UFC 3-520-01
16 January 2025

UNIFIED FACILITIES CRITERIA (UFC)

INTERIOR ELECTRICAL SYSTEMS

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INTERIOR ELECTRICAL SYSTEMS

Indicate the Military Department Preparing Activity responsible for the document.

U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING SYSTEMS COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

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

Change No.	Date	Location

This UFC supersedes UFC 3-520-01, dated 06 October 2015.

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FOREWORD

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

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Military Department's responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Systems Command (NAVFAC), and Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Technical content of UFC is the responsibility of the cognizant DoD working group. Defense Agencies should contact the respective DoD Working Group for document interpretation and improvements. Recommended changes with supporting rationale may be sent to the respective DoD working group by submitting a Criteria Change Request (CCR) via the Internet site listed below.

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

- Whole Building Design Guide website https://www.wbdg.org/dod.

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

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This Unified Facilities Criteria (UFC) has been issued to provide guidance for the design of interior electrical systems. The criteria contained herein are intended to ensure economical, durable, efficient, and reliable systems and installations. Whenever unique conditions and problems are not specifically covered by this UFC, use the applicable referenced industry standards and other documents for design guidance.

UFC 3-501-01 provides the governing criteria for electrical systems, explains the delineation between the different electrical-related UFCs, and refers to UFC 3-520-01 for interior electrical system requirements. Modernization of electrical systems within existing facilities solely for the purpose of meeting design criteria in this UFC is not required. Upgrades or modifications of existing facilities must apply the design criteria in this UFC, but it is not intended that an entire facility require modernization solely because of a minor modification to a part of the facility.

1-2 REISSUES AND CANCELS.

This UFC reissues and cancels UFC 3-520-01, dated 06 October 2015.

1-3 APPLICABILITY.

This UFC applies to planning, design, construction, sustainment, restoration, and modernization of DoD-owned facilities. It applies to all methods of project delivery and levels of construction as defined by UFC 1-200-01, Section 1-3.

1-3.1 UFC Scope.

Compliance with this UFC is mandatory for the design of interior electrical systems at all facilities and bases. This UFC typically applies up to 5 feet beyond the facility envelope. It also applies to:

- Service(s) supplying power from the utility system utilization transformer to the wiring system of the facility.
- Circuits originating from within the facility that extend beyond the facility envelope.
- Wiring and connections for supplemental grounding systems.
- Wiring from and connections to non-utility equipment supplying power to the wiring system of the facility, including engine-generator sets, photovoltaic power systems and fuel cells.

Refer to UFC 3-550-01 for exterior electrical systems.

1-3.2 Host Nation Standards.

In addition to NFPA 70 requirements, facilities located outside of the United States must also comply with the applicable host nation standards. Host nation voltage and frequency as defined in UFC 3-510-01 generally applies. Different wiring and grounding conventions usually apply in other host nations; however, follow the design principles provided in this UFC to the extent practical.

1-4 GENERAL BUILDING REQUIREMENTS.

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

1-5 CYBERSECURITY.

All facility-related control systems (including systems separate from a utility monitoring and control system) must be planned, designed, acquired, executed, and maintained in accordance with UFC 4-010-06, and as required by individual Service Implementation Policy.

Cybersecurity is implemented to mitigate vulnerabilities to all DoD real property facility-related control systems to a level that is acceptable to the System Owner and Authorizing Official. UFC 4-010-06 provides requirements for integrating cybersecurity into the design and construction of control systems.

1-6 DESIGN STANDARDS.

Comply with the requirements of National Fire Protection Association (NFPA) 70, National Electrical Code, and the requirements herein. Electrical safety requirements, including the types of energized work permitted, approval process for energized work, and Personal Protective Equipment (PPE), applicable to the design, installation, and operation of electrical systems are provided in UFC 3-560-01.

Note: When a project, or portion of a project, has been designated as requiring Critical Operations Power Systems (COPS) treatment as a Designated Critical Operations Area (DCOA) per NFPA 70 Article 708, those requirements identified in the Unified Facility Criteria that are more stringent than NFPA 70 requirements take precedence over NFPA requirements. This UFC does not address COPS requirements.

1-7 GLOSSARY.

APPENDIX C contains acronyms, abbreviations, and terms.

1-8 REFERENCES.

APPENDIX D contains a list of references used in this document. The publication date of the code or standard is not included in this document. Unless otherwise specified, the most recent edition of the referenced publication applies.

References applicable to a specific topic are also listed and described in the appropriate sections of this UFC. Codes and standards are referenced throughout this UFC. Follow the guidance provided in UFC 1-200-01, Section 1-3.1 to establish the issue/version of the publication effective for the project.

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CHAPTER 2 GENERAL POWER SYSTEM CRITERIA

2-1 VOLTAGE.

Refer to UFC 3-550-01 for voltage criteria associated with the primary distribution supply voltage.

Unless there are specialty voltage requirements, base the facility system voltage on the interior load requirements as follows:

- Apply 240/120V for facilities with only single-phase loads.
- Apply three-phase, four-wire, 208Y/120V systems for lighting and power demand loads less than 150 kVA.
- Apply three-phase, four-wire, 480Y/277V systems for lighting and power demand loads greater than 150 kVA unless 208Y/120V systems are shown to be more cost-effective. Use step-down transformers inside the facility as required to obtain lower voltages.
- For facilities with demand loads less than or equal to 150 kVA in which potential voltage drop issues have been identified, evaluate the life cycle cost effectiveness of installing larger conductor sizes and/or buck-boost transformers on a 208Y/120V system against the use of a 480Y/277V service utilizing step-down transformers. If determined that the life cycle cost is effective, the use of a 480Y/277V service shall be used in lieu of a 208Y/120V service.

2-2 FREQUENCY.

Apply a frequency of 60 Hz for distribution and utilization power.

In locations in which the commercially supplied frequency is other than 60 Hz, such as 50 Hz, use the available supplied frequency to the extent practical. Where frequencies other than that locally available are required for technical purposes, frequency conversion or generation equipment can be installed. The facility user will normally provide this equipment.

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CHAPTER 3 POWER DISTRIBUTION AND UTILIZATION

3-1 TRANSFORMERS.

The transformer design criteria provided herein apply to interior applications and to dry-type transformers fed by distribution traditionally placed in/for the facility downstream of the main service. Most facilities will be supplied by an exterior utility system pad-mounted transformer.

Interior transformers shall be sized according to the NEC.

3-1.1 Low Voltage Transformers.

Specify dry-type transformers in accordance with NEMA ST 20 and the following:

- For transformers rated for 15 kVA or larger, use transformers with a 428 degrees F (220 degree C) insulation system not to exceed a 239 degrees F (115 degree C) rise capable of carrying continuously 115 percent of nameplate kVA without exceeding insulation rating at a maximum ambient temperature of 104 degrees F (40 degrees C). Provide a transformer of 80 degrees C temperature rise capable of carrying continuously 130 percent of nameplate kVA without exceeding insulation rating when additional overload capacity is required.
- Transformers rated less than 15 kVA can use a 356 degrees F (180 degree C) insulation system not to exceed an 176 degrees F (80 degree C) rise at a maximum ambient temperature of 104 degrees F (40 degrees C).
- When the transformer is located in areas where noise is a factor, specify sound levels at least 3 decibels below recommended values established by NEMA ST 20.
- Derate the transformer in accordance with the manufacturer’s guidance for locations with a maximum ambient temperature above 104 degrees F (40 degrees C) and in accordance NEMA ST 20 for altitudes higher than 3,300 feet (1,000 meters).

Include the following as part of the installation:

- Design system such that transformer vibrations are not transmitted to the surrounding structure. Small transformers can usually be solidly mounted on a reinforced concrete floor or wall. Flexible mounting will be necessary if the transformer is mounted to the structure in a normally low-ambient noise area.
- Use flexible couplings and conduit to minimize vibration transmission through the connection points.

- Locate the transformer in spaces where the sound level is not increased by sound reflection. For example, in terms of sound emission, the least desirable transformer location is in a corner near the ceiling because the walls and ceiling function as a megaphone.
- Provide adequate ventilation in transformer spaces to prevent the temperature rise from exceeding the transformer rating.

Refer to TSEWG TP-05, Interior Transformer Ratings and Installation, at https://wbdg.org/dod/supp-tech-documents for additional information regarding transformers and transformer ratings.

3-1.2 Other Transformer Types.

Do not use unless justified and documented in the design analysis. Refer to Appendix B for additional guidance for applications involving significant harmonic distortion.

3-2 SERVICE ENTRANCE AND DISTRIBUTION EQUIPMENT.

Locate service entrance equipment and other major electrical equipment in a dedicated electrical space. Provide a main breaker on each service entrance either outside of a building or structure or inside nearest the point of entrance of the service conductors in accordance with NFPA 70. Service feeders may be installed under the building only when necessary or for optimal routing. Distances shall be minimal. Locate other electrical equipment, such as electrical panels, in dedicated spaces.

Note: Identify when 100 percent rated circuit breakers are included in the design.

Size circuit breaker interrupting ratings based on the available short circuit current; however, do not select circuit breakers less than 10 kA symmetrical interrupting rating for voltages 240V and below and 14 kA symmetrical interrupting rating for 480V applications. The use of series-rated combinations of breakers to clear a fault that utilize an individual breaker rated at less than the available fault current is prohibited.

Do not use fusible overcurrent devices except when non-fusible overcurrent devices will not comply with NFPA 70 requirements for selective coordination.

3-2.1 Spare Capacity.

Provide a minimum of 15% empty space and 15% spare capacity (ampacity) for all switchgear, switchboards, panelboards, and load centers. For flush-mounted equipment, provide spare conduits extending up above the ceiling and down below raised floors when applicable. For panelboards, provide one spare conduit, minimum of ¾-inch (20 mm), for every three spare circuit breakers and for every three empty pole positions. Round up the sum of spare breakers and empty pole positions to the nearest multiple of three.

