DENVER INTERNATIONAL AIRPORT

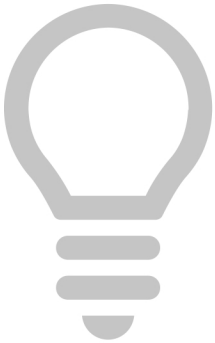
DESIGN STANDARDS MANUAL

Electrical

Denver International Airport

Airport Infrastructure Management

Revised: Q4 2020



Printed in the United States of America

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Summary of Revisions

The following table lists revisions made in the past year to the Electrical Design Standards Manual (DSM).

2020 Revisions

Fourth Quarter Revisions

Reference	Revision Description
Throughout	Heading and body text appearance changes. Notation style for revisions updated from colored text to lines in margin.
2.0.4 Buildings with Multiple Electrical Services	Clarified wording
Table 2-1 - Panelboard Naming Conventions	Updated panel naming requirements for outlying buildings
2.1.17 Automatic Transfer Switches	New section
5.3 Facility Design Guidelines	Various quantitative light level requirements updated. Clarified requirements for restroom vanities versus general areas. Updated Max:Min requirements for aircraft parking areas
5.3.7 Tunnel System	New section
6.5.1 Surface Parking	Added clarification that submetering is not required for surface parking.
6.7.8 Other Outlying Buildings	New section

Second Quarter Revisions

Reference	Revision Description
1.1.1 Normal Electrical Power	Updated description
Table 2 1 - Panelboard Naming Conventions	Clarified naming for emergency/UPS power
2.2.4 Emergency Power Systems	Added requirements for emergency generators, updated requirements for emergency systems
2.2.11 Telecommunication Rooms	Added electrical requirements for telecommunication rooms

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 Denver International Airport (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.

These DEN Design Standards Manuals (DSMs) have 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. All information contained in these standards must be fully explained and shown in all bidding and contract documents.

The DSMs are to be used as a whole, as each manual is complimentary to the others. To understand the overall thematic and design standards for DEN, the manuals must be used together.

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.

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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 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.

1.1. 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 230 kV 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 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 25 kV switchgear to the airport site. These four 25kV feeders from each substation (total of eight feeders) form redundant sources of power for the airport site. Emergency power is not available for these substations.

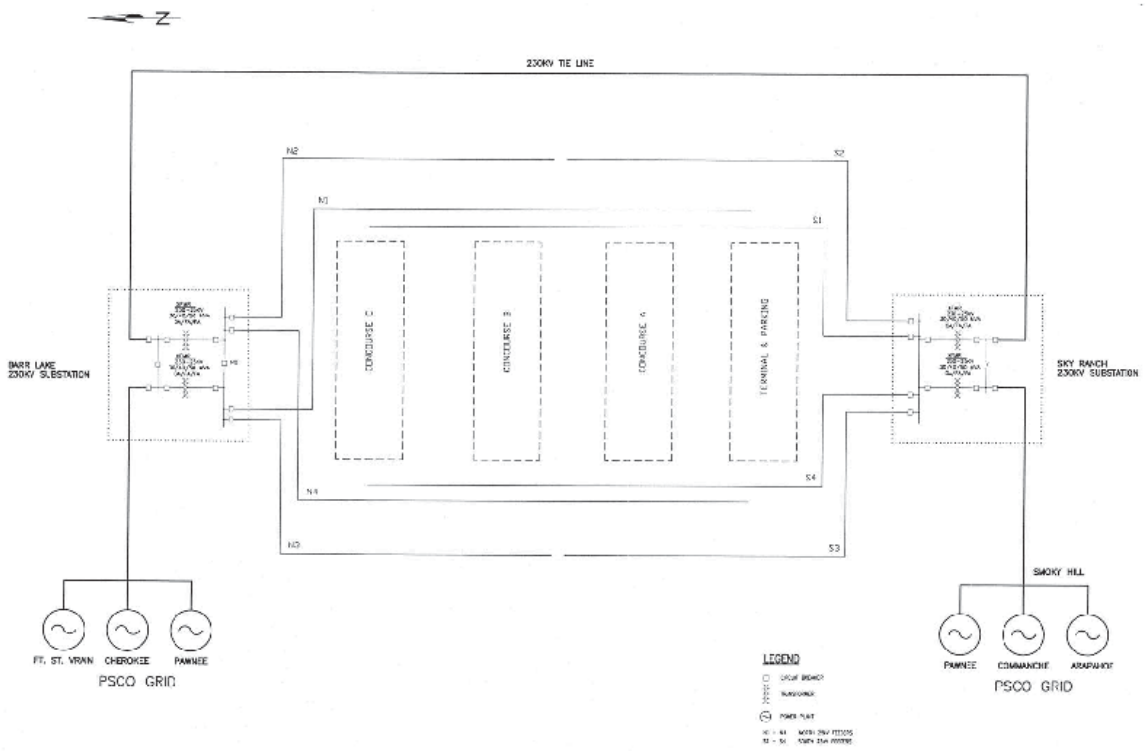

Figure 1-1 - DEN Primary Electrical Distribution Schematic

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 subdistribution 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 in 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

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 economical 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) of limiting of 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 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. 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 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. 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 based on the applicable design standard requirements. Provide verification of availability from repetitive manufacturing sources.

