and jackets;  
therefore, the designer needs to specify a cable  
that meets the needs of the application. Utilize  
either Type MV or "UD/URD" in ducts, keeping in mind  
that the concentric neutral affects bending radius  
and pulling tensions, therefore limiting the maximum  
pull and distance between manholes. Utilize "UD"  
for direct buried applications. Select full  
ampacity concentric neutral for single-phase  
applications and one-third ampacity for three-phase  
applications.  
\*\*\*\*\*

#### 2.4.1.1 General

Cable construction shall be [Type MV, conforming to NFPA 70 and UL 1072] [concentric neutral underground distribution cable conforming to AEIC C8] [metallic armored cables, consisting of three-conductor, multi-conductor cables, with insulation and shielding, as specified, using [a galvanized steel] [an aluminum] interlocked tape armor and thermoplastic jacket]. Cables shall be manufactured for use in [duct] [or] [direct burial] applications [as indicated].

#### 2.4.1.2 Ratings

Cables shall be rated for a circuit voltage [of] [5 kV] [15 kV] [25 kV] [28 kV] [35 kV] [as indicated].

#### 2.4.1.3 Conductor Material

\*\*\*\*\*

NOTE: A concentric compressed conductor has a diameter that is 3 percent less than a regular concentric conductor. A compact conductor has a diameter that is 10 percent less than a regular concentric conductor. Specify compressed or compact conductors where necessary to limit duct fill (i.e. where new conductors are installed in existing ducts). When aluminum is exposed to water, oxidation occurs. To prevent oxidation, the conductor is filled with insulation. Add filled conductor requirement if needed.

\*\*\*\*\*

Underground cables shall be [soft drawn copper complying with ASTM B 3 and ASTM B 8 for regular concentric and compressed stranding or ASTM B 496 for compact stranding] [aluminum alloy 1350, 3/4 hard minimum complying with ASTM B 609/B 609M and ASTM B 231/B 231M for regular concentric and compressed stranding or ASTM B 400 for compacted stranding].

#### 2.4.1.4 Insulation

\*\*\*\*\*

NOTE: In addition to the standard MV-90, NFPA 70 also lists an MV-105 temperature rating. However, MV-105 is not available from all manufacturers. Provide MV-105, only if needed. For projects which require multiple types of insulations, or special types of cables, such as submarine cable, indicate the type for each cable on the project drawings. Choose XLP or tree retardant XLP for "UD or URD" cable, and either XLP or EPR for Type MV cable.

\*\*\*\*\*

Cable insulation shall be [cross-linked thermosetting polyethylene (XLP) insulation conforming to the requirements of AEIC C8] [ethylene-propylene-rubber (EPR) insulation conforming to the requirements of AEIC CS6] [\_\_\_\_\_]. A 133 percent insulation level shall be used on 5 kV, 15 kV and 25 kV rated cables. The Contractor shall comply with EPA requirements in accordance with Section 01670 RECYCLED / RECOVERED MATERIALS.

#### 2.4.1.5 Shielding

\*\*\*\*\*

NOTE: IEEE C2 requires the cable conductor shield to have sufficient ampacity to withstand the effects of available fault current without damage to the conductor (except in the vicinity of the fault). The designer should provide the expected maximum available ground fault current, so the cable manufacturer can size the shield. Testing has shown that for grounded medium voltage systems where a bare ground fault return conductor is installed with phase conductors in metallic duct, 3% - 14% of the available fault current returns along the cable shield. A separate ground fault return conductor (bare copper wire or metallic duct) should always be provided. For circuits not installed in metallic duct, with a ground fault return conductor supplied, the shield can be sized to conduct (until the protective device operates) 15% of the available fault current per cable. Where the available fault current is unknown or cannot be determined, the designer should provide a # 2/0 AWG bare copper ground conductor and delete the ground fault ampacity statement.

\*\*\*\*\*

Cables rated for 2 kV and above shall have a semiconducting conductor shield, a semiconducting insulation shield, and an overall copper [tape] [wire] shield for each phase. The shield [tape] [wire] shall be sized to meet IEEE C2 requirements for a ground fault availability of [\_\_\_\_\_] amperes.

#### 2.4.1.6 Neutrals

\*\*\*\*\*

NOTE: Where high impedance grounded neutral systems are employed, add the following requirement for the neutral to be fully insulated. For high impedance grounded neutral systems, the neutral conductors from the neutral point of the transformer or generator to the connection point at the impedance shall utilize [copper] [aluminum] conductors, employing the same insulation level and construction as the phase conductors.

\*\*\*\*\*

[Neutral conductors of shall be [copper] [aluminum]. employing the same insulation and jacket materials as phase conductors, except that a 600-volt insulation rating is acceptable.] [Concentric neutrals conductors shall be tinned copper, having a combined ampacity [equal to] [1/3 of] the phase conductor ampacity rating.]

#### 2.4.1.7 Jackets

\*\*\*\*\*

NOTE: PVC is acceptable for duct applications. Polyethylene is exceptional for direct burial and in

duct applications where there is significant amounts of water. There are many other types of jacket materials available (neoprene, hypalon, thermoplastic CPE) for special environments involving exposure to sunlight, petroleum products, and corrosive chemicals. Consult local cable representatives to specify the appropriate jacket for the application.

\*\*\*\*\*

Cables shall be provided with a [PVC] [polyethylene] [\_\_\_\_\_] jacket.  
Direct buried cables shall be rated for direct burial.

#### 2.4.2 Low-Voltage Cables

\*\*\*\*\*

NOTE: Coilable plastic duct may be used as an alternative to direct burial where extra physical protection is required. For project applications which require a different insulation than those listed below, reference a Government or industry standard that the cable must meet. For projects which require multiple types of insulations, indicate the type for each cable on the project drawings. See also TM 5-811-2/AFM 88-9 Chapter 2.

\*\*\*\*\*

Cables shall be rated 600 volts and shall conform to the requirements of NFPA 70, and must be UL listed for the application or meet the applicable section of either ICEA or NEMA standards.

##### 2.4.2.1 Conductor Material

Underground cables shall be [annealed copper complying with ASTM B 3 and ASTM B 8] [Type AA-8000 aluminum conductors complying with ASTM B 800 and ASTM B 801]. Intermixing of copper and aluminum conductors is not permitted.

##### 2.4.2.2 Insulation

Insulation must be in accordance with NFPA 70, and must be UL listed for the application or meet the applicable sections of either ICEA, or NEMA standards.

##### 2.4.2.3 Jackets

Multiconductor cables shall have an overall [PVC] [\_\_\_\_\_] outer jacket.

##### 2.4.2.4 Direct Buried

Single and multi-conductor cables shall of a type identified for direct burial. Service entrance cables shall conform to UL 854 for Type USE service entrance cable.

##### 2.4.2.5 In Duct

Cables shall be single-conductor cable, in accordance with NFPA 70. [Cables in factory-installed, coilable-plastic-duct assemblies shall conform to NEMA TC 7].

## 2.5 CABLE JOINTS, TERMINATIONS, AND CONNECTORS

### 2.5.1 Medium-Voltage Cable Joints

Medium-voltage cable joints shall comply with IEEE Std 404. Medium-voltage cable terminations shall comply with IEEE Std 48. Joints shall be the standard products of a manufacturer and shall be either of the factory preformed type or of the kit type containing tapes and other required parts. Joints shall have ratings not less than the ratings of the cables on which they are installed. Splice kits may be of the heat-shrinkable type for voltages up to 15 kV, of the premolded splice and connector type, the conventional taped type, or the resin pressure-filled overcast taped type for voltages up to 35 kV; except that for voltages of 7.5 kV or less a resin pressure-filled type utilizing a plastic-tape mold is acceptable. Joints used in manholes, handholes, vaults and pull boxes shall be certified by the manufacturer for waterproof, submersible applications.

### 2.5.2 Medium-Voltage Separable Insulated Connectors

\*\*\*\*\*

**NOTE: Separable connectors shall not be used in manholes (except where necessary for reason of clearance at an airfield). Loadbreak types are rated by IEEE Std 386 up to 200 amperes. Provide test points only where the local facilities engineer indicates that it is an operational requirement. If loadbreak separable connectors are allowed as substitutes for conventional permanent splices, the Using Agency often presumes that the intent was that they could be used for "switching functions." This type of generic approach can allow unsafe configurations with inadequate space for proper hookstick operation. This substitution is prohibited.**

\*\*\*\*\*

Separable insulated connectors shall comply with IEEE Std 386 and shall be of suitable construction or standard splice kits shall be used. Separable insulated connectors are acceptable for voltages up to 35 kV. Connectors shall be of the loadbreak type as indicated, of suitable construction for the application and the type of cable connected, and shall include cable shield adaptors. Separable insulated connectors shall not be used as substitutes for conventional permanent splices. External clamping points and test points shall be provided.

### 2.5.3 Low-Voltage Cable Splices

Low-voltage cable splices and terminations shall be rated at not less than 600 Volts. Splices in conductors No. 10 AWG and smaller shall be made with an insulated, solderless, pressure type connector, conforming to the applicable requirements of UL 486A-486B. Splices in conductors No. 8 AWG and larger shall be made with noninsulated, solderless, pressure type connector, conforming to the applicable requirements of UL 486A-486B. Splices shall then be covered with an insulation and jacket material equivalent to the conductor insulation and jacket. Splices below grade or in wet locations shall be sealed type conforming to ANSI C119.1 or shall be waterproofed by a sealant-filled, thick wall, heat shrinkable, thermosetting tubing or by pouring a thermosetting resin into a mold that

surrounds the joined conductors.

#### 2.5.4 Terminations

Terminations shall be in accordance with IEEE Std 48, Class 1 or Class 2; of the molded elastomer, wet-process porcelain, prestretched elastomer, heat-shrinkable elastomer, or taped type. Acceptable elastomers are track-resistant silicone rubber or track-resistant ethylene propylene compounds, such as ethylene propylene rubber or ethylene propylene diene monomer. Separable insulated connectors may be used for apparatus terminations, when such apparatus is provided with suitable bushings. Terminations shall be of the outdoor type, except that where installed inside outdoor equipment housings which are sealed against normal infiltration of moisture and outside air, indoor, Class 2 terminations are acceptable. Class 3 terminations are not acceptable. Terminations, where required, shall be provided with mounting brackets suitable for the intended installation and with grounding provisions for the cable shielding, metallic sheath, and armor.

##### 2.5.4.1 Factory Preformed Type

\*\*\*\*\*  
**NOTE: Specify IEEE Std 48 test in areas of heavy fog, salt air, or industrial contamination. Specify track resistant tape in high humidity areas with dust and industrial contaminants.**  
\*\*\*\*\*

Molded elastomer, wet-process porcelain, prestretched, and heat-shrinkable terminations shall utilize factory preformed components to the maximum extent practicable rather than tape build-up. Terminations shall have basic impulse levels as required for the system voltage level. [Leakage distances shall comply with wet withstand voltage test requirements of IEEE Std 48 for the next higher Basic Insulation Level (BIL) level.] [Anti-tracking tape shall be applied over exposed insulation of preformed molded elastomer terminations].

##### 2.5.4.2 Taped Terminations

\*\*\*\*\*  
**NOTE: Normally, specify 317.5 mm (12-1/2 in.) for 5 kV cable, 508.0 mm (20 in.) for 15 kV cable, 635.0 mm (25 in.) for 25 kV cable, and 889.0 mm (35 in.) for 28 kV or 35 kV cable. In contaminated areas, specify next higher voltage level lengths, and 1168.4 mm (46 inches) for 28 kV or 35 kV cables.**  
\*\*\*\*\*

Taped terminations shall use standard termination kits providing terminal connectors, field-fabricated stress cones, and rain hoods. Terminations shall be at least [315] [510] [635] [890] [1200] mm [12-1/2] [20] [25] [35] [46] inches long from the end of the tapered cable jacket to the start of the terminal connector, or not less than the kit manufacturer's recommendations, whichever is greater.

#### 2.6 CONDUIT AND DUCTS

\*\*\*\*\*  
**NOTE: Specify thin-wall for encased burial and**



thick-wall for direct burial. Communication lines run elsewhere will comply with communication agency's policy.

\*\*\*\*\*

[Ducts shall be single, round-bore type, with wall thickness and fittings suitable for the application.] [Duct lines shall be concrete-encased, thin-wall type.] [Duct lines shall be nonencased direct-burial, thick-wall type.] [Duct lines shall be concrete-encased, thin-wall type for duct lines between manholes and for other medium-voltage lines.] [[Low-voltage lines] [or] [Communication lines] run elsewhere may be direct-burial, thick-wall type.] [Where concrete encasement is not required, low-voltage circuits may utilize factory-installed cable in coilable plastic duct.]

#### 2.6.1 Metallic Conduit

Intermediate metal conduit shall comply with UL 1242. Rigid galvanized steel conduit shall comply with UL 6 and ANSI C80.1. Metallic conduit fittings and outlets shall comply with UL 514A and NEMA FB 1.

#### 2.6.2 Nonmetallic Ducts

\*\*\*\*\*

NOTE: Bituminized fiber duct should be specified only for connection to existing bituminized fiber duct systems. Delete the paragraph if not required. Specify thin-wall or schedule 40 plastic duct for concrete encasement and thick-wall or schedule 40 or schedule 80 plastic duct for direct-burial and riser applications (riser bends should be metallic conduit where cables are to be pulled into ductline).

\*\*\*\*\*

##### 2.6.2.1 Bituminized Fiber Duct

UL 1684 for [Type I (Thinwall)][Type II (Thickwall)].

##### 2.6.2.2 Concrete Encased Ducts

UL 651 Schedule 40 or NEMA TC 6 & 8 Type EB.

##### 2.6.2.3 Direct Burial

UL 651 [Schedule 40] [and] [Schedule 80] [as indicated], or NEMA TC 6 & 8 Type DB.