Note: Do not use spare capacity as part of the demand calculations specified in UFC 3-501-01. The overall calculations already account for this spare capacity with the 15% allowance for future load growth specified in UFC 3-501-01 load analysis calculations for the service entrance.

3-2.2 Selection.

Select equipment as follows:

- Specify metal-enclosed switchgear when the equipment is 1200A or larger, and branch and feeder circuits are above 400A or if any branch or feeder circuits is larger than 800A.
- Specify switchboards when the equipment feeds circuit breakers 800A or larger. Utilize switchboards throughout the distribution system where equipment is 1200A or larger.
- Specify distribution system type panelboards when the equipment is 800 – 1200A. Utilize panelboards up to 600A if they can be accommodated in one enclosure.

For all circuit breakers where the continuous current trip setting for the actual overcurrent device in the circuit breaker is rated for or can be adjusted is 1,200 amperes or higher, select the method used to reduce the clearing time for arc energy reduction:

- Zone-selective interlocking, or
- Differential relaying, or
- Energy-reducing maintenance switching with local status indicator, or
- Energy-reducing active arc flash mitigation system or
- An approved equivalent means.

3-2.3 Switchgear.

Design metal-enclosed switchgear per IEEE C37.20.1 and UL 1558. Provide electrically operated circuit breakers. The switchgear and circuit breakers must be the product of the same manufacturer.

Evaluate the following options as part of the switchgear design:

- Arc-resistant switchgear tested and certified to IEEE C37.20.7 to provide added protection for internal arcing faults.
- Infrared viewing windows to allow the use of an infrared camera or thermal imager direct line of site to inspect electrical connections without requiring the opening of panels and doors.
- A remote racking mechanism to allow an operator to rack a circuit breaker in or out at least 20 feet from the front of the equipment.

- Drawout compartment shutters to protect operators from accidental contact with breaker stabs when a circuit breaker is withdrawn from its cubicle.
- Evaluate medium-voltage gas-insulated switchgear (GIS) with vacuum circuit breakers when the facility owner requires more than 99.9% availability, or the switchgear must fit in a small footprint. GIS switchgear must be tested and certified per IEEE C37.20.9

3-2.4 Switchboards.

Design switchboards per NEMA PB2 and UL 891. Devices must be front accessible and must be completely isolated between sections by vertical steel barriers. Switchboards should have hinged fronts to allow safer maintenance access for electrical safety.

3-2.5 Panelboards.

3-2.5.1 Configuration.

Equip panelboards and load centers with separate ground bus bars and insulated neutral bus bars to isolate the bus bar, when required by code. Circuit breakers must be bolt-on type unless where specifically indicated otherwise for load center type panelboards. Do not use dual section panelboards.

Do not use panelboards or load centers with more than 54 poles unless any of the following conditions are met.

- All of the loads are served by a redundant source, or
- The customer accepts in writing the risk of larger outages and the AHJ approves the larger panelboard or load center.

Distribution and branch circuit panelboards should be of the wall-mounted, dead-front type, equipped with bolt-on circuit breakers. Load center style panelboards, with plug-in breakers should be used only where authorized for military family housing. Each panelboard and load center style panelboard must be fed from a dedicated circuit and circuit breaker.

3-2.5.2 Location and Design.

Place panelboards as close as possible to the center of the loads to be served. Provide panelboards with hinged fronts to allow safer maintenance access for electrical safety. Clearly fill out panelboard circuit directories indicating the specific load and location, such as “Lights, Room 102”.

Optimize equipment layout and circuit arrangement. Optimization shall include grouping together circuits going to the same space or area of the building. The phase loading on panelboards shall be balanced as much as practical by the type of loads on the panel.

Take into consideration circuit breaker frame size mismatching when arranging circuits across from each other, as well as additional pole spaces required for specialty features such as 3-pole GFCI electronics and shut trip devices.

3-2.5.3 BEQ/BOQ Facilities and Housing.

Use panelboards for service entrance equipment and electrical distribution in BEQ/BOQ facilities. Load center style panelboards, with plug-in breakers, can be used in housing units and BEQ/BOQ rooms.

3-2.5.4 Arc-Fault Circuit Interrupters.

Provide arc-fault circuit interrupter protection for branch circuits supplying 120V, single-phase,15A and 20A outlets installed in dwelling units as specifically required by NFPA 70.

3-2.6 Motor Control Centers (MCCs).

Comply with UL 845 and NEMA ICS 2.

3-2.7 Power for Fire Protection Systems.

Fire pump and fire pump controller power supply shall satisfy the requirements of NFPA 70 and UFC 3-600-01 rather than the requirements of this subpart.

Provide power for the remainder of the fire protection systems, including fire alarm and mass notification systems, suppression and containment control panels, line voltage indicator systems (such as beacons), transmitter panel, and similar monitoring, control, and reporting equipment but excluding fire pumps and fire pump controllers in accordance with NFPA 72, NFPA 70 Article 760, and as follows:

a. Distribution Configuration(s). A dedicated distribution leg (or multiple legs) shall be supplied from the main distribution equipment to support the fire protection system components described above if either of the following conditions are present:

    1. The building area exceeds 25,000 square feet.

    2. Six or more circuits are required to supply the fire protection system components on a given voltage system (i.e., 208/120V, 480/277V, etc.).

    Circuits for components directly supporting the fire protection components, such as surge protective devices and receptacles in the immediate vicinity of and whose purpose is to perform maintenance on the fire protection components, shall be permitted to be supplied from the dedicated equipment.

    In all other cases, the fire protection system components may be suppled from the portions of the distribution equipment present for other building electrical support, and such distribution components must comply with the succeeding requirements of this section.

Where multiple fire protection circuits are supplied from the same panel not dedicated exclusively to fire protection systems described above, connect the fire protection circuits to physically adjacent pole locations.

Where fire protection circuits for larger equipment (such as nitrogen generators or jockey pumps) are connected to the building main distribution equipment or the main distribution equipment for a backup power system, such circuits do not contribute toward the number of circuits in the threshold listed above. The succeeding requirements apply to the circuits connected directly to the main distribution equipment described in the paragraph.

b. Protection and Control Features. Provide lock-on circuit breakers for all feeders and branch circuits supplying fire protection system components described above. Start providing the lock-on circuit breakers from the load side of the service disconnecting means. Permanently identify in red the lock-on breakers in the branch panelboards, distribution equipment, and dedicated panelboards without obstructing manufacturer’s markings on the breakers.

c. Distribution System Identification. At the distribution equipment, including panelboards, distribution panels, switchboards, switchgear, transformers, enclosed circuit breakers, disconnect switches, transfer switches, and similar equipment which are part of the electrical supply to components described above, provide a label with the following inscription in addition to the equipment nameplate: “Fire Protection/Life safety Equipment.” Construct and fasten the label identical to the panelboard nameplate, except the label must be red laminated plastic with white center core. The service disconnecting means shall not require this supplemental nameplate.

d. Backup Power Sources. For facilities which are provided with emergency power supplies (i.e., engine-driven generator, energy storage system, etc.) supporting life safety functions, fire protection described above must be powered by the backup power supply system. Do not power fire protection systems from UPS systems dedicated to specific compartmentalized functions such as individual telecommunications rooms.

3-2.8 Disconnect Switches.

Fusible disconnect switches should be used only where special considerations require their use. Provide heavy duty type safety switches on systems rated for greater than 240V. Use fused switches that utilize Class R fuseholders and fuses. Use NEMA 4X stainless steel switch enclosures for switches located on building exteriors in areas where salt spray or extended high humidity is a concern.

Utilize non-fused disconnect switches as local disconnects only, properly protected by an upstream protective device.

Note: Selection of disconnect switches must be coordinated with the short circuit calculations. Non-fused disconnects are typically rated to only 10kAIC. In cases where the fault current at a disconnect location is greater than 10KAIC, provide one of the following solutions:

a. Fused disconnect.

b. Enclosed circuit breaker.

c. If NFPA 70 permits for a given application, eliminate the local disconnecting means and provide a lockable circuit breaker at the panel.

3-2.9 Circuit Lockout Requirements.

Circuit breakers, disconnect switches, and other devices that are electrical energy-isolating must be lockable in accordance with NFPA 70E and OSHA 1910.303.

3-2.10 Signage.

Place a safety sign on any cubicles containing more than one voltage source. Refer to ANSI Z535.4 for safety sign criteria.

3-2.11 Interrupting Ratings.

Refer to TSEWG TP-06, Low Voltage Breaker Interrupting Ratings, at https://wbdg.org/dod/supp-tech-documents for additional information regarding low voltage breaker interrupting ratings.

3-2.12 Load Balancing by Phase.

Arrange circuits throughout the distribution system with 5% or less design load imbalance for both single- and three-phase systems. Show load imbalance by phase as a percentage on the panel, switchboard, switchgear, and motor control center schedules. Larger facilities generally will be capable of better phase balancing than smaller facilities. Document within the design analysis the instances where phase balancing below the imbalance threshold is not possible and state the reasons, tradeoffs, and/or broader remedies.

3-2.13 Adjustable Trip Devices.

Where adjustable-trip devices are used and NFPA 70 does not permit use of the maximum trip setting, conductors must be sized with the rated capacity equal to the actual device setting. Perform arc flash calculations based on the actual device setting. In design-bid-build projects, provide contract language requiring the contractor to adjust conductor sizes at the direction of the designer of record should the trip setting on the adjustable devices deviate from the rating indicated on the plans in cases such as complying with selective coordination requirements.

Note: NFPA 70 limits the maximum trip rating for equipment such as transformers and motors. It is also possible for the circuit breaker's trip setting to exceed the bus rating.

Provide labeling on the adjustable-trip device indicating the maximum value to which the conductors are capable of safely carrying after all applicable correction and adjustment factors were applied and voltage drop calculations performed. Additionally, provide warning of the potential for different arc flash conditions should the adjustable trip rating be altered.

