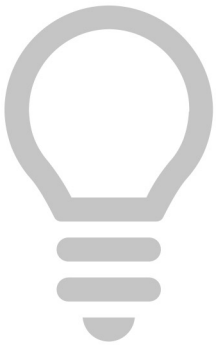
DENVER INTERNATIONAL AIRPORT

DESIGN STANDARDS MANUAL

Electrical

Design, Engineering and Construction

Revised: Q4 2023



Included Technical Specification Requirements	Manual
Division 02: Existing Conditions	Architecture
Division 03: Concrete	Civil
Division 04: Masonry	Structural
Division 05: Metals	Architecture
Division 06: Wood, Plastics, and Composites	Architecture
Division 07: Thermal and Moisture Protection	Architecture
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Summary of Revisions

The following tables list the revisions made int he page year to the Electrical Design Standards Manual (DSM).

2023 Revisions

Fourth Quarter

Reference	Revision Description
Throughout	Minor punctuation and grammar changes
1.2.6 Utility Coordination	Added section on utility coordination
1.3.2 Construction Drawing Requirements	Added requirement
1.3.3 Commissioning Requirements	Added section on commissioning requirement
2.0.2 Criteria	Updated standards
2.0.4.6 Concourse C	Added switchgear information for concourse expansion areas
2.1.13 Receptacles	Added receptacles information
2.2.6.8 Controlled Receptacles	Added section on controlled receptacles
2.2.12 Tenants and Concessions	Added equipment information
5.1.5.3 Occupancy-Based Control	Added information on lighting serving an emergency egress
6.8 Solar Arrays	Added section on Solar Arrays
8.1.4 Electrical Service	Added new information
8.1.8 Tenant Installations	Added tenant installation information
8.2.2 Charging Station Location	Added information on EV charging stations
Section 260510: Testing, Acceptances and Certification	Added Existing Equipment Testing specifications
Section 260533: Raceways and Boxes for Electrical Systems	Added raceway application information
Section 262713: Electricity Metering	Updated meters

Second Quarter

Reference	Revision Description
Throughout	Minor punctuation and grammar changes
2.1.2 Raceways	Updated PVC conduit routing information
2.1.19 Energy Management and Control System	Added Tenant water meters and BTU meters

Second Quarter

Reference	Revision Description
2.2.6.7 Powered Seating	Added new section on Powered Seating
8.1.4 Electrical Service	Updated information
8.1.8 Tenant Installations	Added new section on Tenant Installations
Section 260533: Raceways and Boxes for Electrical Systems	Updated information on buried conduits, under Conduit Installation Schedule
Section 260553: Identification for Electrical Systems	Updated system color coding schedule

2022 Revisions

Fourth Quarter

Reference	Revision Description
Throughout	Minor punctuation and grammar changes
Table 1-1: Definitions	Added Concessions Tenant definition
Table 2-1: Panelboard Naming Conventions	Added Concessions Tenant information
2.1.6 Low Voltage DEN Submetering	Updated submeter equipment communication protocol
2.2.4.4 Emergency Loads	Updated requirements
2.2.8 Electrical Safety	Updated information
2.2.12 Tenants and Concessions	Updated tenant requirements
5.1.5.7 Exterior Lighting Controls	Updated lighting control requirements
5.2.6 Tenants and Concessions	Updated tenant requirements
Table 5-5: Illuminance Recommendations for the Main Terminal	Information presented in new table
6.7 Support and Outlying Buildings	Updated information
7.2 Design Considerations	Updated lighting control requirements
Section 260519: Low-Voltage Electrical Power Conductors and Cables	Added tenant definitions and tenant requirements. Updated MC cable requirements
Section 260529: Hangers and Supports for Electrical Systems	Updated requirements
Section 260553: Identification for Electrical Systems	Updated requirements for the system color coding schedule
Section 260943: Networked Lighting Control	Added Lutron to list of manufacturers

Fourth Quarter

Reference	Revision Description
Section 262200: Low-Voltage Transformers	Added Powersmiths to list of manufacturers and updated transformer requirements
Section 262713:Electricity Metering	Updated requirements
Section 262726: Wiring Devices	Updated receptacle orientation requirements

Second Quarter

Reference	Revision Description
Throughout	Minor punctuation and grammar changes
2.1 Materials and Equipment	Updated content, updated Table 2-1: Panelboard Naming Conventions, updated Table 2-2: UPS Runtime Requirements, added new section 2.1.17 Escalators and Moving Walkways.
2.2. Installations	Updated requirements. Moved 6.1.4 Tenants and Concessions to 2.2.12 Tenants and Concessions
5.1.3 Luminaire Requirements	Updated requirements
5.2 Installations	Updated requirements. Moved 6.2.5 Tenants and Concessions to 5.2.6 Tenants and Concessions
9.2 DEN Technical Requirements- Division 26: Electrical	Updated requirements. Moved 6.2.5 Tenants and Concessions to 5.2.6 Tenants and Concessions

2021 Revisions

Fourth Quarter

Reference	Revision Description
Table 2-1: Panelboard Naming Conventions	Added “EU” designator to all types of panel naming.
2.1.18 Energy Management and Control System	Corrected acronym
2.1.21 Variable Frequency Drives	New paragraph
2.2.11 Telecommunication Rooms	Updated requirements
5.2.3 Emergency Lighting	Updated requirements

Fourth Quarter

Reference	Revision Description
5.3.3.3 Parking Entrance/Exit Canopies	New paragraph
5.3.6 Airfield Facilities	Updated requirements
6.1.4 Tenants and Concessions	Updated requirements for submetering equipment
Section 262713: Electricity Meeting	Updated content
Section 263100: Photovoltaic Collectors	New section

Second Quarter

Reference	Revision Description
1.0.1 Definitions	New table
2.0.4.1 Disconnecting Means at Fire Command Centers	New information
2.1.11 Uninterruptible Power Supply	Updated requirements for runtime
2.1.17 Automatic Transfer Switches	Updated requirements for type of transfer switch
2.1.18 Energy Management and Control System	Added description and requirements
2.1.19 Programmable Logic Controllers in Main Switchgear (PLC)	Added description and requirements
2.1.20 Floor Devices	Added requirements
2.2.4.1 Selective Coordination	Updated process
5.1.2 General Requirements	Expanded lamp prohibitions
5.1.3 Luminaire Requirements	Removed outdated information
5.1.4 Performance Requirements	Updated requirements
5.3 Facility Design Guidelines	Various updates to light level requirements
Chapter 9- Technical Specification Requirements	**NOTE: This information is part of a major process change for DEN design projects**. Refer to the Q2 2021 edition of DSM Standards and Criteria, chapter 11, for additional information regarding DEN technical specification requirements and process.

Revision Notation: Revisions made to this Manual during this revision cycle are annotated as shown in the example below:

A vertical line in the left-hand margin is used to annotate paragraphs that have been added or revised in the current publication. Revisions may include items such as new requirements, clarification of existing requirements, or removal of requirements that no longer apply to projects. Revision annotation is applied to each publication individually; revisions made in past publications are not annotated in subsequent publications.

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Purpose of Design Standards Manuals

The DEN Design Standards have been developed to ensure a unified and consistent approach to the thematic and technical design for DEN. These standards are for use and strict implementation by all consultants under contract to DEN, to tenants, and all other consultants under contract to any other entity for the design of projects at DEN.

The Standards Manuals are working documents, which will be revised and updated, as required, to address the general, conceptual, design, and technical standards for all areas of design for DEN.

This Design Standards Manuals (DSM) for DEN has been prepared for use by competent, professionally licensed architectural and engineering consultants under the direction of DEN Maintenance and Engineering or tenants of DEN.

The Design Standards shall not be quoted, copied, or referenced in any bidding or construction contract documents. Content contained in this Manual shall not be copied in any bidding or construction documents, except where specifically instructed to do so. All information contained in these standards must be fully explained and shown in all bidding and contract documents.

The Design Standards Manuals are intended to be used as a whole, as each manual is complimentary to the other DSMs. To understand the overall thematic and design standards for DEN, the applicable manuals must be utilized together and not separated from the Design Standards Manuals.

The Consultant shall not reproduce, duplicate in any manner, transmit to other consultants or other entities, or use in conjunction with other projects without the express written consent of DEN.

NOTE: This document is optimized for duplex (double-sided) printing.

VARIANCE FROM DEN DESIGN STANDARDS MANUALS

Requests for non-conformance or variance from DEN Design Standards manuals, for any DEN or Tenant Projects, must be formally submitted using the online DSM Variance Request form at the following website:

DEN DSM Variance Request Form

Variance requests may or may not be approved by DEN and response will be communicated to the requestor.

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Chapter 1 - General

1.0 General

The electrical systems for all facilities at the DEN are to be based on the use of proven design techniques. These techniques shall utilize readily available equipment and components. Designs shall conform to the design criteria listed herein, with the highest priority being the safety, convenience, and comfort of the traveling public.

Systems must be serviceable, maintainable, and at the same time, provide flexibility for future addition and/or modification. They must be easy to operate and stable throughout their life. They must serve the public well. All equipment installations, including all their components, must be accessible for adjustment and maintenance. Ample space must be provided to permit the removal and replacement of all equipment items. Systems and components shall be provided with provisions for central monitoring, control, and diagnosis.

Airport facilities are dynamic in that changes, additions, and modifications are to be anticipated, and electrical systems may have to be altered to accommodate these changes. Future technology developments may make system modifications and/or additions desirable. Flexibility in system design will be the key to allow the changes that are an integral part of a modern air transportation facility.

Energy cost savings and conservation shall be criteria in the design of electrical systems. Facility designs must comply with the energy conservation budgets and goals included in these standards. Life cycle cost valuation and first costs are important considerations throughout the design process, from concept to final design and through construction.

1.0.1 Definitions

The definitions shown in Table 1-1: Definitions shall apply to this Manual.

Table 1-1: Definitions

Term	Definition
Tenant	A retail establishment, airline, or other entity which has a space lease agreement with DEN.
Concessions Tenant	A retail establishment, not an airline, which has a space agreement with DEN.

1.1 Utility Descriptions

1.1.1 Normal Electrical Power

The primary power distribution system for DEN is based on the Xcel Energy (Xcel) supplied 25,000-volt, wye, grounded, three-phase system, with a primary selective and looped distribution system.

The 25,000-volt feeders emanate from four redundant 230kV to 25kV Xcel-owned 50 MVA substations located off the airport site. One substation is located north of the site (Barr Lake Substation), and one is located south of the site (Sky Ranch Substation). The substations receive power from the bulk electrical system at 230kV, which includes multiple power source generation points.

At each substation, redundant transformers feeding the breaker buses are utilized. Four dedicated primary feeders extend from each substation's 25kV switchgear to the airport site. These four 25kV feeders from each substation (a

total of eight feeders) form redundant sources of power for the airport site. Emergency power is not available for these substations.

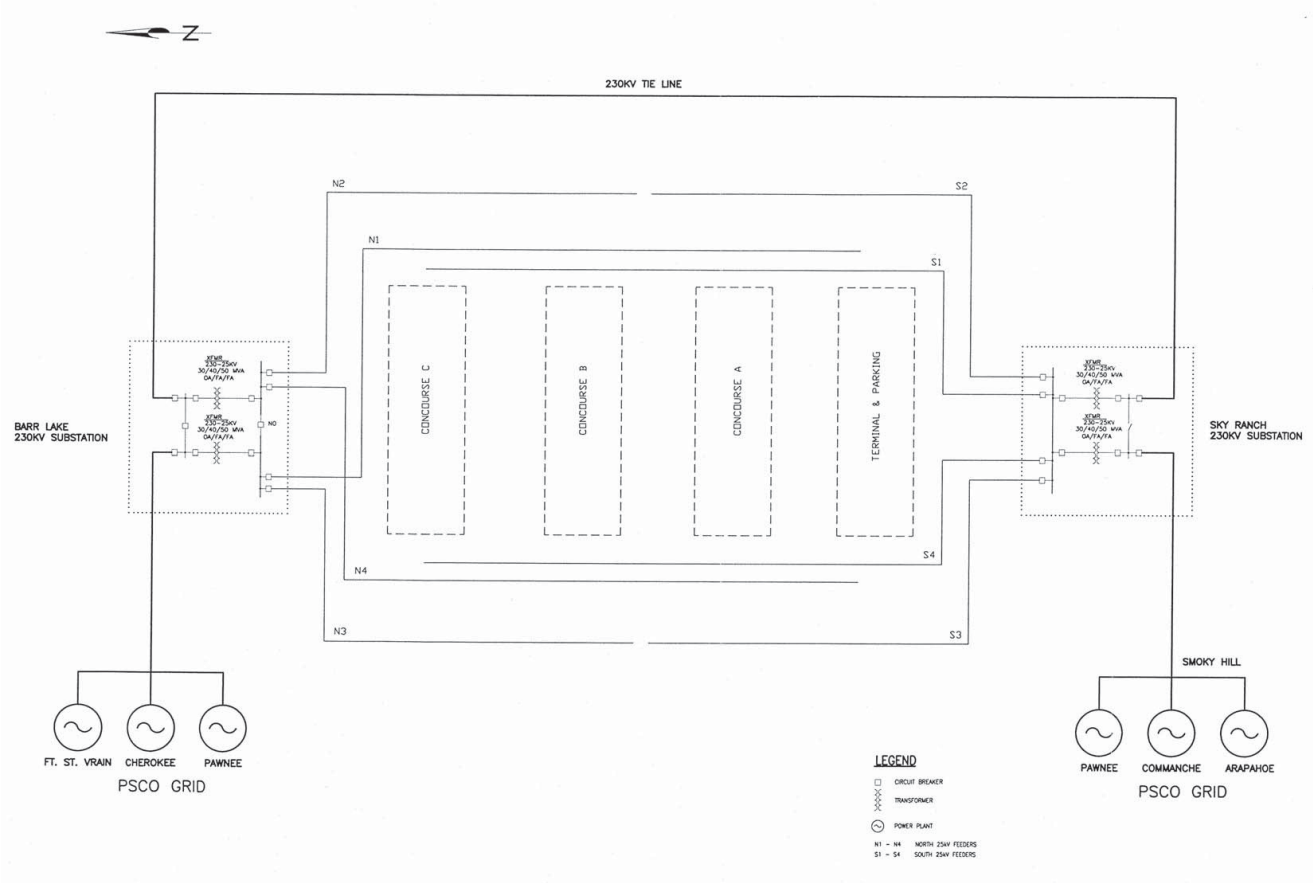

Figure 1-1: DEN Primary Electrical Distribution Schematic

The primary selective feeders are run in an underground concrete-encased duct bank and manhole system located within predetermined utility corridors. These feeders extend through primary switchgear to form a sub-distribution system for primary power service to airport facility transformers.

1.1.2 Communications

Communications services are provided throughout the airport. Generally, communications service is provided to each facility and/or facility tenant at a designated service point near or in the facility. Determination of this designated service point will be on a case-by-case basis. Interior facility and tenant communication systems may be privately owned or leased as determined on a case-by-case basis.

1.1.3 Alarm Systems

Alarms in facilities such as fire, security, and energy management and control system (EMCS) will report alarm conditions to the airport central alarm station at the Communications Center.

1.1.4 Security System

The security system shall be controlled from the central security control center with independent power and redundant CPU capacity integrated with the card access and CCTV.

1.2 Design Parameters

1.2.1 Electrical Equipment Ratings

All electrical equipment selected shall have a minimum capability for installation at 40 degrees C ambient temperature. Equipment shall be designed and rated for installation at a minimum of 5400 feet elevation above mean sea level and in a Seismic 1 Zone. Voltage ratings are defined as:

A. Low Voltage = 0 – 1000 volts phase-to-phase
B. Medium Voltage = 1001 – 72,500 volts phase to phase
C. High Voltage = 72,501 – 242,000 volts phase-to-phase

All equipment that contains a microprocessor that is not powered from an uninterruptible power supply shall be specified to have a line-side surge protection device (SPD). This can be in the form of a surge suppression receptacle for plug-in equipment or a hard-wired SPD for hard-wired equipment. Where several circuits supplied from a panelboard require surge suppression, the SPD can be a hard-wired package at the panelboard to protect the entire panelboard.

1.2.2 Excess Capacity

Electrical power distribution systems and components shall be designed to provide a minimum load growth of 25% without the need for modifications or additions to the electrical system. Special cases may require provisions for larger growth, such as the Central Utility Plant (CUP).

1.2.3 Voltage Drop

The electrical power distribution feeder and branch circuits shall be designed to have a maximum cumulative voltage drop, from source to load, including all system components of 5%. Feeders shall be allowed a maximum of 2% voltage drop, and branch circuits shall be allowed a maximum of 3% voltage drop.

Transformers, motor starters, and feeders shall be designed to limit motor starting voltage drop to 15% at the motor terminals and to 1% at the motor feeder source motor control center or panelboard (0.5% voltage drop on loads that cycle on and off frequently).

1.2.4 Short Circuit Current

Electrical power distribution systems shall be designed, and components selected to limit the short circuit current available to the lowest economic level while still maintaining a high level of efficiency and performance. The design goal is to limit the available short circuit current in systems rated 208Y/120 volts to 10,000 amperes or less whenever possible. The design of systems rated 480Y/277 volts shall have as a goal (as much as is practical, possible, and cost-effective) limiting the available short circuit current to below 14,000 amperes or the standard ratings of the equipment.

All electrical equipment and panelboards shall be fully rated; Series-rated systems and equipment shall not be allowed.

1.2.5 Power Factor

Electrical power distribution systems shall be designed, and components selected to maintain the system power factor at the highest economical level. The design goal is to maintain a system power factor at 95% or better, but in no case should it be allowed to fall below 90%. In general, motors 15 horsepower and larger should have the equipment to correct the power factor to 95% lagging (unless the facility's power factor is corrected by a synchronous motor or a central power factor controller).

1.2.6 Utility Coordination

All designs shall comply with the latest adopted utility design handbook and guidelines. Utility requires a Letter of Authorization (LOA) from the DEN PM prior to substantial design work for any given project.

Adding any load to an existing service requires Xcel Energy to pre-approve the design. This must be done via the application process. For added loads over 301kw a capacity check is required to confirm existing Xcel Energy infrastructure can safely provide service.

New project design shall be a single substation feed unless approved by DEN to utilize a dual substation feed to limit impacts on electrical capacity.

Projects with large electrical infrastructure increases shall coordinate with DEN Sustainability for allocations of electrical capacity available for the project.

A new electrical service may be required if the new capacity exceeds what DEN can provide on existing infrastructure at the building or structure. Coordinate exact requirements with DEN PM and Sustainability.

1.2.7 Listing Agencies

All electrical components and systems shall be UL- or ETL-listed. Unlisted components and systems are prohibited. Any proposed equipment which is listed under alternative, nationally recognized testing laboratories (NRTLs) or anticipated to be field listed by an NRTL shall require approval using the formal substitution request process.

1.3 Design Document Requirements

1.3.1 Design Analysis Requirements

At each phase of project development, a design analysis report shall be prepared in accordance with the Standards and Criteria DSM requirements. The electrical system design analysis shall accompany each progress submittal and shall be a complete, written record of the following data:

A. A brief statement of the design objectives.
B. Design approach- selection of major component types, equipment space locations, and power sources.
C. Calculated estimates of connected and demand loads.
D. Equipment and material selections are based on the applicable design standard requirements. Provide verification of availability from repetitive manufacturing sources.
E. Provide voltage drop calculations. Values are to be shown on the single-line diagram at each point in the system.
F. Provide short-circuit current calculations. Values are to be shown on the single-line diagram at each point in the system.
G. Calculate the necessary wire and cable sizes required that would not be damaged by the short circuit currents available.

Design analysis includes the calculation of estimated electrical loads and the diversified power demand resulting from those loads, plus an anticipated future load growth. Those calculations, proposed equipment electrical ratings, dimensional data, and manufacturer's catalog information, together with a preliminary one-line diagram, are part of the design analysis (design notes) submitted at the concept progress review. The design development submittal shall expand the concept design to include preliminary sizing of the service entrance and main feeders. The design analysis for the 60% completion review also includes a preliminary system fault current (short circuit) and worst-case voltage drop analysis. The design analysis shall be updated and expanded with each subsequent submittal, progressing to a thorough verification of final design conclusions.

1.3.2 Construction Drawing Requirements

Electrical system drawings are prepared in accordance with the standards drawing format detailed in the Standards and Criteria DSM. Separate floor plans shall be provided for:

A. Power
B. Lighting
C. Telephone, Communication, Public Address (PA), CCTV, and Security Systems
D. Fire Alarm/ECS

Refer to Section 105, Deferred Design in the Life Safety Manual.

EXCEPTION: Combinations of lighting, power, and communications shall be allowed on smaller facilities and shall be handled on a case-by-case basis.

Floor plans indicate conduit routing for main electrical services, power distribution, and power feeders to equipment requiring 1" and larger conduit. Refer to the Digital Facilities and Infrastrucutre DSM for detailed conduit modeling and depiction requirements. Conduit and circuiting for lighting and small power apparatus are shown schematically. Locations of conduit runs are provided by notations and legend symbols. All conduit runs are identified by the scheduled circuit number on the plans. Conduit and conductor sizes are provided only in the panelboard schedules.

Detail (1/4" scale) plans shall be provided for mechanical and electrical equipment rooms and other areas of concentrated work.

Provide complete single-line diagrams in all construction drawing sets.

The project plans shall also include large-scale details for all equipment installations that cannot be adequately delineated in the plan review. The required details shall include typical raceway mounting, raceway connection, motor connections, lighting fixture and equipment mounting, and grounding and lightning protection installations.

Construction and Utility coordination cannot proceed until a Letter of Authorization (LOA) is provided by DEN Project Manager.

1.3.3 Commissioning Requirements

Electrical systems at DEN are required to be provided with commissioning above and beyond what is required by the City and County of Denver and the IECC amendments. Designer to utilize requirements within IES LP-8 “The Commissioning Process Applied to Lighting and Control Systems” as a guide and refer to the Commissioning Specification and Commissioning Section of the Sustainability DSM for additional requirements.

End of Chapter

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Chapter 2 - Interior Electrical Power Distribution Systems

2.0 Interior Electrical Power Distribution Systems

2.0.1 Scope

This section includes specific design guidance for the selection and application of equipment and materials to be included in interior electrical systems. This section also presents requirements for bid document preparation.

2.0.2 Criteria

These standards are developed, in part, from publications of the latest edition of the following codes, standards, and guides:

A. American Society of Testing and Material (ASTM) Standards
B. American National Standards Institute (ANSI) Standards, including ANSI C2, “National Electrical Safety Code”
C. Certified Ballast Manufacturers (CBM) Standards
D. Electrical Testing Laboratory (ETL) Standards
E. Electronic Industries Association (EIA) Standards
F. Federal Communications Commission (FCC) Rules and Regulations
G. National Electrical Manufacturers Association (NEMA) Standards
H. National Fire Protection Association (NFPA) Standards:
    a. NFPA 20, “Installation of Centrifugal Fire Pumps”
    b. NFPA 70, “National Electrical Code” (NEC) as adopted and amended by the Denver Building Code, Chapter 59
    c. NFPA 71, “Installation, Maintenance, and Use of Signaling Systems for Central Station Service”
    d. NFPA 72A, “Installation, Maintenance, and Use of Local Protective Signaling Systems for Guard's Tour, Fire Alarm and Supervisory Service”
    e. NFPA 72B, “Installation, Maintenance, and Use of Auxiliary Protective Signaling Systems for Fire Alarm Service
    f. NFPA 72C, “Installation, Maintenance, and Use of Remote Station Protective Signaling Systems”
    g. NFPA 72D, “Installation, Maintenance, and Use of Proprietary Protective Signaling Systems”
    h. NFPA 72E, “Automatic Fire Detectors”
    i. NFPA 72F, “Installation, Maintenance, and Use of Emergency Voice/Alarm Communication Systems”
    j. NFPA 72G, “Installation, Maintenance, and Use of Notification Appliances for Protective Signaling Systems”
    k. NFPA 72H, “Testing Procedures for Local, Auxiliary, Remote Station and Proprietary Protective Signaling Systems”
    l. NFPA 780, “Lightning Protection Code”
    m. NFPA 90A, “Installation of Air Conditioning and Ventilating Systems”
    n. NFPA 101, “Safety to Life from Fire in Buildings and Structures”
    o. NFPA 409, “Aircraft Hangars”
    p. NFPA 415, “Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways”
I. Institute of Electrical and Electronics Engineers (IEEE) Standards:
    a. IEEE 141 “Recommended Practice for Electric Power Distribution for Industrial Plants”
    b. IEEE 142 “Recommended Practice for Grounding Industrial and Commercial Power Systems”
    c. IEEE 241 “Recommended Practice for Electric Power Systems in Commercial Buildings”
    d. IEEE 242 “Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems”

e. IEEE 446 “Recommended Practice for Emergency and Standby Power Systems”

J. Underwriters Laboratories, Inc. (UL) Standards and “Product Directories”

K. Insulated Cable Engineers Association (ICEA) Standards

L. Factory Mutual (FM) “Approved Guide,” and FM “Loss Prevention Data”

M. Illuminating Engineering Society (IES) Lighting Handbook and Lighting Library

N. Department of Labor, “Occupational Safety and Health Standards,“. “Title 29“, Code of Federal Regulations (CFR), Part 1910

O. General Services Administration, Federal Supply Service, “Federal Standards,” and “Federal Specifications”

P. Federal Construction Council, “Federal Construction Guide Specifications;” and Technical Reports Number 46, “Diesel Engines for Use with Generators to Supply Emergency and Short-Term Electric Power,” and Number 42, “Continuously Operating Diesel Engines for Electrical Power Generators”

Q. Xcel Energy’s “Standard for Electric Installation and Use”

2.0.3 Design Approach

Careful planning and design of electrical systems are necessary to ensure that initial and projected power requirements are satisfied. Systems design shall result in the supply of dependable power for present and anticipated future needs. The designs shall also provide optimized safety for normal operating and maintenance procedures. System options relative to conservation and cost of energy shall be carefully evaluated. NEC, ANSI/NFPA-70, as adopted and amended by the Denver Building Code, establishes minimum standards that shall be followed. Where requirements that are more stringent are contained in this section, these requirements shall take precedence. All references to the National Electrical Code or NEC shall be defined as NFPA-70, as adopted and amended by the Denver Building Code Chapter 59 and as amended by this manual. Electrical system materials and equipment shall conform to the applicable standards of those organizations listed above. Manufacturers’ recommendations shall also be considered.

2.0.4 Buildings with Multiple Electrical Services

Where multiple electrical services feed the same building or structure (such as in the terminal complex), electrical service separations shall be maintained. No feeders or branch circuits shall be installed which cross the line(s) of demarcation designated by the DEN Electrical Engineer and the Denver Fire Department.

All power from distribution panel boards to the final point of outlet or device location shall be located on the same floor and in the same smoke zone. Routes may go through other floors but at no time shall feed other floors. The purpose of this service criterion is to simplify power shutoff for the Fire Department in an emergency.

2.0.4.1 Disconnecting Means at Fire Command Centers

Individual disconnecting means for each switchgear shall be provided in the building fire command center to allow emergency personnel to remotely disconnect power for a specific area of the associated building. New switchgear shall be provided with an illuminated remote “shunt trip” push button, utilizing the Fire Alarm system for supervised operation of the switchgear disconnecting means. The design shall comply with all applicable codes and administrative modifications pertaining to the project. Fire command center push buttons shall illuminate upon positive confirmation of power shutdown via a monitoring module at the switchgear. Shunt trip controls at the fire command center shall not disconnect emergency power systems.

Existing legacy systems in the Terminal Complex constructed prior to 2014 utilize an unsupervised (direct-wired) connection to the electrical switchgear. Major modifications to these systems (such as switchgear replacement, relocation, or other work) may require that the existing shunt trip system be upgraded to meet current codes and these design standards.

2.0.4.2 Main Terminal and AOB

The main terminal electrical service is separated by module and between the east and west sides of the terminal. Parking garages are served by separate switchgear. All switchgear is located on level 2 of the main terminal. Refer to Figure 2-1: Terminal and Hotel Transit Center Area Designations for a graphical depiction of service separations.

The Airport Office Building (AOB) is fed by two dedicated switchgear, serving normal and emergency loads. Each switchgear is provided with redundant Xcel feeds and an automatic throw-over mechanism. Local backup is also provided to the AOB through a standby generator.

2.0.4.3 Hotel and Transit Center

The DEN hotel and transit center contains multiple electrical services due to overall building load and service separation requirements. Hotel and DEN electrical services each originate from their own set of utility sources. There are four (4) electrical services entering the building, with (2) located on the west side of the building and (2) located on the east. All power from distribution panel boards to the final point of outlet or device location shall be located on the same side of the building and on the same floor. All power for hotel and conference center spaces shall be fed from hotel distribution panel boards, and all power for transit center and city spaces shall be fed from city distribution panel boards.

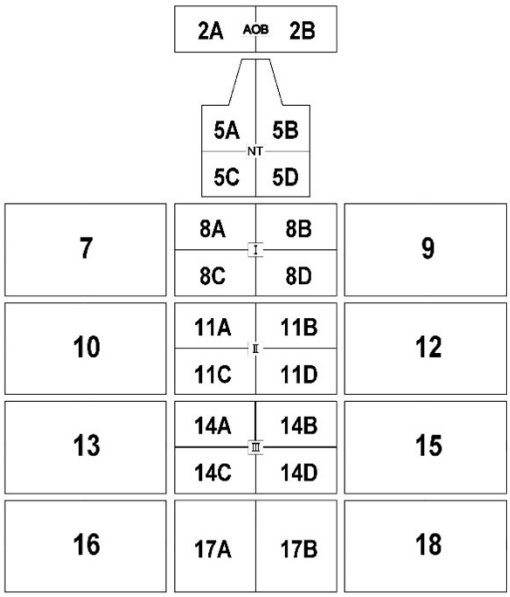

Figure 2-1: Terminal and Hotel Transit Center Area Designations

2.0.4.4 Concourse A

Concourse A contains switchgear in each core area serving general building loads, as well as separate switchgear serving baggage handling system and gate service loads.

Lines of demarcation for switchgear serving building loads are typically located halfway between each subcore and bisecting the center core of the building along the north-south center line. Refer to Figure 2-2: Example Concourse Lines of Demarcation (Concourse C Depicted) for an example of these demarcation lines, using Concourse C as the example.

Switchgear for baggage systems and gate service loads are located in the east and west subcores of Concourse A, and feed gate service and baggage handling loads on each side of the concourse.

2.0.4.5 Concourse B

Concourse B contains switchgear in each core area serving general building loads, as well as separate switchgear serving baggage handling and gate service loads.

Lines of demarcation for switchgear serving building loads are typically located halfway between each subcore and bisecting the center core of the building along the north-south center line. Refer to Figure 2-2: Example Concourse Lines of Demarcation (Concourse C Depicted) for an example of these demarcation lines, using Concourse C as the example.

Switchgear for baggage handling systems and gate service loads are in each of the subcores, serving loads in those core areas only.

The Concourse B south commuter facility, located on the southeast corner of Concourse B, is served by its own switchgear.

2.0.4.6 Concourse C

Concourse C contains switchgear in each core area serving building loads. Lines of demarcation are located halfway between each subcore, as shown in the following figure. All loads, including baggage handling systems and gate service loads, are served by these switchgears in the existing airport areas. Concourse expansion areas (Subcores E2 and E3) have separate gate and baggage switchgears located in the basement.

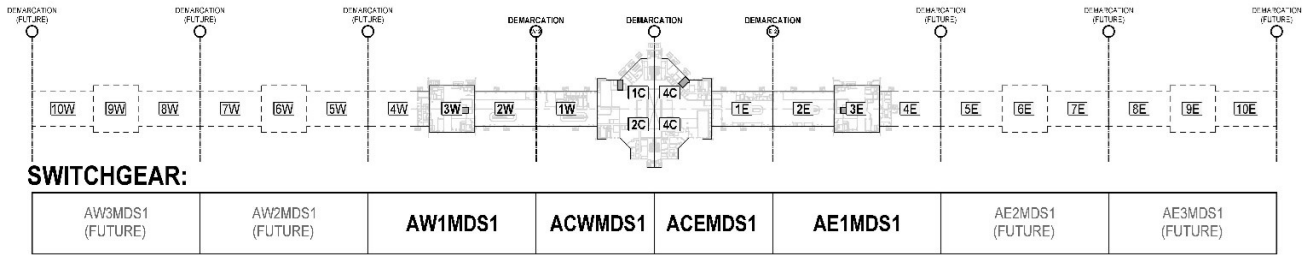

Figure 2-2: Example Concourse Lines of Demarcation (Concourse C Depicted)

2.0.5 Facility Planning

Facility planning shall include consideration for operating and maintenance requirements for electrical systems and equipment for the life of the facility. Safety of life for facility occupants, the public, operating, and maintenance personnel, and protection of property are the most important factors in the planning and design of electrical systems. The simplicity of systems and equipment operation shall be a principal objective. The design of the electrical system shall include considerations for preventive maintenance and for repair, test, and replacement of equipment. Safe accessibility for inspection and repair are important considerations in selecting and locating equipment. Space needs to be provided for inspection, adjustment, and repair. The space shall also be clean, well-lit, dry, and ventilated. The equipment should be located such that replacement, as well as repairs, can be accomplished without the need for dismantling or removing other equipment.

2.0.6 System Planning

System planning, and equipment selections, shall include maintenance considerations, consideration of energy conservation objectives to maximize efficient energy usage, and to minimize energy losses within the electrical system, on a life cycle cost-effective basis.

2.0.7 Energy Management Systems and Devices

A. In the planning and design of interior electrical systems, compatibility with energy management systems (and devices) and the potential benefits from their use shall be considered.

B. Criteria on energy analysis requirements are contained in the Mechanical DSM.

2.1 Materials and Equipment

2.1.1 Conductors

A. Conductors for electrical systems shall be copper.

B. Conductors for power and lighting branch circuits shall be No. 12 AWG, minimum.

C. Conductors for electrical control circuits shall be No. 14 AWG, minimum. Conductor sizes for remote control signaling and power limited circuits, fire protection signaling systems, and communication circuits shall be in accordance with NEC Articles 725, 760, and 800.

D. All circuits shall be provided with their own independent full-size neutral conductor. Electrical branch circuit and interior supply-side circuit conductors shall be suitably color-coded. This coding or labeling shall identify voltage levels, the grounded conductors, the equipment grounding conductors, and ungrounded single-phase or poly-phase conductors. The color coding for electrical systems is shown below.

E. For 240/120-volt, single-phase systems:

Grounded neutral:	White
Grounding conductors:	Green or bare when not routed in conduit
One hot (ungrounded) conductor:	Black
One hot (ungrounded) conductor:	Red

F. For 208Y/120-volt, 3-phase, systems:

Grounded neutral:	White
Grounding conductors	Green or bare when not routed in conduit
Phase A (ungrounded) conductor:	Black
Phase B (ungrounded) conductor:	Red
Phase C (ungrounded) conductor:	Blue

G. For 480Y/277-volt, 3-phase, systems:

Grounded neutral:	Gray
Grounding conductors:	Green or bare when not routed in conduit
Phase A (ungrounded) conductor:	Brown
Phase B (ungrounded) conductor:	Orange
Phase C (ungrounded) conductor:	Yellow

H. For 4160-volt, 3-phase systems:

Grounded neutral:	Bare
Phase A (ungrounded) conductor:	Brown
Phase B (ungrounded) conductor:	Orange
Phase C (ungrounded) conductor:	Yellow

2.1.2 Raceways

Selection and installation of raceways, elbows, couplings, and other fittings shall be in accordance with the provisions of the National Electrical Code, with the following restrictions:

A. Neither aluminum conduit nor electric metallic tubing (EMT) shall be embedded in the concrete or buried in the earth.
B. Only noncombustible raceways shall penetrate fire-rated walls, floors, or ceilings. Raceway penetrations shall be suitably sealed to maintain the established fire ratings.
C. Wireways (NEC Article 362) shall not be wall or partition mounted at elevations less than 4 feet above floor level unless suitable protection against physical damage is provided.
D. Conductors rated more than 1,000 volts shall be installed steel RMC throughout, with portions encased in concrete permitted to be in PVC conduit.

Conduit that is installed in exposed, open locations, such as an atrium (where there is not a way to route the conduit concealed), shall be routed behind structural members and painted the same color as the structural members to “conceal” the conduit from view as much as is possible.

Where circuits are routed through millwork, the circuits shall be routed in conduit and concealed inside of the millwork. Coordinate conduit installation with the millwork fabricator.

Conduit and underfloor duct systems which are embedded in concrete or masonry shall be adequate in number and capacities for the initial and projected facility requirements. Embedded conduits shall be not less than 3/4 inch in size.

Galvanized rigid steel conduit shall be used in all areas except where EMT and aluminum conduit are allowed. Galvanized rigid steel conduit shall be PVC coated where in direct contact with concrete.

EMT shall be considered for indoor non-hazardous locations (except where the conduit would be subject to physical damage, corrosion damage, and including the use restrictions above).

Provide a pull rope in all conduits left empty.

Use wireways only for exposed work. Do not fill wireways over 20 percent of their cross-sectional areas. For special conditions, refer to the National Electrical Code.

Rigid plastic PVC conduit NEMA EPC-40 shall be used for underground and installation below slab on grade. PVC conduit shall transition to PVC coated galvanized rigid steel five feet outside of buildings and where it passes through foundations.

PVC conduit routed outdoors below grade shall be encased in red concrete. All PVC conduit shall have PVC-coated galvanized rigid steel 90-degree bends and risers. PVC conduit installed below concrete slabs on grade or asphalt shall not be required to be concrete encased when containing individual branch circuits or data cabling.

2.1.3 Panelboards and Circuit Breakers

Panelboards rated 600V and below used for lighting and power distribution should be of the dead front type in NEMA 1 general-purpose enclosures or in higher NEMA-rated enclosures as required for the conditions to be encountered. Bus work shall be tin-plated copper. Bus current density shall not exceed 1000 amperes per square inch.

Segregate mechanical equipment loads on the power panelboards as much as is practical. Lighting panelboards and small power panelboards shall be utilized only for lighting and small power (respectively) as much as is practical.

Branch circuit breakers should be of the bolt-on, thermal magnetic, molded case type, with a minimum trip rating of 15 amperes and a minimum interrupting rating of 10,000 amperes (and larger as required by the application). The use of molded case circuit breakers in panelboards should be limited to no greater than the 1,200-ampere trip-rating size.

Where molded case circuit breakers of the "systems type" of from 1,200 to 4,000-ampere trip-rating sizes are to be used, they should be of the drawout type, with contacts accessible for inspection and replacement, and with suitable ground fault protection features adjustable solid-state trip elements.

Panelboards shall be designated with a unique name based on their location and power source. Refer to Table 2-1: Panelboard Naming Conventions

Transformers shall be named according to the panelboard being served, with a "T-" prefix added to indicate that it is a transformer.

Table 2-1: Panelboard Naming Conventions

Grounds and Outlying Buildings Example: FS5 2TDEH1 A	
FS5	Building designation code. Three or more letters. Example: FS5 Choices: Contact DEN DFI Group for building designation code associated with the project. OR If building does not have a three-letter designation, use Crash Grid. Choices: **A** through **FFJ** (West to East) and **1** through **31** (South to North)
2	Floor level (multi-story buildings only). Choices: 1…N or as otherwise designated based on building type.
T	Indicates CONCESSIONS TENANT panel if appropriate. Choices: **T** [TENANT] or blank [no space] if DEN
D	Indicates distribution panel if appropriate. Choices: **D** [DISTRIBUTION] or blank [no space] if NOT DISTRIBUTION
E	Indicates panel feeder function. Choices: **E** [EMERGENCY/ESSENTIAL POWER], **U** [UPS origin], **EU** [EMERGENCY/ESSENTIAL POWER AND UPS ORIGIN], or blank [no space] for normal power.
H	Indicates Panel voltage. Choices: **H** = 600 or 480Y/277 or **L** = 208Y/120 or 240/120
1	Sequence number of this panel supplied from this source. Choices: **1**…**N**

Notes:

1. Main distribution panels for outlying buildings: Include building designation code, followed by "MDP," or "MDS," and sequence number as appropriate.

2. Single-story structures: Omit floor level from panel names.

3. Branch circuit panels: May omit building designation code in panel nameplates and other circuit labels (e.g. junction boxes, faceplates, etc.). Example: 2TDEH1A.

Table 2-1: Panelboard Naming Conventions (Continued)

Concourse Buildings and Tunnel System Example: B AW1TDEL1 A	
B-	Concourse letter. Choices: **A** through **C** (South to North)
A	Floor level. Choices: **T** [tunnel] or B [basement] or **A** [apron] or **C** [concourse] or **M** [mezzanine] or **4** [fourth floor] or **5** [fifth floor] or **R** [roof].
W1	Core Area. Choices: **CE** [center core east side] or **CW** [center core west side] or **E1** … **E3** [sub-core number east of center core] or **W1** … **W3** [sub-core number west of center core]
T	Indicates CONCESSIONS TENANT panel if appropriate. Choices: **T** [TENANT] or blank [no space] if DEN
D	Indicates distribution panel if appropriate. Choices: **D** [DISTRIBUTION] or blank [no space] if NOT DISTRIBUTION
E	Indicates panel feeder function. Choices: **E** [EMERGENCY/ESSENTIAL POWER], **U** [UPS origin], **EU** [EMERGENCY/ESSENTIAL POWER AND UPS ORIGIN], or blank [no space] for normal power.
L	Indicates Panel voltage. Choices: **H** = 600 or 480Y/277 or **L** = 208Y/120 or 240/120
1	Sequence number of this panel supplied from this source. Choices: **1**…**N**
-A	Sub-fed panel suffix, if appropriate. Choices: **-A**… as required.

Terminal, Airport Office Building (AOB) and Parking Structures Example: 6 11CTDEL2 A	
6-	Floor level. Choices: **T** [tunnel] or **1** through **11**, depending on building.
11C	Module designation (See Architectural designation). Choices: **01** through **15** and **A** through **D**.
T	Indicates CONCESSIONS TENANT panel if appropriate. Choices: **T** [TENANT] or blank [no space] if DEN

Terminal, Airport Office Building (AOB) and Parking Structures Example: 6 11CTDEL2 A	
D	Indicates distribution panel if appropriate. Choices: **D** [DISTRIBUTION] or blank [no space] if NOT DISTRIBUTION
E	Indicates panel feeder function. Choices: **E** [EMERGENCY/ESSENTIAL POWER], **U** [UPS origin], **EU** [EMERGENCY/ESSENTIAL POWER AND UPS ORIGIN] or blank [no space] for normal power.
L	Indicates Panel voltage. Choices: **H** = 600 or 480Y/277 or **L** = 208Y/120 or 240/120
2	Sequence number of this panel supplied from this source. Choices: **1**…**N**
-A	Sub-fed panel suffix, if appropriate. Choices: **-A**… as required.

Central Utility Plant Example: L AHDE2A	
L-	Floor Level. Choices: **L** [Lower level], **M** [Mezzanine], **G** [Grade], **B** [Basin], **R** [Roof]
A	Associated Switchgear. Indicates the electrical service from which the panel is fed. Choices: **A** [HGMC-A], **B** [HGMC-B], **C** [HGMC-C].
H	Indicates Panel Voltage. Choices: **H** = 600 or 480Y/277, **L** = 208Y/120 or 120/240, **MV** = 4,160.
D	Indicates distribution panel if appropriate. Choices: **D** [DISTRIBUTION] or blank [no space] if NOT DISTRIBUTION.
E	Indicates panel feeder function. Choices: **E** [EMERGENCY/ESSENTIAL POWER], **U** [UPS origin], **EU** [EMERGENCY/ESSENTIAL POWER AND UPS ORIGIN] or blank [no space] for normal power.
2	Sequence number of this panel supplied form this source. Choices: **1**…**N**
A	Sub-fed panel suffix, if appropriate. Choices: **A**… as required.

Aircraft Gate Distribution Boards Example: C AW1GDH1	
C-	Concourse letter. Choices: **A** through **C** (South to North)
A	Floor level. Choices: **T** [tunnel] or **B** [basement] or **A** [apron] or **C** [concourse] or **M** [mezzanine] or **4** [fourth floor] or **5** [fifth floor] or **R** [roof].
W1	Core Area. Choices: **CE** [center core east side] or **CW** [center core west side] or **E1** … **E3** [sub-core number east of center core] or **W1** … **W3** [sub-core number west of center core]
GD	Indicates gate distribution.
H	Indicates Panel voltage. Choices: **H** = 600 or 480Y/277 or **L** = 208Y/120 or 240/120
1	Sequence number of this board supplied from this source. Choices: **1**…**N**

Aircraft Gate Service Panels Example: C AW1G19H1	
C-	Concourse letter. Choices: **A** through **C** (South to North)
A	Floor level. Choices: **T** [tunnel] or **B** [basement] or **A** [apron] or **C** [concourse] or **M** [mezzanine] or **4** [fourth floor] or **5** [fifth floor] or **R** [roof].
W1	Core Area. Choices: **CE** [center core east side] or **CW** [center core west side] or **E1** … **E3** [sub-core number east of center core] or **W1** … **W3** [sub-core number west of center core]
G19	Indicates gate number.
H	Indicates Panel voltage. Choices: **H** = 600 or 480Y/277 or **L** = 208Y/120 or 240/120
1	Sequence number of this panel supplied from this source for this gate. Choices: **1**…**N**

2.1.4 Low Voltage Switchgear and Switchboards

Low voltage switchgear and switchboards are of the dead-front type, floor mounted, freestanding, metal-enclosed type, insulated case circuit breaker equipped. Circuit breakers shall be stationary or draw-out mounting. (Draw-out mounting shall be used when required by design considerations and where required by the Owner.) "Space only" cubicles and appropriate bus provisions are installed for future protective device additions, as necessary, with provisions to accommodate designed load growth. Circuit breakers shall be lockable in the open position. Bus work shall be tin-plated copper with silver-plated connection joints. Bus current density shall not exceed 1000 amperes per square inch.

For all projects connecting new feeders to existing draw-out switchgear, new circuit breakers shall always be installed. No re-use of existing circuit breakers is allowed unless approved in writing by the DEN project manager.

2.1.5 Low Voltage Utility Metering Equipment

All low-voltage electrical services at DEN shall be metered at the service entrance using Xcel metering equipment. All requirements for service entrance metering, including meter configuration, line-side disconnects (where required), secondary connection cabinets (where required), and any other project-specific requirements shall be fully coordinated with the DEN Project Manager and Xcel.

2.1.6 Low Voltage DEN Submetering

In addition to utility metering, low-voltage submetering equipment shall be provided for use by DEN for internal reporting, engineering analysis, measurement, and verification. Submetering shall be provided for all specified electrical panels and loads in accordance with the facility design descriptions contained in this Manual.

The following types of hardware solutions are recommended for use in submetering at DEN. The Designer shall provide recommendations based on the project requirements and in coordination with the DEN Electrical Engineer.

A. Single-Load External Submeters

   Single-load external submeters are recommended for tenant metering and may be appropriate for other applications. To minimize equipment footprint, all single-load external submeters are required to be specified with built-in BACnet MS/TP or BACnet IP communication capability.

B. Multiple-Input Metering Units

   Multiple-input metering units comprise a single external hardware interface capable of monitoring multiple discrete loads. Loads are monitored by the external interface via current transformers. This type of submetering is recommended for situations in which two or more submetered loads are in close proximity.

C. Branch Circuit Monitoring

   Branch circuit monitoring typically consists of a built-in or drop-in hardware component designed to be installed within a branch circuit panelboard to submeter individual branch circuits. Branch circuit monitoring is recommended for tenant areas where multiple tenants are served by a single panelboard, for individually submetering lighting loads when metering relays, are not available, and for other situations in which individual branch circuits require submetering.

D. Equipment with the integral metering capability

   Where practicable, equipment with built-in metering capabilities, such as variable-frequency drives and metering relays is recommended in lieu of an external metering solution. This type of design reduces equipment footprint and leverages built-in capability to achieve the submetering requirement.

All submetering equipment shall be integrated, via standards-based communication protocol (BACnet MS/TP or BACnet IP), to the DEN Energy Management Control System (EMCS). All submetering equipment must be capable of reporting, at a minimum, kWh usage information as well as peak kW demand. Metering equipment shall be equipped with a local display system on the unit capable of displaying peak demand kW and kWh usage for each

metered load. The designer shall specify labeling requirements such that all external metering equipment clearly identifies the metered loads.

BACnet MS/TP cable shall be routed, in a daisy-chained configuration (two cables supplied to each meter), from the meter installation location to the nearest metering termination point; termination points are typically located in DEN Electrical Rooms. Coordinate the exact location of the nearest termination point on a per-project basis with the DEN Electrical Engineer.

The designer shall specify split-core current transformers to measure the current on each submetered load installed around each phase conductor as it leaves the output lugs of the breaker. The current transformers shall be connected to a multiple-input metering unit within the same electrical room. Metered loads in which electrical usage information can be pulled directly from the load via BACnet MS/TP or BACnet IP protocol, such as self-metering lighting control panelboards or variable frequency drives, may be specified without split-core current transformers. Metered loads may be aggregated into a single current transformer in cases where multiple branch circuits or feeders serving a single metered load are connected to the same phase, provided the equipment is installed in accordance with applicable codes and manufacturer's instructions.