#### 2.6.3 Conduit Sealing Compound

Compounds for sealing ducts and conduit shall have a putty-like consistency workable with the hands at temperatures as low as 2 degrees C 35 degrees F, shall neither slump at a temperature of 150 degrees C 300 degrees F, nor harden materially when exposed to the air. Compounds shall adhere to clean surfaces of fiber or plastic ducts; metallic conduits or conduit coatings; concrete, masonry, or lead; any cable sheaths, jackets, covers, or insulation materials; and the common metals. Compounds shall form a seal without dissolving, noticeably changing characteristics, or removing any of the ingredients. Compounds shall have no injurious effect upon the hands of workmen or upon materials.

## 2.7 MANHOLES, HANDHOLES, AND PULLBOXES

\*\*\*\*\*  
**NOTE: Actual strength figures may need to be  
adjusted to accommodate various manufacturers of  
glass reinforced polymer boxes.**  
\*\*\*\*\*

Manholes, handholes, and pullboxes shall be as indicated. Strength of manholes, handholes, and pullboxes and their frames and covers shall conform to the requirements of IEEE C2. Precast-concrete manholes shall have the required strength established by ASTM C 478, ASTM C 478M. Frames and covers shall be made of gray cast iron and a machine-finished seat shall be provided to ensure a matching joint between frame and cover. Cast iron shall comply with ASTM A 48/A 48M, Class 30B, minimum. Handholes for low voltage cables installed in parking lots, sidewalks, and turfed areas shall be fabricated from an aggregate consisting of sand and with continuous woven glass strands having an overall compressive strength of at least [69] [\_\_\_\_\_] MPa [10,000] [\_\_\_\_\_] psi and a flexural strength of at least [34.5] [\_\_\_\_\_] MPa [5,000] [\_\_\_\_\_] psi. Pullbox and handhole covers in sidewalks, and turfed areas shall be of the same material as the box. Concrete pullboxes shall consist of precast reinforced concrete boxes, extensions, bases, and covers.

## 2.8 POLES AND HARDWARE

\*\*\*\*\*  
**NOTE: For new pole line construction, coordinate  
with UFGS-16370A ELECTRICAL DISTRIBUTION SYSTEM,  
AERIAL. Where the scope of the project is small,  
such as installation of one or two poles, the  
designer may elect to incorporate the pole and  
hardware paragraphs from UFGS-16370A in this section.**  
\*\*\*\*\*

Poles and hardware shall be in accordance with Section 16370A ELECTRICAL DISTRIBUTION SYSTEM, AERIAL.

## 2.9 TRANSFORMERS, SUBSTATIONS, AND SWITCHGEAR

\*\*\*\*\*  
**NOTE: Specify transformer phase sequence in  
accordance with the local practice. Delete tap  
setting requirement where transformers do not have  
primary tap requirements. Provide tap settings in  
accordance with load-flow and voltage drop study  
results. Refer to TM 5-811-1/AF AFJMAN 32-1080 for  
guidance.**  
\*\*\*\*\*

Transformers, substations, and switchgear shall be of the outdoor type having the ratings and arrangements indicated. Medium-voltage ratings of cable terminations shall be [5] [15] [25] [28] [35] kV between phases for 133 percent insulation level.

### 2.9.1 Secondary Unit Substation

Secondary unit substations shall comply with ANSI C37.121 and shall be of the [radial type] [radial type with an outgoing section mounted integrally

on the transformer] [secondary-selective type] [distributed-network type] [spot-network type]. Substations shall be subassembled and coordinated by one manufacturer and shall be shipped in complete sections ready for connection at the site. Complete sections shall include incoming, transformer, and outgoing sections and, where practicable, shall be shipped as one unit.

#### 2.9.1.1 Incoming Section

\*\*\*\*\*

**Note:** For normal reliability systems, the primary distribution will be radial, and the incoming section will be a single metal-enclosed, fused, load-interrupter switch. Where greater reliability is required and there are two incoming primary feeders, a selector switch or a duplex switch will be specified.

A selector switch contains a non-loadbreak incoming-line selector switch unit in series with a separate interrupter unit. The interrupter unit must be open before the selector unit may be changed; the entire metal-enclosed switch assembly is contained in one vertical section of switchgear. A duplex switch contains 2 fully rated interrupter switches connected together at their load side, and requires 2 vertical sections of switchgear.

At installations where space is very tight, the selector switch should be specified, otherwise the duplex switch is preferable and should be specified.

Voltage ratings are listed in IEEE C37.20.3, Table 1. See TM 5-811-1/AF AFJMAN 32-1080 for guidance. Specify current ratings based upon short-circuit study.

Delete reference to SF6 insulating dielectric when not required.

\*\*\*\*\*

Metal-enclosed interrupter switchgear consisting of fused, [air-insulated] [vacuum-insulated] [SF6-insulated], interrupters in series with automatic, visible blade disconnects shall be provided for protection of incoming circuits. [SF6 gas shall conform to ASTM D 2472]. Metal-enclosed interrupter switchgear shall comply with IEEE C37.30 for load-interrupter switches, NEMA SG 2 for power fuses, and shall be of the outdoor no-aisle type that meets or exceeds the requirements of applicable publications listed. Switch construction shall be of the manually-operated, "OPEN-CLOSED," [air-insulated] [vacuum-insulated] [SF6-insulated], load interrupter type equipped with a stored energy operator for quick-make quick-break to make operating speeds independent of manual switch operations. Where indicated, suitable bus or lug connections shall be provided to mount field-installed, slip-on, medium-voltage cable terminations for cable entering via conduit from below [and a flanged throat suitable for direct connection to the associated transformer] [and a bus throat suitable for connection to the associated metal-enclosed bus]. [Surge protection shall be provided in accordance with paragraph SURGE ARRESTERS.] [Switches shall be of the 2-position type, open-closed.]

[Selector switches shall be of the single-compartment, 3-position type, Line 1 - Open - Line 2, consisting of an interrupter switch in series with a selector switch.] [Duplex switches shall be of the dual compartment type with 2 interrupter switches.]

a. Ratings. Fuse continuous current ratings shall be as indicated for the transformer for an incoming line unit and for the line tie unit. Unless otherwise indicated, fuses shall be of the current limiting type. Switch ratings at 60 Hz shall be:

Nominal voltage.....[\_\_\_\_].  
Rated maximum voltage.....[\_\_\_\_].  
Maximum symmetrical interrupting capacity.....[\_\_\_\_].  
Maximum asymmetrical interrupting capacity.....[\_\_\_\_].  
3-Second short time current carrying capacity.....[\_\_\_\_].  
Rated continuous current.....[\_\_\_\_].  
BIL.....[\_\_\_\_].

b. Basic Requirements. The electrical devices listed below shall be rated for the application and voltage and current indicated. Unless otherwise noted, manufacturer's standard devices shall be provided and shall include the following:

- (1) A switch-operating handle with provisions for locking in either the open or closed position.
- (2) A switch mechanical position indicator.
- (3) A heater continuously energized to prevent condensation over an ambient temperature range of [minus [29] [\_\_\_\_] degrees C] to [[40] [\_\_\_\_] degrees C] [minus [20] [\_\_\_\_] degrees F] to [[40] [\_\_\_\_] degrees F] at 90% relative humidity and wired in series with a cabinet door-actuated switch, so the heater is de-energized when doors are open. High-temperature thermal protection shall be included.
- (4) One-pole or 2-pole thermal-magnetic, molded-case circuit breakers suitable for the operating voltage for heater circuits.
- (5) Safety devices as necessary to ensure that the load interrupter switch is in the open position whenever unit doors are in the open position.
- (6) A key interlock if indicated.
- (7) An interface terminal block wired for required exterior connections.

#### 2.9.1.2 Transformer Section

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**NOTE: Refer to TM 5-811-1/AF AFJMAN 32-1080 for guidance. Delete alarm contacts when not required**

\*\*\*\*\*

Transformers shall have two separate windings per phase and shall be of the [mineral oil-insulated] [less-flammable, liquid-insulated] type with [high molecular-weight hydrocarbon] [or] [dimethyl silicone] liquid. Transformers shall be suitable for outdoor use. Liquid-insulated transformers shall comply with IEEE C57.12.00, and shall have two 2-1/2 percent full capacity taps above and two 2-1/2 percent full capacity taps below rated voltage. Transformers shall be of the sealed tank type construction with welded-on cover. High-voltage terminals shall be provided [in an air terminal chamber for incoming [top] [bottom] entry cables] [for direct connection to the incoming line section] [as shown on the drawings]. Low-voltage terminals shall be provided [in an air terminal chamber for incoming [top] [bottom] entry cables] [for direct connection to the outgoing [switchgear section] [bus duct]] [as shown on the drawings]. Low-voltage terminals shall be [on the [left] [right]] [as shown on the drawings] when facing the front, accessory side of the transformer. [Transformers shall be equipped with forced air cooling equipment to give [\_\_\_\_\_] kVA capacity. The equipment shall include the necessary fans, conduit and wiring, motor starters, and top liquid thermometer for fan control.] [Provision shall be made for the future addition of forced air cooling equipment to give [\_\_\_\_\_] kVA capacity. The transformer bushings, leads, and other components shall be designed to carry the increased load. A top liquid thermometer for control of future fans shall be furnished. Provision for future mounting of fans, conduit, and terminal box shall be provided.] Transformer accessories and ratings at 60 Hz shall be as follows:

Three-phase capacity, self-cooled.....[\_\_\_\_\_] kVA.  
Three-phase capacity, (future) forced-cooled.....[\_\_\_\_\_] kVA.  
Impedance..[5.75 percent, standard] [[\_\_\_\_\_] percent nonstandard].  
Temperature rise.....[65 degrees C] [55/65 degrees C].  
High-voltage winding.....[\_\_\_\_\_] volts.  
High-voltage winding connection.....[\_\_\_\_\_] .  
Low-voltage winding.....[\_\_\_\_\_] volts.  
Low-voltage winding connection.....[\_\_\_\_\_] .

Accessories:

- a. drain and filter connection.
- b. filling and top filter press connection.
- c. pressure-vacuum gauge.
- d. dial type thermometer with alarm contacts.
- e. magnetic liquid level indicator with high and low level alarm contacts.
- f. pressure relief device with alarm contacts.
- g. ground connection pad.

- h. provision for jacking, lifting, and towing.
- i. diagram and rating nameplate.

#### 2.9.1.3 Integral Outgoing Section

\*\*\*\*\*

NOTE: In Unit Substation construction consisting of a transformer and low-voltage equipment, the low-voltage section must be integral or mechanically connected with the transformer and must be a busway throat compartment; an integral, dead-front, distribution switchboard/panelboard compartment; or a group of low-voltage, metal-enclosed switchgear. For comparison, nonintegral substation construction consists of free-standing elements (primary switch/transformer/secondary protection) connected by cables. Specify cable compartments when free-standing elements (nonintegral substation construction) are used.

Specify a busway throat compartment and associated busway when the low voltage switchboard or switchgear must be located remote from the transformer and a compact, high ampacity connection is required.

Specify an integral, dead-front, distribution switchboard (typically front and rear accessible, with instruments, for larger installations) or panelboard (typically front accessible only, for smaller installations) when stationary-mounted, nondrawout, molded case circuit breakers are required and the number of feeders/branches requires only one or two panels.

Specify a mechanical, bus-bar-throat connection to a group of low voltage switchgear when large, high capacity, drawout type, low voltage power circuit breakers are required.

Specify individual watthour demand meters for transformers rated 750 kVA and above.

Specify ground fault protection only when required by NFPA 70. See TM 5-811-14 for guidance on GFP devices with double-ended substations.

Incorporate the low-voltage power circuit breaker paragraphs from UFGS-16475A COORDINATED POWER SYSTEM PROTECTION if UFGS-16475A is not part of the project specifications. Delete appropriate paragraphs of this section if 16475A is included.

\*\*\*\*\*

Integral outgoing section shall be of the [busway throat compartment] [dead-front distribution panelboard/switchboard] [metal-enclosed switchgear] type. Each circuit breaker and auxiliary compartment shall

have a suitable metal or laminated plastic nameplate with white cut letters at least 6.4 mm 1/4 inch high on contrasting backgrounds [identifying the breaker unit and/or circuit number] [as shown on the drawings].

a. Busway Throat Compartment Type: Outgoing section shall consist of an enclosure containing metering devices on the main secondary circuit and connections from transformer terminals to suitable busway throats provided for connections to busway installations entering [from above] [as shown]. Connection to porcelain bushings shall be made with flexible jumpers.

b. Dead-Front Distribution Panelboard/Switchboard Type: Outgoing section shall be of the panelboard/switchboard type mounted integrally with the transformer and shall consist of metering devices and main and branch circuit breakers mounted in panelboard/switchboard enclosures. Panelboards shall comply with NEMA PB 1. Switchboards shall comply with NEMA PB 2. Molded-case and low-voltage power circuit breakers shall comply with paragraph METERING AND PROTECTIVE DEVICES. Plug-in type circuit breakers are not acceptable. Directories to indicate loads served by each circuit shall be typed and mounted in holders provided on panelboard doors behind protective coverings.

c. Metal-Enclosed Switchgear Type: [Outgoing section shall be of the metal-enclosed drawout circuit breaker type, in accordance with IEEE C37.20.1 and NEMA SG 6.] Low-voltage power circuit breakers shall comply with the requirements of paragraph METERING AND PROTECTIVE DEVICES.

d. Metering: The main secondary bus of each outgoing section assembly shall include a watthour demand meter with the necessary instrument transformers, and VT and CT test blocks. Metering shall be as specified in paragraph METERING AND PROTECTIVE DEVICES.

e. Ground Fault Protection: Ground fault protection shall be provided utilizing sensors of the zero-sequence type or by the residual connection of phase and neutral current sensors. Ground fault settings shall be [as shown] [as determined by the coordination study].