Size equipment grounding conductors and perform voltage drop calculations based on the respective approach used: Where the rating is based on restricted access, use the actual setting; where the rating is based on unrestricted access, use the maximum setting possible.

3-3 MOTORS AND MOTOR CONTROL CIRCUITS.

3-3.1 Basic Motor Criteria.

3-3.1.1 Efficiency.

Apply premium efficiency ratings per the Energy Policy Act of 2005 (EPACT 2005) to all motors.

3-3.1.2 Application.

Use three-phase motors if more than 0.5 horsepower rating when such service is available. If three-phase service is not available or if three-phase motor is not available, operate motors larger than 0.5 horsepower at phase-to-phase voltage rather than phase-to-neutral voltage. Motors 0.5 horsepower and smaller must be single phase.

Do not use 230V motors on 208V systems because the utilization voltage will commonly be below the -10% tolerance on the voltage rating for which the motor is designed (a 230V motor is intended for use on a nominal 240V system).

3-3.2 Motor Control Circuits.

3-3.2.1 Motor Controllers.

Provide motor controllers (starters) for motors larger than 1/8 horsepower (93.25 watts) and apply the design criteria of NEMA ICS 1 and NEMA ICS 2.

3-3.2.2 Motor Starting.

Use full voltage-type starting unless the motor starting current will result in more than a 20% transient voltage dip or if the analyzed voltage dip is otherwise determined to be unacceptable. For other than full voltage starting, apply one of the following methods for motor starting:

- Reduced Voltage Starters.
- Adjustable Speed Drives (ASDs) are also referred to as Variable Frequency Drives (VFDs). If an ASD is required for other reasons, it can also address motor starting current design needs. Refer to NEMA ICS 7 for design criteria related to the selection and design of ASDs. Appendix A provides additional information regarding the sizing and operational design of ASDs.

3-3.2.3 Manual Control.

Provide manual control capability for all installations having automatic control that operates the motor directly. Use a double-throw, three-position switch or other suitable device (marked MANUAL-OFF-AUTOMATIC) for the manual control. Confirm that all safety control devices, such as low- or high-pressure cutouts, high-temperature cutouts, and motor overload protective devices, remain connected in the motor control circuit in both the manual and automatic positions.

3-4 SURGE PROTECTIVE DEVICES (SPDS).

Provide SPDs for surge protection of sensitive or critical electronic equipment, as required by the activity or equipment manufacturer.

The design criteria provided here apply to permanently installed, hard-wired surge protectors and should not be applied to plug-in type surge protectors (Type 3). Use point-of-use (plug-in type) surge protectors to protect specific critical equipment that plugs into wall receptacles.

3-4.1 Power System Surge Protection.

Use Type 1 or Type 2 SPD and connect on the load side of a dedicated main circuit breaker of the associated equipment. Where multiple service main disconnects are used the device(s) should be placed as recommended by the manufacturer to protect the circuits. Locate as close as practical to the breaker with a maximum lead length of 3 ft (900 mm). Integral SPDs with surge counters visible from the dead front of the panelboard and manufactured by the panelboard manufacturer are permitted. The SPDs must be rated as Type 1 or Type 2 and comply with UL 1449. The SPDs must include the thermal protection measures and overcurrent protection per UL 1449.

For buildings with high concentrations of electronics equipment, employ a multi-level or cascaded system. Coordinate multiple stage surge protection.

Note: Type 1 SPDs are allowed to be installed ahead of the service entrance MCB when other equipment is required to be connected ahead of the MCB.

3-4.1.1 Service Entrance Surge Protection.

Provide the following specification requirements for SPD on the service entrance equipment

a. Use SPD to protect the electrical service entrance equipment.

b. The SPD must meet or have a voltage protection rating that is less than the UL 1449 voltage protection ratings listed below. If surge protection is required as part of a lightning protection system, comply with the more stringent voltage protection ratings specified in NFPA 780.

System Voltage	Protection Modes	Voltage Protection Rating
208/120 or 240/120	L-N	700
	L-G	700
	N-G	700
	L-L	1,200
480/277	L-N	1,200
	L-G	1,200
	N-G	1,200
	L-L	2,000

c. Per mode single pulse surge current rating for an 8x20 ms waveform must be no less than:

L-N 40kA

L-G 40kA

N-G 40kA

L-L 80kA

d. Protection Mode: Provide the following six modes (additional modes are permitted):

Line-to-line

Line-to-ground or line-to-neutral

Wire SPDs at grounded service entrances in a line-to-ground (L–G) or line-to-neutral (L–N) configuration. For services without a neutral, connect the SPD elements line-to-ground (L–G).

e. MCOV for L-N and L-G modes of operation: 120% of nominal voltage for 240 volts and below; 115% of nominal voltage above 240 volts to 480 volts.

f. Surge Life: Greater than 5000 surges of repetitive sequential IEEE C62.41 Category C3 waveforms with less than 10% degradation of measured limiting voltage.

g. Listing: The total unit as installed must be UL 1283 and UL 1449 listed, and not merely the components or modules.

h. Warranty: Not less than a 5-year warranty and include unlimited free replacements of the unit if destroyed by lightning or other transients during the warranty period.

i. Diagnostics: Visual indication unit has malfunctioned or requires replacement. Provide Form C dry contacts for remote monitoring.

3-4.1.2 Branch Panelboard Surge Protection.

Provide the following specification requirements for SPD on all the branch panelboards for facilities requiring cascaded suppression system protection.

a. Use SPD to protect the distribution branch panelboards.

b. The SPD must meet or have a voltage protection rating that is less than the UL 1449 voltage protection ratings listed below.

System Voltage	Protection Modes	Voltage Protection Rating
208/120 or 240/120	L-N L-G N-G L-L	700 700 700 1,200
480/277	L-N L-G N-G L-L	1,200 1,200 1,200 2,000

c. Per mode single pulse surge current rating for an 8x20 ms waveform must be no less than:

L-N 40kA

L-G 40kA

N-G 40kA

L-L 80kA

d. Protection Mode: Provide the following six modes (additional modes are permitted):

Line-to-line

Line-to-ground or line-to-neutral

Wire SPDs at grounded service entrances in a line-to-ground (L–G) or line-to-neutral (L–N) configuration. For services without a neutral, connect SPD elements line-to-ground (L–G).

e. MCOV for L-N, L-G, and N-G modes of operation: 120% of nominal voltage for 240 volts and below; 115% of nominal voltage above 240 volts to 480 volts.

f. Surge Life: Greater than 5000 surges of repetitive sequential IEEE C62.41 Category B3 waveforms with less than 10% degradation of measured limiting voltage.

g. Listing: The total unit as installed must be UL 1283 and UL 1449 listed, and not merely the components or modules.

h. Warranty: Not less than a 5-year warranty and include unlimited free replacements of the unit if destroyed by lightning or other transients during the warranty period.

i. Diagnostics: Visual indication unit has malfunctioned or requires replacement. Provide Form C dry contacts for remote monitoring.

3-4.1.3 Dwelling Unit Surge Protection.

Install as close as practical to the main breaker/lugs. All leads must be as short as possible, with no leads longer than 24 in (610 mm). Provide protection in accordance with branch panelboard surge protection criteria listed above.

3-4.2 Surge Protection for Communications and Related Systems.

3-4.2.1 Systems Requiring Protection.

Provide surge protection for the following systems, including related systems:

- Fire alarm systems.
- Telephone systems.
- Computer data circuits.
- Security systems.
- Television systems.
- Coaxial cable systems.
- Intercom systems.
- Electronic equipment data lines.

3-4.2.2 Protection Levels.

Provide surge protection equipment used for communications and related systems as follows:

- If surge protection is required as part of a lightning protection system, comply with the more stringent voltage protection ratings specified in NFPA 780.

- If surge protection is not required as part of a lightning protection system, provide the following protection UL Listed and tested to UL 497A, or third party verified and tested to UL 497A:
    - Telephone communication interface circuit protection – provide a minimum surge current rating of 9,000A.
    - Central office telephone line protection – provide multi-stage protection with a minimum surge current rating of 4,000A.
    - Intercom circuit protection – provide a minimum surge current rating of 9,000A. Provide protection on points of entry and exit from separate buildings.
- Provide fire alarm and security alarm system loops and addressable circuits that enter or leave separate buildings, UL Listed or third-party verified and tested to UL 497B, with a minimum of 9,000A surge current rating.
- Protect coaxial lines at points of entry and exit from separate buildings.
- Single stage gas discharge protectors can be used for less critical circuits. Multistage protectors utilizing a gas discharge protector with solid-state secondary stages should be used to obtain lower let-through voltages for more critical equipment.

3-4.3 Acceptance Tests.

Perform the following installation checks:

- Inspect for physical damage and compare nameplate data with drawings and specifications.
- Verify that the surge protector rating is appropriate for the voltage.
- Inspect for proper mounting and adequate clearances.
- Verify that the installation achieves the minimum possible lead lengths. Inspect the wiring for loops or sharp bends that add to the overall inductance.
- Check tightness of connections by using a calibrated torque wrench. Refer to the manufacturer’s instructions or Table 10-1 of International Electrical Testing Association (NETA) ATS for the recommended torque.
- Check the ground lead on each device for individual attachment to the ground bus or ground electrode.
- Perform insulation resistance tests in accordance with the manufacturer’s instructions.

- For surge protectors with visual indications of proper operation (indicating lights), verify that the surge protector displays normal operating characteristics.
- Record the date of installation.

3-5 METERING.

Provide advanced metering systems (e.g., with remote reading, monitoring, or activation capabilities) in accordance with service-specific criteria and the DoD directives to comply with EPACT 2005 requirements. Coordinate meters, system components, and meter locations to be compatible with the Activity’s central system.

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

3-6 RACEWAY AND WIRING.

3-6.1 Wiring Devices.