E. Provide voltage drop calculations. Values to be shown on the single line diagram at each point in the system.

F. Provide short-circuit current calculations. Values to be shown on the single line diagram at each point in the system.

G. Calculate necessary wire and cable sizes required that would not be damaged by the short circuit currents available.

Design analysis includes 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 concept progress review. The design development submittal shall expand the concept design to include preliminary sizing of 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 BIM 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 symbol. All conduit runs are identified by 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 plan review. The required details shall include typical raceway mounting, raceway connection, motor connections, lighting fixture and equipment mounting, grounding and lightning protection installations.

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

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"

2.0.3. Design Approach

Careful planning and design of electrical systems are necessary to assure 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 an 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 applicable standards of those organizations listed above. Manufacturer's 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. Individual disconnecting means shall be provided in the fire command center for each individual electrical service.

All power from distribution panel boards to the final point of outlet or device location shall be located on the same floor and 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. 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 stand-by generator

2.0.4.2. 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.

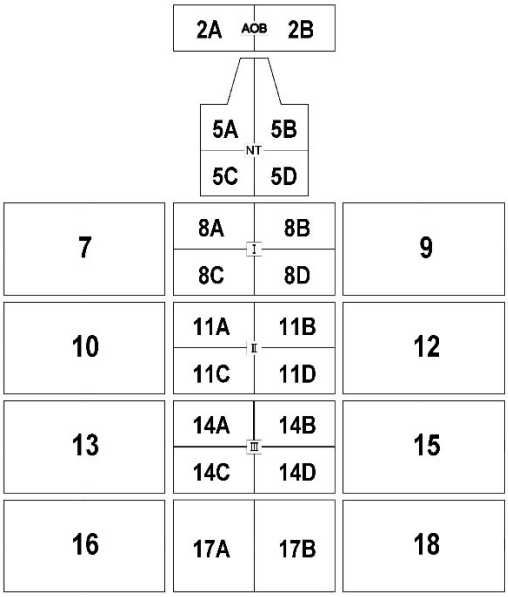

Figure 2-1 - Terminal and Hotel Transit Center Area Designations

2.0.4.3. 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.

2.0.4.4. 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.

2.0.4.5. 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.

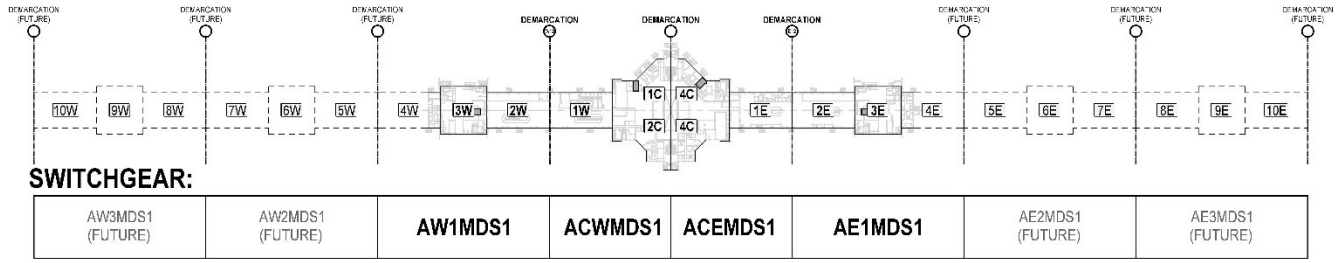

Figure 2-2 – Example Concourse Lines of Demarcation (Concourse C Depicted)

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 the electrical systems. Simplicity of systems and equipment operation shall be a principal objective. 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 is 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 concrete or buried in 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 under floor 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 conduit 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 slabs on grade shall be encased in red concrete when structurally required and when the conduit contains electric service cables.

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 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 and 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 Location grid. Choices: A through J (West to East) and 1 through 10 (North to South)
2	Floor level (multi-story buildings only). Choices: 1…N or as otherwise designated based on building type.
T	Indicates 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
-A	Sub-fed panel suffix, if appropriate. Choices: -A… as required.

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.*

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 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] 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 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] 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.

Central Utility Plant – Example: L-AHDE2A	
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], 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 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 integral metering capability

   Where practicable, equipment with built-in metering capability 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), 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 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 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 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, labelling, 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 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 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 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 1/4-inch (6-mm) by 3-inch (7.6-mm) 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 standby, 15 minutes full load
Energy Management and Control System (EMCS) routers and network interface devices	20 Minutes
Radio Enhancement System	4 Hours
Security Systems	4 Hours
Telephone and Electronic Systems	4 Hours
Terminal Units for Smoke Control	4 Hours
Two-Way Communication System for Life Safety	4 Hours

Note:

Refer to DSM Technology and Communication and DSM Life Safety for additional information regarding the listed systems.

The UPS 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 10 percent of spare capacity for future loads. 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.

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].
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 – 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]

Concourse Buildings – Photovoltaic Collector Modules	
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 be 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 to provide a sign fed from an individual branch circuit rated for at least 20 amps at store entrance.

2.1.16. Elevators

Elevators and elevator cab lighting should be powered from the nearest 480/277V emergency panel board. Electrical requirements for elevators and elevator machine rooms should conform to the NEC. Provide one 120v, 20A GFCI outlet in the elevator equipment room. The lighting and receptacle circuit must be dedicated to the elevator area only.

Elevators 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. Automatic Transfer Switches

Provide 4-pole, open-transition type automatic transfer switches to serve emergency distribution systems. 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.

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. 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 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. Include a protective device selective coordination study with design documents. 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. Escalators

C. Motorized Walkways

D. Emergency Egress/Exit Lighting

E. Smoke Control Equipment

F. Fire Alarm Systems

G. Emergency Communication Systems

H. Public Safety Radio

I. Fire Pumps and controllers

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 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 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
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.

C. 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.

2.2.7. 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 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 electrical equipment, 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 NFPA 70E requirements. Arc flash hazard/warning labels shall indicate the available incident energy and required personal protective equipment (PPE) at each piece of electrical equipment. All printed data shall match as-installed field conditions at the completion of the project.

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.

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 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 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 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, an emergency panelboard should be installed for these loads in the room and sized as required. Typical emergency loads include Emergency Communications systems (ECS), Radio Enhancement System (RES), Distributed Antenna System (DAS), and two-way communications equipment.

UPS systems with surge protection should be provided for Emergency and non-emergency loads within these rooms. These 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.

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 earth for a minimum distance of 10 feet, without joints, immediately adjacent to the ground conductor connection.
   b) Structural steel framework of 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 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 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. 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. Buried conductor used in grids and for riser connections to building steel shall be bare, stranded soft drawn copper, 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 installations 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 conduit, 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 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, 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 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 cable leaves concrete in exposed areas.

C. Suitably protect cable against damage during construction.

D. Replace or suitably repair 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 trench or in other excavations at least 18 inches below finished grade.

B. Maintain 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 assure a low-resistance connection.

B. Install so as not to be susceptible to mechanical damage during 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 unexcavated portion of the earth where possible.

C. Where rods must be installed in excavated areas, drive rods into earth after compaction of backfill is completed.

D. Drive to a depth such that top of rods will be approximately 18 inches below final grade, or subgrade, and connect main grid ground cable thereto.

3.2.6.5. Metallic Conduit Grounds

A. Where conduit enters 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 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 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

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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 design 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 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 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 component.

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 surface.

D. All counterpoise (loop) conductors shall be minimum 2/0 AWG, with minimum strand size 17 AWG.

E. Ground rods shall be 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. 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 final grade.

Exothermic welds are required for all connections below grade.

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.

Roof top 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

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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 publications of the following references:

A. American national Standards Institute (ANSI)

B. Certified Ballast Manufacturers (CBM)

C. Illuminating Engineering Society of North America (IESNA)

D. IESNA 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, 2010 Edition

M. International Energy Conservation Code (IECC), 2015 Edition

5.0.3. Design Approach

Design computations for lighting levels shall be 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 Handbook published by IESNA.

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. Format for the design analysis is specified in the Standards and Criteria DSM. The calculations shall be accompanied with copies of 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 500.3 - 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 a 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

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 IESNA. However, the contribution of all light sources present in a particular area of design shall be appreciated. Refer to 502.4 - Specific Design Guidelines for 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 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. Incandescent, neon, mercury vapor, low pressure sodium, compact fluorescent, and high-pressure sodium 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 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 5.3Facility 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. T8 fluorescent lamps: 3500 K
B. T5 fluorescent lamps: 4100 K
C. Indoor LED fixtures: 3500 K
D. Outdoor LED fixtures (landside areas including parking lots, etc.): 5000 K
E. Outdoor LED fixtures (airside areas including aprons): 4000 K
F. Signage: 5000k
G. Elevators: 3500k

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 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 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 for LED-based luminaires and 25,000 hours for fluorescent and HID luminaires, when the use of HID luminaires is expressly approved by the DEN Project Manager.

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. Designer shall select luminaires to minimize up-light and glare. The target BUG rating for all exterior fixtures shall meet or exceed B2, U2, 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 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, etc. 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 ‘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.

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 2015 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, daylight-responsive controls (photocell-based), 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 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. Minimum distance between adjacent tubing or stems shall be 8 feet. Rod shall not be less than 1/2-inch diameter.

Recessed fixtures shall have adjustable fittings to permit alignment with ceiling panels. Recessed fixtures installed in 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

Exit and emergency lighting systems shall be provided in accordance with NFPA Code no. 101, Safety to Life from Fire in Buildings and Structures. 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 shall be utilized:

A. Electrical and mechanical rooms

B. 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 operation requirements and evaluate 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, fluorescent, metal halide) 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.

5.3. Facility Design Guidelines

5.3.1. Main Terminal Complex

The following guideline for the 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_{ave} shall define required average illuminance, and E_{min} shall define minimum required illuminance. All values are expressed as horizontal foot-candles, at a height of 2' - 6" (for indoor locations) or at ground level (for exterior and structured parking areas).

5.3.1.1. Main Circulation Area – Daytime

A. E_{ave}= 100 fc average maintained for atrium

B. E_{min} = 50 fc maintained

C. Ambiance/qualitative criteria:

a) Daylight ambient for an outdoor atmosphere, sunlight sparkle from natural or direct component electric sources. This direct component would be most suitable over trees and plantings. Maximize daylight potential and minimize direct sun component except over plants and trees.

b) Minimize glare from direct component and glazed areas. Luminance ratios with adjacent surfaces should be no greater than 10:1, preferably 5:1. This should be accomplished through aiming and shielding of luminaries. Consideration shall be given to bi-level automatically switched (or dimmed) lighting systems.

c) Keep surfaces reasonably clean and uncluttered through the selection of unobtrusive equipment placed at strategic locations. One exception would be luminaries intended as architectural features. These architectural luminaries should have minimal brightness.