#### 2.9.1.4 Nonintegral (Cable Compartment) Outgoing Section

\*\*\*\*\*  
NOTE: Specify cable compartment outgoing section  
when the transformer will feed the nonintegral  
low-voltage panelboard/switchboard/switchgear via  
cables. The cable compartment is actually integral  
to the transformer, but by using cables, the  
substation is classified as "nonintegral."  
\*\*\*\*\*

A cable compartment shall be provided on the transformer for cable connections as shown. Clamp type terminations for cables entering from [below] [above] shall be provided for connection to the transformer bushings. Clamp type cable terminations, suitable for [copper] [aluminum] conductors, shall be provided [for the circuit sizes shown] [to match circuit breakers].

#### 2.9.2 Pad-Mounted Transformers

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NOTE: See TM 5-811-1/AF AFJMAN 32-1080 for guidance.

\*\*\*\*\*

Pad-mounted transformers shall comply with ANSI C57.12.26 and shall be of the [radial] [loop feed] type. Pad-mounted transformer stations shall be assembled and coordinated by one manufacturer and each transformer station shall be shipped as a complete unit so that field installation requirements are limited to mounting each unit on a concrete pad and connecting it to primary and secondary lines. Stainless steel pins and hinges shall be provided. Barriers shall be provided between high- and low-voltage compartments. High-voltage compartment doors shall be interlocked with low-voltage compartment doors to prevent access to any high-voltage section unless its associated low-voltage section door has first been opened. Compartments shall be sized to meet the specific dimensional requirements of ANSI C57.12.26. Pentahead locking bolts shall be provided with provisions for a padlock.

#### 2.9.2.1 High-Voltage Compartments

\*\*\*\*\*

NOTE: Select transformer fuse type and characteristics to provide protection of the transformer and coordination with upstream protective devices.

There are two types of fuses utilized in deadfront, pad-mounted transformer protection: expulsion-type, and current-limiting type. Expulsion-type fuses contain a fuse link that melts when subjected to either overload or fault current. The fuse-holding device operates such that the arc of the melting fuse link is extinguished under the transformer insulating dielectric (oil-immersed applications). Current limiting fuses create a physical circuit gap by the melting of the fuse. The opening arc is extinguished by the gases created by melting of the fuse element (drywell applications).

Fuse mounting configurations for deadfront pad-mounted transformers include: drywell mounting, where a canister is provided in the transformer tank (separated and sealed from the insulating dielectric); and "oil-immersed bayonet" mounting, where the fuse holder is mounted through the wall of the transformer tank, such that the fuse element is immersed in the transformer dielectric.

Drawout, dry-well mounted, current-limiting fuses are significantly more expensive than expulsion-type fuses and have more limited voltage- and current range operating characteristics. When specifying this fuse type, care must be exercised to ensure coordination with upstream protective devices. Although they operate on a more limited voltage range than other fuses, they are the preferred fuse type because the current limiting characteristics provides enhanced fault protection for the transformer.



Oil-immersed, bayonet-type, current limiting fuses and oil-immersed, bayonet type, overload fuses in series with a partial range current-limiting fuse, may be preferable to the drawout, drywell mounted, current-limiting fuse because of the operating characteristics, relative cost, and off-the-shelf availability. Oil-immersed fuse operation can contaminate the transformer oil, although numerous fuse operations are required (on the order of 100) before the contamination is significant.

Delete faulted circuit indicators unless required by the operating installation.

\*\*\*\*\*

The high-voltage compartment shall be dead-front construction. Primary switching and protective devices shall include loadbreak switching, [drawout, dry-well-mounted, current-limiting fuses] [oil-immersed, current-limiting, bayonet-type fuses] [oil-immersed, bayonet-type, overload fuse in series with a partial range current-limiting fuse], medium-voltage separable loadbreak connectors, universal bushing wells and inserts or integral one piece bushings and surge arresters. Fuses shall comply with the requirements of paragraph METERING AND PROTECTIVE DEVICES. The switch shall be mounted inside transformer tank with switch operating handle located in high-voltage compartment and equipped with metal loop for hook stick operation. Fuses shall be interlocked with switches so that fuses can be removed only when the associated switch is in the "OPEN" position. Adjacent to medium-voltage cable connections, a nameplate or equivalent stencilled inscription shall be provided inscribed "DO NOT OPEN CABLE CONNECTORS UNLESS SWITCH IS OPEN." Surge arresters shall be fully insulated and configured to terminate on [the same bushing as the primary cable by means of a loadbreak, feed-through bushing insert] [a second set of high voltage bushings].

#### 2.9.2.2 Load-Break Switch

\*\*\*\*\*

**NOTE: Choose one of the following options.**

\*\*\*\*\*

a. [Radial-feed oil-immersed type rated at [15] [\_\_\_\_\_] kV, [95] [\_\_\_\_\_] kV BIL, with a continuous current rating and load-break rating of [200] [\_\_\_\_\_] ampere, and a make-and-latch rating of 10,000 rms amperes symmetrical. Locate the switch handle in the high-voltage compartment.]

b. [Loop feed sectionalizer switches: Provide three, two-position, oil-immersed type switches to permit closed transition loop feed and sectionalizing. Each switch shall be rated at [15] [\_\_\_\_\_] kV, [95] [\_\_\_\_\_] kV BIL, with a continuous current rating and load-break rating of [200] [\_\_\_\_\_] amperes, and a make-and-latch rating of 10,000 rms amperes symmetrical. Locate the switch handle in the high-voltage compartment.] Operation of switches shall be as follows:

ARRANGEMENT #	DESCRIPTION OF SWITCH ARRANGEMENT	SWITCH POSITION		
		LINE A SW	LINE B SW	XFMR SW
		OPEN CLOSE	OPEN CLOSE	OPEN CLOSE
1	Line A connected to Line B and both	X	X	X

ARRANGEMENT #	DESCRIPTION OF SWITCH ARRANGEMENT lines connected to transformer	SWITCH POSITION			
		LINE A SW		LINE B SW	
		OPEN	CLOSE	OPEN	CLOSE
2	Transformer connected to Line A only		X	X	
3	Transformer connected to Line B only	X		X	
4	Transformer open and loop closed		X	X	X
5	Transformer open and loop open	X		X	X

#### 2.9.2.3 Transformer Tank Sections

\*\*\*\*\*

NOTE: For 480Y/277 volt secondaries, 2 primary taps above and 2 primary taps below are standard. For 208Y/120 volt secondaries, 4 primary taps below are standard. Normally, the design should use standard impedances in conjunction with circuit breakers having adequate interrupting ratings. ANSI C57.12.26, Table 2, lists 5.75 percent for 750 kVA - 2500 kVA. For 75 kVA - 500 kVA, use manufacturer's standard.

\*\*\*\*\*

Transformers shall comply with IEEE C57.12.00, ANSI C57.12.21, and ANSI C57.12.26 and shall be of the [mineral oil-insulated type] [less-flammable, liquid-insulated type with [high molecular-weight hydrocarbon] [or] [dimethyl silicone] liquid]. Transformers shall be suitable for outdoor use and shall have 2 separate windings per phase. Standard NEMA primary taps shall be provided. Where primary taps are not specified, 4, 2-1/2 percent rated kVA high-voltage taps shall be provided [2 above and 2 below] [below] rated, primary voltage. Operating handles for primary tap changers for de-energized operation shall be located within high-voltage compartments, externally to transformer tanks. Adjacent to the tap changer operating handle, a nameplate or equivalent stenciled inscription shall be provided and inscribed "DO NOT OPERATE UNDER LOAD." Transformer ratings at 60 Hz shall be as follows:

Three-phase capacity.....[\_\_\_\_\_] kVA.

Impedance.....[\_\_\_\_\_] .

Temperature Rise.....65 degrees C.

High-voltage winding.....[\_\_\_\_\_] volts.

High-voltage winding connections.....[\_\_\_\_] .  
Low-voltage winding.....[\_\_\_\_] volts.  
Low-voltage winding connections..... [\_\_\_\_]

#### 2.9.2.4 Low-Voltage Cable Compartments

Neutrals shall be provided with fully-insulated bushings. Clamp type cable terminations, suitable for [copper] [aluminum] conductors entering from below, shall be provided as necessary.

#### 2.9.2.5 Accessories

\*\*\*\*\*  
**NOTE: Specify thermometer, liquid level gauge, and  
a sampling device only where requested by the Using  
Agency.**  
\*\*\*\*\*

High-voltage warning signs shall be permanently attached to each side of transformer stations. Voltage warning signs shall comply with IEEE C2. Copper-faced steel or stainless steel ground connection pads shall be provided in both the high- and low-voltage compartments. Dial-type thermometer, liquid-level gauge, and drain valve with built-in sampling device shall be provided for each transformer station. Insulated-bushing-type parking stands shall be provided adjacent to each separable load-break elbow to provide for cable isolation during sectionalizing operations.

#### 2.9.3 Busways

Busways shall comply with NEMA BU 1 and UL 857 and shall be of the voltage, phase, and continuous current ratings indicated. Neutrals shall be [full size] [half size]. Busways shall have short-circuit ratings not less than the maximum short-circuit currents of associated transformers, assuming primary sources of infinite capacity. Busways shall be feeder-low-impedance type and of outdoor or indoor service construction as suitable to the location. Busways shall be complete with elbows, fittings, flanges, end-closures, tees, crosses, cable-tap boxes, accessories, and other devices required for the indicated installation, and shall be coordinated for connection to the indicated equipment. For wet/damp locations, bus duct shall be heated, nonventilated enclosure, nonsegregated phase type in accordance with IEEE C37.23. Detail drawings for busway supports and bracing shall be submitted in accordance with the detail drawings portion of paragraph SUBMITTALS and shall indicate that busways are adequately supported for the seismic forces specified in paragraph GENERAL REQUIREMENTS (sub-paragraph Service Conditions).

#### 2.9.4 Pad-Mounted, Metal-Enclosed, Switchgear

The switchgear shall be configured with [[2] [\_\_\_\_] incoming compartments for loop-feed arrangement] [one incoming compartment for radial-feed], equipped with [air-insulated, load-interrupter switches] [oil-insulated, load-interrupter switches] [SF6-insulated, load-interrupter switches], as indicated. The outgoing compartments shall be provided with [fused disconnects] [non-reclosing vacuum-type interrupters or circuit breakers], as indicated.

#### 2.9.4.1 Ratings at 60 Hz shall be:

Nominal voltage (kV).....[\_\_\_\_].  
Rated maximum voltage (kV).....[\_\_\_\_].  
Rated continuous current (A).....[\_\_\_\_].  
Maximum symmetrical interrupting capacity (kA).....[\_\_\_\_].  
Maximum asymmetrical interrupting capacity (kA).....[\_\_\_\_].  
Three-second short-time current-carrying capacity (kA).....[\_\_\_\_].  
BIL (kV).....[\_\_\_\_].

#### 2.9.4.2 Operators, Devices, and Controls

Operators and controls shall be provided for the switchgear as follows:

- a. Switches shall be provided with a manual, handle-type operator or a push-button mechanical spring tripping mechanism, utilizing a stored-energy (spring-driven) mechanism to simultaneously open or close all phases. The switchgear shall be configured so that the switch actuator is padlockable, but may be accessed without opening the switch compartment doors.
- b. Fused disconnects shall be hook-stick operated.
- c. Switches shall be provided with an automatic switch operator configured for local and remote opening and closing. An actuator charging motor shall be provide which operates at [12 V dc], [24 V dc] [120 V ac]. Switches shall be provided with remote telemetry units (RTUs) for remote operation and integration with supervisory, control, and data acquisition systems. Systems, components, and equipment shall conform to the requirements and recommendations of IEEE C37.1.
- d. Vacuum type interrupters shall be provided with an electronic controller for trip initiation. Manual trip initiation shall be provided by a push button or switch. Automatic trip shall be initiated by detection of excessive current. The electronic controller shall provide trip current selection capability according to present time-current response curves, as indicated. Each interrupter shall be provided with a 3 phase, gang-operated handle mechanism for trip and reset.

#### 2.9.4.3 Enclosures

Switchgear enclosures shall be of freestanding, self-supporting construction provided with separate incoming and outgoing compartments configured for bottom cable entry. Enclosures shall be of deadfront construction, provided with a hinged door for access to each compartment, and conform to the requirements of ANSI C57.12.28, ANSI C37.72, and IEEE C37.20.3, Category A.

#### 2.9.5 Pad-Mounted Sectionalizers

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**NOTE: Sectionalizer operation must be coordinated  
with substation recloser operating characteristics.**

\*\*\*\*\*

Pad-mounted, sectionalizing switches shall conform to the requirements of IEEE C37.63. The switchgear shall be configured with [[2] [\_\_\_\_\_] incoming compartments for loop-feed arrangement] [one incoming compartment for radial-feed] equipped with [air-insulated, load-interrupter switches] [oil-insulated, load-interrupters switches] [SF6-insulated load-interrupter switches], as indicated. The outgoing compartments shall be provided with non-reclosing sectionalizers.

#### 2.9.5.1 Ratings

Ratings at 60 Hz shall be:

Nominal voltage (kV).....[\_\_\_\_\_] .

Rated maximum voltage (kV).....[\_\_\_\_\_] .

Rated continuous current (A).....[\_\_\_\_\_] .

Three-second short-time current-carrying capacity (kA).....[\_\_\_\_\_] .

BIL (kV).....[\_\_\_\_\_] .

#### 2.9.5.2 Enclosures

Switchgear enclosures shall be of freestanding, self-supporting construction provided with separate incoming and outgoing compartments configured for bottom cable entry. Enclosures shall be of deadfront construction, provided with a hinged door for access to each compartment, and conform to the requirements of ANSI C57.12.28, ANSI C37.72, and IEEE C37.20.3, Category A.