Wiring devices and faceplate colors must match and be consistent with the interior wall types and colors. Use grounding type wiring devices. Outlet boxes must not be placed back-to-back. Provide a minimum of 12 inch (300 mm) of separation between outlet boxes located on opposite sides on common walls.

3-6.1.1 Switches.

Toggle switches must be specification grade, quiet type, and rated minimum 120/277V, 20A, totally enclosed with bodies of thermoplastic and/or thermoset plastic and mounting strap with grounding screw. Use silver-cadmium contacts and one-piece copper alloy contact arm.

When specified, pilot lights must be integrally constructed as a part of the switch's handle.

3-6.1.2 Receptacles.

Provide general purpose convenience outlets that are specification grade, 20 A, 120 V, duplex. Identify locations where split receptacles will be used with one receptacle controlled by a separate manual or automatic switching device. Provide GFI and AFCI protection in accordance with NFPA 70.

Where required by ASHRAE 90.1, all workstations and work areas must have controlled and non-controlled outlets. For non-systems furniture, duplex receptacles must be split yoke with controlled and non-controlled outlets. Duplex receptacle outlets must be fed from the same circuit. Double duplex receptacles must have controlled and non-controlled outlets fed from the same circuit, but split yoke outlets are not required. Note that GFCI receptacles typically cannot be split wired where both split wiring and GFCI are required. Provide either a GFCI device ahead of the wiring split (such as at the panelboard) or provide a double duplex arrangement where each yoke has a GFCI feature.

In addition to the location requirements specified by NFPA 70, locate general purpose, and dedicated (on an individual circuit) outlets in accordance with the following:

a. Mechanical equipment: Provide receptacle within 25 ft (7.6 m) of mechanical equipment on the interior and exterior of buildings, including roof mounted mechanical equipment.

b. Office, staff-support spaces, and other workstation locations: Minimum of two duplex receptacles, one double duplex, or one quadraplex receptacle for each workstation. Where systems furniture is not to be provided, provide double duplex receptacles a minimum of every 20-ft (5.2 m) of wall space at the floor line. Where there is less than 20-ft (5.2 m) of wall at the floor line in offices and where there are no other provisions for powering workstations (such as with systems furniture), provide a minimum of two duplex receptacles spaced appropriately to anticipate furniture relocations. Limit loads to a maximum of four (4) workstations per 20A circuit.

c. Conference rooms and training rooms: One for every 12 ft (3.6 m) of wall space at the floor line. Ensure one receptacle is located next to each voice/data outlet in all areas of the room (floor, wall, and ceiling). Provide one receptacle in the ceiling, faceplate flush with ceiling, to support video projection device, if necessary, and one receptacle in the wall to support a wall mounted monitor. Extend circuit to wall location for connection to motorized screen. When it is expected that a conference room table will be specifically dedicated to floor space in a conference room, ensure not less than one (1) floor-mounted receptacle is located under the table. This receptacle may be part of combination power/communications outlet. Ensure signal pathway exists between conference room table and wall or ceiling mounted displays.

d. Provide power outlets throughout the building to serve all proposed equipment, including government furnished equipment, and allow for future reconfiguration of equipment layout. Provide power connections to all ancillary office equipment such as printers, faxes, plotters, and shredders. Provide dedicated circuits where warranted.

e. In each telecommunications room provide a dedicated 20A circuit with a receptacle adjacent to each rack or backboard for each of the following:

- CCTV for training systems
- CCSTV for security systems
- CATV

- Voice systems
- Data systems.

f. Provide receptacles supplying television monitors on circuits dedicated for such equipment and associated specialty equipment. Multiple receptacles, television monitors, and associated specialty equipment receptacles may be connected to the same circuit dedicated to this purpose provided the total connected load satisfies the limits permitted by NFPA 70 for a standard 15- or 20-amp receptacle circuit as applicable. These outlets will typically be located near the ceiling level for wall mounted television monitors.

g. Corridors: One every 50 ft (15 m) with a minimum of one per corridor.

h. Janitor's closet and toilet rooms: One GFI receptacle per closet. Provide GFI receptacles at counter height for each counter in toilets such that there is a minimum of one outlet for each two sinks.

i. Space with counter tops: One for every 4 ft (1.2 m) of countertop, with a minimum of one outlet.

j. Building exterior: GFCI protected, weather-resistant (WR) and identified as extra-duty, within 25 ft (7.5 m) of each exterior door and near HVAC equipment in accordance with NFPA 70 requirements. An exception to the requirement for a receptacle in proximity to each exterior door is permitted for doors providing direct entrance into living units for barracks and dormitories. In such cases, one is to be provided for every 50 ft (15 m) wall length with a minimum of one per exterior wall; additionally, one is to be installed within 10 ft (3m) of each exterior door which does not provide direct entrance into a living unit.

k. Kitchen non-residential: One for each 10 ft (3 m) of wall space at the floor line.

l. Dwelling units, Child Development Centers, and other child occupied spaces (including toilets): Provide listed tamper-resistant receptacles.

m. All other rooms: One for every 25 ft (7.6 m) of wall space at the floor line. When 25 ft (7.6 m) or less of wall at the floor line exists in a room, provide a minimum of two receptacles spaced appropriately to anticipate furniture relocations.

n. Special purpose receptacles: Coordinate with the user to provide any special purpose outlets required. Provide outlets to allow connection of equipment in special use rooms.

o. Permanently installed equipment: Do not use cord and plug connections for permanently installed equipment in areas requiring GFI-protected receptacles. Provide hard-wired connections instead.

3-6.2 Cable and Raceway Criteria.

3-6.2.1 Installation.

Minimum permitted size conduit permitted is 1/2 in (15 mm). Provide an insulated green equipment grounding conductor or supply-side bonding jumper for all circuit(s) installed in raceways. Do not rely on the metallic raceway as the only boding path. Conceal raceways above ceilings and in finished areas that have finished walls or finished surfaces.

The above minimum conduit size does not apply to conduit that is part of a factory installed assembly, such as lighting fixtures.

3-6.2.2 Approved Cable and Raceway Types.

Specify cables and raceway in accordance with NFPA 70 as follows:

- The Uses Permitted are as modified by Table 3-1.
- The Uses Not Permitted are:
    - As specified in NFPA 70.
    - When restricted by other UFCs for specific types of buildings such as medical facilities.

For instances where NFPA 70 does not allow an installation based on “subject to physical damage” or “subject to severe physical damage,” refer to Appendix C-2 for baseline definitions of these conditions.

Provide a plan in the contract documents that graphically depicts the areas subject to physical damage or subject to severe physical damage along with the descriptions (such as the heights given in Appendix C-2) for installation purposes. Alternatively, as another option, provide a narrative list in the specifications indicating such descriptions in the portion of the specifications pertaining to areas subject to physical damage and subject to severe physical damage, respectively.

Table 3-1 Authorized Cable and Raceway Types

NFPA 70 Article	Raceway/Cable Type	Authorization
320	AC – Armored Cable	Prohibited for feeder circuits. Prohibited for embedded locations. Allowed for branch circuits only in the following dry locations: • New construction in exposed locations. • Renovations in exposed locations. • Concealed in renovations in existing areas where walls and ceilings are not disturbed. • Cable trays.
322	FC – Flat Cable Assemblies	Authorized.
324	FCC – Flat Conductor Cable	Authorized.
326	IGS – Integrated Gas Spacer Cable	Prohibited.
328	MV – Medium Voltage Cable	Authorized. For interior applications, MV cable must be installed in raceway or a fully enclosed cable tray. Refer to UFC 3-550-01 for additional applications.

NFPA 70 Article	Raceway/Cable Type	Authorization
330	MC – Metal-Clad Cable	Prohibited for feeder circuits other than feeder circuits for aerial messengers between buildings. Prohibited for embedded or direct buried locations. Prohibited for concealed locations, except as allowed below. Allowed for branch circuits only in the following dry locations: • New construction in exposed locations. • Renovations in exposed locations. • Concealed in renovations in existing areas where walls and ceilings are not disturbed. • Cable trays.
332	MI – Mineral-Insulated, Metal-Sheathed Cable	Authorized.
334	NM, NMC, NMS – Nonmetallic-Sheathed Cable	Allowed only in one- and two-family dwellings and their attached or detached garages, and their storage buildings.
336	TC – Power and Control Tray Cable	Authorized.
338	SE, USE – Service-Entrance Cable	Authorized.
340	UF – Underground Feeder and Branch-Circuit Cable	Prohibited.
342	IMC – Intermediate Metal Conduit	Authorized.
344	RMC – Rigid Metal Conduit	Authorized. Only threaded-type fittings are allowed for wet and damp locations.

NFPA 70 Article	Raceway/Cable Type	Authorization
348	FMC – Flexible Metal Conduit	Flexible metal conduit can be used, limited to 6 ft length, for recessed and semirecessed lighting fixtures; for equipment subject to vibration; and for motors other than pumps. Use liquidtight flexible metal conduit in damp and wet locations and for pumps.
350	LFMC – Liquidtight Flexible Metal Conduit	Use LFMC where authorized for FMC in damp and wet locations and for pumps.
352	PVC – Rigid Polyvinyl Chloride Conduit	Authorized. Minimum allowed size is PVC Schedule 40. For exterior use, comply with UFC 3-550-01.
353	HDPE – High Density Polyethylene Conduit	For exterior use only. Comply with UFC 3-550-01.
354	NUCC – Nonmetallic Underground Conduit with Conductors	Authorized only for exterior branch circuits and for feeder circuits between buildings.
355	RTRC – Reinforced Thermosetting Resin Conduit	Authorized.
356	LFNC – Liquidtight Flexible Nonmetallic Conduit	Prohibited.
358	EMT – Electrical Metallic Tubing	Specify EMT for branch circuits and feeders above suspended ceilings or exposed where not subject to severe physical damage. Only steel or stainless steel EMT may be used where subject to physical damage. Do not use EMT underground, encased in concrete, mortar or grout, in hazardous locations, where exposed to physical damage, outdoors or in fire pump rooms.
360	FMT – Flexible Metallic Tubing	Prohibited.
362	ENT – Electrical Nonmetallic Tubing	Prohibited.
366	Auxiliary Gutters	Authorized and must be listed for the application.