All submetering equipment shall meet the requirements of ANSI C12.20 with an accuracy class of 0.5% or better. The designer shall ensure that any metering components intended to replace or be connected to existing metering equipment, such as current transformers, shall be listed and verified for use with the associated equipment such that the entire metering system complies with the requirements of ANSI C12.20.

The Designer shall ensure that all required hardware modifications, graphics, labeling, programming, and address assignments are performed as part of each project where new metering equipment is installed, as directed by the DEN Project Manager.

2.1.7 Low Voltage Motor Control

Low voltage motor controls, normally, shall be of the magnetic, across-the-line type. Reduced voltage type starters shall be used when starting results in more than a 15 percent transient voltage dip. Reduced voltage starters shall be used when supplied from a limited power source, such as an emergency engine generator. Variable Frequency Drive motor controls shall be used where variable speed motors are required. Manual controllers may be used within the limitations imposed by the NEC, where appropriate. Motor control centers having motor circuit protectors and motor controllers mounted in a single assembly shall be used where several motors are grouped in a particular area (i.e., mechanical equipment rooms). Bus work shall be tin-plated copper with silver-plated connection joints. Bus current density shall not exceed 1000 amperes per square inch.

Generally, motors having greater than 1/2 horsepower rating shall be three-phase.

2.1.8 4,160-Volt Switchgear

The 4,160-volt switchgear shall be of the indoor metal-clad type utilizing vacuum circuit breakers in a two-high arrangement. The switchgear shall consist of incoming line, tie, auxiliary compartments, and feeder circuit breaker units as required. Compartments shall be provided as required to accommodate indicated auxiliary equipment. The indicated number of active and spare circuit breakers shall be provided. The equipment shall be completely assembled, wired, and tested at the factory, ready for installation when received at the site. All interfacing and required field connections shall be tagged and labeled to correspond to the interconnection diagrams. Units denoted for "spare" shall consist of items of all equipment indicated, including the power circuit breakers. Circuit breakers, instrument transformers, instruments, instrument switches, and relays shall be provided for equipped space or future units. Continuous current rating of future units shall be as required. Switchgear shall be vented according to the manufacturer's standard practice. Intake openings shall be screened and filtered. Exhaust openings need to be screened only. Bus bars shall be tin-plated copper, except joints and connections shall be silver-plated. Maximum bus current density shall be 1,000 amperes per square inch.

Provide each circuit breaker with a local digital metering package that will also communicate with a digital monitoring system that will record and remotely indicate (via metering network) to a central PC (personal computer) the following: Amperes of all three phases, voltage of all three phases, kW, kVA, kVAR, power factor,

kWH, kVARH, frequency, breaker static trip settings, peak kW, time of peak kW, programmable audible alarm limits, breaker status, date and time of breaker trip, and date and time when amperes exceeded programmable limits.

2.1.9 Unit Substations

Unit substations shall be of the double-ended, indoor, metal-enclosed type. All metal-enclosed switchgear, primary load-interrupter switches, fuses, bus bars, structure supports, insulators, transformers, and all other component parts shall be manufactured and constructed in conformance with the latest publications of NEMA Standards PB2, SG6, TR1, and TR27. Each cubicle shall be a self-supporting, independently constructed unit.

Compartment doors shall be provided with handles with padlocking provisions. Rear access panels shall be hinged with bolt fasteners. General and modular arrangement of the unit substations, including all its component parts, shall be in conformance with the standard design of the equipment manufacturer unless specifically noted otherwise hereinafter or on the drawings. The completed unit substation assemblies shall be available for the Owner's inspection at the manufacturer's plant before shipment. The manufacturer shall submit satisfactory test data to prove the operation and performance of the unit substations in accordance with the intent of this specification. The unit substations shall be provided with leveling and alignment channels for the securing of the substation. All bus bars shall be copper with tin-plated joints with a maximum current density of 1,000A per square inch with a conductivity factor of 98 percent. Cubicles shall be properly ventilated to limit the conductor temperature rise to 149 degrees F (65 degrees C) over an ambient of 122 degrees F (50 degrees C). The continuous-rated main bus shall be properly braced for the full system short circuit as required. The main bus shall be supported on NEMA-rated insulators for the voltage class and shall have a continuous coating of PVC. Each cubicle shall contain a 1/4-inch by 3-inch silver-plated, copper ground bus accessible for connection to the ground system and provided with at least one lug for such connections. All permanent bus connections shall have a minimum of two bolts per connection. The maximum size shipping section shall not exceed 9 feet (2.7 meters) in length.

Provide each circuit breaker with a local digital metering package that will also communicate with a digital monitoring system that will record and remotely indicate (via metering network) to a central PC (personal computer) the following: Amperes of all three phases, voltage of all three phases, kW, kVA, kVAR, power factor, kWH, kVARH, frequency, transformer temperature, breaker static trip settings, peak kW, time of peak kW, programmable audible alarm limits, breaker status, date and time of breaker trip, and date and time when amperes exceed programmable limits.

2.1.10 4,160-Volt Motor Control

The 4,160-volt motor control shall be provided from line-ups of NEMA Class E2 motor controllers fed from a common bus. Each controller section shall be provided with a quick-make, quick-break, fused isolation switch. Controllers shall be vacuum break, fused contactor type, providing a minimum of 400 MVA, 3-phase, symmetrical interrupting rating at 4800 volts. Controllers shall be load rated and arranged in a one or two high lineup depending on size and type of contactor and motor to be controlled. Enclosures shall be compartmented into a low-voltage control compartment with separate door, high-voltage compartment with separate interlocked door, AC bus compartment with protective barriers, and cable entrance compartment. Each controller shall provide single-phase protection. Controls for synchronous motors shall be reduced voltage autotransformer type.

Induction motors rated 4,160-volt, 250 horsepower and smaller shall be squirrel cage, high power-factor type and controlled for across-the-line starting. Induction motors larger than 250 horsepower and less than 800 horsepower shall be provided with part winding (two-step control), primary reactor, autotransformer, or star-delta type controller. Motors larger than 800 horsepower shall be synchronous, brushless type and provided with auto transformer-type, reduced-voltage motor control.

Provide each circuit breaker with a local digital metering package that will also communicate with a digital monitoring system, that will record and remotely indicate (via metering network) to a central PC (personal computer) the following: amperes of all three phases, voltage of all three phases, kW, kVA, kVAR, power factor, kWH, kVARH, frequency, breaker static trip settings, peak kW, time of peak kW, programmable audible alarm

limits, breaker status, date and time of breaker trip, and date and time when amperes exceed programmable limits.

2.1.11 Uninterruptible Power Supply

Uninterruptible power supply (UPS) shall be included to provide conditioned power to the following loads, at the following minimum required run times at the design load shown in Table 2-2: UPS Runtime Requirements.

Table 2-2: UPS Runtime Requirements

Load Type	Required Runtime
AGTS Control Room	1 Hour
Communications Equipment	4 Hours
Computer Equipment	4 Hours
Emergency Communication System	4 Hours quiescent load plus 15 minutes full load
Energy Management and Control System (EMCS) routers and network interface devices	1 Hour
Radio Enhancement System	4 Hours
Security Systems	4 Hours
Telephone and Electronic Systems	4 Hours
Computer Based Graphic Displays for Smoke Control	4 Hours
Two-Way Communication System for Life Safety	4 Hours

Notes:
1. Refer to DSM Technology and Communication and DSM Life Safety for additional information regarding the listed systems.
2. If a UPS serves multiple loads, the most stringent runtime requirement shall apply.

Any UPS over 3kVA shall contain the rectifier/battery charger, pulse-width-modulated inverter, no-break automatic static bypass transfer switch, and maintenance bypass switch. The UPS shall be sized such that the total single-phase load does not exceed 75 percent of the UPS-rated three-phase load. The UPS shall be sized for a minimum of10 percent of spare capacity for future loads, plus an additional 20% capacity to accommodate for battery degradation over its useful life. The load supplied by the UPS shall be designed such that the maximum phase imbalance shall not exceed 20 percent. All UPS loads shall be designed to have isolated ground receptacles or isolated ground hard-wired terminations. In general, motors and incandescent lighting shall not be supplied from UPS systems because of the electrical spikes and noise generated by switching these types of loads. The UPS should be located as close to the load as is practical. If an isolation transformer is used, the transformer shall be de-rated for harmonics, temperature, and altitude.

2.1.12 Central Lighting Inverters

All central lighting inverters used for powering emergency egress lighting shall be installed in electrical rooms. Where possible, install in the same level as the lighting being powered. Provide UL924-listed equipment. Provide lighting inverter with minimum 25% spare capacity and 90-minute runtime. For models with expandable chassis, provide physical space in the electrical room for expansion.

2.1.13 Receptacles

All electrical receptacles shall be specification grade and standard NEMA configuration types. Minimum receptacle rating is 20A, NEMA 5-20R grounding-type.

Split wire, controlled receptacles shall utilize factory markings for indicating controlled vs always-on outlet.

Refer to specifications for color coding requirements of receptacles.

2.1.14 Concourse Photovoltaic Systems

Concourse photovoltaic (PV) systems shall be designed and installed in accordance with all currently adopted building codes and policies. Maintain service separations such that PV modules and inverters are located in the same core area.

Utilize the naming conventions provided in Table 2-3: Photovoltaic Equipment Naming Conventions for equipment associated with grid-tied photovoltaic systems installed in the concourse buildings.

Table 2-3: Photovoltaic Equipment Naming Conventions

Concourse Buildings AC Photovoltaic (PV) aggregation/combiner panelboards	
B-	Concourse letter
M	Floor level Choices: **T** [tunnel] or **B** [basement] or **A** [apron] or **C** [concourse] or **M** [mezzanine] or **4** [fourth floor] or **5** [fifth floor] or **R** [roof].
E4	Core Area Choices: **CE** [center core east side] or **CW** [center core west side] or **E1** … **E4** [sub-core number east of center core] or **W1** … **W4** [sub-core number west of center core]
PV	Indicates associated with a photovoltaic system.
C	Indicates combiner panel.
H	Indicates Panel voltage. Choices: **H** = 600 or 480Y/277 or **L** = 208Y/120 or 240/120
1	Sequence number of this panel connected to this utility source. Choices: **1**…**N**

Concourse Buildings AC Photovoltaic (PV) Inverters	
B-	Concourse letter
M	Floor level Choices: **T** [tunnel] or **B** [basement] or **A** [apron] or **C** [concourse] or **M** [mezzanine] or **4** [fourth floor] or **5** [fifth floor] or **R** [roof].

Concourse Buildings AC Photovoltaic (PV) Inverters	
E4	Core Area Choices: **CE** [center core east side] or **CW** [center core west side] or **E1** … **E4** [sub-core number east of center core] or **W1** … **W4** [sub-core number west of center core]
PV	Indicates equipment associated with a photovoltaic system.
I	Indicates inverter.
H	Indicates Panel voltage. Choices: **H** = 600 or 480Y/277 or **L** = 208Y/120 or 240/120
1	Sequence number of this inverter connected to this utility source. Choices: **1**…**N**

Concourse Buildings AC Photovoltaic Collector Modules	
B-	Concourse letter
R	Floor level Choices: **T** [tunnel] or **B** [basement] or **A** [apron] or **C** [concourse] or **M** [mezzanine] or **4** [fourth floor] or **5** [fifth floor] or **R** [roof]. Note: Collectors will typically be roof-mounted.
E4	Indicates Core Area of associated inverter. Choices: **CE** [center core east side] or **CW** [center core west side] or **E1** … **E4** [sub-core number east of center core] or **W1** … **W4** [sub-core number west of center core]
PV	Indicates equipment associated with a photovoltaic system.
P	Indicates module type. Choices: **P** = standard module or **PO** = module with optimizer
-1	Indicates associated inverter number. Choices: **1**…**N**
-1	Indicates string number on associated inverter. Choices: **1**…**N**
-01	Indicates module number on associated string. Choices: **1**…**N**

Note:
PV Modules shall be numbered sequentially on each series-connected string, with "1" being the module closest to the associated inverter.

2.1.15 Signage

Signage within buildings must be fed with a separate circuit from the nearest panelboard on the same level without crossing electrical service demarcation lines. Signage must be LED and dimmable and connected to the nearest lighting control panel for dimming and control.

Signage located on-site should be fed from a separate electrical service, typically 120/240V, 1ph, 3w. Exact requirements should be coordinated with Xcel Energy depending on service availability. Signage should be dimmable and controlled by a dimming control device or panel.

Each tenant is to provide a sign fed from an individual branch circuit rated for at least 20 amps at the store entrance.

2.1.16 Elevators

Elevators and elevator cab lighting should be powered from the nearest 480/277V emergency panel board. Provide one 120v, 20A GFCI outlet in the elevator equipment room. The lighting and receptacle circuit must be dedicated to the elevator area only. Elevator room lighting is to be on emergency power.

Elevators are to be provided with a battery backup unit that lowers it to a pre-determined level, typically the ground floor, upon loss of normal power. The doors should open to allow passengers to exit the car and then close once they have left. The elevator should remain in this position until power is restored.

Smoke detectors for elevator shafts, equipment rooms, etc. shall be provided in accordance with NFPA 72.

2.1.17 Escalators and Moving Walkways

Escalators and moving walkways should be powered from the nearest 480/277v normal power panelboard. Renovated or modernized escalators or moving walkways will remain on their current electrical service, whether it is normal or emergency power.

If an escalator is deemed to be used as an egress pathway (such as at the AGTS station), then a fire alarm interface will be required to ensure they shut down in case of an emergency.

2.1.18 Automatic Transfer Switches

Provide 4-pole, open-transition type automatic transfer switches to serve emergency distribution systems when fed from the main switchgear. Providing a 4-pole switch minimizes the possibility of ground faults and satisfies requirements set forth in a memorandum of understanding (MOU) established between the authority having jurisdiction and DEN. Open transition is required for all transfer switches connected to multiple utility sources because synchronization of utilities is not guaranteed.

Provide 4-pole, closed-transition type automatic transfer switches to serve distribution systems when fed from engine generators. Providing a 4-pole transfer switch minimizes the possibility of ground faults and will eliminate power interruption when normal power is restored.

2.1.19 Energy Management and Control System

DEN has an Energy monitoring and Control system throughout the Terminal and Main Concourses. Mechanical and Electrical systems and devices should be tied into this system for monitoring and control. Refer to the Communication and Electronic Systems DSM for additional information and requirements. A list of electrical equipment to be monitored includes:

1. PLCs located in the main switchgear
2. Automatic Transfer switches
3. Electricity Metering
4. Lighting Controls
5. Lighting Inverter Systems
6. UPS systems

7. Photovoltaic Inverters
8. Surge protection devices
9. Generators
10. Ground Power Units (GPUs)
11. Sump pump controllers
12. Tenant Water Meters
13. Tenant BTU Meters

2.1.20 Programmable Logic controllers in Main Switchgear (PLC)

All of the existing Switchgear located at the Terminal and Concourses have been retrofitted with a Programmable logic controller (PLC) to monitor power coming in from each of the two transformers that serve the Switchgear. They contain the logic and control which main breakers open/close so that power is not interrupted in case of an outage. Any new switchgear installed that has dual feeds from the utility should also have a PLC installed. All PLCs shall tie into the fire alarm system and output these trouble codes:

1. PLC low battery
2. System Error
3. Software Fault
4. Bad Ram
5. Application Fault
6. CPU Hardware Fault
7. I/O module loss
8. Main 1 tripped
9. Main 2 tripped
10. Fire Dept Control Relay (86 Relay or LOR) Tripped

2.1.21 Floor Devices

DEN has specific requirements for floor devices providing power and/or data service that must be adhered to concerning the type of material used, shape, height above the floor, and different finishes for specific areas. Specific box characteristics have been chosen based on employee and passenger safety and to maintain consistency throughout the airport. Refer to Chapter 9- Technical Specification Requirements for additional details and requirements.

2.1.22 Variable Frequency Drives

DEN has many large motors associated with HVAC and other systems located throughout the airport. VFD drives are the preferred method of the motor controller. In an effort to mitigate harmonic distortions on DEN's power systems, harmonic filters should be installed on the line side of the VFD for all motors 15hp and larger. A local disconnect should also be provided on the line side of the harmonic filter for each VFD unit and between the VFD and the motor. The designer must properly depict all of this equipment on the design drawings and verify that there is adequate space and proper clearance provided. The designer should also coordinate with the mechanical engineer to verify that these items do not block access to any HVAC systems that may need to be serviced.

2.2 Installations

2.2.1 Design

The design of all installations shall be in accordance with NEC, and codes and ordinances of the City of Denver, as the minimum requirement. Exterior and interior installations shall be coordinated with the architectural designs. The local electrical utility is Xcel.

Electrical service for equipment controls components shall originate from the same source as the equipment. For control systems associated with multiple pieces of equipment fed from multiple sources, controls power shall be

powered from the source feeding the largest amount of equipment, or the most critical equipment as directed by the DEN Electrical Engineer.

2.2.2 Systems

The following systems will be utilized:

A. Utility primary feeders- in general, shall be 25 kV, three-phase, 60-hertz.

B. Multiple service facilities will be provided with metered, main secondary switchgear for 480Y/277 or 208Y/120-volt, grounded distribution circuits.

C. Single service facilities shall be provided with utility service. Transformers shall be provided by the utility. All such secondary services shall be planned to accommodate utility metering equipment.

D. Building main power distribution will be 480Y/277 or 208Y/120 volt as required, three-phase. Provide main power distribution switchboard for feeders to miscellaneous power and HVAC system load concentrations; lighting system distribution panels; motor control centers; and dry-type 480-208Y/120-volt three-phase transformers (if required) and panelboards for small power and receptacle loads. Mechanical HVAC loads shall be segregated from lighting and small power (convenience receptacle) systems where practical.

E. Central plant distribution is 4,160-volt, three phase.

2.2.3 Services

Service locations shall be determined to minimize the length of entrance conductors and be readily accessible from the building exterior. Service entrances shall be installed underground.

Main service equipment shall be located in a nonhazardous, well-lighted, clean, dry, corrosion-free, ventilated, and accessible space. Equipment shall be properly identified by labeling or stenciling at the time of installation. Where indoor transformer-switchgear vaults, indoor emergency power equipment rooms, or other large indoor equipment installations are included in the facility, they shall be so located to provide direct access to outside open areas for ease of equipment installation, removal, ventilation and in such a manner that replacement (as well as repairs) can be accomplished without the need for dismantling or removing other equipment.

Metering requirements: equipment shall be provided, and metering equipment locations shall be coordinated with the supplying utility company. Each tenant space shall be individually metered. Factors affecting metering requirements will include the applicable utility rate structure, class of service, power demand penalties, power factor penalties, and other conditions of the service agreement.

Service disconnect devices shall be located as close as practical to the point of service entrance. Switching and switchgear facilities and arrangements shall satisfy the system flexibility requirements with minimum operating complexity.

Transformers provided for service to or within the facility shall be kept to the minimum necessary, consistent with initial and projected facility loads and operating continuity or other critical requirements. Standard unit-type substations shall be used, where feasible, for power transformer installations. Power transformers shall be equipped with integral forced air fan cooling or suitable provisions for adding forced air cooling with temperature indicators and alarm features.

Power and distribution transformers shall be furnished with standard high-voltage winding taps for voltage adjustment purposes. Duplicate transformers in a double-ended transformer/ switchgear arrangement should be provided where operating continuity requirements or other critical requirements dictate the needs. Consideration shall be given to transformer maintenance requirements over the life of the facility.

2.2.4 Emergency Power Systems

Emergency power systems and “standby systems” (if legally required) shall conform to requirements in Article 700, “Emergency Systems,” and Article 701, “Legally Required Standby Systems,” of the National Electrical Code, as appropriate. The systems shall also conform to applicable requirements in NFPA 101, “Life Safety Code,” and shall

be as required regarding practical need. The design should conform to IEEE Standard 446, “Recommended Practice for Emergency and Standby Power Systems.”

These types of equipment shall be carefully sized to satisfy not only the requirements for safeguarding the health, life, property, and critical operations but also to provide effective security of the facilities.

2.2.4.1 Selective Coordination

All new emergency system components shall be selectively coordinated as required by NEC 700.28. The engineer of record is responsible for providing a design that allows selective coordination to be achieved. The contractor shall be instructed to include a protective device selective coordination study in their scope of work and submit the coordination study with equipment submittals. Coordination studies for existing emergency systems may also be required based on the scope of work.

2.2.4.2 Emergency Circuits

Emergency circuits shall not be run in the same conduit or raceway with normal circuits. Consideration shall be given to complete physical separation of routing. Emergency power and emergency lighting conduit and boxes shall be painted red.

All emergency power distribution systems shall be protected from transients by UL-listed SPDs. Provide UL Type 1 and Type 2 devices, where appropriate. UL Type 3 and Type 4 devices may be required for sensitive equipment and shall be evaluated for use in accordance with project requirements.

2.2.4.3 Dual Source Utility Emergency Power

Where permissible by the currently adopted Denver Building Code Amendments, supply to essential services may be connected to the normal power service by providing a separate disconnect switch and over-current protection on the line side (incoming side) of the main power service disconnects in lieu of locally generated emergency power. Dual-source electrical switchgear must be monitored by the Fire Alarm System.

2.2.4.4 Emergency Loads

All loads designated as emergency loads in the Denver Building Code Amendments, Appendix S, are required to be connected to Emergency Power. Emergency loads include, but may not be limited to the following:

A. Elevators
B. Emergency Egress/Exit Lighting
C. Computer-Based Graphic Displays for Smoke Control
D. Smoke Control Equipment
E. Fire Alarm Systems
F. Emergency Communication Systems
G. Public Safety Radio
H. Fire Pumps and controllers
I. Emergency Fuel Shutoff System (EFSO)

Refer to the Life Safety DSM for additional discussion and specific requirements associated with life safety systems.

2.2.4.5 Emergency Generators

The preferred method for providing emergency power at DEN is through the use of the dual source utility feed, with local UPS backup for loads requiring short-term local backup. However, locally generated emergency power may be necessary for certain critical loads where demands are too high or the duration is too long for UPS power. All new generator installations, including those for emergency loads, must be evaluated in the context of DEN’s overall fossil fuel emissions targets and must be coordinated with the DEN Sustainability group and the DEN Project Manager.

The designer shall evaluate the installation of emergency generators where dual-source utility or UPS power is inadequate to meet the needs of the emergency system, such as for life safety systems in high-rise structures. DEN has several facilities which can be considered high-rise buildings, including air traffic control towers, the Hotel and Transit Center (HTC), and the Airport Office Building (AOB).

Where emergency generators are provided, equipment must comply with NFPA 110 requirements for a Level 1 Emergency Power Supply System (EPSS) and must be provided with sufficient on-site fuel to support the required runtime. Where emergency generators are required, combustion diesel (or natural gas) engine-generator sets with on-site fuel storage shall be provided.

2.2.4.6 Standby Generators

The preferred method for providing standby power at DEN is through the use of the dual source utility feed, as described in Chapter 1. Where dual service is not available and/or a system requires locally generated standby power to mitigate significant operational risk or hazards, standby generators may be provided. All new generator installations, including those for emergency loads, must be evaluated in the context of DEN's overall fossil fuel emissions targets and must be coordinated with the DEN Sustainability group and the DEN Project Manager.

Where standby generators are required, combustion diesel (or natural gas) engine-generator sets shall be provided.

2.2.5 Wiring Systems

All wiring methods and materials shall comply with the NEC. Electrical materials and equipment shall also conform to applicable standards of the Underwriters' Laboratories Inc. (UL) or other recognized testing agencies or laboratories to the maximum extent practicable.

Wiring systems shall be designed so that all components operate within their capacities and with a 25-percent allowance for anticipated load growth.

A. Feeder circuit voltage drops should not exceed 2 percent.
B. Branch circuit voltage drops should not exceed 3 percent.

The Design Consultant shall oversize neutral conductors as required to compensate for the heating effects of third-order harmonics generated by single-phase, high-frequency switching power supplies contained in electronic microprocessor and computer equipment.

Transformer loading shall be de-rated for harmonics, maximum ambient temperature, and an altitude of 5400 feet above mean sea level. Project design loads shall not utilize any of a transformer's capacity that is derived from forced air fan cooling. (This will be reserved for future loads.) Design all transformers, transformer primary (and secondary) feeders, panelboards, switchboards, and associated feeders for a minimum of 25 percent capacity for future loads. Where a transformer supplies a 100 percent induction motor load, the transformer capacity shall be as indicated in Table 2-4: Transformer Capacity.

Table 2-4: Transformer Capacity

HP	Minimum Three Phase Transformer kVA*	HP	Minimum Three Phase Transformer kVA**
1	1.5	15	30
2	3	20	30
3	6	30	45
5	9	50	75
7-1/2	15	75	112.5

Table 2-4: Transformer Capacity (Continued)

HP	Minimum Three Phase Transformer kVA*	HP	Minimum Three Phase Transformer kVA**
10	15	100	112.5

**Increase by 15 percent if motor service factor -1.15*
***Increase by 20 percent if motor is started more than once per hour.*

Where a transformer supplies motor and non-motor loads, the largest motor's rated horsepower shall not exceed 20 percent of the transformer's rated kVA.

Motor starting voltage drop shall not exceed 1 percent at the source panelboard, switchboard, switchgear, or substation terminals and 15 percent at motor terminals.

2.2.6 Branch Circuit Requirements

In general, branch circuits shall be segregated by load type. In addition, meet the following specific requirements:

2.2.6.1 Access Control Systems

Provide dedicated, 120V, 20A branch circuit for each Intelligent Door Controller (IDC).

2.2.6.2 HVAC Controls

Provide dedicated 120V, 20A branch circuits for HVAC control transformers. Multiple transformers may be fed from the same circuit, with a maximum load not to exceed 80% of the circuit rating.

2.2.6.3 Vending Machines

A. Provide dedicated, 120V, 20A, GFCI-protected branch circuit for each vending machine.
B. Utilize GFCI circuit breakers to provide accessible GFCI protection of the vending machine.

2.2.6.4 Interior Lighting Maintained by DEN

Provide dedicated 277V, 20A branch circuits for interior lighting, with a maximum load not to exceed 70% of the circuit rating.

2.2.6.5 Kitchen Equipment

A. Provide dedicated 120V, 20A branch circuits for kitchen equipment such as coffee makers, microwaves, toasters, etc.
B. Provide (1) dedicated 120V, 20A branch circuit for every (2) receptacles located on a counter.

2.2.6.6 Offices and Office Equipment

A. Provide dedicated, 120V, 20A branch circuit for each copier and plotter. Equipment requiring special voltage/amperage shall be provided with dedicated receptacle coordinated with vendor requirements.
B. Provide dedicated, 120V, 20A branch circuit for every (2) enclosed offices.

Provide dedicated 120V branch circuits for pre-wired furniture to comply with manufacturer’s recommended circuit configuration. Breakers feeding pre-wired furniture shall be grouped in the panel board to allow breaker ties to be installed, as required by NEC.

2.2.6.7 Powered Seating

In concourse hold rooms and other passenger waiting areas, provide 120V outlets and/or USB charging stations for passenger use. In traditional seating arrangements, particularly for the first several rows of seats near windows, provide at least one charge station for every two individual seats. Provide sufficient charging stations to serve users at bar and lounge-style seating areas as coordinated with the architect and DEN Project Manager. Refer to the Architectural DSM for additional guidance.

Select products designed to integrate with the seating for ease of access, and ensured selected products are designed for heavy duty use in public spaces. USB charging stations shall be evaluated for susceptibility to malware attacks and provided with countermeasures where available.

Provide dedicated branch circuits for seating power devices, with no more than (10) individual seats, or (5) individual charging stations, served per 20A circuit.

2.2.6.8 Controlled Receptacles

Automatic receptacle control shall be provided where required by code on all new or renovated spaces. Receptacles shall utilize split controlled design where one outlet in duplex is switched and one is always on (uncontrolled). Automatic switch control shall tie into lighting occupancy sensor, where they are utilized for lighting control. Where lighting is controlled via a lighting control system, automatic receptacle control should utilize programming in the system to meet code requirements.

Receptacles serving critical airport operations or otherwise designated for continuous operation shall not be required to be controlled. Coordinate with DEN Project Manager for exact requirements for these projects.

2.2.7 System Protection

Circuit breakers, fuses, and related protection equipment shall be as selected, sized, and sequenced in their operation as to limit damage to system components and power interruptions within the facility when abnormal conditions such as overloads, voltage surges, and electrical short circuits occur. The protective equipment shall have adequate load current capacities and adequate fault current interrupting ratings for the initial and projected loads and available short circuit currents. For design guidance, refer to IEEE Standard 242, “Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems,” IEEE Standard 141, “Recommended Practice for Electric Power Distribution for Industrial Plants,” and IEEE Standard 241, “Recommended Practice for Electric Power Systems in Commercial Buildings.”

For all new construction and remodel projects, include a protective device coordination study for the entirety of the electrical distribution system. Where existing electrical distribution systems are utilized as a part of a remodel project, provide a coordination study including all affected distribution equipment. The protective device coordination study may be included in the design documents or specified as part of the construction package if the study is performed by a licensed professional engineer and reflects the actual equipment installed in the project. All device settings adjustments shall be performed per the recommendations of the study, including for existing equipment.

For all new construction and remodel projects, protect power distribution equipment with UL-listed SPDs. Provide UL Type 1 and Type 2 devices, where appropriate. UL Type 3 and Type 4 devices may be required for sensitive equipment and shall be evaluated for use in accordance with project requirements.

Requirements for ground fault protection, as well as over current and phase-to-phase fault protection, shall be provided. Article 230.95, “Ground Fault Protection of Equipment,” of the National Electrical Code, requires that ground fault protection be provided for solidly grounded wye electrical services of more than 150 volts to ground, but not exceeding 600 volts phase-to-phase, for each service or feeder disconnecting means rated 1000 amperes or more, with two listed exceptions. This requirement most specifically applies to 480Y/277-volt grounded systems. Refer to Article 230.95 for this and for other associated requirements that need to be satisfied where ground fault protection is provided.

In locations where the provision of electrical receptacles and use of low-voltage equipment result in inherent personnel shock hazards from the possible line-to-ground passage of current through the human body, ground-fault circuit-interrupters (GFCI) shall be provided in accordance with the National Electrical Code.

A. These devices shall be UL listed and capable of detecting the passage of currents to ground and interrupt the circuit or circuits at a sufficiently short millisecond interrupting time to protect human life.
B. Particularly hazardous areas include those where electrical tools, appliances, fixed electrical equipment, or portable electrical equipment are used and where there is a probability of physical contact with fixed electrical ground points or surfaces by equipment operators. The most common are kitchen areas, bathrooms, and other areas where installations of sinks, plumbing, workbenches, etc., provide exposed electrical ground points and surfaces, particularly in basement areas and wherever moist or wet conditions exist within buildings or in adjacent outside areas; and at outdoor receptacles within 6'-6" of grade level (or floor level when on rooftops).

2.2.8 Electrical Safety

For all new construction and remodel projects, include an arc flash hazard analysis for all new and existing electrical equipment in the scope of the project, including distribution switchgear, switchboards, panel boards, transformers, safety switches and other equipment likely to be examined, tested, or worked on while energized. Provide printed hazard/warning labels formatted in accordance with the most recent NFPA 70 and NFPA 70E requirements. Include arc flash analysis for affected existing equipment, only if changes warrant a new study. All printed data shall match as-installed field conditions at the completion of the project.

A. In areas where arc flash hazard labels are already present, the designer shall evaluate the impact of the new work on the existing conditions and provide new labels where conditions are changed. At the completion of the project, all equipment shall be properly labeled with the correct data.
B. The arc flash hazard analysis and warning labels may be provided as part of the design package or specified as part of the construction package if the analysis is performed by a licensed professional engineer. The hazard/warning labels shall be permanently affixed to all equipment prior to final acceptance of the project.

2.2.9 Lightning Protection

Criteria for lightning protection of buildings, structure, and protection of incoming power services, are contained in Chapter 4- Lightning Protection Systems of this standard.

2.2.10 Energy Conservation Measures

The following measures shall be given consideration and adopted wherever practical in the design and construction of electrical systems. This listing is not necessarily complete, and other electrical energy conservation methods that are determined to have a safe and practical application should be considered.

A. Use higher distribution voltages, consistent with code and other safety requirements.
B. Increase feeder and branch circuit conductor sizes to reduce energy losses in service lines to utilization equipment (where cost-effective).
C. Reduce the length of branch circuit runs by locating power distribution centers as close as practical to the loads.
D. Provide three-phase utilization equipment rather than single-phase equipment.
E. Install electrical service entrance equipment as near as possible to the epicenter of the electrical load.
F. Design for balanced loads in three-phase systems (and correct experienced unbalances during preoperational inspection and tests).
G. Design for an overall facility load power factor of 95 percent (90 percent minimum). Provide capacitors on motors and other inductive loads that require power factor correction. Provide power factor controllers for motors with widely varying loads.

H. Motor-driven equipment should be designed to start in an unloaded condition to reduce starting power requirements. Two-speed or variable-speed motors should be considered for HVAC applications to reduce energy consumption during non-peak or off-duty hours.

I. Provide the highest practical standard voltage motors (e.g., 460-volt instead of 230 or 200-volt).

J. Provide high-efficiency electric motors and power and distribution transformers.

K. The Design Consultant shall perform a life cycle cost analysis on all proposed energy-conserving measures. The Design Consultant shall review the cost analysis and the payback period with the Project Management Team for possible inclusion of the energy-conserving measure into the project.

L. Design ventilation and cooling systems for the required maximum ambient temperature of sensitive electronic and electrical equipment.

M. All appliances shall be EnergyStar rated.

2.2.11 Telecommunication Rooms

Telecommunication rooms at DEN serve various systems and, with a number of exceptions, are typically located next to Electrical rooms. To best serve power requirements, all telecommunication rooms must be provided with a minimum of a 100A panelboard fed from a normal power source. All non-emergency loads located within this room should be powered from this panelboard. If any emergency systems, as deemed by the fire department, are present in the room, a 100A minimum emergency panelboard should be installed for these loads in the room. Typical emergency loads include Emergency Communications systems (ECS), Radio Enhancement System (RES), Distributed Antenna System (DAS), and two-way communications equipment. All emergency loads that have dual power supplies are to be fed from an emergency circuit and a normal power circuit.

UPS systems with surge protection should be provided for Emergency and non-emergency loads within these rooms. UPS systems should be sized depending on the type of load.

All communications loads should all be coordinated with DEN Business Technologies. Refer to 2.1.11 Uninterruptible Power Supply for a listing of all UPS loads and runtimes.

2.2.12 Tenants and Concessions

Existing normal electrical power for systems and equipment is provided at 480Y/277 volts and 208Y/120 volts. Tenants should feed their space from a distribution switchboard that is located on the same level. Public area HVAC equipment, lighting systems, elevators, escalators, and general convenience power shall be from DEN's metered service. Separate, individually metered tenant electric service shall be provided at 480Y/277 volts or 208Y/120 volts for all tenant spaces requiring more than (1) 120-volt, 20A circuit. For 480Y/277 volt installations, tenants should provide a disconnecting means on the primary side of the transformer located in their space for servicing tenant equipment. Tenant vending machines will not be required to be metered. Power requirements are to be coordinated with DEN PM at the design stage.

The tenant's electrical distribution equipment should be installed within the tenant space and cannot be located in any other DEN area or DEN electrical room. The tenant's electrical distribution equipment must be located out of the site of public view and located in such a way that NEC clearance can always be maintained. Tenant panelboards cannot be located behind doors or in any area that would pose a danger to anyone working on the equipment.

Telecommunication carriers shall provide separate metering when they require more than (6) 20A 120V circuits, or (3)-20A 208V circuits in any specific area or section of the airport. Associated electrical equipment and sub-metering equipment should be installed next to carrier equipment and cannot be located in any other DEN area or DEN electrical room. If 6 or more spaces within a panel are needed, then the tenant should provide a metered panelboard within their own space fed from the DEN panel.

Emergency electrical power for systems and equipment will provide at 480Y/277 volts and 208Y/120 volts. Emergency electrical power is distributed throughout DEN to serve elevators, DEN exit and egress lighting, fire detection and alarm, central corrected clock, PA system, EMCS, security, communications, and data systems. Any tenant connection to a DEN emergency system must be pre-approved by the DEN PM.

All concession spaces shall be separately metered. Associated sub-metering equipment should be installed in the tenant space. Refer to Chapter 2- Interior Electrical Power Distribution Systems for additional information about metering requirements. When remodeling an existing concession space, the Designer shall ensure the existing electrical service meets the currently adopted metering requirements. If it does not meet these requirements, it shall be upgraded as necessary.

Tenants shall provide 120V and 20A receptacles throughout the space for general maintenance. Tenants are to provide a minimum of (1) 20A outlet per hallway. Tenants are to provide a minimum of (1) 20A outlet per enclosed space. Tenants are to provide (1) 20A outlet next to each electrical panel installed.

Communication raceway systems will be installed to provide for the distribution of the communications system throughout the space. The distribution will provide service for telephones, courtesy telephones, data communications, and other telephone system-related communications.

The security system will be extended into and throughout the space to monitor and/or alarm activities in the general public areas and other areas as deemed appropriate and necessary. The security system shall be connected to the central airport security system.

Do not route other systems (HVAC, plumbing, etc.) in electrical spaces.

Designers shall limit the electrical power consumption in the tenant spacing in accordance with the following guidelines.

2.2.12.1 Basic Tenants

A. Basic Office Tenant:
    a. Lighting: 2.0 VA/SQ FT
    b. Receptacles: 2.0 VA/SQ FT

B. Basic Retail Tenant:
    a. Lighting: 2.0 VA/SQ FT
    b. Receptacles: 1.0 VA/SQ FT

2.2.12.2 Concession Tenants

A. Restaurant Tenant
    a. Kitchen: 40 VA/SQ FT
    b. Dining: 20 VA/SQ FT

    Electrical water heaters shall not count against the overall load calculation.

B. Food Court Tenant:
    a. 70 VA/SQ FT

    Electrical water heaters shall not count against the overall load calculation.

C. Storage Spaces:
    a. 2.0 VA /SQ FT

End of Chapter

Chapter 3 - Grounding Systems

3.0 Grounding Systems

3.0.1 Scope

This chapter provides design guidance in the selection of materials and methods of installation to provide system and equipment grounding. Emphasis is placed on the safe operation of electrical systems, provided by a measured, acceptable grounding system installed in a protected, and accessible manner for future testing.

3.0.2 Criteria

These standards are developed, in part, from requirements contained in publications of the following references:

A. American Society for Testing and Materials (ASTM)
    a. B8 – Concentric-Lay Stranded-Copper Conductors, Hard, Medium-Hard, or Soft.
B. National Electrical Code (NEC)
C. National Electrical Safety Code (NESC)
D. National Fire Protection Association (NFPA)
    a. NFPA No. 780 – Standard for the Installation of Lightning Protection
E. Underwriters' Laboratories, Inc. (UL)
    a. 467 – Electrical Grounding and Bonding Equipment
F. Institute of Electrical and Electronic Engineers (IEEE)
    a. 142 – Recommended Practice for Grounding Industrial and Commercial Power Systems

3.0.3 Design Approach

All separately derived electrical systems are grounded at the source and, if remote, at each service entrance to separate premises. Equipment grounding systems shall provide electrical continuity between all noncurrent-carrying metallic parts of the system and shall have one common grounding electrode with the system ground.

System grounding for the central security control center shall be an isolated ground system for the central computer center (CCC).

System grounds are provided as follows for alternating current systems:

A. Single-phase, 3-wire – Neutral conductor is grounded
B. Multiphase system having one wire common to all phases – Neutral conductor is grounded
C. Grounding electrode systems, including the bonding (interconnection) of all the following elements applicable at each building or facility served:
    a. Metal underground water pipe in direct contact with the earth for a minimum distance of 10 feet, without joints, immediately adjacent to the ground conductor connection.
    b. The structural steel framework of the building where effectively bonded members are connected by copper conductors to driven ground rods.
    c. Perimeter ground grids of buried copper (or galvanized steel in corrosive soil) conductors and driven ground rods, including counterpoise grounds, where provided.
    d. Driven ground rods of copper-clad steel of a minimum diameter of ¾ inch and length of 10 feet.
    e. Concrete-encased electrodes furnished per NEC 250.52(A)(3).

Design calculations for the design of perimeter ground grids shall be in accordance with IEEE Standard 8-1976, Art. 42 – Analytical Expression for Resistance of Grounding Systems. System and equipment grounding shall be in accordance with the NEC. The voltage difference between noncurrent-carrying metal parts and the ground shall be essentially zero to minimize personnel hazards. Equipment ground conductors shall be sized large enough to allow

sufficient current to flow to trip the short-circuit protection devices. Grounding conductors shall also have adequate capacity to carry the maximum available fault current without damage and be large enough to withstand possible physical and corrosive damage. The ground resistance should be low as practicable and in no case, exceed generally accepted values for the application. Refer to IEEE Standard #142, Recommended Practice for Grounding Industrial and Commercial Power Systems.

The CCC isolated ground system shall be a low impedance ground, 3 ohms or less.

3.0.4 Design Task Categories

Design tasks require four basic attentions:

A. Effective grounding of the system neutral at the point of service.
B. Ensuring continuity of the equipment grounding system throughout the facility.
C. Providing a grounding electrode conductor and grounding electrode system that provides a suitable low resistance to earth ground.
D. Provide static grounding grids for the access flooring located within the central security control center.

3.0.5 Design Analysis Requirements

A. Uniform presentation of grounding methods and materials.
B. Calculations shall be included for grounding grids or counterpoise configurations.
C. Selection of grounding electrodes, conductor size, physical protection, and connection to electrode system.
D. Selection of equipment grounding conductors for each segment of the system based on the requirements of the NEC.
E. Provision for adequately grounding equipment requiring flexible conduit or cord connections.
F. Provision for ground fault interruption at services and protective devices at other utilization points in accordance with NEC.

3.1 Materials

3.1.1 General

Grounding materials shall be selected from the following types:

3.1.1.1 Grounding Conductors

Insulated green-colored copper conductor. Solid in sizes No. 10 AWG and smaller and stranded in larger sizes. In lieu of green insulation for #4 AWG and larger size conductors, 1-inch wide green-color plastic tape shall be applied at each end and at all pull and junction boxes. The buried conductor used in grids and for riser connections to building steel shall be bare, stranded soft drawn copper, with a minimum size of 4/0 AWG.

3.1.1.2 Ground Rods

Copper-clad steel or hardened copper-alloy (sectional type if required) with pointed end – 3/4 inch in diameter and 10 feet long (minimum).

3.1.1.3 Connection Materials

Cable-to-cable and cable to rod connections shall be made using exothermic-welding-type process. Connections to equipment shall be exothermic-welding-type or copper alloy connectors attached with silicon bronze bolts and lock washers.

3.1.1.4 Protective Tape Wrapping

Rubber type

3.1.1.5 Cable Supports

Nonmagnetic, clap type supports.

3.1.1.6 Connection to Water Line

Cast bronze clamp with silicon, bronze bolts, and nuts. Provide with ground hub for conduit termination.

3.1.1.7 Ground Bus Bar

Ninety-eight (98) percent IACs copper with maximum rated current density of 1000 amperes per square inch.

3.1.1.8 Coatings

Coal tar compound.

3.1.1.9 Grounding Receptacles

Ground receptacles shall have cast bronze body suitable for flush floor mounting with brass ground stud, cover cap, and chain. Body shall have ¾-inch thread for threading onto a ground rod with suitable stud connector and clip.

3.1.1.10 CCC Isolated Ground

CCC isolated ground shall consist of a 20-foot length of 2.125-inch outside diameter Type K copper with U-bolt pressure plate.

3.2 Installations

3.2.1 General

A. Grounding systems installation requirements shall be described and delineated in detail.
B. Provide for system inspection before covering connection on buried work.
C. All exposed non-current-carrying metallic parts of equipment connected to or operated by the electrical system shall be included in the equipment grounding system.
D. Provide for grounding of metallic raceway systems, where utilized as the grounding conductor of the system.
E. Provide a *green* insulated ground conductor for all circuits that are feeders to panel boards, switchboards, motor control centers, transformers, 480-volt (and higher) motor circuits, and all isolated ground circuits.
F. The Design Consultant shall evaluate the length of all other feeder and branch circuit conduits, the conduit impedance, and the short-circuit protection to determine if an equipment ground conductor is required for safe operation during a ground fault.
G. Provide bonding across (or within) all flexible conduit and expansion couplings (and fittings).

3.2.2 System Ground

A. The neutral conductor of the supply system (including the secondary neutral of all power and control power transformers) shall be solidly grounded at the main service equipment and extended to the point of entrance of the metallic water service and grounding electrode.
B. Connection to the water pipe shall be made with a suitable ground clamp.
C. Where flanged water pipes are encountered, a grounding connection shall be made on the street side of the flange connection.
D. Metallic water service shall be grounded as described by NFPA.
E. Where there are no metallic water services to the building, system ground connection shall be made only to driven ground rods.

F. A building outer perimeter ground grid shall be provided if required to obtain sufficiently low resistance.
G. The system grounding conductor shall be in conduit and continuous, without splices or joints, to the electrode connection.

3.2.3 Equipment Grounding

A. The system shall provide an insulated, green-colored equipment grounding conductor for all feeders to panel boards, switchboards, motor control centers, transformers, 480-volt (and higher) motor branch circuits, and all isolated grounds.
B. This conductor shall be separate from the electrical system neutral conductor.
C. For conductors #4 AWG and larger, the wire can be identified by a 1-inch-wide band of green tape at each end and at each pull and junction box.

3.2.4 Building Ground Electrode Systems

Building grounding electrode grid systems shall comply with the requirements of Article 250 of the NEC. Connections to the grounding grid and ground rods shall be made with exothermic welded joints.

3.2.5 Equipment Ground Bus

A. A separate equipment ground bus shall be provided in each panel board, switchgear assembly, and switchboard for the grounding and bonding of the equipment grounding conductors.
B. The equipment ground bus required in each panel board shall be sized in conformance with the requirements of the NEC.
C. Noncurrent-carrying metal parts of electric equipment shall be effectively grounded by solid bonding to the equipment ground bus.
D. The equipment ground bus in the unit substations and 480-volt switchgear shall be bonded to both the system neutral water-service ground, and to the ground grid systems.
E. The equipment ground bus shall be of flat tinned copper in one piece.
F. Connection and splices shall be of the pressure-connector type.

3.2.6 Other Grounding System Installations

Provide for the proper installation of other grounding system components as follows:

3.2.6.1 Wire and Cable

A. Install using as few joints as possible.
B. Protect against abrasion by several wrappings of rubber tape at all points where the cable leaves concrete in exposed areas.
C. Suitably protect the cable against damage during construction.
D. Replace or suitably repair the cable if damaged before final acceptance.

3.2.6.2 Exposed Installations

A. Route runs in conduit.
B. Route along the webs of columns and beams, and in corners where possible for maximum physical protection.
C. Support at intervals of 3 feet or less with nonmagnetic clamp-type supports.

3.2.6.3 Buried Installations

A. Lay in the bottom of the trench or in other excavations at least 18 inches below the finished grade.

B. Maintain a clearance of at least 12 inches from all underground metal piping or structures, except where connections thereto are specifically indicated.
C. Chemically degrease and dry completely before welding.
D. Apply one coat of coal tar coating at 15 mils dry film thickness to all exothermic-welded connections to be buried.

Make connections to equipment as follows:

A. Make up clean and tight to ensure a low-resistance connection.
B. Install so as not to be susceptible to mechanical damage during the operation or maintenance of equipment.
C. Provide direct copper connection to buried ground grid system.

3.2.6.4 Ground Rods

A. Install rods as indicated by driving and not by drilling or jetting.
   EXCEPTION: CCC isolated ground shall be drilled.
B. Drive rods into an unexcavated portion of the earth where possible.
C. Where rods must be installed in excavated areas, drive rods into the earth after the compaction of backfill is completed.
D. Drive to a depth such that the top of rods will be approximately 18 inches below final grade or subgrade, and connect the main grid ground cable thereto.

3.2.6.5 Metallic Conduit Grounds

A. Where conduit enters the cable tray, adequately ground to cable tray, with a cable tray conduit clamp and a conduit grounding bushing connected to the ground cable in the tray.
B. Adequately and properly ground all terminal points and wherever isolated from equipment or grounded steel.
C. Where extending into switchgear or other floor-mounted equipment from below, connect to metallic conduit grounding bushing and equipment ground bus (or frame if there is no bus).
D. Where extending into a manhole, handhole, or cable trench, connect to the ground riser or cable at that structure using grounding bushings.

3.2.6.6 Cable Tray and Rack Grounds

A. Ground at proper intervals.
B. Ground all continuous runs as well as an isolated section at least at one point.

3.2.6.7 Manhole Grounds

A. Ground all hardware-to-ground rod extensions in manholes with bare copper unless indicated otherwise.
B. Connect manhole ground rods to the underground duct system ground conductors.

3.2.6.8 Medium Voltage Box Grounds

Ground all medium voltage pull and junction boxes by direct copper connection to the buried ground grid system.

3.2.6.9 Grounding Bus

Insulate and support grounding bus at proper intervals.

3.2.6.10 Ground Fence Enclosure

A. Ground fence enclosure at each post with connectors designed for the application.
B. Install flexible braid straps across all hinge points and gates for fence enclosures.

3.2.6.11 Motor Frames

A. Ground all motor frames larger than 75 hp and associated equipment enclosures to the ground grid.
B. Ground all 480-volt (and higher) motors with identified ground conductors in addition to the conduit system.
C. Route in conduit with phase conductors.