#### 2.9.6 Cable Terminating Cabinets

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**NOTE: Cable terminating cabinets may be used for  
above ground applications only. They may be  
utilized in place of manholes for cable splicing  
where the local water table does not allow for  
manhole drainage, or in limited applications where  
it is desirable to provide a dead-break circuit  
sectionalizing point for circuit isolation.  
Loadbreak connectors are not available for  
applications above 200 A.**

\*\*\*\*\*

Cable terminating cabinets shall be hook-stick operable, deadfront construction conforming to the requirements of IEEE C37.20.3, Category A. Cabinets shall be provided with [with 200 A. loadbreak junctions and elbow-type separable loadbreak connectors, cable parking stands, and grounding lugs] [with 600 A. dead-break junctions and elbow-type separable dead-break connectors, cable parking stands, and grounding lugs]. The cable terminating equipments shall conform to IEEE Std 386.

Ratings at 60 Hz shall be:

Nominal voltage (kV).....[\_\_\_\_] .  
Rated maximum voltage (kV).....[\_\_\_\_] .  
Rated continuous current (A).....[\_\_\_\_] .  
Three-second short-time current-carrying capacity (kA).....[\_\_\_\_] .  
BIL (kV).....[\_\_\_\_] .

## 2.10 METERING AND PROTECTIVE DEVICES

### 2.10.1 Circuit Breakers, Low-Voltage

#### 2.10.1.1 Low-Voltage Power Circuit Breakers

##### a. Construction

Low-voltage power circuit breakers shall conform to IEEE C37.13, ANSI C37.16, and NEMA SG 6 and shall be three-pole, single-throw, stored energy, [manually] [electrically] operated, with drawout mounting. Solid-state trip elements which require no external power connections shall be provided. Circuit breakers shall have an open/close contact indicator, primary disconnect devices, and a mechanical interlock to prevent making or breaking contact of primary disconnections when the circuit breaker is closed. Control voltage shall be [[24] [48] [125] V dc] [120 V ac] [as indicated]. The circuit breaker enclosure shall be suitable for its intended location.

##### b. Ratings

Voltage ratings shall be not less than the applicable circuit voltage. Circuit breakers shall be rated for 100 percent continuous duty and shall have trip current ratings and frame sizes as shown. Nominal voltage ratings, maximum continuous-current ratings, and maximum short-circuit interrupting ratings shall be in accordance with ANSI C37.16. Tripping features shall be as follows:

1. Long-time current pick-up, adjustable from 50 percent to 100 percent of sensor current rating.
2. Adjustable long-time delay.
3. Short-time current pick-up, adjustable from 1.5 to 9 times long-time current setting.
4. Adjustable short-time delay.
5. [Short-time I<sup>2</sup>t switch.]
6. Instantaneous current pick-up, adjustable from 1.5 to 9 times long-time current setting.
7. Ground-fault pick-up, adjustable from 20 percent to 60 percent of sensor rating, but in no case greater than 1200 amperes. Sensing of ground-fault current at the main bonding jumper or ground strap shall not be permitted. [Zone-selective interlocking shall be provided as shown.]

8. [Fixed] [Adjustable] ground-fault delay.
9. [Ground-fault I2t switch.]
10. [Overload] [and] [short-circuit] [and] [ground-fault] trip indicators shall be provided.

#### 2.10.1.2 Molded-Case Circuit Breakers

NEMA AB 1 and UL 489.

#### 2.10.2 Fuses, Medium-Voltage, Including Current-Limiting

##### 2.10.2.1 Construction

Units shall be suitable for outdoor use. Fuses shall have integral blown-fuse indicators. All ratings shall be clearly visible.

##### 2.10.2.2 Ratings

[Expulsion-type] [Current-limiting] power fuses shall have ratings in accordance with ANSI C37.46 and as follows:

Nominal voltage.....[\_\_\_\_].  
Rated maximum voltage.....[\_\_\_\_].  
Maximum symmetrical interrupting capacity.....[\_\_\_\_].  
Rated continuous current.....[\_\_\_\_].  
BIL.....[\_\_\_\_].

##### 2.10.2.3 E-Rated, Current-Limiting Power Fuses

E-rated, current-limiting, power fuses shall conform to ANSI C37.46.

##### 2.10.2.4 C-Rated, Current-Limiting Power Fuses

C-rated, current-limiting power fuses shall open in 1000 seconds at currents between 170 and 240 percent of the C rating.

#### 2.10.3 Fuses, Low-Voltage, Including Current-Limiting

Low-voltage fuses shall conform to NEMA FU 1. Time delay and nontime delay options shall be as [shown] [specified]. Equipment provided under this contract shall be provided with a complete set of properly rated fuses when the equipment manufacturer utilizes fuses in the manufacture of the equipment, or if current-limiting fuses are required to be installed to limit the ampere-interrupting capacity of circuit breakers or equipment to less than the maximum available fault current at the location of the equipment to be installed. Fuses shall have a voltage rating of not less than the phase-to-phase circuit voltage, and shall have the time-current characteristics required for effective power system coordination.

##### 2.10.3.1 Cartridge Fuses

\*\*\*\*\*

**NOTE: Class RK1 provides high current limitation**

with both time-delay and nontime-delay. RK5 provides moderate current limitation, time-delay option.

\*\*\*\*\*

Cartridge fuses, current-limiting type, Class [G] [J] [K] [L] [RK1] [RK5] [RK9] [T] [CC] shall have tested interrupting capacity not less than [100,000] [200,000] amperes. Fuse holders shall be the type that will reject Class H fuses.

- a. Class [G] [J] [L] [CC] fuses shall conform to UL 198C.
- b. Class K fuses shall conform to UL 198D.
- c. Class R fuses shall conform to UL 198E.
- d. Class T fuses shall conform to UL 198H.

#### 2.10.3.2 Transformer Circuit Fuses

Transformer circuit fuses shall be Class RK1 or RK5, current-limiting, time-delay with 200,000 amperes interrupting capacity.

#### 2.10.4 Instrument Transformers

##### 2.10.4.1 General

Instrument transformers shall comply with ANSI C12.11 and IEEE C57.13. Instrument transformers shall be configured for mounting in/on the device to which they are applied. Polarity marks on instrument transformers shall be visually evident and shown on drawings.

##### 2.10.4.2 Current Transformers

\*\*\*\*\*

NOTE: See TM 5-811-1/AF AFJMAN 32-1080 regarding guidance on current transformers. Accuracy class ratings of current transformers (CTs) at standard burdens are listed in IEEE C57.13. The minimum standard current transformer accuracies for metal-clad switchgear are listed in ANSI C37.20.2. In general, ANSI C12.11 requires a 0.3 accuracy class for up to a B-0.5 burden, except for some 200 and 400 ampere units. Where metering current transformers are provided, this accuracy class should be specified, if available for the ampere rating and burden needed. A "C" classification means the ratio error can be calculated, whereas a "T" classification is one which has to be derived by testing. IEEE C37.20.2 permits either classification up to the indicated ratings.

\*\*\*\*\*

Unless otherwise indicated, bar, wound, or window-type transformers are acceptable; and except for window-type units installed over insulated buses, transformers shall have a BIL rating consistent with the rated BIL of the associated switchgear or electric power apparatus bushings, buses or conductors. Current transformers shall have the indicated ratios. The continuous thermal-current rating factor shall not be less than [1.0] [1.2]



[1.5] [2.0] [3.0] [4.0]. Other thermal and mechanical ratings of current transformers and their primary leads shall be coordinated with the design of the circuit breaker and shall be not less than the momentary rating of the associated circuit breaker. Circuit protectors shall be provided across secondary leads of the current transformers to prevent the accident open-circuiting of the transformers while energized. Each terminal of each current transformer shall be connected to a short-circuiting terminal block in the circuit interrupting mechanism cabinet, power transformer terminal cabinet, and in the associated instrument and relay cabinets.

#### 2.10.4.3 Current Transformers for Power Transformers

\*\*\*\*\*  
**NOTE: ANSI C57.12.10, Table 20 gives recommended values.**  
 \*\*\*\*\*

[Single-ratio] [Multi-ratio] bushing type current transformers shall be provided internally around power transformer bushings as shown.  
 [Single-ratio units shall have a minimum relaying accuracy class of [0.6B-0.5] [0.3B-0.5].] [Multi-ratio units shall have a minimum relaying accuracy voltage class of [\_\_\_\_\_] for either a C or T classification.]

#### 2.10.4.4 Current Transformers for Metal-Enclosed Switchgear

Single-ratio units, used for metering and relaying, shall have a metering accuracy class rating of [\_\_\_\_\_] [B.\_\_\_\_\_] . Single-ratio units, used only for relaying, shall have a relaying accuracy class rating of [\_\_\_\_\_] for [either] a C [or T] classification.

#### 2.10.4.5 Current Transformers for Kwh and Demand Metering (Low-Voltage)

\*\*\*\*\*  
**NOTE: Use the following guidelines for specifying current transformers.**

1. Select the standard current transformer (CT) primary rating which is just below the full load current of the serving power transformer, i.e., for a 500 kVA transformer with a full load of 1387 amps at 208 volts-select a 1200/5 CT ratio; for a 750 kVA transformer with a full load of 902 amps at 480 volts-select a 800/5 CT ratio.

2. Select a continuous-thermal-current rating factor (RF) in accordance with the following Table:

RATIO	RF at 30 degrees C
200/5	4.0
300/5	3.0
400/5	4.0
600/5	3.0
800/5	2.0
1200/5	1.5
1500/5	1.5
2000/5	1.5
3000/5	1.33

3. Select an ANSI Metering Accuracy Class in accordance with the following Table:

Primary Amp Rating (of CT)	Accuracy Class
200	0.3 thru B-0.1
300-400	0.3 thru B-0.2
600-1200	0.3 thru B-0.5
1500	0.3 thru B-0.9
2000-3000	0.3 thru B-1.8

\*\*\*\*\*

Current transformers shall conform to IEEE C57.13. Provide current transformers with a metering accuracy Class of 0.3 through [\_\_\_\_], with a minimum RF of [\_\_\_\_] at 30 degrees C, with 600-volt insulations, and 10 kV BIL. Provide butyl-molded, window-type current transformers mounted [on the transformer low-voltage bushings. Route current transformer leads in a location as remote as possible from the power transformer secondary cables to permit current measurements to be taken with hook-on-ammeters.] [in the current transformer cabinet.]

2.10.4.6 Voltage Transformers

\*\*\*\*\*

NOTE: See TM 5-811-1/AF AFJMAN 32-1080 for guidance regarding voltage transformers. Minimum standard potential transformer accuracies for metal-clad switchgear are not listed in IEEE C37.20.2. Accuracy classes as listed in IEEE C57.13 are 0.3, 0.6, and 1.2. Standard burdens for each accuracy class are W, X, Y, ZZ, and M. The designer should check the burdens connected to determine the actual accuracy class and burden required. In general, ANSI C12.11 requires 0.3 accuracy class for up to Y burdens, except for voltages of 5 kV and below. Where metering potential transformers are provided, a 0.3 accuracy class should be specified, if available for the voltage rating and burden needed.

\*\*\*\*\*

Voltage transformers shall have indicated ratios. Units shall have an accuracy class rating of [\_\_\_\_]. Voltage transformers shall be of the drawout type having current-limiting fuses in both primary and secondary circuits. Mechanical interlocks shall prevent removal of fuses, unless the associated voltage transformer is in a drawout position. Voltage transformer compartments shall have hinged doors.

2.10.5 Watthour Meters

\*\*\*\*\*

NOTE: Coordinate demand interval with local utility. Coordinate devices with EMCS equipment. For small, non-critical installations, residential-type watthour meters may be adequate. Revise paragraph as required.

\*\*\*\*\*

Watthour meters shall conform to ANSI C12.10, except numbered terminal wiring sequence and case size may be the manufacturer's standard. Watthour

meters shall be of the [drawout switchboard type] [socket mounted [outdoor] [indoor] type] having a [15] [30] [60] [\_\_\_\_\_] minute, cumulative form, demand register meeting ANSI C12.4 and provided with not less than 2-1/2 stators. [Watthour demand meters shall have factory-installed electronic pulse initiators. Pulse initiators shall be solid-state devices incorporating light-emitting diodes, phototransistors, and power transistors, except that mercury-wetted output contacts are acceptable. Initiators shall be totally contained within watthour demand meter enclosures, shall be capable of operating up to speeds of 500 pulses per minute with no false pulses, and shall require no field adjustments. Initiators shall be calibrated for a pulse rate output of 1 pulse per 1/4 disc revolution of the associated meter and shall be compatible with the indicated equipment].

#### 2.10.6 Protective Relaying

\*\*\*\*\*  
**NOTE: Ranges selected will be based on the coordination study. Refer to TM 5-811-1/AF AFJMAN 32-1080 and TM 5-811-14 for guidance regarding protective relays.**  
\*\*\*\*\*

##### 2.10.6.1 General

[Solid-state] [Microprocessor-based] protective relays shall be provided as shown and shall be of a type specifically designed for use on power switchgear or associated electric power apparatus. Protective relays shall conform to IEEE C37.90. Relays and auxiliaries shall be suitable for operation with the instrument transformer ratios and connections provided.

##### 2.10.6.2 Construction

Relays shall be dustproof and moisture resistant. Necessary test devices shall be incorporated within each relay and shall provide a means for testing either from an external source of electric power or from associated instrument transformers. Each relay shall be provided with an operation indicator and an external target reset device. Relays shall have necessary auxiliaries for proper operation. Relays and auxiliaries shall be suitable for operation with the instrument transformer ratios and connections provided.

##### 2.10.6.3 Ratings

Relays shall be the manufacturer's standard items of equipment with appropriate ranges for time dial, tap, and other settings. Relay device numbers shall correspond to the function names and descriptions of IEEE C37.2.

#### 2.11 SURGE ARRESTERS

\*\*\*\*\*  
**NOTE: Surge arresters should be located at both the riser pole and at the equipment. Dead front transformer primary compartments may require special provisions to accommodate the arresters.**  
\*\*\*\*\*

Surge arresters shall comply with NEMA LA 1, IEEE C62.1, ANSI C62.2, and

IEEE C62.11 and shall be provided where indicated. Arresters shall be [station] [intermediate] [distribution] class, rated as shown. Arresters for use at elevations in excess of 1.8 km 6000 feet above mean sea level shall be specifically rated for that purpose. Arresters shall be equipped with mounting brackets suitable for the indicated installations. Arresters shall be of the [valve] [or] [metal-oxide varistor] [or] [combination valve-metal-oxide varistor] type.

## 2.12 GROUNDING AND BONDING

### 2.12.1 Driven Ground Rods

Ground rods shall be [copper-clad steel conforming to UL 467] [zinc-coated steel conforming to ANSI C135.30] [solid stainless steel] not less than [15.9 mm 5/8 inch] [19 mm 3/4 inch] in diameter by [3.1 m 10 feet] [2.44 m 8 feet] in length. Sectional type rods may be used.

### 2.12.2 Grounding Conductors

Grounding conductors shall be bare, except where installed in conduit with associated phase conductors. Insulated conductors shall be of the same material as phase conductors and green color-coded, except that conductors shall be rated no more than 600 volts. Bare conductors shall be ASTM B 8 soft-drawn unless otherwise indicated. Aluminum is not acceptable.

## 2.13 CONCRETE AND REINFORCEMENT

Concrete work shall have minimum 20 MPa 3000 psi compressive strength and conform to the requirements of Section 03300A CAST-IN-PLACE STRUCTURAL CONCRETE. Concrete reinforcing shall be as specified in Section 03200A CONCRETE REINFORCEMENT.

## 2.14 PADLOCKS

Padlocks shall comply with Section 08710 DOOR HARDWARE.

## 2.15 CABLE FIREPROOFING SYSTEMS

Cable fireproofing systems shall be listed in FM P7825a as a fire-protective coating or tape approved for grouped electrical conductors and shall be suitable for application on the type of medium-voltage cables provided. After being fully cured, materials shall be suitable for use where exposed to oil, water, gases, salt water, sewage, and fungus and shall not damage cable jackets or insulation. Asbestos materials are not acceptable.

### 2.15.1 Fireproof Coating

Cable fireproofing coatings shall be compounded of water-based thermoplastic resins, flame-retardant chemicals, and inorganic noncombustible fibers and shall be suitable for the application methods used. Coatings applied on bundled cables shall have a derating factor of less than 5 percent, and a dielectric strength of 95 volts per mil minimum after curing.

### 2.15.2 Fireproofing Tape

Fireproofing tape shall be at least 50 mm 2 inches wide and shall be a flexible, conformable, polymeric, elastomer tape designed specifically for

fireproofing cables.

### 2.15.3 Plastic Tape

Preapplication plastic tape shall be pressure sensitive, 0.254 mm 10 mil thick, conforming to UL 510.

### 2.16 LIQUID DIELECTRICS

\*\*\*\*\*  
**NOTE: Select 2 ppm for Air Force projects.**  
\*\*\*\*\*

Liquid dielectrics for transformers, capacitors, reclosers, and other liquid-filled electrical equipment shall be non-polychlorinated biphenyl (PCB) mineral-oil or less-flammable liquid as specified. Nonflammable fluids shall not be used. Tetrachloroethylene (perchloroethylene) and 1, 2, 4 trichlorobenzene fluids shall not be used. Liquid dielectrics in retrofitted equipment shall be certified by the manufacturer as having less than [50] [2] parts per million (ppm) PCB content. In lieu of the manufacturer's certification, the Contractor may submit a test sample of the dielectric in accordance with ASTM D 923 and have tests performed per ASTM D 4059 at a testing facility approved by the Contracting Officer. Equipment with test results indicating PCB level exceeding [50] [2] ppm shall be replaced.

### 2.17 FACTORY TESTS

\*\*\*\*\*  
**NOTE: Delete tests that are not applicable to the project. Refer to TM 5-811-1/AF AFJMAN 32-1080. Tests must be justified.**  
\*\*\*\*\*

Factory tests shall be performed, as follows, in accordance with the applicable publications and with other requirements of these specifications. The Contracting Officer shall be notified at least [10] [\_\_\_\_\_] days before the equipment is ready for testing. The Contracting Officer reserves the right to witness the tests.

- a. Transformers: Manufacturer's standard [routine] [design] [and] [other] tests in accordance with IEEE C57.12.00.
- b. Transformers rated 200 kVA and above: Reduced full-wave, chopped-wave, and full-wave impulse test on each line and neutral terminal, in accordance with IEEE C57.98.
- c. High-Voltage Air Switches: Manufacturer's standard tests in accordance with IEEE C37.34 and IEEE C37.41.
- d. Protective Relays: Seismic tests in accordance with IEEE C37.98. Surge withstand tests in accordance with IEEE C37.90.1.
- e. Relaying Current Transformers: Manufacturer's standard tests in accordance with IEEE C57.13.
- f. Instrument Current Transformers: Manufacturer's standard tests in accordance with IEEE C57.13.

- g. Factory Preformed Terminations: Wet withstand voltage tests in accordance with IEEE Std 48 for the next higher BIL level.
- h. Outdoor Switchgear: Manufacturer's standard tests in accordance with IEEE C37.20.1, IEEE C37.20.2, and IEEE C37.20.3.
- i. Electrical Power Insulators: Manufacturer's standard tests in accordance with ANSI C29.1.
- j. [\_\_\_\_].

## 2.18 FENCING

Fencing shall conform to the requirements of Section 02821A FENCING.

## 2.19 COORDINATED POWER SYSTEM PROTECTION

\*\*\*\*\*

NOTE: The requirement for the studies in this section depends on the complexity and extent of the power system. Delete this requirement for: project of limited scope; projects having protective devices which are not adjustable or for which coordination is not possible (standard molded case circuit breakers); projects involving simple extension of 600 volt level service to a building or facility from an existing transformer (750 kVA or less); or projects involving simple extension of 600 volt level service to a building or facility from a new transformer (750 kVA or less).

The designer will be responsible for specifying the requirement for fuses, circuit breakers, protective relays, or other protective devices associated with the project and depicting them on the drawings. The protective devices should be selected and specified to protect electrical power system conductors or equipment against sustained overloads, in-rush conditions, electrical faults, or other abnormal power system or equipment operating conditions, in accordance with TM 5-811-14, COORDINATED POWER SYSTEMS PROTECTION and IEEE Std 242, and IEEE Std 141.

The complexity and extent of coordinated power system protection depends on the type of buildings or facilities or utilities required, on the load demand of facilities, and on the quantity and types of facilities to be constructed. Facilities having a relatively-low power demand (e.g., 2500 kVA or less) generally require protection of an incoming aerial distribution line or underground, medium-voltage feeder, low-voltage feeders to individual items of equipment, or to power distribution equipment, and branch circuits. More complex projects such as facilities with generating capacity, large motors, or larger load demands, will require more detailed and extensive coordinated power system protection.

Independent of the type or types of facilities or load demands, the coordinated power system protection will be based on: economics, simplicity, and the electrical power availability dictated by the Using Agency or Service, or by the functional use of the facilities or utilities; required to provide maximum power service with a minimum of power interruptions; and the operating speed of protective devices required to minimize damage to electrical components or items of equipment and to prevent injury to personnel and nuisance tripping.

Unless otherwise approved, a dc power source will be shown and specified to ensure proper closing and tripping of protective devices which require a reliable power source during outage of the normal alternating-current power source.

\*\*\*\*\*

Analyses shall be prepared to demonstrate that the equipment selected and system constructed meet the contract requirements for equipment ratings, coordination, and protection. They shall include a load flow analysis, a fault current analysis, and a protective device coordination study. The studies shall be performed by a registered professional engineer with demonstrated experience in power system coordination in the last three years. The Contractor shall provide a list of references complete with points of contact, addresses and telephone numbers. The selection of the engineer is subject to the approval of the Contracting Officer.

#### 2.19.1 Scope of Analyses

The fault current analysis, and protective device coordination study shall begin at: [the source bus and extend down to system bused where fault availability is 10,000 amperes (symmetrical) for building/facility 600 volt level distribution buses.] [the source bus and extended through the secondary side of transformers for medium voltage distribution feeders.] [the source bus and extend through [outgoing breakers] [outgoing medium voltage feeders, down to the individual protective devices for medium voltage radial taps] [outgoing medium voltage feeders, through the secondary side of transformers] [as indicated] for main electric supply substations.] [the nearest upstream device in the existing source system and extend through the downstream devices at the load end.]

#### 2.19.2 Determination of Facts

\*\*\*\*\*

NOTE: Require the Contractor to obtain an available fault capacity at the power source or provide a fault capacity on which he is to base his analysis. Delete the unused option.

\*\*\*\*\*

The time-current characteristics, features, and nameplate data for each existing protective device shall be determined and documented. [The Contractor shall coordinate with the [commercial power company] [\_\_\_\_\_] for fault current availability at the site.] [The Contractor shall utilize the fault current availability indicated as a basis for fault current studies.]

### 2.19.3 Single Line Diagram

A single line diagram shall be prepared to show the electrical system buses, devices, transformation points, and all sources of fault current (including generator and motor contributions). A fault-impedance diagram or a computer analysis diagram may be provided. Each bus, device or transformation point shall have a unique identifier. If a fault-impedance diagram is provided, impedance data shall be shown. Locations of switches, breakers, and circuit interrupting devices shall be shown on the diagram together with available fault data, and the device interrupting rating.

### 2.19.4 Fault Current Analysis

#### 2.19.4.1 Method

The fault current analysis shall be performed in accordance with methods described in IEEE Std 242, and IEEE Std 399.

#### 2.19.4.2 Data

Actual data shall be utilized in fault calculations. Bus characteristics and transformer impedances shall be those proposed. Data shall be documented in the report.

### 2.19.5 Coordination Study

The study shall demonstrate that the maximum possible degree of selectivity has been obtained between devices specified, consistent with protection of equipment and conductors from damage from overloads and fault conditions. The study shall include a description of the coordination of the protective devices in this project. Provide a written narrative that describes: which devices may operate in the event of a fault at each bus; the logic used to arrive at device ratings and settings; situations where system coordination is not achievable due to device limitations (an analysis of any device curves which overlap); coordination between upstream and downstream devices; and any relay settings. Recommendations to improve or enhance system reliability, and detail where such changes would involve additions or modifications to the contract and cost changes (addition or reduction) shall be provided. Composite coordination plots shall be provided on log-log graph paper.

### 2.19.6 Study Report

- a. The report shall include a narrative describing: the analyses performed; the bases and methods used; and the desired method of coordinated protection of the power system.
- b. The study shall include descriptive and technical data for existing devices and new protective devices proposed. The data shall include manufacturers published data, nameplate data, and definition of the fixed or adjustable features of the existing or new protective devices.
- c. The report shall document [utility company data including system voltages, fault MVA, system X/R ratio, time-current characteristics curves, current transformer ratios, and relay device numbers and settings;] [and] [existing power system data including time-current characteristic curves and protective device ratings and settings.]
- d. The report shall contain fully coordinated composite time-current



characteristic curves for each bus in the system, as required to ensure coordinated power system protection between protective devices or equipment. The report shall include recommended ratings and settings of all protective devices in tabulated form.

e. The report shall provide the calculation performed for the analyses, including computer analysis programs utilized. The name of the software package, developer, and version number shall be provided.

## PART 3 EXECUTION

### 3.1 INSTALLATION REQUIREMENTS

Equipment and devices shall be installed and energized in accordance with the manufacturer's published instructions. Circuits installed aerially shall conform to the requirements of Section 16370A ELECTRICAL DISTRIBUTION SYSTEM, AERIAL. Steel conduits installed underground shall be installed and protected from corrosion in conformance with the requirements of Section 16402 INTERIOR DISTRIBUTION SYSTEM. Except as covered herein, excavation, trenching, and backfilling shall conform to the requirements of Section 02300 EARTHWORK. Concrete work shall have minimum 20 MPa 3000 psi compressive strength and conform to the requirements of Section 03300A CAST-IN-PLACE STRUCTURAL CONCRETE.

#### 3.1.1 Conformance to Codes

The installation shall comply with the requirements and recommendations of NFPA 70 and IEEE C2 as applicable.

#### 3.1.2 Verification of Dimensions

The Contractor shall become familiar with details of the work, shall verify dimensions in the field, and shall advise the Contracting Officer of any discrepancy before performing any work.

#### 3.1.3 Disposal of Liquid Dielectrics

PCB-contaminated dielectrics must be marked as PCB and transported to and incinerated by an approved EPA waste disposal facility. The Contractor shall furnish certification of proper disposal. Contaminated dielectrics shall not be diluted to lower the contamination level.

### 3.2 CABLE AND BUSWAY INSTALLATION

The Contractor shall obtain from the manufacturer an installation manual or set of instructions which addresses such aspects as cable construction, insulation type, cable diameter, bending radius, cable temperature, lubricants, coefficient of friction, conduit cleaning, storage procedures, moisture seals, testing for and purging moisture, etc. The Contractor shall then [prepare a checklist of significant requirements] [perform pulling calculations and prepare a pulling plan] which shall be submitted along with the manufacturers instructions in accordance with SUBMITTALS.

#### 3.2.1 Cable Installation Plan and Procedure

Cable shall be installed strictly in accordance with the cable manufacturer's recommendations. Each circuit shall be identified by means of a fiber, laminated plastic, or non-ferrous metal tags, or approved equal, in each manhole, handhole, junction box, and each terminal. Each

tag shall contain the following information; cable type, conductor size, circuit number, circuit voltage, cable destination and phase identification.

#### 3.2.1.1 Cable Inspection

The cable reel shall be inspected for correct storage positions, signs of physical damage, and broken end seals. If end seal is broken, moisture shall be removed from cable in accordance with the cable manufacturer's recommendations.

#### 3.2.1.2 Duct Cleaning

Duct shall be cleaned with an assembly that consists of a flexible mandrel (manufacturers standard product in lengths recommended for the specific size and type of duct) that is 6.4 mm 1/4 inch less than inside diameter of duct, 2 wire brushes, and a rag. The cleaning assembly shall be pulled through conduit a minimum of 2 times or until less than a volume of 131 cubic centimeters 8 cubic inches of debris is expelled from the duct.

#### 3.2.1.3 Duct Lubrication

The cable lubricant shall be compatible with the cable jacket for cable that is being installed. Application of lubricant shall be in accordance with lubricant manufacturer's recommendations.

#### 3.2.1.4 Cable Installation

The Contractor shall provide a cable feeding truck and a cable pulling winch as required. The Contractor shall provide a pulling grip or pulling eye in accordance with cable manufacturer's recommendations. The pulling grip or pulling eye apparatus shall be attached to polypropylene or manilla rope followed by lubricant front end packs and then by power cables. A dynamometer shall be used to monitor pulling tension. Pulling tension shall not exceed cable manufacturer's recommendations. The Contractor shall not allow cables to cross over while cables are being fed into duct. For cable installation in cold weather, cables shall be kept at 10 degrees C 50 degrees F temperature for at least 24 hours before installation.

#### 3.2.1.5 Cable Installation Plan

The Contractor shall submit a cable installation plan for all cable pulls in accordance with the detail drawings portion of paragraph SUBMITTALS. Cable installation plan shall include:

- a. Site layout drawing with cable pulls identified in numeric order of expected pulling sequence and direction of cable pull.
- b. List of cable installation equipment.
- c. Lubricant manufacturer's application instructions.
- d. Procedure for resealing cable ends to prevent moisture from entering cable.
- e. Cable pulling tension calculations of all cable pulls.
- f. Cable percentage conduit fill.
- g. Cable sidewall thrust pressure.

- h. Cable minimum bend radius and minimum diameter of pulling wheels used.
- i. Cable jam ratio.
- j. Maximum allowable pulling tension on each different type and size of conductor.
- k. Maximum allowable pulling tension on pulling device.

### 3.2.2 Duct Line

[Low-voltage cables] [Cables] shall be installed in duct lines where indicated. [Cable splices in low-voltage cables shall be made in manholes and handholes only, except as otherwise noted.] [Cable joints in medium-voltage cables shall be made in manholes or approved pullboxes only.] Neutral and grounding conductors shall be installed in the same duct with their associated phase conductors.

### 3.2.3 Direct-Burial

\*\*\*\*\*  
**NOTE: Specify cover requirements in accordance with  
NFPA 70 and IEEE C2. Specify depth of frost line.  
Coordinate with UFGS-02300 EARTHWORK for trenching  
and backfilling requirements.**  
\*\*\*\*\*

[Medium-voltage cables] [Cables] shall be buried directly in the earth as indicated. Minimum cover from the top of a cable to finished grade shall be [\_\_\_\_\_] mm inches but not less than the depth of the frost line, [\_\_\_\_\_] .

#### 3.2.3.1 Trenching

Trenches for direct-burial cables shall be excavated to depths required to provide the minimum necessary cable cover. Bottoms of trenches shall be smooth and free of stones and sharp objects. Where bottoms of trenches comprise materials other than sand, a 75 mm 3 inch layer of sand shall be laid first and compacted to approximate densities of surrounding firm soil.

#### 3.2.3.2 Cable Burial

\*\*\*\*\*  
**NOTE: Where soil is known to be rocky, provide  
selected backfill for cable protection. Specify  
bend radius in accordance with NFPA 70.**  
\*\*\*\*\*

Cables shall be unreeled along the sides of or in trenches and carefully placed on sand or earth bottoms. Pulling cables into direct-burial trenches from a fixed reel position will not be permitted, except as required to pull cables through conduits under paving or railroad tracks. Where cables cross, a separation of at least 75 mm 3 inches shall be provided, unless each cable circuit is protected by a nonmetallic conduit sleeve at the crossing. Where single-conductor cable is installed, all 3 phases and the neutral shall be installed in the same sleeve. Bend radius of any cable shall be not less than [8] [12] [\_\_\_\_\_] times the diameter of the cable. In no case shall cables be left under longitudinal tension.

The first 150 mm 6 inch layer of backfill shall be of sand. Machine compaction shall not be used within 150 mm 6 inches of the cable.

#### 3.2.3.3 Other Requirements

Where direct-burial cables cross under roads or other paving exceeding 1.5 m 5 feet in width, such cables shall be installed in concrete-encased ducts. Where direct-burial cables cross under railroad tracks, such cables shall be installed in reinforced concrete-encased ducts. Ducts shall extend at least 300 mm 1 foot beyond each edge of any paving and at least 1.5 m 5 feet beyond each side of any railroad tracks. Cables may be pulled into duct from a fixed reel where suitable rollers are provided in the trench. Where direct burial cable transitions to duct-enclosed cable, direct-burial cables shall be centered in duct entrances, and a waterproof nonhardening mastic compound shall be used to facilitate such centering. If paving or railroad tracks are in place where cables are to be installed, coated rigid steel conduits driven under the paving or railroad tracks may be used in lieu of concrete-encased ducts. Damage to conduit coatings shall be prevented by providing ferrous pipe jackets or by predrilling. Where cuts are made in any paving, the paving and subbase shall be restored to their original condition.

#### 3.2.3.4 Cable Joints or SplicesMedium-Voltage Cable Joints or Low-Voltage Cable Splices

Cable joints or splices in direct-burial cables are not permitted in runs of 305 m 1000 feet or less, nor at intervals of less than 305 m 1000 feet in longer runs, except as required for taps. Locations of cable joints or splices in shorter intervals, where required to avoid obstructions or damage to cables, shall be approved. Cable joints or splices in direct burial installations shall be installed in above-ground junction boxes or in cast metal splice boxes suitable for direct burial use. Cable joints or splices in duct banks shall be made only in manholes, handholes, or pullboxes.

#### 3.2.3.5 Cable Markers

\*\*\*\*\*  
**NOTE: Coordinate with UFGS-02300 EARTHWORK, for  
underground marking requirements.**  
\*\*\*\*\*

Markers shall be located [as indicated] [near the ends of cable runs, at each cable joint or splice, at approximately every 150 m 500 feet along cable runs, and at changes in direction of cable runs]. In addition to markers, a 0.127 mm 5 mil, brightly colored plastic tape not less than 75 mm 3 inches in width and suitably inscribed at not more than 3 m 10 feet on centers, or other approved dig-in warning indication, shall be placed approximately 300 mm 12 inches below finished grade levels of trenches.

#### 3.2.4 Insect and Rodent Damage

\*\*\*\*\*  
**NOTE: In areas where insect and rodent damage to  
buried cable is a problem, the following steps  
should be considered:**

- a. Specify armored cable.

- b. Specify next higher cable voltage rating. Utility company research indicates that the greater dielectric strength is effective.
- c. Specify full concentric neutral.
- d. Specify animal guards around existing concrete pads. Animal guards include fences, and also guards to close holes in concrete pads.
- e. On new installations, specify buried fiberglass pads that animals cannot get under.
- f. Avoid toxic chemicals.
- g. Specify fenced enclosure where required.

\*\*\*\*\*

[Animal guards shall be installed as shown.] [Buried fiberglass pads shall be installed as shown.]

### 3.2.5 Electric Manholes

Cables shall be routed around the interior walls and securely supported from walls on cables racks. Cable routing shall minimize cable crossover, provide access space for maintenance and installation of additional cables, and maintain cable separation in accordance with IEEE C2.

### 3.2.6 Busway Installation

Busways penetrating walls shall have wall flanges installed on both surfaces of walls. Wall openings shall be approximately 6.4 mm 1/4 inch larger than the busway on each of the 4 busway sides, and openings shall be sealed with a suitable compound. Fire barriers shall be provided when penetrating fire rated walls. Fire barriers shall have a rating equal to the fire wall rating. A weather barrier shall be used when a busway penetrates an exterior wall. Busways shall be supported at intervals not exceeding 3 m 10 feet and shall be braced to prevent lateral movement.

### 3.3 CABLE JOINTS

Medium-voltage cable joints shall be made by qualified cable splicers only. Qualifications of cable splicers shall be submitted in accordance with paragraph SUBMITTALS. Shields shall be applied as required to continue the shielding system through each entire cable joint. Shields may be integrally molded parts of preformed joints. Shields shall be grounded at each joint or in accordance with manufacturer's recommended practice. Cable joints shall provide insulation and jacket equivalent to that of the associated cable. Armored cable joints shall be enclosed in compound-filled, cast-iron or alloy, splice boxes equipped with stuffing boxes and armor clamps of a suitable type and size for the cable being installed.

### 3.4 FIREPROOFING

\*\*\*\*\*

NOTE: Refer to TM 5-811-1/AF AFJMAN 32-1080 for guidance regarding flameproofing of cables in manholes.

\*\*\*\*\*

[Each medium-voltage cable and conductor in manholes shall be fire-proofed for their entire length within the manhole. Where cables and conductors have been lubricated to enhance pulling into ducts, the lubricant shall be removed from cables and conductors exposed in the manhole before fireproofing.] [Fire-stops shall be installed in each conduit entering or leaving a manhole.]

#### 3.4.1 Tape Method

Before application of fireproofing tape, plastic tape wrapping shall be applied over exposed metallic items such as the cable ground wire, metallic outer covering, or armor to minimize the possibility of corrosion from the fireproofing materials and moisture. Before applying fireproofing tape, irregularities of cables, such as at cable joints, shall be evened out with insulation putty. A flexible conformable polymeric elastomer fireproof tape shall be wrapped tightly around each cable spirally in 1/2 lapped wrapping or in 2 butt-jointed wrappings with the second wrapping covering the joints of the first.

#### 3.4.2 Sprayable Method

Manholes shall be power ventilated until coatings are dry and dewatered and the coatings are cured. Ventilation requirements shall be in accordance with the manufacturer's instruction, but not less than 10 air changes per hour shall be provided. Cable coatings shall be applied by spray, brush, or glove to a wet film thickness that reduces to the dry film thickness approved for fireproofing by FM P7825a. Application methods and necessary safety precautions shall be in accordance with the manufacturers instructions. After application, cable coatings shall be dry to the touch in 1 to 2 hours and fully cured in 48 hours, except where the manufacturer has stated that because of unusual humidity or temperature, longer periods may be necessary.

### 3.5 DUCT LINES

#### 3.5.1 Requirements

Numbers and sizes of ducts shall be as indicated. Duct lines shall be laid with a minimum slope of 100 mm per 30 m 4 inches per 100 feet. Depending on the contour of the finished grade, the high-point may be at a terminal, a manhole, a handhole, or between manholes or handholes. Short-radius manufactured 90-degree duct bends may be used only for pole or equipment risers, unless specifically indicated as acceptable. The minimum manufactured bend radius shall be 450 mm 18 inches for ducts of less than 80 mm 3 inch diameter, and 900 mm 36 inches for ducts 80 mm 3 inches or greater in diameter. Otherwise, long sweep bends having a minimum radius of 7.6 m 25 feet shall be used for a change of direction of more than 5 degrees, either horizontally or vertically. Both curved and straight sections may be used to form long sweep bends, but the maximum curve used shall be 30 degrees and manufactured bends shall be used. Ducts shall be provided with end bells whenever duct lines terminate in manholes or handholes.

#### 3.5.2 Treatment

Ducts shall be kept clean of concrete, dirt, or foreign substances during construction. Field cuts requiring tapers shall be made with proper tools

and match factory tapers. A coupling recommended by the duct manufacturer shall be used whenever an existing duct is connected to a duct of different material or shape. Ducts shall be stored to avoid warping and deterioration with ends sufficiently plugged to prevent entry of any water or solid substances. Ducts shall be thoroughly cleaned before being laid. Plastic ducts shall be stored on a flat surface and protected from the direct rays of the sun.

### 3.5.3 Concrete Encasement

\*\*\*\*\*  
**NOTE: For crossings of existing railroads and  
airfield pavements greater than 15.2 m (50 feet) in  
length, the pre-drilling method or the  
jack-and-sleeve method will be used.**  
\*\*\*\*\*

Ducts requiring concrete encasements shall comply with NFPA 70, except that electrical duct bank configurations for ducts 150 mm 6 inches in diameter shall be determined by calculation and as shown on the drawings. The separation between adjacent electric power and communication ducts shall conform to IEEE C2. Duct line encasements shall be monolithic construction. Where a connection is made to a previously poured encasement, the new encasement shall be well bonded or doweled to the existing encasement. The Contractor shall submit proposed bonding method for approval in accordance with the detail drawing portion of paragraph SUBMITTALS. At any point, except railroad and airfield crossings, tops of concrete encasements shall be not less than the cover requirements listed in NFPA 70. At railroad and airfield crossings, duct lines shall be encased with concrete and reinforced as indicated to withstand specified surface loadings. Tops of concrete encasements shall be not less than 1.5 m 5 feet below tops of rails or airfield paving unless otherwise indicated. Where ducts are jacked under existing pavement, rigid steel conduit will be installed because of its strength. To protect the corrosion-resistant conduit coating, predrilling or installing conduit inside a larger iron pipe sleeve (jack-and-sleeve) is required. For crossings of existing railroads and airfield pavements greater than 15 m 50 feet in length, the predrilling method or the jack-and-sleeve method will be used. Separators or spacing blocks shall be made of steel, concrete, plastic, or a combination of these materials placed not farther apart than 1.2 m 4 feet on centers. Ducts shall be securely anchored to prevent movement during the placement of concrete and joints shall be staggered at least 150 mm 6 inches vertically.