NFPA 70 Article	Raceway/Cable Type	Authorization
368	Busways	Authorized. For low voltage busway, provide UL 857 listed busway. For medium voltage busway, comply with IEEE C37.23.
370	Cablebus	Authorized.
372	Cellular Concrete Floor Raceways	Authorized. Requires a unique Unified Facilities Guide Specification to be developed as part of any design.
374	Cellular Metal Floor Raceways	Authorized. Requires a unique Unified Facilities Guide Specification to be developed as part of any design.
376	Metal Wireways	Authorized and must be listed for the application.
378	Nonmetallic Wireways	Authorized. *Note: The UFC definition of "subject to physical damage" prohibits the use of nonmetallic wireways for exterior applications installed less than 8 ft above finished grade or 8 ft above floor elevation for raceways on elevated platforms, loading docks, or stairwells.*
380	Multioutlet Assembly	Authorized for building improvements or renovations, or for applications where a variety of cord-and-plug connected equipment will be utilized in a limited space, such as in some areas of medical facilities, shops, and laboratories. Authorized for Sensitive Compartmented Information Facilities (SCIF) to limit the number of electrical penetrations through the SCIF boundary.
382	Nonmetallic Extensions	Prohibited.
384	Strut-Type Channel Raceway	Authorized.

NFPA 70 Article	Raceway/Cable Type	Authorization
386	Surface Metal Raceways	Authorized for use only for building improvements or renovations, or for applications where a variety of cord-and-plug connected equipment will be utilized in a limited space, such as in some areas of medical facilities, shops, and laboratories. Authorized for Sensitive Compartmented Information Facilities (SCIF) to limit the number of electrical penetrations through the SCIF boundary.
388	Surface Nonmetallic Raceways	Prohibited.
390	Underfloor Raceways	Authorized for listed underfloor raceways.
392	Cable Trays	Authorized. Provide and maintain a minimum of 12 inches (300 mm) access headroom above a cable tray system and a minimum of 18 inches (450 mm) side access clearance on one side of the cable tray system. The AHJ may approve side and top encroachments totaling up to 3 feet (914 mm) in a 20-foot (6096 mm) section of cable tray provided the encroachments do not prohibit access to raceways that feed into the tray.
393	Low-Voltage Suspended Ceiling Power Distribution Systems	Authorized.
394	Concealed Knob-and-Tube Wiring	Prohibited.
396	Messenger-Supported Wiring	Authorized only for exterior applications.
398	Open Wiring on Insulators	Prohibited.
399	Outdoor Overhead Conductors over 1000 Volts	Authorized.

3-6.2.3 Enclosures and Hazardous Locations.

Refer to TSEWG TP-08, Electrical Equipment Enclosures and Hazardous Locations, at https://www.wbdg.org/dod/supp-tech-documents

3-6.3 Conductors.

3-6.3.1 Baseline Requirements.

Specify conductors in accordance with NFPA 70 and the following:

- Conductors #6 AWG and smaller must be copper. Aluminum conductors of equivalent ampacity can be used instead of copper for #4 AWG and larger sizes.
- Feeder and branch circuit conductors, including power and lighting applications, will in no case be less than #12 AWG. Provide branch circuit breakers rated for 20 amperes minimum, except where lesser ratings are required for specific applications, such as fractional horsepower motor circuits.
- Circuit conductors must be sized based on the 60 degrees C ampacity for circuits rated 100 amperes or less (#12 AWG through #1 AWG) and the 75 degrees C ampacity for circuits rated over 100 amperes (larger than #1 AWG).
    - Higher temperature ampacity ratings for conductors may only be used for ampacity adjustment or correction as permitted by NFPA 70.
    - Where conductor sizing for ambient temperature correction is based on an insulation value greater than 60 degrees C for circuits rated 100 amperes or less (#12 AWG through #1 AWG) and greater than 75 degrees C ampacity for circuits rated over 100 amperes (larger than #1 AWG), explicitly indicate such in the contract documents for the circuits deviating from this convention.
    - All sizing for ampacity shall incorporate ambient temperature corrections and current-carrying conductor adjustments. Indicate whether neutral conductors are current-carrying elements.

3-6.3.2 Conductor Sizing Adjustment.

- Adjust conductor size and/or insulation type based on the ambient temperature anticipated to be encountered on the logical circuit routing path. Utilize NFPA 70 correction factors and exceptions in conductor sizing determinations. Utilize information from the Air Force Engineering Weather Data website (https://climate.af.mil/) or similar data sources such as ASHRAE for location-specific historical temperature information.

Coordinate with the HVAC designer to determine expected maximum ambient temperatures in each building space, including ceiling cavities and plenums where conductors will be routed, perimeter walls, and the building exterior. Do not assume less than 78 degrees F (25 degrees C) for ambient temperature correction factors.

Note: Recommend documenting these determinations graphically on a plan using the applicable temperature ranges for which adjustments are made in NFPA 70 Article 310 for graphical depiction. Require further adjustments to be made during construction based on the contractor exercising their routing discretion for routing not explicitly shown. Indicate on the contract documents the ambient temperature the design considered for sizing conductors and require further adjustments should the contractor's final routing path traverse an area of higher ambient temperature.

Note: Circuits are typically sized individually and consolidation of circuits into a common raceway may occur during construction, requiring further adjustments to be made during construction based on the contractor exercising their discretion to consolidate multiple circuits into a common raceway for lengths exceeding the exception threshold for adjustments and corrections in NFPA 70. Indicate on the contract documents the number of conductors the design considered to be current carrying. This information is useful when resizing conductors due to potential circuit consolidation.

- For voltage drop requirements, see UFC 3-501-01.
- For ambient temperature and voltage drop calculations, include anticipated routing of circuits in all directions (lateral and vertical). Unless explicitly identified to be installed in such a manner, do not assume underground routing will occur for conductor sizing factor purposes; overhead routing will typically require additional circuit lengths. Assume conduit routing at right angles to the building structure unless specifically shown on the plans; diagonal routing may be used for calculations only if indicated on the plans.

  Note: Routing concept adapted from the ASHRAE 90.1 User's Manual. This estimate should account for any known conditions shown on the plans including room and structure geometry.
- Where conductor size increases to mitigate voltage drop exceed the maximum permitted by a given device termination, the conductor size may be reduced to terminate properly in accordance with manufacturer requirements. Select splice kits, junctions, cable-reducing adapters, etc., to accommodate the increased wire size. Where a conductor size has been adjusted to mitigate voltage drop and conductor size reduction is required, the following restrictions will apply:

- o The total length of conductor to be reduced below the size adjusted to mitigate voltage drop must not exceed 10 feet or 10 percent of the circuit length, whichever is less.
- o Conductors must not be reduced below the maximum size permitted by the terminations in question.
- o Conductors must not be reduced in size smaller than required by ambient temperature and current-carrying conductor ampacity corrections and adjustments; utilize increased conductor insulation as necessary.
- o Alternatively, increase the equipment frame size to a class that will accommodate the termination of larger conductor sizes. This strategy may be used in combination with adapters for conductors whose size was increased to account for voltage drop, ampacity correction, or adjustment factors. Do not adjust the overcurrent protection ratings as a result of the frame size increase.

3-6.4 Wiring Annotation.

When using homerun symbols, point the homerun symbol in the general direction of the source equipment. Combine one-pole branch circuits to minimize number of homeruns.

3-7 LIGHTING.

Design lighting, including ASHRAE 90.1 criteria, in accordance with UFC 3-530-01.

3-8 GENERATORS.

Comply with UFC 3-540-01.

Coordinate with the Activity to establish marking requirements for receptacles and panelboards served by backup power systems.

3-9 AUTOMATIC TRANSFER EQUIPMENT.

Comply with UFC 3-540-01. Refer to NFPA 99 for any transfer switch applications involving medical facilities.

Refer to TSEWG TP-09, Automatic Transfer Equipment, at https://www.wbdg.org/dod/supp-tech-documents for additional information regarding ATS design and application.

3-10 UNINTERRUPTIBLE POWER SUPPLY.

Uninterruptible power supply (UPS) selection and sizing information is in TSEWG TP-19, Static Uninterruptible Power Supply, at the following site: https://www.wbdg.org/dod/supp-tech-documents

3-11 STATIONARY BATTERIES AND BATTERY CHARGERS.

3-11.1 Selection.

3-11.1.1 Vented Lead Acid Batteries.

Use vented lead acid batteries preferentially for switchgear control power and UPS applications. Batteries for switchgear or backup power applications should be rated for general purpose, switchgear, or utility use. Batteries for UPS applications should be rated for UPS or high-rate use.

3-11.1.2 Valve-Regulated Lead Acid Batteries.

As a general practice, do not use a valve-regulated lead acid (VRLA) battery if a vented lead-acid battery will satisfy the design and installation requirements. VRLA batteries have exhibited a shorter service life than vented equivalents and have shown a tendency to fail without warning. Refer to IEEE Std 1189 for additional information regarding the unique failure modes and shorter service life of this battery type. For the Air Force, refer also to AFPAM 32-1186 for additional information regarding VRLA batteries.

3-11.1.2.1 Allowed Applications.

VRLA batteries are allowed to be used in the following types of applications:

- Installations with small footprints such that a vented battery with adequate power density will not fit within the available space.
- Locations in which the consequences of electrolyte leakage cannot be allowed. UPS systems are often located in areas that necessitate the use of a VRLA battery.

3-11.1.2.2 Prohibited Applications.

Do not use VRLA batteries in the following types of applications:

- Unregulated environments that can experience abnormally high and low temperatures.
- Unmonitored locations that seldom receive periodic maintenance checks. VRLA batteries have shown a tendency to fail within only a few years after installation.