3.2.6.12 Lightning Arrester Grounds

A. Where three arresters are mounted together on the same structure or transformer, connect them to a riser loop ground cable, connected at each end to the buried ground grid.
B. Do not enclose in magnetic conduit or permit close magnetic encirclement of conductors.

3.2.6.13 Computer and Telephone Equipment

Computer and telephone equipment shall be provided with isolated ground receptacles whenever possible.

3.2.6.14 Miscellaneous Systems

Other miscellaneous electronic systems shall be provided with isolated ground receptacles whenever possible.

3.2.6.15 Wireway Sections

Each section of wireway shall be grounded a minimum of one time or every 10 feet, whichever is greater.

3.2.6.16 Perimeter Building Expansion Joints

A bare copper 500 MCM grounding conductor shall be looped between each perimeter building expansion joint and bonded to structural steel on each side of the expansion joint.

End of Chapter

Chapter 4 - Lightning Protection Systems

4.0 Lightning Protection Systems

4.0.1 Scope

This chapter provides design guidance for the provision of lightning protection systems for all types of structures other than structures used for the production, handling, or storage of ammunition, explosives, flammable liquids or gases, or explosive ingredients. Requirements for materials and procedures for special or unusual designs shall be added as necessary for specific facilities.

4.0.2 Criteria

All designs shall be according to the latest editions of these criteria or according to this chapter, whichever is more stringent:

A. NFPA Publications
    a. NFPA 70- NEC as adopted and amended by the Denver Building Code.
    b. NFPA 780- Standard for the Installation of Lightning Protection
B. UL publication
    a. UL 96- Lightning Protection Components
    b. UL 96A- Installation Requirements for Lightning Protection Systems
    c. UL 467- Grounding and Bonding Equipment

4.0.3 Design Approach

Most existing DEN structures were originally constructed with a Lightning Protection System. All new structures at DEN shall be provided with a Lightning Protection System. The Designer shall inquire with the DEN Project Manager whether Lightning protection will be required on the specific structure; Lightning protection shall be required unless the Designer is instructed otherwise, in writing, by the DEN Project Manager.

For design work on existing structures, whether the existing structure has lightning protection or not, the Designer shall also seek guidance from the DEN Project Manager. The Project Manager shall instruct the Designer, in writing, whether to add lightning protection or to upgrade existing lightning protection.

The lightning protection system design shall be considered at the earliest stages of design so that the system can be functionally and aesthetically incorporated with all other design features.

Lightning protection shall be designed to comply with standards listed in the Criteria section above and any other appropriate code or standard. Lightning protection systems shall generally be designed and installed according to UL 96A, such that a UL Master Label can be granted. In some cases, due to architectural or other features, a Master Label may not be possible; in these cases, the lightning protection system design shall nevertheless be designed, as closely as feasible, according to the requirements and intent of UL96A and NFPA 780. Variations from Master Label requirements shall be discussed with and approved by the DEN Project Manager.

4.0.4 Design Analysis Requirements

In addition to the requirements in the Standards and Criteria DSM, designs require a uniform presentation of factors considered as follows:

A. Dimensioned plan and elevation of structure or structure element to be protected.
B. Placement of air terminals.
C. Conductor routing and size.
D. Location and type of conductor supports.
E. Location of bonding to service entrances to building steel, etc.
F. Provisions for its physical protection of components.

G. Location and type of grounding electrodes, test wells, counterpoise, etc.
H. Calculations of the approximate resistance of the electrode system to earth ground.
I. Provision for field measurement of resistance.
J. Detail drawings as needed for clarity of design.

4.1 Materials

4.1.1 General

Use materials as described in the documents listed in previous chapters. The following requirements are in addition to those:

A. Copper shall be the material of choice for all lightning protection systems at DEN.
B. Where the roofing system or other building components may be galvanically incompatible with copper, lightning protection system components (such as galvalume parapet caps) and the lightning protection system shall be designed and configured to prevent direct contact of the copper with such components.
C. Aluminum lightning protection components may be used to protect aluminum building components or equipment where no UL-listed fittings exist to prevent direct contact of the lightning protection component with such a surface.
D. All counterpoise (loop) conductors shall be a minimum of 2/0 AWG, with a minimum strand size of 17 AWG.
E. Ground rods shall be a minimum of ¾" diameter, 10' length, copper clad.

4.2 Installations

4.2.1 General

Where feasible and appropriate, DEN encourages the use of structural steel as the down conductor, as allowed by UL96A, the intent being to minimize the possibility of damage to the conductors, as well as to improve aesthetics. The design shall ensure that all structural steel is electrically continuous and that all metallic components are bonded, either inherently or through approved bonding connections.

In addition to the ground rods required by previous chapters and by other requirements of this chapter, a ground rod shall be included at every change of direction of the building footprint unless accepted by the DEN Project Manager.

A test well shall be installed to allow future access to each ground rod for testing and inspection purposes. The test well and cover must meet the maximum traffic ratings required for the anticipated use of the area.

A counterpoise loop conductor shall interconnect all ground rods. The ground rods and counterpoise shall be approximately 3 feet outside of the foundation (at least 2 feet), and the counterpoise shall be buried approximately 30 inches below the final grade.

Exothermic welds are required for all connections below grade.

The design of the lightning protection system shall consider likely damage that may occur to components, and a means shall be designed to avoid and/or easily repair that damage.

Rooftop metal light masts and other such appurtenances shall be bonded to the lightning protection system. Any luminaire or other fixture less than 3/16" in thickness shall be fitted with an air terminal and bonded appropriately to the mast.

End of Chapter

Chapter 5 - Lighting Systems

5.0 Lighting Systems

5.0.1 Scope

This chapter includes design guidance for the selection and application of indoor and outdoor lighting equipment. Emphasis is placed on equipment quality, maintainability, energy efficiency, and aesthetic integration with architectural design. Lighting systems are developed to provide required illuminance based on the type of space use, activity, or operational criteria, with considerations for comfortable visibility with adequate intensities for safe and effective task accomplishment. It is the intention that lighting designs integrate with architectural and other planning, and operations & maintenance objectives to the maximum extent practicable.

5.0.2 Criteria

These standards are developed, in part, from requirements contained in latest adopted publications of the following references:

A. American National Standards Institute (ANSI)
B. Certified Ballast Manufacturers (CBM)
C. Illuminating Engineering Society (IES)
D. IES RP-37 Recommended Practice for Outdoor Lighting in the Airport Environment
E. National Fire Protection Agency (NFPA)
F. NFPA 70, National Electrical Code
G. NFPA 101, Life Safety Code
H. National Electrical Manufacturer's Association (NEMA)
I. Reflector and Lamp Manufacturer's (RLM) Standards Institute
J. Underwriter's Laboratories (UL)
K. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)
L. ASHRAE Standard 90.1 – Energy Standard for Buildings
M. International Energy Conservation Code (IECC)

5.0.3 Design Approach

Design computations for lighting levels shall be a zonal cavity or equivalent sphere illumination (ESI) methods for all applications except floodlighting. Floodlighting, special lighting techniques, and emergency lighting shall be calculated with the point-to-point method. Complex geometric spaces shall require glare analysis (light source and wall luminance), source color matching, and point-to-point calculations. Lighting levels shall be in general accordance with the most current version of the Lighting Library published by IES and any published documents within the IES Lighting Library.

5.0.4 Design Task Categories

Design tasks have two basic equipment application categories defined as follows:

5.0.4.1 Interior

Environmentally controlled spaces within buildings.

5.0.4.2 Exterior

Non-controlled environments within structures or outdoors and regularly exposed to the elements of moisture/rain, dust, extreme temperatures, and high humidity.

5.0.5 Design Standards Nomenclature

The use of the following standard nomenclature is applied herein and is encouraged throughout the design development.

5.0.5.1 Large Area

Common purpose area with uniform ceiling height, construction, and having floor areas generally 1,200 square feet (or larger). This description excludes corridors, passageways, and other narrow space utilizations generally less than 16 feet in width.

5.0.5.2 General Area Lighting

Application of design technique affording an average, overall illuminance with the application of uniform, regularly spaced luminaries.

5.0.5.3 Supplementary Lighting

Provisions for a relatively small area of lighting with the objective of providing higher lighting levels for particular visual tasks. Special task lighting levels are limited to 5 times that of the general surroundings. Lighting for merchandise may be up to 10 times that of the general surroundings.

5.0.5.4 Special Task Lighting

Provisions for a relatively small area of lighting with the objective of providing higher lighting levels for particular visual tasks. Special task lighting levels are limited to 5 times that of the general surroundings. Lighting for merchandise may be up to 10 times that of the general surroundings.

5.0.5.5 Special Effect Lighting

Designed to accentuate sizes, shapes, colors, or to enhance and coordinate the aesthetics of a space and/or objects within the space.

5.0.5.6 Normal Mounting Height

A space affording a fixture mounting height of 14'-0" or less. (Mounting height is defined as the height above the finished floor level to the bottom of the luminaire whether surface mounted, recess mounted or suspended.)

5.0.5.7 Low-Bay Area

A space requiring a fixture mounting height greater than 14 feet and less than 28 feet.

5.0.5.8 High-Bay Area

A space requiring a fixture mounting height of 28 feet and greater.

5.0.5.9 Photometrics

Luminaire performance data consisting of candela values and a zonal cavity coefficient of utilization table.

5.0.5.10 Light Source Acronyms

Table 5-1: Light Source Acronyms

Light Source	Abbreviation
Color Rendering Index	CRI
Compact Fluorescent	CFL
Correlated Color Temperature	CCT
High Intensity Discharge	HID
High Pressure Sodium A type of HID source	HPS
Light Emitting Diode	LED
Metal Halide A type of HID source	MH

5.0.6 Design Analysis Requirements

Designs require a uniform presentation of each lighting task calculation. The format for the design analysis is specified in the Standards and Criteria DSM. The calculations shall be accompanied with copies of the catalog or other manufacturer's data for the equipment. Data shall include photometrics, fixture dimensions, and descriptions of construction and component conformance with these standards.

Point-by-point illuminance calculations shall be submitted for each non-repetitive lighting design task. All point-by-point layouts shall be accompanied by a statistical table indicating the following illuminance statistics: Average (foot-candles), Maximum, Minimum, Max/Min, and Average/Min. Other calculations listed in 5.0.3 Design Approach may be requested.

The Design Consultant shall consider lumen depreciation over the lifespan of lighting equipment in their design to ensure that spaces will remain adequately lit over the lifespan of the equipment. Consider the use of automatic lumen maintenance technology to avoid initially over-lighting spaces. Consider complete lighting system efficacy, rather than lamp efficacy, in all depreciation calculations.

The Design Consultant shall anticipate the daylight component and shall assist in the coordination of architectural elements to eliminate direct and reflected glare from both natural and electric light sources. The designs shall be developed from an appraisal of all the factors involved. This shall include knowledge of interior finishes, interior designs, and desired color appreciation. Design for the main terminal building and concourses must be responsive to the following separate objectives that must be satisfied with a minimum of conflict:

A. General area illumination
B. Emergency (egress and exit) illumination
C. Signage illumination (airport information and tenant displays)
D. Special task illumination
E. Special effect illumination

The design shall address discomfort glare, both direct and reflected (glare shall be minimized), based on an evaluation of each type of ambient lighting. Fixture visual comfort probability (VCP) values for applicable room size and mounting heights, which are presented in the photometric data, shall be used for this evaluation.

Design illuminance levels shall generally conform to the recommendations of the IES. However, the contribution of all light sources present in a particular area of design shall be appreciated. Refer to 5.3.1 Main Terminal Complex.

All required control wiring (low voltage dimming, sensors, etc.) shall be clearly specified in the construction plans, specifications, and/or details. Include a description of wiring requirements and controls approaches in the design analysis report.

5.1 Equipment

5.1.1 Standardization of Equipment

Basic lighting equipment types, light sources, and luminaire components shall be standardized to achieve optimum installation, commissioning, operating, and maintenance costs. Designs that require special-purpose lighting utilizing non-standard fixtures or components shall be carefully selected to avoid difficult maintenance issues and ensure the availability of replacement components.

5.1.2 General Requirements

Light fixtures shall be of standard, high-efficiency, commercial grade. LED lighting shall be utilized whenever possible due to its higher efficacy, controllability, and long service life. Fluorescent, incandescent, neon and all types of gas discharge arc lamps are prohibited except where allowed in writing by the DEN Project Manager. All lighting equipment shall be UL-listed, and luminaires shall be designed to be powered directly from the building's electrical distribution system. Proprietary power distribution systems, wiring, and equipment, such as power-over-Ethernet (POE), are prohibited for use in building lighting systems.

Emphasis shall be placed on aesthetics, performance, and energy efficiency of fixtures, selected based on minimum life-cycle costs and satisfaction of visual task requirements. Proper consideration shall be given to glare and color rendition.

5.1.3 Luminaire Requirements

It shall be the designer's responsibility to consider the correlated color temperature (CCT), measured in Kelvins, of luminaires in surrounding areas. Specify light fixtures and lamps to match the surrounding lighting as closely as possible. Refer to 5.3 Facility Design Guidelines for color temperature requirements. Where no requirement is listed for the specific application, comply with the color temperature requirements listed as follows.

A. Indoor LED fixtures: 3500K
B. Restroom Vanity LED Lighting: 3000K
C. Decorative LED Pendants: 3000K
D. Outdoor LED fixtures (landside areas including parking lots, etc.): 5000-K
E. Outdoor LED fixtures (airside areas including aprons): 4000-K
F. LED Signage: 5000K
G. Elevators: 3500K
H. Artwork: May vary from different color temperatures to color-changing LED as designed by the artist.

All luminaires shall be provided with a minimum color-rendering index (CRI) of 70 for outdoor lighting and 80 for indoor lighting. Some areas require luminaires with a higher CRI, as noted below.

Lamp holders for the industrial, strip, and other open type fluorescent fixtures shall be of the type requiring forced movement along the longitudinal axis of the lamp for insertion and removal of the lamp.

Accessories such as straps, mounting plates, nipples, brackets, cord and plugs, special hangers, and receptacles necessary for proper installation shall be specified to be furnished with the fixtures.

For fixtures located in exits, stairways, ramps, elevators, and landings, the diffusers and lenses shall be constructed of noncombustible materials.

Luminaires shall be selected to limit the overall mercury content for the project to a maximum of 70 picograms per lumen hour. Consideration shall be given to further limit mercury content to 35 picograms per lumen hour where feasible for the project.

5.1.4 Performance Requirements

All lighting equipment shall meet the performance requirements listed as follows. Any deviations from these requirements must be approved in writing by the DEN Project Manager.

A. Provide luminaires with a minimum lamp life of 50,000 hours.
    a. Minimum lamp life for non-LED luminaires (where allowed): 25,000 hours.
B. All light sources shall have a minimum luminous efficacy of 90 lumens per watt total output.
C. All luminaires qualified for energy efficiency rebates shall be listed in the DesignLights Consortium® Qualified Product List (DLC QPL listed).
D. All exterior area lighting shall be characterized using the BUG rating method. The designer shall select luminaires to minimize up-light and glare. The target BUG rating for all exterior fixtures shall meet or exceed B2, U2, and G2, where requirements stated herein do not specify more stringent performance.

5.1.5 Lighting Control Requirements

5.1.5.1 Applicability

The requirements of this section shall apply to all new construction and remodel projects.

5.1.5.2 Network Connectivity

For projects located in the Terminal Complex, provide a central lighting control system with networked control panels and the ability to connect to the Energy Management and Control System (EMCS). Refer to DSM Communication and Electronic Systems for EMCS information. For remodel projects in areas where an existing lighting control system is installed, connect lighting to the existing central controls if all controllability requirements can be met. If the existing system is incapable of providing the required functionality, replace it with a new system. Replacement systems shall be compatible with the existing system where they are to be networked.

5.1.5.3 Occupancy-Based Control

Provide occupant sensor controls for areas with transient occupancy, such as copy/print rooms, break rooms, storage rooms, closets, locker rooms, conference rooms, training rooms, corridors, and where required by current code. Occupancy sensors shall be designed to provide full coverage of the space, with either ultrasonic, passive infrared, or dual technology, whichever is most appropriate for the space and results in the lowest probability of nuisance switching. Sensors located in areas likely to have momentary occupancy shall be configured with a 'walk-through' mode to maximize energy savings.

In interior spaces where 24-hour lighting is required for safety and security, such as concourse hold rooms, public restrooms, circulation spaces, ticketing, and baggage claim areas, provide occupancy sensor controls that can dim the lighting to 50% when no occupants are detected after a period of 30 minutes.

Lighting serving emergency egress shall have fire alarm input to override occupancy sensor input to com back up to 100% upon activation of fire alarm system.

5.1.5.4 Light Level Reduction Controls

Where occupancy sensors are not provided, provide light-level reduction controls that can reduce the light output in the space to 50% or less.

5.1.5.5 Daylight Controls

Provide fully dimming (1-100%), automatic daylight-responsive lighting controls for all lighting within daylight zones. Daylight zones are defined in the 2021 IECC, Chapter 4, Section C405, but additional areas may be included if deemed appropriate.

5.1.5.6 Controller Locations

Do not provide manual lighting controls in public spaces. All lighting controls for public circulation spaces shall be in access-controlled areas.

5.1.5.7 Exterior Lighting Controls

All exterior area lighting shall be controlled using dusk-to-dawn via an astronomical time clock with a photocell as backup, with timeclock override for those lights that are not required to be on from dusk until dawn.

5.2 Installations

5.2.1 Installations

Lighting designs shall provide for economical installation and ease of future maintenance. Installation in low and high bay areas shall anticipate the method of access and make appropriate provisions, such as portable elevating platforms where accessible from below or top re-lamping in areas accessible from above.

Ceiling fixtures shall be coordinated with and suitable for installation in or suspended from the ceiling type provided. Installation and support of fixtures shall be in accordance with NFPA 70 and the manufacturer's recommendations. Surface-mounted fixtures shall be suitable for fastening to the structural support for ceiling panels.

Suspended fixtures shall be provided with swivel hangers to ensure a plumb installation. Pendants 4 feet or longer shall be braced to limit swinging. Single-unit suspended fluorescent fixtures shall have twin-stem for wiring at one point and a tubing or rod suspension provided for each section of chassis, including one at each end. The minimum distance between adjacent tubing or stems shall be 8 feet. Rod shall not be less than 1/2-inch in diameter.

Recessed fixtures shall have adjustable fittings to permit alignment with ceiling panels. Recessed fixtures installed in the fire-resistive type of suspended ceiling construction shall have the same fire rating as the ceiling or shall be provided with fireproofing boxes having materials of the same fire rating as the ceiling panels, in conformance with the Building Materials Directory of Underwriters Laboratories, Inc.

5.2.2 Luminaire Selection

LED shall be the preferred light source for all applications. Light sources with high-color-rendering accuracy (80 or higher) shall be provided in areas where finer visual tasks are performed and for general ambient lighting. The following are some examples of such areas:

A. The Central Utility Plant (CUP)
B. Maintenance facilities
C. Air cargo facility
D. Aircraft hangars
E. Fire, crash, and rescue facility
F. Rental car support facilities
G. Parking structures
H. Large area, low and high-bay, general lighting (interior), where color rendition is of concern, fixtures shall be selected with a CRI of 80 or higher. Typical areas of application are as follows:
    a. Terminal building passenger ticketing level, baggage claim level, and atrium
    b. Concourses
    c. Train station exit pavilions, loading platform, train skids
    d. Hotel lobbies

5.2.3 Emergency Lighting

Emergency lighting systems shall be provided in accordance with NFPA Code no. 101, Safety to Life from Fire in Buildings and Structures. Emergency lighting should be provided throughout all areas of the airport, especially in sections where occupants are not familiar with the area they are in. In addition, limited emergency lighting shall be provided for outdoor walkways and parking structures. All emergency lighting systems shall be connected to the emergency power distribution system, where available.

Emergency lighting shall be switched with area lighting and configured to automatically activate upon loss of power, except in the following spaces where night lights fed from an emergency source shall be utilized:

A. Electrical and mechanical rooms
B. Telecommunication rooms
C. Passenger loading bridges

For all new construction and renovation projects, provide a central battery lighting inverter for local backup of emergency lights. The lighting inverter shall be connected to the emergency power distribution system, where available. Emergency lighting systems with integral battery backup may be used where approved in writing by the DEN Project Manager and for tenant-maintained lighting systems, such as in concession spaces.

A. Passenger-loading bridges shall be provided with emergency exit lighting in accordance with NFPA 101. All emergency lighting in passenger loading bridges shall consist of UL924-listed self-contained battery-powered lighting tied to the lighting branch circuit feeding the interior lighting in the passenger loading bridge. Emergency lighting shall automatically activate upon loss of power to the bridge lighting circuit.

5.2.4 Large Area, Normal Mounting Height Lighting

For finished interior spaces – terminal areas, offices, tenant spaces, and other areas accessible to the public, specification-grade fixtures shall be utilized.

For interior maintenance and utility areas, surface and pendant-mounted industrial fixtures shall be applied. Use closed, gasketed fixtures for interior washdown spaces or spaces with a high level of dust and debris.

In maintenance and utility areas defined as an exterior space: closed, gasketed, surface and pendant mounted, industrial fixtures shall be used.

5.2.5 Efficiency Considerations

In addition to minimum sustainability requirements, the lighting system designer shall consider the following energy efficiency considerations in their design. Provide recommendations and supporting data for measures incorporated in the system.

A. The Designer is responsible to ensure that Xcel Energy Demand Side Management rebates are considered in the design process, that any pre-approvals are submitted, and that other steps are taken as required to ensure that applicable rebates are collected. At the beginning of the Design process, the Designer shall check the Xcel website for availability and requirements for rebates. The DEN Energy Manager can also provide some guidance on rebates, and shall be included in the design process. The verification of any applicable rebates is also required if substantial revisions occur to the design solution which would affect or invalidate the original rebate application.
B. Provide highly flexible manual/automatic switching or dimming systems that will permit turning off or dimming all unused or unnecessary lights. Consider connecting lighting system zones to a central supervisory control system when available in the building.
C. Install automatic photo-controls on lighting circuits that control interior lighting along exterior walls of facilities, where sunlight transmitted through windows will provide ample illumination without electric lighting.

D. Where appropriate, photocells for daylight-responsive lighting control may be installed on individual fixtures. Where individual fixtures cannot include daylight-responsive controls, every effort shall be made to zone lighting circuits such that entire circuits can be equipped with lighting controls for zone-dimming capabilities.
E. Design for luminaire relocation flexibility to meet changing operational requirements and evaluate the use of low voltage switching or dimming systems (24 volts or lower) for flexible switching and remote operational capability.
F. Provide continuous or multi-level or dimming ballasts/drivers to permit varying lumen output for fixtures. Ensure that the system components are tested for compatibility over the entire dimming or control range without flicker or audible buzz and ensure manufacturer-documented compatibility between solid-state lighting drivers and lamps.
G. Provide the most efficient luminaires, lamps, and ballasts/drivers available within project constraints.
H. Design lighting for the tasks and locate luminaires as directly over the task area as practical, within the limits of the luminaire supporting systems.
I. Use higher lighting circuit voltages (e.g., 277-volt systems), together with low voltage (24-volt) switching and control systems.
J. Provide more energy-efficient light sources (e.g., LED) for lamp selections.
K. Evaluate use of greater contrast between task lighting (workstation) and background lighting (work area), such as 8-to-1 and 10-to-1, consistent with safety and operation requirements.

5.2.6 Tenants and Concessions

Tenant lighting design is generally left up to the tenant's needs and individual standards. Efficacy ratings of light fixtures and lamps must, however, meet DEN standards and conform to local energy codes. This allows the tenant to have flexibility on their layouts and design while also providing for an energy-efficient design. Tenant lighting must be fed from the tenant's electrical panel so that it is metered along with all their other loads. Tenant lighting can be 277v or 120v, depending on the design the tenant incorporates into their space.

Tenants are allowed to choose the type and color of cover plates for light switches, thermostats, data outlets, sensors, and receptacles and are not limited to DEN standards for these devices.

Emergency lighting is the responsibility of the tenant and must be provided by them throughout the entire tenant space. DEN does not provide any type of emergency circuits or the ability to add to DEN's emergency lighting system. Generally, tenant emergency lighting will consist of unit battery equipment within existing light fixtures or a lighting inverter. Emergency lighting should also be provided at each panel board location.

Tenant lighting should be routed through a lighting control panel and zoned such that specific areas can be programmed. A dedicated circuit should be provided for signage at the front of the tenant space.

Refer to 2.2.12 Tenants and Concessions for lighting electrical power consumption charts.

5.3 Facility Design Guidelines

5.3.1 Main Terminal Complex

The following guideline for terminal lighting has been separated into various public areas with distinctive functions and environments. The average illuminance levels listed reflect the general design objective. The minimum acceptable illuminance levels are also listed for each area. E_{avg} shall define required average illuminance, and E_{min} shall define minimum required illuminance. All values are expressed as horizontal foot candles, at the height of 2'-6" (for indoor task locations) or at ground level (for indoor circulation areas or exterior and structured parking areas).

Table 5-2: Illuminance Recommendations for the Main Terminal

Application	Horizontal Target (fc)	Gauge	Vertical Target (fc)	Gauge	Uniformity Targets			Typical Area of Coverage
					Max: Avg	Avg: Min	Max: Min	(Room or Task)
Main Circulation Area[1]								
Heavy traffic areas	50	avg				2:1		Room
Moderate traffic areas	25	avg				4:1		Room
Atriums	10	avg				6:1		Room
Ticket Counters[2]								
Counter Surface	50	avg				2:1		Task
Work Areas	35	avg				3:1		Room
Circulation	25	avg				4:1		Room
Baggage Claim[3]								
Baggage Claim Carousels	50	avg				4:1		Task
Wall-mounted Artwork			50	avg		4:1		
Circulation	25	avg				6:1		Room
Rental Car Counters								
Counter Surface	50	avg						Task
Work Areas	35	avg						Room
Circulation	25	avg						Room
Ground Transportation								
Platforms	25	avg						Room
Circulation	20	avg						Room
Roadway	5	avg						Room
Restrooms								
Vanity Areas			50	avg				Task
Stalls	15	avg						Room
Circulation	15	avg						Room

Table 5-2: Illuminance Recommendations for the Main Terminal (Continued)

Application	Horizontal Target (fc)	Gauge	Vertical Target (fc)	Gauge	Uniformity Targets			Typical Area of Coverage
					Max: Avg	Avg: Min	Max: Min	(Room or Task)
First Aid Rooms								
Exam Areas	50	avg						Task
Circulation	15	avg						Room
Telephone Kiosks								
Counter Surface	30	avg						Task
Circulation	15	avg						Room
Information Booths								
Counter Area	50	avg						Task
Work Areas	40	avg						Room
Seating Areas								
Circulation	15	avg				6:1		Room
AGTS Areas								
Boarding Zones	15	avg						
Platform Circulation	15	avg						
Train Interior	30	avg						
Conveyances								
Escalator Landings	35	avg						
Escalators	20	avg						
Elevator Interiors	25	avg						
Utility Spaces								
Electrical Rooms	30	avg				4:1		
Mechanical Rooms	30	avg				4:1		
Communications Rooms	50	avg				4:1		

Notes:

[1]Main Circulation Area:

a. Daylight ambient for an outdoor atmosphere but minimize direct sunlight where possible.

b. Minimize glare from direct component and glazed areas.

c. Luminaires should be simple and uncluttered, and placed strategically to maintain an unobtrusive appearance, except where fixtures are intended as architectural features.

d. Source colors should be in keeping with outdoor atmosphere. Consideration shall be given to color tuning technology to correspond with different times of the day.

[2]Ticket Counters:

a. Provides direct lighting above counters for task illumination.
b. Provide adequate vertical illuminations for people recognition.
c. Minimize glare from light sources.
d. Company branding on back wall shall be self-illuminated or illuminated with linear wallwash fixtures. Do not allow branding lighting to present glare on video screens.

[3]Baggage Claim:

a. Provide a bright, uniform illumination with a good horizontal and vertical distribution for ease in reading luggage tags.
b. Deemphasize the long lobby by using indirect lighting and creating a repeating pattern across the ceiling.
c. Provide direct/indirect fixtures at columns.
d. Highlight artwork
e. Signage should be self-illuminated or highlighted and easily recognizable with the immediate surroundings.

5.3.2 Concourse Facilities

5.3.2.1 Circulation Areas

A. E_{avg} = 20 fc average maintained
B. E_{min} = 15 fc maintained
C. Circulation areas shall include main central walkways between hold rooms, and center core circulation areas
D. Qualitative criteria:
    a. Provide consistent uniformity throughout.
    b. Provide a combination of direct and indirect lighting, to avoid a cave effect in the space.

5.3.2.2 Seating and Boarding Areas

A. General Areas: E_{avg} = 20 fc average maintained
B. Airline Podiums and ticketing areas: 35 fc average maintained at the counter top
C. E_{min} = 15 fc maintained, for general areas
D. Qualitative criteria:
    a. Provide consistent uniformity throughout.
    b. Maximize illumination at podiums using task lighting or additional ceiling lighting at those locations.

5.3.2.3 Pet Relief Areas

A. E_{avg} = 25 fc average maintained
B. E_{min} = 20 fc maintained
C. Qualitative criteria:
    a. Create the perception of a clean, bright space by utilizing bright surfaces.
    b. Provide high uniformity throughout the space.

5.3.2.4 Nursing Mother Rooms

A. E_{avg} = 25 fc average maintained
B. E_{min} = 20 fc maintained
C. Qualitative criteria:

a. Create the perception of a clean, bright space by utilizing bright surfaces.
b. Provide high uniformity throughout the space.

5.3.2.5 Escalators

A. E_{avg} = 35 fc average maintained at landings (minimum)
B. E_{min} = 20 fc maintained
C. Qualitative criteria:
    a. Minimize vertical glare going up or down.
    b. Provide some indirect component of illumination to minimize shadows.

5.3.2.6 Restrooms

A. E_{avg} = 15 fc horizontal average ambient light level, throughout restroom
B. E_{avg} = 50 fc vertical average maintained at lavatory vanities
C. E_{min} = 35 fc maintained
D. Qualitative criteria:
    a. Create the perception of a clean, bright space by utilizing bright surfaces within general areas and stalls.
    b. Provide high uniformity throughout the space.
    c. Minimize direct glare and reflections in the mirrors.
    d. Provide a high vertical foot-candle level at the mirrors.
    e. The source chosen shall have excellent color rendering characteristics, particularly for skin tones.

5.3.2.7 Electrical and Mechanical Rooms

A. E_{avg} = 30 fc average maintained
B. E_{min} = 20 fc maintained
C. Qualitative criteria:
    a. Provide high uniformity throughout the space.
    b. Provide sealed and gasketed fixtures, designed for industrial environments.
    c. Ensure that luminaires are located to avoid shadows in equipment aisles and areas likely to require service.
    d. Avoid locating luminaires in likely pathways for conduit, piping, ductwork, or other systems

5.3.2.8 Communication Rooms

A. E_{avg} = 50 fc average maintained
B. E_{min} = 30 fc maintained
C. Qualitative criteria:
    a. Provide high uniformity throughout the space.
    b. Provide sealed and gasketed fixtures, designed for industrial environments.
    c. Ensure that luminaires are located to avoid shadows in equipment aisles and areas likely to require service.
    d. Avoid locating luminaires in likely pathways for conduit, piping, cable-tray, ductwork or other systems.

5.3.3 Parking Facilities

5.3.3.1 Parking Structures

A. E_{avg} = 4 fc average, maintained

B. E_{min} = 2 fc maintained

C. Color temperature requirements:
   a. LED fixtures within parking structures: 4000 K
   b. All fixtures in terminal Levels 4 and 5 passenger pickup and commercial walkways: 4000 K
   c. All fixtures in terminal Levels 4 and 5 Drive aisles: 5700 K

D. Qualitative criteria:
   a. Minimize glare.
   b. Maximize uniformity of lighting to enhance safety.

5.3.3.2 Surface Parking

A. E_{avg} = 2 fc average maintained

B. E_{min} = 1fc maintained

C. Color temperature requirements:
   a. LED fixtures within surface parking lots: 5000 K.

D. Qualitative criteria:
   a. Minimize Glare
   b. Maximize Uniformity of lighting to enhance safety

5.3.3.3 Parking Entrance/Exit Canopies

A. E_{avg} = 10 fc average maintained for drive lanes

B. E_{avg} = 20-30 fc average maintained at ticket machines

C. Color temperature requirements:
   a. LED fixtures: 5000 K

D. Qualitative criteria:
   a. Minimize Glare providing louvers as necessary.
   b. Utilize a combination of direct and indirect lighting.
   c. Utilize linear led strip light fixtures that are outdoor rated with finishes to match structure.

5.3.4 Maintenance Facilities

5.3.4.1 Work Areas

A. E_{avg} = 50 fc average maintained

A. E_{min} = 30 fc maintained

5.3.4.2 Ancillary Areas

A. E_{avg} = 40 fc average maintained for stock rooms, break rooms, and meeting/training rooms

B. E_{avg} = 20 fc average maintained for circulation areas and corridors

5.3.4.3 Qualitative Criteria

A. For work areas, arrange lighting to minimize shadows, taking into consideration the presence of large equipment
B. Provide lighting equipment that can be easily cleaned to mitigate dust build-up

5.3.5 Vehicle Storage Facilities

5.3.5.1 Drive Lanes

A. E_{avg} = 30 fc maintained

5.3.5.2 Vehicle Parking

A. E_{avg} = 30 fc maintained

5.3.5.3 Qualitative Criteria

A. Minimize glare.
B. Maximize uniformity of lighting to enhance safety.
C. Provide lighting equipment that can be easily cleaned to mitigate dust build-up.
D. Ensure light fixture mounting heights are sufficient to accommodate all types of planned vehicle traffic.

5.3.6 Airfield Facilities

A. All luminaires installed in the aircraft parking areas shall have a correlated color temperature of 4000k.
B. All new poles installed on the airfield must be coordinated with DEN airport planning for appropriate permitting requirements. Poles added to existing concourse facilities shall match the height of existing poles; Concourse A pole height is 90 feet, Concourse B pole height is 85 feet, Concourse C pole height is 75 feet. Maximum pole height for aircraft parking areas shall be 100 feet.
C. Aircraft parking areas shall meet the following illuminance criteria detailed in Table 5-3: Aircraft Parking Area Illumination.

Table 5-3: Aircraft Parking Area Illumination

Area Type	Horizontal Illuminance Criteria				Vertical Illuminance Criteria		Grid Spacing
	Minimum (distance) [1, 2]	Average (range) [1, 3]	Uniformity Max:/Min (range) [1,4]	Max. at boundary (boundary distance) [1,3]	Min (height/ distance) [1, 6]	Max glare at boundary (height/ distance) [1,7]	
Mainline Gates - no deicing	1.5fc (200ft), 0.5fc (250ft)	3.0fc (0-200ft)	5:1 (200ft)	0.3fc (300ft)	3.0fc (3ft/100-200ft)	0.25fc (50ft/250ft), 0.10fc (100ft/250 ft)	10ft x 10ft

Table 5-3: Aircraft Parking Area Illumination (Continued)

Area Type	Horizontal Illuminance Criteria				Vertical Illuminance Criteria		Grid Spacing
	Minimum (distance) [1, 2]	Average (range) [1, 3]	Uniformity Max:/Min (range) [1,4]	Max. at boundary (boundary distance) [1,3]	Min (height/ distance) [1, 6]	Max glare at boundary (height/ distance) [1,7]	
Mainline Gates - with deicing	2.5fc (200ft), 0.5fc (250ft)	5.0fc (0-200ft)	5:1 (200ft)	0.3fc (300ft)	5.0fc (3ft/100-200ft)	0.25fc (50ft/250ft), 0.10fc (100ft/250 ft)	10ft x 10ft
Ground Load Gates	1.25fc (200ft), 0.3fc (250ft)	2.0fc (0-200ft)	6:1 (200ft)	0.3fc (300ft)	2.0fc (3ft/100-200ft)	0.25fc (50ft/250ft), 0.10fc (100ft/250 ft)	10ft x 10ft
Remain Overnight (RON) Positions[8]	1.0fc (200ft), 0.2fc (250ft)	1.5fc (0-200ft)	6:1 (200ft)	0.3fc (300ft)	1.5fc (3ft/100-200ft)	0.25fc (50ft/250ft), 0.10fc (100ft/250 ft)	10ft x 10ft
Cargo Facilities	2.5fc (200ft), 0.5fc (250ft)	5.0fc (0-200ft)	5:1 (200ft)	0.3fc (300ft)	5.0fc (3ft/100-200ft)	0.25fc (50ft/250ft), 0.10fc (100ft/250 ft)	10ft x 10ft
Regional Jet and Commuter Gates[9]	1.5fc (150ft), 0.5fc (200ft)	3.0fc (0-150ft)	5:1 (150ft)	0.3fc (275ft)	2.0fc (3ft/75-150ft)	0.25fc (50ft/250ft), 0.10fc (100ft/250 ft)	10ft x 10ft

Notes:

1. *Side-to-side boundaries of parking positions shall be defined as either (1) the midpoint between the subject area and the adjacent area, or (2) 25 feet beyond the wingtip of the largest planned aircraft type where no adjacent parking position exists.*
2. *Minimum illuminance: Measured at the specified horizontal distance from the building or pavement edge at ground level and any point between the side-to-side boundary.*
3. *Average: Calculated based on all points measured within the specified range from the building or pavement edge and bounded by the edges of the subject area.*
4. *Uniformity: Calculated based on all points measured within the specified range from the building or pavement edge and bounded by the edges of the subject area.*
5. *Maximum glare: Specifies the maximum horizontal illuminance imparted on the ground at the glare boundary, measured along the specified boundary distance from the associated building or pavement edge.*
6. *Vertical Minimum: Specifies the minimum vertical illuminance at the noted working height, throughout the noted distance range from the building.*

7. *Vertical Maximum: Specifies the maximum vertical illuminance at the noted height(s), and boundary distance. Illuminance levels shall be maintained below the specified targets to minimize glare.*
8. *Specified illuminance criteria for RON positions shall apply to parking areas not located at a concourse building. RON positions at the concourse building shall be designed to meet the criteria for mainline gates.*
9. *Specified illuminance criteria for Regional Jet and Commuter gates shall apply to facilities and gates which are dedicated for commuter aircraft, typically serving ADG II aircraft. Gates which are designed to service both narrow-body and commuter aircraft shall be designed to meet the criteria for mainline gates.*

5.3.6.1 Airfield Lighting Vaults

A. Work areas

E_{avg} = 50 fc average maintained for work areas.

B. CCR room

E_{avg} = 20 fc average maintained.

C. Switchgear and generator room

E_{avg} = 30 fc average maintained.

D. Qualitative criteria
   a. For work areas, CCR room and switchgear and generator rooms, arrange lighting to minimize shadows, taking into consideration the presence of large equipment.
   b. Provide lighting equipment that can be easily cleaned to mitigate dust build-up.

5.3.7 Tunnel System

5.3.7.1 Baggage Tunnel

A. E_{avg} = 15 fc at all automated baggage handling and drive lanes
B. E_{avg} = 30 fc at manual baggage makeup areas
C. Qualitative Criteria
   a. Minimize glare
   b. Maximize uniformity of lighting to enhance safety
   c. Provide lighting equipment that can be easily cleaned to mitigate dust build-up
   d. Ensure light fixture mounting heights are sufficient to accommodate all types of planned vehicle traffic

5.3.7.2 Utility Tunnel

A. E_{avg} = 15 fc
B. Qualitative Criteria
   a. Provide means of automatic shutoff in areas that are not regularly occupied.

5.3.7.3 AGTS Tunnel

Contact the DEN Electrical Engineer for lighting requirements in the AGTS tunnel.

5.4 Lighting Retrofits and Replacements

5.4.1 General

For major remodel projects, retrofit and/or replace lighting equipment in areas relevant to the project to upgrade all lighting and controls in the project to meet the currently adopted lighting design standards. At the start of the project, coordinate with the DEN Project Manager to determine areas that are required to be upgraded.

5.4.2 Concourse Expansions

For concourse expansion projects, comply with all applicable lighting design standards for the expansion area.

Apron area lighting shall comply with all applicable lighting design standards for the expansion area.

5.4.3 Parking Lots

For parking lot expansion projects, comply with all applicable lighting design standards for the entire parking lot. Upgrade existing lighting and controls as directed by the DEN Project Manager.

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Chapter 6 - Facility Design Descriptions

6.0 Facility Design Descriptions

6.0.1 Scope

This chapter includes design guidance for facility-specific requirements not covered under other chapters of this document.

6.0.2 Criteria

All electrical designs shall meet the requirements set forth in the remainder of this document. Refer to the Electrical Drawing chapter in the Standards and Criteria DSM for additional requirements pertaining to electrical drawings.

6.0.3 Design Approach

Design choices for remodels of existing spaces at DEN should take into consideration all currently accepted design methods, including new energy-efficient products such as light fixtures and lighting controls. Design choices for new buildings and building additions at DEN will vary depending on the building type, intended purpose, location, and other factors.

The guidelines below shall be considered as general guidelines. The actual design of any new building or remodeled space at DEN must be carefully tailored to the use case of that building or space.

6.1 Passenger Terminal

The primary purpose of the passenger terminal is to support incoming and outgoing passenger flow. Outgoing passengers will utilize the terminal primarily for parking/drop-off, ticketing, baggage check, and TSA security. Incoming passengers will utilize the terminal primarily for baggage claim, ground transportation, and pick-up.

Secondary purposes of the passenger terminal include concessions, office space, storage, maintenance, and other uses.

Where new electrical rooms are added to the existing (or new) buildings in support of new spaces, ensure that the electrical room is sized to accommodate a minimum of 25% additional future equipment and provide wall space to accommodate the same. Ensure that the extra wall space provided for future equipment also takes all code-required equipment clearances and working space into consideration. All electrical equipment shall be mounted to or located next to perimeter walls within the room.

6.1.1 Electrical Submetering

Electrical submetering shall be provided, in accordance with this Manual, for all areas of the passenger terminal to monitor electrical usage of the following:

A. Electrical switchgear and switchboards.
B. Electrical distribution panelboards.
C. Branch circuit panelboards.
D. Motor control centers.
E. Lighting loads, as follows:
    a. Select lighting control systems equipped with integral power metering where feasible.
    b. If integral power metering is not available, provide individual branch circuit metering at the panel board. Integrated solutions built into the panel board are preferred to minimize metering equipment space requirements.
F. Tenant loads shall be submetered by leased space.

a. Tenant submetering equipment shall be located within the tenant space.
b. Tenants with dedicated electrical service: Provide submetering at the service distribution point.
c. Tenants with shared electrical service: Provide individual branch circuit submetering aggregated by phase.

6.1.2 Ticketing and Baggage Claim Areas

Existing normal electrical power for systems and equipment is provided at 480Y/277 volts and 208Y/120 volts. Electrical power service is distributed throughout the space to serve HVAC equipment, lighting systems, elevators, escalators, baggage conveyors, and general convenience power.

Existing lighting controls shall be upgraded where necessary to meet currently adopted codes and design standards. Provide occupancy/vacancy sensors in offices and other non-public spaces. Any existing automatic controls (daylight harvesting controls, low-voltage controls with relay panels, etc.) may be reused only if the equipment is serviceable and in good condition and the manufacturer of the equipment is still supporting it with spare parts and technical support. Any existing fluorescent lighting that is not to be removed and is still utilizing any fluorescent lamping shall be retrofitted to LED.

Existing emergency power shall be modified and extended for new loads. Where required, upgrade emergency power to meet currently adopted codes. Emergency egress lighting shall be provided with battery backup. The preferred method of backup is via central inverter systems. Where central inverters are not practical, provide local battery backup of individual luminaires.

The existing fire sprinkler system shall be modified and extended as required to provide coverage of remodeled spaces. Refer to the Life Safety DSM for all fire detection and alarm system descriptions and requirements.

When remodeling ticketing and baggage claim spaces (for new carriers, for example), the Designer should take care to maintain power and lighting connections to adjacent areas and, where possible, reuse existing systems in the area.

6.1.3 Rental Car Area

Normal electrical power for systems and equipment is provided at 480Y/277 volts and 208Y/120 volts. Electrical power service will be distributed throughout the space to serve HVAC equipment, lighting systems, escalators, elevators, and general convenience power.

Emergency electrical power for systems and equipment will be provided at 480Y/277 volts and 208Y/120 volts. Emergency electrical power will be distributed throughout the space to serve elevators, exit, and egress lighting, fire detection, and alarm, central corrected clock, EMCS, PA system, security, communications, data systems, and airline reservations and flight information equipment.

Existing lighting controls shall be upgraded where necessary to meet currently adopted codes and design standards. Provide occupancy/vacancy sensors in offices and other non-public spaces. Any existing automatic controls (daylight harvesting controls, low-voltage controls with relay panels, etc.) may be reused only if the equipment is serviceable and in good condition and the manufacturer of the equipment is still supporting it with spare parts and technical support. Any existing fluorescent lighting that is not to be removed and is still utilizing any florescent lamping shall be retrofitted to LED.

Existing emergency power shall be modified and extended for new loads. Where required, upgrade emergency power to meet currently adopted codes. Emergency egress lighting shall be provided with battery backup. The preferred method of backup is via central inverter systems. Where central inverters are not practical, provide local battery backup of individual luminaires.

The existing fire sprinkler system shall be modified and extended as required to provide coverage of remodeled spaces. Refer to the Life Safety DSM for all fire detection and alarm system descriptions and requirements.

When remodeling rental car areas, the Designer should take care to maintain power and lighting connections to adjacent areas and, where possible, reuse existing systems in the area.

6.2 Concourse Buildings

The primary purpose of the concourse buildings is to support aircraft and passengers. This includes but is not limited to parking, servicing, and fueling of aircraft; staging, loading, and unloading of passengers; and transport, loading, and unloading of baggage. All concourse buildings should be designed with these activities considered first and foremost.

Secondary purposes of the concourse buildings include providing concession spaces for food, beverage, and retail sales; providing office spaces for tenants; and providing supplemental storage, servicing, and staff space for air carriers.

The electrical service is provided by Xcel at multiple points along the airside perimeter of each building. Secondary service (480Y/277 volts and/or 208Y/120 volts) is provided through DEN's secondary metering type distribution equipment. Metered service is taken at DEN's metering equipment to serve the general building systems and equipment.

Existing lighting controls shall be upgraded where necessary to meet currently adopted codes and design standards. Provide occupancy/vacancy sensors in offices and other non-public spaces. Any existing automatic controls (daylight harvesting controls, low-voltage controls with relay panels, etc.) may be reused only if the equipment is serviceable and in good condition and the manufacturer of the equipment is still supporting it with spare parts and technical support. Any existing fluorescent lighting that is not to be removed and is still utilizing any fluorescent lamping shall be retrofitted to LED.

6.2.1 Electrical Submetering

Electrical submetering shall be provided, in accordance with this Manual, for all areas of the concourse building to monitor electrical usage of the following:

A. Electrical switchgear and switchboards.
B. Electrical distribution panelboards, including gate power panels.
C. Branch circuit panelboards.
D. Motor control centers.
E. Lighting loads, as follows:
    a. Select lighting control systems equipped with integral power metering where feasible.
    b. If integral power metering is not available, provide individual branch circuit metering at the panel board. Integrated solutions built into the panel board are preferred to minimize metering equipment space requirements.
F. Tenant loads shall be submetered by leased space.
    a. Tenant submetering equipment shall be located within the tenant space.
    b. Tenants with dedicated electrical service:
    Provide submetering at the service distribution point.
    c. Tenants with shared electrical service:
    Provide individual branch circuit submetering aggregated by phase.

6.2.2 Hold Room Areas

When remodeling existing hold room areas, the Designer shall ensure that adequate power is available for all systems, such as air carrier podiums, back walls, flight information display systems (FIDS), gate information display systems (GIDS), gate portals, and hold room seating power systems. Provide new electrical panels and distribution infrastructure as needed to fully support the planned and future loads.

The existing emergency communications system shall be modified as necessary to provide for emergency announcements to all occupants. All screens larger than 14", including FIDS/GIDS, tenant displays, air carrier information displays, etc., shall be equipped with a shunt device to display emergency information when the emergency communications system is activated.

All new hold room lighting shall be dimmable LED type, with daylight dimming control via automatic photocell controls, unless instructed otherwise by the DEN Project Manager.

All new seating shall be provided with floor-based power feeds, with under-seat power receptacles for use by hold room occupants. Coordinate exact power requirements and seating locations with the DEN Project Manager.

6.2.3 Concourse Restrooms

All new restrooms shall follow the currently accepted DEN prototype for restroom design. Provide decorative LED lighting at the lavatories, slot-style LED lighting, decorative LED lighting in the general areas, and LED cove lighting where indicated. Coordinate exact requirements with the architectural plans and the DEN Project Manager.

6.2.4 Office Space Remodels

Existing office spaces being remodeled shall be brought into compliance with currently adopted electrical and energy codes, including lighting controls requirements and lighting power density requirements.

Refer to the Tenant Design Guidelines for more specific requirements related to tenant space build-outs.

6.2.5 Additions to Existing Concourses

Each of the three existing concourse buildings is serviced from multiple electrical services. Each service provides power to a portion of the concourse building.

In general, the central cores of each concourse have two 277/480-Volt, 3-phase, 3000-Ampere electrical services. These services are fed from Xcel transformers, either installed pad-mounted on the apron or in transformer vaults in the basement. Each service is double-ended, with power supply from both the Barr Lake and Sky Ranch substations. For additional information, refer to Chapter 2- Interior Electrical Power Distribution Systems Separation of service in the central core is made on a diagonal through the center of the building; all power on each side is fed from the associated service on that side.