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

e) Diffuse brightly illuminated ceiling, walls, and other appropriate surfaces.

5.3.1.2. Main Circulation Area – Nighttime

A. E_{ave} = 25 fc average maintained (minimum for heavy traffic areas)

B. E_{min} = 20 fc maintained

C. Ambiance/qualitative criteria:

a) Create a smaller, more intimate, human scale conveyed through corresponding scale of lighting.

b) Provide a soft ceiling glow that shall be achieved with unobtrusive luminaries to avoid the cave effect.

c) Provide a brighter light level below 20 feet, uniform for safety, yet not a constant level in appearance for atmosphere.

d) Minimize reflections from the floor and glazing.

e) Sparkle shall be created through dramatic highlighting of trees, paintings, sculptures, and artwork.

f) Minimize glare and brightness from any pedestrian-scale lighting.

g) Maintain adequate luminance ratios (5:1 or 10:1) between retail stores and adjacent surfaces, thus making them easily recognizable and attractive to enter.

h) Avoid visual noise that could compete with meaningful information such as signage, etc. Examples of this are highlighted, unattractive, meaningless objects or high glare lighting systems.

i) Provide an adequate inter-reflected component to soften shadowing, especially on people's faces.

j) Lamp colors shall be warm in tone.

5.3.1.3. Ticket Counters

A. E_{ave} = 60 fc average maintained

B. E_{min} = 40 fc maintained

C. Qualitative criteria:

a) Provide a uniform light level on the counters with a direct lighting system above the counters.

b) Provide adequate vertical brightness for improved people recognition, set apart from adjacent circulation areas.

c) Minimize glare from electric lighting for both passengers and employees.

d) Back wall company logos should be highlighted with a continuous linear wall wash yet shall not display veiling reflections on video display terminal (VDT) screens

5.3.1.4. Baggage Claim

A. E_{ave} = 50 fc average maintained

B. E_{min} = 35 fc maintained

C. Qualitative criteria:

a) Provide a bright, uniform illumination with a good horizontal and vertical distribution for ease in identifying luggage and reading tags.

b) Brighten the space and deemphasize the long lobby by using an indirect lighting system that creates a repeating pattern across the ceiling. Highlight soffits at both ends and allow them to go darker in the middle. Provide direct/indirect luminaries for the columns.

c) Highlight wall-mounted artwork.

d) Signage shall be easily recognizable and should contrast with the immediate surroundings.

e) Luminance ratios between baggage claim devices and artwork shall be between 3:1 and 5:1.

5.3.1.5. Rental Car Counters

A. E_{ave} = 60 fc average maintained

B. E_{min} = 40 fc maintained

C. Qualitative criteria:

a) Provide a uniform light level on the counters with a direct lighting system above the counters.

b) Provide adequate vertical brightness for improved people recognition, set apart from adjacent circulation areas.

c) Minimize glare from electric lighting for both passengers and employees.

d) Back wall company logos should be highlighted with a continuous linear wall wash yet shall not display veiling reflections on video display terminal (VDT) screens.

5.3.1.6. Ground Transportation Centers

A. E_{ave} = 35 fc average maintained

B. E_{min} = 25 fc maintained

C. Qualitative criteria:

a) Provide a sufficient contrast between signage and surroundings to aid in identification. Luminance ratios shall be between 3:1 and 5:1. Provide direct and indirect systems. Illuminate vaulted ceiling sections, which shall add contrast to the flat sections of the ceiling.

5.3.1.7. Restrooms

A. E_{ave} = 15 fc horizontal average ambient light level, throughout restroom

B. E_{ave} = 50 fc vertical average, maintained at lavatory vanities

C. E_{min} = 35 fc vertical maintained at vanities

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.

5.3.1.8. First Aid Rooms

A. E_{ave} = 50 fc maintained

B. Qualitative criteria:

a) Provide a high uniform light level with bright surfaces in the examination area. Create subdued lighting with warm color rendition for the resting and waiting area.

b) Provide adequate and uniform vertical illuminance for the administration of first aid.

5.3.1.9. Interior Space Features

A. E_{min} = 500-1,000 fc average maintained at the top of trees (a minimum of 8 hours per day).

B. E_{min} = 250 fc average maintained at base of trees (a minimum of 10 hours per day).

C. E_{min} = 50 – 200 fc (in general) for other plantings. Coordinate the lighting intensity for each application with the interior landscape Design Consultant. Also, coordinate the direction of the lighting and control of the lighting with the interior landscape Design Consultant.

D. Provide LED or clear metal halide lamps for all trees and plantings.

E. Qualitative criteria:

a) Provide a strong direct component over tree canopies for part of the daytime. LED or metal halide is recommended.

b) Provide a subdued lighting level for the nighttime to provide a dormant period.

c) Highlight vertical faces and underside of tree canopies and shrubs to create a dramatic effect.

5.3.1.10. Telephone Kiosks

A. E_{ave} = 30 fc average maintained on counter.

B. E_{min} = 20 fc maintained on counter.

C. Qualitative criteria:

a) Provide a low glare system.

b) Provide adequate vertical illumination on the telephones.

c) Concealed source continuous fluorescent fixture at junction of planting bed and surrounding plaza areas.

5.3.1.11. Information Booths

A. E_{ave} = 50 fc average maintained (minimum)

B. E_{min} = 40 fc maintained

C. Qualitative criteria:

a) Create a sufficient contrast with the immediate surroundings by highlighting vertical surfaces for easy identification.

5.3.1.12. Seating Areas

A. E_{ave} = 10 – 60 fc average maintained.

B. Qualitative criteria:

a) Create the following different moods:

- Public area shall be brightly illuminated (waiting groups, people with children, etc.) Create a bright atmosphere with uniform, ambient, bright vertical surfaces, and some visual interest with color.
- More subdued, intimate, and private areas shall contain non-uniform lighting for reading, relaxing sleeping, etc. Provide varying levels, or illumination for each activity, with some darker surfaces at strategic locations. Also, provide some diffuse lighting for reading, writing, etc. Consideration shall be given to bi-level automatically switched (or dimmed) lighting systems.
- Add visual interest by highlighting artwork, sculptures, etc.

5.3.1.13. AGTS

A. E_{ave} = 30 fc maintained on trains (minimum)

B. E_{ave} = 15 fc maintained at boarding zones (minimum)

C. Qualitative criteria:

a) On the train, provide uniform, brightly illuminated surfaces to promote the perception of a clean environment.

b) Provide a low-glare system.

c) Boarding zones shall be brightly illuminated vertical surfaces of the trains and signs, etc.

d) The track area within the stations shall only be illuminated when the train is in the station.

e) Reinforce the train station theme with wall-mounted, LED pedestrian luminaries mounted above signage. Provide recessed down-lights along the underside of the atrium level barrier to supplement the ambient lighting from the indirectly illuminated roof above. Highlight and backlight obelisks, columns (in-floor mounted lights can also be utilized) and arch forms along the upper wall (concealed linear LED tape light can be utilized).

f) Provide illumination for easy visual identification of signs, etc. – minimize visual noise.

g) The AGT corridor lighting shall provide special interest for passengers.

5.3.1.14. Escalators

A. E_{ave} = 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.

c) Integrate the lighting with the main lobby. Highlight interior landscaping below escalators as a main focus area. Highlight selected trees and plants with shielded accent lights, creating a natural shadowing effect.

5.3.1.15. Elevators

A. E_{ave} = 25 fc average maintained

B. Qualitative criteria:

a) Tamper-proof

b) Minimize glare with combination of concealed and direct sources in the ceiling.

c) Ceiling lighting shall also wash walls to enlarge the space.

d) Do not use inefficient incandescent or HID sources that will produce a large amount of heat. Use LED lamps instead.

5.3.1.16. Atriums

A. E_{ave} = 10 fc maintained (nighttime)

B. Qualitative criteria:

a) Create an *outdoor village at dusk* atmosphere with glowing *historic* pedestrian lights casting pools of light on the ground. Provide wall-mounted lights similar to those in the AGTS area, except these will have concealed uplights in addition to the direct-down lights.

b) The ceiling overhead shall be illuminated with floodlights to give a rosy hue at the *horizon* (ceiling perimeter) and a darker blue-violet overhead.

c) Interior landscaped areas are the main attraction of the space. Concealed (or camouflaged) post-mounted area lights and ground-mounted floodlight shall highlight, bring out colors, emphasize textures and define overall shapes of the interior landscape, providing strong light/dark will stimulate an evening marketplace environment. All obstacles shall be illuminated so that safety is not compromised. Glowing storefronts shall spill light into the streets.

5.3.1.17. Electrical and Mechanical Rooms

A. Eave = 30 fc average maintained

B. Emin = 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. Concourse Facilities

5.3.2.1. Circulation Areas

A. Eave = 20 fc average maintained

B. Emin = 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: Eave = 20 fc average maintained

B. Airline Podiums and ticketing areas: 35 fc average maintained at the counter top

C. Emin = 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. Eave = 25 fc average maintained

B. Emin = 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. Eave = 25 fc average maintained

B. Emin = 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. Eave = 40 fc average maintained at landings (minimum)

B. Emin = 25 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. Eave = 15 fc horizontal average ambient light level, throughout restroom

B. Eave = 50 fc vertical average maintained at lavatory vanities

C. Emin = 35 fc maintained at vanities

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. Eave = 30 fc average maintained

B. Emin = 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.

5.3.3. Parking Facilities

5.3.3.1. Parking Structures

A. E_{ave} = 4 fc average, maintained, 2fc minimum for parking structures

B. 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

C. Qualitative criteria:

a) Minimize glare.

b) Maximize uniformity of lighting to enhance safety.

5.3.3.2. Surface Parking

A. E_{ave} = 2 fc average maintained for surface parking

B. Qualitative criteria:

a) Minimize Glare

d) Maximize Uniformity of lighting to enhance safety

5.3.4. Maintenance Facilities

5.3.4.1. Work Areas

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

5.3.4.2. Ancillary Areas

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

B. E_{ave} = 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_{ave} = 30 fc maintained

5.3.5.2. Vehicle Parking

A. E_{ave} = 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.

D. Aircraft parking areas shall meet the following illuminance criteria detailed in Table 5-2 - Aircraft Parking Area Illumination.

Table 5-2 - 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)[1,5]	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/250ft)	10ft x 10ft
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/250ft)	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/250ft)	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/250ft)	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/250ft)	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/250ft)	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_{ave} = 50 fc average maintained for work areas.

B. CCR room

E_{ave} = 20 fc average maintained.

C. Switchgear and generator room

E_{ave} = 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. Eave = 15 fc at all automated baggage handling and drive lanes

B. Eave = 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. Eave = 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 T12 lamping shall be retrofitted to T8, T5, or LED depending on application.

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 T12 lamping shall be retrofitted to T8, T5 or LED depending on application.

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.

6.1.4. Tenants and Concessions

Existing normal electrical power for systems and equipment is provided at 480Y/277 volts and 208Y/120 volts. Separate, individually metered tenant electric service shall be provided at 480Y/277 volts for all tenant spaces requiring more than (1) 120-volt, 20A circuit. Public area HVAC equipment, lighting systems, elevators, escalators, and general convenience power shall be from DEN's metered service.

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, PA system, EMCS, security, communications and data systems.

All concession spaces shall be separately metered. 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 that the existing electrical service meets the currently adopted metering requirements. If it does not meet these requirements, it shall be upgraded as necessary.

Communication raceway systems will be installed to provide for 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 is 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 space in accordance with the following guidelines.

6.1.4.1. Basic Tenants

A. Basic Office Tenant

   a) Lighting: 3.0 VA/SQ FT

   b) Receptacles 2.0 VA/SQ FT

B. Basic Retail Tenant

   a) Lighting: 4.0 VA/SQ FT

   b) Receptacles: 1.0 VA/SQ FT

6.1.4.2. Concession Tenants

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

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

C. Storage Spaces
   a) 2.0 VA/SQ FT

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 T12 lamping shall be retrofitted to T8, T5 or LED depending on application.

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 fluorescent lighting, and 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. Tenants and Concessions

Existing normal electrical power for systems and equipment is provided at 480Y/277 volts and 208Y/120 volts. Separate, individually metered tenant electric service shall be provided at 480Y/277 volts for all tenant spaces requiring more than (1) 120-volt, 20A circuit. Public area HVAC equipment, lighting systems, elevators, escalators, and general convenience power shall be from DEN's metered service. Tenant services will be extended by the tenant from DEN's metering equipment to the tenant's main distribution panelboard located in their space.

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 fire detection and alarm, central corrected clock, PA system, EMCS, security, communications and data systems. Emergency lighting within the tenant's space shall be served from tenant distribution equipment. When remodeling an existing concession space, the Designer shall ensure that the existing electrical service meets the currently adopted metering requirements. If it does not meet these requirements, it shall be upgraded as necessary.

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

Designers shall limit electrical power consumption in the tenant space in accordance with the following guidelines:

6.2.5.1. Basic Tenants

A. Basic Office Tenant
   a) Lighting: 3.0 VA/SQ FT
   b) Receptacles: 2.0 VA/SQ FT

B. Basic Retail Tenant
   a) Lighting: 4.0 VA/SQ FT
   b) Receptacles: 1.0 VA/SQ FT

6.2.5.2. Concession Tenants

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

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

C. Storage Spaces
   a) 2.0 VA/SQ FT

6.2.6. 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 an 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 the concourse buildings that shell space such as basements and storage rooms are later remodeled into offices, support space, 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 or fluorescent luminaries will be used for special purpose and architectural accent lighting. Industrial LED or fluorescent luminaries will be used to light storage areas, equipment rooms, and similar spaces. Industrial LED or fluorescent 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.

6.2.6.1. 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.

6.2.7. 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 or fluorescent luminaries will be used for special purpose and architectural accent lighting. Industrial LED or fluorescent luminaries will be used to light storage areas, equipment rooms, and similar spaces. Industrial LED or fluorescent 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 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 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 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 is 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:

6.2.7.1. 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 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 T12 fluorescent fixtures shall be retrofitted to T8 or replaced. Provide new fluorescent or LED luminaires where required. Lighting control will be by use of occupancy/vacancy sensor control in individual offices and toggle switches in open areas as appropriate. Provide dual level 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 to 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 concourse 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 run 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 level 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 fluorescent lighting. Provide occupancy/vacancy sensors where appropriate. Any existing lighting to be reused with T12 lamps should be retrofit to T8. 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.

6.4.1.1. 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 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 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 control. Provide individual photocell mounted on the south-facing side of a structure and provide 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 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 T12 lamps with T8, T5 or LED based on application. 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 or fluorescent luminaries will be used for special purpose and architectural accent lighting. Industrial LED or fluorescent luminaries will be used to light storage areas, equipment rooms, and similar spaces. Industrial LED or fluorescent 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 at the perimeter of the building. Secondary service (4,160V, 3-Phase, 3-Wire) is provided through the owner's secondary metering type distribution equipment via (3) local 25kV-4,160-Volt Substations. Metered service is taken at the owner's metering equipment to serve plant loads.

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 ramp 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 alarm, 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 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 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, derive 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.

Communication raceway systems will be installed to provide for distribution of the communications system throughout the facility. The system will provide service for telephones, data communication, and other telephone system related communications. Refer to the Communication and Electronic Systems DSM for communications system requirements.

The existing access control and security systems installed in the building shall be modified where necessary for new remodel projects.

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 at the perimeter of the building. Secondary service (480Y/277 volts) is provided through the owner's secondary metering type distribution equipment. Metered service is taken at the owner's metering equipment to serve the general building and process systems and equipment. Electrical power service (480Y/277 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, elevators, fire detection and alarm systems, security system, general convenience power, and other similar systems and equipment. Process systems and equipment includes computer systems, shop equipment, vehicle lifts, and other similar system and equipment.

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, security, communications, and data systems.

Fluorescent or LED luminaries will be used to light offices and other similar low ceiling spaces. Fluorescent or LED fixtures will be used to light the high ceiling maintenance areas of the facility. Industrial fluorescent or LED luminaries will be used to light storage areas, equipment rooms, and similar spaces. Recessed luminaries will be utilized in all finished spaces. Lighting control will be by use of occupancy/vacancy sensors in offices and smaller spaces where appropriate.

The interior space is 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 NFPA 90A. 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 exits. Manual alarm initiating devices will be installed in all areas near exits. Audible and visual alarm devices will be installed throughout the facility. The fire alarm system shall be connected to the central airport fire alarm system. Refer to the Life Safety DSM for all fire detection and alarm system descriptions and requirements.

Communication raceway systems will be installed to provide for distribution of the telephone and communications system throughout the facility. The system will provide service for telephones, data communication, and other telephone system related communications. Refer to the Communication and Electronic Systems DSM for communications systems requirements.

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 at the perimeter of the building. Secondary service (480Y/277 volts) is provided through the facility's secondary metering type distribution equipment. Electrical power service (480Y/277) 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, elevators, fire detection and alarm systems, security system, general convenience power, and other similar systems and equipment. Process systems and equipment includes computer systems, material handling systems, and other similar systems and equipment.

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, security communications and data systems.

Fluorescent luminaries will be used to light offices and other similar low-ceiling spaces. Fluorescent or LED luminaries will be used to light the high ceiling areas of the facility. Industrial fluorescent luminaries will be used to light storage areas, equipment rooms, and similar spaces. Recessed luminaries will be utilized in all finished spaces. Lighting control will be by use of occupancy/vacancy sensors in offices and smaller spaces where appropriate.

The interior space will be fire sprinklered and the 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 serving these areas, when required by NFPA 90A. Thermal detection devices will be 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 will be installed in all areas near exits. Audible and visual alarm devices will be installed throughout the facility. The fire alarm system shall be connected to the central airport fire alarm system. Refer to the Life Safety DSM for all fire detection and alarm system descriptions and requirements.

Communication raceway systems will be installed to provide for distribution of the telephone and communication system throughout the facility. The system will provide service for telephones, data communication, and other telephone system related communications. Refer to the Communication and Electronic Systems DSM for communications system requirements.

An access control/security system will be installed throughout the facility to monitor and/or alarm all activities in the facility. The security system shall be connected to the central airport security system.

6.7.4. Aircraft Hangars

The electrical service is provided by Xcel at the perimeter of the building. Secondary service (480Y/277 volts) is provided through the facility's secondary metering type distribution equipment. Metered service is taken at the facility's metering equipment to serve the general building and process systems and equipment. Electrical power service (480Y/277 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, elevators, fire detection and alarm systems, security system general convenience power, and other similar systems and equipment. Process systems and equipment includes computer systems, show equipment, and other similar systems and equipment.

Emergency electrical power shall be provided by a separate dedicated diesel (or natural gas) engine generator installed in the building. Generation will be at 480Y/277 volts and 208Y/120 volts emergency power to serve systems and equipment shall be provided as required. Emergency electrical power is distributed throughout the facility to serve elevators, exit and egress lighting, fire detection and alarm security systems.

Fluorescent luminaries will be used to light offices, shops, and similar low ceiling spaces. Fluorescent or LED luminaries will be used to light the hangar bays and other high ceiling areas of the facility. Industrial fluorescent luminaries will be used to light storage areas, equipment rooms, and similar spaces. Recessed luminaries will be utilized in all finished spaces. Lighting control will be by used of local switching in offices, shops, and similar spaces.

Hangar offices, hangar shops, and small hangar bays shall be equipped with a wet pipe sprinkler system. The interior space shall be fire sprinklered and the fire sprinkler system shall be alarmed and supervised. Large hangar bays shall be equipped with a foam/water deluge system. Smoke detection will be provided in all non-sprinklered

areas and in the HVAC supply and return air systems, when required by NFPA 90A. 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. Manual alarm initiating devices will be installed in all areas near exits. The building fire protection sprinkler systems and foam/water deluge systems will be alarmed and supervised. Audible and visual alarms devices will be installed throughout the facility. The fire alarm system shall be connected to the central airport fire alarm system.

Communication raceway systems will be installed to provide for distribution of the telephone and communications system throughout the facility. The system will provide service for public telephones, private telephones, data communication, and other telephone system related communications. 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 facility. The security system shall be connected to the central airport security system.

6.7.5. Flight Kitchens

The electrical service will be provided by Xcel at the perimeter of the building. Secondary service (480Y/277 volts) will be provided through the facility's secondary metering type distribution equipment. Metered service will be taken at the facility's metering equipment to serve the general building and process systems and equipment. Building systems and equipment includes HVAC equipment, lighting systems, elevators, fire protection and alarm systems, security system, general convenience power, and other similar systems and equipment. Process systems and equipment includes computer systems, kitchen equipment, and other similar systems and equipment.

Emergency electrical power will be provided by separate dedicated diesel (or natural gas) engine-generators installed in the building. Generation will be at 480Y/277 volts. Distribution of 480Y/277 volts and 208Y/120 volts emergency power to serve systems and equipment shall be provided as required. Emergency electrical power will be distributed throughout the facility to serve passenger elevators, exit and egress lighting, fire detection and alarm, security, communications, refrigerated food storage equipment and other designated critical systems and equipment.

Fluorescent luminaries will be used to light all areas of the facility. Recessed luminaries will be utilized in all finished spaces. Preferred lighting control will be use of local occupancy/vacancy sensor switching, EMCS control or other lighting control will be permitted.

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 the HVAC supply and return air systems, when required by NFPA 90A. All kitchen hoods equipped with fixed carbon dioxide extinguished systems shall have a system discharge pressure switch to automatically activate the fire alarm. Thermal detection devices will be installed in all non-sprinklered spaces where the used of smoke detectors are not appropriate due to the normal or expected presence of products of combustion. Manual alarm initiating devices will be installed in all areas near exits. Audible and visual alarms devices will be installed throughout the facility. The fire alarm system shall be connected to the central airport fire alarm system. Refer to the Life Safety DSM for all fire detection and alarm system descriptions and requirements.

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

A security system will be installed throughout the facility to monitor and/or alarm activities in the facility. The security system shall be connected to the central airport security system.

6.7.6. Snow Removal Equipment Facilities

The electrical service will be provided by Xcel at the perimeter of the building. Secondary service (480Y/277 volts) will be provided through the facility's secondary metering type distribution equipment. Metered service will be taken at the facility's metering equipment to serve the general building and process systems and equipment. Electrical power service (480Y/277 and 208Y/120 volts) will be distributed throughout the facility to serve building and process systems and equipment. Electrical power service (480Y/277 and 208Y/120 volts) will be 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 power, and other similar systems and equipment. Process systems and equipment includes computer systems, shot equipment, vehicle lifts, and other similar system and equipment.

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, security, communications, and data systems.

Fluorescent luminaries will be used to light office and other similar low ceiling spaces. High-pressure sodium luminaries will be used to light the high ceiling maintenance and vehicle storage areas of the facility. Industrial fluorescent luminaries will be used to light storage areas, equipment rooms, and similar space. Recessed luminaries will be utilized in all finished spaces. Lighting control will be by use of local switching in offices and similar spaces.

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 the HVAC supply and return air systems, when required by NFPA 90A. Thermal detection devices will be installed in all non-sprinklered spaces where the used of smoke detectors are not appropriate due to the normal or expected presence of products of combustion. Manual alarm initiating devices will be installed in all areas near exits. Audible and visual alarm devices will be installed throughout the facility. The fire alarm system shall be connected to the central airport fire alarm system. Refer to the Life Safety DSM for all fire detection and alarm system descriptions and requirements.

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

A security system will be installed throughout the space to monitor and/or alarm all activities in the facility. The security system shall be connected to the central airport security system.

6.7.7. Fire Crash Rescue Facilities

The electrical service will be provided by Xcel at the perimeter of the building. Secondary service (480Y/277 volts) will be provided through the facility's secondary metering type distribution equipment. Metered service will be taken at the facility's metering equipment to serve the general building and process systems and equipment. Electrical power service (480Y/277 and 208Y/120 volts) will be 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 system security system, general convenience power, other similar systems and equipment and electric snow melting on approach ramps (if installed). Process systems and equipment includes computer systems, shop equipment, and other similar systems and equipment.

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's 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.

Fluorescent luminaries will be used to light offices and other similar low ceiling spaces. Fluorescent and high-pressure sodium luminaries will be used to light the high ceiling vehicle garage areas of the facility. Industrial fluorescent luminaries will be used to light storage areas, equipment rooms, and similar spaces. Recessed luminaries will be utilized in all finished spaces. Lighting control will be by use of local switching in offices and similar spaces.

6.7.7.1. 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

6.7.8. Other Outlying Buildings

The electrical service will be provided by Xcel at the perimeter of the building. Secondary service (480Y/277 volts or 208Y/120 volts, as required) will be provided through the facility's secondary metering type distribution equipment. Metered service will be taken at the facility's metering equipment to serve the general building and process systems and equipment. Electrical power service (480Y/277 and 208Y/120 volts) will be distributed throughout the facility to serve building and process systems and equipment.

6.7.8.1. Electrical Submetering

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

End of Chapter

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 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	Abbreviation	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. Sizing of the transformer and panelboard shall be selected by the Designer. 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, and 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 on to 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 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 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 photocell-based controls, 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 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, as defined in SAE J1772, are listed in Table 8-2 – Charge Methods.

Table 8-2 – Charge Methods

Charge Method	Nominal Supply Voltage (Volts)	Maximum Current (Amps, Continuous)	Brach Circuit Breaker Rating (Amps)
AC Level 1 (aka Level 1)	120 VAC, 1 – Phase	12A	20A (minimum)
AC Level 2 (aka Level 2)	208 – 240 VAC, 1 – Phase	32A	40A*
DC Charging (aka Level 3)	600 VDC Maximum	400A Maximum	As Required

**A lower circuit breaker rating may be selected based on charging station manufacturer's recommendations.*

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 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% space capacity. Provide sufficient breaker space in the branch circuit panel to serve all planned and future stations plus 25% spare.

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 a 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 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 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.

8.2. Parking Considerations

8.2.1. Signage and Pavement Markings

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.

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