- Critical applications, unless the installation location requires the features available only in a VRLA battery.

3-11.1.3 Nickel-Cadmium Batteries.

Nickel-cadmium batteries are often more expensive than vented lead-acid batteries and should be considered primarily for extreme temperature environments or engine-starting applications. Nickel-cadmium batteries are preferred for engine starting applications because of their high-rate discharge capability and their more predictable failure modes.

3-11.1.4 Lithium Batteries.

Do not use lithium-ion, lithium metal polymer, or other lithium-based batteries for stationary applications in occupied buildings.

3-11.1.5 Battery Life for Life-Cycle Cost Analyses.

Apply the following service life for life-cycle cost comparisons of stationary batteries (small would be facility generators and large would be facility energy storage systems):

- Small VRLA batteries – 3 years.
- Large VRLA batteries – 7 years.
- Small vented lead acid batteries – 10 years.
- Large vented lead acid batteries – 15 years.
- Nickel-cadmium batteries – 15 years.

3-11.2 Battery Areas and Battery Racks.

Comply with UFC 3-520-05.

3-11.3 Installation Design.

3-11.3.1 Industry Standards.

Review the following IEEE standards, as applicable for the battery type, prior to the installation:

- IEEE Std 450—provides maintenance and test criteria for vented lead acid batteries.
- IEEE Std 484—provides installation criteria for vented lead acid batteries.
- IEEE Std 485—defines battery sizing requirements for lead acid batteries.

IEEE Std 1106—provides maintenance and test criteria for nickel cadmium batteries.

- IEEE Std 1115—defines battery sizing requirements for nickel cadmium batteries.
- IEEE Std 1184—provides application and sizing criteria for UPS applications.
- IEEE Std 1187—provides installation criteria for valve-regulated lead acid batteries.
- IEEE Std 1188—provides maintenance and test criteria for valve-regulated lead acid batteries.
- IEEE Std 1189—explains application limitations for valve-regulated lead acid batteries.

Note: the above industry standards apply to lead acid and nickel cadmium batteries. There are no industry standards available yet for the selection, specification, sizing, design, installation, maintenance, and testing of lithium-ion, lithium metal polymer, or other lithium-based batteries for stationary applications.

3-11.3.2 Design Requirements.

Size the battery in accordance with IEEE Std 485, IEEE Std 1115, or IEEE Std 1184 as appropriate for the selected battery type and application.

Refer to TSEWG TP-04, Stationary Battery and Charger Sizing, at https://www.wbdg.org/dod/supp-tech-documents for additional information regarding battery sizing principles.

3-11.3.3 Installation Requirements.

Design and install the battery in accordance with IEEE Std 484, IEEE Std 1187, or IEEE Std 1106 as appropriate for the selected battery type. Refer to the above industry standards and NETA ATS for acceptance test criteria.

3-11.3.4 Battery Chargers.

Use single-phase chargers for smaller applications. Rate single-phase battery chargers for 240V single phase, unless only 120V is available. Use three-phase chargers if the charger's dc output current rating will be greater than 75A. Unless the battery has specific requirements to the contrary, all chargers should be of the constant voltage type.

3-11.3.5 Battery Protection.

Install a circuit breaker or fused protection device as close to the battery as possible.

Provide overcurrent protection for each string in a parallel battery system. Refer to IEEE Std 1375 for additional guidance.

3-12 GROUNDING, BONDING, AND STATIC PROTECTION.

The below requirements apply for the identified subset of acceptable techniques.

3-12.1 Ground Rods.

3-12.1.1 Design.

For ground rod composition, minimum spacing requirements and connections, conform to requirements of NFPA 70 Article 250 except that minimum ground rod dimensions are 10 feet (3.0 m) in length and ¾ inch (19 mm) diameter. Provide copper-clad steel, solid copper, or stainless steel ground rods.

3-12.1.2 Connections.

All connections to ground rods below ground level must be by exothermic weld connection or with a high compression connection using a hydraulic or electric compression tool to provide the correct circumferential pressure. Accessible connections above ground level and in test wells can be accomplished by clamping.

3-12.1.3 Spacing and Location.

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

Install ground rods (and ground ring, if applicable) 3 ft to 8 ft (0.9 m to 2.4 m) beyond the perimeter of the building foundation and at least beyond the drip line for the facility. If another UFC requires the installation of one or more ground rods inside a facility, follow the requirements specified in that UFC.

3-12.2 Ground Rings.

Coordinate requirements for the ground ring of a lightning protection system with UFC 3-575-01. Provide a ground ring (counterpoise) for facilities with sensitive electronic equipment or other applications when identified by project requirements.

Provide a ground ring with at least two ground rods located diagonally at opposite corners. When required by a specific activity or facility, provide a ground rod at each change in direction of the ground ring and install test wells for at least two of the corner ground rods to allow for testing of the system. Assemble test wells with bolted connections to facilitate future testing.

3-12.3 Communication-Electronics Facilities.

Provide grounding electrode systems for Communications-Electronics (C-E) facilities in accordance with MIL-HDBK 419A when identified by project requirements.

3-12.4 Static Electricity Protection.

Comply with UFC 3-575-01 for static protection requirements.

3-12.5 Aircraft Hangars.

Refer to UFC 3-575-01 for grounding criteria for power systems and static electricity protection for aircraft hangars.

3-12.6 Ammunition and Explosive Storage Magazines.

Refer to UFC 4-420-01 and NAVSEA OP 5 for Navy project for grounding, bonding, and lightning protection criteria.

3-13 LIGHTNING PROTECTION SYSTEMS.

Provide lightning protection systems in accordance with UFC 3-575-01.

3-14 400-HERTZ DISTRIBUTION SYSTEMS.

Design 400 hertz power systems in accordance with UFC 3-555-01.

3-15 270-VOLT DC DISTRIBUTION SYSTEMS.

System requirements are specified in UFGS 26 35 44.

3-16 POWER FACTOR CORRECTION.

The power factor within a facility is normally 0.9 lagging or greater; therefore, power factor correction is not routinely required for interior electrical systems. However, if the facility design incorporates large motor applications or other specific loads that may adversely affect the power factor, provide an evaluation that includes the considerations identified in TSEWG TP-02, Capacitors for Power Factor Correction, at https://www.wbdg.org/dod/supp-tech-documents.

If the evaluation supports the need for power factor correction, contact the AHJ for authorization prior to providing power factor correction equipment.

3-17 POWER QUALITY.

Design secondary electrical systems to mitigate the harmonic effects of non-linear loads as a result of connections to electronic loads, including computer work stations, file servers, UPS, and electronic ballasts. Refer to Appendix B for power quality design criteria.

3-18 SYSTEMS FURNITURE.

3-18.1 Planning.

When systems furniture is utilized, the electrical designer, the architect, and the interior designer must coordinate during the design process. Systems furniture is typically specified and ordered when construction is nearing completion; therefore, if proper coordination has not occurred earlier in the design process, field interface problems will occur.

3-18.2 Design.

Systems furniture is pre-wired to a wiring harness. Unless specified otherwise, select a standard wiring harness that meets one of the following configurations:

- 8-wire harness consisting of 3 circuit conductors, 3 neutral conductors and 2 equipment grounding conductors.
- 10-wire harness consisting of 4 circuit conductors, 4 neutral conductors and 2 separate equipment grounding conductors.

Serve 8-wire harnesses with 2 separate circuits and 10-wire harnesses with 4 separate circuits. Provide harnesses that have a neutral conductor per phase conductor and a green ground conductor. Balance loads between circuits and phases. A single circuit must not serve more than 4 workstations under any circumstances.

3-19 ASHRAE COMPLIANCE.

Verify per UFC 1-200-02 the version of ASHRAE 90.1 that is currently used.

Provide automatic receptacle control in accordance with ASHRAE 90.1. The detailed electrical energy monitoring requirements of ASHRAE 90.1are permissible on projects when authorized in writing by the activity in order to coordinate with their existing industrial controls program.

3-20 ELECTRIC VEHICLE SUPPLY EQUIPMENT.

Provide Electric Vehicle Supply Equipment (EVSE) for Government Owned Vehicle (GOEV) for Type 1, Type 2, and Type Direct Current (dc) Fast Charging complying with requirements of NFPA 70.

3-20.1 Site and Equipment Considerations.

The following are some of the site and equipment issues that must be considered when designing for a EVSE installation.

3-20.1.1 Physical Protection of EVSE.

Provide wheel stops or bollards for physical protection in front of EVSE when curbing of sidewalks is not present.

3-20.1.2 Signage for EVSE.

Provide signage as indicated by Manual on Uniform Traffic Control Devices (MUTCD), that indicates EVSE.

3-20.1.3 Avoiding Hazards.

Cords and wires associated with EVSE should not interfere with pedestrian traffic or present tripping hazards. Charging spaces should not be located near potentially hazardous areas.

3-20.1.4 Ventilation.

When EVSE is located in an enclosed space, there must be adequate ventilation, which may include installation of fans, ducts, and air handlers. Verify the installation and ventilation requirements with the manufacturer’s documentation.

3-20.1.5 Battery Temperature Limits.

Because some EV batteries have operating and charging temperature limits, EVSE may need to be located within an enclosed, climate-controlled area in extreme climates. Verify resulting installation environment is compatible with EVSE manufacturer’s installation requirements.

3-20.1.6 Metering.

Separate or sub-metering for electricity used by EVSE may be a requirement so that vehicle charging can be isolated from the rest of a building or structure’s energy usage. Verify if metering is a requirement with the activity.

APPENDIX A ADJUSTABLE SPEED DRIVES

A-1 ADJUSTABLE SPEED DRIVES (ASD).

A-1.1 ASD Sizing.