Similarly, each sub-core is provided with its own double-ended 277/480V, 3-Ph, 3000A service. Separation of service is made at the mid-point between the subcore and the central core (or next subcore).

Emergency power is provided via the DEN dual redundant primary network. At each service, a tap ahead of the main breakers on each end of the switchgear feed a separate automatic transfer switch and, in turn, an emergency distribution switchboard. The switchboard serves all emergency loads, including smoke control equipment, fire alarm, emergency lighting, and other emergency equipment.

The Designer should coordinate with the DEN Project Manager to determine when a new Xcel electrical service will be required. Typically, a new service is required when adding new sub-cores, or a significant number of new gates and floor area to an existing concourse. Where required, a new electrical service shall be provided using new aboveground, pad-mounted utility transformers. Each electrical service installed in the concourse building shall be dual-fed from both the Barr Lake and Sky Ranch substations using the existing 25kV primary distribution network installed at DEN. Coordinate installation of all new switching and utility transformation equipment with Xcel. Provide Xcel metering equipment on all electrical services.

Main switchboards shall be drawout-type, double-ended, circuit-breaker style switchboards with integral metering equipment for facility use. Metering outputs shall be integrated into the EMCS in accordance with this Manual. Where installed in addition or subcore with planned future expansion, provide sufficient ampacity as well as spare drawout cubicles to support planned expansion, plus an additional 25% spare. It is often the case in concourse buildings that shell spaces, such as basements and storage rooms are later remodeled into offices, support spaces, break rooms, maintenance areas, and other uses. Consideration should be taken for these scenarios when designing the electrical service for any building addition.

When new services are added, provide dual emergency taps ahead of the main circuit breakers, similar to existing services. Provide automatic transfer equipment and a separate emergency power distribution switchboard. Note that all emergency overcurrent protection devices shall be selectively coordinated as required by the NEC.

Where new electrical rooms are added to the existing (or new) buildings in support of new spaces, ensure that the electrical room is sized to accommodate a minimum of 25% additional future equipment and provide wall space to accommodate the same. Ensure that the extra wall space provided for future equipment also takes all code-required equipment clearances and working space into consideration. All electrical equipment shall be mounted to or located next to perimeter walls within the room.

LED luminaries will be used to light the large, open, high-ceiling areas of the facility. LED luminaries will be used for a special purpose and architectural accent lighting. Industrial LED luminaries will be used to light storage areas, equipment rooms, and similar spaces. Industrial LED luminaries will be used to light the baggage and operations areas. Recessed luminaries shall be used in all finished areas. Lighting control will be by use of occupancy/vacancy sensors in offices and other non-public spaces. Ambient lighting control using continuous dimming will be utilized in spaces where daylighting is possible. Microprocessor-based, remote-controlled, low-voltage switching systems will be utilized for lighting control in all spaces where it can be justified by occupancy and life cycle cost analysis. Refer to Chapter 5- Lighting Systems for additional lighting requirements.

Where possible, avoid installing other systems (HVAC, plumbing, etc.) in electrical room spaces.

Coordinate specific hold room, air carrier podium, signage, and general power requirements with the DEN Project Manager.

6.2.5.1 Electrical Submetering

Electrical submetering shall be provided, in accordance with this Manual, for all areas of the concourse expansion to monitor electrical usage of the following:

A. Electrical switchgear and switchboards.
B. Electrical distribution panelboards, including gate power panels.
C. Branch circuit panelboards.
D. Motor control centers.
E. Lighting loads, as follows:
    a. Select lighting control systems equipped with integral power metering where feasible.
    b. If integral power metering is not available, provide individual branch circuit metering at the panel board. Integrated solutions built into the panel board are preferred to minimize metering equipment space requirements.
F. Tenant loads shall be submetered by leased space as follows:
    a. Tenant submetering equipment shall be located within the tenant space.
    b. Tenants with dedicated electrical service:
    Provide submetering at the service distribution point.
    c. Tenants with shared electrical service:
    Provide individual branch circuit submetering aggregated by phase.

6.2.6 New Concourse Buildings

Completely new concourse buildings may be added to the airport as outlined in the DEN master plan. Any new concourse buildings shall be designed around the same functionality described for the existing concourse buildings.

Provide new 277/480-Volt, 3-Phase, 4-Wire electrical service for the new building. Electrical service shall be provided using new aboveground, pad-mounted utility transformers. Each electrical service installed in the concourse building shall be dual-fed from both the Barr Lake and Sky Ranch substations using the existing 25kV primary distribution network installed at DEN. Coordinate installation of all new switching and utility transformation equipment with Xcel. Provide Xcel metering equipment on all electrical services.

Main switchboards shall be drawout-type, double-ended, circuit-breaker style switchboards with integral metering equipment for facility use. Metering outputs shall be integrated into the EMCS in accordance with this Manual. Where installed in a new building with planned future expansion, provide sufficient spare drawout cubicles to support planned expansion, plus an additional 25% spare.

Ensure that all electrical rooms are sized to accommodate a minimum of 25% additional future equipment and provide wall space to accommodate the same. Ensure that the extra wall space provided for future equipment also takes all code-required equipment clearances and working space into consideration.

Emergency power is provided via the DEN dual redundant primary network. At each service, a tap ahead of the main breakers on each end of the switchgear shall feed a separate automatic transfer switch and, in turn, an emergency distribution switchboard. The switchboard shall serve all emergency loads, including smoke control equipment, fire alarm, elevators, emergency lighting (via inverter), and other emergency equipment.

Provide a central lighting inverter for emergency egress lighting, with either an integral distribution panel or an external distribution panel. The lighting inverter shall be UL924-listed and capable of powering its full rated capacity for at least 90 minutes. Size new lighting inverters to support all emergency lighting to be installed in the building or area served, including planned future expansion, plus 25% spare.

LED luminaries will be used to light the large, open, high-ceiling areas of the facility. LED luminaries will be used for a special purpose and architectural accent lighting. Industrial LED luminaries will be used to light storage areas, equipment rooms, and similar spaces. Industrial LED luminaries will be used to light the baggage and operations areas. Recessed luminaries shall be used in all finished areas. Lighting control will be by use of occupancy/vacancy sensors in offices and other non-public spaces. Ambient lighting control using continuous dimming will be utilized in spaces where daylighting is possible. Microprocessor-based, remote-controlled, low-voltage switching systems will be utilized for lighting control in all spaces where it can be justified by occupancy and life cycle cost analysis. Refer to Chapter 5- Lighting Systems for additional lighting requirements.

The interior space will be fire sprinklered, and the fire sprinkler system shall be alarmed and supervised. Smoke detection will be provided in all non-sprinklered areas and in the HVAC supply and return air systems when required by code. Thermal detection devices will be installed in all non-sprinklered spaces where the use of smoke detectors is not appropriate due to the normal or expected presence of products of combustion. Refer to the Life Safety DSM for all fire detection and alarm system descriptions and requirements.

A PA system will be installed throughout the facility to provide for general paging announcements and evacuation and alarm signals and announcements. The system in this area will be served from a central master system and zoned as required to accommodate local, general area, and system-wide paging announcements. PA input stations will be provided with airline ticket lift counters at passenger loading bridge doorways.

An emergency communications system will be installed throughout the facility to provide for emergency announcements.

Communication raceway systems will be installed to provide for the distribution of the telephone and communications system throughout the facility. The system will provide service for telephones, courtesy telephones, data communication, and other related communications. A separate communication raceway system will be installed to provide for the distribution of airline reservations, flight information, baggage information, and other data communication wiring. Refer to the Communication and Electronic Systems DSM for communications system requirements.

A security system will be installed throughout the facility to monitor and/or alarm all activities in the general public areas and other areas as deemed appropriate and necessary. The security system shall be connected to the central airport security system. An access control system shall be installed to control access between public areas, secured areas, and non-public areas.

Electrical submetering shall be provided, in accordance with this Manual, for all areas of the concourse building to monitor electrical usage of the following:

6.2.6.1 Electrical Submetering

Electrical submetering shall be provided, in accordance with this Manual, for all areas of the concourse expansion to monitor electrical usage of the following:

A. Electrical switchgear and switchboards.
B. Electrical distribution panelboards, including gate power panels.

C. Branch circuit panelboards.
D. Motor control centers.
E. Lighting loads, as follows:
    a. Select lighting control systems equipped with integral power metering where feasible.
    b. If integral power metering is not available, provide individual branch circuit metering at the panel board. Integrated solutions built into the panel board are preferred to minimize metering equipment space requirements.
F. Tenant loads shall be submetered by leased space as follows:
    a. Tenant submetering equipment shall be located within the tenant space.
    b. Tenants with dedicated electrical service:
        • Provide submetering at the service distribution point.
    c. Tenants with shared electrical service:
        • Provide individual branch circuit submetering aggregated by phase.

6.3 Airport Office Building

The AOB is primarily office space, with some special-use areas such as control rooms. The existing electrical distribution system is comprised primarily of a 277/480V, 3-phase plug-in bus duct serving individual panelboards on each floor. Some special systems are fed separately via standby power or UPS power. Coordinate any special system power requirements with the DEN Project Manager.

Each floor of the AOB is provided with a step-down transformer serving 120/208V, 3-phase general power panelboards. If the insufficient spare capacity or breaker space is available in the existing panelboards, coordinate the installation (location, sizing, etc.) of additional panels and/or step-down transformers with the DEN Project Manager.

Existing lighting fixtures shall be reused where possible. Any existing fluorescent fixtures shall be retrofitted to LED or replaced. Provide new LED luminaires where required. Lighting control will be by use of occupancy/vacancy sensor control in individual offices and zoned occupancy sensors per code requirements in open areas as appropriate. Provide dimming switching capability in individual offices and conference rooms. Refer to Chapter 5-Lighting Systems for additional lighting requirements.

Fire alarm systems shall be modified as necessary to support the remodeled spaces. Maintain connections and functionality of all fire alarm initiation and annunciation devices and wiring that are disturbed during construction. Refer to the Life Safety DSM for all fire detection and alarm system descriptions and requirements.

Fire sprinkler systems shall be modified as necessary to support the remodeled spaces. Maintain connections and functionality of all piping and sprinkler heads that are disturbed during construction.

Access control and security systems shall be modified as necessary to support the project. Coordinate with the DEN Project Manager to determine which rooms will require access control. Existing access controls in the building shall not be interrupted during construction.

Remodels of the AOB shall be designed to minimize impact on adjacent tenants. Protocols shall be implemented to limit work that will disrupt adjacent tenants and floors to non-working hours.

6.3.1 Electrical Submetering

Electrical submetering shall be provided, in accordance with this Manual, for all areas of the AOB to monitor electrical usage of the following:

A. Electrical switchgear and switchboards.
B. Electrical distribution panelboards.
C. Branch circuit panelboards.
D. Motor control centers.
E. Lighting loads, as follows:

a. Select lighting control systems equipped with integral power metering where feasible.
b. If integral power metering is not available, provide individual branch circuit metering at the panel board. Integrated solutions built into the panel board are preferred to minimize metering equipment space requirements.

6.4 Control Towers

DEN has three control towers on-site. The FAA air traffic control tower (FAA Tower) and (2) additional control towers for ground traffic. The FAA tower is located at the center of Concourse C. The ground traffic control towers are located at Concourses A and B.

The Designer shall provide general convenience power for all areas in the control tower and additional power for occupant equipment where required. In the control tower cab (top level), provide receptacles for built-in computer terminals, radar screens, radios, etc., as needed. Provide a raised floor system in the cab level for routing of all power and communications cabling. Coordinate all new work with the DEN Project Manager to determine exact requirements. Where possible, conceal receptacles within millwork to avoid cables running across floors and minimize trip hazards.

Lighting in the control tower cab area should be selected to maximize the direct downlight component and minimize indirect light to avoid glare on tower windows and desktop display units. Light fixtures should be dimmable incandescent or LED for occupant adjustability. The primary visual tasks performed in the control tower cab are visually spotting aircraft on the airport apron and runways and viewing information at desk levels, such as radar screens and computer terminals. Light fixture placement should be selected to avoid direct glare to occupants where possible.

Ancillary areas in the control tower such as stairwells, break rooms, storage rooms, and offices should be lit with standard LED lighting. Provide occupancy/vacancy sensors where appropriate. Any existing lighting to be reused with fluorescent lamps should be retrofit to LED. Refer to Chapter 5- Lighting Systems for additional lighting requirements.

Remodel projects in the existing control towers should be performed with consideration for the critical nature of operations in these control towers. Standby power generation equipment should be considered as part of the design. Review power reliability requirements and generator requirements with the DEN Project Manager on a case-by-case basis.

6.4.1 Electrical Submetering

Electrical submetering shall be provided, in accordance with this Manual, for all areas of the control towers to monitor electrical usage of the following:

A. Electrical switchgear and switchboards
B. Electrical distribution panels
C. Branch circuit panelboards
D. Motor control centers
E. Lighting loads, as follows
    a. Select lighting control systems equipped with integral power metering where feasible.
    b. If integral power metering is not available, provide individual branch circuit metering at the panel board. Integrated solutions built into the panel board are preferred to minimize metering equipment space requirements.

6.4.2 FAA Tower

The electrical service at the FAA tower is provided by Xcel at the perimeter of the building. Secondary service (480Y/277 volts) is provided through the FAA's secondary metering type distribution equipment. Metered service is taken at the FAA's metering equipment to serve the general building and process systems and equipment. Electrical power service is distributed throughout the facility to serve building and process systems and equipment. Building

systems and equipment includes HVAC equipment, lighting systems, elevators, fire detection and alarm systems, security system, general convenience, and other similar systems and equipment. Process systems and equipment includes computer systems, aircraft monitoring systems, aircraft communication systems, airfield systems monitoring and control, and other similar systems and equipment.

Emergency electrical power at the FAA tower is provided by separate dedicated diesel (or natural gas) engine generators installed in the building. Electrical power is generated at 480Y/277 volts. Emergency electrical power is distributed throughout the facility to serve elevators, exit, and egress lighting, fire detection and alarm, security, smoke ventilation, communications, data systems, and the building process systems and equipment determined to require emergency power.

6.4.3 Ramp Towers

Electrical service at the ramp towers is provided through the associated concourse's electrical distribution system. Emergency/standby electrical power is provided through local battery backup and UPS systems.

6.5 Parking Facilities

6.5.1 Surface Parking

Where new or modified surface parking is to be built, provide new pole-mounted LED roadway lighting. Where possible, match the appearance and light output of currently installed LED area light fixtures. All new lighting shall be LED. Do not provide new high-pressure sodium lighting in any site areas unless allowed by the DEN Project Manager. Refer to Chapter 5- Lighting Systems for illuminance requirements at the parking area.

Lighting control shall be via photocell and motion sensor dimming control. Provide individual photocell mounted on the south-facing side of a structure and provide a relay panel. Ensure all equipment installed outdoors is rated for outdoor installation.

6.5.1.1 Electrical Submetering

Electrical submetering is not required for surface parking, unless directed otherwise by the DEN Project Manager.

6.5.2 Structured Parking

For any new structured parking, provide LED parking garage lighting to match existing LED lighting in the garages. Where possible, use the same fixtures already installed. Refer to Chapter 5- Lighting Systems for illuminance requirements at the parking area.

6.5.2.1 Electrical Submetering

Electrical submetering shall be provided, in accordance with this Manual, for all areas of the structured parking to monitor electrical usage of the following:

A. Electrical switchgear and switchboards
B. Electrical distribution panelboards
C. Branch circuit panelboards
D. Motor control centers
E. Lighting loads, as follows:
    a. Select lighting control systems equipped with integral power metering where feasible.
    b. If integral power metering is not available, provide individual branch circuit metering at the panel board. Integrated solutions built into the panel board are preferred to minimize metering equipment space requirements.

6.5.3 Parking Toll Plazas

The electrical service for the parking toll plaza is provided by Xcel at the perimeter of the building. Secondary service (480Y/277 volts) is provided through DEN's secondary metering type distribution equipment. Metered service is taken at DEN's metering equipment to serve the general building and process systems and equipment. Electrical power service (480Y/277 volts and 208Y/120 volts) is distributed throughout the facility to serve building and process systems and equipment. Building systems and equipment includes HVAC equipment, lighting systems, fire detection and alarm systems, security system, general convenience power, and other similar systems and equipment. Process systems and equipment includes computer systems, parking lot entrance and exit control, and other similar systems and equipment.

Emergency electrical power is provided by the use of battery backup systems for exit and egress lighting, fire detection and alarm, security, communications, and data systems.

When remodeling existing toll plazas, the Designer should ensure that all existing systems to be reused are brought into compliance with currently adopted codes, including energy codes. Replace existing incandescent and high-pressure sodium luminaires with LED where practical. Replace existing fluorescent lamps with LED. Provide occupancy or vacancy sensor lighting controls in individual offices and storerooms as appropriate.

6.6 Hotel and Transit Center

The hotel and transit center are known collectively as the HTC.

6.6.1 Hotel

All equipment and infrastructure within the hotel is maintained and operated by a third-party hotel operator. Contact the DEN Project Manager for requirements.

6.6.2 Public Transit Center

Electrical service for the public transit center (PTC) is provided by Xcel at the perimeter of the building. Secondary service (480Y/277 volts) is provided through DEN's secondary metering type distribution equipment. Metered service is taken at DEN's metering equipment to serve general building and process systems and equipment. Electrical power service (480Y/277 volts and 208Y/120 volts) is distributed throughout the facility to serve building and process systems and equipment.

The PTC electrical service is separated, with east portions of the building powered from the east switchgear and west portions of the building powered from the west switchgear. All main switchgear is located on Level 1.

Emergency power is provided via the DEN dual redundant primary network. At each service, a tap ahead of the main breakers on each end of the switchgear feeds a separate automatic transfer switch and, in turn, an emergency distribution switchboard. The switchboard serves all emergency loads, including smoke control equipment, fire alarm, elevators, emergency lighting (via inverter), and other emergency equipment.

Existing lighting controls shall be upgraded where necessary to meet currently adopted codes and design standards. Provide occupancy/vacancy sensors in offices and other non-public spaces. Any existing automatic controls (daylight harvesting controls, low-voltage controls with relay panels, etc.) may be reused only if the equipment is serviceable and in good condition and the manufacturer of the equipment is still supporting it with spare parts and technical support.

Existing lighting fixtures shall be reused where possible. LED luminaries will be used to light the large, open, high-ceiling areas of the facility. LED luminaries will be used for a special purpose and architectural accent lighting. Industrial LED luminaries will be used to light storage areas, equipment rooms, and similar spaces. Industrial LED luminaries will be used to light the baggage and operations areas. Recessed luminaries shall be used in all finished areas. Lighting control will be by use of occupancy/vacancy sensors in offices and other non-public spaces. Ambient lighting control using continuous dimming will be utilized in spaces where daylighting is possible. Microprocessor-based, remote-controlled, low-voltage switching systems will be utilized for lighting control in all spaces where it can be justified by occupancy and life cycle cost analysis.

6.6.2.1 Electrical Submetering

Electrical submetering shall be provided, in accordance with this Manual, for all areas of the PTC to monitor electrical usage of the following:

A. Electrical switchgear and switchboards
B. Electrical distribution panelboards
C. Branch circuit panelboards
D. Motor control centers
E. Lighting loads, as follows:
    a. Select lighting control systems equipped with integral power metering where feasible.
    b. If integral power metering is not available, provide individual branch circuit metering at the panel board. Integrated solutions built into the panel board are preferred to minimize metering equipment space requirements.
F. Tenant loads shall be submetered by leased space as follows:
    a. Tenant submetering equipment shall be located within the tenant space.
    b. Tenants with dedicated electrical service: Provide submetering at the service distribution point.
    c. Tenants with shared electrical service: Provide individual branch circuit submetering aggregated by phase.

6.6.3 Commuter Rail Station

Contact the DEN Project Manager for requirements.

6.7 Support and Outlying Buildings

Electrical design requirements for support and outlying buildings will vary based on the intended use of the building. For specific requirements for any particular project, contact the DEN Project Manager.

6.7.1 Central Utility Plant

Electrical service at the Central Utility Plant (CUP) is provided by Xcel. The utility secondary service will be (4,160V, 3-Phase, 3-Wire) and metered on the load side of the utility transformer. Electrical power will be distributed throughout the facility to serve the building.

Emergency power is provided via the DEN dual redundant primary network. (2) existing 277/480V, 3-Phase, 4-Wire pad-mounted transformers are installed at the west end of the CUP at apron level. These pad-mount transformers, in turn, feed an alarmed automatic transfer switch and, in turn, an emergency distribution switchboard. The switchboard serves all emergency loads, including elevators, fire alarms, emergency lighting, and other emergency equipment. Emergency egress lighting is supplied with backup batteries installed in individual fixtures for redundancy.

The design of the CUP has been modified extensively since its original construction. The primary electrical change was the conversion of the original natural gas internal combustion engine-driven chillers to electric motor-driven units. This modification, completed around 2001, placed a significant additional electrical load on the (2) existing 4,160-Volt, 3-phase services, designated as service ‘A’ and service ‘B.’ A new 2,000A 4,160V, 3-Ph electrical service, designated service ‘C,’ was added to the building to supplement the existing service for powering the large electrical loads. In addition to the chillers, the 4,160V system also supports various large pumps to circulate chilled water and heating water through the primary loop serving buildings in the Terminal Complex and process water within the CUP.

Step-down transformers are provided in the plant for low-voltage (277/480V and 120/208V) power where needed. Most low-voltage equipment loads are fed from a series of (6) 1000 kVA dry-type step-down transformers serving motor control center lineups in the main electrical room. Designated MCC A1 through A3 and MCC B1 through B3, these motor control centers distribute power to boilers, pumps, valves, and other equipment throughout the CUP.

All new distribution equipment (panelboards, switchboards, transformers, etc) installed in the CUP shall utilize DEN electrical equipment naming standards defined herein.

Where speed control is required, motor-driven equipment shall be specified with variable frequency drives (VFDs). As the CUP has adopted a variable flow sequence of operation, many components of the system require speed control. VFDs shall be located near their associated equipment or installed within a motor control center. Provide housekeeping pads for all floor-mounted drives.

Equipment control panels shall be located near the associated equipment. All control power shall be derived from the same electrical service as the associated equipment. Where control power is associated with multiple pieces of equipment fed from multiple services, derived from the service powering the majority of the equipment, or powering the most critical equipment, as directed by the DEN Electrical Engineer.

The interior space of the CUP is fire sprinklered, and the fire sprinkler system is alarmed and supervised. Remodel projects in the plant shall include relocation and modification of the existing sprinkler system alarm devices as necessary.

Smoke detection is provided in all office and control room areas and in the HVAC supply and return air systems, as required by NFPA 90A. Thermal detection devices are installed in all non-sprinklered spaces where the use of smoke detectors is not appropriate due to the normal expected presence of products of combustion. Manual alarm-initiating devices are installed in all areas near exits. Audible and visual alarm devices are installed throughout the facility. The fire alarm system shall be connected to the central airport fire alarm system. All remodel projects shall maintain fire alarm functionality in all spaces.

6.7.1.1 Electrical Submetering

Electrical submetering shall be provided, in accordance with this Manual, for all areas of the CUP. Submetering equipment shall be in the associated electrical room. Provide submetering to monitor electrical usage of the following:

A. 208V and 480V Electrical switchgear and switchboards.
B. 208V and 480V Electrical distribution panelboards.
C. 208V and 480V Branch circuit panelboards.
D. 208V and 480V Motor control centers.
E. Mechanical equipment, including but not limited to:
    a. Chillers
    b. Boilers
    c. Pumps
    d. Fans
F. Lighting loads, as follows:
    a. Select lighting control systems equipped with integral power metering where feasible.
    b. If integral power metering is not available, provide individual branch circuit metering at the panel board. Integrated solutions built into the panel board are preferred to minimize metering equipment space requirements.

6.7.2 Maintenance Facility

The electrical service at the maintenance facility is provided by Xcel. The utility secondary service will be 480Y/277 volts and metered on the load side of the utility transformer. Electrical power will be distributed throughout the facility to serve the building.

Emergency electrical power is provided by battery backup as required for each separate system or equipment item. Emergency electrical power is provided to serve exit and egress lighting, fire detection, and alarm.

6.7.2.1 Electrical Submetering

Electrical submetering shall be provided in accordance with this Manual. Submetering equipment shall be in the associated electrical room. Provide submetering to monitor electrical usage of the following:

A. 208V and 480V Electrical switchgear and switchboards
B. 208V and 480V Electrical distribution panelboards
C. 208V and 480V Branch circuit panelboards
D. 208V and 480V Motor control centers

6.7.3 Air Cargo Facilities

The electrical service for new air cargo facilities will be provided by Xcel. The utility secondary service will be 480Y/277 volts and metered on the load side of the utility transformer. Electrical power will be distributed throughout the facility to serve the building.

Emergency electrical power will be provided by battery backup as required for each separate system or equipment item. Emergency electrical power will be provided to serve exit and egress lighting, fire detection, and alarm.

6.7.4 Aircraft Hangars

The electrical service is provided by Xcel. The utility secondary service will be 480Y/277 volts and metered on the load side of the utility transformer. Electrical power will be distributed throughout the facility to serve the building.

Emergency electrical power will be provided by battery backup as required for each separate system or equipment item. Emergency electrical power will be provided to serve exit and egress lighting, fire detection, and alarm.

6.7.5 Flight Kitchens

The electrical service will be provided by Xcel. The utility secondary service will be 480Y/277 volts and metered on the load side of the utility transformer. Electrical power will be distributed throughout the facility to serve the building.

Backup electrical power can be provided by an emergency or a standby generator following guidelines in sections 2.2.4.5 and 2.2.4.6. Emergency electrical power will be provided to serve exit and egress lighting, fire detection, and alarm.

6.7.6 Snow Removal Equipment Facilities

The electrical service will be provided by Xcel. The utility secondary service will be 480Y/277 volts and metered on the load side of the utility transformer. Electrical power will be distributed throughout the facility to serve the building.

Emergency electrical power will be provided by batter backup as required for each separate system or equipment item. Emergency electrical power will be provided to serve exit and egress lighting, fire detection, and alarm.

6.7.7 Fire Crash Rescue Facilities

The electrical service will be provided by Xcel. The utility secondary service will be 480Y/277 volts and metered on the load side of the utility transformer. Electrical power will be distributed throughout the facility to serve the building.

Emergency electrical power will be provided by a separate dedicated diesel (or natural gas) engine generator installed in the building. Generation will be at 480Y/277 volts. The generator shall be fed from a fuel tank of sufficient capacity to run the generator at full load (100%) plus 20% for 72 hours. The 20% factor is intended to allow for additional (new) electrical loads placed on the system in future years. The design of the generator system, including the fuel storage installation and its monitoring system, should comply with all local and manufacturer requirements. The generator should be installed outdoors, nearby to the building, and secured to a concrete pad of

sufficient density to accommodate the weight of the generator and the fuel supply tank. A permanent load bank shall be installed on-site for generator testing purposes. Refer to FAA Advisory Circular 150/5210-15A (Aircraft Rescue and Firefighting Station Building Design) for additional information.

6.7.7.1 Electrical Submetering

DEN electrical submetering shall be provided in accordance with this Manual. Submetering equipment shall be in the associated electrical room. Provide submetering to monitor electrical usage of the following:

A. 208V and 480V Electrical switchgear and switchboards
B. 208V and 480V Electrical distribution panelboards
C. 208V and 480V Branch circuit panelboards
D. 208V and 480V Motor control centers

6.7.8 Other Outlying Buildings

The electrical service will be provided by Xcel. The utility secondary service will be 480Y/277 volts or 208Y/120 volts, as required, and metered on the load side of the utility transformer. Electrical power will be distributed throughout the facility to serve the building.

Emergency electrical power will be provided by battery backup as required for each separate system or equipment item. Emergency electrical power will be provided to serve exit and egress lighting, fire detection, and alarm.

6.7.8.1 Electrical Submetering

DEN electrical submetering is not required for other outlying buildings unless directed otherwise by the DEN Project Manager.

6.8 Solar Arrays

DEN has large and diverse portfolio of solar installations throughout the airport property. These facilities may be developed utilizing various ownership and interconnection models. The design and construction of these facilities is reviewed by DEN for compliance with airport standards, based on the model chosen.

6.8.1 DEN Owned, Behind-the-Meter Interconnection

These installations are typically required to comply with all airport design standards, the “Xcel Energy Standard for Electric Installation and Use”, the most current version of IEEE 1547, and all applicable codes, whichever is most stringent. These projects are also required to apply for interconnection utilizing the “Master Distributed Energy Resource Interconnection Agreement” between Public Service Company of Colorado and the City and County of Denver, by and through its Department of Aviation.

6.8.2 Developer Owned, Behind-the-Meter Interconnection

For the portions of the system that are owned, operated, and maintained solely by the developer, these installations are typically required to comply with the “Excel Energy Standard for Electric Installation and Use”, the most current version of IEEE 1547, and all applicable codes, whichever is most stringent. Aluminum wiring may be an acceptable alternative to DSM Section: 260519 2.1.B.B. The requirement for concrete encasement of conduit in DSM Section: 260543 3.1 B may be waived.

6.8.3 Developer Owned, In-Front of-the-Meter Interconnection (Community Solar Garden)

These installations are typically contained entirely within the leased/licensed area and interconnect directly to the utility’s distribution infrastructure. For the portions of the system that are owned, operated, and maintained solely by the developer and or utility, these installations are typically required to comply with the “Xcel Energy Standard

for Electric Installation and Use", the most current version of IEEE 1547, and all applicable codes, whichever is most stringent. Aluminum wiring may be an acceptable alternative to DSM Section: 260519 2.1.B B. The requirement for concrete encasement of conduit in DSM Section: 260543 3.1 B may be waived.

For any portion of the system owned, operated, or maintained by the airport, or that directly connects to any airport system, including the entire path from the point of utility service to the main panel, the airport design standards shall also apply.

End of Chapter

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Chapter 7 - Gate Services

7.0 Gate Services

7.0.1 Scope

This chapter describes the specific requirements related to gate services to be included in the overall electrical system designs and specifications for the issuance of construction documents suitable for bidding and permitting. These designs and specifications shall include the necessary electrical design for all gate service equipment, as described below.

7.0.2 Criteria

Designs for gate services shall meet all applicable electrical requirements contained in this Electrical DSM, including those criteria referenced in other chapters.

7.0.3 Abbreviations and Definitions

Table 7-1: Gate Services Abbreviations

Term	Abbreviations	Definition
Fixed Walkway		An enclosed, fixed connector that extends from an airport concourse gate to a loading bridge for allowing passengers aircraft/concourse access without direct exposure to the elements.
Ground power unit	GPU	A self-contained unit that supplies power to aircraft while they are parked in a gate.
Passenger Loading Bridge	PLB	An enclosed, movable connector that extends from an airport concourse gate or fixed walkway to an aircraft allowing passengers aircraft/concourse access without direct exposure to the elements.
Pre-conditioned air	PCA	
Potable water cabinet	PWC	
Ground service equipment	GSE	A general term to describe ground-based (fixed or portable) equipment designed to support an aircraft while parked at a gate or elsewhere.

7.0.4 General Requirements

The DEN commercial airline concourse buildings serve a diverse aircraft mix from many airline carriers. In general, services at each gate are sized based on that gate's expected aircraft mix. When new gates are constructed, careful consideration must be taken of the following factors when selecting gate service equipment:

A. At a minimum, all GSE specified at each new gate must be able to support all the aircraft types that the prospective carrier plans to utilize at the gate at the time of design/construction.

B. When a new gate is physically capable of supporting larger aircraft, but the carrier is not planning to use it as such, the design shall take into consideration the larger aircraft that may be utilized, either by the carrier

or other carriers in the future and provide spare capacity on GSE to support these aircraft where practicable.

C. When spare capacity (for larger aircraft, for example) is designed into the system, it shall be described in the design analysis report (DAR). Include in the DAR reasoning for the design choice implications for future gate work (for example, limitations of the electrical service for supporting additional gates), implications for future tenants, and construction cost implications.

7.1 Gate Electrical Components

7.1.1 Electrical Service

Each gate shall be provided with a 277/480-Volt, 3-Phase, 4-Wire distribution panelboard dedicated to that gate and associated GSE. In general, 277/480V gate panelboards are rated between 400A and 800A. The Designer shall select a panelboard size that is appropriate for the expected loads at the gate. All panelboards shall meet the spare capacity requirements outlined in Chapter 2- Interior Electrical Power Distribution Systems. Gate panelboard ratings shall not be less than the total demand load of the panelboard plus applicable spare capacity requirements. Sizing of upstream distribution equipment serving multiple gates may incorporate a diversity factor of 60% for GSE, subject to approval by the Authority Having Jurisdiction.

Each gate shall be provided with a 480-120/208V, 3-phase delta-wye step-down transformer and 120/208V, 3-phase, 4-wire panelboard to serve 120/208V loads at the gate. In general, transformers are less than 75 KVA. The sizing of the transformer and panelboard shall be selected by the Designer. The minimum transformer size shall be 15 kVA.

The 277/480V gate panelboard shall be fed from a distribution panel. Provide electrical submetering in accordance with this Manual for all feeder breakers. Refer to Chapter 2- Interior Electrical Power Distribution Systems for additional information regarding submetering.

Refer to Chapter 2- Interior Electrical Power Distribution Systems for panelboard naming conventions.

7.1.2 Passenger Loading Bridge

Each jet bridge shall be provided with electrical power from the gate electrical panel. The passenger loading bridge itself is typically provided as a manufactured unit by the supplier and, as such, will have a single point of connection. It is the Designer's responsibility to coordinate with the supplier to determine exact electrical connection requirements and wiring details.

The passenger loading bridge typically includes a set of drive wheels controlled from a driver station in the bridge. The wheels are driven by electric motors. The wheel assembly also includes a raise/lowering mechanism to adjust the height of the bridge to match the aircraft boarding door. General lighting is provided within the bridge. These systems often require both 480-volt, 3-phase power (for drive wheels and height adjustment) and 120-volt, single-phase power (for the lighting and controls). Typically, a controller box is provided at the base of the passenger loading bridge with a single-point input connection, which includes several internal circuit breakers and transformers to serve bridge systems. It is the Designer's responsibility to ensure that their design includes all components required such that the bridge and any connection points supplied by the bridge manufacturer can be connected as needed. Include connections to and within controller boxes as required.

While exact installation details vary, the passenger loading bridge controller box may include ancillary power connections to other gate service equipment, such as the GPU or PCA. Equipment will typically be powered by separate incoming feeders with a circuit breaker in the controller box for local disconnecting means of each piece of equipment. Units are often specified to be installed directly onto the passenger loading bridge. In all future Passenger Loading Bridges (PLBs), the Electric Power Conductors shall be attached to and associated with the PLB by means of a "Pantograph" mechanism as is used in the newer existing PLBs. Existing PLBs with Service Transport Units (STU) shall be retrofitted to Pantograph as required. The Designer must coordinate with the design team, including the Mechanical Designer, to determine equipment installation locations and requirements.

Passenger-loading bridges are provided with auto-leveling systems. The auto-leveling system shall be supplied with an alarm circuit to indicate if the system is out of order or not functioning properly. This local alarm shall sound at the end of the bridge to indicate system trouble. The consultant shall specify an additional remote alarm to be installed and connected in parallel with the local alarm. This remote alarm shall consist of a flush-mounted, vibrating horn device installed just inside the concourse building above the passenger loading bridge door.

Passenger loading bridges shall be provided with LED lighting for normal and emergency lighting, including exit signage directing passengers to the path of egress. A single lighting circuit shall be used for all interior lighting. Refer to Chapter 5- Lighting Systems for emergency lighting requirements.

7.1.3 Ground Power Unit

The ground power unit (GPU) is the main point of the electrical connection for parked aircraft. This unit supplies the aircraft with 115/200-volt, 3-phase, 400-Hz AC electrical power, as well as 28.5-Volt DC electrical power when needed.

A typical GPU is a solid-state frequency converter unit with an output rating ranging from 45 to 180 kVA. Larger aircraft may sometimes require multiple GPUs; typically, one GPU is provided per passenger loading bridge.

The GPU may be supplied with the passenger loading bridge and selected by others, but it is the Designer's responsibility to coordinate the sizing of this unit and ensure that the corresponding electrical service is provided.

Actual equipment sizing shall be coordinated on a per-project and per-gate basis. Contact the DEN Project Manager to discuss equipment sizing and limitations for each project.

7.1.4 Pre-Conditioned Air Unit

The Pre-conditioned air unit (PCA) supplies conditioned air to the aircraft interior while it is parked. DEN uses a mix of both hydronic and Dx PCA units. Refer to the Gate Services chapter in the Mechanical DSM for additional information.

The Electrical Designer shall ensure that adequate electrical power is provided to operate this unit. Coordination with the Mechanical Consultant is necessary to ensure that all electrical loads within the PCA (heating, cooling, and accessories) are accounted for.

7.1.5 Potable Water Cabinet

The potable water cabinet (PWC) supplies potable water to the aircraft while it is parked.

The Electrical Designer shall ensure that adequate electrical power is provided to the PWC to operate internal heating elements, heat trace, and any other associated electrical loads. Refer to the Gate Services chapter in the Mechanical DSM for additional information.

7.1.6 Miscellaneous

The Designer shall provide adequate convenience power (weatherproof, GFCI receptacles) around the vicinity of the gate, installed on the exterior wall of the concourse building. Coordinate additional carrier-specific equipment and convenience power requirements with the DEN Project Manager.

7.2 Design Considerations

The Designer shall ensure that all apron areas around gates are adequately illuminated. The primary method of illuminating the apron is via pole-mounted floodlights installed on the roof of the concourse building. Supplemental lighting may be required in areas where obstructions, such as fixed walkways, reduce the lighting to an unsafe level. All apron lighting shall be controlled via an astronomical time clock with photocell-based controls as a backup, to be turned on at dusk and off at dawn.

Where possible, install gate service panels indoors to reduce equipment cost (NEMA 1 versus NEMA 3R) and maintenance issues. Install on the inside wall of the apron level adjacent to the passenger loading bridge. If an

appropriate area indoors is not available for panel installation, install panels outdoors and provide NEMA 3R equipment.

When designing electrical distribution for new gates, ensure that the upstream distribution is ultimately fed from the nearest core or subcore. Fire department personnel must be able to disconnect all electrical service in and around the building from the main disconnects associated with that area.

Coordinate emergency fuel shutoff (EFSO) requirements with the DEN Project Manager. Refer to the Life Safety DSM for all fire detection and alarm system descriptions and requirements.

End of Chapter

Chapter 8 - Electric Vehicle Charging Stations

8.0 Electric Vehicle Charging Stations

8.0.1 Scope

This chapter describes the specific requirements related to electric vehicle charging stations to be included in the overall electrical system designs and specifications for the issuance of construction documents suitable for bidding and permitting. These designs and specifications shall include the necessary electrical design for all Electric Vehicle Charging Stations, as described below.

8.0.2 Criteria

Designs for Electric Vehicle Charging Stations shall meet all applicable electrical requirements contained in this Electrical DSM, including those criteria referenced in other chapters. These standards are developed, in part, from publications of the latest edition of the following codes, standards, and guides:

A. NFPA 70 (National Electric Code), Article 625: Electric Vehicle Charging System
B. SAE J1772: North American Standard for Electric Vehicle and Plug-in Hybrid Electric Vehicle Conductive Charge Coupler
C. SAE J2293: Energy Transfer System for Electric Vehicles
D. UL Standard 2202: EV Charging System Equipment
E. UL Standard 2251: Plugs, Receptacles, and couplers for Electric Vehicles

8.0.3 Abbreviations and Definitions

Table 8-1: Electric Vehicle Charging Station Definitions

Term	Abbreviation	Definition
Electric Vehicle	EV	Any vehicle that is either a BEV or a PHEV.
Electric Vehicle Supply Equipment	EVSE	Self-contained equipment designed to recharge EVs.
Plug-in, Battery-only Electric Vehicle	BEV	Any vehicle that runs on an electric motor that is powered by batteries and needs an external electrical source to charge.
Plug-in Hybrid Electric Vehicle	PHEV	Any hybrid vehicle that has on-board batteries that can be charged from an external electrical source.
EV Charging Station		A permanently fixed-in-place EVSE supplied by the nearest building electric power distribution system, provided with a charge cord and connector

8.0.3.1 Charge Methods

The charge methods for EVSE installed at DEN shall conform with SAE J1772 or other industry standards where approved by the DEN Project Manager.

8.1 Design Requirements

8.1.1 General

DEN currently has both level one and level two electric vehicle-charging stations located in the east and west parking garages and employee lots. As demand increases, DEN will continue to expand the number of charging stations throughout the airport.

For each parking facility or as dictated by the project requirements, the designer shall provide EV Charging Stations in several parking spaces in proportion with the expected demand. In general, personal vehicle parking facilities shall be equipped with either AC Level 1 or AC Level 2 charging stations.

8.1.2 Passenger Parking Facilities

Passenger parking facilities shall be provided with EV Charging Stations. The quantity of stations shall be selected based on project requirements, with a baseline goal to provide stations in 2% of the total quantity of parking spaces to meet the requirements of LEED v4, Location and Transportation – Green Vehicles Credit.

8.1.3 Employee Parking Facilities

Employee parking facilities shall be provided with EV Charging Stations. Quantity of stations shall be selected based on project requirements, with a baseline goal to provide charging stations in 2% of the total quantity of parking spaces to meet the requirements of LEED v4, Location and Transportation – Green Vehicles Credit.

8.1.4 Electrical Service

Where more than three charging stations are being installed in a single location, provide a dedicated branch circuit panel to serve charging stations. Where the building's electrical distribution system voltage is 480-Volts, provide a step-down transformer as necessary to serve the charging stations. Provide sufficient electrical capacity to serve all stations, including future equipment, plus an additional 25% spare capacity. Provide sufficient breaker space in the branch circuit panel to serve all planned and future stations, plus 25% spare. Load calculations to include a 125 percent demand factor as required by NEC. Available fault currents must be calculated and limited to fall within the fault current rating of the EV charging stations.

A separate service may be required where the new load exceeds the capacity of the building or structure. Coordinate large load additions with DEN PM and Sustainability.

8.1.5 EV Charging Station Equipment

Charging Stations installed in groups shall be specified to be supplied from a single manufacturer, and all grouped equipment shall share the same charge method. In cases where new charging stations are to be installed adjacent to existing ones, provide equipment from the same manufacturer and of the same of similar model.

8.1.5.1 Mounting

Charging stations may be bollard or wall-mounted. Bollard-mount charging stations are preferred.

A. Bollard or pedestal-mount is the preferred mounting method. Pedestal-mount charging stations shall be provided with built-in support means suitable for installation on a concrete base installed at grade level. The designer shall include all concrete work necessary for installation.
B. Wall mounts are to be specified only where pedestal mounting is impractical and where approved by the DEN Project manager. When grouped with pedestal-mounted charging stations, match the height of charge connectors while docked.

8.1.6 Protection

Charging stations are subject to vehicle damage. Provide protective bollards for each charging station, arranged to ensure the equipment is protected from all sides from vehicle impacts. The designer shall coordinate the type of bollard and bollard location with the DEN Project Manager.

8.1.7 Miscellaneous

Where new electrical distribution equipment is added, comply with metering requirement of Chapter 2- Interior Electrical Power Distribution Systems.

8.1.8 Tenant Installations

Tenants shall coordinate EV charging requirements with DEN, DFD, and the local utility before installation. DEN may limit the available power requested to the area or site depending on the number of future projects in the area and/or the available power on the feeder that serves that site. DFD may limit areas and/or locations of EV charging stations.

8.2 Parking Considerations

8.2.1 Signage and Pavement Markings

The designer must ensure all new charging station parking areas are properly marked for the designation of Electric Vehicle parking only, with spaces numbered sequentially. This includes both signage and pavement markings in each parking spot designated specifically for Electric Vehicle parking only.

8.2.2 Charging Station Location

Locate charging stations in a preferred location within the parking area, such as close in to the building, or nearest to the point of entry/pickup to the parking facility. These locations are typically adjacent to handicap spaces. EV charging stations shall not be located in the basement and/or underground tunnel areas of the airport.

8.2.3 Fees and Usage Limitations

As a benefit to passengers and employees, DEN Parking currently does not charge a fee for the use of EV charging stations. Usage of parking spaces containing charging stations in both employee lots and public parking facilities is limited only to BEVs and PHEVs which are capable of being recharged using the standard SAE J1772 connector. All other vehicles are subject to towing.

End of Chapter

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Chapter 9 - Technical Specification Requirements

9.0 General

Designers are required to provide project specifications on all DEN projects in accordance with the Standards and Criteria DSM, Chapter 11. The project specifications should encompass all aspects of the project and be based on industry-standard construction methods and products, with content based on the DEN Standard Specifications (where available) or from an industry-standard guide specification.

9.0.1 How to Use This Chapter

9.0.1.1 DEN Standard Specifications

The DEN Standard Specifications listed in this chapter have been developed to ensure project consistency and compliance with DEN policy and procedure. For sections available as DEN Standard Specifications, the designer must obtain and use these sections for their project.

9.0.1.2 DEN Technical Requirements

This chapter, as well as similar chapters in other DSMs, provides DEN-specific requirements that must be included in nonstandard specifications for all DEN projects. An itemized list of DEN-specific technical specification requirements is provided, which may include general requirements, product requirements, and execution requirements. The designer shall incorporate these requirements into their project specification content as appropriate for the project scope. Requirements are provided in an outline format similar to construction specifications for ease of incorporation. Content may be copied directly from this chapter, with article/paragraph numbering and structure modifications as needed to ensure a cohesive document.

Note: This chapter is intended to be used as an aid to the development of a project specification and ***is not intended to represent a complete specification as presented.***

The designer is responsible for developing a complete specification, incorporating the requirements of this chapter, which encompasses all aspects of the project and complies with general specification requirements outlined in the Standards & Criteria DSM, Chapter 11. After incorporating the requirements listed herein, the project specification should be reviewed to ensure it is free of redundant and/or conflicting information.

9.0.1.3 Notes to the Designer

Notes to the designer are included throughout the chapter, shown in red highlighted text. These are provided for guidance and clarification of requirements and are intended for use only by the designer in development of their specification.

Notes to the designer shall not be incorporated into the final project specifications.

9.0.2 Specification Numbering

9.0.2.1 Numbering of Deliverables

Project deliverables should utilize Section names and numbers contained in the latest edition of *MasterFormat Numbers & Titles* at the time of project kickoff, which may vary from those in this chapter. It is the designer's responsibility to ensure that all applicable DEN requirements are reflected accurately in the appropriate sections of the project specifications.

9.0.2.2 Numbering Provided in This Chapter

Specification section names and numbers provided in this chapter are based on *MasterFormat Numbers & Titles*, 2014 edition.

9.0.2.3 Product and Manufacturer Listings

Where manufacturers and products are listed in this chapter, they represent approved manufacturers and/or products. Do not include additional manufacturers and/or products for that Article or paragraph without written permission from the DEN Project Manager.

For sections without manufacturer and/or products listed in this chapter, the designer shall select a basis of design based on current industry standards which comply with all applicable requirements in this and other DEN DSMs, the DEN Standard Specifications, and the Denver Building Code. Provide at least (2) acceptable alternatives to the basis of design for all products, for a total of (3) or more acceptable products, except where a sole-source selection has been approved in writing by the DEN Project Manager.

9.1 DEN Standard Electrical Specifications

Refer to Table 9-1: DEN Standard Specifications – Division 26: Electrical for a listing of DEN standard electrical specification sections. The following Sections must be obtained from the DEN Project Manager for use in the project.

Table 9-1: DEN Standard Specifications – Division 26: Electrical

Section No.	Section Title
263544	Aircraft Ground Power Units
265650	Exterior Lighting – Airside

9.2 DEN Technical Requirements – Division 26: Electrical

Except where directed by designer notes, add the following requirements to all project specification sections. Where there are similar or matching specification section names, include all content below in addition to the content in the generic specifications. The content below may be omitted where related equipment, mechanical systems, and furnishments are not in the project scope.

Section 260400: Basic Electrical Requirements

PART 1 GENERAL

1.01 DEFINITIONS

A. Terminal Complex refers to the Main Terminal (Great Hall), Concourses, Central Utility Plant (CUP), Hotel, and the Transportation Center.

1.02 SUMMARY

A. Where a panel is installed, at least 25% of panel capacity, accounting for serving panel capacity, shall remain as spare capacity after project completion.

B. Where existing panels are used for additional work, when six (6) or less spaces remain a new panel shall be installed.

C. All electrical/electronic circuits, including audio, video, and fire alarm systems, shall be in an approved raceway system. No “wild circuits” will be accepted.

D. The Designer of Record shall not design or specify and the Contractor shall not install rigid metal conduit, electrical metallic tubing, flexible steel conduit, liquid-tight flexible steel conduit, non-metallic rigid conduit or innerduct in any horizontal or vertical concrete wall or slab structures or portions thereof, e.g., cast-in-place concrete floor slab on steel decking; cast-in-place concrete

slabs integral with concrete structural support systems; prestressed concrete slabs; post-tensioned concrete slabs; precast concrete construction with or without field applied or plant fabricated concrete topping slabs, slabs on grade, foundation walls or in concrete cast-in-place walls, etc.

E. Excessive use of wire nuts is prohibited. All efforts must be made to install electrical circuits continuous and in a neat arrangement.

1.03 COORDINATION

A. Prior to fabrication or installation of any electrical work, participate in detailed coordination planning meetings with all other building utilities system trades, under the direction of the General Contractor, so as to completely establish routings, elevations, space requirements, and coordination of access, layout, and suspension requirements in relationship to the building structure and the work of all other trades.

B. Any electrical work penetrating concrete walls or floors shall require saw cutting and/or core drilling and shall require approval by the DEN Project Manager. The Contractor shall perform all necessary imaging (x-rays, etc.) as specified, and submit shop drawings of any saw cutting or core drilling to the DEN Project Manager prior to performing the Work. Refer to Section 017330 “Cutting and Patching” for additional requirements.

C. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.

1.04 COORDINATION DRAWINGS

A. Where the Contractor modifies the design, through selection of equipment differing from that shown, coordination drawings shall be provided by the Contractor in accordance with Division 1 to a scale of 1/4"=1'0" or larger for equipment rooms, details, congested areas and sections; other plans at a scale of 1/8"=1'0". These drawings are to detail major elements, components, and systems of electrical equipment and materials in relationship with other systems, installations, and building components.

B. Coordination drawings shall be in accordance with current DEN standards for format, and as outlined in Division 1.

C. The Contractor shall indicate locations where space is limited for installation and access and where sequencing and coordination of installations are of importance to the efficient flow of the Work, including (but not necessarily limited to) the following:

1. Indicate the proposed locations of raceway systems, equipment, and materials. Include the following:
    a. Clearances for servicing equipment, including space for equipment disassembly required for periodic maintenance.
    b. Exterior wall and foundation penetrations.
    c. Fire-rated wall and floor penetrations.
    d. Equipment connections and support details.
    e. Sizes and location of required concrete pads and bases.
    f. Support details.
2. Indicate scheduling, sequencing, movement, and positioning of large equipment into the building during construction.
3. Floor plans, elevations, and appropriate details are required to indicate penetrations in floors, walls, and ceilings and their relationship to other penetrations and installations.

1.05 ENVIRONMENTAL CONDITIONS

A. The equipment shall be designed and constructed to operate successfully at the rated values under the following environmental conditions:

Use below values as applicable.

1. Altitude: 5,500 feet above sea level.
2. Ambient Temperature Range: Minus 30 deg F to 104 deg F.
3. Wind Load: 120 mph with gust factor of 1.3.
4. Relative humidity: 95% non-condensing.

Section 260505: Selective Demolition for Electrical

PART 1 GENERAL

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 PROCEDURES

A. No area; new, remodeled, or existing shall be without a fully operational electrical system, except for scheduled outages.

B. The contractor shall remove, relocate, or replace any electrical equipment or systems as required for installation of any structural, mechanical, or plumbing equipment.

C. Maintain all existing electrical, control, communication, and signaling systems to the extent required by the owner.

D. Where remodel or demolition interferes with circuits outside of the work area, schedule outages to rework the circuits as required.

E. All items, including but not limited to equipment, devices, circuits, and conduits, that are removed and not designated by the Project Manager to be used or turned over to the owner shall be removed from the airport.

Section 260510: Testing, Acceptances and Certification

PART 1 GENERAL

1.01 SUBMITTALS

A. Power cable high potential test reports:

1. Insulation resistance tests.
2. Continuity tests.

B. Transformer test reports to include where applicable:

1. Transformer turns ratio.
2. Winding resistance.
3. Insulation power factor.
4. K Factor.

C. All electrical/electronic equipment and systems functional test report.

D. All other reports required by individual specification sections.

E. Generator load bank test report.

F. Transfer Switch test report.

G. Load balance report for each switch board, panel board and switch gear.

PART 2 PRODUCTS

2.01 GENERAL REQUIREMENTS

A. The electrical and mechanical equipment shall be completely tested in the field in the presence of DEN Inspectors in accordance with good and accepted industry engineering practices to assure that:

1. The equipment has not been damaged during manufacturing, shipping, or installation.
2. The equipment has been installed according to the requirements Contract Documents.
3. The equipment meets the requirements of the Contract Documents.

2.02 CONDUCTOR INSULATION TEST

A. Prior to energizing, all building service cables feeders to and/or from transformers, switchboards, panel boards are to be tested with a 1000-volt insulation megohm meter to determine insulation resistance levels. Test cables rated for three hundred volt with a 500-volt megohm meter or as recommended by the manufacturer. All field test data is to be recorded, corrected to a baseline temperature, and furnished to the DEN Project Manager. A test is to include meggering between conductors and between each conductor and ground. Cables are to be meggered after installation with cables disconnected at both ends. Insulation test values shall meet or exceed the values given below:

Conductor Size (AWG or KCMIL)	**Resistance** (Megaohms - 1,000 ft.)
12-8	200
6-2/0	100
3/0-750	100

Designer to include any relevant testing requirements for existing equipment impacted by the project.

2.03 EXISTING EQUIPMENT TESTING

A. Existing equipment impacted by the project shall be evaluated and tested in the field in the presence of DEN inspectors to ensure that:

1. The equipment is in good working order.
2. The equipment has not been damaged during construction.
3. The equipment as installed meets current code requirements where updates are required due to work in the area.

PART 3 EXECUTION

3.01 GENERAL

A. If the Contractor finds during the testing that any piece of equipment failed to satisfactorily pass the required field test, the DEN Project Manager shall be promptly notified and the Contractor shall take the necessary actions for the prompt repair of replacement.

3.02 TESTING

A. The Contractor shall allow only certified personnel to perform the testing.

B. The Contractor shall perform the testing using all necessary safety precautions and proper test equipment.

C. The Contractor shall notify the DEN Project Manager three (3) days in advance of the proposed testing dates.

D. Witness of testing by DEN Inspector, Electrical Maintenance and Electrical Inspector.

Section 260513: Medium-Voltage Cables

PART 1 GENERAL

1.01 SUMMARY

A. Section includes cables and related cable splices, terminations, and accessories for medium-voltage (2001 to 35,000 V) electrical distribution systems.

PART 2 PRODUCTS

2.01 CABLES

A. Conductor: Copper

2.02 SOLID TERMINATIONS

A. Nonshielded-Cable Terminations: Kit with compression-type connector. Include silicone-rubber tape, cold-shrink-rubber sleeve, or heat-shrink plastic-sleeve moisture seal for end of insulation whether or not supplied with kits.

2.03 SEPARABLE INSULATED CONNECTORS

A. Dead-Break Cable Terminators: Elbow-type unit with 600-A continuous-current rating; designed for de-energized disconnecting and connecting; coordinated with insulation diameter, conductor size, and material of cable being terminated. Include test point on terminator body that is capacitance coupled.

PART 3 EXECUTION

3.01 INSTALLATION

A. Determine routing to avoid interference with other work.

B. Place an equal number of conductors for each phase in the same raceway.

C. Neatly train and lace wiring inside boxes, equipment, and panel boards. Make temporary connections to panel board devices with sufficient slack conductor to facilitate reconnections required for balancing loads between phases.

D. All building wire and cable shall be installed in an approved raceway.

E. All buried conduits containing medium-voltage cabling shall be installed in concrete encased duct banks.

1. Conductors shall not be pulled in concrete encased conduits before concrete is placed.

F. Arc Proofing: Unless otherwise indicated, arc proof medium-voltage cable at locations not protected by conduit, cable tray, direct burial, or termination materials. In addition to arc-proofing tape manufacturer's written instructions, apply arc proofing as follows:

1. Band arc-proofing tape with 1-inch- wide bands of half-lapped, adhesive, glass-cloth tape 2 inches o.c.

G. A full-size neutral conductor shall be provided for each single-phase circuit.

Section 260519: Low-Voltage Electrical Power Conductors and Cables

PART 1 GENERAL

1.01 DEFINITIONS:

A. Concessions tenant- A retail establishment, not an airline, that leases space at the airport.

PART 2 PRODUCTS

2.01 CONDUCTORS AND CABLES

A. All conductors shall be copper.

B. AC cable and Modular wiring are not permitted.

C. MC Cable: Comply with NEMA WC 70. Provide internal equipment grounding conductor throughout. Can only be used as noted in EXECUTION section of this specification.

D. Remote Control and Signal Cable

1. Control Cable for Class 1 Remote Control and Signal Circuits: Copper conductor, 600 volt insulation, rated at 60 deg C, individual conductors twisted together, shielded, and covered with a PVC jacket.
2. Control Cable for Class 2 or Class 3 Remote Control and Signal Circuits: Copper conductor, individual conductors twisted together, shielded, and covered with a PVC jacket; UL listed.

PART 3 EXECUTION

3.01 CONDUCTOR MATERIAL APPLICATIONS

A. Feeders: Copper. Solid for No. 12 AWG and smaller; stranded for No. 10 AWG and larger.

B. Branch Circuits: Copper. Solid for No. 12 AWG and smaller; stranded for No. 10 AWG and larger, except for connection to vibrating equipment then stranded shall be used.

C. Prohibited Cable Types: UF, NM, SE, AC.

3.02 CONDUCTOR INSULATION AND MULTICONDUCTOR CABLE APPLICATIONS AND WIRING METHODS

A. Service Entrance: Type XHHW, single conductors in raceway.

B. Exposed Feeders: Type THHN-THWN, single conductors in raceway.

C. Feeders Concealed in Ceilings, Walls, Partitions, and Crawlspaces: Type THHN-THWN, single conductors in raceway.

D. Feeders below Slabs-on-Grade, and Underground: Type THHN-THWN, single conductors in raceway.

E. Feeders Installed below Raised Flooring: Type THHN-THWN, single conductors in raceway.

F. Exposed Branch Circuits, Including in Crawlspaces: Type THHN-THWN, single conductors in raceway.

G. Branch Circuits Concealed in Ceilings, Walls, and Partitions: Type THHN-THWN, single conductors in raceway.

H. Branch Circuits Concealed in Concrete, below Slabs-on-Grade, and Underground: Type THHN-THWN, single conductors in raceway.

I. Branch Circuits Installed below Raised Flooring: Type THHN-THWN, single conductors in raceway.

J. Branch Circuits in Cable Tray: Type THHN-THWN, single conductors in raceway.

K. Class 1 Remote Control and Signal Circuits: Type THHN-THWN, in raceway or cable tray as applicable, or Copper conductor, 600 volt insulation, individual conductors twisted together, shielded, and covered with a PVC jacket.

L. Class 2 Remote Control and Signal Circuits: Type THHN-THWN, in raceway or cable tray as applicable, or Copper conductor, individual conductors twisted together, shielded, and covered with a PVC jacket; UL listed.

M. All power, control, data, communication and signal wire or cable shall be installed in an approved raceway.

N. MC Cable: Only allowed under the following conditions:

1. Light fixture whips when prewired at the factory.
2. Concession Tenant installations
   No other uses of MC cable are allowed unless authorization is obtained in advance from DEN project manager. Cable shall be run concealed in all locations. Where circuiting must be exposed, provide single conductor building wire in approved raceway. MC cable shall be supported using approved methods throughout. Do not run cables unsupported in any area including above accessible ceilings, in unfinished area, etc.

3.03 INSTALLATION OF CONDUCTORS

A. All power, control, data, communication, and signal wire or cable shall be installed in an approved raceway (raceway shall be defined as conduit or cable tray as applicable).

B. Install exposed cables parallel and perpendicular to surfaces of exposed structural members and follow surface contours where possible.

C. Neatly train wiring inside boxes, equipment, and panel boards. Make temporary connections to panel board devices with sufficient slack conductor to facilitate reconnections required for balancing loads between phases.

D. Conductors shall not be pulled in concrete encased conduits before concrete is placed.

1. Conduits encased in concrete are not allowed unless prior authorization is received from DEN project manager.

E. For connection to vibrating equipment, stranded wire shall be used.

F. All conduits to be new. Existing conduits shall not be used unless approved by the DEN Project Manager.

G. Where harmonic currents exist on feeders that supply panelboards that serve electronic equipment of 40 percent or more of the panelboards total ampacity, two (2) full size neutral conductors or a neutral conductor rated at 200 percent shall be provided to the panelboard being served. A neutral bus bar rated at 200 percent shall also be provided in the panelboard.

H. Shared Neutrals: Prohibited. A full-size neutral conductor shall be provided for each single-phase circuit.

3.04 CONNECTIONS

A. Splice only in accessible junction and outlet boxes.

B. Wiring at Outlets: Install conductor at each outlet, with at least 6 inches of slack.

3.05 IDENTIFICATION

A. Identify and color-code conductors and cables according to Section 260553 “Identification for Electrical Systems.”

B. Identify each spare conductor at each end with identity number and location of other end of conductor and identify as spare conductor.

3.06 FIELD QUALITY CONTROL

A. Perform tests and inspections and prepare test reports.

1. Field inspection and testing will be performed under provisions of Division 01.
2. After installing conductors and cables and before electrical circuitry has been energized, test service entrance and feeder conductors, and conductors feeding the following critical equipment and services for compliance with requirements.
   a. Prior to energizing, all building service cables, feeders to and/or from transformers, switchboards and panel boards are to be tested with a 500-volt insulation megohm meter to determine insulation resistance levels. All field test data is to be recorded, corrected to

a baseline temperature, and furnished to the DEN Project Manager. A test is to include meggering for one minute between conductors and between each conductor and ground. Cables are to be meggered after installation with cables disconnected at both ends. Insulation test values shall meet or exceed the values given below.

Conductor Size (AWG or KCMIL):	Resistance (Megaohms-1,000ft):
12-8	**200**
6-2/0	100
3/0-750	100

3. Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each splice in cables and conductors No. 3 AWG and larger. Remove box and equipment covers so splices are accessible to portable scanner.
   a. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each splice eleven (11) months after date of Substantial Completion.
   b. Instrument: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
   c. Record of Infrared Scanning: Prepare a certified report that identifies splices checked and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.
4. Inspect wire and cable for physical damage and proper connection.

B. Test and Inspection Reports: Prepare a written report to record the following:
1. Test procedures used.
   a. Test results that comply with requirements.
   b. Test results that do not comply with requirements and corrective action taken to achieve compliance with requirements.

C. Remove and replace malfunctioning units and retest as specified above.

Section 260523: Control-Voltage Electrical Power Cables

PART 1 GENERAL

1.01 QUALITY ASSURANCE

A. Testing Agency Qualifications: Member company of an NRTL.
1. Testing Agency's Field Supervisor: Currently certified by BICSI as an RCDD to supervise on-site testing.

B. Surface-Burning Characteristics: As determined by testing identical products according to ASTM E 84 by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
1. Flame-Spread Index: 25 or less.
2. Smoke-Developed Index: (Depending on location 50 or 450) or less.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

1.02 DELIVERY, STORAGE, AND HANDLING

A. Test cables upon receipt at Project site.
1. Test optical fiber cable to determine the continuity of the strand end to end. Use optical fiber flashlight or optical loss test set.

2. Test optical fiber cable on reels. Use an optical time domain reflectometer to verify the cable length and locate cable defects, splices, and connector; include the loss value of each. Retain test data and include the record in maintenance data.
3. Test each pair of cable for open and short circuits.

1.03 PROJECT CONDITIONS

A. Environmental Limitations: Do not deliver or install cables and connecting materials until wet work in spaces is complete and dry, and temporary HVAC system is operating and maintaining ambient temperature and humidity conditions at occupancy levels during the remainder of the construction period.

PART 2 PRODUCTS

2.01 PATHWAYS

A. Support of Open Cabling: NRTL labeled for support of (Category 5e or Category 6 per design) cabling, designed to prevent degradation of cable performance and pinch points that could damage cable.

1. Support brackets with cable tie slots for fastening cable ties to brackets.
2. Lacing bars, spools, J-hooks, and D-rings.
3. Straps and other devices.

B. Cable Trays:

1. Cable Tray Materials: Metal, suitable for indoors and protected against corrosion by electroplated zinc galvanizing, complying with ASTM B 633, Type 1, not less than 0.000472 inch thick or hot-dip galvanizing, complying with ASTM A 123/A 123M, Grade 0.55, not less than 0.002165 inch thick.

C. Conduit and Boxes: Comply with requirements in Division 26 Section “Raceway and Boxes for Electrical Systems.” Flexible metal conduit shall not be used.

1. Outlet boxes shall be no smaller than 2 inches wide, 3 inches high, and 2-1/2 inches deep.

2.02 RS-485 BACNET MS/TP DATA TRANSMISSION CABLE

A. Subject to compliance with requirements, provide products by one of the following:

1. Southwire
2. Windy City Wire: WCW-22/3BLU-WC
3. Or approved equal

B. Description: UL Listed C(UL) US CMP or FPLP (UL).

1. Shielded, Plenum-rated
2. (3) 22AWG insulated conductors with 24AWG bare copper drain
3. Overall jacket color: Blue
4. Conductor colors: Black/White/Blue
5. Marking: “POWER METERING CONTROL SYSTEM”

PART 3 EXECUTION

3.01 INSTALLATION OF PATHWAYS

A. Cable Trays: Comply with NEMA VE 2 and TIA/EIA-569-A-7.

B. Comply with TIA/EIA-569-A for pull-box sizing and length of conduit and number of bends between pull points.

C. Install manufactured conduit sweeps and long-radius elbows if possible.

D. Pathway Installation in Equipment Rooms:

1. Position conduit ends adjacent to a corner on backboard if a single piece of plywood is installed or in the corner of room if multiple sheets of plywood are installed around perimeter walls of room.
2. Install cable trays to route cables if conduits cannot be located in these positions.
3. Secure conduits to backboard if entering room from overhead.
4. Extend conduits 3 inches above finished floor.
5. Install metal conduits with grounding bushings and connect with grounding conductor to grounding system.

E. Backboards: Install backboards with 96-inch dimension vertical. Butt adjacent sheets tightly and form smooth gap-free corners and joints.

3.02 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Optical Fiber Cable Tests:
   a. Test instruments shall meet or exceed applicable requirements in TIA/EIA-568-B.1. Use only test cords and adapters that are qualified by test equipment manufacturer for channel or link test configuration.
   b. Link End-to-End Attenuation Tests:
      1. Multimode Link Measurements: Test at 850 or 1300 nm in one direction according to TIA/EIA-526-14-A, Method B, One Reference Jumper.
      2. Attenuation test results for links shall be less than 2.0 dB. Attenuation test results shall be less than that calculated according to equation in TIA/EIA-568-B.1.

Section 260526: Grounding and Bonding for Electrical Systems

PART 1 GENERAL

1.01 SYSTEM DESCRIPTION

A. External (underground) metal pipers, water, gas, fuel, drain/sewer etc., are not available for electrical grounding. This is due to extensive cathodic protection and isolation joints of all underground metal pipes at DEN. These systems shall be bonded to the grounding system on the building side only.

PART 2 PRODUCTS

2.01 CONDUCTORS

A. All ground wires shall be copper, sized according to the NEC or as shown on the drawings whichever is larger.

B. Insulated Conductors: Copper or tinned-copper wire or cable insulated for 600 V unless otherwise required by applicable Codes.

C. Bare Copper Conductors:

1. Bonding Cable: 28 kcmil, 14 strands of No. 17 AWG conductor, 1/4 inch in diameter.
2. Bonding Conductor: No. 4 or No. 6 AWG, stranded conductor.
3. Bonding Jumper: Copper tape, braided conductors terminated with copper ferrules; 1-5/8 inches wide and 1/16 inch thick.
4. Tinned Bonding Jumper: Tinned-copper tape, braided conductors terminated with copper ferrules; 1-5/8 inches wide and 1/16 inch thick.

D. Grounding Bus: Predrilled rectangular bars of annealed copper, 1/4 by 4 inches in cross section, with 9/32-inch holes spaced 1-1/8 inches apart. Stand-off insulators for mounting shall comply with UL 891 for use in switchboards, 600 V. Lexan or PVC, impulse tested at 5000 V.

2.02 CONNECTORS

A. Bolted Connectors for Conductors and Pipes: Copper or copper alloy, pressure type with at least two bolts.

1. Pipe Connectors: Clamp type, sized for pipe.

B. Welded Connectors: Exothermic-welding kits of types recommended by kit manufacturer for materials being joined and installation conditions. Exothermic welded connections are required where grounding conductors connect to underground grounding conductors and to underground grounding electrodes, and for bonding to steel. All underground connections shall be exothermic welded.

C. Bus-bar Connectors: Mechanical type, cast silicon bronze, solderless compression exothermic-type wire terminals, and long-barrel, two-bolt connection to ground bus bar.

D. Grounding Connection Accessories:

1. Electrical insulating tape, heat-shrinkable insulating tubing, welding materials, bonding straps, as recommended by accessories manufacturers for type of service required.

2.03 GROUNDING ELECTRODES

A. Ground Rods: Copper-clad; 3/4-inch diameter and a minimum length of 10 feet.

B. Ground Rods in manholes: Stainless steel; 3/4-inch diameter and a minimum length of 10 feet.

PART 3 EXECUTION

3.01 APPLICATIONS

A. Conductors: Install solid conductor for No. 12 AWG and smaller, and stranded conductors for No. 10 AWG and larger unless otherwise indicated.

B. Underground Grounding Conductors: Install bare copper conductor, No. 2/0 AWG minimum.

1. Bury at least 30 inchesbelow grade.
2. Duct-Bank Grounding Conductor: Bury 12 inches above duct bank when indicated as part of duct-bank installation.

C. Isolated Grounding Conductors: Green-colored insulation with continuous yellow stripe. On feeders with isolated ground, identify grounding conductor where visible to normal inspection, with alternating bands of green and yellow tape, with at least three bands of green and two bands of yellow.

D. Grounding Bus: Install in electrical and telephone equipment rooms, in rooms housing service equipment, and elsewhere as indicated.

1. Install bus on insulated spacers 2 inches minimum from wall, 6 inches above finished floor unless otherwise indicated.
2. Where indicated on both sides of doorways, route bus up to top of doorframe, across top of doorway, and down to specified height above floor; connect to horizontal bus.

E. Conductor Terminations and Connections:

1. Pipe and Equipment Grounding Conductor Terminations: Bolted connectors.
2. Underground Connections: Welded connectors except at test wells and as otherwise indicated.
3. Connections to Ground Rods at Test Wells: Bolted connectors.

4. Connections to Structural Steel: Welded connectors.

3.02 GROUNDING UNDERGROUND DISTRIBUTION SYSTEM COMPONENTS

A. Grounding Manholes and Handholes: Install a driven ground rod through manhole or handhole floor, close to wall, and set rod depth so 4 inches will extend above finished floor. If necessary, install ground rod before manhole is placed and provide No. 1/0 AWG bare, tinned-copper conductor from ground rod into manhole through a waterproof sleeve in manhole wall. Protect ground rods passing through concrete floor with a double wrapping of pressure-sensitive insulating tape or heat-shrunk insulating sleeve from 2 inches above to 6 inches below concrete. Seal floor opening with waterproof, non-shrink grout.

B. Grounding Connections to Manhole Components: Bond exposed-metal parts such as inserts, cable racks, pulling irons, ladders, and cable shields within each manhole or handhole, to ground rod or grounding conductor. Make connections with No. 4 AWG minimum, stranded, hard-drawn copper bonding conductor. Train conductors level or plumb around corners and fasten to manhole walls. Connect to cable armor and cable shields according to written instructions by manufacturer of splicing and termination kits.

C. Pad-Mounted Transformers and Switches: Install two ground rods and ground ring around the pad. Ground pad-mounted equipment and noncurrent-carrying metal items associated with substations by connecting them to underground cable and grounding electrodes. Install tinned-copper conductor not less than No. 2 AWG for ground ring and for taps to equipment grounding terminals. Bury ground ring not less than 6 inches from the foundation.

3.03 EQUIPMENT GROUNDING

A. Install insulated equipment grounding conductors with all feeders and branch circuits.

B. Install insulated equipment grounding conductors with the following items, in addition to those required by NFPA 70:

1. Feeders and branch circuits
2. Lighting circuits
3. Receptacle circuits
4. Single-phase motor and appliance branch circuits
5. Three-phase motor and appliance branch circuits
6. Flexible raceway runs
7. Metal-clad cable runs
8. Busway Supply Circuits: Install insulated equipment grounding conductor from grounding bus in the switchgear, switchboard, or distribution panel to equipment grounding bar terminal on busway.
9. Computer and Rack-Mounted Electronic Equipment Circuits: Install insulated equipment grounding conductor in branch-circuit runs from equipment-area power panels and power-distribution units.
10. X-Ray Equipment Circuits: Install insulated equipment grounding conductor in circuits supplying x-ray equipment.

C. Air-Duct Equipment Circuits: Install insulated equipment grounding conductor to duct-mounted electrical devices operating at 120 V and more, including air cleaners, heaters, dampers, humidifiers, and other duct electrical equipment.

D. Water Heater, Heat-Tracing, and Anti-frost Heating Cables: Install a separate insulated equipment grounding conductor to each electric water heater and heat-tracing cable. Bond conductor to heater units, piping, connected equipment, and components.

E. Isolated Grounding Receptacle Circuits: Install an insulated equipment grounding conductor connected to the receptacle grounding terminal. Isolate conductor from raceway and from

panelboard grounding terminals. Terminate at equipment grounding conductor terminal of the applicable derived system or service unless otherwise indicated.

F. Isolated Equipment Enclosure Circuits: For designated equipment supplied by a branch circuit or feeder, isolate equipment enclosure from supply circuit raceway with a nonmetallic raceway fitting listed for the purpose. Install fitting where raceway enters enclosure and install a separate insulated equipment grounding conductor. Isolate conductor from raceway and from panelboard grounding terminals. Terminate at equipment grounding conductor terminal of the applicable derived system or service unless otherwise indicated.

G. Signal and Communication Equipment: In addition to grounding and bonding required by NFPA 70, provide a separate grounding system complying with requirements in TIA/ATIS J-STD-607-A.

1. For telephone, alarm, voice and data, and other communication equipment, provide No. 4 AWG minimum insulated grounding conductor in raceway from grounding electrode system to each service location, terminal cabinet, wiring closet, and central equipment location.
2. Service and Central Equipment Locations and Wiring Closets: Terminate grounding conductor on a 1/4-by-4-by-12-inch grounding bus.
3. Terminal Cabinets: Terminate grounding conductor on cabinet grounding terminal.

H. Metal and Wood Poles Supporting Outdoor Lighting Fixtures: Install grounding electrode and a separate insulated equipment grounding conductor in addition to grounding conductor installed with branch-circuit conductors.

3.04 INSTALLATION

A. Grounding Conductors: Route along shortest and straightest paths possible unless otherwise indicated or required by Code. Avoid obstructing access or placing conductors where they may be subjected to strain, impact, or damage.

B. Ground Bonding Common with Lightning Protection System: Comply with NFPA 780 and UL 96 when interconnecting with lightning protection system. Bond electrical power system ground directly to lightning protection system grounding conductor at closest point to electrical service grounding electrode. Use bonding conductor sized same as system grounding electrode conductor and install in conduit.

C. Ground Rods: Drive rods until tops are 2 inches below finished floor or final grade unless otherwise indicated.

1. Interconnect ground rods with grounding electrode conductor below grade and as otherwise indicated. Make connections without exposing steel or damaging coating if any.
2. For grounding electrode system, install at least three (3) rods spaced at least one-rod length from each other and located at least the same distance from other grounding electrodes, and connect to the service grounding electrode conductor.

D. Test Wells: Ground rod driven through drilled hole in bottom of handhole. Handholes are specified in Section 260543 “Underground Ducts and Raceways for Electrical Systems” and shall be at least 12 inches deep, with cover.

1. Test Wells: Install at least one (1) test well for each service unless otherwise indicated. Install at the ground rod electrically closest to service entrance. Set top of test well flush with finished grade or floor.

E. Bonding Straps and Jumpers: Install in locations accessible for inspection and maintenance except where routed through short lengths of conduit.

1. Bonding to Structure: Bond straps directly to basic structure, taking care not to penetrate any adjacent parts.
2. Bonding to Equipment Mounted on Vibration Isolation Hangers and Supports: Install bonding so vibration is not transmitted to rigidly mounted equipment.

3. Use exothermic-welded connectors for outdoor locations; if a disconnect-type connection is required, use a bolted clamp.

F. Grounding and Bonding for Piping:

1. Metal Water Service Pipe: Install insulated copper grounding conductors, in conduit, from building's main service equipment, or grounding bus, to main metal water service entrances to building. Connect grounding conductors to main metal water service pipes; use a bolted clamp connector or bolt a lug-type connector to a pipe flange by using one of the lug bolts of the flange. Where a dielectric main water fitting is installed, connect grounding conductor on street side of fitting. Bond metal grounding conductor conduit or sleeve to conductor at each end.
2. Water Meter Piping: Use braided-type bonding jumpers to electrically bypass water meters. Connect to pipe with a bolted connector.
3. Bond each aboveground portion of gas piping system downstream from equipment shutoff valve.

G. Bonding Interior Metal Ducts: Bond metal air ducts to equipment grounding conductors of associated fans, blowers, electric heaters, and air cleaners. Install bonding jumper to bond across flexible duct connections to achieve continuity.

H. Grounding for Steel Building Structure: Install a driven ground rod at base of each corner column and at intermediate exterior columns at distances not more than 60 feet apart.

I. Ground Ring: Install a grounding conductor, electrically connected to each building structure ground rod and to each steel column, extending around the perimeter of building, area or item indicated.

1. Install tinned-copper conductor not less than No. 2/0 AWG for ground ring and for taps to building steel.
2. Bury ground ring not less than 24 inches from building's foundation.

J. Ufer Ground (Concrete-Encased Grounding Electrode): Fabricate according to NFPA 70; use a minimum of 20 feet of bare copper conductor not smaller than No. 4 AWG.

1. If concrete foundation is less than 20 feet long, coil excess conductor within base of foundation.

K. Bond grounding conductor to reinforcing steel in at least four locations and to anchor bolts. Extend grounding conductor below grade and connect to building's grounding grid or to grounding electrode external to concrete.

3.05 LABELING

A. Install labels at the telecommunications bonding conductor and grounding equalizer and at the grounding electrode conductor where exposed.

1. Label Text: “If this connector or cable is loose or if it must be removed for any reason, notify the facility manager.”

3.06 FIELD QUALITY CONTROL

A. Report measured ground resistances that exceed the following values:

1. Power and Lighting Equipment or System with Capacity of 500 kVA and Less: 10 ohms
2. Power and Lighting Equipment or System with Capacity of 500 to 1000 kVA: 5 ohms
3. Power and Lighting Equipment or System with Capacity More Than 1000 kVA: 3 ohms
4. Power Distribution Units or Panelboards Serving Electronic Equipment: 1 ohm
5. Substations and Pad-Mounted Equipment: 5 ohms
6. Manhole Grounds: 10 ohms

7. Ground resistance to earth of each ground rod: > 5 ohms

B. Excessive Ground Resistance: If resistance to ground exceeds specified values, notify DEN Electrical Engineer promptly and include recommendations to reduce ground resistance.

Section 260529: Hangers and Supports for Electrical Systems

PART 1 GENERAL

1.01 PERFORMANCE REQUIREMENTS

A. Delegated Design: Design supports for multiple raceways, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.

B. Design supports for multiple raceways capable of supporting combined weight of supported systems and its contents.

C. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 SUPPORT INSTALLATION

A. Drill holes for expansion anchors in concrete at locations and to depths that avoid reinforcing bars.

B. Do not fasten supports to piping, ductwork, mechanical equipment, cable tray or conduit.

C. The use of pneumatic-actuated anchors is not allowed except at ceilings. Obtain DEN Project Manager approval prior to ordering materials or performing work.

D. The use of powder-actuated anchors is not allowed.

E. Do not drill structural steel members.

F. Install surface-mounted cabinets and panelboards with minimum of four anchors

G. Suspended conduit or box supports shall not be less than 1/4" diameter steel rod. Rod used as pedestal support is not acceptable. The contractor shall not use tie wire or wire of any type to support conduits, junction boxes or pull boxes.

H. No more than five (5) 1/2" conduits, three (3) 3/4" conduits or two (2) 1" conduits shall be supported on a single 1/4" diameter steel rod.

I. All conduits shall be supported by approved hangers. Supports installed and used by other trades such as duct hangers, pipe hangers, ceiling hangers, etc. shall not be used for conduit support.

J. All light fixtures shall be independently supported at opposite corners from structure, or from trapeze supported from structure by the electrical contractor.

K. Wall-mounted fixtures shall be supported from building structure with backing support as approved by the DEN Project Manager to prevent any damage to the wall.

L. Use vibration isolation pads for vibrating equipment such as transformers.

M. Plastic or fiber anchors are prohibited.

N. Anchoring in overhead cast in place, pre-tensioned or post-tensioned concrete is prohibited unless x-ray or ground penetrating radar study are performed and approved by the DEN Project Manager.

O. Route conduit through roof openings provided for piping and ductwork where possible; otherwise, route through roof jack with sealant approved by the roofing manufacturer.

3.02 CONCRETE BASES

A. Install all freestanding electrical equipment on a 4" concrete housekeeping pad.

B. Construct concrete bases of dimensions indicated but not less than 4 inches larger in both directions than supported unit, and so anchors will be a minimum of 10 bolt diameters from edge of the base.

C. Use 3000-psi (20.7-MPa), 28-day compressive-strength concrete.

3.03 PAINTING

A. Touchup: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.

1. Apply paint by brush or spray to provide minimum dry film thickness of 2.0 mils.

Section 260533: Raceways and Boxes for Electrical Systems

PART 1 GENERAL

1.01 PROHIBITED MATERIALS

A. Intermediate conduits

B. Aluminum conduit

1. Multi-conductor assemblies, unless written authorization is obtained from DEN Project Manager, or specifically allowed within specification.

1.02 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Conduit routing plans, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of items involved:

1. Structural members in paths of conduit groups with common supports.
2. HVAC and plumbing items and architectural features in paths of conduit groups with common supports.

PART 2 PRODUCTS

2.01 METAL CONDUITS, TUBING, AND FITTINGS

A. Fittings for Metal Conduit:

1. Material: Steel
   a. Type: Set screw or compression.
   b. Provide throated connectors where entering junction boxes.
2. Expansion Fittings: PVC or steel to match conduit type, complying with UL 651, rated for environmental conditions where installed, and including flexible external bonding jumper.

2.02 METAL WIREWAYS AND AUXILIARY GUTTERS

A. Wireway Covers: Hinged type or screw cover.

B. Finish: Manufacturer's standard enamel finish

2.03 BOXES, ENCLOSURES, AND CABINETS

A. Sheet Metal Outlet and Device Boxes: Galvanized steel. Comply with NEMA OS 1 and UL 514A.

B. Cast-Metal Outlet and Device Boxes: Comply with NEMA FB 1, ferrous alloy, Type FD, with gasketed cover. Provide threaded hubs.

C. Nonmetallic Outlet and Device Boxes: Prohibited, unless specifically allowed in writing by the DEN Project Manager.

D. Metal Floor Boxes:

1. Material: Cast metal.
2. Finish: Unless otherwise noted all floor boxes shall be Brass; Brushed aluminum shall be provided for floor boxes providing power to hold room seating.
3. Type: Fully adjustable.
4. Shape: Round.

E. Nonmetallic Floor Boxes: Prohibited, unless specifically allowed by the DEN Project Manager.

F. Luminaire Outlet Boxes: Nonadjustable, designed for attachment of luminaire weighing 50lb. Outlet boxes designed for attachment of luminaires weighing more than 50lb shall be listed and marked for the maximum allowable weight.

G. Paddle Fan Outlet Boxes: Nonadjustable, designed for attachment of paddle fan weighing 70lb.

H. Device Box Dimensions: 4 inches square by 2-1/8 inches deep or as approved by DEN Project Manager.

I. Hinged-Cover Enclosures: Comply with UL 50 and NEMA 250, Type 1, Type 3R or Type 4x as appropriate, with continuous-hinge cover with flush latch unless otherwise indicated. Screw cover enclosures: VL50 & NEMA 1.

1. Metal Enclosures: Steel, finished inside and out with manufacturer's standard enamel.
2. Nonmetallic Enclosures: Plastic or Fiberglass.
3. Interior Panels: Steel; 14 gage steel, 12 gage if floor mounted, all sides finished with manufacturer's standard enamel, white.
4. Large Pull Boxes: Boxes larger than 100 cubic inches in volume or 12 inches in any dimension.
   a. Interior Dry Locations: Use hinged or screw covered enclosure.
   b. Interior damp or wet locations: Use NEMA 3R hinged cover boxes.

2.04 HANDHOLES AND BOXES FOR EXTERIOR UNDERGROUND WIRING

A. Polymer-Concrete Handholes and Boxes with Polymer-Concrete or stainless steel Cover: Molded of sand and aggregate, bound together with polymer resin, and reinforced with steel, fiberglass, or a combination of the two.

PART 3 EXECUTION

3.01 RACEWAY APPLICATION

A. Raceways shall not be installed in stairways or on the exterior of any building, unless specifically allowed by DEN Project Manager.

B. Raceways shall be installed as tight to structure as possible. Raceway routing to be coordinated with DEN Project Manager prior to installation for existing buildings.

C. Raceways should never be run under water pipes.

D. Outdoors: Apply raceway products as specified below unless otherwise indicated:

1. Exposed Conduit: RMC.
2. Concealed Conduit, Aboveground: RMC.
3. Underground Conduit: Encased in direct buried conduits per Section 260543, "Underground Ducts and Raceways for Electrical Systems."
   a. Direct buried conduits are not allowed unless specifically allowed by the DEN Project Manager.

b. Solar farm installation may utilize direct buried conduits in ground.

4. Exposed Conduit in Parking Garages or other covered structures open to environment:
   a. Below 8'-0" AFF or within 10-0" of extent of covered area: Galvanized RMC.
   b. Above 8'-0" AFF and more than 10'-0" from extent of covered area: EMT with compression-type weatherproof/rain-tight connectors.
5. Connection to Vibrating Equipment (Including Transformers and Hydraulic, Pneumatic, Electric Solenoid, or Motor-Driven Equipment): LFMC.
6. Boxes and Enclosures, Aboveground: NEMA 250, Type 3R Type 4.

E. Indoors: Apply raceway products as specified below unless otherwise indicated:

1. Exposed, Not Subject to Physical Damage: EMT.
2. Exposed, and Subject to Physical Damage: GRC. Raceway locations include the following:
   a. Loading dock
   b. Baggage tunnels
3. Concealed in Ceilings and Interior Walls and Partitions: EMT.
4. Connection to Vibrating Equipment (Including Transformers and Hydraulic, Pneumatic, Electric Solenoid, or Motor-Driven Equipment): FMC, except use LFMC in damp or wet locations.
5. Wet Locations: GRC.
6. Boxes and Enclosures: NEMA 250, Type 1, except use NEMA 250, Type 4 stainless steel in institutional and commercial kitchens and damp or wet locations.

F. CONDUIT INSTALLATION SCHEDULE

1. Underground Installations More Than Five Feet from Foundation Wall: Polyvinyl Chloride (PVC) conduit Schedule 40 encased in concrete. All bends greater than 45 degrees in non-metallic conduit shall be galvanized rigid steel conduit with a factory coating of polyvinyl chloride (PVC).
2. Installation in Concrete Slab: Not allowed unless approved by DEN Project manager.
3. All buried conduits containing cabling shall be installed in concrete encased duct banks, except for conduits containing branch circuits or data cabling routed-under concrete or asphalt.
4. In Slab Above Grade: Not allowed
5. Wet Interior Locations: Rigid steel
6. Concealed Dry Interior Locations: Electrical metallic tubing.
7. In Existing Walls of Existing Structure: Electrical metallic tubing or MC Cable with approval from DEN project manager.

G. Minimum Raceway Size: 3/4-inch trade size.

H. Raceway Fittings: Compatible with raceways and suitable for use and location.

1. Rigid Steel Conduit: Use threaded rigid steel conduit fittings unless otherwise indicated.
2. PVC Externally Coated, Rigid Steel Conduits: Use only fittings listed for use with this type of conduit. Patch and seal all joints, nicks, and scrapes in PVC coating after installing conduits and fittings. Use sealant recommended by fitting manufacturer and apply in thickness and number of coats recommended by manufacturer.
3. EMT: Use setscrew, or compression, steel fittings.
   a. Setscrew fittings to be used for indoor applications in dry locations only.
   b. Compression fittings may be used in indoor or outdoor locations for damp or wet locations.
4. Flexible Conduit: Use only fittings listed for use with flexible conduit.

I. Install surface raceways only where indicated on Drawings.

J. Do not install nonmetallic conduit where ambient temperature exceeds 120 deg F.

K. Unless otherwise indicated and where not otherwise restricted, use the conduit type indicated for the specified applications. Where more than one listed application applies, comply with the most restrictive requirements. Where conduit type for a particular application is not specified, use Galvanized Rigid Conduit.

3.02 INSTALLATION

A. Maintain a minimum of 6 inches between conduit and other piping. Maintain twelve inches (12”) clearance between conduit and a heat source such as heating pipes, exhaust flues and heating appliances. Install horizontal raceway runs above water and steam piping.

First paragraph below is more restrictive than NFPA 70, which permits up to four quarter bends in a conduit run. Retain paragraph for more conservative design, with less stress being placed on conductors being pulled in. Allowance of 360-degrees of bends is discouraged as a general rule and must be approved in writing by the DEN Project Manager.

B. Install no more than the equivalent of three 90-degree bends in any conduit run except for control wiring conduits, for which fewer bends are allowed. Support within 24 inches of changes in direction.

C. Conceal conduit and EMT within finished walls, ceilings, and floors unless otherwise indicated. Install conduits parallel or perpendicular to building lines. Use conduit bodies to make changes in direction around beams or columns.

D. Support conduit within 24 inches of enclosures to which attached. Support conduit at a maximum of 8 feet on center, within two (2) feet of a box or fitting.

E. Avoid moisture traps where possible; where unavoidable, provide junction box with drain fitting at conduit low point.

F. Use PVC-coated rigid steel factory elbows for bends greater than 45 degrees in plastic conduit runs.

G. Exposed conduits subject to physical damage to be rigid steel to 6'-0" above floor, deck or grating except in electrical, communications and mechanical rooms.

H. Conduit stubbed up shall be two inches above slab or housekeeping pad and the empty conduits shall be capped. Under freestanding equipment conduits with conductors shall be sealed with duct seal.

I. Flexible steel conduit runs shall not exceed 6' in length when connecting equipment, 6' in length when connecting light fixtures or when fished in hollow spaces with written approval by DEN Project Manager and shall contain a grounding conductor.

J. Stub-ups to Above Recessed Ceilings:

1. Use EMT or RMC for raceways.
2. Use a conduit bushing or insulated fitting to terminate stub-ups not terminated in hubs or in an enclosure.

K. Threaded Conduit Joints, Exposed to Wet, Damp, Corrosive, or Outdoor Conditions: Apply listed compound to threads of raceway and fittings before making up joints. Follow compound manufacturer's written instructions.

L. Raceway Terminations at Locations Subject to Moisture or Vibration: Use insulating bushings to protect conductors including conductors smaller than No. 4 AWG.

M. Terminate threaded conduits into threaded hubs or with locknuts on inside and outside of boxes or cabinets. Install bushings on conduits up to 1-1/4-inch trade size and insulated throat metal bushings on 1-1/2-inch trade size and larger conduits terminated with locknuts. Install insulated throat metal grounding bushings on service conduits.

N. Install pull wires in empty raceways. Use polypropylene or monofilament plastic line with not less than 160-lb tensile strength. Leave at least 12 inches of slack at each end of pull wire. Cap underground raceways designated as spare above grade alongside raceways in use.

O. Expansion-Joint Fittings:

1. Install expansion fittings at all locations where conduits cross building or structure expansion joints.
2. Provide external bonding jumper for all expansion fittings.

P. Do not support conduit from cable tray or cable tray supports.

X-ray is the preferred option, unless there are areas around the construction site that cannot be evacuated to perform the x-ray. Coordinate desired approach with the DEN Project Manager.

Q. X-ray [or ground penetrating radar] studies shall be made of concrete floors, walls or CMU walls prior to drilling or cutting of concrete and submitted to the DEN Project Manager for review and approval.

R. Inaccessible Ceiling Areas: Install outlet and junction boxes no more than 6 inches from ceiling access panel or from removable recessed light fixture.

S. Support boxes in the ceiling with ¼" threaded rod as a minimum.

T. Use 4-inch square box with plaster ring for single device outlets.

U. Minimum junction and pull box size 4-11/16" x 4-11/16" x 2-1/8".

V. Minimum outlet box size 4" x 4" x 2-1/8" including feed through outlet boxes.

W. Minimum junction box size for fire alarm pull stations, control module, monitor module, 4" x 4" x 2-1/8". Provide plaster ring at all pull station locations.

Section 260536: Cable Trays for Electrical Systems

PART 1 GENERAL

PART 2 PRODUCTS

2.01 VERTICAL (BACKBONE) COMMUNICATIONS PATHWAYS- CABLE TRAY

A. Cable trays shall utilize dual side rails with 6-inch maximum rung spacing or solid bottom construction. When rung construction is utilized, the top of each rung shall be flat (required for fiber-optic cable). Cable tray covers are generally not required (or desired), however, when the use of covers is mandated, covers shall be hinged. Cable tray systems should be installed with a minimum number of horizontal bends and vertical transitions. Where such transitions are required, provide transition pieces manufactured for the purpose by the cable tray manufacturer. Field fabricated transitions or sections of tray abutting without transition pieces shall not be acceptable. The radius of all transitions for vertical communications pathways shall be a minimum of nine (9) feet measured to the inside rail of the tray.

B. Cable tray size and supporting system shall be designed for the initial cabling requirements with spare capacity to support 100 percent future growth.

C. Cable tray shall be installed with as much clearance as possible from other building facilities. A minimum clearance of 8-inches shall be maintained above any cable tray. Maintain 12-inches clearance on both sides of tray.

D. Cable tray should generally not be installed above inaccessible hard ceiling locations. Where such conditions are unavoidable, person sized access panels shall be provided at 20 feet intervals and at any change of direction greater than 15 degrees. A complete cable tray rope and pulley system

shall be installed in tray segments above inaccessible ceiling systems. Where used in plenum areas, pulley cord shall be constructed of plenum rated material.

E. Cable tray shall terminate at the outside wall of communications room. The communications room penetration shall be made with a group of 4-inch metallic conduits equivalent in cross sectional area to the tray. Conduits shall be secured to both sides of the equipment room wall with unistrut and 4-inch unistrut clamps. Bonding bushings shall be provided on both sides of penetrating sleeves and bonded to tray / cable ladder on both sides. Firesafe between conduits and wall.

F. When complete, tray shall be free and clear of all obstructions and free of burrs, sharp edges, and protrusions. Label tray “DEN Telecommunications” at 6'-0" intervals.

PART 3 EXECUTION

3.01 CABLE TRAY APPLICATION

A. Cable trays installed in public areas shall be provided with a solid bottom.

3.02 CABLE TRAY GROUNDING

A. Install equipment ground bond between conduit and cable tray.

3.03 CABLE INSTALLATION

A. Fasten cables on horizontal runs with cable clamps or cable ties according to NEMA VE 2. Tighten clamps only enough to secure the cable, without indenting the cable jacket. Install cable ties with a tool that includes an automatic pressure-limiting device.

Section 260539: Underfloor Raceways for Electrical Systems

PART 1 GENERAL

1.01 QUALITY ASSURANCE

A. Source Limitations for Electrified Cellular Steel Floor-Deck Components: Obtain electrical components such as preset inserts, afterset inserts, service fittings, header ducts, and trench header ducts from the cellular steel floor-deck manufacturer.

B. Source Limitations: Obtain underfloor raceway components for each system through one source from single manufacturer.

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 INSTALLATION

A. Adjust supports to maintain a 1/16- to 3/8-inch finished concrete cover over preset inserts.

B. Ground underfloor raceway components.

Section 260543: Underground Ducts and Raceways for Electrical Systems

PART 1 GENERAL

1.01 INFORMATIONAL SUBMITTALS

Retain coordination drawings paragraph and subparagraphs below if Drawings do not include detailed plans or if Project involves unusual coordination requirements.

A. Duct-Bank Coordination Drawings: Show duct profiles and coordination with other utilities and underground structures.

1. Include plans and sections, drawn to scale, and show bends and locations of expansion fittings.

2. Drawings shall be signed and sealed by a qualified professional engineer.

1.02 COORDINATION

A. Coordinate layout and installation of ducts, manholes, handholes, and boxes with final arrangement of other utilities, site grading, and surface features as determined in the field.

B. Coordinate elevations of ducts and duct-bank entrances into manholes, handholes, and boxes with final locations and profiles of ducts and duct banks as determined by coordination with other utilities, underground obstructions, and surface features. Revise locations and elevations from those indicated as required to suit field conditions and to ensure that duct runs drain to manholes and handholes, and as approved by DEN Project Manager.

PART 2 PRODUCTS

2.01 NONMETALLIC DUCTS AND DUCT ACCESSORIES

A. Duct accessories:

1. Pull Tape shall be 3/4" wide woven Aramid fiber with no more than 4% elongation at yield. Tape shall provide a tensile strength of 2500 lbs. Tape shall be provided with accurate sequential footage marks at one foot intervals.
2. Red concrete for encasement shall be 3,000 psi minimum, 28-day compressive strength and 3/8-inch maximum aggregate size. The color shall be Davis Color “Baja Red.” Use Davis Color # 160 at a ratio of two (2) pounds powder dose for each sack of cement in the mix or equal as determined by the manufacturer and DEN Project Manager to achieve desired color.
3. Counterpoise conductor shall be #6 bare hard drawn or soft drawn copper. Exothermic welds shall be utilized at all connections.

2.02 PRECAST MANHOLES

A. Joint Sealant: Asphaltic-butyl material with adhesion, cohesion, flexibility, and durability properties necessary to withstand maximum hydrostatic pressures at the installation location with the ground-water level at grade.

2.03 PRECAST UNDERGROUND COMMUNICATIONS VAULT S (UCV'S)

A. Manufacturers: Subject to compliance with requirements, provide products by the following:

1. Amcor Precast (Oldcastle).

B. Precast underground communications vaults shall be provided in the following sizes:

1. 12'-0"L x 6'-0"W x 7'-0"H nominal interior dimension
2. 6'-0"L x 4'-0"W x 7'-0"H nominal interior dimension

C. Vaults shall be of two part construction consisting of separate top and bottom sections. Bottom section shall be equipped with four internal lifting points. Top section shall be equipped with four external lifting points. Top section of vault shall contain a 30-inch round opening to receive precast grade rings and UCV collar. Bottom section of vault shall be provided with 12" diameter x 3.5" deep passive sump with removable stainless steel grating.

D. 12'-0" x 6'-0" vaults shall be provided with forty (40) embedded PVC belled ends to accept standard schedule 40 PVC conduit. 6'-0" x 4'-0" vaults shall be provided with twelve (12) embedded PVC belled ends. All embedded adapters shall be constructed with a break-out PVC diaphragm which shall remain in place on unused openings. Duct conduits shall be attached to adapters using solvent cement.

E. 12'-0" x 6'-0" vaults shall be equipped with eight (8) stainless steel pulling irons embedded in the precast base section. 6'-0" x 4'-0" vaults shall be provided with four (4) embedded pulling irons.

F. 12'-0" x 6'-0" vaults shall be provided with the following accessory equipment:

1. Sixteen (16) 47-hole cable support racks, stainless steel.
2. Forty (40) L-Bracket for cable support racks, stainless steel.
3. Four (4) 7'-0" vertical copper bonding ribbon (two per long side)
4. Bolt-on ladder bracket, hot-dip galvanized
5. Hook ladder, stainless steel
6. Grade ring(s), precast, 30-inch inside diameter
7. Collar ring, cast steel, 30-inch inside diameter
8. Cover, cast steel, 30-inch diameter (Marked “DEN Communications”)

G. 6'-0" x 4"-0" vaults shall be provided with the following accessory equipment:

1. Nine (9) 47-hole cable support racks, stainless steel.
2. Eight (8) L-Bracket for cable support racks, stainless steel.
3. Two (2) 7'-0" vertical copper bonding ribbon (duct entry side only)
4. Bolt-on ladder bracket, hot-dip galvanized
5. Hook ladder, stainless steel
6. Grade ring(s), precast, 30-inch inside diameter
7. Collar ring, cast steel, 30-inch inside diameter
8. Cover, cast steel, 30-inch diameter (Marked “DEN Communications”).

H. Vaults shall be designed for AASHTO HS-20 Loading and according to ASTM C857-87 and ASTM C858-83.

I. The specified UCV's are manufactured with factory embedded PVC belled ends for all port positions. These fittings contain a break-out plastic diaphragm which must be removed during conduit installation. Diaphragm shall remain in place on all unused ports. Provide rubber expansion plugs on all ports with installed. Plugs shall provide a tight seal between conduit and pull tapes and shall withstand a minimum of 15 psi of hydrostatic pressure.

2.04 AIRCRAFT RATED UCVS

A. UCVs located in apron or taxiway areas may be either precast or cast in place. All aircraft rated UCVs shall be engineered for aircraft loading. Contact DEN Engineering for required loading values for each location where aircraft rated UCVs will be required.

PART 3 EXECUTION

3.01 UNDERGROUND DUCT APPLICATION

A. Underground conduits shall be Poly-vinyl Chloride (PVC) schedule 40 or greater, or Galvanized Rigid Conduit (GRC) with factory bonded 40 mil. PVC coating.

B. All underground duct banks inside and outside of the building shall be encased in red concrete, supported on listed conduit spacers every five (5) feet, with a minimum of three (3) inches of cover on all sides and two (2) inches between conduits at a minimum depth of 36- inches from top of concrete encasement to finished grade. A 3" wide red metallized foil core detectable warning tape shall be placed over the duct bank at a depth not exceeding the manufacturer’s recommendations.

C. Concrete encased duct banks shall be utilized for all primary duct banks at DEN. Primary duct banks are considered those duct banks that form the main arteries of the DEN duct bank system and those serving any DEN owned facility or structure. Concrete encasement shall also be used on segments of direct buried duct bank that cross under paved roadways or other locations subject to vehicular traffic.

D. Include a bare #2 copper ground conductor above conduits in all concrete encased duct banks.

E. A 1-inch minimum size shall be used for underground conduit.

F. The minimum size of any underground high voltage (above 1,000 volt) conduit shall be 4".

G. Steel reinforced, concrete encased duct banks shall be utilized for all duct bank segments running under aprons, taxiways, and other aircraft movement areas.

3.02 UNDERGROUND ENCLOSURE APPLICATION

A. The underground concrete vaults (UCV's) and pull boxes used throughout non-aircraft movement areas at DEN are pre-cast units which conform to regulated telephone company specifications. These units are described more completely in part two of this section.

1. Mid-sized UCV's (12'-0" L x 6'-0" W x 7'-0" H interior dimension) shall be utilized for all main duct banks at DEN. Main duct banks shall be considered those duct banks serving more than one facility or containing more than four (4) 4-inch conduits. Mid-sized UCV's may contain fiber-optic cabling, copper cabling or both. Many of the mid-sized UCV's will contain splice cases, repeaters, and other outside plant devices.
2. Small UCV's (6'-0" L x 4'-0" W x 7'-0" H interior dimension) may be utilized for branch connections which serve only a single facility and contain four (4) or fewer ducts. These UCV's may contain fiber-optic cabling, copper cabling or a combination of both. These UCV's are not suitable for housing splice cases, repeaters, etc. Small UCV's should be reserved for straight through pulls of copper or fiber cabling.

B. The standard DEN pull box is a round unit approximately 48-inches in internal diameter and approximately 48-inches deep. This pull box is to be used on duct bank runs containing no more than two conduits and supporting fiber-optic cable only. These boxes do not provide sufficient space for copper splice cases.

C. UCV's shall be placed within 100-feet of any 90-degree turn in the duct bank and at intervals of approximately 500-feet. Pull boxes on fiber-optic only duct banks may be placed at intervals of approximately 750-feet. Adjust spacing to avoid paved areas and traveled roadways.

D. The standard DEN UCV contains break out ports for 4-inch schedule 40 PVC on two opposing ends. UCV's should not be placed directly at the corner point for a 90-degree duct bank turn. Do not modify UCV's with sidewall openings where no conduit ports exist as to do so complicates cable racking and splice case placement on larger cable sizes.

E. The standard DEN pull box contains break-out waffle panels at intervals around the pull box circumference. Arrange ducts to enter and exit the pull box on directly opposite break-out panels to allow for straight-through cable pulls.

F. When arranging ducts in UCV's and pull boxes, utilize the lower ports first, starting with the bottom most port and working upward. Ensure that the pattern of ducts (ie:1, 2, 3, 4 etc.) remains the same on both ends of a duct run. For example, on a north-south duct run the lowest duct on the east side leaving one UCV would also be the lowest duct on the east side at the next UCV.

Section 260548: Vibration and Seismic Controls for Electrical Systems

PART 1 GENERAL

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 FIELD QUALITY CONTROL

A. Schedule test with Owner, through DEN Project Manager, before connecting anchorage device to restrained component (unless post connection testing has been approved), and with at least seven (7) days' advance notice.

B. Obtain DEN Project Manager's approval before transmitting test loads to structure. Provide temporary load-spreading members.

C. Test at least four (4) of each type and size of installed anchors and fasteners selected by DEN Project Manager.

Section 260553: Identification for Electrical Systems

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Identification Schedule: An index of nomenclature of electrical equipment and system components used in identification signs and labels.

PART 2 PRODUCTS

2.01 POWER RACEWAY IDENTIFICATION MATERIALS

A. Colors for Raceways Carrying Circuits at More Than 600 V:

1. Black letters on an orange field.
2. Legend: “DANGER CONCEALED HIGH VOLTAGE WIRING” with 3-inch high letters on 20-inch centers.

B. Tape and Stencil for Raceways Carrying Circuits More Than 600 V: 4-inch- wide black stripes on 10-inch centers diagonally over orange background that extends full length of raceway or duct and is 12 inches wide. Stop stripes at legends.

2.02 EQUIPMENT IDENTIFICATION LABELS

A. Emergency Equipment labels shall be white letters on red background.

B. Provide nameplates with a minimum letter height as indicated below. Examples are given below for the size of letters to use for a given application and this not a list of the equipment to be identified. All equipment is required to be identified.

1. For equipment designation: switchboards and motor control centers: 1/2-inch, panel boards: 1/4 inch. For voltage, bus ampacity, feeder source, and circuit number: 1/8 inch.
2. Individual circuit breakers and or motor starters in motor control centers: For equipment designation and section number: 1/4 inch, for load served and location of load: 1/8 inch. Inside the door, a typed label shall provide complete motor data including nameplate horsepower, full load amperes, code letter, service factor, and voltage/phase rating.
3. Individual breakers in switchgears and switchboards: for breaker number (address number) and equipment designation; 1/4 inch, for breaker frame size and trip setting; 1/8 inch.
4. Individual circuit breaker and spaces in panel boards: for numbers (section number) 1/4 inch.
5. Individual circuit breakers in distribution panel boards: 1/4 inch for panel being fed and 1/8 inch for its location.
6. Transformers: 1/4 inch for equipment designation and size; 1/8 inch for primary and secondary voltages, primary source and circuit number, secondary load, and its location.
7. Individual remote indicating lights, meters, instruments, and control switches: 1/8 inch, indicate unit, equipment, or fire detector being monitored and condition indicated by illumination.
8. Individual switches and pilots: 1/8 inch, identify mechanical unit being served.
9. Disconnects, relay panels, lighting contactors: 1/4 inch for voltage and source circuit number.

Include the following paragraph on projects including new switchgears.

2.03 UTILITY METER IDENTIFICATION TAGS

A. Brass tags identifying Xcel meters ahead of DEN switchgears must be coordinated with Xcel's liaison and labeled as indicated in the table below:

Example Name	Description
26900 E. 84TH AVE.	Service Address
2-14BSG1	Unit No. / Switchgear No.
SWGR M1	Switchgear M1/ M2 (Switchgear main breaker downstream of the meter)
357-777	Transformer Grid Number / Field Stencil (Number from the utility transformer)

2.04 CABLE TIES

A. General-Purpose Cable Ties: Fungus inert, self-extinguishing, one piece, self-locking, Type 6/6 nylon.

1. Minimum Width: 1/8 inch.
2. Tensile Strength at 73 deg F, According to ASTM D 638: 12,000 psi.
3. Temperature Range: Minus 40 to plus 185 deg F.

B. UV-Stabilized Cable Ties: Fungus inert, designed for continuous exposure to exterior sunlight, self-extinguishing, one piece, self-locking, Type 6/6 nylon.

1. Minimum Width: 3/16 inch
2. Tensile Strength at 73 deg F, According to ASTM D 638: 12,000 psi.
3. Temperature Range: Minus 40 to plus 185 deg F.

C. Plenum-Rated Cable Ties: Self-extinguishing, UV stabilized, one piece, self-locking.

1. Minimum Width: 3/16 inch.
2. Tensile Strength at 73 deg F, According to ASTM D 638: 7000 psi.
3. UL 94 Flame Rating: 94V-0.
4. Temperature Range: Minus 50 to plus 284 deg F.

PART 3 EXECUTION

3.01 IDENTIFICATION SCHEDULE

A. Wire and Cable Marker:

1. For wire/cables smaller than No. 2/0 use manufacturer's standard cable/conductor markers of wrap-around, pre-numbered plastic-coated type are to be used and numbered to show circuit identification.
2. For cables No. 4 AWG and larger heat shrink sleeving is to be used for phase color-coding.

B. Cable/Conductor Identification:

1. The application of cable/conductor identification, with circuit number, on each wire / cable in each box/enclosure/cabinet is required. The identification shall match the marking system used in panel boards, shop drawings, and contract documents.
   a. Provide labels on all wires, including in boxes where wires are pulled through but not terminated, such as junction boxes.

C. System Color Coding Schedule:

1. Electrical emergency power conduits, including all feeders and branch circuits serving or connected to emergency systems as defined in NEC 700.2, shall have “RED” stripes on each section every 5 feet of electrical conduit (visible from the floor or above a suspended ceiling) and within 3 feet of all equipment. All associated junction or pull boxes shall have the cover painted red.
2. ECS conduits installed to serve systems specified in Section 275123 “Emergency Communications System” shall have “GREEN” bands on 5' centers for the entire length of conduit run, or be continuously painted green. All junction or pull boxes shall have the cover painted green with the associated zone number written neatly on the box cover with permanent marker.
3. Conduits serving temperature control, metering data cabling, lighting control BACNet cabling, and other EMCS integration cabling systems shall have “BROWN” bands, 5' on centers for the entire length, or be continuously painted brown. All junction or pull boxes shall have the cover painted brown.
4. Fire Alarm conduit shall be a continuous red factory finish.

D. Concealed Raceways, Duct Banks, More Than 600 V, within Buildings: Tape and stencil 4-inch wide black stripes on 10-inch centers over orange background that extends full length of raceway or duct and is 12 inches wide. Stencil legend “DANGER CONCEALED HIGH VOLTAGE WIRING” with 3-inch high black letters on 20-inch centers. Stop stripes at legends. Apply to the following finished surfaces:

1. Floor surface directly above conduits running beneath and within 12 inches of a floor that is in contact with earth or is framed above unexcavated space.
2. Wall surfaces directly external to raceways concealed within wall.
3. Accessible surfaces of concrete envelope around raceways in vertical shafts, exposed in the building, or concealed above suspended ceilings.

E. Junction and Pull Box ID: Identify the covers of each junction and pull box of the following systems with self-adhesive vinyl labels with the wiring system legend and system voltage. System legends shall be as follows:

1. Emergency Work: EM
2. Power
3. Uninterruptible Power Supply: UPS
4. Fiber Optics: FO
5. Closed Circuit Television: CCTV
6. Paging System: PA
7. Radio Frequency: RF
8. Fire Alarm: FA
9. Temperature Control: TC

F. Workspace Indication: Install floor marking tape to show working clearances in the direction of access to live parts. Workspace shall be as required by NFPA 70 and 29 CFR 1926.403 unless otherwise indicated. Do not install at flush-mounted panelboards and similar equipment in finished spaces.

G. Caution Signs:

1. The following red caution sign is to be provided for all circuit breakers and switchboards where turning off a circuit will automatically start an emergency operation:
2. “Caution Turning Off this Circuit will Automatically Start Emergency Operation”

H. The following red caution sign is to be provided for all automatic transfer switches, switches, circuit breakers, equipment, and emergency panels that are energized by the emergency power system

1. "Caution Automatically Energized by Emergency Power Supply System"

I. Equipment Identification Labels: On each unit of equipment, install unique designation label that is consistent with wiring diagrams, schedules, and the Operation and Maintenance Manual. Apply labels to disconnect switches and protection equipment, central or master units, control panels, control stations, terminal cabinets, and racks of each system. Systems include power, lighting, control, communication, signal, monitoring, and alarm systems unless equipment is provided with its own identification.

1. Labeling Instructions:
   a. Indoor Equipment: Mechanically fastened, engraved, laminated acrylic or melamine label. Unless otherwise indicated, provide a single line of text with 1/2-inch high letters on 1-1/2-inch high label; where two lines of text are required, use labels 2 inches high. Use black lettering on white field for normal and white letters on a red field for emergency. Provide text matching terminology and numbering of the contract documents and shop drawings. The sign shall include unit designation, source circuit number, circuit voltage, and other data specifically indicated. Also, the sign shall indicate normal source circuit number ("Fed from . . .") and emergency source circuit number when the equipment is a transfer switch or fed directly from a transfer switch.
   c. Outdoor Equipment: Engraved, laminated acrylic or melamine label Stenciled legend 4 inches high.
   d. Elevated Components: Increase sizes of labels and letters to those appropriate for viewing from the floor.
   e. Fasten labels with appropriate mechanical fasteners that do not change the NEMA or NRTL rating of the enclosure.
2. Equipment to Be Labeled:
   a. Panelboards: include main bus ampacity on sign. Typewritten directory of circuits in the location provided by panelboard manufacturer. Panelboard identification shall be engraved, laminated acrylic or melamine label.
   b. Enclosures and electrical cabinets
   c. Access doors and panels for concealed electrical items
   d. Switchgear
   e. Switchboards
   f. Disconnect switch
   g. Transformers: Label that includes tag designation shown on Drawings for the transformer, feeder, and panelboards or equipment supplied by the secondary.
   h. Substations
   i. Emergency system boxes and enclosures
   j. Motor-control centers
   k. Enclosed switches
   l. Selector switches, indicating lights. (Circuit number and voltage not required on sign)
   m. Enclosed circuit breakers
   n. Enclosed controllers
   o. Variable-speed controllers
   p. Push-button stations
   q. Power transfer equipment
   r. Photovoltaic inverters
   s. Photovoltaic modules
   t. Contactors

u. Remote-controlled switches, dimmer modules, and control devices
v. Battery-inverter units
w. Battery racks
x. Power-generating units
y. Monitoring and control equipment
z. UPS equipment
aa. Telephone cabinets and switching equipment. (Circuit number and voltage not required on sign).
ab. Fire alarm panels
ac. Security monitoring master station
ad. Relays
ae. Lighting contactors
af. Individual distribution circuit breakers

3.02 EQUIPMENT NAMING

A. Electrical Panels shall be named according to the panel names indicated on the drawings.

B. Naming Disconnects and Transformers

1. Disconnects shall have the same name as the equipment they serve.
2. Transformers shall be named according to the transformer designation indicated on the drawings. If no transformer designation is indicated on the drawings, transformers shall have the same name as the low-voltage panel they supply power to with the prefix of “T-“.

Section 260583: Electrical Connections for Equipment

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Complete wiring diagrams and/or shop drawings for installation purposes shall be furnished under the Mechanical or other Divisions, as required by DEN Project Manager, prior to installation.

PART 2 PRODUCTS

2.01 MECHANICAL AND ELECTRICAL COORDINATION

A. Verify location, size, and characteristics of all mechanical equipment before installation of electric service. In all cases of the installation of heating, ventilating, air conditioning, plumbing, and other mechanical equipment, the Contractor is responsible for all revisions, changes, and modifications necessary to properly supply electric services to the equipment.

PART 3 EXECUTION

3.01 INSTALLATION

A. Make conduit connections to equipment using flexible conduit. Use liquid-tight flexible conduit in damp or wet locations. Length shall be six feet (6') maximum.

B. Install pre-finished cord set where connection with attachment plug is indicated or specified, use attachment plug with suitable strain-relief clamps.

C. Provide suitable strain-relief clamps for cord connections to outlet boxes and equipment connection boxes.

D. Make wiring connections in control panel or in wiring compartment of pre-wired equipment in accordance with manufacturer’s instructions. Provide interconnecting wiring as required for a complete operating system.

E. Install disconnect switches, controllers, control stations, and control devices such as limit switches and temperature switches as required for a complete operating system. Connect with conduit and wiring as required for a complete operating system.

3.02 INSTALLATION OF ELECTRICAL CONNECTIONS

A. Electrical connections shall be installed in accordance with equipment manufacturer's written instructions and with recognized industry practices, and complying with applicable requirements of UL, NEC and NECA's "Standard of Installation" to ensure that products fulfill requirements.

1. As a minimum: Each feeder circuit to panelboards, switchboards, motor control centers, transformers, and 480-volt (and higher) motor circuits shall have an insulated equipment ground conductor.
2. Electrical service and feeders are to be maintained to occupied areas and operational facilities when temporary service is required during interruptions to existing facilities. Momentary outages for replacing existing wiring systems with new wiring systems shall be scheduled. When the "cutting-over" has been successfully accomplished, temporary wiring is to be removed.
3. Cables and wires shall be trimmed as long as practicable, and routing shall be arranged to facilitate inspection, testing, and maintenance.

B. Connections to fixed and vibrating equipment.

1. Standard wire nuts are not allowed for connections that are subject to vibrations. Utilize anti-vibration wire nuts or push-in type wire connectors.
2. Cord and plug shall not be allowed for fixed or vibrating equipment.

3.03 FIELD QUALITY CONTROL

A. The correct direction of rotation of each motor is to be verified.

B. Provide measured torquing value checklist with witness signature to DEN Project Manager.

Section 260800: Commissioning of Electrical Systems

PART 1 GENERAL

1.01 SUBMITTALS

A. CxP shall submit electrical commissioning activity matrix not less than (30) days prior to start of first planned activity.

B. Not less than (60) days before any onsite testing activities are conducted, Contractor shall submit an overall electrical testing plan and schedule for electrical systems as described in Part 1. Testing activities shall be included in the construction schedule.

C. CxP shall review Contractor's electrical testing plan and revise commissioning activity matrix to include all activities as described in Contractor's testing plan.

D. Contractor shall submit test procedures for each type of equipment not less than (14) days prior to start of testing of that equipment type.

E. Contractor shall submit test results not more than (14) days following completion of associated testing, or as directed by the DEN Project Manager.

1.02 TESTING

A. Contractor shall perform pre-testing of all equipment to verify proper operation.

B. Refer to Section 019113 "General Commissioning Requirements" for test sampling and procedures related to nonconforming work.

C. Test procedures for dynamic equipment:

1. Dynamic electrical equipment is equipment which includes multiple operating modes, responses and/or sequences, and shall include but is not limited to the following:
   a. Scheduled, occupancy-based or daylight-responsive lighting controls.
   b. Emergency and standby generators.
   c. UPS systems.
   d. Fire Alarm systems.
2. Test procedures for dynamic equipment shall be written as step-by-step testing instructions, including expected responses and sample results.

D. Test procedures for static equipment:

1. Static equipment includes electrical equipment designed for static operation and shall include but is not limited to the following:
   a. Panel boards
   b. Switchgear
   c. Transformers
   d. Circuit breakers and safety switches
   e. Lighting

E. Test procedures for static equipment may be written in a checklist format, as appropriate for the equipment.

Section 260923: Lighting Control Devices

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Coordination Drawings: Include drawings to show lighting control equipment layouts and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements.

1.02 QUALITY ASSURANCE

A. Source Limitations: Obtain lighting control equipment components through one source from a single manufacturer.

B. Firms responding to this specification shall provide proof that they have been regularly engaged in the design, manufacturing and testing of lighting control equipment for not less than five (5) years.

PART 2 PRODUCTS

2.01 TIME SWITCHES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Cooper Industries, Inc
2. Intermatic, Inc
3. Invensys Controls
4. NSi Industries LLC; TORK Products
5. Tyco Electronics; ALR Brand

2.02 OUTDOOR PHOTOELECTRIC SWITCHES

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Cooper Industries, Inc
2. Intermatic, Inc
3. NSi Industries LLC; TORK Products
4. Tyco Electronics; ALR Brand

2.03 PHOTOELECTRIC CONTROL

A. Description: Completely self-contained, adjustable type, in NEMA 1 enclosure with adjustable 0 to 15 minutes minimum time delay to provide a dead band zone for temporary changes in daylighting.

B. Automatic Operation:

1. Daylight Only Lighting Level 50 Footcandles or More: No fixtures on.
2. Daylight Only Lighting Level less than 50 Footcandles: Photocell No. 1 (PC 1) activates SW 1 lamps in Daylighting fixtures.
3. Daylight Only Lighting Level Less than 25 Footcandles: Photocell No. 2 (PC 2) activates SW 2 lamps in Daylighting fixtures with SW 1 lamps previously activated. All fixture lamps activated.

C. Footcandle Lighting Level Readings: Measured at the "Workplane" at 3 feet above finish floor.

2.04 DAYLIGHT-HARVESTING SWITCHING CONTROLS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Cooper Industries, Inc
2. Eaton Corporation
3. Hubbell Building Automation, Inc
4. Lithonia Lighting; Acuity Brands Lighting, Inc
5. NSi Industries LLC; TORK Products
6. Sensor Switch, Inc
7. Tyco Electronics; ALR Brand
8. Watt Stopper

2.05 DAYLIGHT-HARVESTING DIMMING CONTROLS

A. Daylight-harvesting dimming control devices connected to a networked lighting control system shall be fully compatible with all features of the system and be of the same manufacturer.

B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Cooper Industries, Inc
2. Hubbell Building Automation, Inc
3. Lithonia Lighting; Acuity Lighting Group, Inc
4. Watt Stopper
5. Power Pack: Sensor has 24-V dc, Class 2 power source, as defined by NFPA 70

2.06 INDOOR OCCUPANCY SENSORS

A. Occupancy sensors connected to a networked lighting control system shall be fully compatible with all features of the system, and be of the same manufacturer.

2.07 SWITCHBOX-MOUNTED OCCUPANCY SENSORS

A. Occupancy sensors connected to a networked lighting control system shall be fully compatible with all features of the system, and be of the same manufacturer

B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Cooper Industries, Inc
2. Hubbell Building Automation, Inc
3. Lightolier Controls
4. Lithonia Lighting; Acuity Brands Lighting, Inc
5. Lutron Electronics Co., Inc
6. NSi Industries LLC; TORK Products
7. Sensor Switch, Inc
8. Watt Stopper

2.08 OUTDOOR MOTION SENSORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Bryant Electric
2. Cooper Industries, Inc
3. Hubbell Building Automation, Inc
4. Lithonia Lighting; Acuity Brands Lighting, Inc
5. NSi Industries LLC; TORK Products
6. RAB Lighting
7. Sensor Switch, Inc
8. Watt Stopper

B. General Requirements for Sensors: Solid-state outdoor motion sensors.

1. PIR or Dual-technology (PIR and infrared) type per design, weatherproof. Detect occurrences of 6-inch- minimum movement of any portion of a human body that presents a target of not less than 36 sq. in. Comply with UL 773A.

2.09 LIGHTING CONTACTORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Allen-Bradley/Rockwell Automation
2. ASCO Power Technologies, LP
3. Eaton Corporation
4. General Electric Company; GE Consumer & Industrial- Electrical Distribution; Total Lighting Control
5. Square D

2.10 EMERGENCY SHUNT RELAY

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Lighting Control and Design

B. Watt Stopper

PART 3 EXECUTION

3.01 WIRING INSTALLATION

A. Wiring within Enclosures: Comply with NECA 1. Separate power-limited and nonpower-limited conductors according to conductor manufacturer's written instructions.

B. Tighten lighting control equipment assembly joints with torque wrench or similar tool recommended by bus assembly manufacturer. Tighten joints again after lighting systems have been energized for 30 days.

C. Connect lighting control equipment assemblies and components to wiring system and to ground as indicated and instructed by manufacturer.

D. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A.

E. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.

3.02 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to evaluate lighting control devices and perform tests and inspections.

3.03 CLEANING

A. After completing system installation, including outlet fittings and devices, inspect exposed finish. Remove burrs, dirt, and construction debris. Repair damaged finish to match original finish.

3.04 PROTECTION

A. Provide final protection to ensure that moisture does not enter lighting control equipment assembly.

3.05 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain lighting control devices.

B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 260943: Networked Lighting Control

PART 1 GENERAL

1.01 DEFINITIONS

A. BACNet: Communications protocol for Building Automation and Control (BAC) network based on ASHRAE, ANSI, and ISO 164845 standard protocol.

B. BACNet MS/TP: RS-485 based communication layer defined in the BACNet protocol.

C. DDC: Direct Digital Controls in a centralized network-oriented approach to control systems that are integrated into the EMCS including HVAC, Electrical Metering, Lighting, and others.

D. EMCS: Energy Management Control System, DEN centralized, networked supervision and control system for HVAC control and energy management. The EMCS consists of multiple systems, including Honeywell Enterprise Buildings Integrator (EBI), and Johnson Controls Metasys.

E. Network Automation Engine

PART 2 PRODUCTS

2.01 GENERAL

A. Manufacturers

1. Wattstopper
2. Eaton

3. Acuity Brands
4. Lutron

2.02 MANUAL SWITCHES AND PLATES

A. Switches: Modular, momentary pushbutton, low-voltage type.

1. Color: Gray unless otherwise indicated.
2. Integral Pilot Light: Indicate when circuit is on. Use where indicated.
3. Locator Light: Internal illumination.
4. Legend: Engraved or permanently silk-screened on wall plate where indicated. Use designations indicated on Drawings.

2.03 EMCS INTERFACE

A. DDC Controller Spare Processing Capacity:

1. Include spare processing memory from each controller, RAM, PROM, or EEPROM will implement requirements indicated with the following spare memory:
   a. Network Controllers: Not less than 30 percent spare capacity.
   b. Programmable Application Controllers: Not less than 30 percent spare capacity.
   c. Application: Specific Controllers: Not less than 30 percent spare capacity.

B. Provide hardware and software to enable the DEN EMCS to monitor, control, display, and record data for use in operating the system and processing reports.

1. Communication Interface: Comply with ASHRAE 135. The communication interface shall enable the EMCS operator to remotely control and monitor lighting from a EMCS operator workstation. Control features and monitoring points displayed locally at lighting panel shall be available through the EMCS.

C. Standard BACnet objects shall be provided as follows:

1. Read/write the normal or after hours schedule state for the room
2. Read the detection state of each occupancy sensor
3. Read the aggregate occupancy state of the room
4. Read/write the On/Off state of loads
5. Read/write the dimmed light level of loads
6. Activate a preset scene for the room
7. Read/write day and night setpoints
8. Read the current light level, in foot-candles, from interior and exterior photosensors and photocells
9. Set daylight sensor operating mode (Enable/Disable)
10. Read/write wall switch lock status

D. BACnet object information shall be available for the following daylighting sensor objects, based on the specific photocell's settings:

1. Light level
2. Photocell Inhibiting
3. Day and night setpoints
4. Off time delay
5. On and off setpoints
6. Up to three zone setpoints
7. Operating mode- on/off, and dimming

E. Network bridge shall automatically create standard BACnet objects for selected devices to allow any BACnet-compliant BAS to include lighting control and power monitoring features as provided by the devices on each local network. BACnet objects will be created for the addition or replacement of any given device for the installed life of the system. Products requiring that an application-specific point database be loaded to create or map BACnet objects are not acceptable. Systems not capable of providing BACnet data for control devices via a dedicated BACnet Device ID and physical MS/TP termination per room are not acceptable.

PART 3 EXECUTION

A. EMCS GRAPHICS

Section 261116: Secondary Unit Substations

PART 1 GENERAL

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. ABB Control, Inc
2. Cooper Industries, Inc.; Cooper Power Systems Division
3. Cutler-Hammer
4. GE Electrical Distribution & Control
5. Siemens Energy & Automation, Inc
6. Square D; Schneider Electric

PART 3 EXECUTION

Section 261200: Medium-Voltage Transformers

PART 1 GENERAL

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Acme Electric Corporation; Power Distribution Products Division
2. Cooper Industries; Cooper Power Systems Division
3. Eaton Cutler-Hammer
4. Federal Pacific Transformer Company; Division of Electro-Mechanical Corp
5. GE Electrical Distribution & Control
6. Hammond Manufacturing; Transformer Group
7. Kuhlman Electric Corporation
8. Pauwels Transformers
9. Pioneer Transformers
10. Siemens Energy & Automation, Inc
11. Square D; Schneider Electric
12. Uptegraff, R. E. Mfg. Co
13. Virginia Transformer Corp
14. Sorgel

15. Sola/Hevi-Duty

B. EXECUTION

Section 261300: Medium-Voltage Switchgear

PART 1 GENERAL

PART 2 PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Eaton
2. GE Electrical Distribution & Control
3. Square D; Schneider Electric

PART 3 EXECUTION

3.01 AUTOMATIC THROWOVER CONTROL SCHEME

A. Sequence of Operation:

1. If Service #1 is selected as the preferred service, Breaker 52M1 will be closed and Breaker 52M2 will be open. Switchboard will be supported by Service #1.
2. If Service #2 is selected as the preferred service, Breaker 52M2 will be closed and Breaker 52M1 will be open. Switchboard will be supported by Service #2.
3. If Service #1 is selected as the preferred service, and Service #1 fails with Service #2 available and Breaker 52M1 not tripped due to a fault (bell alarm lockout) proceed as follows:
   a. After an adjustable time delay (1.5- 15 seconds) trip Breaker 52M1.
   b. Once Breaker 52M1 is open, close Breaker 52M2. Note that this is an open transition transfer with no paralleling.
   c. Continue to operate entire switchboard on Service #2.
4. If Service #1 is selected as the preferred service, Step "3" has occurred, and Service #1 returns to service, proceed as follows:
   a. Initiate an adjustable time delay (6- 60 minutes).
   b. Upon expiration of the time delay trip Breaker 52M2.
   c. After an adjustable time delay (.2-60 seconds) close Breaker 52M1.
   d. System is restored to normal.
5. Service #2 is selected as the preferred service, and Service #2 fails with Service #1 available and Breaker 52M2 not tripped due to a fault (bell alarm lockout), proceed as follows:
   a. After an adjustable time delay (1.5- 15 seconds) trip Breaker 52M2.
   b. Once Breaker 52M2 is open, close Breaker 52M1. Note that this is an open transition transfer with no paralleling.
   c. Continue to operate entire Switchboard on Service #1.
6. If Service #2 is selected as the preferred service, step "5" has occurred and Service #2 returns to service, proceed as follows:
   a. Initiate an adjustable time delay (6- 60 minutes).
   b. Upon expiration of the time delay trip Breaker 52M1.
   c. After an adjustable time delay (.2- 60 seconds) close Breaker 52M2.
   d. System is restored to normal.
7. Remote service equipment shutdown. (86 relay)

a. In case of an emergency, the service equipment main circuit breakers 52 MI and 52 M2, to be remotely disconnected and to remain in open position until manually reset locally by a trained electrician. Remote indicator lights shall be located at outside entrance to switchgear room to indicate when the (86 relay) is engaged.

B. Additional Features:

1. Provide bell alarm lockouts such that upon a fault in the distribution bus, both main breakers shall be given trip signals and locked out from closing until reset.
2. Provide electrical interlocks to ensure that only one of the two main breakers can be closed at the same time.
3. A manual/auto selector switch to completely disable the automatic throwover scheme.
4. A time delay bypass switch on retransfer to normal to allow immediate return to normal configuration upon restoration of the failed transformer (momentary contact).
5. A selector switch to advise the automatic throwover scheme as to which transformer is preferred.
6. Provide a control power transfer scheme. Control power transformers shall be connected on the line side of each secondary main breaker and the scheme shall automatically transfer to the source that is available to supply control power to the switchboard.
7. Provide control switches for Breakers 52M1 and 52M2.
8. Provide pilot lights for the following conditions:
   a. Automatic mode
   b. Manual mode (flashing)
   c. Breaker 52M1 open
   d. Breaker 52M1 closed
   e. Breaker 52M1 trip
   f. Breaker 52M2 open
   g. Breaker 52M2 closed
   h. Breaker 52M2 trip
   i. Service #1 preferred
   j. Service #2 preferred
   k. Service #1 available
   l. Service #2 available
   m. Switchboard on alternate transformer (flashing)
   n. Remote indicators outside of main switchgear electrical room
      1. Remote disconnect engaged
      2. M1 open
      3. M2 open
9. Push to test feature on all pilot lights
10. Dry contact relay outputs for the following conditions:
    a. Manual-auto switch-auto
    b. Manual-auto switch-manual
    c. Switchboard on alternate service
    d. Alternate service unavailable
    e. Preferred service failed
    f. Breaker 52M1 tripped (bell alarm)
    g. Breaker 52M2 tripped (bell alarm)
    h. Outage on switchboard
    i. Control power failed

11. All necessary relays, selector switches, pilot lights (except for potential transformers and control transformers) and other components for the automatic throwover and emergency remote service equipment shutdown scheme shall be located in a cubicle shown on the drawings.
12. Mount all control switches and pilot lights on the cubicle door such that they are accessible from outside. Provide suitable nameplates for all devices.
13. Provide a complete relay schedule listing all relays and controls as well as a complete circuit operation description. Indicate in detail the operation of all relays and contacts for all contingencies.
14. All device numbering should conform to ANSI/IEEE Standards.
15. Breakers 52M1 and 52M2:
16. Provide the following features and accessories on Breakers 52M1 and 52M2 to interface with the automatic throwover control scheme:
    a. All auxiliary contacts required for the operation of the automatic throwover and emergency remote service equipment shutdown control scheme.
    b. Four spare sets of Form "C" (normally open/normally closed auxiliary contacts)

C. 120 volt electric operators. Note that these breakers will be operated by relay logic. Do not provide local (at breaker) push buttons or controls. In addition, make provisions to block local manual closing to prevent override of interlocking scheme.

Section 262200: Low-Voltage Transformers

PART 1 GENERAL

PART 2 PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Manufacturers: Match existing equipment in the vicinity, if applicable. Subject to compliance with requirements, provide products by one of the following:

1. Eaton Electrical Inc.; Cutler-Hammer Products
2. General Electric Company
3. Square D; Schneider Electric
4. Powersmiths

B. Winding material:

1. Transformers: Copper windings required

C. Energy Efficiency for Transformers Rated 15 kVA and Larger:

1. Complying with NEMA TP 1, Class 1 efficiency levels

D. Insulation Class: 220 deg C, UL-component-recognized insulation system with a maximum of 80 deg C rise above 40 deg C ambient temperature.

E. Low-Sound-Level Requirements: Maximum sound levels shall be as follows:

1. 1 to 5 kVA: 40dB
2. 6 to 25 kVA: 45dB
3. 26 to 150 kVA: 53dB
4. 151 to 225 kVA: 58dB
5. 226 to 300 kVA: 58dB
6. 301 to 500 kVA: 63dB

PART 3 EXECUTION

3.01 INSTALLATION

A. Install transformers level and plumb on a concrete base with vibration-dampening supports. Locate transformers away from corners and not parallel to adjacent wall surface. Wall-mounted and structure-mounted transformers are also allowed depending on size and weight.

B. Nameplates: Engraved, laminated-plastic or metal nameplate for each distribution and buck-boost transformer, mounted with corrosion-resistant screws.

3.02 ADJUSTING

A. Record transformer secondary voltage at each unit for at least 48 hours of typical occupancy period. Adjust transformer taps to provide optimum voltage conditions at secondary terminals. Optimum is defined as not exceeding nameplate voltage plus 10 percent and not being lower than nameplate voltage minus 3 percent at maximum load conditions. Submit recording and tap settings as test results.

3.03 TESTING

A. Infrared Scanning: Two months after Substantial Completion, perform an infrared scan of transformer connections.

1. Use an infrared-scanning device designed to measure temperature or detect significant deviations from normal values. Provide documentation of device calibration.
2. Perform two (2) follow-up infrared scans of transformers, one at four months and the other at 11 months after Substantial Completion.

B. Prepare a certified report identifying transformer checked and describing results of scanning. Include notation of deficiencies detected, remedial action taken, and scanning observations after remedial action.

Section 262300: Low-Voltage Switchgear

PART 1 GENERAL

1.01 QUALITY ASSURANCE

A. Factory Testing and Witness Testing:

1. The following tests shall be performed at the factory and shall be witnessed by the Engineer of Record and DEN Project Manager, or their duly authorized representative:
   a. A complete visual inspection of the equipment, both internally and externally.
   b. A complete test of all automatic transfer schemes including all operation and failure modes.
   c. A complete test of all control panels and controls including dry contact outputs.
   d. Verification of proper operation of all metering.
   e. Verify mechanical operation; interlocks and interchangeability of selected breakers.
2. The testing outlined above shall be performed only on one main switchgear. In order to perform such testing, all breakers shall be shipped to the switchboard factory and installed in their respective cubicles in a completely assembled Distribution Section.
3. Test 208 volt and /or 480 volt, 3-phase power sources shall be connected to the incoming side of each secondary main such that the sources may be individually applied and removed to completely simulate and test all features of the distribution sections.
4. Submit to the DEN Project Manager ninety (90) calendar days prior to scheduled testing all test procedures for approval and notify the DEN Project Manager four (4) weeks duration of the tests.

B. Source Limitations: Obtain switchgear through one source from a single manufacturer.

1.02 PROJECT CONDITIONS

A. Installation Pathway: Remove and replace building components and structures to provide pathway for moving switchgear into place.

Ensure that design drawings conform to description below; maximum dimensions and equipment clearances should be depicted to ensure proper fit within the room/space. Designer shall coordinate equipment dimensions with the basis of design manufacturer.

B. Product Selection for Restricted Space: Drawings indicate maximum dimensions for switchgear, including clearances between switchgear and adjacent surfaces and other items. Comply with indicated maximum dimensions.

PART 2 PRODUCTS

2.01 LOW-VOLTAGE SWITCHGEAR

A. Manufacturers: Match existing manufacturer in the immediate area, if applicable. Subject to compliance with requirements, provide products by one of the following:

1. Eaton Electrical Inc.; Cutler-Hammer Business Unit
2. General Electric Company; GE Consumer & Industrial- Electrical Distribution
3. Square D; a brand of Schneider Electric

PART 3 EXECUTION

3.01 INSTALLATION

A. Equipment Mounting: Install switchgear on concrete base, 4-inch nominal thickness.

B. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.

C. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.

D. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

E. Install anchor bolts to elevations required for proper attachment to switchgear.

3.02 IDENTIFICATION

A. Mimic Bus: Continuous mimic bus, arranged in single-line diagram format, using symbols and lettered designations consistent with approved mimic-bus diagram.

1. Mimic-bus segments coordinated with devices in switchgear sections to which applied, to produce a concise visual presentation of principal switchgear components and connections.
2. Medium: Painted graphics, as selected by DEN Project Manager.
3. Color: Contrasting with factory-finish background; Black.

Section 262313: Paralleling Low-Voltage Switchgear

PART 1 GENERAL

1.01 QUALITY ASSURANCE

A. Factory Testing and Witness Testing:

1. The following tests shall be performed at the factory and shall be witnessed by the Engineer of Record and DEN Project Manager, or their duly authorized representative:
   a. A complete visual inspection of the equipment, both internally and externally.

b. A complete test of all automatic transfer schemes including all operation and failure modes.

c. A complete test of all control panels and controls including dry contact outputs.

d. Verification of proper operation of all metering.

e. Verify mechanical operation; interlocks and interchangeability of selected breakers.

2. The testing outlined above shall be performed only on one main switchgear. In order to perform such testing, all breakers shall be shipped to the switchboard factory and installed in their respective cubicles in a completely assembled Distribution Section.

3. Test 208 volt and /or 480 volt, 3-phase power sources shall be connected to the incoming side of each secondary main such that the sources may be individually applied and removed to completely simulate and test all features of the distribution sections.

4. Submit to the DEN Project Manager ninety (90) calendar days prior to scheduled testing all test procedures for approval and notify the DEN Project Manager four (4) weeks duration of the tests.

B. Source Limitations: Obtain switchgear through one source from a single manufacturer.

1.02 PROJECT CONDITIONS

A. Installation Pathway: Remove and replace building components and structures to provide pathway for moving switchgear into place.

Ensure that design drawings conform to description below; maximum dimensions and equipment clearances should be depicted to ensure proper fit within the room/space. Designer shall coordinate equipment dimensions with the basis of design manufacturer.

B. Product Selection for Restricted Space: Drawings indicate maximum dimensions for switchgear, including clearances between switchgear and adjacent surfaces and other items. Comply with indicated maximum dimensions.

PART 2 PRODUCTS

2.01 PARALLELING SWITCHGEAR

A. Manufacturers: Match existing manufacturer in the immediate area, if applicable. Subject to compliance with requirements, provide products by one of the following:

1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
2. General Electric Company; GE Consumer & Industrial- Electrical Distribution.
3. Square D; a brand of Schneider Electric.

PART 3 EXECUTION

3.01 INSTALLATION

A. Equipment Mounting: Install switchgear on concrete base, 4-inch nominal thickness.

B. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.

C. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.

D. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

E. Install anchor bolts to elevations required for proper attachment to switchgear.

Section 262413: Switchboards

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Product Data: For each type of switchboard, overcurrent protective device, transient voltage suppression device, ground-fault protector, accessory, and component indicated. Include dimensions and manufacturers' technical data on features, performance, electrical characteristics, ratings, accessories, and finishes.

1. Include data substantiating that materials comply with requirements.

B. Shop Drawings: For each switchboard and related equipment.

1. Include dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment. Show tabulations of installed devices, equipment features, and ratings.
2. Detail enclosure types for types other than NEMA 250, Type 1.
3. Detail bus configuration, current, and voltage ratings.
4. Detail short-circuit current rating of switchboards and overcurrent protective devices.
5. Include descriptive documentation of optional barriers specified for electrical insulation and isolation.
6. Detail utility company's metering provisions with indication of approval by utility company.
7. Detail features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.
8. Include time-current coordination curves for each type and rating of overcurrent protective device included in switchboards. Include selectable ranges for each type of overcurrent protective device.
9. Include detailed coordination study to achieve selective coordination for all emergency systems.
10. Include diagram and details of proposed mimic bus.
11. Include schematic and wiring diagrams for power, signal, and control wiring.

1.02 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Potential Transformer Fuses: No fewer than two (2) of each size and type.
2. Control-Power Fuses: No fewer than two (2) of each size and type.
3. Fuses and Fusible Devices for Fused Circuit Breakers: No fewer than three (3) of each size and type.
4. Fuses for Fused Switches: No fewer than three (3) of each size and type.
5. Fuses for Fused Power-Circuit Devices: No fewer than three (3) of each size and type.
6. Indicating Lights: No less than one (1) of each size and type.

1.03 QUALITY ASSURANCE

A. Source Limitations: Obtain switchboards, overcurrent protective devices, components, and accessories from single source from single manufacturer.

Ensure that design drawings conform to description below; maximum dimensions and equipment clearances should be depicted to ensure proper fit within the room/space. Designer shall coordinate equipment dimensions with the basis of design manufacturer.

B. Product Selection for Restricted Space: Drawings indicate maximum dimensions for switchboards including clearances between switchboards and adjacent surfaces and other items. Comply with indicated maximum dimensions.

1.04 PROJECT CONDITIONS

A. Installation Pathway: Remove and replace access fencing, doors, lift-out panels, and structures to provide pathway for moving switchboards into place.

1.05 COORDINATION

A. Coordinate layout and installation of switchboards and components with other construction that penetrates walls or is supported by them, including electrical and other types of equipment, raceways, piping, encumbrances to workspace clearance requirements, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

B. Coordinate sizes and locations of concrete bases with actual equipment provided. Concrete, reinforcement, and formwork requirements are specified in Division 3.

PART 2 PRODUCTS

2.01 SWITCHBOARDS

A. Manufacturers: Match existing manufacturer in the immediate area, if applicable. Subject to compliance with requirements, provide products by one of the following:

1. Eaton Electrical Inc.; Cutler-Hammer Business Unit
2. General Electric Company; GE Consumer & Industrial- Electrical Distribution
3. Square D; a brand of Schneider Electric

PART 3 EXECUTION

3.01 INSTALLATION

A. Equipment Mounting: Install switchboards on concrete base, 4-inch nominal thickness.

B. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.

C. For supported equipment, install anchor bolts that extend through concrete base and anchor into structural concrete floor.

D. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

E. Install anchor bolts to elevations required for proper attachment to switchboards.

3.02 IDENTIFICATION

A. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.

B. Switchboard Nameplates: Label each switchboard compartment with a nameplate.

C. Device Nameplates: Label each disconnecting and overcurrent protective device and each meter and control device mounted in compartment doors with a nameplate.

3.03 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain switchboards, overcurrent protective devices, instrumentation, and accessories, [and to use and reprogram microprocessor-based trip, monitoring, and communication units].

B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 262416: Panelboards

PART 1 GENERAL

1.01 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Keys: Two (2) spares for each type of panelboard cabinet lock.
2. Circuit Breakers Including GFCI and Ground Fault Equipment Protection (GFEP) Types: Two (2) spares for each panelboard.
3. Fuses for Fused Switches: Equal to 10 percent of quantity installed for each size and type, but no fewer than three of each size and type.
4. Fuses for Fused Power-Circuit Devices: Equal to 10 percent of quantity installed for each size and type, but no fewer than three of each size and type.

1.02 QUALITY ASSURANCE

A. Source Limitations: Obtain panelboards, overcurrent protective devices, components, and accessories from single source from single manufacturer.

Ensure that design drawings conform to description below; maximum dimensions and equipment clearances should be depicted to ensure proper fit within the room/space. Designer shall coordinate equipment dimensions with the basis of design manufacturer.

B. Product Selection for Restricted Space: Drawings indicate maximum dimensions for panelboards including clearances between panelboards and adjacent surfaces and other items. Comply with indicated maximum dimensions.

1.03 COORDINATION

A. Coordinate layout and installation of panelboards and components with other construction that penetrates walls or is supported by them, including electrical and other types of equipment, raceways, piping, encumbrances to workspace clearance requirements, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

1.04 WARRANTY

A. Special Warranty: for Surge Suppression Devices Manufacturer's standard form in which manufacturer agrees to repair or replace transient voltage suppression devices that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Minimum five (5) years from date of Substantial Completion.