### 3.5.4 Nonencased Direct-Burial

\*\*\*\*\*  
**NOTE: Specify cover requirements in accordance with  
NFPA 70 and IEEE C2. Specify frost line depth.**  
\*\*\*\*\*

Top of duct lines shall be below the frost line depth of [\_\_\_\_\_] mm inches, but not less than [\_\_\_\_\_] mm inches below finished grade and shall be installed with a minimum of 75 mm 3 inches of earth around each duct, except that between adjacent electric power and communication ducts, 300 mm 12 inches of earth is required. Bottoms of trenches shall be graded toward manholes or handholes and shall be smooth and free of stones, soft spots, and sharp objects. Where bottoms of trenches comprise materials other than sand, a 75 mm 3 inch layer of sand shall be laid first and compacted to

approximate densities of surrounding firm soil before installing ducts. Joints in adjacent tiers of duct shall be vertically staggered at least 150 mm 6 inches. The first 150 mm 6 inch layer of backfill cover shall be sand compacted as previously specified. The rest of the excavation shall be backfilled and compacted in 75 to 150 mm 3 to 6 inch layers. Duct banks may be held in alignment with earth. However, high-tiered banks shall use a wooden frame or equivalent form to hold ducts in alignment prior to backfilling.

### 3.5.5 Installation of Couplings

Joints in each type of duct shall be made up in accordance with the manufacturer's recommendations for the particular type of duct and coupling selected and as approved.

#### 3.5.5.1 Bituminized-Fiber Ducts

\*\*\*\*\*  
**NOTE: Bituminized fiber duct should be specified only for connection to existing bituminized fiber duct systems. Delete the paragraph if not required. Specify thin-wall or schedule 40 plastic duct for concrete encasement and thick-wall or schedule 40 or schedule 80 plastic duct for direct-burial and riser applications (riser bends should be metallic conduit where cables are to be pulled into ductline).**  
\*\*\*\*\*

Bituminized-fiber ducts shall be used to interface with existing bituminized-fiber duct as shown. To ensure a watertight joint, tapered ends or joints of the same material as the ducts shall be swabbed with bituminous or joint-sealing compound before couplings are applied. Plastic or nonmetallic couplings shall be tightly driven onto unswabbed ducts. Due to the brittleness of plastic couplings at low temperatures, such couplings shall not be installed when temperatures are below minus 18 degrees C 0 degrees F. Couplings shall be warmed in hot water or by another approved method when installed at temperatures below 0 degrees C 32 degrees F.

#### 3.5.5.2 Plastic Duct

Duct joints shall be made by brushing a plastic solvent cement on insides of plastic coupling fittings and on outsides of duct ends. Each duct and fitting shall then be slipped together with a quick 1/4-turn twist to set the joint tightly.

#### 3.5.6 Duct Line Markers

\*\*\*\*\*  
**NOTE: Coordinate with UF-02300 for underground marking requirements.**  
\*\*\*\*\*

Duct line markers shall be provided [as indicated] [at the ends of long duct line stubouts or for other ducts whose locations are indeterminate because of duct curvature or terminations at completely below-grade structures]. In addition to markers, a 0.127 mm 5 mil brightly colored plastic tape, not less than 75 mm 3 inches in width and suitably inscribed at not more than 3 m 10 feet on centers with a continuous metallic backing and a corrosion-resistant 0.0254 mm 1 mil metallic foil core to permit easy



location of the duct line, shall be placed approximately 300 mm 12 inches below finished grade levels of such lines.

### 3.6 MANHOLES, HANDHOLES, AND PULLBOXES

#### 3.6.1 General

Manholes shall be constructed approximately where shown. The exact location of each manhole shall be determined after careful consideration has been given to the location of other utilities, grading, and paving. The location of each manhole shall be approved by the Contracting Officer before construction of the manhole is started. Manholes shall be the type noted on the drawings and shall be constructed in accordance with the applicable details as indicated. Top, walls, and bottom shall consist of reinforced concrete. Walls and bottom shall be of monolithic concrete construction. The Contractor may at his option utilize monolithically constructed precast-concrete manholes having the required strength and inside dimensions as required by the drawings or specifications. In paved areas, frames and covers for manhole and handhole entrances in vehicular traffic areas shall be flush with the finished surface of the paving. In unpaved areas, the top of manhole covers shall be approximately 15 mm 1/2 inch above the finished grade. Where existing grades that are higher than finished grades are encountered, concrete assemblies designed for the purpose shall be installed to elevate temporarily the manhole cover to existing grade level. All duct lines entering manholes must be installed on compact soil or otherwise supported when entering a manhole to prevent shear stress on the duct at the point of entrance to the manhole. Duct lines entering cast-in-place concrete manholes shall be cast in-place with the manhole. Duct lines entering precast concrete manholes through a precast knockout penetration shall be grouted tight with a portland cement mortar. PVC duct lines entering precast manholes through a PVC endbell shall be solvent welded to the endbell. A cast metal grille-type sump frame and cover shall be installed over the manhole sump. A cable-pulling iron shall be installed in the wall opposite each duct line entrance.

#### 3.6.2 Electric Manholes

\*\*\*\*\*  
**NOTE: Provide the plastic coating or supports where  
corrosive conditions in manholes are anticipated.  
Determine from the Using Agency what types of  
communication cables the Contractor should provide.**  
\*\*\*\*\*

Cables shall be securely supported from walls by hot-dip galvanized cable racks with a plastic coating over the galvanizing and equipped with adjustable hooks and insulators. The number of cable racks indicated shall be installed in each manhole and not less than 2 spare hooks shall be installed on each cable rack. Insulators shall be made of high-glazed porcelain. Insulators will not be required on spare hooks.

#### 3.6.3 Communications Manholes

The number of hot-dip galvanized cable racks with a plastic coating over the galvanizing indicated shall be installed in each telephone manhole. Each cable rack shall be provided with 2 cable hooks. Cables for the telephone and communication systems will be installed by others.

#### 3.6.4 Handholes

Handholes shall be located approximately as shown. Handholes shall be of the type noted on the drawings and shall be constructed in accordance with the details shown.

#### 3.6.5 Pullboxes

Pullbox tops shall be flush with sidewalks or curbs or placed 15 mm 1/2 inch above surrounding grades when remote from curbed roadways or sidewalks. Covers shall be marked "Low-Voltage" and provided with 2 lifting eyes and 2 hold-down bolts. Each box shall have a suitable opening for a ground rod. Conduit, cable, ground rod entrances, and unused openings shall be sealed with mortar.

#### 3.6.6 Ground Rods

A ground rod shall be installed at the manholes, handholes and pullboxes. Ground rods shall be driven into the earth before the manhole floor is poured so that approximately 100 mm 4 inches of the ground rod will extend above the manhole floor. When precast concrete manholes are used, the top of the ground rod may be below the manhole floor and a No. 1/0 AWG ground conductor brought into the manhole through a watertight sleeve in the manhole wall.

### 3.7 PAD-MOUNTED EQUIPMENT INSTALLATION

\*\*\*\*\*  
**NOTE: Provide a typical concrete pad detail for each different piece of equipment by size range (typical dimensions and weight). The pad detail should depict welded wire fabric or steel reinforcing bars, sized and spaced as required to support the equipment. Exact pad dimensions are equipment specific and are the responsibility of the Contractor. Require grouting of rectangular holes (windows) in the concrete pad if rodent intrusion is a problem.**  
\*\*\*\*\*

Pad-mounted equipment, shall be installed on concrete pads in accordance with the manufacturer's published, standard installation drawings and procedures, except that they shall be modified to meet the requirements of this document. Units shall be installed so that they do not damage equipment or scratch painted or coated surfaces. After installation, surfaces shall be inspected and scratches touched up with a paint or coating provided by the manufacturer especially for this purpose. Three-phase transformers shall be installed with [\_\_\_\_\_] phase sequence. Primary taps shall be set at [\_\_\_\_\_].

#### 3.7.1 Concrete Pads

##### 3.7.1.1 Construction

Concrete pads for pad-mounted electrical equipment [may be either pre-fabricated or] [shall be] poured-in-place. Pads shall be constructed as indicated, except that exact pad dimensions and mounting details are equipment specific and are the responsibility of the Contractor. Tops of concrete pads shall be level and shall project 100 mm 4 inches above

finished [floor] [paving or grade] and sloped to drain. Edges of concrete pads shall have 19 mm 3/4 inch chamfer. Conduits for primary, secondary, and grounding conductors shall be set in place prior to placement of concrete pads. Where grounding electrode conductors are installed through concrete pads, PVC conduit sleeves shall be installed through the concrete to provide physical protection. To facilitate cable installation and termination, the concrete pad shall be provided with a rectangular hole below the primary and secondary compartments, sized in accordance with the manufacturer's recommended dimensions. Upon completion of equipment installation the rectangular hole shall be filled with masonry grout.

#### 3.7.1.2 Concrete and Reinforcement

Concrete work shall have minimum 20 MPa 3000 psi compressive strength and conform to the requirements of Section 03300A CAST-IN-PLACE STRUCTURAL CONCRETE. Concrete pad reinforcement shall be in accordance with Section 03200A CONCRETE REINFORCEMENT.

#### 3.7.1.3 Sealing

When the installation is complete, the Contractor shall seal all conduit and other entries into the equipment enclosure with an approved sealing compound. Seals shall be of sufficient strength and durability to protect all energized live parts of the equipment from rodents, insects, or other foreign matter.

#### 3.7.2 Padlocks

Padlocks shall be provided for pad-mounted equipment and for each fence gate. Padlocks shall be keyed [alike] [as directed by the Contracting Officer].

#### 3.7.3 Fencing

\*\*\*\*\*  
**NOTE: Delete this paragraph when fencing is not required. Ensure adequate space between the transformer and the fence for equipment operation in accordance with IEEE C2.**  
\*\*\*\*\*

Fencing shall conform to the requirement of and be installed in accordance with Section 02821A FENCING. Fences shall provide working clearances for operation and maintenance in accordance with IEEE C2. The entire space between fences and concrete pads shall be excavated to a minimum depth of 100 mm 4 inches below finished gradelines, shall be graded to reasonably level surfaces, and filled with well-compacted clean coarse gravel or crushed stone of 13 to 40 mm 1/2 to 1-1/2 inches graded size up to finished gradelines. Space between fences and concrete pads shall be excavated to a minimum depth of 100 mm 4 inches below finished gradelines, shall be graded to reasonably level surfaces, and filled with well-compacted clean coarse gravel or crushed stone of 13 to 40 mm 1/2 to 1-1/2 inches graded size up to finished gradelines.

#### 3.8 CONNECTIONS BETWEEN AERIAL AND UNDERGROUND SYSTEMS

Connections between aerial and underground systems shall be made as shown. Underground cables shall be extended up poles in [guards] [conduit] to cable terminations. Conduits shall be secured to the poles by 2-hole

galvanized steel pipe straps spaced not more than 3 m 10 feet apart and with 1 strap not more than 300 mm 12 inches from any bend or termination. Cable guards shall be secured to poles in accordance with the manufacturer's published procedures. Conduits shall be equipped with bushings to protect cables and minimize water entry. Capnut potheads shall be used to terminate medium-voltage multiple-conductor cable. Cables shall be supported by devices separate from the conduit or guard, near their point of exit from the conduit or guard. Pole installation shall be in accordance with Section 16370A ELECTRICAL DISTRIBUTION SYSTEM, AERIAL.

### 3.9 CONNECTIONS TO BUILDINGS

\*\*\*\*\*  
**NOTE: Specify a depth below the frost line and coordinate with UFGS-16402 INTERIOR DISTRIBUTION SYSTEM. Specify or depict conduit sealing method.**  
\*\*\*\*\*

Cables shall be extended into the various buildings as indicated, and shall be connected to the first applicable termination point in each building. Interfacing with building interior conduit systems shall be at conduit stubouts terminating 1.5 m 5 feet outside of a building and [600] [\_\_\_\_\_] mm [2] [\_\_\_\_\_] feet below finished grade as specified and provided under Section 16402 INTERIOR DISTRIBUTION SYSTEM. After installation of cables, conduits shall be sealed [with caulking compound] [\_\_\_\_\_] to prevent entrance of moisture or gases into buildings.

### 3.10 GROUNDING

\*\*\*\*\*  
**NOTE: The designer will specify the grounding configuration and the number and type of electrodes required. See TM 5-811-1/AF AFJMAN 32-1080 for guidance. Coordinate with NFPA 70 and IEEE C2.**  
\*\*\*\*\*

A ground [mat] [ring] consisting of the indicated configuration of bare copper conductors and driven ground rods shall be installed [under] [around] pad-mounted equipment as shown. Equipment frames of metal-enclosed equipment, and other noncurrent-carrying metal parts, such as cable shields, cable sheaths and armor, and metallic conduit shall be grounded. At least 2 connections shall be provided from [a transformer,] [a switchgear ground bus,] [and] [a unit substation] to the ground mat. Metallic frames and covers of handholes and pull boxes shall be grounded by use of a braided, copper ground strap with equivalent ampacity of No. 6 AWG.

#### 3.10.1 Grounding Electrodes

\*\*\*\*\*  
**NOTE: Modify and/or delete in accordance with project requirements.**

The designer should investigate the soil resistivity during the preliminary design phase to determine the design required to ensure that the grounding values are obtained. For areas where the water table is low and/or the soil resistivity is high (such as volcanic soils, sand, or rock), delete the additional electrode provisions and provide a design

to meet the site requirements.