At the rated full load of the driven equipment, the output voltage and frequency of the ASD should be the same as the motor's rating. Note that this design requirement places limits on the motor design; the motor should not have a significantly higher full load horsepower or speed rating than the driven load. Mismatches can easily cause operational problems, including efficiency losses and increased ASD input current. In extreme cases, a mismatch can cause the ASD to trip on overcurrent during motor starting or cause the ASD input current to be substantially higher than the design without the ASD.

The ASD short term current rating should be adequate to produce the required motor starting torque, including loads with high starting torque.

A-1.2 Motor Considerations.

Specify a motor with a minimum 1.15 service factor or ensure the motor is rated well above the actual load it will carry. Verify with the manufacturer that the motor is capable of acceptable operation with an ASD. Standard motors can often operate down to 50% of rated speed, high efficiency motors can often operate down to 20% of rated speed, and "inverter duty" motors can operate below 20% of rated speed without problems in a variable load application.

A-1.3 Power Quality.

Ensure that the final installation does not create voltage or current harmonic distortion beyond acceptable limits. Take power quality field measurements after installation to confirm that the system total harmonic distortion is not degraded beyond acceptable levels. If the ASD can be provided power from a standby generator upon loss of normal commercial power, the harmonic distortion evaluation must include the system effects when powered from the standby generator.

Voltage sags can cause nuisance tripping. Ensure that the ASD either has a minimum of 3 cycle ride-through capability or automatic reset circuitry.

A-1.4 Capacitor Switching Effects.

Nearby capacitor switching can cause transient overvoltages, resulting in nuisance tripping. In this case, ensure the ASD either has input filtering to reduce the overvoltage or automatic reset circuitry.

A-1.5 Bypass Capability.

Important applications should include bypass operation capability to allow motor operation independent of the ASD.

APPENDIX B POWER QUALITY

B-1 INTRODUCTION.

Unlike other electrical design requirements, power quality design solutions are very dependent on the types of transients and disturbances that can and will occur in power systems. In many cases, it will be easier to provide protection and power quality design features to specific equipment rather than generically throughout the facility.

B-2 UNBALANCED VOLTAGES.

Evaluate the loading on each phase and balance the loads as well as possible. As part of acceptance testing, monitor the degree of unbalance and make corrections if necessary.

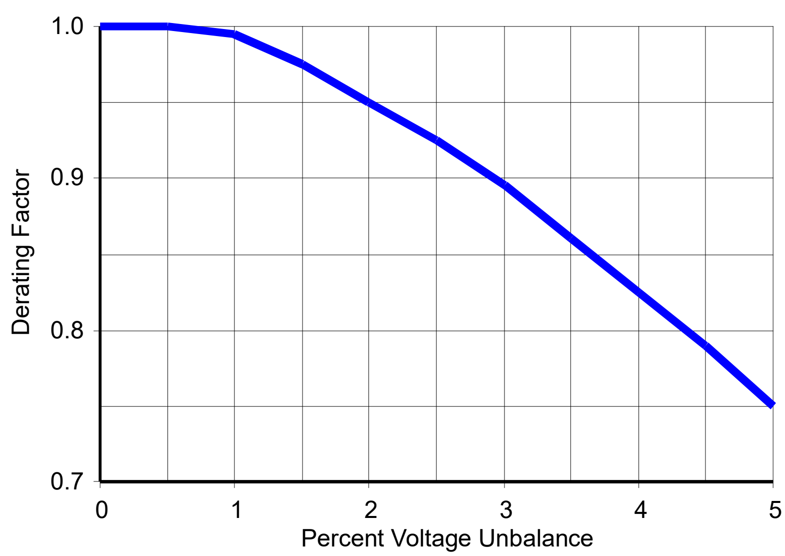
B-2.1 Calculation.

Calculate voltage unbalance as follows:

B-2.2 Effect on Motors.

The rated load capability of three-phase equipment is reduced by voltage unbalance. Figure B-1 shows a typical derating factor for three-phase induction motors as a function of voltage unbalance.

Figure B-1 Typical Derating Factor for Three-Phase Induction Motors



B-3 HARMONIC DISTORTION EVALUATION.

If a significant number of nonlinear loads are installed in the facility, perform a harmonic distortion evaluation during the facility design phase. If the effect of nonlinear loads is expected to be minor, a detailed harmonic distortion evaluation is not required.

IEEE Std 519 provides the industry-accepted method of evaluating harmonic voltages and currents. IEEE Std 519 provides system level guidance, not equipment specific guidance; harmonic distortion limits are established for the facility and the installation of any equipment should not degrade the system to beyond acceptable levels

B-4 DERATING TRANSFORMERS FOR HARMONIC CURRENT EFFECTS.

Whenever significant nonlinear loads are expected in a facility, evaluate the system in accordance with IEEE C57.110 to determine if transformer derating will be required. For transformers without a k-factor rating, derating must be used to determine the maximum fundamental load current that the transformer can maintain with the additional harmonic currents.

Note: Derating applies to the full-load capability of the transformer when applied in an environment containing significant harmonic distortion. If the transformer is not fully loaded, the derating process might have little or no practical significance unless it is expected that the transformer will eventually be fully loaded. Nationwide surveys indicate average loading levels for dry-type transformers of between 35% for commercial facilities and 50% for industrial facilities. Military facilities are commonly loaded to less than 25% of the service entrance transformer full-load capability during periods of peak demand.

If it is determined that a transformer will require derating because of harmonic distortion, perform the following additional reviews:

- Verify the expected transformer loading assumptions for a new design or actual metering data for an existing design to confirm that the transformer is fully loaded; most transformers are never fully loaded.
- Determine if the harmonic distortion environment can be improved by design changes for the most offending loads.
- If the transformer requires more than 10% derating, evaluate the feasibility of installing a new transformer designed for a harmonic distortion environment (harmonic mitigating transformer). Include delivery and replacement time scheduling as well as cost in the evaluation.
- If transformer derating is the selected option, annotate the percent derating on the applicable design drawings and install a label near the transformer nameplate indicating that the transformer has been derated. The purpose of these actions is to prevent inadvertent overloading of the transformer in the future.

B-5 NONLINEAR LOAD DESIGN CONSIDERATIONS.

Analyze planned electrical loads on new projects to determine whether or not they are considered potential nonlinear loads with high harmonic content. The following guidelines are provided if nonlinear loads are a significant portion of the total load.

- Derate transformer, motor, and generator outputs if necessary to prevent overheating or burnout. Ensure that design documents and equipment nameplates reflect the derated capability.
- If standby generators represent the only power source upon loss of normal power, the generator design must account for nonlinear loads.
- Use a single three-phase transformer with common core, delta connected primary and wye connected secondary instead of three single-phase transformers connected for three-phase service. Evaluate the use of a harmonic mitigating transformer if a standard transformer has to be derated by more than 10%.

  Note: Refer to TSEWG TP-05, Interior Transformer Ratings and Installation, at https://www.wbdg.org/dod/supp-tech-documents *for additional information regarding harmonic mitigating transformers.*

- Specify harmonic filters as necessary to minimize the localized effects of harmonics. If separate harmonic filters are installed specifically to protect against offending loads, locate each filter as close to each load as practical.
- Specify true RMS sensing meters, relays, and circuit breaker trip elements.

Analysis alone will not always adequately predict power quality problems. Refer to IEEE Std 1159 for additional information regarding power quality monitoring.

B-6 NEUTRAL CIRCUIT SIZING FOR NONLINEAR LOAD CONDITIONS.

Minimize neutral circuit overheating by specifying separate neutral conductors for line-to-neutral connected nonlinear loads with high harmonic content. Treat the neutral conductors as current carrying conductors in the design analysis. When a shared neutral conductor must be used for three-phase, four-wire systems, size the neutral conductor to have an ampacity equal to at least 1.73 times the ampacity of the phase conductors.

Two paralleled, full size neutral conductors can be used to obtain the required neutral ampacity for conductors sized #1/0 AWG and larger. Size the neutral conductor between the transformer and all downstream distribution equipment to be a minimum of 1.73 times the ampacity of the phase conductors. Select panelboards that have been rated for nonlinear loads.

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APPENDIX C GLOSSARY

C-1 ACRONYMS.

A	Amperes
AC	Alternating Current
AC	Armored Cable
AFCI	Arc Fault Current Interrupter
AFPA	Air Force Pamphlet
AHJ	Authority Having Jurisdiction
ANSI	American National Standards Institute
ASD	Adjustable Speed Drive
ATS	Automatic Transfer Switch
AWG	American Wire Gauge
BEQ	Bachelor’s Enlisted Quarters
BOQ	Bachelor’s Officer Quarters
CCTV	Closed Circuit Television
CATV	Cable Television
CFR	Code of Federal Regulations
COPS	Critical Operations Power System
Dc	Direct Current
DCOA	Designated Critical Operations Area
EGSA	Electrical Generating Systems Association
EMT	Electrical Metallic Tubing
ENT	Electrical Non-Metallic Tubing
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment

FC	Flat Cable Assemblies
FCC	Flat Conductor Cable
FMC	Flexible Metal Conduit
FMT	Flexible Metallic Tubing
Ft	Feet
GFI	Ground Fault Circuit Interrupter
GRS	Galvanized Rigid Steel
HDPE	High Density Polyethylene Conduit
HID	High Intensity Discharge
Hz	Hertz
IEEE	formerly Institute of Electrical and Electronics Engineers
IMC	Intermediate Metal Conduit
kA	Kilo-Amperes
kVA	Kilo-Volt-Amperes
kW	Kilowatt
LFMC	Liquidtight Flexible Metal Conduit
LFNC	Liquidtight Flexible Nonmetallic Conduit
M	Meter
MCC	Motor Control Center
MCOV	Maximum Continuous Overvoltage Rating
Mm	Millimeter
MC	Metal-Clad Cable
MI	Mineral-Insulated, Metal-Sheathed Cable
MV	Medium Voltage Cable
NAVFAC	Naval Facilities Engineering Systems Command

NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NETA	International Electrical Testing Association
NFPA	National Fire Protection Association
NM, NMC, NMS	Nonmetallic-Sheathed Cable
NUCC	Nonmetallic Underground Conduit with Conductors
OSHA	Occupational Safety and Health Administration
PVC	Rigid Polyvinyl Chloride Conduit
RMC	Rigid Metal Conduit
RMS	Root-Mean-Square
RTRC	Reinforced Thermosetting Resin Conduit
SCIF	Sensitive Compartmented Information Facilities
SE, USE	Service-Entrance Cable
SPD	Surge Protective Devices
SWD	Switching Duty
TC	Power and Control Tray Cable
TSEWG	Tri-Service Electrical Working Group
UF	Underground Feeder and Branch-Circuit Cable
UFC	Unified Facilities Criteria
UL	Underwriters Laboratories
UPS	Uninterruptible Power Supply
USACE	U.S. Army Corps of Engineers
V	Volts
VFD	Variable Frequency Drive (see ASD)
VRLA	Valve-Regulated Lead Acid

C-2 DEFINITION OF TERMS

Note: The terms listed here are provided for clarification of the design criteria provided in this UFC. Refer to IEEE Std 100 for additional electrical-related definitions.