PART 2 PRODUCTS

2.01 GENERAL REQUIREMENTS FOR PANELBOARDS

A. Manufacturers: Match existing manufacturer in the immediate area, if applicable. Subject to compliance with requirements, provide products by one of the following:

1. Eaton Electrical Inc.; Cutler-Hammer Business Unit.
2. General Electric Company; GE Consumer & Industrial- Electrical Distribution.
3. Square D; a brand of Schneider Electric.

B. Enclosures shall be at least 20 inches wide made from galvanized sheet steel in the sizes and NEMA types indicated, code gauge, minimum 16-gauge thickness

C. Panelboard Short-Circuit Current Rating: Fully rated to interrupt symmetrical short-circuit current available at terminals.

D. General Requirements for Branch Circuit Panelboards:

1. Bolt-on type, heavy-duty, quick-make, quick-break, single- and multi-pole circuit breakers, of the types specified herein, shall be provided for each circuit with toggle handles that indicate when unit has tripped.
2. Circuit breakers shall be thermal magnetic type with common type handle for all multiple pole circuit breakers. Circuit breakers shall be minimum 100-ampere frame and up through 100-ampere trip sizes shall take up the same pole spacing. Circuit breakers shall be UL listed as Type SWD for lighting circuits.
   a. Circuit breaker handle locks shall be provided for all circuits that supply exit signs, emergency lights, energy management and control system (EMCS) panels and fire alarm panels.
   b. Main circuit breaker, when shown, shall be vertical mounted top or bottom as required. Chassis mounted reverse fed main circuit breaker is not acceptable.
3. Circuit breakers shall have a minimum interrupting rating of 10,000 amperes symmetrical at 240 volts and 14,000 amperes symmetrical at 480 volts.
4. Panelboards to be door in door construction so that there are no exposed hardware, and no tools are required for installation.

2.02 PANELBOARD SUPPRESSORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Current Technology; a subsidiary of Danahar Corporation
2. Eaton Electrical Inc.; Cutler-Hammer Business Unit
3. General Electric Company; GE Consumer & Industrial- Electrical Distribution
4. Liebert Corporation
5. Square D; a brand of Schneider Electric

PART 3 EXECUTION

3.01 INSTALLATION

A. Stub five 1-inch empty conduits from panelboard into accessible ceiling space or space designated to be ceiling space in the future. Stub five 1-inch empty conduits into raised floor space or below slab not on grade.

3.02 PANELBOARD SCHEDULE

A. Panelboards shall be furnished and equipped as follows, except as otherwise specified:

1. Manufacturer: 120/208V:277/480V:600- 1200A:
2. Cutler HammerPRL-1 PRL-2 PRL-3 or 4
3. Square-DNQOD NEHB I-LINE
4. GE NLAB NHB CCB

B. Panelboards may contain not more than one sub-feed breaker with ratings in excess of 100A, but less than 225A.

1. Distribution panelboard shall be scheduled where more than one sub-feed breaker rated in excess of 100A is required, and for any panelboard containing breakers with ratings of 225A or more.

3.03 IDENTIFICATION

A. Identify field-installed conductors, interconnecting wiring, and components.

B. Create a directory to indicate installed circuit loads; incorporate Owner's final room designations. Clearly identify the load on each circuit, equipment serviced and location. Revise directory to reflect circuiting changes required to balance phase loads. In all instances where a contractor installs or disconnects a circuit in any panel, a newly typed panel schedule shall be furnished. The new or revised panel schedule shall have the date and Contractor's name typed at the top right hand corner. Obtain approval before installing. Use a computer or typewriter to create directory; handwritten directories are not acceptable.

C. Panelboard Nameplates: Label each panelboard with a nameplate complying with requirements for identification specified in Section "Identification for Electrical Systems."

D. Device Nameplates: Label each branch circuit device in distribution panelboards with a nameplate complying with requirements for identification specified in Section "Identification for Electrical Systems."

3.04 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Perform the following infrared scan tests and inspections, preparing a written report for each including test results:
   a. Initial Infrared Scanning: After Substantial Completion, but not more than sixty (60) days after Final Acceptance, perform an infrared scan of each panelboard. Remove front panels so joints and connections are accessible to portable scanner.
   b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each panelboard eleven (11) months after date of Substantial Completion.
   c. Instruments and Equipment:
      1. Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

Section 262416.16: Electronically Operated Circuit-Breaker Panelboards

PART 1 GENERAL

1.01 MAINTENANCE MATERIAL SUBMITTALS

A. Electrically Operated, Molded-Case Circuit Breakers: Equal to <Insert number> percent of amount installed [for each size indicated], but no fewer than <Insert number>.

1.02 WARRANTY

A. Special Warranty: Manufacturer agrees to repair or replace transient voltage suppression devices that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Minimum five (5) years from date of Substantial Completion.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Products: Match existing manufacturer in the immediate area, if applicable. Subject to compliance with requirements, provide one of the following:

1. Eaton Corporation, Cutler-Hammer Business Unit; Pow-R-Command Control Panelboards.

2. General Electric Company, GE Consumer & Industrial- Electrical Distribution; A-Series Control Panels.
3. Square D, a brand of Schneider Electric; PowerLink G3 Control Panelboards.

B. Source Limitations: Obtain electrically operated circuit breakers and power distribution components from single manufacturer.

PART 3 EXECUTION

3.01 PANELBOARDS

A. Electronically operated, circuit-breaker panelboards may contain remotely operated circuit breakers and standard branch circuit breakers specified in Section 262416 “Panelboards.”

B. Panelboard Short-Circuit Current Rating: Fully rated to interrupt the full short-circuit current available at terminals.

C. Material: Hard-drawn copper, 98 percent conductivity.

D. Main and Neutral Lugs: Mechanical type.

E. Ground Lugs and Bus-Configured Terminators: Mechanical type.

3.02 CONTROL NETWORK

A. Compliance with ASHRAE 135: Controllers shall support serial MS/TP and Ethernet IP communications and shall be able to communicate directly via BAS RS-485 serial networks and Ethernet 10Base-T networks as a native device.

3.03 PANELBOARD INSTALLATION

A. Mounting Height: 78 inches to top of trim above finished floor unless otherwise indicated.

3.04 IDENTIFICATION

A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 260553 “Identification for Electrical Systems.”

B. Create a directory to indicate loads served by each circuit; incorporate Owner's final room designations. Obtain approval before installing. Use a computer or typewriter to create directory; handwritten directories are unacceptable.

C. Panelboard Nameplates: Label each panelboard with a nameplate complying with requirements for identification specified in Section 260553 “Identification for Electrical Systems.”

3.05 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain control modules.

B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 262419: Motor-Control Centers

PART 1 GENERAL

1.01 QUALITY ASSURANCE

A. The Manufacturer of this equipment shall have been pre-qualified by Owner.

B. When requested by the DEN Project Manager, an acceptable list of installations with similar equipment shall be provided demonstrating compliance with this requirement.

1.02 PROJECT CONDITIONS

Ensure that design drawings conform to description below; maximum dimensions and equipment clearances should be depicted to ensure proper fit within the room/space. Designer shall coordinate equipment dimensions with the basis of design manufacturer.

A. Product Selection for Restricted Space: Drawings indicate maximum dimensions for MCCs, including clearances between MCCs and adjacent surfaces and other items.

B. Field Measurements: Verify existing dimensions by field measurements. Verify clearances and locate obstructions within manufacturing and installation tolerances of enclosed bus assemblies.

1.03 COORDINATION

A. Coordinate sizes and locations of concrete bases. Cast anchor-bolt inserts into bases.

B. Coordinate features of MCCs, installed units, and accessory devices with remote pilot devices and control circuits to which they connect.

C. Coordinate features, accessories, and functions of each MCC, each controller, and each installed unit with ratings and characteristics of supply circuits, motors, required control sequences, and duty cycle of motors and loads.

1.04 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace TVSS, VFCs that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Minimum five (5) years from date of Substantial Completion.

PART 2 PRODUCTS

2.01 MANUFACTURED UNITS

A. Motor Control Centers shall be as designed or approved equal and shall have been tested in a high power laboratory to prove adequate mechanical and electrical capabilities. All major components shall have been individually design tested and guaranteed by the manufacturer. Wiring shall be as per specified NEMA standards.

B. Manufacturers: Match existing manufacturer in the immediate area, if applicable. Subject to compliance with requirements, provide products by one of the following:

1. ABB; Control Products
2. Eaton Electrical Inc.; Cutler-Hammer Business Unit
3. General Electric Company; GE Industrial Systems
4. Rockwell Automation, Inc.; Allen-Bradley Brand
5. Siemens Energy & Automation, Inc.; Power Distribution
6. Square D; a brand of Schneider Electric

C. The type of enclosure shall be in accordance with NEMA Standards for Type 1A with gasketed doors. All enclosing sheet steel, wireways and unit doors shall be gasketed.

D. Provide a shunt trip device for the main circuit breaker in the motor control center. The shunt trip shall operate on 120v A.C. Power for the shunt trip shall be provided by the control power for the transformer and capacitor trip device specified under the incoming line metering section of the specification. Undervoltage and single-phase protection for the motor control center shall be provided when the microprocessor metering module output contact energizes the shunt trip of the main circuit breaker.

2.02 FUNCTIONAL FEATURES

A. Description: Modular arrangement of main units, controller units, control devices, feeder-tap units, instruments, metering, auxiliary devices, and other items mounted in vertical sections of MCC.

B. Controller Units: Combination controller units.

1. Install units up to and including Size 3 on drawout mountings with connectors that automatically line up and connect with vertical-section buses while being racked into their normal, energized positions.
2. Equip units in Type B and Type C MCCs with pull-apart terminal strips for external control connections.

C. Feeder-Tap Units: Through 225-A rating shall have drawout mountings with connectors that automatically line up and connect with vertical-section buses while being racked into their normal, energized positions.

D. Future Units: Compartments fully bused and equipped with guide rails or equivalent, ready for insertion of drawout units.

E. Spare Units: Installed in compartments indicated “spare.”

2.03 INCOMING MAINS

A. MCCB: Comply with UL 489, with interrupting capacity to meet available fault currents.

1. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
2. Adjustable Instantaneous-Trip Circuit Breakers: Magnetic trip element with front-mounted, field-adjustable trip setting.
3. Electronic trip circuit breakers with rms sensing; field-replaceable rating plug or field-replicable electronic trip; and the following field-adjustable settings:
   a. Instantaneous trip.
   b. Long- and short-time pickup levels.
   c. Long- and short-time, time adjustments.
   d. Ground-fault pickup level, time delay, and I2t response.
4. Current-Limiting Circuit Breakers: Frame sizes 400 A and smaller; let-through ratings less than NEMA FU 1, RK-5.
5. Integrally Fused Circuit Breakers: Thermal-magnetic trip element with integral limiter-style fuse listed for use with circuit breaker; trip activation on fuse opening or on opening of fuse compartment door.

PART 3 EXECUTION

3.01 HARMONIC ANALYSIS STUDY

A. Perform a harmonic analysis study to identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze [possible] [designated] operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) at the defined PCC to specified levels.

B. Prepare a harmonic analysis study report complying with IEEE 399 and NETA Acceptance Testing Specification.

3.02 INSTALLATION

A. Coordinate layout and installation of MCCs with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

B. Floor-Mounting Controllers: Install MCCs on 4-inch nominal thickness concrete base. Comply with requirements for concrete base.

1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.
2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
4. Install anchor bolts to elevations required for proper attachment to supported equipment.

3.03 IDENTIFICATION

A. Comply with requirements in Section 260553 “Identification for Electrical Systems” for identification of MCC, MCC components, and control wiring.

1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
2. Label MCC and each cubicle with engraved nameplate.
3. Label each enclosure-mounted control and pilot device.
4. Mark up a set of manufacturer's connection wiring diagrams with field-assigned wiring identifications and return to manufacturer for inclusion in Record Drawings.

B. Operating Instructions: Frame printed operating instructions for MCCs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of MCCs.

3.04 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Perform the following infrared (thermographic) scan tests and inspections and prepare reports:
   a. Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each multipole enclosed controller. Remove front panels so joints and connections are accessible to portable scanner.
   b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each multipole enclosed controller 11 months after date of Substantial Completion.
   c. Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

3.05 DEMONSTRATION

A. Engage a factory-authorized service representative to assist with training of Owner's maintenance personnel to adjust, operate, and maintain enclosed controllers, and to use and reprogram microprocessor-based, reduced-voltage, solid-state controllers.

B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

C. Train Owner's maintenance personnel on procedures and schedules for starting up and shutting down, troubleshooting, servicing, and maintaining equipment and schedules.

3.06 COMMISSIONING

A. Infrared Scanning: Two (2) months after Substantial Completion, perform an infrared scan of bus assembly including joints and plug-in units.

1. Use an infrared scanning device designed to measure temperature or detect significant deviations from normal values. Provide documentation of device calibration.
2. Perform two follow-up infrared scans of bus assembly, one at four (4) months and the other at eleven (11) months after Substantial Completion.

Section 262500: Enclosed Bus Assemblies

PART 1 GENERAL

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Calvert Company (The)
2. Eaton Electrical Inc.; Cutler-Hammer Products
3. Electric Busway Corp
4. General Electric Company; Electrical Distribution & Control Division
5. Siemens Energy & Automation, Inc
6. Square D; Schneider Electric

2.02 ENCLOSED BUS ASSEMBLIES

A. Bus Materials: Current-carrying copper conductors, fully insulated with Class 130C insulation except at joints; plated surface at joints.

PART 3 EXECUTION

3.01 INSTALLATION

A. Support bus assemblies independent of supports for other elements such as equipment enclosures at connections to panelboards and switchboards, pipes, conduits, ceilings, and ducts.

B. Install a concrete curb at least 4 inches high around bus-assembly floor penetrations.

C. Coordinate bus-assembly terminations to equipment enclosures to ensure proper phasing, connection, and closure.

D. Install bus-assembly, plug-in units. Support connecting conduit independent of plug-in unit.

3.02 FIELD QUALITY CONTROL

A. Infrared Scanning: Two months after Substantial Completion, perform an infrared scan of bus assembly including joints and plug-in units.

1. Use an infrared-scanning device designed to measure temperature or detect significant deviations from normal values. Provide documentation of device calibration.
2. Perform two (2) follow-up infrared scans of bus assembly, one at four (4) months and the other at eleven (11) months after Substantial Completion.
3. Prepare a certified report identifying bus assembly checked and describing results of scanning. Include notation of deficiencies detected, remedial action taken, and scanning observations after remedial action.

Section 262419: Motor-Control Centers

PART 1 GENERAL

1.01 QUALITY ASSURANCE

A. The Manufacturer of this equipment shall have been pre-qualified by Owner.

B. When requested by the DEN Project Manager, an acceptable list of installations with similar equipment shall be provided demonstrating compliance with this requirement.

1.02 PROJECT CONDITIONS

Ensure that design drawings conform to description below; maximum dimensions and equipment clearances should be depicted to ensure proper fit within the room/space. Designer shall coordinate equipment dimensions with the basis of design manufacturer.

A. Product Selection for Restricted Space: Drawings indicate maximum dimensions for MCCs, including clearances between MCCs and adjacent surfaces and other items.

B. Field Measurements: Verify existing dimensions by field measurements. Verify clearances and locate obstructions within manufacturing and installation tolerances of enclosed bus assemblies.

1.03 COORDINATION

A. Coordinate sizes and locations of concrete bases. Cast anchor-bolt inserts into bases.

B. Coordinate features of MCCs, installed units, and accessory devices with remote pilot devices and control circuits to which they connect.

C. Coordinate features, accessories, and functions of each MCC, each controller, and each installed unit with ratings and characteristics of supply circuits, motors, required control sequences, and duty cycle of motors and loads.

1.04 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace TVSS, VFCs that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Minimum five (5) years from date of Substantial Completion.

PART 2 PRODUCTS

2.01 MANUFACTURED UNITS

A. Motor Control Centers shall be as designed or approved equal and shall have been tested in a high power laboratory to prove adequate mechanical and electrical capabilities. All major components shall have been individually design tested and guaranteed by the manufacturer. Wiring shall be as per specified NEMA standards.

B. Manufacturers: Match existing manufacturer in the immediate area, if applicable. Subject to compliance with requirements, provide products by one of the following:

1. ABB; Control Products
2. Eaton Electrical Inc.; Cutler-Hammer Business Unit
3. General Electric Company; GE Industrial Systems
4. Rockwell Automation, Inc.; Allen-Bradley Brand
5. Siemens Energy & Automation, Inc.; Power Distribution
6. Square D; a brand of Schneider Electric

C. The type of enclosure shall be in accordance with NEMA Standards for Type 1A with gasketed doors. All enclosing sheet steel, wireways and unit doors shall be gasketed.

D. Provide a shunt trip device for the main circuit breaker in the motor control center. The shunt trip shall operate on 120v A.C. Power for the shunt trip shall be provided by the control power for the transformer and capacitor trip device specified under the incoming line metering section of the specification. Undervoltage and single-phase protection for the motor control center shall be provided when the microprocessor metering module output contact energizes the shunt trip of the main circuit breaker.

2.02 FUNCTIONAL FEATURES

A. Description: Modular arrangement of main units, controller units, control devices, feeder-tap units, instruments, metering, auxiliary devices, and other items mounted in vertical sections of MCC.

B. Controller Units: Combination controller units.

1. Install units up to and including Size 3 on drawout mountings with connectors that automatically line up and connect with vertical-section buses while being racked into their normal, energized positions.
2. Equip units in Type B and Type C MCCs with pull-apart terminal strips for external control connections.

C. Feeder-Tap Units: Through 225-A rating shall have drawout mountings with connectors that automatically line up and connect with vertical-section buses while being racked into their normal, energized positions.

D. Future Units: Compartments fully bused and equipped with guide rails or equivalent, ready for insertion of drawout units.

E. Spare Units: Installed in compartments indicated "spare."

2.03 INCOMING MAINS

A. MCCB: Comply with UL 489, with interrupting capacity to meet available fault currents.

1. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
2. Adjustable Instantaneous-Trip Circuit Breakers: Magnetic trip element with front-mounted, field-adjustable trip setting.
3. Electronic trip circuit breakers with rms sensing; field-replaceable rating plug or field-replicable electronic trip; and the following field-adjustable settings:
   a. Instantaneous trip
   b. Long- and short-time pickup levels
   c. Long- and short-time, time adjustments
   d. Ground-fault pickup level, time delay, and I2t response
4. Current-Limiting Circuit Breakers: Frame sizes 400 A and smaller; let-through ratings less than NEMA FU 1, RK-5.
5. Integrally Fused Circuit Breakers: Thermal-magnetic trip element with integral limiter-style fuse listed for use with circuit breaker; trip activation on fuse opening or on opening of fuse compartment door.

PART 3 EXECUTION

3.01 HARMONIC ANALYSIS STUDY

A. Perform a harmonic analysis study to identify the effects of nonlinear loads and their associated harmonic contributions on the voltages and currents throughout the electrical system. Analyze [possible] [designated] operating scenarios, including recommendations for VFC input filtering to limit TDD and THD(V) at the defined PCC to specified levels.

B. Prepare a harmonic analysis study report complying with IEEE 399 and NETA Acceptance Testing Specification.

3.02 INSTALLATION

A. Coordinate layout and installation of MCCs with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

B. Floor-Mounting Controllers: Install MCCs on 4-inch nominal thickness concrete base. Comply with requirements for concrete base.

1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base.
2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete base and anchor into structural concrete floor.
3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
4. Install anchor bolts to elevations required for proper attachment to supported equipment.

3.03 IDENTIFICATION

A. Comply with requirements in Section 260553 “Identification for Electrical Systems” for identification of MCC, MCC components, and control wiring.

1. Identify field-installed conductors, interconnecting wiring, and components; provide warning signs.
2. Label MCC and each cubicle with engraved nameplate.
3. Label each enclosure-mounted control and pilot device.
4. Mark up a set of manufacturer's connection wiring diagrams with field-assigned wiring identifications and return to manufacturer for inclusion in Record Drawings.

B. Operating Instructions: Frame printed operating instructions for MCCs, including control sequences and emergency procedures. Fabricate frame of finished metal, and cover instructions with clear acrylic plastic. Mount on front of MCCs.

3.04 FIELD QUALITY CONTROL

A. Tests and Inspections:

1. Perform the following infrared (thermographic) scan tests and inspections and prepare reports:
   a. Initial Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each multipole enclosed controller. Remove front panels so joints and connections are accessible to portable scanner.
   b. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each multipole enclosed controller 11 months after date of Substantial Completion.
   c. Instruments and Equipment: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.

3.05 DEMONSTRATION

A. Engage a factory-authorized service representative to assist with training of Owner's maintenance personnel to adjust, operate, and maintain enclosed controllers, and to use and reprogram microprocessor-based, reduced-voltage, solid-state controllers.

B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

C. Train Owner's maintenance personnel on procedures and schedules for starting up and shutting down, troubleshooting, servicing, and maintaining equipment and schedules.

3.06 COMMISSIONING

A. Infrared Scanning: Two (2) months after Substantial Completion, perform an infrared scan of bus assembly including joints and plug-in units.

1. Use an infrared scanning device designed to measure temperature or detect significant deviations from normal values. Provide documentation of device calibration.
2. Perform two follow-up infrared scans of bus assembly, one at four (4) months and the other at eleven (11) months after Substantial Completion.

Section 262500: Enclosed Bus Assemblies

PART 1 GENERAL

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Calvert Company (The)
2. Eaton Electrical Inc.; Cutler-Hammer Products
3. Electric Busway Corp
4. General Electric Company; Electrical Distribution & Control Division
5. Siemens Energy & Automation, Inc
6. Square D; Schneider Electric

2.02 ENCLOSED BUS ASSEMBLIES

A. Bus Materials: Current-carrying copper conductors, fully insulated with Class 130C insulation except at joints; plated surface at joints.

PART 3 EXECUTION

3.01 INSTALLATION

A. Support bus assemblies independent of supports for other elements such as equipment enclosures at connections to panelboards and switchboards, pipes, conduits, ceilings, and ducts.

B. Install a concrete curb at least 4 inches high around bus-assembly floor penetrations.

C. Coordinate bus-assembly terminations to equipment enclosures to ensure proper phasing, connection, and closure.

D. Install bus-assembly, plug-in units. Support connecting conduit independent of plug-in unit.

3.02 FIELD QUALITY CONTROL

A. Infrared Scanning: Two months after Substantial Completion, perform an infrared scan of bus assembly including joints and plug-in units.

1. Use an infrared-scanning device designed to measure temperature or detect significant deviations from normal values. Provide documentation of device calibration.
2. Perform two (2) follow-up infrared scans of bus assembly, one at four (4) months and the other at eleven (11) months after Substantial Completion.
3. Prepare a certified report identifying bus assembly checked and describing results of scanning. Include notation of deficiencies detected, remedial action taken, and scanning observations after remedial action.

Section 262713: Electricity Metering

PART 1 GENERAL

1.01 DEFINITIONS

A. BACNet: Communications protocol for Building Automation and Control (BAC) network based on ASHRAE, ANSI, and ISO 16484-5 standard protocol.

B. BACNet MS/TP: RS-485 based communication layer defined in the BACNet protocol.

C. EMCS: Energy Management Control System. DEN centralized, networked supervision and control system for HVAC control and energy management. The EMCS consists of multiple systems, including Honeywell Enterprise Buildings Integrator (EBI), and Johnson Controls Metasys.

1.02 ACTION SUBMITTALS

A. Product Data: For each type of product indicated.

1. For BACNet-connected devices, submit BACNet Protocol Implementation Conformance (PIC) Statement with product data.

B. Shop Drawings: For Owner electricity-metering equipment.

1. Include floor plans depicting EMCS system connections, associated existing devices, and conduit pathways.
2. Graphics Modifications: For EMCS. Include all new or modified graphics pages, submitted in PDF format. All vector-based graphics shall be scaled to match display resolution on a typical PC workstation, and all bitmap graphics shall be shown at full resolution.
3. Qualification Data: For factory-authorized EMCS programmer.

1.03 QUALITY ASSURANCE

A. Personnel performing modifications to the EMCS shall be trained and factory-authorized by the EMCS software developer, with minimum of (5) years of experience programming and operating the software that comprises the DEN EMCS.

1.04 PROJECT CONDITIONS

A. Interruption of Existing Electrical Service: Do not interrupt electrical service to facilities occupied by Owner or others unless permitted under the following conditions and then only after arranging to provide temporary electrical service according to requirements indicated:

1. Any power outages necessary to install or test electrical systems and/or equipment shall be coordinated with Denver International Airport Maintenance/Engineering.
2. A written shutdown request form shall be submitted to and approved by the DEN Project Manager two (2) weeks prior to the shutdown.
3. Do not proceed with interruption of electrical service without DEN Project Manager's written permission.

1.05 SOFTWARE SERVICE AGREEMENT

Edit to suit project.

A. Technical Support: Beginning with Substantial Completion, provide software support for all EMCS modifications associated with this project for [two (2)] <Insert number> years.

PART 2 PRODUCTS

2.01 EQUIPMENT FOR ELECTRICITY METERING BY OWNER OR TENANT

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Meters
   a. Eaton: PXM350

b. Schneider ElectricUSA, Inc: PowerLogic METSEEM3560
c. Gauge Systems eGauge Pro EG4030
d. <Insert product>

2. BACNet IP routers
a. LOYTEC electronics: LIP-ME201C

B. General Requirements for Owner's/Tenant's Meters:

1. All submetering equipment shall be compatible with the existing BACNet MS/TP EMCS network.
2. Meters shall have an accuracy of [0.2] [0.5] percent of reading, complying with requirements in ANSI C12.20.
3. Identification: Provide self-adhesive label on front of meter specifying the metered panel name and/or tenant name, as directed by the DEN Project Manager. Comply with requirements in Section 260553 "Identification for Electrical Systems."
4. Sensors: Current-sensing type, with current or voltage output, selected for optimum range and accuracy for meters indicated for this application. Provide sensors from the same manufacturer as the associated meter and obtained from the same source.

Split-core sensor is the default installation method. Split-core CTs may be installed in the switchboard or panelboard without disturbing feeder connections but is less accurate. Solid-core sensors, where required, necessitate electrical outages for servicing and must be approved in writing by the DEN Project Manager prior to specifying for use. Solid-core CTs are usually installed in a separate compartment or in a separate current-transformer cabinet. Coordinate with Drawings.

a. Type: Split core
b. No splices are allowed in CT circuit wiring

5. Match signal to EMCS input and arrange to convey the instantaneous, integrated, demand level measured by meter to provide data for processing and possible programmed demand control action by destination system.

2.02 RS-485 BACNET MS/TP DATA TRANSMISSION CABLE

A. Description: UL Listed C(UL) US CMP or FPLP (UL).

1. Shielded, Plenum-rated
2. (3) 22AWG insulated conductors with 24AWG bare copper drain
3. Overall jacket color: Blue
4. Conductor colors: Black/White/Blue
5. Marking: "POWER METERING CONTROL SYSTEM"

PART 3 EXECUTION

3.01 INSTALLATION OF OWNER OR TENANT METERING

Retain Article below for projects where owner metering is provided. These requirements refer to the drawings. The engineer shall ensure that metering location and installation requirements are clearly depicted on the drawings to complement this specification. The engineer shall include existing conditions, where applicable, on the drawings. Existing conditions depicted shall include existing MMU enclosure as well as other equipment in the room, to allow for adequate understanding of required scope of work.

A. Install DIN-mountable meter modules in the associated electrical room as indicated on the drawings.

B. Owner meters shall be installed in new or existing enclosures, as indicated on drawings. Enclosures shall comply with this Section, and the requirements in Section 260533 "Raceways and Boxes for Electrical Systems."

1. New metering modules may be installed in existing metering enclosures, where existing enclosures meet the requirements of this Section, and where sufficient extra space is available for such installation.
2. All metering equipment shall be installed on DIN rail, with cables neatly trained within cable management pathways inside each enclosure.
3. Maintain physical separation between line-voltage cabling (sensor leads and voltage reference leads) and BACNet MS/TP cabling throughout.
4. Provide dedicated raceway system for BACNet cabling.

C. Install current sensors in accordance with manufacturer's recommendations. Verify correct sensor orientation.

D. Single unit meters shall be connected to the EMCS using BACnet MS/TP cabling.

1. BACnet MS/TP connection requires a router to transmit BACnet protocol over IP. Contractor shall provide and integrate DEN approved router in places where a metering router is not available.
2. All BACnet MS/TP meters must be integrated into BACnet over IP routers dedicated to metering purposes only. No mixing with other equipment such as HVAC controllers is allowed.
3. Install (2) RS-485 BACnet MS/TP transmission cables as specified in this Section, in a single raceway, routed from the meter to the BACnet termination point as indicated on the drawings.

E. Multicard meters are allowed in congested places with multiple loads. These meters can utilize either EMCS connection via BACnet MS/TP or direct BACnet over IP network connection type.

F. Provide printed labels on each cable, at each end and at every junction and pull box. Labels shall indicate the metered load name as follows:

1. Tenants: Tenant name.
2. Lighting loads: Lighting control panel name and circuit number, where appropriate.
3. Motors, pumps, and other labeled equipment: Equipment name.
4. Panelboards and distribution panels (non-tenant): Panelboard or distribution panel name.
5. Final terminations and addressing shall be fully coordinated with the DEN EMCS administrator.

G. Verify proper values per load conditions are displayed in EMCS. Document at least two different load points showing matching electrical panel usage and graphical output in EMCS in both Metasys and EBI as applicable per the following section. Document system voltage, amperes, and load.

3.02 SOFTWARE MODIFICATIONS

A. Engage the services of a factory-authorized programmer to provide modifications to the EMCS to accommodate the addition of owner meters as required.

B. Provide graphics pages depicting metering data for each meter. Tenant meters must be integrated graphically into two separate systems: maintenance system (Metasys) and billing system (EBI). Owner meters must be integrated into the maintenance system (Metasys) only. Coordinate with the DEN Project Manager and DEN EMCS Administrator for graphics standards. All meters in EBI must have automatically generating billing reports available on monthly bases. The usage statistics must be available via the web access of the Energy Builder. The following graphical status points must be included in Metasys and EBI:

Integration Point	Units	Status	Command	Trend
Total Energy Consumed (3 phases combined)	kWh	Yes	No	Yes
Total demand (3 phases combined)	kW	Yes	No	Yes

Integration Point	Units	Status	Command	Trend
Total demand (per phase)	kW	Yes	No	Yes
Voltage (per phase)	V	Yes	No	Yes
Current (per phase)	A	Yes	No	Yes
Peak demand (3 phases combined)	kW	Yes	No	No
Real time power factor	N/A	Yes	No	Yes

Section 262726: Wiring Devices

PART 1 GENERAL

1.01 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Floor Service-Outlet Assemblies: One for every 10, but no fewer than two.
2. Poke-Through, Fire-Rated Closure Plugs: One for every five floor service outlets installed, but no fewer than two.
3. TVSS Receptacles: One for every 10 of each type installed, but no fewer than two of each type.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Manufacturers' Names: Shortened versions (shown in parentheses) of the following manufacturers' names are used in other Part 2 articles:

1. Cooper Wiring Devices; Division of Cooper Industries, Inc. (Cooper)
2. Hubbell Incorporated; Wiring Device-Kellems (Hubbell)
3. Leviton Mfg. Company Inc. (Leviton)
4. Pass & Seymour/Legrand (Pass & Seymour)

B. Source Limitations: Obtain each type of wiring device and associated wall plate from single source from single manufacturer.

2.02 GENERAL WIRING-DEVICE REQUIREMENTS

A. Devices that are manufactured with modular plug-in connectors are prohibited.

2.03 FINISHES

A. Device Color:

1. All wiring Devices Connected to Normal Power System: Gray
2. All wiring Devices Connected to Emergency Power System: Red
3. SPD Devices: Blue.
4. Isolated-Ground Receptacles: Orange

2.04 WALL PLATES

A. Single and combination types shall match corresponding wiring devices.

1. Plate-Securing Screws: Metal with head color to match plate finish.
2. Material for Finished Spaces: Type 302/304 stainless steel 0.04 inch thick.

3. Material for Unfinished Spaces: Type 302/304 stainless steel 0.04 inch thick.
4. Material for Damp Locations: Type 302/304 stainless steel 0.04 inch thick.
5. Plastic covers will not be accepted.

B. Wet-Location, Weatherproof Cover Plates: NEMA 250, complying with Type 3R, weather-resistant, Type 302/304 satin stainless steel with lockable cover.

2.05 FLOOR SERVICE FITTINGS

A. Service Plate: Round, 302/304 stainless steel with satin finish.

1. Plastic covers will not be accepted.

B. Protrusion above finished floor: 0.15", maximum.

2.06 POKE-THROUGH ASSEMBLIES

1. Protrusion above finished floor: 0.15", maximum.

PART 3 EXECUTION

3.01 INSTALLATION

A. Coordination with Other Trades:

1. Protect installed devices and their boxes. Do not place wall finish materials over device boxes and do not cut holes for boxes with routers that are guided by riding against outside of boxes.
2. Keep outlet boxes free of plaster, drywall joint compound, mortar, cement, concrete, dust, paint, and other material that may contaminate the raceway system, conductors, and cables.
3. Install device boxes in brick or block walls so that the cover plate does not cross a joint unless the joint is troweled flush with the face of the wall.
4. Install wiring devices after all wall preparation, including painting, is complete.

B. Conductors:

1. Do not strip insulation from conductors until right before they are spliced or terminated on devices.
2. Strip insulation evenly around the conductor using tools designed for the purpose. Avoid scoring or nicking of solid wire or cutting strands from stranded wire.
3. The length of free conductors at outlets for devices shall meet provisions of NFPA 70, Article 300, without pigtails.
4. Existing Conductors:
   a. Cut back and pigtail or replace all damaged conductors.
   b. Straighten conductors that remain and remove corrosion and foreign matter.
   c. Pigtailing existing conductors is permitted, provided the outlet box is large enough.

C. Device Installation:

1. Mounting heights shall be as shown on drawings. If no heights noted, standard device heights above finished floor are as follows:
   a. Wall switches: 48"
   b. Convenience receptacles: 18"

D. Receptacle Orientation:

1. Ground pin down, Sideways mounted outlets shall have the ground pin to the left.
2. Install ground pin of vertically mounted receptacles down, and on horizontally mounted receptacles install ground pin to the right.

E. Device Plates: Do not use oversized or extra-deep plates. Repair wall finishes and remount outlet boxes when standard device plates do not fit flush or do not cover rough wall opening.

F. Dimmers:

1. Install dimmers within terms of their listing, with appropriate altitude de-rating.
2. Verify that dimmers used for fan speed control are listed for that application.

G. Adjust locations of floor service outlets to suit arrangement of partitions and furnishings.

3.02 IDENTIFICATION

A. Identify each receptacle with panelboard identification and circuit number. Use hot, stamped, or engraved machine printing with black filled lettering on face of plate, and durable wire markers or tags inside outlet boxes.

3.03 FIELD QUALITY CONTROL

A. Line voltage: Acceptable range is 114v to 126v.

B. Percent voltage drop under a 15 amp load not to exceed 5 percent.

Section 262813: Fuses

PART 1 GENERAL

1.01 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fuses: Equal to ten (10) percent of quantity installed for each size and type, but no fewer than three (3) of each size and type.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Cooper Bussmann
2. Edison; a brand of Cooper Bussmann
3. Ferraz Shawmut, Inc
4. Littelfuse, Inc
5. General Electric
6. Gould
7. Reliance

Section 263100: Photovoltaic Collectors

PART 1 GENERAL

1.01 INFORMATION SUBMITTALS

A. Roofing system inspection: Provide a third-party roofing inspection of the completed roofing installation prior to performing any work, or locating any materials on the roof, related to the rooftop photovoltaic collects installation. Third party inspector shall be independent of the photovoltaic collectors manufacture and installers and shall certify that all recommendations and requirements of the roofing manufacture related to the inspection have been followed and completed.

1. Obtain roofing manufacturer’s written recommendations, requirements, and forms from the manufacturer of the roofing system. Forms to be filled out shall include an Overburden form.

1.02 WARRANTY

A. Manufacturer's special materials and workmanship warranty: Manufacturer agrees to repair or replace components of the PV system that fail in materials or workmanship withing the specified warranty period:

1. Warranty Period: Minimum five years from date of substantial completion.

PART 2 PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. PV Modules:
   a. Hanwha Q-cells
   b. SunPower
   c. Jinko Solar
   d. LG
   e. Panasonic
2. Inverters:
   a. SolarEdge
   b. Or approved equal as long as the inverters and power optimizers are from the same manufacturer.
3. Power Optimizer:
   a. SolarEdge
   b. Or approved equal as long as the inverters and power optimizers are from the same manufacturer.
4. Mounting:
   a. SolarDock

B. The photovoltaic system has been designed to the specified manufacturer's electrical and physical characteristics. Should substitutions be made the contractor shall bear full responsibility for the installation, coordination, and operation of the system as well as any engineering and redesign costs.

2.02 PERFORMANCE REQUIREMENTS

A. NRTL (Nationally Recognized Testing Laboratory) Listing: Entire assembly shall be listed and labeled by a qualified testing agency acceptable to authorities having jurisdiction for electrical and fire safety, Class A, according to UL 1703.

B. FM approved for NFPA 70, Class 1, Division 2, Group C and Group D hazardous locations.

2.03 SYSTEM DESCRIPTION

A. Grid-Tied PV System:

1. Connected via a utility meter to the electrical utility.

B. Cell Materials: Monocrystalline

1. c-Si

C. Module Construction:

1. Nominal size: 39.5 inches wide by 79.3 inches long.
2. Weight: TBD by pv module selected.

D. Front Panel: Antireflective coating glass.

E. Bypass Diode Protection: Internal.

F. Junction Box:

1. Size: Per manufactured module
2. Manufactured fully potted, vandal resistant, with bypass diodes
3. IP code: IP67
4. Flammability Test: UL 1703

G. Output Cabling:

1. Manufactured quick, multi-connect, polarized connectors.
2. Series Fuse Rating: 20A.

2.04 CAPACITIES AND CHARACTERISTICS

A. PV Module Minimum Electrical Characteristics:

1. Rated open circuit voltage (Voc): 49 Vdc
2. Maximum System Voltage: 1500 Vdc.
3. Maximum power at Voltage (Vpm): 41.04 Vdc.
4. Short-Circuit Temperature Coefficient: +.04 %/K.
5. Short-Circuit Current (Isc): 10.24 A.
6. Rated Operation Current (Imp): 9.75 A.
7. Maximum Power at STC (Pmax): 400 W.

B. Additional Electrical Characteristics:

1. Series Fuse Rating: 20A.
2. Module Efficiency: 19 percent or greater.
3. Temperature Cycling Range:-49 to +85 deg C.
4. Wind load/Snow load: 2400 Pa/5400 PA.

2.05 MODULE FRAMING

A. PV laminates mounted in anodized extruded-aluminum frames.

1. Entire assembly UL listed for electrical and fire safety, Class A, according to UL 1703, complying with IEC 61215.
2. Frame strength exceeding requirements of certifying agencies in subparagraph above.

2.06 ARRAY CONSTRUCTION

A. Framing:

1. Material: Mill grade aluminum and stainless steel.

B. Flat-Roof Mounting:

1. No roof penetrations
2. Self-ballasting
3. Tilt Angle: 25 degrees
4. Azimuth Angle: 145 degrees
5. Wind-tunnel tested to 150 mph wind
6. Service Life: 25 years
7. Freestanding system

C. The existing or new roof must be protected per manufacturers guidelines.

2.07 INVERTER

A. Inverter Electrical Characteristics:

1. Maximum Recommended PV input power: TBD
2. Maximum Input Current: 40 Adc
3. Number of String Inputs: 3
4. Nominal Output Voltage: 480 Vac
5. Maximum Output Current: 40A
6. CEC Weighted Efficiency: 98.5 percent
7. CEC Night Tare Loss: <4 W
8. DC/AC Terminal Range (AWG): TBD
9. NEMA 3R Protection Rating

B. Operating Conditions:

1. All parts of the systems must meet or exceed environmental conditions as described in Section 260400: Basic Electrical Requirements.

C. Enclosure:

1. NEMA 250, type 3R.
2. Cooling Methods:
   a. Fan convection cooling.
3. Protective Functions:
   a. AC over/under voltage
   b. AC over/under frequency
   c. Ground over current
   d. Over temperature
   e. AC and DC overcurrent
   f. DC over voltage
4. Standard liquid crystal display, four lines, 20 characters, with user display on/off toggle switch.
   a. All consideration must be taken to not have the screen face direct sunlight in the final inverter configuration.
5. Weight: 99.5 lb
6. Dimensions: 30.5 by 12.5 by 10.5 inches

D. Disconnects:

1. Low voltage disconnects
2. Low voltage reconnects
3. High temperature disconnects
4. High temperature re-connects

E. Regulatory Approvals:

1. IEEE 1547.1
2. IEEE 1547.3
3. UL 1741

2.08 SYSTEM OVERCURRENT PROTECTION

A. Combiner Box:

1. Fuses: per plan
2. Circuit Breakers: per plan

2.09 DC POWER OPTIMIZER

A. Electrical Characteristics:

1. Maximum Power per string: 15,300w
2. Maximum System Voltage: 1,000 Vdc
3. Rated Input DC power: 860W
4. Maximum Input Voltage: 60 Vdc
5. Weighted Efficiency: 98.6%.
6. Maximum Short Circuit Current: 22 A dc
7. Maximum Output Current: 18 A dc
8. Maximum Output Voltage: 85Vdc

B. Operating Conditions:

1. Operating Temperature Range:-40 to +185 deg F/-40 to +85 deg C
2. Relative Humidity: 0-100%

C. Characteristics:

1. Maximum String Length: 30 power optimizers/ 60 PV modules
2. Enclosure: IP68 / NEMA 6P
3. Dimensions: 5 x 6.61 x 2.32 in/ 128 x 168 x 59 mm
4. Weight: 2.34 lb/ 1064 gr

D. Standards Compliance:

1. PV Rapid Shutdown System: NEC 2017
2. Safety: IEC62109-1 (class II safety), UL1741
3. Material: UL-94 (5-VA), UV Resistant

2.10 UTILITY PRODUCTION METER

A. Metering arrangement, materials, and installation shall be furnished by the contractor as required by Xcel Energy

2.11 PV RAPID SHUTDOWN EOP PUSH BUTTON

A. Standards Compliance:

1. PV Rapid Shutdown System: per latest edition of the NEC

PART 3 EXECUTION

3.01 EXAMINATION

A. Examine substrate areas and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Do not begin installation until mounting surfaces have been properly prepared.

C. If preparation of mounting surfaces is the responsibility of another installer, notify DEN Project Manager of unsatisfactory preparation before proceeding.

D. Examine modules and array frame before installation. Reject modules and arrays that are wet, moisture damaged, or mold damaged.

E. Examine roofs, supports, and supporting structures for suitable conditions where PV system will be installed.

F. Proceed with installation only after unsatisfactory conditions have been corrected.

G. Ensure marking and labeling adheres to the applicable NEC sections.

3.02 INSTALLATION

A. Install photovoltaic system in strict accordance with manufacturer's written instructions.

B. Install components according to National Electric Code Article 690 and National Electric Code Article 705.

C. Size DC source circuit conductors. Ampacity calculations must take into account appropriate de-ratings as required. All conductors in the system are subject to a 125% National Electric Code (NEC) de-rate, and all DC source circuit conductors and overcurrent devices must include an additional 125% de-rate for solar radiation enhancement. Appropriate temperature de-ratings for conductors used in module junction boxes must be considered for peak module operating temperatures, as well as de-ratings for instances where more than three current carrying conductors are enclosed in a conduit.

D. Voltage drop in array DC source circuits shall be limited to no more than 2% due to losses in conductors and no more than 5% including losses through all fuses, blocking diodes and termination points.

E. All overcurrent devices shall have trip ratings no greater than the de-rated ampacity of the conductors that it protects.

F. All series connected strings of modules must include a series fuse as required by UL and National Electric Code (NEC) to prevent wiring to other system components. Parallel connections of modules in individual source circuits are not permitted.

G. All series connected strings of modules must also include a blocking diode to prevent reverse currents. These diodes shall have a low voltage drop to meet the requirements above and have voltage and current ratings (at temperature) at least twice the open-circuit voltage and short-circuit ratings of the source circuits.

H. Parallel strings of modules shall have individual string circuit protection as specified in Article 690.9 (A) of the National Electric Code.

I. The PV modules shall be grounded in compliance with Article 690 of the National Electric Code.

J. Tighten all mounting hardware and electrical terminations to manufacturer recommended torque specifications.

K. Wiring located on the exterior of the roof must be secured or protected in such a way that will not lead to abrasion or damage of the wire due to wind, ice, or precipitation.

L. All terminations must use listed box terminal or compression type connections. Twist on wire splices, crimped, soldered, or taped connections are not permitted for the field-installed wiring. Proper torque specifications should be provided for all of the required field connections.

M. All module frames, mounting/support structures, metal enclosures, panelboards, and inverters shall be provided with connections for bonding to a common grounding conductor and terminating at the ground rod at the utility service entrance point. Under no circumstances should multiple connections to ground be specified for current carrying conductors in the system.

N. Provide the mechanical hardware for mounting the photovoltaic arrays, and all other hardware required for assembling the photovoltaic modules and support structures. All hardware/fasteners shall be stainless steel to prevent corrosion. Provide all hardware for mounting the inverters, including uni strut framing support and painted fire-resistant plywood backer panels.

O. The PV array, including modules, hardware, and attachments shall be able to withstand wind loads as indicated in the specifications and must comply with all existing local and national codes. If there is a discrepancy/conflict the more stringent value shall apply.

P. Spacing between individual modules shall be kept to a minimum and shall create a uniform array appearance.

Q. Where possible, all mechanical hardware, conduit, junction boxes and other equipment shall be concealed beneath and/or behind the array or concealed within the support structure framing.

R. Coordinate monitoring equipment installation with communications cabling contractor and customer.

S. Install components plumb and level, accurately fitted, free from distortion or defects.

T. Exercise care when installing components so as not to damage finish surfaces. Temporarily store panels on roof on top of protective material such as plywood and in accordance with the roofing manufacturers and installer's written recommendations.

U. Remove all protective masking from material immediately after installation.

V. Coordinate conduit penetrations in roof with Roofing Contractor to maintain roof warranty.

3.03 IDENTIFICATION

A. Install permanent plaques, labels, and mapping for identification as required by the National Electric Code and by local electric utility.

3.04 CONNECTIONS

A. Ground equipment according to Section 26 05 26 – Grounding and Bonding for Electrical Systems.

B. PV modules shall be grounded in compliance with Article 690 of the National Electric Code (NEC).

3.05 FIELD QUALITY CONTROL

A. Perform tests and inspections with the assistance of a factory-authorized service representative.

B. PV components will be considered defective if they do not pass tests and inspections.

C. Prepare test and inspection reports.

3.06 SOFTWARE MODIFICATIONS

A. Engage the services of a factory-authorized programmer to provide modifications to the EMCS to accommodate the addition of owner photovoltaic systems as required.

B. Provide graphics pages depicting data for each inverter. Owner photovoltaic systems must be integrated into the maintenance system (Metasys) only. Coordinate with the DEN Project Manager and DEN EMCS Administrator for graphics standards. The following graphical status points must be included in Metasys for each inverter:

Integration Point	Units	Status	Command	Trend
Trouble Arm	True/False	Yes	No	No
Total Energy Produced	kWh	Yes	No	Yes
Total Power Output (3 phases combined)	kW	Yes	No	Yes
Peak Power Output (3 phases combined)	kW	Yes	No	Yes
Output Voltage (per phase)	V	Yes	No	Yes
Output Current (per phase)	A	Yes	No	Yes

Section 263213: Engine Generators

PART 1 GENERAL

1.01 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fuses: One (1) for every ten (10) of each type and rating, but no fewer than one of each.
2. Indicator Lamps: Two (2) for every six (6) of each type used, but no fewer than two (2) of each.
3. Filters: One set each of lubricating oil, fuel, and combustion-air filters.

1.02 QUALITY ASSURANCE

A. Installer Qualifications: Manufacturer's authorized representative who is trained and approved for installation of units required for this Project.

1. Maintenance Proximity: Not more than four (4) hours' normal travel time from Installer's place of business to Project site.
2. Engineering Responsibility: Preparation of data for vibration isolators and seismic restraints of engine skid mounts, including Shop Drawings, based on testing and engineering analysis of manufacturer's standard units in assemblies similar to those indicated for this Project.

B. Manufacturer Qualifications: A qualified manufacturer. Maintain, within 200 miles of Project site, a service center capable of providing training, parts, and emergency maintenance repairs.

C. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a member company of the International Electrical Testing Association or is a nationally recognized testing laboratory (NRTL), and that is acceptable to authorities having jurisdiction.

1. Testing Agency's Field Supervisor: Person currently certified by the International Electrical Testing Association or the National Institute for Certification in Engineering Technologies to supervise on-site testing specified in Part 3.

D. Source Limitations: Obtain packaged generator sets and auxiliary components through one source from a single manufacturer.

E. Diesel engines for generators shall comply with EPA Tier 4.

1.03 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of packaged engine generators and associated auxiliary components that fail in materials or workmanship within specified warranty period.

B. Warranty Period: Minimum five (5) years from date of Substantial Completion. Warranty shall cover unlimited replacement of emergency generator modules during the warranty period.

1. Provide minimum three (3) year prorata warranty on engine-starting batteries.

1.04 MAINTENANCE SERVICE

A. Initial Maintenance Service: Beginning at Substantial Completion, provide twelve (12) months' full maintenance by skilled employees of manufacturer's designated service organization. Include quarterly exercising to check for proper starting, load transfer, and running under load. Include routine preventive maintenance as recommended by manufacturer and adjusting as required for proper operation. Provide parts and supplies same as those used in the manufacture and installation of original equipment.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Caterpillar; Engine Div
2. Onan/Cummins Power Generation; Industrial Business Group
3. or approved equal

Section 263353: Static Uninterruptible Power Supply

PART 1 GENERAL

PART 2 PRODUCTS

2.01 UPS SYSTEMS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Eaton Corporation
2. Liebert Corporation
3. MGE UPS SYSTEMS
4. Mitsubishi Electric Automation, Inc
5. Toshiba Corporation; Industrial Systems

Section 263533: Power Factor Correction Equipment

PART 1 GENERAL

1.01 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. Fuses: One (1) for every three (3) of each type and rating, but no fewer than three of each.

1.02 COORDINATION

A. Coordinate sensor-communication module package with data network and with monitoring equipment specified in Section 260913 "Electrical Power Monitoring and Control" for successful transmission and remote readout of remote monitoring data specified in this Section.

B. Coordinate with all construction trades and equipment manufacturers the location and installation of equipment supplied under this Section.

1.03 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace capacitor-bank components that fail in materials or workmanship within specified warranty period.

1. Warranty Period: Minimum five (5) years from date of Substantial Completion.

PART 2 PRODUCTS

2.01 CAPACITORS, GENERAL

A. Construction: Multiple capacitor cells or elements, factory wired in three-phase groups and mounted in metal enclosures.

2.02 AUTOMATIC POWER FACTOR CORRECTION UNITS

A. Buses: Plated copper

PART 3 EXECUTION

3.01 INSTALLATION

A. Install freestanding equipment on concrete bases.

B. Connect remote monitoring communication module to electrical power monitoring and control data network through appropriate network interface unit.

C. Identify components according to Section 260553 “Identification for Electrical Systems.”

Section 263600: Transfer Switches

PART 1 GENERAL

1.01 QUALITY ASSURANCE

A. Manufacturer Qualifications: Maintain a service center capable of providing training, parts, and emergency maintenance repairs within a response period of less than eight hours from time of notification.

B. Testing Agency Qualifications: An independent agency, with the experience and capability to conduct the testing indicated, that is a member company of the InterNational Electrical Testing Association or is a nationally recognized testing laboratory (NRTL) as defined by OSHA in 29 CFR 1910.7, and that is acceptable to authorities having jurisdiction.

1. Testing Agency's Field Supervisor: Person currently certified by the InterNational Electrical Testing Association or the National Institute for Certification in Engineering Technologies to supervise on-site testing specified in Part 3.

1.02 COORDINATION

A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases.

1.03 AUTOMATIC SEQUENCE OF OPERATION

A. Initiate adjustable Time Delay (1 to 6 seconds) set at 1 second to Engine start upon loss of normal source. If normal source returns before time delay times out no action will be taken. If normal source power fails to return before the time delay times out, a start signal will be sent to the emergency engine generator.

B. After the emergency engine generator is started, an adjustable time delay (0 to 5 minutes) set at 0 seconds, will start timing. If normal power returns during the timing of this time delay no action will be taken, and the engine generator will continue to run unloaded until the adjustable cool down time delay expires. If the commit to transfer is enabled, the switch will transfer to emergency even if normal power returns before the adjustable transfer to emergency time delay times out.

C. If the Automatic transfer switch transfers to emergency power, the transfer switch will monitor the normal source side to see when normal power returns. When normal power returns an adjustable (0 to 30 minutes) time delay set at 20 minutes, starts timing out before re-transfer back to the normal power source. If during the timing of this time delay normal power is lost, the timer will be reset when normal power returns. If the emergency generator fails during this time delay and normal power is available, the automatic transfer switch must transfer back to normal. Otherwise, normal power must be available for the full duration of the time delay.

D. After the automatic transfer switch transfers back to normal, an adjustable engine cool down timer (0 to 60 minutes) set at 10 minutes, will start timing. This allows the engine to run unloaded to cool down before shutting the engine down. If normal power fails during this time the automatic transfer switch will transfer to emergency after the transfer to emergency time delay times out and then resets all other time delays. If there is no failure of the normal power source during the cool down timer, the emergency engine generator set will shut down and the transfer switch is set for the next normal source power failure.

E. An in-phase monitor or a synchronizer should be used when transferring in either direction when both sources are available to prevent excessive inrush currents due to out-of-phase switching of large inductive loads.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. Caterpillar; Engine Div
2. Emerson; ASCO Power Technologies, LP
3. GE Zenith Controls
4. Onan/Cummins Power Generation; Industrial Business Group
5. Russelectric, Inc

B. Transfer Switches Using Molded-Case Switches or Circuit Breakers:

1. Eaton Electrical Inc.; Cutler-Hammer
2. GE Zenith Controls
3. Hubbell Industrial Controls, Inc

PART 3 EXECUTION

3.01 INSTALLATION

A. Floor-Mounting Switch: Anchor to floor by bolting.

1. Concrete Bases: 4 inches, reinforced, with chamfered edges. Extend base no more than 4 inches100 mm in all directions beyond the maximum dimensions of switch, unless otherwise indicated or unless required for seismic support. Construct concrete bases according to Section 260529 “Hangers and Supports for Electrical Systems.”

3.02 FIELD QUALITY CONTROL

A. Perform the following tests and inspections and prepare test reports.

1. The transfer switch manufacturer’s representative shall perform a startup test. The Contractor, DEN Project Manager and DEN Maintenance will witness the test. The test shall be conducted in accordance with the manufacturer’s recommendations. Operation of the Isolation Bypass Automatic Transfer Switch will be verified. This test will verify the interlocks in all positions and the automatic transfer operation to emergency and back to normal as well as the cool down function.

B. Infrared Scanning: After Substantial Completion, but not more than 60 days after Final Acceptance, perform an infrared scan of each switch. Remove all access panels so joints and connections are accessible to portable scanner.

1. Follow-up Infrared Scanning: Perform an additional follow-up infrared scan of each switch 11 months after date of Substantial Completion.
2. Instrument: Use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
3. Record of Infrared Scanning: Prepare a certified report that identifies switches checked and that describes scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

3.03 DEMONSTRATION

A. Engage a factory-authorized service representative to assist Contractor and train Owner's maintenance personnel to adjust, operate, and maintain transfer switches and related equipment as specified below. Refer to Section 017900 “Demonstration and Training.”

B. Coordinate this training with that for generator equipment.

1. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

Section 264113: Lightning Protection for Structures

PART 1 GENERAL

PART 2 PRODUCTS

PART 3 EXECUTION

3.01 INSTALLATION

A. When conductors are installed in CMU or concrete wall, they shall be installed in nonmetallic PVC raceway, Schedule 40, (minimum), or rigid steel when exposed below eight feet above finished floor or grade. Where steel conduit is used, follow Reference Standards and choke conduit on both ends. All bends shall have a minimum elbow radius of 8 inches. Nonmetallic conduit clamps shall be used on nonmetallic conduit.

B. Ground Loop: Install ground-level, potential equalization conductor and extend around the perimeter of area or item indicated.

1. Bury ground ring not less than 24 inches from building foundation.
2. Bond ground terminals to the ground loop.
3. Bond grounded building systems to the ground loop conductor within 12 feet of grade level.

C. Ground grid cable shall be a minimum of 2/0 cable.

D. Ground rods shall be placed on the ground loop at each change of direction and spaced not over 100 feet apart.

E. On spacings of not more than 100 feet, test wells, with accessible test leads, shall be provided to provide contact with the ground loop for future ground impedance testing. The test well shall have a hand-hole cover of appropriate traffic or aircraft rating.

F. Due to extensive cathodic protection of and isolation joints on all underground metal pipes at DEN, these systems shall be bonded to the lightning protection system on the building side only.

3.02 CORROSION PROTECTION

A. It is the intent of this section that only copper lightning protection system components be used. Where roofing system components exist that may be galvanically incompatible with copper lightning protection system components (such as galvalume parapet caps), the lighting protection system shall be designed and configured to prevent direct contact of the copper with such roofing component. Aluminum lightning protection components may be used only to protect aluminum surfaces or equipment where no UL Listed fittings exist to prevent direct contact of the lightning protection component with such surface.

B. Where galvanically incompatible metals are connected, use bi-metallic fittings. Where conditions exist that may cause deterioration or corrosion of conductors or other components, use components with suitable protective coatings, sleeves, spacers, or other UL listed fittings.

3.03 FIELD QUALITY CONTROL

A. Notify DEN Project Manager at least 48 hours in advance of inspection before concealing lightning protection components.

B. Test the ground resistance to earth of each ground rod prior to connection to the system and submit test results to the DEN Project Manager. Where the resistance to ground is over 5 ohms, specifically notify the DEN Project Manager.

C. Document all inspections on required UL inspection forms. One copy of each completed form shall be given to the DEN Project Manager.

D. On existing structures, if, due to pre-existing conditions beyond control of the Contractor, the UL Master Label cannot be obtained, then the Contractor shall obtain a UL "Letter of Findings" (inspection to NFPA 780). If the Letter of Findings is also not possible, also due only to pre-existing conditions, then all work shall nevertheless comply with all other portions of this Specification and Reference Standards.

Section 264200: Cathodic Protection

PART 1 GENERAL

1.01 SUMMARY

Edit to suit project.

A. Section includes passive cathodic protection systems that use **[magnesium] [zinc]** anodes to protect **[iron and steel piping] [and] [tanks]**.

B. Section includes impressed current systems, for use only with approval by DEN Project Manager.

C. The galvanic or sacrificial anode system provides protective current to metals by electrically coupling the metal to be protected with another metal that appears higher in the electromotive force series. This sets up a galvanic coupling, because the medium in which both metals are contained acts as an electrolyte. The metal of higher potential becomes the anode, and sacrificially corrodes to protect installations such as piping or tanks that act as the cathode. The return path for current is through an electrical connection between the anode and the cathode. When sufficient current flows through the electrolyte to suppress all local action currents on the protected metal, cathodic protection is complete. This type system requires no external power supply; it uses sacrificial anodes.

D. Denver International Airport prefers the application of sacrificial or galvanic corrosion protection systems over the use of impressed current system due to the density of infrastructures and the potential for interference corrosion. There will be localized situations where impressed current systems can be successfully installed and represent advantages over the use of sacrificial or galvanic systems. when this situation occurs, the designer should review the specifics with the DEN Project Manager and get their approval along with the DEN Engineering Design Manager's concurrence that an impressed current system is safe and applicable. Thereafter the designer and installer have the responsibility to design and install a system that will not create interference corrosion problems on any existing facilities. In fact, any alterations required to protect existing facilities from new impressed current systems are the responsibility of the systems designer and installation contractor.

E. The impressed current system employs the principle of providing direct current from an external source, such as provision of a rectifier or fuel driven direct current generator. The current is driven to ground through a ground bed (which consists of a group of anodes), and then drained from the anode bed to the metallic structures to be protected. This type of system, in a deep well fluidized ground bed configuration, shall be utilized as the main area wide cathodic protection system.

F. Impressed current systems are more difficult and dangerous to apply due to problems with stray current corrosion and are not preferred throughout the airport. the use of this type of system will require written approval by the airport project engineer in consultation with the DIA director of engineering or their representative. The installation will require a post construction stray current analysis and any resistance drainage bonds, and their maintenance shall be the responsibility of the impressed current system operator.

1.02 PERFORMANCE REQUIREMENTS

A. Sacrificial anode systems may be used only where current requirements are low. Minimum negative voltage potential between structure and Cu/CuSO4 reference electrode shall be 0.85 volts.

Edit to suit project.

B. Select anodes and accessories relevant to level of protection. Design anodes for an estimated life of forty (40) <Insert number> years before replacement. Provide a twenty (20) <Insert number> year design life for the deep ground bed system

C. The drawings are diagrammatic and indicate the general arrangement of electrical work. Locations are approximate and shall be subject to minor modifications as dictated by field conditions and as directed by DEN Project Manager.

D. Deliver sufficient current to the facilities and systems to be protected and distribute this current so that the criterion for cathodic protection is efficiently attained.

E. Minimize the interference currents on neighboring underground structures.

F. Provide adequate allowance for anticipated changes in current requirements with time.

G. Placement of anodes where the possibility of disturbance or damage is minimal.

H. The cathodic protection system shall protect all metallic surfaces presently being installed and providing for expansion capabilities for future installed items.

I. Provide monitoring and alarm system for protection of DG current generation.

J. Provide sufficient test stations to check the system's performance.

K. Cathodic protection shall be provided for, but not limited to the following structures:

1. Metallic pipelines
2. Metallic underground structures, i.e., tanks, vaults, etc
3. Grounding mats, rods, etc
4. Metallic structures in contact with earth

L. All systems protected shall be bonded and be electrically continuous.

M. All surfaces to be cathodically protected shall be coated in conformance to mechanical standards.

N. Stray currents will be avoided.

O. Contractor Responsibilities: The function of the cathodic protection system shall include the following:

1. Recognition of hazardous conditions prevailing at the site and the selection and specification of materials and installation practices in conformance with these standards and which will assure the safe installation and operation of the cathodic protection system.
2. Perform a pre engineering field survey consisting of determining or measuring the following characteristics of the electrolyte and the structures to be protected:
   a. Collect and compile soil tests with provision for future testing, as required.
   b. Resistivity of the electrolyte.
   c. Structure to electrolyte potential (if new installation, base requirement. on design calculations, field tests can only be run on existing structures).
   d. Cathodic protection current requirements.
   e. Electrolyte characteristics such as variations and water content of soils, salinity and oxygen content of water, and maximum and minimum temperature.
   f. Proximity of structure to be protected to other structures.

g. Compile characteristics of pipe coatings utilized.

h. Source of magnitude of stray currents including free electricity from electrical transmission lines and. strong RF fields, if any.

i. Locations of isolation between the protected structure and other metallic structures.

j. Locations of resistance bond stations (drain stations).

k. Electrical continuity test requirements for the metallic structures and lines that are to be protected, if available.

l. Locations of anode beds and rectifiers.

3. The design of cathodic protection system is for optimum economy of installation, maintenance, and operation.

4. Compliance with specification of materials and installation practices which will assure dependable operation throughout the intended operating life of the cathodic protection system.

5. Operation of a system is to minimize excessive protective currents or earth potential gradients, which can cause detrimental effects on pipe, coating, or neighboring buried or submerged metallic structures.

6. Direction of cooperative investigations to determine mutually satisfactory solution(s) of interference problems.

7. Coordinate with cathodic protection designers and installers involved in a common deep well ground bed system. to insure minimum interference currents between systems.

8. Prepare suitable drawings to designate the over all layout of the piping or other structures to be protected and the location of significant items of structure hardware, corrosion control test stations, electrical bonds, electrical insulators, and neighboring buried or submerged metallic structures.

9. Layout shop drawings shall be prepared for each impressed current cathodic protection installation, showing the details and location of the components of the cathodic protection system with respect to the protected structures and to major physical landmarks.

10. The locations of galvanic anode installations shall be recorded on drawings or in tabular form, with appropriate notes as to anode type, weight, spacing, depth, and backfill.

P. Impressed-Current Deep Ground Bed System:

1. An impressed current, deep ground bed, cathodic protection system shall be utilized for all protected structures within the area indicated on drawings. The area referred to as the “terminal corridor” shall include all protected structures around the terminal and parking structures, car rental areas, concourses, airport and airline support areas, air cargo facilities, airline maintenance areas, airline offices, fuel farm and other miscellaneous facilities within the terminal corridor area. The area referred to as the pipeline corridor shall include all pipelines and structures within its limits.

2. Basic electrical requirements for the impressed current system shall include the following using Cu/CuSO4 reference electrodes:

a. A negative potential of at least 0.85 volts with a normal negative potential of 1.0 volts measured between the structure and a reference electrode.

b. A polarization decay voltage shift of at least 0.10 volts, after the rectifier is turned off, between the structure and the reference electrode.

c. A negative voltage shift of at least 0.30 volts between the structure and reference electrode when the protective current is first applied.

1.03 CLOSEOUT SUBMITTALS

A. Post-Installation Report:

1. A report, prepared by the design consultant and contractor, shall be issued to the DEN Project Manager, which will include all data obtained, analysis of data, record drawings, an Operations and Maintenance Manual and any further recommendations.
2. All impressed current systems will be analyzed for stray current interference with any other buried metallic systems. If interferences are located they will be removed by the contractor using good corrosion engineering practices.

1.04 QUALITY ASSURANCE

A. The designer of the cathodic protection system shall be a personnel trained in cathodic protection sciences under a registered Professional Engineer with cathodic protection and corrosion prevention expertise or a NACE certified Corrosion Specialist. The design shall be signed and sealed by a Professional Engineer.

1.05 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace permanent reference electrodes that fail in materials or workmanship within specified warranty period.

Edit to suit project.

1. Warranty Period: Minimum forty (40) **<Insert number>** years for sacrificial anode system.
2. Warranty Period: Minimum twenty (20) **<Insert number>** years for deep ground bed system.

PART 2 PRODUCTS

2.01 PERMANENT REFERENCE ELECTRODES

A. The system shall be equipped with at least two reference electrodes for each rectifier, coper copper sulfate (Cu/CuSO4) suitable for direct burial. Electrode shall be guaranteed by supplier for min. forty (40) years' service in the installed environment. One electrode shall be installed in a location expecting minimum protection and the other in a location expecting maximum protection.

2.02 WIRE AND CABLE

A. Where several anodes are connected to one header cable, compute the allowable voltage drop in that cable. Select the cable size in accordance with standard electrical engineering practice. Directly buried conductors should be properly insulated to prevent current leakage, and of a sufficient size to prevent mechanical damage.

B. All lead wire conductors shall be exothermic welded at splices and to protected surfaces and sealed with a protective coating.

C. All cad welded pipeline leads will include two wires to the test stations to allow for the loss of one line during the life of the installation.

D. Splicing underground cables should be avoided where possible. Necessary splices be made with manufactured, UL. approved, splice kits.

E. The DC conductors shall be run in rigid conduits of a size large enough to accommodate 1/0 cable or #8 AWG cable to the anodes to a depth of at least 18" below grade. DC conductors below 18" may be run direct buried. All conduits shall be terminated in the ground with a plastic bushing.

F. The negative DC lead from the rectifier units shall be connected to the protected structure by an exothermic weld connection. The connection shall be coated with a heavy coat of coal tar enamel, or equal with a plastic backfill shield installed over that.

G. All underground pipe joints, except welded joints, shall be electrically bonded using a #2 AWG HMWPE insulated conductor, exothermic welded to each pipe section, and all component parts except bolts.

2.03 TEST STATIONS

A. Potential Stations:

1. This subject pertains to those situations where direct and uninterrupted surface contact to the soil surrounding the cathodically protected structure is not available. Examples include piping that is under concrete, piping that is below an environmental geomembrane, piping that is below coarse grade materials (such as gravel) that are not part of the electrolyte body, and above ground storage tank bottoms that have cathodic protection applied. Easy replacement of reference electrodes in the above mentioned location must be addressed in the design of the referenced electrode's installation. Elimination of the access problem for replacement through the use of test stations that allow access to native soil should be used where possible.
2. Potential stations located in areas with soil surface shall consist of a precast concrete housing, which is open at the bottom and shall be furnished with a cast iron traffic cover marked CP on the top of the cover. The station shall be filled to within 3 inches of its top with clean soil.

2.04 IMPRESSED-CURRENT ANODES:

A. Anodes for deep well impressed current systems shall be specified to be high silicon iron chromium durichlor type CD with the following analysis and requirements:

1. Silicon: 14.5% min
2. Manganese: 0.75% min
3. Carbon: 0.95% min
4. Chromium: 4.5% min
5. Iron: Remainder
6. The anode lead wire shall be #8 AWG 7/S, l/C copper with HMWPE insulation, and shall be connected to the interior center of the anode. The anode anchoring device shall withstand a 2,000 pound pull and have a maximum anode to anchoring device electrical resistance of .0009 ohms. Anchoring devices shall be covered with a sealing compound.
7. The use of tubular series wired anode assemblies is not recommended. Anodes with individual lead wires extended up to an above grade junction box is recommended.
8. Resistive localized anodes are acceptable if the installation is designed and certified by a registered Corrosion Engineer or NACE certified Corrosion Specialist.

B. Impressed-Current Backfill:

1. The backfill shall be tamped calcined coke breeze material screened to provide a particle size from 1/81' to 3/811. Resistivity shall not exceed 25 ohm cm at a moisture content of not more than 1%, with a bulk density of 46 to 50 lb/ft' and the following composition:
   a. Fixed Carbon: 99.4% guaranteed typical (99.0% min., dry basis)
   b. Ash: 0.3% guaranteed typical (0.5% max., dry basis)
   c. Volatile matter: 0.3% guaranteed typical (0.5% max., dry basis)
   d. Sulfur: 0.8% guaranteed typical (1.2% max., dry basis)
   e. Moisture: 0.02% guaranteed typical (1.0 max.)

C. Impressed-Current Anode Shunt Junction Boxes:

1. Enclosures shall be watertight stainless steel or nonmetallic boxes complete with terminal blocks, shunts, copper jumpers, and bus bars. Shunts shall be in accordance with IEEE 316, 0.01 ohms, 8 amperes.

D. Impressed-Current Rectifiers:

1. Rectifier units shall supply the proper voltage and current output as required in Article 2.12. The Design shall factor in “attenuation” determined from attenuation curves, or the total current required to give protection at the points most distant from the drainage point.
2. The rectifier shall be specified to be of the adjustable type, with a minimum of 20 even adjustments, with conveniently accessible taps over the full voltage output range. This will allow for changes in voltage requirements as a result of seasonal variations in soil resistivity. For above ground tank bottom cathodic protection systems located within release control liners, the rectifiers shall be supplied with variable constant current controls.
3. Rectifier shall be specified to be of the silicone type meeting NEMA MR 20 standards. Semiconductors shall be rated to provide adequate margin for over voltage and over current surges. They shall be mounted on a heat sink designed to maintain junction temperatures well below manufacturer's recommended maximum temperatures when operating in a 120 F (50 C) ambient. The rectifier stack shall be a single three¬ phase, full wave, bridge connected. Silicone diodes shall be protected on input and output sides with zener type selenium surge plates and lightning arresters.
4. The rectifier unit transformer shall be specified to be a two winding type with 428 F (220 C) insulation to operate at rated kVA with a temperature rise not exceeding 220 F (105 C) above a 120 F (50 C) ambient. The secondary winding shall have minimum of four course and five fine voltage control taps to provide adjustable output voltages in equal steps over the entire operating range. Voltage control taps shall be studs and links shall be rated to carry 125 percent of the rectifier full load current. The transformers shall conform to NEMA ST 1. Provisions for remote monitoring and alarms shall also be provided.
5. The efficiency of the basic rectifier shall be a minimum of 70 percent. Each rectifier unit shall be complete with enclosure, transformer, voltage control taps, and necessary appurtenances. Voltage, phase, AC input, and DC output ratings shall be as necessary. The enclosures shall be in accordance with NEMA ICS 6 110. Sunshades shall be provided for each outdoor rectifier.
6. Rectifiers shall be enclosed in sheet metal enclosures with welded seams in accordance with NF14A MR 20. The enclosures shall be provided with hinged doors. Circuit breakers, ammeters, and voltmeter shall be mounted on an inside panel. The rectifier shall have a ground lug for a minimum 67.44mm~ (No. 2/0 AWG) ground wire and shall be suitable for wall, post, or pad mounting, with knockouts provided for conduit entrance.
7. Each rectifier unit shall have internally mounted meters to read DC current and DC voltage. The ammeter shall be provided with an external shunt. The meters shall be red lined at approximately the three quarter point of the rectifier unit “full scale” rated value. The meters shall have an accuracy of +/- 2 percent.
8. The main circuit breaker shall be molded case, trip free, flush mounted with toggle handle readily accessible. An overload or short circuit through any single pole shall open all poles simultaneously. The circuit breaker shall conform to NEMA AB 1.
9. Fuses of the non renewable type shall be installed in the secondary side of the rectifier and shall be mounted on the front of the rectifier panel.

E. Impressed-Current Deep Ground Bed Hardware:

1. Casings shall be ES ABS pipe sized as required. Pipe shall be supplied with 1 1/4" diameter holes drilled at an angle of approximately 450 from the longitudinal axis of the pipe.
2. Approximately 50 holes per running foot of pipe is required. Holes shall be positioned in a symmetric and distributed manner so as not to reduce the strength of the pipe. on the outside of the drilled portion of the pipe, a 28 gauge metal membrane shall be installed in a secure manner.
3. Vent pipes shall be 1" PVC with 201 couplings and having 3/16" holes on 611 centers drilled from the bottom of the hole to 51 above the top anode.

PART 3 EXECUTION

3.01 GENERAL INSTALLATION REQUIREMENTS

A. Install at the locations shown on drawings for anodes and provide for symmetrical spacing to obtain uniform current distribution. Low, poorly drained areas are generally good locations for anodes and are highly desirable for efficient anode operation. Locate anodes in areas having the lowest resistance and nearest those points where corrosion has been determined to be the most severe; space anodes not closer than four (4) feet from the protected structure and space a minimum of twenty (20) feet from foreign structures. Place anodes at a depth that is below the bottom of the structure to be protected. For protection of tank interior or other structure where rod type magnesium anodes are not practicable, zinc anodes can be mounted directly on, but separated by an insulating strip form, the surface of the steel to be protected.

3.02 MAGNESIUM ANODE INSTALLATION

A. Packaged galvanic anodes shall be wetted and then backfilled with compacted native soil. Where anodes and special chemical backfill are provided separately, anodes shall be centered in special backfill that would be compacted prior to backfilling with native soil. Care should be exercised so that lead wires and connections are not damaged during backfill operations. Sufficient slack should exist in lead wires to avoid strain.

3.03 TEST STATIONS

A. Install test stations as follows:

1. At all insulating underground joints (bond site).
2. Where a carrier pipe is used under roads, railroads, etc.
3. For sacrificial anodes added to the fuel system.

B. Test stations will not be required within 300' of a riser pipe or any place where the pipe may be readily accessible.

C. Test stations consist of a weatherproof NEMA: terminal box, with removable cover, test lead wires and five terminals, installed approximately 3 feet above surface. Limit above grade test stations to protected areas only.

D. Flush type test stations approximately 4" x 18" or 5" x 181 long plastic pipe and heavy cast iron loading covers and collars suitable for both curb and roadway installation shall be installed in all paved areas.

E. Test station conductors shall be minimum #12 AWG HMWPE insulated, and color coded as required.

F. Test stations shall be labeled with coded identification and shall be carefully located.

3.04 INSULATING PIPE SLEEVES

A. Provide electrical isolation between piping systems protected by different cathodic protection systems, at each building riser pipe, and at other points where a short to another pipe or a foreign structure may occur. Provide electrical isolation between anchor plates, leak plates and any other structure penetration.

B. Electrical isolation shall be provided at the first flange inside any building with the remainder of buried pipe protected. Note the DEN electrical specification which denies the use of water supply up to this flange from the exterior for use as an electrical ground.

3.05 IMPRESSED-CURRENT INSTALLATION REQUIREMENTS

A. Deep ground bed anode locations shall be installed as determined by the Design Consultant's Corrosion Engineer's standard design calculations, and field surveys.

B. The deep ground bed installation shall be of the replaceable type in locations in paved areas, and areas where any construction work may interfere with air traffic operations. In other areas, ground beds may be of the non-replaceable type.

C. The ground beds shall not be placed at a depth greater than 51". The Engineer shall determine if greater limitations are required. The deep ground bed casing shall be positioned at a section of the casing. Upon completing the installation of the perforated and solid plastic casing, enough coke breeze should be pumped to fill the annulus between the casing and the periphery of the drilled hole up to a point 101 above the top anode. The inside casing should then be flushed to remove contaminants until the water is finally clear. The anodes, along with the 1" PVC vent pipe, should then be lowered down the hold to their respective determined depths. The inside casing should be pumped with the proper amount of coke breeze slurry (51" above the top anodes). After 24 hours of settling, the coke breeze height shall be the annulus of the hole to grade with washed gravel. The top of the plastic casing shall be capped off at grade and a metallic/concrete vault installed.

D. The individual anode lead wires shall be run to the anode lead junction box mounted adjacent to the hole at the earth surface.

E. The rectifier units shall be mounted on a concrete pad at least 6” larger and wider than the rectifier base dimensions and 4" thick. The rectifiers shall be located convenient to the deep well ground beds.

3.06 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Impressed Current Deep Ground Bed System:

1. After the installation is complete, the deep well anode systems shall be energized and tested to determine that the underground structures are receiving adequate protection in accordance with the criteria as set forth in the National Association of Corrosion Engineers, Standard RP 01 69, Latest Revision. All testing shall be performed under the direct supervision of a Corrosion Specialist as certified by the National Association of Corrosion Engineers.
2. Interference testing shall be conducted.
3. Static Potential Measurements: Before the ground beds are energized, a complete set of “static” potential measurements shall be obtained at the following locations:
    a. Fire Water Line at all hydrant and valves.
    b. Fuel line at all hydrant and valves.
    c. Above Ground Storage Tanks four (4) readings per tank with tanks greater than 10 ft diameter.
    d. Above Ground Storage Tanks two (2) reading per tank with tanks less than or equal to 10 ft diameter.
    e. Main Pipeline Corridors pipe to soil measurements, minimum of 100 ft apart.
    f. Anode Output As the anodes are energized, current output shall be measured. The values obtained, date, time, and locations shall be recorded.
4. Interference Testing before final acceptance, interference tests shall be made with respect to any foreign pipelines, tanks, or wells in cooperation with the owner of the foreign structure. A full report of the tests giving all details shall be made. Any methods recommended to eliminate interference shall be reported to DEN Project Manager. It is the responsibility of the new installation designer and contractor to assure the resolution to any electrical interference problems resulting from the cathodic protection prior to system acceptance and to resolve any interferences found post construction that are deemed the result of said construction.
5. Anode Output As the anodes are energized, current output shall be measured. The values obtained, date, time, and locations shall be recorded.

Section 264313: Transient-Voltage Suppression for Low-Voltage Electrical Power Circuits

PART 1 GENERAL

1.01 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

B. Replaceable Protection Modules: One (1) of each size and type installed.

1.02 WARRANTY

A. Warranty Period: Minimum five 5 years.

B. Special Warranty for Cord-Connected, Plug-in Surge Suppressors: Manufacturer's standard form in which manufacturer agrees to repair or replace electronic equipment connected to circuits protected by surge suppressors.

PART 2 PRODUCTS

2.01 MANUFACTURERS

A. Other manufacturers, who have been engaged in the design and manufacturer of the specified system for a minimum of seven (7) years, desiring approval shall provide detailed compliance or exception statements to all provisions of this specification and shall comply with Division 01.

PART 3 EXECUTION

3.01 INSTALLATION

A. The unit(s) shall be installed as close as practical to the facility's wiring system in accordance with applicable national/local electrical codes and the manufacturer's recommended installation instructions.

B. Install TVSS devices at service entrance on load side, with ground lead bonded to service entrance ground.

C. Install TVSS devices for panelboards and auxiliary panels with conductors or buses between suppressor and points of attachment as short and straight as possible. Do not exceed manufacturer's recommended lead length. Do not bond neutral and ground.

1. Provide multiple, [30] [60] [100]-A circuit breaker as a dedicated disconnecting means for TVSS unless otherwise indicated.

D. Connection shall be with the following size of copper conductor or larger and not be any longer than necessary, avoiding unnecessary bends:

1. High exposure service entrance (MP) #2 AWG
2. Medium exposure distribution panelboard (DP) #4 AWG
3. Lower exposure distribution panelboard (DPA) #8 AWG

E. Torque Values: Submit torque values for all connections with a torque schedule and witness signature.

3.02 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Perform tests and inspections.

1. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect components, assemblies, and equipment installations, including connections, and to assist in testing.

C. Tests and Inspections:

1. Perform each visual and mechanical inspection and electrical test stated in NETA ATS, “Surge Arresters, Low-Voltage Surge Protection Devices” Section. Certify compliance with test parameters.
2. After installing TVSS devices but before electrical circuitry has been energized, test for compliance with requirements.
3. Complete startup checks according to manufacturer's written instructions.

3.03 STARTUP SERVICE

A. Do not perform insulation resistance tests of the distribution wiring equipment with the TVSS installed. Disconnect before conducting insulation resistance tests and reconnect immediately after the testing is over.

Section 265100: Interior Lighting

PART 1 GENERAL

1.01 ACTION SUBMITTALS

A. Shop Drawings: For non-standard or custom lighting fixtures. Include plans, elevations, sections, details, and attachments to other work.

1. Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
2. Wiring Diagrams: For power, signal, and control wiring.
3. Light fixture shop drawings shall be in booklet form with a separate sheet for each fixture, assembled in “luminaire type” alphabetical or numerical order, with proposed fixture, lamp type, and accessories clearly indicated on each sheet. Details indicating compatibility with ceiling grid system are required.

B. Substitutions:

1. Substitutions: Under provisions of Division 01. One sample of each proposed light fixture substitution unless the DEN Project Manager waives requirement.
2. Printed physical, electrical, and photometric data clearly highlighted to show the differences between the proposed substitutions and the specified light fixture.
3. Photometric information in IES standard format on a disc and printed on 8½" x 11" pages.
4. Point to point lighting calculation for all typical spaces.

1.02 INFORMATIONAL SUBMITTALS

A. Coordination Drawings: Reflected ceiling plan(s) and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:

1. Lighting fixtures
2. Suspended ceiling components
3. Partitions and millwork that penetrate the ceiling or extends to within 12 inches of the plane of the luminaires.
4. Ceiling-mounted projectors
5. Structural members to which suspension systems for lighting fixtures will be attached.
6. Other items in finished ceiling including the following:
7. Air outlets and inlets
8. Speakers
9. Sprinklers

10. Smoke and fire detectors
11. Occupancy sensors
12. Access panels
13. Perimeter moldings

1.03 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. LED Fixtures; Three (3) for every 100 but not less than two (2) of each type and rating installed.
2. Non-LED Fixtures: Provide the following:
   a. Lamps: Ten (10) for every 100 but not less than two (2) of each type and rating installed.
   b. Plastic Diffusers and Lenses: One for every 100 of each type and rating installed. Furnish at least one of each type.
   c. Globes and Guards: One for every 20 of each type and rating installed. Furnish at least one of each type.
3. Emergency lighting units, emergency battery packs: One for every 20 emergency lighting unit.

1.04 QUALITY ASSURANCE

A. Comply with the requirements of the reference standards noted herein, except where more stringent requirements are listed herein or otherwise required by the Contract Documents. All equipment furnished under this section shall carry a UL Listing.

B. FM Global Compliance: Lighting fixtures for hazardous locations shall be listed and labeled for indicated class and division of hazard by FM Global.

C. Mockups: Provide interior lighting fixtures for room or module mockups, complete with power and control connections.

1. Obtain DEN Project Manager's approval of fixtures for mockups before starting installations.
2. Maintain mockups during construction in an undisturbed condition as a standard for judging the completed Work.
3. Approved fixtures in mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

1.05 COORDINATION

A. Coordinate layout and installation of lighting fixtures and suspension system with other construction that penetrates ceilings or is supported by them, including HVAC equipment, fire-suppression system, and partition assemblies.

B. The drawings are diagrammatic and indicate the general arrangement of electrical work. Locations are approximate and shall be subject to minor modifications as dictated by field conditions and as directed by DEN Project Manager.

1.06 WARRANTY

A. Special Warranty for Emergency Lighting Batteries: Manufacturer's standard form in which manufacturer of battery-powered emergency lighting unit agrees to repair or replace components of rechargeable batteries that fail in materials or workmanship within specified warranty period.

1. Warranty Period for Emergency Lighting Unit Batteries: Minimum three (3) years from date of Substantial Completion. Full warranty shall apply for first year, and prorated warranty for the remaining two years.
2. Warranty Period for Emergency Fluorescent Ballast and Self-Powered Exit Sign Batteries: Minimum Three (3) years from date of Substantial Completion. Full warranty shall apply for first year, and prorated warranty for the remaining two (2) years.

PART 2 PRODUCTS

2.01 GENERAL REQUIREMENTS FOR LIGHTING FIXTURES AND COMPONENTS

A. Color Rendering Index: All luminaires furnished as part of the project shall have a minimum color rendering index (CRI) of 80.

2.02 DRIVERS FOR SOLID-STATE LAMPS

A. Description: Listed, electronic, RoHS compliant, meeting the requirements of ANSI C82.77 and UL 8750.

1. Dimming: Where required. Meet or exceed specified dimming percentage. Provide 4-wire (0-10V DC Voltage Controlled) dimming drivers which meet the following requirements:
   a. Compatible with solid-state devices within the range of 1%-100% of the power supply output.
   b. Meet IEC 60929 Annex E for General White Lighting LED drivers.
   c. Connect to devices compatible with class 2 0-10V analog control protocol.
   d. 0-10V control interface shall be completely isolated from the line-voltage AC power supply.
   e. Available sink current for each driver on the 0-10V interface shall not exceed 1 mA.
2. Rated Life: 50,000 hours minimum.

2.03 EXIT SIGNS

A. General Requirements for Exit Signs: Comply with UL 924; for sign colors, visibility, luminance, and lettering size, comply with authorities having jurisdiction.

1. All exit signs shall have green illuminated lettering on a white background.

B. Internally Lighted Signs:

1. Lamps for AC Operation: LEDs, 50,000 hours minimum rated lamp life.
2. Self-Powered Exit Signs (Battery Type): Integral automatic charger in a self-contained power pack.
   a. Integral Self-Test: Factory-installed electronic device automatically initiates code-required test of unit emergency operation at required intervals. Test failure is annunciated by an integral audible alarm and a flashing red LED.

C. Self-Luminous Signs: Prohibited

2.04 SOLID-STATE LAMPS

A. Minimum CRI: 80.

B. Minimum LED life: 60,000 hours at a lumen output no less than 70% of original output. Lumen maintenance measurements and calculations must conform to IES LM-80 and IES TM-21.

C. Lumen output shall be as specified on the drawings. Conform to IES LM-79.

PART 3 EXECUTION

3.01 INSTALLATION

A. Sequencing and scheduling: The interior lighting installation is to be sequenced and scheduled with other work to minimize possibility of interference with pipes, ductwork, and conduit. Lighting fixtures shall be protected from damage and soiling during the remainder of construction period.

B. Lighting Fixtures:

1. Each single phase circuit feeding light fixtures with ballasts shall have a dedicated neutral.
2. Light fixtures in storage areas and fixtures mounted below 8’ shall have a guard to protect the lamps.

C. Emergency Lighting:

1. All emergency lighting conductors are to be routed in a conduit separate from the normal power circuits.

D. Temporary Lighting: Do not use permanent lighting for temporary lighting.

3.02 IDENTIFICATION

A. Install labels with panel and circuit numbers on concealed junction and outlet boxes. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."

3.03 FIELD QUALITY CONTROL

A. Test for Emergency Lighting: Interrupt power supply to demonstrate proper operation. Verify transfer from normal power to battery and retransfer to normal.

3.04 DEMONSTRATION

A. Upon completion of the installation of interior lighting fixtures, and after building circuitry has been energized, the interior lighting system and emergency lighting system shall be operated to demonstrate capability and compliance with requirements.

B. Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice.

3.05 ADJUSTING AND CLEANING

A. Interior lighting fixtures are to be cleaned of dust, dirt, fingerprints, smudges, and construction debris upon completion of the installation.

B. Installed fixtures are to be protected from damage during the remainder of the construction period.

C. Occupancy Adjustments: When requested within twelve (12) months of date of Substantial Completion, provide on-site assistance in adjusting aimable luminaires to suit actual occupied conditions. Provide up to 2 visits to Project during other-than-normal occupancy hours for this purpose. Some of this work may be required after dark.

1. Adjust aimable luminaires in the presence of DEN Project Manager.

Section 265600: Exterior Lighting

PART 1 GENERAL

1.01 STRUCTURAL ANALYSIS CRITERIA FOR POLE SELECTION

Confirm structural analysis criteria with structural engineer and currently adopted building code(s).

A. Live Load: Single load of 500 lbf, distributed as stated in AASHTO LTS-4-M.

B. Ice Load: Load of 3 lbf/sq. ft., applied as stated in AASHTO LTS-4-M Ice Load Map.

C. Wind Load: Pressure of wind on pole and luminaire and banners and banner arms, calculated and applied as stated in AASHTO LTS-4-M.

1. Basic wind speed for calculating wind load for poles exceeding 50 feet in height is 115 mph.
   a. Wind Importance Factor: 1.3
   b. Minimum Design Life: 50 years
   c. Velocity Conversion Factors: 1.3
2. Basic wind speed for calculating wind load for poles 50 feet high or less is 115 mph
   a. Wind Importance Factor: 1.3.

3. Minimum Design Life: 25 years
4. Velocity Conversion Factors: 1.3.

1.02 CLOSEOUT SUBMITTALS

A. Contractor shall provide to the DEN Project Manager a Point-by-Point report showing the light level readings taken after the lighting has been properly aimed and the fixtures have had at least 50 hours of actual run time in the field. The grid spacing for the readings shall be the same as the calculations submitted prior to start of construction.

1.03 MAINTENANCE MATERIAL SUBMITTALS

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

1. LED Fixtures; Three (3) for every 100 but not less than two (2) of each type and rating installed.
2. Non-LED Fixtures: Provide the following:
   a. Lamps: Ten (10) for every 100 but not less than two (2) of each type and rating installed.
   b. Plastic Diffusers and Lenses: One for every 100 of each type and rating installed. Furnish at least one of each type.
   c. Globes and Guards: One for every 20 of each type and rating installed. Furnish at least one of each type.
3. Emergency lighting units, emergency battery packs: One for every 20 emergency lighting units.

1.04 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace products that fail in materials or workmanship; that corrode; or that fade, stain, perforate, erode, or chalk due to effects of weather or solar radiation within specified warranty period. Manufacturer may exclude lightning damage, hail damage, vandalism, abuse, or unauthorized repairs or alterations from special warranty coverage.

1. Warranty Period for Luminaires: Minimum five (5) years from date of Substantial Completion.
2. Warranty Period for Metal Corrosion: Minimum five (5) years from date of Substantial Completion.
3. Warranty Period for Color Retention: Minimum five (5) years from date of Substantial Completion.
4. Warranty Period for Poles: Repair or replace lighting poles and standards that fail in finish, materials, and workmanship within manufacturer's standard warranty period, but not less than three (3) years from date of Substantial Completion.

PART 2 PRODUCTS

2.01 GENERAL REQUIREMENTS FOR LUMINAIRES

A. Exposed Hardware Material: Stainless steel.

B. Plastic Parts: High resistance to yellowing and other changes due to aging, exposure to heat, and UV radiation.

C. Color: As selected by DEN Project Manager from manufacturer's standard catalog of colors.

2.02 DRIVERS FOR SOLID-STATE LAMPS

A. Description: Listed, electronic, RoHS compliant, meeting the requirements of ANSI C82.77 and UL 8750.

1. Dimming: Where required. Meet or exceed specified dimming percentage. Provide 4-wire (0-10V DC Voltage Controlled) dimming drivers which meet the following requirements:

a. Compatible with solid-state devices within the range of 1%-100% of the power supply output.
b. Meet IEC 60929 Annex E for General White Lighting LED drivers.
c. Connect to devices compatible with class 2, 0-10V analog lighting control protocol.
d. 0-10V control interface shall be completely isolated from the line-voltage AC power supply.
e. Available sink current for each driver on the 0-10V interface shall not exceed 1mA.

2. Temperature rating: Match or exceed environmental requirements.
3. Rated Life: 50,000 hours minimum.

2.03 SOLID-STATE LAMPS

A. Minimum CRI: 70.

B. Minimum LED life: 60,000 hours at a lumen output no less than 70% of original output. Lumen maintenance measurements and calculations shall conform to IES LM-80 and TM-21.

2.04 STEEL POLES

A. Poles: Comply with ASTM A 500, Grade B, carbon steel with a minimum yield of 46,000 psig; one-piece construction with access handhole in pole wall.

1. Shape: Round, tapered.

B. Color: As selected by DEN Project Manager from manufacturer's full range.

2.05 POLE ACCESSORIES

A. Duplex Receptacle: 120 V, 20 A in a weatherproof assembly complying with Section 262726 “Wiring Devices” for ground-fault circuit-interrupter type.

1. Recessed, 12 inches above finished grade.
2. Nonmetallic polycarbonate plastic or reinforced fiberglass, weatherproof in use, cover, color to match pole, that when mounted results in NEMA 250, Type 3R enclosure.
3. With cord opening.
4. With lockable hasp and latch that complies with OSHA lockout and tag-out requirements.

B. Minimum 1800-W transformer, protected by replaceable fuses, mounted behind access cover.

C. Base Covers: Manufacturers' standard metal units, arranged to cover pole's mounting bolts and nuts. Finish same as pole.

D. Transformer Type Base: Same material and color as pole. Coordinate dimensions to suit pole's base flange and accept ballast(s).

2.06 LOWERING SYSTEM FOR LUMINAIRES

A. Arrange system to lower luminaire assembly to a servicing position within 36 inches of finished grade in winds up to 40 mph and to provide for manual plug connection to electrical power in the lowered position for testing.

B. Coordinate with luminaire and pole manufacturers for assembly details, wind-load and vibration analysis, and compatibility of materials for electrolysis-free attachment and connection for luminaire mounting assembly, lowering device, lowering cable, and portable winch.

C. Structural and Mechanical Design: Use a minimum safety factor of 5.0 for static and dynamic loads of load-bearing components, including cable.

D. Luminaire Mounting and Disconnect Arrangement: Multiple mounted luminaires, arranged for lowering and rising as a group.

1. Electrical cable for normal operating power to luminaires manually disconnects inside pole base, using weatherproof multipin connector, and shall be arranged to move within the pole during lowering and rising of luminaire assembly.
2. Electrical cable for normal operating power to luminaires automatically disconnects at a weatherproof multipin connector within the pole-top lowering head at the beginning of the lowering cycle and reconnects when luminaire or luminaire assembly is raised to the operating position.

E. Lowering Device: Weatherproof, cast-aluminum housing and multiple mechanical latches. Moving parts of latching assembly shall be located in the portion of the unit that is lowered to the servicing position. Positive latching in the operating position shall be indicated to the operator at the base of the pole by a clear visual signal, or by other means acceptable to Owner or authorities having jurisdiction.

F. Lowering Cable: Stainless steel aircraft cable.

G. Portable Winch: 120-V electric type. One required per 20 poles.

1. Winch Power Connection: Cord and plug
2. Winch Raise-Lower Control: Remote-control station with 15 feet of cable

H. Winch Transformer: Portable, totally enclosed, encapsulated, single-phase, dry type. Primary rated at lighting-circuit voltage; secondary rated at 120 V. Permanent, primary and secondary, twist-locking plug connectors on pigtails shall match pole-base power outlet and winch plug.

PART 3 EXECUTION

3.01 INSTALLATION GENERAL

A. Install individual fuses at each pole.

B. Clearances: Maintain the following minimum clear horizontal distances of poles from surface and underground features unless otherwise indicated on Drawings:

1. Fire Hydrants and Storm Drainage Piping: 5 feet
2. Water, Gas, Electric, Communication, and Sewer Lines: 10 feet
3. Trees: 15 feet from tree trunk

3.02 INSTALLATION OF INDIVIDUAL GROUND-MOUNTING LUMINAIRES

A. Install on concrete base. Match existing luminaire bases in the surrounding area.

3.03 CORROSION PREVENTION

A. Aluminum: Do not use in contact with earth or concrete. When in direct contact with a dissimilar metal, protect aluminum by insulating fittings or treatment.

3.04 GROUNDING

A. Ground nonmetallic poles and support structures.

1. Install grounding electrode for each pole
2. Install grounding conductor and conductor protector
3. Ground metallic components of pole accessories and foundations

3.05 FIELD QUALITY CONTROL

A. Illumination tests

1. Measure light intensities at night.
2. Prepare a written report of tests, inspections, observations, and verifications indicating and interpreting results. If adjustments are made to lighting system, retest to demonstrate compliance with standards.

3.06 DEMONSTRATION

A. All lighting fixtures having an adjustable type beam spread or pole mounted apron ramp area being of the adjustable aiming type shall be field adjusted or aimed at the Contractor's expense and to the satisfaction of the DEN Project Manager.

B. All fixtures shall be field adjusted in accordance with the manufacturer's aiming recommendations, and as indicated on the drawings and as required in the field. Include an allowance in the bid to cover all costs of aiming or adjusting these fixtures. Include an overtime allowance in the bid for aiming or adjusting exterior fixtures at night.

C. Submit photometric report of light levels in all exterior areas to DEN Project Manager. All photometric readings shall be taken after a minimum of forty (40) hours burn-in of light fixtures.

1. Contractor shall provide to the DEN Project Manager a Point by Point report showing the light level readings taken after the area has been properly aimed. The grid spacing for the readings shall be the same as the calculations submitted prior to start of construction.

D. Training: Schedule training with Owner, through DEN Project Manager, with at least seven (7) days advance notice. Engage a factory-authorized service representative to assist Contractor and train DEN maintenance personnel to adjust, operate, and maintain all exterior lighting components, and luminaire lowering devices, if any.

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