\*\*\*\*\*

Grounding electrodes shall be installed as shown on the drawings and as follows:

a. Driven rod electrodes - Unless otherwise indicated, ground rods shall be driven into the earth until the tops of the rods are approximately 300 mm 1 foot below finished grade.

b. Ground mat - A ground mat shall be installed as shown consisting of bare copper conductors installed [300] [450] [600] mm [12] [18] [24] inches, plus or minus 75 mm 3 inches, below the finished top of soil grade. Mat conductors shall be bonded to all rod electrodes, electrolytic electrodes, and to all other intersecting mat conductors. Mat conductors shall be sized as shown on the drawings.

c. Ground ring - A ground ring shall be installed as shown consisting of bare copper conductors installed [300] [450] [600] mm [12] [18] [24] inches, plus or minus 75 mm 3 inches below finished top of soil grade. Ground ring conductors shall be [sized as shown] [No. 2 AWG, minimum].

d. Additional electrodes - When the required ground resistance is not met, additional electrodes shall be provided [interconnected with grounding conductors] [as indicated] to achieve the specified ground resistance. The additional electrodes will be [up to three, [2.4] [3] m [8] [10] feet rods spaced a minimum of [3] [3.7] m [10] [12] feet apart] [a single extension-type rod, [15.9] [19.1] mm [5/8] [3/4] inch diameter, up to 9.1 m 30 feet long, [driven perpendicular to grade] [coupled and driven with the first rod]]. In high ground resistance, UL listed chemically charged ground rods may be used. If the resultant resistance exceeds 25 ohms measured not less than 48 hours after rainfall, the Contracting Officer shall be notified immediately.

### 3.10.2 Grounding and Bonding Connections

Connections above grade shall be made by the fusion-welding process or with bolted solderless connectors, in compliance with UL 467, and those below grade shall be made by a fusion-welding process. Where grounding conductors are connected to aluminum-composition conductors, specially treated or lined copper-to-aluminum connectors suitable for this purpose shall be used.

### 3.10.3 Grounding and Bonding Conductors

Grounding and bonding conductors include conductors used to bond transformer enclosures and equipment frames to the grounding electrode system. Grounding and bonding conductors shall be sized as shown, and located to provide maximum physical protection. Bends greater than 45 degrees in ground conductors are not permitted. Routing of ground conductors through concrete shall be avoided. When concrete penetration is necessary, nonmetallic conduit shall be cast flush with the points of concrete entrance and exit so as to provide an opening for the ground conductor, and the opening shall be sealed with a suitable compound after installation.

### 3.10.4 Surge Arrester Grounding

\*\*\*\*\*

**NOTE: Provide a "detail" for surge arrester grounding. See TM 5-811-1/AF AFJMAN 32-1080 for guidance. For ungrounded and single-grounded systems, modify paragraph in accordance with IEEE C2 and TM 5-811-1/AF AFJMAN 32-1080.**

\*\*\*\*\*

Surge arresters and neutrals shall be bonded directly to the transformer enclosure and then to the grounding electrode system with a bare copper conductor, sized as shown. Lead lengths shall be kept as short as practicable with no kinks or sharp bends.

### 3.10.5 Manhole, Handhole, or Concrete Pullbox Grounding

Ground rods installed in manholes, handholes, or concrete pullboxes shall be connected to cable racks, cable-pulling irons, the cable shielding, metallic sheath, and armor at each cable joint or splice by means of a No. 4 AWG braided tinned copper wire. Connections to metallic cable sheaths shall be by means of tinned terminals soldered to ground wires and to cable sheaths. Care shall be taken in soldering not to damage metallic cable sheaths or shields. Ground rods shall be protected with a double wrapping of pressure-sensitive plastic tape for a distance of 50 mm 2 inches above and 150 mm 6 inches below concrete penetrations. Grounding electrode conductors shall be neatly and firmly attached to manhole or handhole walls and the amount of exposed bare wire shall be held to a minimum.

### 3.10.6 Metal Splice Case Grounding

Metal splice cases for medium-voltage direct-burial cable shall be grounded by connection to a driven ground rod located within 600 mm 2 feet of each splice box using a grounding electrode conductor having a current-carrying capacity of at least 20 percent of the individual phase conductors in the associated splice box, but not less than No. 6 AWG.

### 3.10.7 Riser Pole Grounding

A single continuous vertical grounding electrode conductor shall be installed on each riser pole and connected directly to the grounding electrodes indicated on the drawings or required by these specifications. All equipment, neutrals, surge arresters, and items required to be grounded shall be connected directly to this vertical conductor. The grounding electrode conductor shall be sized as shown. Grounding electrode conductors shall be stapled to wood poles at intervals not exceeding 600 mm 2 feet.

## 3.11 FIELD TESTING

\*\*\*\*\*

**NOTE: Select types to suit project conditions and delete all others. Delete all paragraphs not applicable. Tests must be justified.**

\*\*\*\*\*

### 3.11.1 General

Field testing shall be performed in the presence of the Contracting Officer. The Contractor shall notify the Contracting Officer [\_\_\_\_\_] days prior to conducting tests. The Contractor shall furnish all materials, labor, and equipment necessary to conduct field tests. The Contractor

shall perform all tests and inspections recommended by the manufacturer unless specifically waived by the Contracting Officer. The Contractor shall maintain a written record of all tests which includes date, test performed, personnel involved, devices tested, serial number and name of test equipment, and test results. Field test reports shall be signed and dated by the Contractor.

#### 3.11.2 Safety

The Contractor shall provide and use safety devices such as rubber gloves, protective barriers, and danger signs to protect and warn personnel in the test vicinity. The Contractor shall replace any devices or equipment which are damaged due to improper test procedures or handling.

#### 3.11.3 Ground-Resistance Tests

The resistance of [each grounding electrode] [each grounding electrode system] [the ground mat] [the ground ring] shall be measured using the fall-of-potential method defined in IEEE Std 81. Ground resistance measurements shall be made before the electrical distribution system is energized and shall be made in normally dry conditions not less than 48 hours after the last rainfall. Resistance measurements of separate grounding electrode systems shall be made before the systems are bonded together below grade. The combined resistance of separate systems may be used to meet the required resistance, but the specified number of electrodes must still be provided.

- a. Single rod electrode - [25] [\_\_\_\_\_] ohms.
- b. Multiple rod electrodes - [\_\_\_\_\_] ohms.
- c. Ground mat - [\_\_\_\_\_] ohms.
- d. Ground ring - [\_\_\_\_\_] ohms.

#### 3.11.4 Ground-Mat Connection Inspection

All below-grade ground-mat connections will be visually inspected by the Contracting Officer before backfilling. The Contractor shall notify the Contracting Officer [\_\_\_\_\_] hours before the site is ready for inspection.

#### 3.11.5 Medium-Voltage Cable Test

\*\*\*\*\*  
NOTE: If the installation is tapping a new feeder to an existing feeder using a "T" splice, modify the paragraph to indicate that when existing cable cannot be readily disconnected, the system should only be tested to the lower (after installation) voltage.  
\*\*\*\*\*

After installation and before the operating test or connection to an existing system, the medium-voltage cable system shall be given a high potential test. Direct-current voltage shall be applied on each phase conductor of the system by connecting conductors as one terminal and connecting grounds or metallic shieldings or sheaths of the cable as the other terminal for each test. Prior to making the test, the cables shall be isolated by opening applicable protective devices and disconnecting

equipment. The test shall be conducted with all splices, connectors, and terminations in place. The method, voltage, length of time, and other characteristics of the test for initial installation shall be for the particular type of cable installed, except that 28 kV and 35 kV insulation test voltages shall be in accordance with either AEIC C8 or AEIC CS6 as applicable, and shall not exceed the recommendations of IEEE Std 404 for cable joints and IEEE Std 48 for cable terminations unless the cable and accessory manufacturers indicate higher voltages are acceptable for testing. Should any cable fail due to a weakness of conductor insulation or due to defects or injuries incidental to the installation or because of improper installation of cable, cable joints, terminations, or other connections, the Contractor shall make necessary repairs or replace cables as directed. Repaired or replaced cables shall be retested.

#### 3.11.6 Low-Voltage Cable Test

\*\*\*\*\*  
**NOTE: The insulation resistance test (dielectric test) value is based on the recommendation contained in IEEE Std 525, IEEE Guide for the Design and Installation of Cable Systems in Substations.**  
\*\*\*\*\*

Low-voltage cable, complete with splices, shall be tested for insulation resistance after the cables are installed, in their final configuration, ready for connection to the equipment, and prior to energization. The test voltage shall be 500 volts dc, applied for one minute between each conductor and ground and between all possible combinations conductors in the same trench, duct, or cable, with all other conductors in the same trench, duct, or conduit. The minimum value of insulation shall be:

$R \text{ in megohms} = (\text{rated voltage in kV} + 1) \times 304.8 / (\text{length of cable in meters})$

$R \text{ in megohms} = (\text{rated voltage in kV} + 1) \times 1000 / (\text{length of cable in feet})$

Each cable failing this test shall be repaired or replaced. The repaired cable shall be retested until failures have been eliminated.

#### 3.11.7 Liquid-Filled Transformer Tests

The following field tests shall be performed on [all liquid-filled transformers] [liquid-filled transformers [\_\_\_\_\_] kVA and above]. Pass-fail criteria shall be in accordance with transformer manufacturer's specifications.

- a. Insulation resistance test phase-to-ground.
- b. Turns ratio test.
- c. Correct phase sequence.
- d. Correct operation of tap changer.
- e. [\_\_\_\_\_]

#### 3.11.8 Dry-Type Transformer Tests

The following field tests shall be performed on [all dry-type transformers] [dry-type transformer [\_\_\_\_\_] kVA and above]. Pass-fail criteria shall be



in accordance with the transformer manufacturer's specifications.

- a. Insulation resistance test phase-to-ground.
- b. Turns ratio test.
- c. [\_\_\_\_\_]

#### 3.11.9 Circuit Breaker Tests

The following field tests shall be performed on circuit breakers. Pass-fail criteria shall be in accordance with the circuit breaker manufacturer's specifications.

- a. Insulation resistance test phase-to-phase.
- b. Insulation resistance test phase-to-ground.
- c. Closed breaker contact resistance test.
- d. Power factor test.
- e. High-potential test.
- f. [Manual] [and] [electrical] operation of the breaker.

#### 3.11.10 Power Circuit Breaker Tests

\*\*\*\*\*  
**NOTE: List specific breakers to be tested. Delete  
entirely if test not required.**  
\*\*\*\*\*

The following power circuit breakers shall be tested in accordance with ANSI C37.50.

- a. [\_\_\_\_\_].
- b. [\_\_\_\_\_].
- c. [\_\_\_\_\_].

#### 3.11.11 Protective Relays

Protective relays shall be visually and mechanically inspected, adjusted, tested, and calibrated in accordance with the manufacturer's published instructions. Tests shall include pick-up, timing, contact action, restraint, and other aspects necessary to ensure proper calibration and operation. Relay settings shall be implemented in accordance with the coordination study. Relay contacts shall be manually or electrically operated to verify that the proper breakers and alarms initiate. Relaying current transformers shall be field tested in accordance with IEEE C57.13.

#### 3.11.12 Pre-Energization Services

Calibration, testing, adjustment, and placing into service of the installation shall be accomplished by a manufacturer's product field service engineer or independent testing company with a minimum of 2 years of current product experience. The following services shall be performed

on the equipment listed below. These services shall be performed subsequent to testing but prior to the initial energization. The equipment shall be inspected to ensure that installation is in compliance with the recommendations of the manufacturer and as shown on the detail drawings. Terminations of conductors at major equipment shall be inspected to ensure the adequacy of connections. Bare and insulated conductors between such terminations shall be inspected to detect possible damage during installation. If factory tests were not performed on completed assemblies, tests shall be performed after the installation of completed assemblies. Components shall be inspected for damage caused during installation or shipment to ensure packaging materials have been removed. Components capable of being both manually and electrically operated shall be operated manually prior to the first electrical operation. Components capable of being calibrated, adjusted, and tested shall be calibrated, adjusted, and tested in accordance with the instructions of the equipment manufacturer. Items for which such services shall be provided, but are not limited to, are the following:

- a. Secondary unit substation
- b. Pad-mounted transformers
- c. Panelboards
- d. Switchboards
- e. Metal-enclosed switchgear
- f. Busways
- g. Switches

#### 3.11.13 Operating Tests

After the installation is completed, and at such times as the Contracting Officer may direct, the Contractor shall conduct operating tests for approval. The equipment shall be demonstrated to operate in accordance with the requirements herein. An operating test report shall be submitted including the following:

- a. A list of equipment used, with calibration certifications.
- b. A copy of measurements taken.
- c. The dates of testing.
- d. The equipment and values to be verified.
- e. The condition specified for the test.
- f. The test results, signed and dated.
- g. A description of adjustments made.

#### 3.12 MANUFACTURER'S FIELD SERVICE

\*\*\*\*\*  
NOTE: Delete if not required.  
\*\*\*\*\*

#### 3.12.1 Onsite Training

The Contractor shall conduct a training course for the operating staff as designated by the Contracting Officer. The training period shall consist of a total of [\_\_\_\_\_] hours of normal working time and shall start after the system is functionally completed but prior to final acceptance tests. The course instruction shall cover pertinent points involved in operating, starting, stopping, and servicing the equipment, as well as all major elements of the operation and maintenance manuals. Additionally, the course instructions shall demonstrate all routine maintenance operations. A [\_\_\_\_\_] [VHS] format video tape of the entire training session shall be submitted.

#### 3.12.2 Installation Engineer

After delivery of the equipment, the Contractor shall furnish one or more field engineers, regularly employed by the equipment manufacturer to supervise the installation of the equipment, assist in the performance of the onsite tests, initial operation, and instruct personnel as to the operational and maintenance features of the equipment.

#### 3.13 ACCEPTANCE

Final acceptance of the facility will not be given until the Contractor has successfully completed all tests and after all defects in installation, material or operation have been corrected.

-- End of Section --