Automatic Transfer Switch (ATS): A switch designed to sense the loss of one power source and automatically transfer the load to another source of power.

Branch Circuit: The circuit conductors and components between the final overcurrent device protecting the circuit and the equipment.

Closed Transition Switch: Transfer switch that provides a momentary paralleling of both power sources during a transfer in either direction. The closed transition is possible only when the sources are properly interfaced and synchronized.

Existing Facility: A facility is existing if changes to be made are cosmetic or minor in nature.

Harmonic: A sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the fundamental frequency.

Linear Load: An electrical load device that presents an essentially constant load impedance to the power source throughout the cycle of applied voltage in steady-state operation.

Listed: Applies to equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction. The organization periodically inspects production and certifies that the items meet appropriate standards or tests as suitable for a specific use.

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

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

Molded Case Circuit Breaker: A low voltage circuit breaker assembled as an integral unit in an enclosing housing of insulating material. It is designed to open and close by nonautomatic means, and to open a circuit automatically on a predetermined overcurrent, without damage to itself, when applied properly within its rating.

Motor Control Center: A piece of equipment that centralizes motor starters, associated equipment, bus and wiring in one continuous enclosed assembly.

New Construction: A facility is considered new if changes to be made are more than cosmetic or minor, such as major renovations, additions, or new facilities.

Nonlinear Load: A steady state electrical load that draws current discontinuously or has the impedance vary throughout the input ac voltage waveform cycle. Alternatively, a load that draws a nonsinusoidal current when supplied by a sinusoidal voltage source.

Power Quality: The concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that equipment.

Service Voltage: Voltage at the facility service entrance location.

Short Circuit: An abnormal condition (including an arc) of relatively low impedance, whether made accidentally or intentionally, between two points of different potential.

Subject to Physical Damage (or Subject to Severe Physical Damage): Locations that are subject to physical damage or severe physical damage include:

- Exposed interior raceways installed less than 6 ft above finished floor elevation where personnel are operating mechanized equipment on a recurring basis. Mechanized equipment that might be operated on a recurring basis includes vehicles, carts, forklifts, and pallet-handling units.
- Exposed exterior raceways installed less than 8 ft above finished grade or 8 ft above floor elevation for raceways on elevated platforms, loading docks, or stairwells.
- Exposed raceways where personnel operate mobile or fixed-in-place hoisting equipment.

Surge Protector: A device composed of any combination of linear or nonlinear circuit elements and intended for limiting surge voltages on equipment by diverting or limiting surge current; it prevents continued flow of current and is capable of repeating these functions as specified.

Transfer Switch: A device for transferring one or more load conductor connections from one power source to another.

Uninterruptible Power Supply System: A system that converts unregulated input power to voltage and frequency controlled filtered ac power that continues without interruption even with the deterioration of the input ac power.

Utilization Voltage: The voltage at the line terminals of utilization equipment.

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APPENDIX D REFERENCES

UNIFIED FACILITIES CRITERIA

https://www.wbdg.org/dod/ufc

UFC 1-200-01, *DoD Building Code*

UFC 1-200-02, *High Performance and Sustainable Building Requirements*

UFC 3-501-01, *Electrical Engineering*

UFC 3-510-01, *Foreign Voltages and Frequencies Guides*

UFC 3-520-05, *Stationary and Mission Batteries*

UFC 3-530-01, I*nterior and Exterior Lighting Systems*

UFC 3-540-01, *Engine-Driven Generator Systems for Prime and Standby Power Applications*

UFC 3-550-01, *Exterior Electrical Power Distribution*

UFC 3-555-01, *Aircraft Point-of-Use Power Systems*

UFC 3-560-01, *Operation and Maintenance: Electrical Safety*

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

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

UFC 4-010-06, *Cybersecurity of Facility-Related Control Systems (FRCS)*

UFC 4-420-01, *Ammunition And Explosives Storage Magazines*

UNIFIED FACILTIES GUIDE SPECFICATIONS

https://www.wbdg.org/dod/ufgs

UFGS 26 35 44, *70 VDC Solid State Converter*

TRI-SERVICE ELECTRICAL WORKING GROUP

https://www.wbdg.org/dod/supp-tech-documents

TSEWG TP-02, *Capacitors for Power Factor Correction*

TSEWG TP-04, *Stationary Battery and Charger Sizing*

TSEWG TP-05, *Interior Transformer Ratings and Installation*

TSEWG TP-08, *Equipment Enclosures and Hazardous Locations*

TSEWG TP-09, *Automatic Transfer Equipment*

TSEWG TP-19, *Static Uninterruptible Power Supply (UPS)*

DEPARTMENT OF THE AIR FORCE

AFPAM 32-1186, *Valve-Regulated Lead-Acid Batteries for Stationary Applications*

DEPARTMENT OF THE NAVY

NAVSEA OP-5, *Ammunition and Explosives Safety Ashore*

OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

https://www.osha.gov

29 CFR 1910.305, *Wiring Methods, Components and Equipment for General Use — Design Safety Standards for Electrical Systems*

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

https://www.ansi.org/

Note: Many ANSI documents are sponsored or co-sponsored by other organizations, such as NEMA or IEEE.

ANSI C84.1, *Electric Power Systems Voltage Ratings (60 Hz)*

ANSI Z535.4, *Product Safety Signs and Labels*

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

https://www.ashrae.org/

ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low Rise Residential Buildings*, (Refer to UFC 1-200-02, for applicable publication date)

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

https://www.netaworld.org/home

ANSI/NETA ATS, *Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems*

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

https://www.ieee.org/

IEEE C37.20.1, *IEEE Standard for Metal-Enclosed Low-Voltage (1000 Vac and below, 3200 Vdc and below) Power Circuit Breaker Switchgear*

IEEE C37.20.7, *IEEE Guide for Testing Switchgear Rated Up to 52 kV for Internal Arcing Faults*

IEEE C37.20.9, *IEEE Standard for Metal-Enclosed Switchgear Rated 1 kV to 52 kV Incorporating Gas Insulating Systems*

IEEE C37.23, *IEEE Standard for Metal-Enclosed Bus*

IEEE C57.110, *IEEE Recommended Practice for Establishing Liquid-Immersed and Dry-Type Power and Distribution Transformer Capability When Supplying Nonsinusoidal Load Currents*

IEEE C62.41, *IEEE Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits*

IEEE Std 100, *The Authoritative Dictionary of IEEE Standards Terms*

IEEE Std 450, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*

IEEE Std 484, *IEEE Recommended Practice for Installation Design and Installation of Vented Lead-Acid Batteries for Stationary Applications*

IEEE Std 485, *IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications*

IEEE Std 519, *IEEE Standard for Harmonic Control in Electrical Power Systems*

IEEE Std 1106, *IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*

IEEE Std 1115, *IEEE Recommended Practice for Sizing Nickel-Cadmium Batteries for Stationary Applications*

IEEE Std 1159, *IEEE Recommended Practice for Monitoring Electric Power Quality*

IEEE Std 1184, *IEEE Guide for Batteries for Uninterruptible Power Supply Systems*

IEEE Std 1187, *IEEE Recommended Practice for Installation Design and Installation of Valve-Regulated Lead-Acid Storage Batteries for Stationary Applications*

IEEE Std 1188, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Valve Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*

IEEE Std 1189, *Guide for Selection of Valve Regulated Lead-Acid (VRLA) Batteries for Stationary Applications*

IEEE Std 1375, *Guide for the Protection of Stationary Battery Systems*

NATIONAL ELECTRICAL MANUFACTURER'S ASSOCIATION (NEMA)

https://www.nema.org/

NEMA ICS 1, *Standard for Industrial Control and Systems: General Requirements*

NEMA ICS 2, *Industrial Control and Systems Controllers, Contactors, and Overload Relays Rated 600 Volts*

NEMA ICS 7, *Adjustable-Speed Drives*

NEMA PB 2, *Deadfront Distribution Switchboards*

NEMA ST 20, *Dry Type Transformers for General Applications*

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

https://www.nfpa.org/

NFPA 70, *National Electrical Code (NEC)*

NFPA 70E, *Standard for Electrical Safety in the Workplace*

NFPA 72, *National Fire Alarm and Signaling Code*

NFPA 99, *Health Care Facilities Code*

NFPA 780, *Standard for the Installation of Lightning Protection Systems*

UNDERWRITER'S LABORATORY

UL 497A, *Standard for Secondary Protectors for Communications Circuit*

UL 497B, *Protectors for Data Communications and Fire-Alarm Circuits*

UL 845, *Motor Control Centers*

UL 891, *Standard for Switchboards*

UL 1283, *Standard for Electromagnetic Interference Filters*

UL 1449, *Standard for Surge Protective Devices*

UL 1558, *Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear*