



DENVER INTERNATIONAL AIRPORT

DESIGN STANDARD MANUAL

Tenant

Design, Engineering and Construction

Revised: Q2 2026



Copyright ©1989-2026 by City and County of Denver, Denver International Airport

Content has been reviewed and edited by Design, Engineering and Construction.

While the City provides the information in this document to anyone, the City retains copyright on all text, graphic images and other content. This means that user may not: (1) distribute the text or graphics to others without the express written permission of the City and County of Denver; (2) mirror or copy this information to another document without permission; or (3) modify or re-use the text graphics in this document. Users may print copies of the information for personal and reference for their own documents. Commercial use of the materials is prohibited without the written permission of the City. In all copies of this information, users must retain this notice and any other copyright notices originally included.

Denver International Airport reserves all other rights.

Printed in the United States of America

Table of Contents

Summary of Revisions	xxxi
Purpose of Design Standards Manuals	xxxv
Tenant Development Guidelines	37
Chapter 1 - General	37
1.0 Introduction	37
1.0.1 Scope of this Manual	37
1.0.2 Tenant-Designer Coordination	37
1.0.3 ORAT Requirements	37
1.1 Tenant Project Delivery - Non-Concessions Projects	37
1.1.1 Required Items	38
1.1.2 Project Delivery Process	38
1.1.3 Project Closeout	39
1.2 Tenant Project Delivery - Concession Projects	40
1.2.1 Required Items	40
1.2.2 Project Delivery Process	40
Volume 1 - Architectural	45
Chapter 1 - General	45
1.1.0 Design Intent.....	45
1.1.0.1 DEN Design Principles	45
1.1.0.2 Design Review Committee (DRC)	45
1.1.1 Code Information	45
1.1.1.1 Terminal Building Height	45
1.1.1.2 Concourse Building Height	46
1.1.1.3 Building Area	46
1.1.1.4 Building Area – Concourses	46
1.1.1.5 Occupancy Classifications	47
1.1.1.6 Construction Type: Existing Building Elements	48
1.1.1.7 New Building Elements	48
1.1.1.8 Interior Finish	49
1.1.1.9 Atrium Combustible Loading Restrictions	50
1.1.1.10 Storage Use Restrictions	50
1.1.1.11 Other Special Uses	50
1.1.1.12 References	51
1.1.2 Accessibility	51
1.1.2.1 Accessible Interior Design Intent	51
1.1.2.2 Doors	51
Chapter 2 - Interior Environment	53
1.2.0 General Architectural Information.....	53
1.2.0.1 Aesthetic Considerations	53
1.2.0.2 Elements of Design	53
1.2.0.3 Criteria and Guidelines	54
1.2.0.4 STC Rating Charts	55
1.2.1 Interior Design Features	55
1.2.1.1 Exposed Concrete Surfaces	55
1.2.1.2 Stone Surfaces	56
1.2.1.3 Metal Finish	56
1.2.1.4 Ceilings	56
1.2.1.5 Diffusers	56
1.2.1.6 Glare	56
1.2.1.7 Exposed Conduit	56

1.2.1.8 Cameras/Monitors	56
1.2.1.9 IECC Compliance	56
1.2.1.10 Window Treatments	56
1.2.1.11 Sustainability	57
1.2.1.12 Application and Use of Materials	57
1.2.1.13 Millwork	57
1.2.2 Food Courts, Concession Common Areas, and Common Seating Areas	57
1.2.2.1 Food Courts/Concession Common Areas/Common Seating Areas	57
1.2.2.2 Concession Back of House Areas	59
1.2.3 Concessions.....	60
1.2.3.1 Introduction	60
1.2.3.2 Stairs	60
1.2.4 Non-Passenger Restrooms.....	61
1.2.4.1 Introduction	61
1.2.4.2 Non-Public (service/ back of house)	61
Volume 2 - Communications and Electronic Systems	63
Chapter 1 - General System Information	63
2.1.0 Communication and Electronic System Information	63
2.1.0.1 System Information and Requirements	63
2.1.1 Drawing Requirements.....	63
2.1.1.1 Drawings	63
2.1.1.2 Definition	63
2.1.1.3 Completeness	63
2.1.1.4 Drawing Sequence	64
2.1.1.5 General Notes, Drawing Index, Symbols, and Abbreviations	64
2.1.1.6 Site Plan	64
2.1.1.7 Floor, Roof, and Reflected Ceiling Plans	64
2.1.1.8 Equipment Room Layouts and Elevations (DEN and Tenant)	64
2.1.1.9 Point-to-Point Wiring Diagrams	65
2.1.1.10 System Riser Diagrams	65
2.1.1.11 Conduit/Cable Tray Riser Diagrams	65
2.1.1.12 System Details	66
2.1.1.13 Communications and Electronic Systems	66
2.1.1.14 Symbols for Other Functional Disciplines	66
2.1.1.15 Functional Designations	66
2.1.1.16 Drawing Delineation Types	67
2.1.1.17 Delineation Drawings	67
2.1.1.18 Specification Relationship	67
Chapter 2 - Premise Wire and Communications	69
2.2.0 System Overview	69
2.2.0.1 Description	69
2.2.0.2 Addition of Telecommunications Facilities	69
2.2.1 Conduit Requirements	70
2.2.1.1 Telecommunications Outlet	70
2.2.1.2 Telecommunications Outlet - Wall-Mounted Telephones	70
2.2.1.3 System Color Coding	70
Chapter 3 - Telecommunication and Networking	73
2.3.0 System Overview	73
2.3.0.1 Scope	73
2.3.0.2 Criteria	73
2.3.1 Networks and Services	73
2.3.1.1 Telecommunication Service	73
2.3.1.2 Local Area Networks	73

2.3.1.3 Wireless Networking	74
2.3.2 Design Criteria.....	74
2.3.2.1 Telecommunications Service	74
2.3.2.2 Local Area Networks	74
2.3.2.3 Public Wi-Fi Network	74
2.3.3 Design Requirements	75
2.3.3.1 Design Development Coordination	75
2.3.3.2 Design Analysis Report	76
2.3.3.3 Design Drawings	76
Chapter 4 - DEN Television	77
2.4.0 System Overview	77
2.4.0.1 Scope	77
2.4.0.2 Criteria	77
2.4.1 Television Service.....	77
2.4.1.1 Tenant Drops	77
2.4.2 Design Criteria.....	78
2.4.2.1 Cabling and Conduit	78
2.4.2.2 Fiber	78
2.4.3 Drawing Requirements.....	78
Chapter 5 - Radio Frequency	79
5.0 General	79
Chapter 6 - Energy Management and Control	81
2.6.0 System Overview	81
2.6.0.1 Scope	81
2.6.0.2 Criteria	81
2.6.0.3 Definitions	81
2.6.1 Networks and Services	81
2.6.1.1 Basic EMCS Network Architecture	81
2.6.1.2 BACNet IP Networks	82
2.6.1.3 BACNet MS/TP Networks	82
2.6.1.4 Physical Integration with DEN	82
2.6.2 Design Criteria.....	82
2.6.2.1 General Network Requirements	82
2.6.2.2 Electrical Metering Networks	83
2.6.3 Design Requirements	84
2.6.3.1 Drawing Requirements	84
2.6.4 EMCS Graphics	84
2.6.4.1 General	84
2.6.4.2 Metasys UI Graphics	84
2.6.4.3 Integration with Existing Systems	84
2.6.4.4 Equipment Page Design	84
Volume 3 - Electrical	87
Chapter 1 - General	87
3.1.0 General	87
3.1.0.1 Definitions	87
3.1.1 Design Parameters	87
3.1.1.1 Electrical Equipment Ratings	87
3.1.1.2 Voltage Drop	87
3.1.1.3 Short Circuit Current	87
3.1.1.4 Utility Coordination	88
3.1.2 Design Document Requirements	88
3.1.2.1 Construction Drawing Requirements	88

Chapter 2 - Interior Electrical Power Distribution Systems	89
3.2.0 Interior Electrical Power Distribution Systems	89
3.2.0.1 Scope	89
3.2.1 Materials and Equipment	89
3.2.1.1 Conductors	89
3.2.1.2 Raceways	90
3.2.2 Panelboards and Circuit Breakers	90
3.2.2.1 Low Voltage Switchgear and Switchboards	92
3.2.2.2 Low Voltage DEN Submetering	92
3.2.2.3 Receptacles	93
3.2.2.4 Signage	93
3.2.2.5 Floor Devices	93
3.2.3 Installations	94
3.2.3.1 Design	94
3.2.3.2 Wiring Systems	94
3.2.3.3 Branch Circuit Requirements	94
3.2.3.4 System Protection	95
3.2.3.5 Electrical Safety	96
3.2.3.6 Energy Conservation Measures	96
3.2.3.7 Tenants and Concessions	97
Chapter 3 - Grounding Systems	99
3.3.0 Grounding Systems	99
3.3.0.1 Scope	99
3.3.0.2 Criteria	99
3.3.0.3 Design Approach	99
3.3.0.4 Design Task Categories	99
3.3.0.5 Design Analysis Requirements	99
3.3.1 Materials.....	99
3.3.1.1 General	99
3.3.2 Installations	100
3.3.2.1 General	100
3.3.2.2 Equipment Grounding	100
3.3.2.3 Equipment Ground Bus	100
3.3.2.4 Other Grounding System Requirements	100
Chapter 4 - Lighting Systems	101
3.4.0 Lighting Systems.....	101
3.4.0.1 Scope	101
3.4.0.2 Criteria	101
3.4.0.3 Design Approach	101
3.4.0.4 Design Task Categories	101
3.4.0.5 Design Standards Nomenclature	102
3.4.0.6 Design Analysis Requirements	103
3.4.1 Equipment	103
3.4.1.1 General Requirements	103
3.4.1.2 Luminaire Requirements	103
3.4.1.3 Lighting Control Requirements	104
3.4.2 Installations	104
3.4.2.1 Luminaire Selection	104
3.4.2.2 Emergency Lighting	104
3.4.2.3 Efficiency Considerations	104
3.4.2.4 Tenants and Concessions	104
Volume 4 - Life Safety	107
Chapter 1 - General	107

4.1.0 Overview.....	107
4.1.1 General	107
4.1.2 Common Terms.....	107
4.1.3 System Definitions	108
4.1.3.1 Fire Protection Systems	108
4.1.3.2 Fire Alarm and Detection System	108
4.1.3.3 Emergency Communication System	108
4.1.3.4 Smoke Control System	109
4.1.3.5 Emergency Alarm System	109
4.1.4 System Design.....	109
4.1.5 Design	109
4.1.5.1 A/E Construction Drawings	109
4.1.5.2 Shop Drawings (Installer)	109
4.1.5.3 Interim Drawings	109
4.1.5.4 More Stringent Document Requirements	110
4.1.5.5 Reviews	110
4.1.5.6 Drawing Format	110
4.1.5.7 Zone Designation / Nomenclature	110
4.1.6 Referenced Codes and Standards	111
4.1.6.1 Denver Building Code Amendments	111
Chapter 2 - Fire Protection System	113
4.2.0 General	113
4.2.1 Scope	113
4.2.2 System Description	113
4.2.3 Criteria	113
4.2.4 Tenant Spaces	113
4.2.5 Drawing Requirements.....	113
4.2.5.1 A/E 30% Drawings	113
4.2.5.2 A/E 60% Drawings	113
4.2.5.3 A/E 90% Drawings	114
4.2.5.4 Design Documents	114
4.2.5.5 Interim System Documents	114
4.2.5.6 Sequence of Operation	114
4.2.6 Design Analysis Requirements.....	114
4.2.6.1 Building Description	114
4.2.6.2 Applicable Codes	115
4.2.6.3 Design Responsibility	115
4.2.6.4 Sprinkler Design Densities	115
4.2.6.5 Piping / Valves	115
4.2.6.6 Pump Water Flow Meter	116
4.2.7 Associated Systems	116
4.2.7.1 Sprinkler System	116
4.2.7.2 Dry System	116
4.2.7.3 Kitchen Hood Systems	116
4.2.7.4 Coordinated with Smoke Control Zones	116
4.2.8 Specific Building Requirements	117
4.2.8.1 Airport Terminal and Concourse Buildings	117
Chapter 3 - Fire Alarm and Detection System	119
4.3.0 General	119
4.3.1 Scope	119
4.3.2 System Description	119
4.3.3 Criteria	119
4.3.4 Drawing Requirements.....	119

4.3.4.1 A/E 30% Drawings	119
4.3.4.2 A/E 60% Drawings	119
4.3.4.3 A/E 90% Drawings	120
4.3.4.4 Fire Alarm System Interim Drawings	120
4.3.5 Design Analysis Requirements.....	121
4.3.5.1 Applicable Code	122
4.3.5.2 Design Responsibility	122
4.3.6 Initiating Devices.....	122
4.3.6.1 Heat Detectors	122
4.3.6.2 Smoke Detectors	122
4.3.6.3 Carbon Monoxide Detectors	122
4.3.6.4 Duct Detectors	122
4.3.6.5 Pull Stations	122
4.3.6.6 Water Flow Switches	122
4.3.6.7 Kitchen Hood	123
4.3.6.8 Dry System Pressure Switch	123
4.3.6.9 Other System Alarm Monitoring	123
4.3.7 Monitoring.....	123
4.3.7.1 Tamper Swatches	123
4.3.7.2 Pressure Switches	123
4.3.8 Control.....	123
4.3.8.1 Elevator Recall	123
4.3.8.2 Door Holder Release	123
4.3.8.3 Media Shunt	124
4.3.9 Notification Devices	124
4.3.9.1 Strobes	124
4.3.9.2 Speakers	124
4.3.9.3 Supervision	125
4.3.10 Survivability	125
4.3.10.1 Extended System	125
4.3.10.2 Signaling Line Circuits	125
4.3.11 Graphic Annunciation.....	125
4.3.11.1 Terminal Complex (Jeppesen Terminal, Concourses, HTC)	125
Chapter 4 - Emergency Communication System	127
4.4.0 General	127
4.4.1 Scope	127
4.4.2 System Description	127
4.4.2.1 The ECS Audio	127
4.4.2.2 Manufacturer Limitation	127
4.4.3 Drawing Requirements.....	128
4.4.3.1 A/E 30% Drawings	128
4.4.3.2 A/E 60% Drawings	128
4.4.3.3 A/E 90% Drawings	128
4.4.4 Conduit and Wire	128
4.4.4.1 Loudspeaker Cable	128
4.4.4.0.3 Whip to Speaker Cable	129
4.4.4.1 Conduit Color & Wire Integrity	129
4.4.5 Criteria	129
4.4.6 ECS Interim Documents	130
4.4.7 Design Analysis Requirements.....	130
4.4.7.1 Applicable Codes	130
4.4.7.2 Design Responsibility	130
4.4.7.3 Ambient Noise Levels	130

4.4.8 Loudspeakers.....	131
4.4.9 Fire Alarm System Interface	132
4.4.9.1 ECS	132
4.4.10 ECS Operational Plan	132
4.4.10.1 Introduction	132
4.4.11 Operational Sequences.....	132
4.4.11.2 Media Shunt	132
4.4.12 Fire Alarm System Notification Appliances	133
4.4.12.3 ECS/ Paging System Notification Appliances	133
4.4.13 ECS Operation	134
4.4.13.1 System Description	134
4.4.14 ECS Screens	137
4.4.14.1 TSW Prerecorded Message Screen	137
4.4.14.2 ECS System Live Voice Selection	138
Chapter 5 - Smoke Control System	141
4.5.0 General	141
4.5.1 Scope	141
4.5.2 System Description	141
4.5.3 Criteria	141
4.5.4 Tenant Spaces	141
4.5.5 Drawing Requirements.....	141
4.5.5.1 A/E 60% Drawings	141
4.5.5.2 A/E 90% Drawings	141
4.5.5.3 Preparation	142
4.5.6 Design Analysis Requirements.....	142
4.5.6.1 Applicable Codes	142
4.5.6.2 Design Responsibility	142
4.5.7 Equipment	142
4.5.8 Equipment / Zone Identification.....	143
4.5.8.1 Transfer Air	143
4.5.8.2 Smoke Zone and Airflow Diagrams	143
4.5.8.3 System Initiation	143
4.5.9 Terminal Smoke Control Operation Overview	144
4.5.9.1 Great Hall	144
4.5.9.2 Levels 5 and 6 Ticketing, Baggage Claim and Tenant Areas	144
4.5.9.3 Level 1 Offices	144
4.5.9.4 Water Flow Activation in Public Areas	144
4.5.10 North Terminal Smoke Control Operation Overview.....	144
4.5.10.1 Level 4 Offices and Communications Area	144
4.5.11 Concourse A Smoke Control Operation Overview	144
4.5.11.1 Center-core and International Smoke Control Zones	145
4.5.11.2 Sub-core, Holdroom, and International Walkway Smoke Control Zones	145
4.5.11.3 Tenant Space Smoke Control Zones	145
4.5.12 Concourse B Smoke Control Operation Overview	145
4.5.12.1 Center Core Smoke Control Zones	145
4.5.12.2 Sub-core and Holdroom Smoke Control Zones	146
4.5.12.3 Ventilation/Smoke Control Fans (VSCFs)	146
4.5.12.4 Tenant Space Smoke Control Zones	146
4.5.13 Concourse C Smoke Control Operation Overview	146
4.5.13.1 Center Core Smoke Control Zones	146
4.5.13.2 Sub-core Smoke Control Zones	147
4.5.13.3 Tenant Space Smoke Control Zones	147
4.5.14 Tenant Spaces	147

4.5.15 Construction Documents	147
4.5.16 Smoke Control System Testing	148
4.5.17 Renovation Work	148
Chapter 6 - Emergency Alarm Systems	149
4.6.0 General	149
4.6.1 Scope	149
4.6.2 System Description	149
4.6.3 Criteria	149
4.6.4 Drawing Requirements.....	149
4.6.4.1 A/E 30% Drawings	149
4.6.4.2 A/E 60% Drawings	149
4.6.4.3 A/E 90% Drawings	150
4.6.5 Design Analysis Requirements.....	150
4.6.5.1 Applicable Codes	150
4.6.5.2 Design Responsibility	150
4.6.6 System Requirements	150
4.6.6.1 Inert Gas	150
4.6.7 Beverage Dispensing Carbon Dioxide Emergency Alarm Systems.....	151
4.6.7.1 Alarm Set Points	151
4.6.8 Inert Gas Emergency Alarm Systems	151
4.6.8.1 Alarm Set Points	151
4.6.9 Mechanical Ventilation	151
4.6.10 UPS Backup	152
Chapter 7 - Two-Way Communication System	153
4.7.0 General	153
4.7.1 System Description	153
4.7.2 Criteria	153
4.7.3 Tenant Spaces	153
Chapter 8 - Area Specific Life Safety Systems	155
4.8.0 Scope	155
4.8.1 System Description	155
4.8.2 Criteria	155
4.8.3 Tenant Spaces	155
Chapter 9 - Systems Testing and Commissioning	157
4.9.0 General	157
4.9.1 Scope	157
4.9.2 System Description	157
4.9.3 Criteria	157
4.9.4 Documentation	157
Chapter 10 - Other Life Safety Systems	159
4.10.0 Design Review	159
4.10.1 Code Requirements	159
4.10.2 Fire Pump.....	159
Volume 5 - Mechanical	161
Chapter 1 - General	161
5.1.0 General	161
5.1.0.1 Intent	161
5.1.0.2 Definitions	161
5.1.0.3 General	161
5.1.0.4 Mechanical Engineer	162
5.1.0.5 Regulatory Requirements	162
5.1.0.6 Work Sequence, Coordination, and Installation	162

5.1.0.7 Site Conditions	163
5.1.1 Design Criteria.....	163
5.1.1.1 System Criteria	163
5.1.1.2 Mechanical Design Criteria — Flexibility	163
5.1.1.3 Ventilation Standards	164
5.1.1.4 Energy Efficiency Requirements	165
5.1.1.5 Noise Criteria	165
5.1.1.6 Altitude Correction	166
5.1.1.7 Supports and Penetrations	166
5.1.2 Equipment Identification.....	166
5.1.2.1 General	166
5.1.2.2 Air Handling Unit, Unitary Equipment, and Hydronic Equipment Identification	167
5.1.2.3 Dependent Unit Equipment Identifier	168
5.1.3 DEN Mechanical/Plumbing Equipment Naming Components — Identifiers	169
5.1.4 Submittals.....	171
5.1.4.1 Design Submittals	171
5.1.4.2 As-Built Submittals	171
5.1.5 Equipment Supports and Thermal Expansion Compensations.....	171
5.1.5.1 Design	171
5.1.6 Workmanship.....	171
Chapter 2 - Central Utility Plant	173
5.2.0 Equipment	173
5.2.0.1 Piping and Valves	173
Chapter 3 - HVAC Systems	175
5.3.0 HVAC Systems	175
5.3.0.1 Air Handling Systems	175
5.3.0.2 Roof-Mounted HVAC Systems	175
5.3.0.3 HVAC for Unfinished (Tenant) Areas	176
5.3.1 Ventilation Systems	177
5.3.1.1 Outdoor Air Requirements	177
5.3.1.2 Air Economizer Control	177
5.3.1.3 Return Air/Transfer Air	177
5.3.1.4 Ventilation Rates	177
5.3.2 Existing Systems.....	178
5.3.2.1 General	178
5.3.2.2 Existing Air Handling Systems	178
5.3.2.3 Existing HVAC Air Distribution	179
5.3.3 Tenant Remodel Requirements	179
5.3.3.1 Tenant Design Parameters	179
5.3.3.1.1 Existing Base Building Mechanical Design Capabilities	179
5.3.3.2 VAV Terminal Air Units	180
5.3.3.3 New Tenant HVAC Systems	180
5.3.3.4 New Tenant Air Handling Units	181
5.3.3.5 Food and Beverage Tenant Equipment	181
5.3.4 Sustainability	182
Chapter 4 - Air Distribution Systems	183
5.4.0 Air Distribution Systems.....	183
5.4.0.1 Ductwork Design	183
5.4.0.2 Ductwork Requirements	183
5.4.0.3 Dampers	184
5.4.0.4 Diffusers	184
5.4.0.5 Grilles	184
5.4.0.6 Transfer Air	184

5.4.0.7 VAV Terminal Air Units	184
5.4.0.8 Security Gates	185
5.4.0.9 Ductwork Supports	185
5.4.0.10 Presentation of Ductwork Systems	185
Chapter 5 - Controls	187
5.5.0 Controls	187
5.5.0.1 General	187
5.5.0.2 Existing Base Building HVAC Control Systems	188
5.5.0.3 New and Replacement HVAC Control Systems	189
5.5.1 Sample Control Components and Requirements	190
5.5.1.1 VAV Terminal Unit Controls	190
5.5.1.2 Unit Heaters Controls	190
a. Split Systems - Fan Coil Units (FCU)	190
5.5.1.3 Exhaust Fan	191
5.5.1.4 Pump Controls	191
5.5.1.5 Monitoring	191
5.5.1.6 HVAC Control Functions	191
5.5.1.7 Thermostats and Temperature Sensors	193
5.5.2 Sequence of Operation.....	193
5.5.2.1 Emergency Shutdown	194
5.5.2.2 Automatic Shutdown	194
5.5.2.3 Automatic System Restart	194
5.5.3 Controls Points Naming	194
5.5.3.1 General	194
5.5.3.2 Supervisory Controller Point Naming	195
5.5.4 Non-supervisory Controller Point Numbering	196
5.5.5 Equipment Alarming	197
5.5.5.1 Alarms in the EMCS	197
5.5.5.2 Alarm Points Only Trended in SkySpark	199
Chapter 6 - Hydronic Systems	203
5.6.0 Hydronic Systems	203
5.6.0.1 Existing Campus Heating/Cooling Systems Operation	203
5.6.1 Equipment	203
5.6.1.1 Chilled Water System	203
5.6.1.2 Hydronic Requirements	203
5.6.1.3 Tenant Loops	204
5.6.1.4 Piping and Valves	204
5.6.2 Design Criteria.....	204
5.6.2.1 General Requirements	204
5.6.3 Piping Supports	206
5.6.3.1 Design	206
5.6.3.2 Products	206
5.6.4 Existing Systems.....	207
5.6.4.1 Hydronic Requirements	207
5.6.5 Update of Standard Diagrams	207
5.6.5.1 Flow Diagrams	207
Chapter 7 - Space Requirements and Maintainability	209
5.7.0 Space Requirements and Maintainability	209
5.7.0.1 General	209
Chapter 8 - Plumbing Requirements	211
5.8.0 Plumbing Requirements	211
5.8.0.1 General	211
5.8.0.2 System Requirements	211

5.8.1 Plumbing Design Parameters.....	211
5.8.1.1 General	211
5.8.1.2 Calculations	211
5.8.1.3 Grease Traps	212
5.8.1.4 Floor Drains	214
5.8.1.5 Cleanouts	214
5.8.1.6 Industrial Waste	214
5.8.1.7 Backflow Prevention	214
5.8.1.8 HVAC Coil Condensate Drains	214
5.8.1.9 Secondary Condensate Drains	215
5.8.2 Plumbing System Components.....	215
5.8.2.1 General	215
5.8.2.2 Plumbing Fixtures and Equipment	216
5.8.2.3 Piping	216
5.8.2.4 Plumbing Pumps	216
5.8.2.5 Plumbing Sumps	216
5.8.2.6 Heat Trace Systems	217
5.8.3 Energy Conservation in Plumbing System Design.....	217
5.8.3.1 Domestic Hot Water	217
5.8.3.2 Temperature	217
5.8.3.3 Safety Devices	217
5.8.4 Natural Gas	217
5.8.4.1 Sizing	217
5.8.4.2 Metering	218
5.8.4.3 Gas Systems Protection	218
5.8.4.4 Sustainability	219
5.8.5 Tenant Remodel Requirements	219
5.8.5.1 Plumbing Requirements	219
5.8.5.2 Grease Waste	220
5.8.5.3 Water Heaters	220
5.8.5.4 Water Meters	220
5.8.5.5 Backflow Prevention	220
5.8.5.6 Roof Water	220
Chapter 9 - Facility Design	221
5.9.0 Passenger Terminal — Concessions and Services	221
5.9.0.1 Design Conditions	221
5.9.0.2 Air Handling Systems	221
5.9.0.3 Outdoor Air Requirements	221
5.9.0.4 Kitchen Exhaust	221
5.9.0.5 Ventilation Rates	222
5.9.0.6 Filtration	222
5.9.1 Domestic Concourse — Tenant Spaces	222
5.9.1.1 Design Conditions	222
5.9.1.2 Air Handling Systems	222
5.9.1.3 Perimeter Systems	223
5.9.1.4 Outdoor Air Requirements	223
5.9.1.5 Ventilation Rates	223
5.9.1.6 Kitchen Exhaust	223
5.9.1.7 Filtration	223
5.9.1.8 AHU Controls	223
5.9.1.9 Central Utility Plant	223
5.9.1.10 Plumbing Requirements	223
5.9.1.11 Fire Protection	223

5.9.1.12 Smoke Control	224
5.9.1.13 Simplicity of Systems	224
Appendix A - Controls Points Abbreviations	225
Matrix A: DEN Concourse A West Expansion Concessions	235
Matrix B: DEN CEP Concourse B West Expansion Concessions	237
Matrix C: DEN Concourse C East Expansion Concessions	239
Volume 6 - Standards and Criteria	241
Chapter 1 - Administration	241
6.1.0 Administration	241
6.1.0.1 References	241
6.1.0.2 Purpose	241
6.1.0.3 Scope	241
6.1.0.4 Format	241
6.1.0.5 Procedures	241
6.1.0.6 Exclusions	241
6.1.1 Compliance with Codes and Regulations	242
6.1.2 Variance and Interpretation	242
6.1.2.1 Request Submittals	242
6.1.2.2 Request Format	242
6.1.2.3 Consultant Notification	242
6.1.3 Progress Meeting	242
6.1.4 Coordination and Administration	243
6.1.4.1 Procedures	243
6.1.4.2 Coordination	243
6.1.4.3 Design Standards	243
6.1.4.4 Communication with Consultant	243
6.1.4.5 Design Review Committee	243
6.1.4.6 Design Project Closeout	243
6.1.5 Field Verification	244
Chapter 2 - Design Phases	245
6.2.0 Design Phases	245
6.2.0.1 Tenant Project Design Phases	245
Chapter 3 - Contract Documents	247
6.3.0 Contract Documents.....	247
6.3.0.1 Intent	247
6.3.0.2 Referenced Standards	247
6.3.0.3 Precedence of Contract Documents	247
6.3.0.4 Scope of Work	248
6.3.1 Contract Documents, Technical Specifications, and Technical Reports.....	249
6.3.1.1 Construction Documents	249
6.3.2 Submittal Requirements.....	249
6.3.3 System Compatibility	249
Chapter 4 - Record Documents	251
6.4.0 Record Documents	251
6.4.0.1 Record Drawings	251
6.4.0.2 Specifications	251
6.4.0.3 Final Design Analysis Report (Conformed)	251
6.4.0.4 Certification	251
6.4.0.5 Submittal	251
Chapter 5 - Design Contract Closeout/Task Closeout	253
6.5.0 Design Contract Closeout/Task Closeout	253
6.5.0.1 Document Inspection	253

6.5.0.2 Final Review	253
6.5.0.3 City Review	253
Chapter 6 - Specification Requirements	255
6.6.0 Specification Requirements.....	255
6.6.0.1 Consultant Requirements	255
6.6.0.2 Compliance	255
6.6.0.3 Location	255
6.6.0.4 Consultant Preparation	255
6.6.0.5 DEN Technical Requirements	257
6.6.0.6 Coversheet, Index and Certification Page	257
6.6.1 Format	258
6.6.1.1 Style	258
6.6.1.2 Construction Specification Institute Divisions	258
6.6.2 Standard Text Elements	258
6.6.2.1 General	258
6.6.2.2 Margins	258
6.6.2.3 Typeface and Line Spacing	258
6.6.2.4 Tab Set	258
6.6.2.5 Header	259
6.6.2.6 Footer	259
6.6.3 Table of Contents Page and Paragraph Numbering System.....	259
6.6.3.1 Location	259
6.6.3.2 Line Spacing	260
6.6.3.3 Line Numbering	260
6.6.3.4 Page Numbers	260
6.6.3.5 Section Title	260
6.6.4 Text Pages.....	260
6.6.4.1 Exceptions	260
6.6.5 Table and Figure Indexes.....	261
6.6.5.1 Location	261
6.6.5.2 Titles	261
6.6.5.3 Format	261
6.6.6 Tables and Charts	261
6.6.6.1 Location	261
6.6.6.2 Numbering	261
6.6.6.3 Title	261
6.6.6.4 Typeface	261
6.6.7 Nomenclature	262
6.6.7.1 Terminology	262
6.6.7.2 Abbreviations	262
6.6.7.3 Generic Terms	262
6.6.8 Detail Specifications	262
6.6.8.1 General Requirements	262
6.6.8.2 DEN Standard Technical Specifications	262
6.6.8.3 DEN Technical Requirements	264
6.6.8.4 Products and Materials	264
6.6.8.5 Specifying and Reviewing Products and Material Submittals	264
6.6.9 Redundancy	264
6.6.10 Reference	265
6.6.11 Industry Codes and Standards	265
6.6.12 Design Standards	265
6.6.13 FAA Requirements	265
6.6.14 Redline DEN Standard Technical Specifications	265

6.6.15 Submittal Registrar	265
6.6.16 Overstock Materials	265
Chapter 7 - Architectural Drawings	267
6.7.0 Architectural Drawings	267
6.7.0.1 Contents	267
6.7.0.2 Design Requirements	267
6.7.0.3 Sequence	267
6.7.1 Plans	267
6.7.1.1 Floor Plans	267
6.7.1.2 Reflected Ceiling Plans	268
6.7.1.3 Large Scale Plans	268
6.7.1.4 Precedence	268
6.7.1.5 Roof Plans	268
6.7.2 Sections	268
6.7.2.1 Precedence	268
6.7.2.2 Sections	268
6.7.3 Elevations	268
6.7.3.1 Exterior Elevations	268
6.7.3.2 Interior Elevations	268
6.7.3.3 Material Definitions	269
6.7.4 Demolition Drawings.....	269
6.7.4.1 General	269
6.7.5 Composite Drawings	269
6.7.5.1 Egress Plans	269
Chapter 8 - Structural Drawings	271
6.8.0 Structural Drawings.....	271
6.8.0.1 Definition	271
6.8.0.2 Sequence	271
6.8.1 Floor Plans	271
6.8.1.1 Structural Steel Framing	271
6.8.1.2 Floor Plans	271
6.8.1.3 Roof Plans	271
6.8.2 Elevations and Wall Sections	272
6.8.2.1 General	272
6.8.3 Standard Drawings, Schedules, Tables and Details	272
6.8.3.1 Drawings	272
Chapter 9 - Mechanical Drawings	275
6.9.0 Mechanical Drawings	275
6.9.0.1 Definitions	275
6.9.0.2 General Requirements	275
6.9.0.3 Design Requirements	275
6.9.1 Sequence	275
6.9.1.1 Numbering	275
6.9.1.2 Demolition	275
6.9.2 Flow Diagrams	275
6.9.2.1 Schematic Illustrations	275
6.9.2.2 Key Drawings	276
6.9.2.3 Flow Diagrams	276
6.9.3 Flow and Control Diagram Requirements	276
6.9.3.1 General Requirements	276
6.9.3.2 Flow Direction	276
6.9.3.3 Limits of Construction	276
6.9.3.4 Instruments and Controls	276

6.9.3.5 Set Points	277
6.9.3.6 Logic/Control	277
6.9.3.7 Operating Controls	277
6.9.3.8 Identification Tags	277
6.9.3.9 Existing System Tie-In	277
6.9.3.10 Symbols	277
6.9.3.11 Gravity Drainage	277
6.9.3.12 Space Pressurization Diagrams	277
6.9.4 Drawings for Mechanical Systems	278
6.9.4.1 General	278
6.9.4.2 Flow Diagrams	278
6.9.4.3 Enlarged Plans	278
6.9.4.4 Drawing Delineation	278
6.9.4.5 Demolition Drawings	281
6.9.4.6 Mechanical Details	281
6.9.5 Update of Standard Diagrams	282
6.9.6 Heating, Ventilating, Air Conditioning	282
6.9.6.1 General	282
6.9.6.2 Combined Drawings	282
6.9.6.3 Drawing Delineation	282
6.9.7 Mechanical Design Submittal Requirements.....	283
6.9.7.1 General	283
Chapter 10 - Plumbing Drawings	287
6.10.0 Plumbing Drawings	287
6.10.0.1 Definitions	287
6.10.0.2 General Requirements	287
6.10.0.3 Design Requirements	287
6.10.1 Sequence	287
6.10.1.1 Numbering	287
6.10.1.2 Demolition	287
6.10.2 Flow Diagrams.....	287
6.10.2.1 Schematic Illustrations	287
6.10.2.2 Key Drawings	288
6.10.2.3 Requirements	288
6.10.3 Flow Diagram Requirements	288
6.10.3.1 General	288
6.10.3.2 Flow	288
6.10.3.3 Limits of Construction	288
6.10.3.4 Instruments	288
6.10.3.5 Set Points	289
6.10.3.6 Controls	289
6.10.3.7 Operating Conditions	289
6.10.3.8 Identification Tags	289
6.10.3.9 Existing System Tie-In	289
6.10.3.10 Symbols	289
6.10.3.11 Gravity Drainage	289
6.10.4 Drawings for Piping	289
6.10.4.1 General	289
6.10.4.2 Drawing Delineation	290
6.10.4.3 Plumbing Details	290
6.10.5 Plumbing.....	290
6.10.5.1 General	290
6.10.5.2 Detailing Requirements	291

6.10.5.3 Demolition Drawings	292
6.10.5.4 Service Diagrams	292
6.10.6 Update of Standard Diagrams.....	293
6.10.7 Plumbing Design Submittal Requirements.....	293
6.10.7.1 General	293
Chapter 11 - Fire Protection Drawings	297
6.11.0 Fire Protection Drawings	297
6.11.0.1 Definitions	297
6.11.0.2 Design Requirements	297
6.11.1 Sequence	297
6.11.1.1 General	297
6.11.2 Flow Diagrams.....	297
6.11.2.1 Schematic	297
6.11.2.2 Key Drawings	297
6.11.2.3 Requirements	297
6.11.3 Flow Diagram Requirements	298
6.11.4 Drawings for Piping	298
6.11.4.1 General	298
6.11.4.2 One-line Diagrams	298
6.11.4.3 Demolition	298
6.11.4.4 Existing System Tie-In	298
6.11.4.5 Delineation	298
6.11.4.6 Detailing	299
6.11.5 Update of Standard Diagrams.....	300
6.11.6 Life Safety Design Submittal Requirements	300
6.11.6.1 Sprinkler System	300
6.11.6.2 Fire Alarm Systems	300
6.11.6.3 Emergency Communication System	301
Chapter 12 - Electrical Drawings	303
6.12.0 Electrical Drawings	303
6.12.0.1 General Information and Requirements	303
6.12.0.2 Definition	303
6.12.0.3 Design Requirements	303
6.12.0.4 Completeness	303
6.12.0.5 Sequence	303
6.12.0.6 Electrical and Electronic Symbols	303
6.12.0.7 Delineation Types	303
6.12.0.8 Delineation Drawings	304
6.12.0.9 Legend	304
6.12.0.10 Specification Relationship	304
6.12.1 Electrical Plans	304
6.12.1.1 Definition	304
6.12.1.2 Symbols	305
6.12.1.3 Arrows on Wires	305
6.12.1.4 Views	305
6.12.1.5 Details	305
6.12.1.6 Devices	305
6.12.1.7 Scale	305
6.12.2 Facility Electrical Power Distribution Plans	306
6.12.2.1 Definition	306
6.12.2.2 Panelboard Schedules	306
6.12.2.3 Panelboard Drawings	306
6.12.3 Facility Lighting Plans	306

6.12.3.1 Definition	306
6.12.3.2 Emergency Lighting	306
6.12.4 One-Line Diagrams	306
6.12.4.1 Definition	306
6.12.4.2 Requirements	307
12.13 Symbols for Electrical Drawings.....	308
12.13.1 Definition	308
12.13.2 Symbols	308
12.13.3 Labels	308
6.12.4 Electrical Design Submittal Requirements	309
6.12.4.1 General	309
6.12.4.2 90% Submittal Requirements	309
6.12.4.3 100% Submittal Requirements	310
Chapter 13 - Communications/Electronic Systems	313
6.13.0 Communications/Electronic Systems.....	313
6.13.0.1 General Information and Requirements	313
6.13.1 Drawings.....	313
6.13.1.1 Drawings	313
6.13.1.2 Definition	313
6.13.1.3 Completeness	313
6.13.1.4 Drawing Sequence	314
6.13.1.5 General Notes, Drawing Index, Symbols, and Abbreviations	314
6.13.1.6 Site Plan	314
6.13.1.7 Floor Plans/Roof Plans	314
6.13.1.8 Equipment Rooms Layouts and Elevations	314
6.13.0.1 Functional Block Interconnection Diagrams	315
6.13.0.2 Point-to-Point Wiring Diagrams	316
6.13.0.3 System Riser Diagrams	316
6.13.0.4 Conduit/Cable Tray Riser Diagrams	316
6.13.0.5 System Details	317
6.13.0.6 Communications and Electronic Systems Symbols	317
6.13.0.7 Symbols for Other Functional Disciplines	317
6.13.0.8 Functional Designations	317
6.13.0.9 Drawing Delineation Types	317
6.13.1.9 Delineation Drawings	318
6.13.1.9.1 Specification Relationship	318
Chapter 14 - Signage and Graphic Drawings	319
6.14.0 Signage and Graphic Drawings.....	319
6.14.0.1 General Design Requirements	319
6.14.0.2 Sign Construction	319
6.14.1 Drawings.....	319
6.14.1.1 Content	319
6.14.1.2 Static and Dynamic	319
6.14.1.3 Static Signage Drawings	320
6.14.1.4 Dynamic Signage Drawings	320
6.14.1.5 Minimum Requirements	320
6.14.1.6 Sections and Interior Elevations	320
6.14.1.7 Details	320
6.14.1.8 Continuation	320
6.14.2 Structural Requirements	320
6.14.3 Mechanical Requirements	321
6.14.4 Electrical Requirements.....	321
6.14.4.1 Building/Structure (Exterior) Numbering	321

Chapter 15 - GIS/CADD Requirements	323
6.15.0 GIS/CADD Requirements	323
Chapter 16 - Surveys	325
16.0 Field Measurements.....	325
Chapter 17 - Testing Agency Reports	327
6.17.0 Testing Agency Reports	327
6.17.0.1 Testing Requirements	327
6.17.0.2 Testing Agency	327
6.17.1 Testing Agency	327
6.17.1.1 General	327
6.17.1.2 Control of Measuring and Test Equipment	328
6.17.1.3 Surveillance of Inspections	328
6.17.1.4 Retain Tested Materials and Data	328
6.17.2 Documentation	328
6.17.2.1 Submittal	328
6.17.2.2 Document Control	328
6.17.2.3 Test Results	328
6.17.2.4 Records	329
Chapter 18 - Codes and Compliance	331
6.18.0 Codes and Compliance	331
6.18.0.1 Consultant Responsibility	331
6.18.0.2 Compliance	331
6.18.0.3 Variances	331
6.18.1 Agencies.....	331
6.18.1.1 Building Code	331
6.18.1.2 Denver Fire Department	332
6.18.1.3 Department of Health and Hospitals	332
6.18.1.4 Wastewater Management Division	332
6.18.1.5 Denver Zoning Administration	332
6.18.1.6 FAA Requirements	332
6.18.1.7 Public Health Service	333
Chapter 19 - Construction Schedule	335
6.19.0 Construction Schedule.....	335
6.19.1 Schedule Requirements.....	335
6.19.2 Submittal Format	335
Chapter 20 - Submittals	337
6.20.0 Submittals.....	337
6.20.0.1 General Information and Requirements	337
6.20.0.2 Submittal Certification	337
6.20.0.3 Consultant Design Quality Control Program	337
6.20.0.4 Review by DEN	337
6.20.0.5 Schedule of Review Submittals by DEN	338
6.20.0.6 DEN Review Format	338
6.20.0.7 Consultant Response to Reviews	338
6.20.1 Typed Submittals – Specifications, Tables, Estimates, Design Analysis.....	338
6.20.1.1 Format	338
6.20.1.2 Specifications	338
6.20.1.3 Data and Product Cut Sheets	339
6.20.2 Submittal Format – Drawings	339
6.20.3 Building Information Management/Revit.....	339
6.20.3.1 Submittal Schedule	339
6.20.3.2 Labeling of Media	339
6.20.4 PDF Submittal Requirements.....	339

6.20.4.1 Specifications	339
6.20.4.2 Drawings	340
6.20.4.3 Reports	340
6.20.4.4 Calculations	340
6.20.5 Contract Documents Phase. 90% Submittal	341
6.20.5.1 General	341
6.20.5.2 Review by DEN	341
6.20.5.3 Minimum Submittal Requirements and Quantities	341
6.20.5.4 Construction Documents 90% Submittal	341
6.20.6 Contract Document Phase 100% Final Submittal.....	342
6.20.6.1 General	342
6.20.6.2 Review by DEN – Final Review Meeting	342
6.20.6.3 Construction Document, 100% Submittal	343
6.20.6.4 Final Construction Documents	343
6.20.6.5 Certification Requirements	344
6.20.7 Submittals Concurrent to Final Contract Document Submittal	344
6.20.7.1 Agency and Utilities, Applications, and Permits	344
6.20.8 Other In-Progress Submittals.....	344
6.20.9 Building Department Document Review Submittal	345
6.20.9.1 Building Department Review	345
6.20.10 Issue for Construction Submittals	345
6.20.10.1 General	345
6.20.10.2 Minimum Submittal Requirements and Quantities	345
6.20.11 Record Document Submittal.....	345
6.20.11.1 General	345
6.20.11.2 Minimum Submittal Requirements and Quantities	345
Volume 7 - Structural	347
Chapter 1 - General	347
7.1.0 General	347
7.1.1 Abbreviations.....	347
7.1.2 Structural Codes and Standards.....	349
7.1.2.1 Applicable Standards	349
7.1.3 Quality Assurance Program	349
7.1.4 References	350
Chapter 2 - Task Requirements by Phase	351
7.2.0 Task Requirements by Phase	351
7.2.1 Schematic Design Requirements	351
7.2.2 Design Development Requirements	351
7.2.2.1 Calculations	351
7.2.2.2 Plans and Elevations	351
7.2.2.3 Coordination Requirements	351
7.2.2.4 Geotechnical Specification Requirements	352
7.2.2.5 Cost Estimates	352
7.2.2.6 Documentation Requirements	352
7.2.3 60% Design Review	352
7.2.4 Final (100%) Review	353
7.2.5 Bid Document Requirements.....	353
7.2.6 Bidding Period Requirements.....	353
7.2.7 Construction Period Requirements.....	353
Chapter 3 - Structural Systems	355
7.3.0 Structural Systems	355
7.3.1 Foundations	355
7.3.1.1 Shallow Foundations	355

7.3.1.2 Deep Foundations	355
7.3.2 Superstructure Types	355
7.3.2.1 Steel Structures	355
7.3.2.2 Cast-In-Place Concrete Structures	356
7.3.2.3 Precast Concrete	356
7.3.2.4 Tilt-Up Concrete	357
7.3.2.5 Concrete Masonry Units (Concrete Blocks)	357
Chapter 4 - Structural Design	359
7.4.0 Structural Design.....	359
7.4.0.1 Dead Load	359
7.4.0.2 Live Load	359
7.4.0.3 Snow Load	359
7.4.0.4 Wind Load	359
7.4.0.5 Earthquake Load	360
7.4.0.6 Other Loads	361
7.4.0.7 Major Structural Components	362
7.4.1 Passenger Terminal	363
7.4.1.1 Minimum Floor Live Loads	363
7.4.2 Other Buildings – Minimum Floor Live Loads	363
7.4.2.1 International Concourse	363
7.4.2.2 Domestic Concourse	364
7.4.3 Miscellaneous Structures Other Than Buildings	364
7.4.3.1 Lighting and Sign Supports	364
7.4.3.2 Metal Structures on Concrete Slab	364
Volume 8 - Sustainability	365
Chapter 1 - Background and Introduction	365
8.1.0 Purpose and Background.....	365
8.1.0.1 Intended User	365
8.1.0.2 Summary	365
8.1.0.3 Scope	365
8.1.1 Environmental Policy	366
8.1.2 Sustainability Policy	366
8.1.3 Vision 100	366
8.1.3.1 Empowering Our People	366
8.1.3.2 Growing Our Infrastructure	366
8.1.3.3 Maintaining What We Have	366
8.1.3.4 Expanding Our Global Connections	367
8.1.4 DEN Community Demographics.....	367
8.1.5 Equity, Diversity, and Inclusion.....	367
8.1.6 Codes, Regulations, and Ordinances.....	367
8.1.6.1 City and County of Denver Executive Order 123 (XO123)	367
8.1.6.2 City and County of Denver Green Building Ordinance	367
8.1.6.3 Building Codes and Amendments	368
8.1.6.4 Environmental Permits & Guidelines	368
8.1.6.5 Energize Denver Ordinance	368
8.1.6.6 Universal Recycling and Composting Ordinance	369
8.1.6.7 Denver One Water Plan	369
8.1.6.8 Net Zero	369
8.1.7 Applicability	369
8.1.7.1 New Construction or Major Renovation – Heavy Civil	369
8.1.7.2 New Construction – Buildings	370
8.1.7.3 Major Renovation – Buildings	370
8.1.7.4 Commissioning Projects	370

8.1.8 Definitions, Abbreviations, and Terminology	370
8.1.9 Compliance Paths	374
Chapter 2 - Plan	375
8.2.0 Stakeholder Identification/Engagement	375
8.2.1 Project Charter	375
8.2.1.1 Goals/OPR	375
8.2.1.2 Energy and Utility Goals	375
8.2.1.3 LEED and Envision Credit Assessment	375
8.2.2 Sustainability Elements of DEN Projects	375
8.2.2.1 LCA	375
8.2.2.2 LCCA	376
8.2.2.3 Envision®	376
8.2.2.4 LEED®	376
8.2.2.5 Project Location	376
8.2.3 Net Zero	376
Chapter 3 - Define	377
8.3.0 Stakeholder Engagement	377
8.3.0.1 Identify Stakeholders	377
8.3.1 LEED®	377
8.3.1.1 General	377
8.3.1.2 Goals	377
8.3.1.3 Project Requirements	378
8.3.2 High-Performance Design Requirements	380
8.3.2.1 Design Assessment	380
8.3.2.2 Siting and Orientation	381
8.3.2.3 Energy Modeling	381
8.3.2.4 Energy Performance Criteria	382
8.3.2.5 Energy Efficiency	382
8.3.2.6 Mechanical Equipment	382
8.3.2.7 Electrical Equipment	383
8.3.2.8 Water Efficiency	383
8.3.2.9 Water Management Plan	383
8.3.2.10 Water Metering	383
8.3.2.11 Indoor Water Use Reduction	383
8.3.2.12 Indoor Environmental Performance	383
8.3.2.13 Innovation	383
8.3.3 Commissioning	383
8.3.3.1 Commissioning Scope of Work	384
8.3.3.2 Milestones	384
8.3.3.3 NCCx	384
8.3.3.4 EBCx	384
8.3.3.5 Reporting and Documentation	384
8.3.3.6 Targeted Audits	384
8.3.4 Net Zero	385
8.3.4.1 Goals	385
Chapter 4 - Deliver	387
8.4.0 Stakeholder Engagement	387
8.4.0.1 Initial Project Concept Review Meeting	387
8.4.0.2 30/60/90 Design Review	387
8.4.1 Envision®	387
8.4.2 LEED®	387
8.4.3 Net Zero	387
Chapter 5 - Closeout	389

8.5.0 Stakeholder Engagement	389
8.5.1 Envision®	389
8.5.2 LEED®	389
8.5.3 Net Zero	389
Chapter 6 - Commissioning Activities	391
8.6.0 Pre-Design.....	391
8.6.0.1 Owner’s Project Requirements	391
8.6.0.2 Commissioning Plan (Cx Plan)	391
8.6.1 Deliver – Design Stage	391
8.6.1.1 Review Basis of Design	391
8.6.1.2 Design Reviews	392
8.6.1.3 Commissioning Meetings – Design	392
8.6.1.4 Integration Meetings	392
8.6.1.5 Commissioning Specifications	392
8.6.1.6 Provide IECC Cx Permit Letter	392
8.6.1.7 Develop Systems Manual Scope and Format	392
8.6.1.8 Develop Training Requirements	393
8.6.1.9 Develop Monitoring Based Commissioning (MBCx) Plan	393
8.6.2 Deliver - Construction Stage	393
8.6.2.1 Update Construction-Phase Cx Plan	393
8.6.2.2 Coordinate Cx Activities (Scheduling)	394
8.6.2.3 Commissioning Meetings – Construction	394
8.6.2.4 Review Submittals	394
8.6.2.5 Develop Construction Checklists	394
8.6.2.6 Prepare Functional Performance Tests (FPTs)	394
8.6.2.7 Identify and Track Issues	394
8.6.2.8 Conduct Site Visits and Issue Site Observation Reports	395
8.6.2.9 Review Requests for Information	395
8.6.2.10 Coordination and Shop Drawing Review	395
8.6.2.11 Monitoring-Based Commissioning (MBCx) Implementation & Coordination	395
8.6.2.12 Integrate SkySpark Points	395
8.6.3 Deliver – Asset Handover Stage.....	395
8.6.3.1 Commissioning Meetings – Acceptance	395
8.6.3.2 Verify Pre-Functional Checklists (PFCs) and Point Verification Tests (PVTs)	396
8.6.3.3 Review Completed Start-Up and TAB Reports	396
8.6.3.4 Execute Functional Performance Tests	396
8.6.3.5 Review Operation & Maintenance Manuals	396
8.6.3.6 Verify Completion of Training	396
8.6.3.7 Complete IECC Cx Compliant Checklist	397
8.6.3.8 Prepare Preliminary Cx Report	397
8.6.3.9 Compile Systems Manual	397
8.6.3.10 Compile Current Facility Requirements and O&M Plan	397
8.6.3.11 Deliver Post Construction Documents	397
8.6.3.12 LEED Submissions	398
8.6.4 Closeout Phase.....	398
8.6.4.1 Review As-Built Drawings	398
8.6.4.2 Troubleshooting/Optimization	398
8.6.4.3 Develop Ongoing Cx Plan	398
8.6.4.4 Finalize Cx Report	398
8.6.4.5 Execute Seasonal Testing	398
8.6.4.6 Update/Resolve Cx Issues Log	398
8.6.4.7 Conduct MBCx Quarterly Checks	399
8.6.4.8 Conduct Operations and Warranty Review	399

Chapter 7 - Monitoring-Based Commissioning (MBCx) 401

8.7.0 MBCx Goals and Objectives 401

8.7.1 MBCx System Description..... 401

 8.7.1.1 IT and SkySpark Configuration 401

8.7.2 Planning 401

 8.7.2.1 Design Coordination and Reviews 401

 8.7.2.2 MBCx Plan 401

 8.7.2.3 Contractor Coordination 401

 8.7.2.4 User Access Setup 401

8.7.3 Acceptance – Integration and Initial Commissioning..... 402

 8.7.3.1 Project/Site Setup 402

 8.7.3.2 Equipment Setup and Naming 402

 8.7.3.3 Points and Tagging 403

 8.7.3.4 Rules 403

 8.7.3.5 Dashboards 403

 8.7.3.6 Key Performance Indicator (KPIs) 404

 8.7.3.7 Automated Tests and TAB Verification 404

 8.7.3.8 Contractor Coordination for Issue Resolution 404

8.7.4 Ongoing Monitoring and Maintenance..... 404

 8.7.4.1 Ongoing Issues Tracking Process 404

 8.7.4.2 Issue Resolution Mapping, Roles, and Responsibilities 404

 8.7.4.3 Warranty Management Process 404

 8.7.4.4 Quarterly Checkups 404

 8.7.4.5 Energy Monitoring/Measurement and Verification (M&V) 404

8.7.5 SkySpark Quality Control..... 405

 8.7.5.1 Quality Control Submittals 405

This page is intentionally blank.

Table of Figures

Volume 4 - Life Safety	107
Chapter 3 - Fire Alarm and Detection System.....	119
Figure 4.3-1: Typical ALERT Strobes	124
Chapter 4 - Emergency Communication System	127
Figure 4.4-1: Typical Ceiling Loudspeaker with ECS Indicator	134
Figure 4.4-2: NFPA Visual Character Height Resources	136
Figure 4.4-3: Example of Large Video Advertising Displays	137
Figure 4.4-4: TSW ECS Control Screen	138
Figure 4.4-5: IED Paging Panel (Director Panel) and Digital Microphone Station	139
Figure 4.4-6: Fire Alarm/Textual ECS Interface Cabinet	140
Volume 5 - Mechanical	161
Chapter 4 - Air Distribution Systems	183
Figure 5.4-1: Allowable Duct Static Pressure Callouts Examples	186
Chapter 5 - Controls.....	187
Figure 5.5-1: AHU Control	192
Figure 5.5-2: VAV Contol	193
Chapter 8 - Plumbing Requirements	211
Figure 5.8-1: Concourse B: Tug Damage to Wall	218
Figure 5.8-2: Gas Piping Strike: Side and Front Views	219
Volume 6 - Standards and Criteria	241
Chapter 6 - Specification Requirements	255
Figure 6.6-1: Technical Specification General Format	260
Chapter 9 - Mechanical Drawings	275
Figure 6.9-1: Air Distribution Device Identification	280
Figure 6.9-2: Exhaust Air Callout Diagram	280
Figure 6.9-3: Mechanical Piping Abbreviations and Line Types	281
Chapter 10 - Plumbing Drawings.....	287
Figure 6.10-1: Plumbing Piping Abbreviations and Line Types	292
Chapter 20 - Submittals	337
Figure 6.20-1: Drawing Bookmark	340
Volume 7 - Structural	347
Chapter 4 - Structural Design	359
Figure 7.4-1: Local Design Wind Speed Zones - Hotel Plaza	360
Figure 7.4-2: Example of Base Connection Detail - Metal Structure on Concrete Tab	364

This page is intentionally blank.

Table of Tables

Volume 1- Architectural	45
Chapter 1 - General	45
Table 1.1-1: Terminal Occupancy Classification	47
Table 1.1-2: Building Elements: Type I, FR	48
Table 1.1-3: Building Elements: Type 1A	49
Chapter 2 - Interior Environment	53
Table 1.2-1: Definitions	54
Table 1.2-2: Typical STC Rating Expectations	55
Table 1.2-3: DEN STC Standards by Room Type and Adjacencies	55
Volume 2- Communications and Electronic Systems.....	63
Chapter 6 - Energy Management and Control	81
Table 2.6-1: EMCS Definitions	81
Table 2.6-2: Metering EMCS Integration Points	83
Volume 3- Electrical	87
Chapter 1 - General	87
Table 3.1-1: Definitions	87
Chapter 2 - Interior Electrical Power Distribution Systems	89
Table 3.2-1: Panelboard Naming Conventions	91
Table 2-3: Transformer Capacity	94
Chapter 4 - Lighting Systems	101
Table 3.4-1: Light Source Acronyms	102
Volume 4- Life Safety	107
Chapter 1 - General	107
Table 4.1-1: Common Terms	107
Table 4.1-2: Fire and Smoke Zone Designation Level	110
Chapter 2 - Fire Protection System	113
Table 4.2-1: Sprinkler Design Density Table	115
Chapter 3 - Fire Alarm and Detection System	119
Table 4.3-1: Fire Alarm Systems Wiring Requirements	125
Chapter 4 - Emergency Communication System	127
Table 4.4-1: Measured Average Ambient Noise Level	130
Table 4.4-2: NFPA, 72 ADA Sign Requirement	136
Chapter 5 - Smoke Control System	141
Table 4.5-1: Smoke Control Equipment Identification	143
Chapter 6 - Emergency Alarm Systems	149
Table 4.6-1: Inert Gas Maximum Storage Amounts	150
Chapter 7 - Two-Way Communication System	153
Chapter 8 - Area Specific Life Safety Systems	155
Chapter 9 - Systems Testing and Commissioning	157
Chapter 10 - Other Life Safety Systems	159
Volume 5- Mechanical	161
Chapter 1 - General	161
Table 5.1-1: NC Criteria by Space	165
Table 5.1-2: Equipment Abbreviations	169
Chapter 2 - Central Utility Plant	173
Table 5.2-1: Water Piping Sizing	173
Table 5.2-2: Water Piping Friction Factors	173
Chapter 3 - HVAC Systems	175

Table 5.3-1: Basis for Existing Air Handling System Air Supply	178
Chapter 4 - Air Distribution Systems	183
Table 5.4-1: Ductwork Air Velocity Limits	183
Table 5.4-2: Allowable Direction Callouts	185
Chapter 5 - Controls	187
Table 5.5-1: Alarms in the EMCS	197
Table 5.5-2: Alarm Points Only Trended in SkySpark	199
Chapter 6 - Hydronic Systems	203
Table 5.6-1: Water Piping Sizing	205
Table 5.6-2: Water Piping Friction Factors	205
Chapter 8 - Plumbing Requirements	211
Table 5.8-1: Grease Trap Capacities	212
Chapter 2 - Appendix A - Controls Points Abbreviations	225
Appendix A - Control Point Abbreviations	225
Appendix A - VAV Points Abbreviations	231
Chapter 14 - Matrix A: DEN Concourse A West Expansion Concessions	235
DEN Concourse A West Expansion Concessions Matrix	235
Chapter 14 - Matrix B: DEN CEP Concourse B West Expansion Concessions	237
DEN CEP Concourse B West Expansion Concessions Matrix	237
Chapter 14 - Matrix C: DEN Concourse C East Expansion Concessions	239
DEN Concourse C East Expansion Concessions Matrix	239
Volume 6- Standards and Criteria.....	241
Chapter 6 - Specification Requirements	255
Table 6.6-1: Part II Specifications	255
Table 6.6-2: Technical Specification Header Layout	259
Table 6.6-3: Technical Specification Footer Layout	259
Table 6.6-4: DEN Standard Specifications: Division 02-33	263
Chapter 9 - Mechanical Drawings	275
Table 6.9-1: Submittal Requirements	284
Chapter 10 - Plumbing Drawings	287
Table 6.10.1: Submittals	293
Volume 7- Structural	347
Chapter 1 - General	347
Table 7.1-1: Abbreviations	347
Chapter 4 - Structural Design	359
Table 7.4-1: Vibration Criteria	362
Volume 8- Sustainability	365
Chapter 1 - Background and Introduction	365
Table 8.1-1: Definitions	370
Table 8.1-2: Abbreviations and Terminology	371
Table 8.1-3: Project Personnel	372
Table 8.1-4: Cx Terms	372
Chapter 3 - Define	377
Table> 8.3-1: Project Requirements for New Construction and Major Renovations	378

Summary of Revisions

The following tables list the revisions made to the Tenant DSM.

2026 Revisions

Second Quarter

Reference	Revision Description
Tenant Development Guideliness	Updated entire section
Volume 2-.Communications and Electronic Systems	Multiple changes, see Communications and Electronic Systems DSM
Volume 3-.Electrical	Multiple changes, see Electrical DSM
Volume 4-.Life Safety	Multiple changes, see Life Safety DSM
Volume 5-.Mechanical	Multiple changes, see Mechanical DSM
Volume 6-.Standards and Criteria	Multiple changes, see Standards and Criteria DSM
Volume 8-.Sustainability	Multiple changes, see Sustainability DSM

2025 Revisions

Fourth Quarter

Reference	Revision Description
Throughout	Minor grammatical and hyperlink corrections
Tenant Development Guidelines	Updated information
Volume 1-Architectural 1.2.1.13.Millwork	Updated information
Volume 1-Architectural 1.2.2.2.2.Floor	Added information
Volume 1-Architectural 1.2.4.1.Introduction	Added a note for the design team
Volume 3-Electrical 3.2.1.5.Low Voltage DEN Submetering	Added information for installation with a tenant
Volume 3-Electrical- 3.2.2.7.Tenants and Concessions	Added circuit information
Volume 4-Life Safety- 4.5.15.Construction Documents	Added information design team should include in Construction Documents
Volume 5-Mechanical 5.3.3.6.Food and Beverage Tenant Equipment	Added and updated information
Volume 5-Mechanical 5.5.0.1.General and 5.5.0.3.New and Replacement HVAC Control Systems	Updated information
Volume 5-Mechanical 5.5.1.3.Exhaust Fan	Added exceptions

Fourth Quarter

Reference	Revision Description
Volume 5-Mechanical 5.8.5.4.Water Meters	Updated information
Volume 6-Standards and Criteria 6.1.2.2.Request Format and 6.1.4.6.Design Project Closeout	Updated information
Volume 6-Standards and Criteria 6.3.0.1.Intent	Updated information
Volume 6-Standards and Criteria 6.3.0.4.1.Obtain Notice to Proceed (NTP)	Added NTP Document list
Volume 6-Standards and Criteria 6.3.0.4.2.Part II — Technical Specifications	Updated information
Volume 6-Standards and Criteria 6.6.0.3.Loca- tion	Updated information
Volume 6-Standards and Criteria 6.6.8.12.Submittal Registrar	Updated information
Volume 6-Standards and Criteria 6.6.8.13.Overstock Materials	Concession projects do not require overstock materials
Volume 6-Standards and Criteria 6.7.1.1.Floor Plans	Added information
Volume 6-Standards and Criteria 6.9.0.3.Design Requirements	Added mechanical drawing information
Volume 6-Standards and Criteria 6.11.4.6.Detailing	Added information
Volume 6-Standards and Criteria 6.19.0.Con- struction Schedule	Updated information
Volume 6-Standards and Criteria 6.20.0.1.General Information and Require- ments	Updated information
Volume 6-Standards and Criteria 6.20.6.3.Construction Document, 100% Sub- mittal	Added information
Volume 6-Standards and Criteria 6.20.9.1.Building Department Review	Updated information

Second Quarter

Reference	Revision Description
Tenant Development Guidelines	Updated section
Volume 1-Architectural 1.2.1.13.Millwork	Added section

Second Quarter (Continued)

Reference	Revision Description
Volume 2-.Communications and Electronic Systems	Multiple changes, see Communications and Electronic Systems DSM
Volume 3-.Electrical	Multiple changes, see Electrical DSM for Revision Summary
Volume 4-.Life Safety	Multiple changes, see Life Safety DSM for Revision Summary
Volume 5-.Mechanical	Added multiple changes to section Multiple changes, see Mechanical DSM for Revision Summary
Volume 6-.Standards and Criteria	Multiple changes, see Standards and Criteria DSM for Revision Summary
Volume 7-.Structural	Multiple changes, see Structural DSM for Revision Summary
Volume 8-.Sustainability	Multiple changes, see Sustainability DSM for Revision Summary

2024 Revisions***Fourth Quarter***

Reference	Revision Description
Throughout	Accessibility improvements
Chapter 1- General	Updated 1.0.4 ORAT Requirements Updated 1.1.2 Project Delivery Process
Volume 1- Architectural	Multiple changes, see Architectural DSM
Volume 2- Communication and Electronic Systems	Multiple changes, see Communications and Electronic Systems DSM
Volume 3- Electrical	Multiple changes, see Electrical DSM for Revision Summary
Volume 4- Life Safety	Multiple changes, see Life Safety DSM for Revision Summary
Volume 5- Mechanical	Added information to 5.1.0.3 General Added workmanship information 5.1.6 Workmanship Multiple changes, see Mechanical DSM for Revision Summary
Volume 6- Standards and Criteria	Multiple changes, see Standards and Criteria DSM for Revision Summary

Fourth Quarter (Continued)

Reference	Revision Description
Volume 7- Structural	Multiple changes, see Structural DSM for Revision Summary
Volume 8- Sustainability	Multiple changes, see Sustainability DSM for Revision Summary

Second Quarter

Reference	Revision Description
Tenant Development Guidelines	Updated 1.1.2 Project Delivery Process
Volume 2- Communication and Electronic Systems	Added 2.6.1.4 Physical Integration with DEN Multiple changes, see Communications and Electronic Systems DSM
Volume 3- Electrical	Multiple changes, see Electrical DSM for Revision Summary
Volume 4- Life Safety	Multiple changes, see Life Safety DSM for Revision Summary
Volume 5- Mechanical	Multiple changes, see Mechanical DSM for Revision Summary
Volume 6- Standards and Criteria	Multiple changes, see Standards and Criteria DSM for Revision Summary

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, clarifications 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.

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.

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

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

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

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

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

VARIANCE FROM DEN DESIGN STANDARDS MANUALS

Requests for non-conformance or variance from DEN Design Standards manuals, for any DEN or Tenant Projects, must be formally submitted in writing to the DEN Project Manager for routing and review. Variance requests may or may not be approved by DEN and response will be communicated to the requestor.

This page is intentionally blank.

Tenant Development Guidelines

Chapter 1 - General

1.0 Introduction

This chapter is intended to serve as an overview of the Tenant Design Standards Manual (DSM). The Tenant DSM was developed, in part, to provide a condensed set of design guidelines intended specifically for typical tenant projects delivered at DEN. The requirements contained herein are derived from the DEN DSMs.

1.0.1 Scope of this Manual

The scope of this manual is intended to cover DEN design guidelines for typical tenant projects delivered at DEN. Tenants may be subject to additional permitting, construction, and implementation requirements as set forth in their lease agreement.

Regardless of project type, the designer shall familiarize themselves with all DEN DSMs to ensure that any applicable requirements are met for their project. While this manual provides a condensed set of design guidelines for typical tenant projects, it does not supersede the requirements contained in other DSMs.

1.0.2 Tenant-Designer Coordination

DEN reviewers primarily review tenant projects to ensure their compatibility with DEN's systems, to verify that DEN's general design standards for Tenants have been met, and to ensure any DEN equipment in the Tenant's lease area is maintainable. DEN reviewers may not necessarily identify constructability or maintenance issues of Tenant-owned equipment. DEN reviewers also do not review Tenant Contract Documents for code compliance.

The tenant design consultant is responsible for ensuring that their design is constructable. Tenant design consultants are also recommended to ensure that Tenant-owned equipment is maintainable. DEN-owned equipment has strict maintenance clearance standards, and Tenants designers are encouraged to follow these standards for Tenant-owned and maintained equipment. These standards are included in the volumes of this Design Standards Manual for their respective disciplines, and more information can be found in each discipline's Design Standards Manual.

1.0.3 ORAT Requirements

The Operational Readiness, Activation, and Transition (ORAT) team at DEN plays a critical role in ensuring that DEN's Design Standards Manuals integrate operational requirements throughout the design and construction phases. By collaborating closely with project teams, architects, and engineers, ORAT ensures that the DSMs align with the airport's functional and operational needs. This alignment is achieved by gathering feedback based on operational expertise, identifying potential challenges in facility layouts, and ensuring that the final design facilitates a seamless transition to full-scale operations. Program and project design teams are expected to be familiar with the DEN ORAT Standards Manual (OSM) and actively participate in ORAT-led meetings, charrettes, workshops, trials, and testing at the request of the DEN Project Manager.

1.1 Tenant Project Delivery - Non-Concessions Projects

The requirements in this section apply to all tenant projects delivered in coordination with the DEN Design, Engineering & Construction division. Contact the DEN Tenant Project Manager to confirm requirements for your project.

1.1.1 Required Items

DEN requires the following items on a typical tenant funded project:

- A. Approval of the project from DEN.
- B. Contact information of designer, builder, and owner's reps.
- C. Address/location of the project.
- D. Scope of work (high level) describing the disturbance area.
- E. Anticipated schedule.
- F. Site plan of the proposed project (if applicable).
- G. A copy of the contract/proposal with the contractor if already established.
- H. Any changes to the airport landscape whether temporary (cranes, batch plants...) or permanent (buildings, fences...) needs to be processed through DEN Planning + Design to check several things including the impact any structure has on airspace. Please complete the FAA Form 7460-1 Notice of Proposed Construction or Alteration provided by DEN for any project located on airport property. The contractor or tenant must complete DEN's 7460 from and coordinate with [Camilla Soechtig](mailto:camilla.soechtig@flydenver.com) camilla.soechtig@flydenver.com for submittal.

DEN Planning will submit the 7460-1 to the FAA and send the Determination Letter back to the project manager once received with instructions for completing the required Airfield Operation Notification Form so necessary NOTAMs can be issued. These letters are valid for 18 months and can be extended through coordination with Camilla Soechtig. The Aeronautical Study process for new obstructions/construction takes 90-120 days. Deviations to the procedure will result in the submittal documents to be returned without action and possible delay for the project.

I. To determine whether a National Environmental Policy Act (NEPA) review or Categorical Exclusion (CatEx) is required for your project, please complete a DEN Environmental Review Form. Coordinate with DEN PM to receive form.

1. **Important Note:** If a [National Environmental Policy Act \(NEPA\)](#) review is required, FAA approval may take approximately six to nine months.

Upon receiving the above information/documents, the DEN PM will assign a DEN tenant project name and number: "tenant abbreviation" _ "number"

1.1.2 Project Delivery Process

City of Denver Permit Office will not review plan submittals or issue permits until it receives a signed Letter of Authorization (LOA) from DEN

A Letter of Authorization (LOA) is a required document that must be obtained from DEN before any plans can be uploaded in E-Permits to [The City of Denver Permit Office](#). The DEN Project Manager will email the signed LOA to the Tenant/Contractor after all prerequisite steps outlined above have been completed. The LOA shall be included with the submittal when uploading documents to E-Permits.

Division of Small Business Opportunity (DSBO)

M/WBE goals may be required on tenant design and construction contracts. Questions? Contact DSBO@flydenver.com anytime during the process and please copy your DEN Project Manager.

Denver Prevailing Wage Requirements

Denver's Prevailing Wage Ordinance (20-76) mandates that contractors and subcontractors working on city-funded projects or city-owned property pay workers the prevailing wage. This applies to contracts of \$2,000 or more for construction and demolition. The Auditor's Office enforces compliance and ensures workers are properly classified and paid. The most current wage determinations are available on the Denver Auditor's website. Contractors on DEN projects must regularly submit payroll data via LCPtracker to demonstrate compliance with prevailing wage requirements.

The Auditor's Office is available to assist with questions, call the hotline at 720-913-5000.

To initiate tracking email the Pre-NTP form and a copy of the executed contract or proposal to Rudy.Lopez@denvergov.org, and copy the DEN Project Manager.

1.1.2.1 Notice to Proceed Requirements

A Notice to Proceed (NTP) letter is a required document that must be obtained from DEN before any construction work can begin. The DEN Project Manager will email the signed NTP to the Tenant/Contractor after all prerequisite steps outlined above have been completed.

Following is the current list of documents required to obtain Notice to Proceed (NTP) from DEN.

- A. Copy of contract between tenant and contractor
- B. Original tenant payment bond, for full contract amount.
- C. Original contractor performance bond, labor and material payment bond, and dual obligee rider. For full contract amounts.
- D. Copy of contractor's evidence of insurance.
- E. Copy of tenant's evidence of insurance.
- F. Copy of DSBO's evaluation on how participation will be obtained.
- G. Indication from Auditor's Office of Prevailing Wage that the project is set up in LCP Tracker.
- H. Copy of permitted plans.
- I. Copy of contractor's safety plan, including site specific job hazard analysis (JHA).
- J. Construction schedule.

Projects that are under \$15,000, but more than \$2,000 have the following NTP requirements:

- A. Indication from the Auditor's Office that the project is set up in LCP tracker, and statement from general contractor that all subcontractors have been set up in LCP tracker (for prevailing wages).
- B. Copy of permits.
- C. Indication that DEN has approved the drawings and/or scope of work.

1.1.3 Project Closeout

When the following items are complete, the DEN PM will release all bonds:

- A. Submittals affecting DEN Assets to DEN PM, O&M manuals, warranty certificates, etc., Life Safety, Systems Group, Planning & Design, Asset Management.
- B. Submittal of As-Built drawings uploaded to the ACC environment.
- C. The Tenant will be required to provide their own QA for any closeout of permits. Request pre-qualified consulting firms from DEN PM as needed.

- D. Submittal of copy of the final/closed out permits to DEN PM.
- E. Submittal of test reports (concrete strength, density, water pressure, etc.)
- F. Prevailing wage representative confirms that all wages have been reported by all subs.
- G. DSBO confirms that participation requirements have been satisfied.
- H. Confirmation that tenant is satisfied with the work.

Please contact the DEN PM for tenant projects with any comments/questions.

1.2 Tenant Project Delivery - Concession Projects

The requirements in this section apply to all tenant projects delivered via the DEN Concessions program. Contact the DEN Project Manager to confirm requirements for your project.

1.2.1 Required Items

DEN requires the following items on a typical tenant funded project:

- A. Concept approval DEN Concessions.
- B. Address/location of the project.
- C. Scope of work (high level) describing the disturbance area.
- D. Anticipated schedule.
- E. Please complete the FAA Form 7460-1 Notice of Proposed Construction or Alteration provided by DEN for any project located on airport property. The contractor or tenant must complete DEN's 7460 form and coordinate with Camilla Soechtig camilla.soechtig@flydenver.com for submittal.

DEN Planning will submit the 7460-1 to the FAA and send the Determination Letter back to the project manager once received with instructions for completing the required Airfield Operation Notification Form so necessary NOTAMs can be issued. These letters are valid for 18 months and can be extended through coordination with Camilla Soechtig. The Aeronautical Study process for new obstructions/construction takes 90-120 days. Deviations to the procedure will result in the submittal documents to be returned without action and possible delay for the project. The FAA Form 7460 must be active and in place prior to any crane activity.

Upon receiving the above information/documents, the DEN PM will assign a DEN tenant project name and number: "tenant abbreviation" "number"

1.2.2 Project Delivery Process

City of Denver Permit Office will not review submittals or issue permits until it receives a signed Letter of Authorization (LOA) from DEN

A Letter of Authorization (LOA) is a required document that must be obtained from DEN before any plans can be uploaded in E-Permits to The City of Denver Permit Office. The DEN Project Manager will email the signed LOA to the Tenant/Contractor after the 100% construction drawings and specifications have been reviewed by DEN, and DEN has determined that the documents substantially comply with DEN's Design Standard Manuals. The LOA shall be included with the submittal when uploading documents to E-Permits.

Division of Small Business Opportunity (DSBO)

M/WBE goals may be required on tenant design and construction contracts. Questions? Contact DSBO@flydenver.com anytime during the process, and please copy your DEN Project Manager.

Denver Prevailing Wage Requirements

Denver's Prevailing Wage Ordinance (20-76) mandates that contractors and subcontractors working city-owned property pay workers the prevailing wage. This applies to contracts of \$2,000 or more for construction and demolition. The Auditor's Office enforces compliance and ensures workers are properly classified and paid. The most current wage determinations are available on the Denver Auditor's website. Contractors on DEN projects must regularly submit payroll data via LCPtracker to demonstrate compliance with prevailing wage requirements.

The Auditor's Office is available to assist with questions, call the hotline at 720-913-5000.

To initiate tracking email the Pre-NTP form and a copy of the executed contract or proposal to Rudy.Lopez@denvergov.org, and copy the DEN Project Manager.

Requirements for a concessionaire to obtain a Notice to Proceed are as follows:

- A. Following is the current list of documents required to obtain Notice to Proceed (NTP) from DEN for concession projects that exceed \$15,000
- B. Copy of contract between tenant and contractor
- C. Original tenant payment bond, for a minimum of 50% of the full contract amount, on DEN form.
- D. Original contractor performance bond, labor and material payment bond, and dual obligee rider, for full contract amounts, and on DEN forms.
- E. Establish a goal through DSBO. Contact dsbo@flydenver.com. Copy your assigned DEN Project Manager on all correspondence with DSBO. Once a goal is assigned, you will need to submit appropriate document to DSBO to prove how you will obtain the minimum required participation. Provide a copy of DSBO's approval on how participation will be obtained.
- F. Indication from the Auditor's Office of Prevailing Wage that the project is set up in LCP tracker, and statement from general contractor that all subcontractors have been set up in LCP tracker (for prevailing wages).
- G. Copy of contractor's evidence of insurance.
- H. Copy of concessionaire's evidence of insurance.
- I. Copy of building department approved construction drawings.
- J. Copy of Commcon permit, or demolition permit for demolition only projects.
- K. Copy of contractors safety plan, including site specific job hazard analysis (JHA).
- L. Construction schedule
- M. Copy of concession agreement with the City and County of Denver.
- N. Indication that drawings and specifications have been approved by DEN.
- O. Copy of report from ADA consultant confirming there are no ADA issues with the design.
- P. Copy of the contractor's Equity, Diversity, and Inclusion (EDI) plan. If the team has questions on the EDI plan, contact your assigned DEN Project Manager.
- Q. Documentation that the contractor has obtained a trilogy cypher lock, and the lock has been programmed and keyed by the DEN Lockshop. This is to ensure that the lock can be installed immediately upon erection of the temporary construction wall.

Projects that are under \$15,000 but more than \$2,000 have the following NTP requirements:

- A. Indication from the Auditor's Office that the project is set up in LCP tracker, and statement from general contractor that all subcontractors have been set up in LCP tracker (for prevailing wages).
- B. Copy of permits.

- C. Indication that DEN has approved the drawings and/or scope of work.

Projects under \$2,000 only need to submit applicable permits and indication that DEN has approved the scope of work.

All NTP documents need to be submitted as one combined bookmarked package, with all documents including the appropriate DEN Project Number.

A Notice to Proceed (NTP) letter is a required document that must be obtained from DEN before any construction work can begin. The DEN Project Manager will email the NTP to the Tenant/Contractor after all prerequisite steps outlined above have been completed.

Please contact DEN PM for tenant projects with any comments/questions.



Insurance Requirements and Assumptions Risk

When the following items are complete, your DEN PM will notify the project team that the project is considered closed. The language in the bonds renders the bonds null and void upon satisfying all contract obligations. DEN Concessions does not return or release the bonds:

- A. Completion of all punch list items.
- B. Complete and accurate as builds- REVIT and PDF.
- C. Provide complete and final unconditional waiver and/ or release of any and all lien rights and liens from each subcontractor of all tiers, material men, supplier, manufacturer and dealer for all labor, equipment, furnishing and material used or furnished by each on the Work. Use DEN form.
- D. Provide complete and final unconditional waiver and/ or release of any and all lien rights and liens from the General Contractor, on DEN form.
- E. An affidavit from the General Contractor stating that all claims, liens, or other obligations incurred by the tenant, the tenants contractor, and all its subcontractors of all tiers in connection with the performance of the Work have been paid and settled, and that there are no outstanding prevailing wage claims or disputes at either the City Auditor's Office or the U.S. Department of Labor.
- F. Copy of the Certificate of Occupancy or signed inspection card.
- G. Copy of the Consent of Surety to Final Payment, AIA form G707.
- H. Statement from the Auditor's Office that there are no outstanding prevailing wage issues.
- I. Statement from DSBO that all closeout requirements of DSBO have been satisfied.
- J. Copy of the test and balance (TAB) report.
- K. Architect's certificate reflecting that the project was built per the approved plans.
- L. Certified statement of project cost with appropriate detail itemizing design fees, original construction contract amount, total change orders, and owner provided materials and equipment.
- M. Inspection report from third party ADA consult confirming there are no ADA violations in the space. Any identified issues will be added to the scope of the project as a punchlist item.
- N. Locations that have kitchen exhaust systems shall provide a report from a hood cleaning contractor that confirms the system is completely accessible for atmosphere to atmosphere cleaning. Any required modifications to allow for complete system cleaning will be added to the project as a punchlist item.
- O. Third party inspection for all areas not readily accessible during normal work hours. This inspection will be to confirm and document that all construction has been done in accordance with code and the approved

project drawings and specifications. Primary areas of concern are firestopping and labeling, ¼" per foot slope on waste lines, proper line labeling, confirmation that none of the project work has impacted access or working clearances to systems or equipment, i.e. VAV boxes, MAU, AHU, etc.

- P. Confirmation that all construction dumpsters have been removed from the site. Site walk with DEN Project Manager and project superintendent to ensure all areas supporting the project are free of debris and construction materials, equipment, etc.

End of Chapter

This page is intentionally blank.

Volume 1 - Architectural

Chapter 1 - General

1.1.0 Design Intent

The object for providing design standards is to achieve coherence, continuity, and comparability for all buildings on City and County of Denver property managed by Denver International Airport. The design standards set forth here are intended to assist designers in providing a design which supports DEN's initiative to provide a timeless, world class facility which is conducive to supporting operational, maintenance and life cycle needs.

1.1.0.1 DEN Design Principles

DEN strives to enable design professionals to fulfill DEN's aspiration that the airport's architecture and interiors became a seamless, unified embodiment of their design values and brand idea. Such visions are demonstrated in the DEN Design Principles.

For more information on the Design Principles, visit the website:



[DEN Design Principles](#)

1.1.0.2 Design Review Committee (DRC)

The intent of the design review process is to ensure that the proposed projects and design are compatible with, and enhance, the aesthetic intent and design quality of airport facilities and wayfinding systems. This document describes the design review process for airport facilities and tenant improvements and the role the Design Review Committee (DRC) plays in that process.

For more information on the Design Review Committee (DRC), visit website:



[DEN Design Review](#)

1.1.1 Code Information

1.1.1.1 Terminal Building Height

The Terminal Building Height is defined in IBC Section 202 as the vertical distance from the Grade Plane to the highest roof surface (Height, Building definition from IBC Section 202). The Grade Plane is located at an elevation of 5,347.0 feet.

1.1.1.1.1 Terminal

The fabric roof system extends from the flat-roof plane over Level 6 (Level 7) to the highest peak over the Great Hall at an elevation of 5,536 feet (189 feet above Grade Plane). The main Terminal Building has a total of 6 stories

above Grade Plane plus mechanical penthouses on Level 7. Level 6 is located approximately 85 feet above Grade Plane. Buildings of Construction Type IA are permitted to be of unlimited height.

1.1.1.1.2 Number of Stories

The highest portion of each Concourse is the Center Core area, which consists of four stories above ground, plus a penthouse and a basement level as follows:

- Level 0- Basement Level
- Level 1- Apron Level (grade level)
- Level 2- Concourse Level
- Level 3- Mezzanine Level (only occurs at Center Core and Sub-core)
- Level 4- (only occurs at Center Core and Sub-core)
- Level 5- Mechanical Penthouse (only occurs at Center Core)

1.1.1.2 Concourse Building Height

The Concourse Building Height is defined as the vertical distance from the Grade Plane to the highest roof surface.

1.1.1.2.1 Concourse A

For Concourse A, the Grade Plane is located at an elevation of 5,376 feet. The highest roof level is 5,460 at the roof of the atrium for a height at the center core of 84 feet. The highest occupied floor is at an elevation of 5,433 feet, which is 57 feet above grade. Based on this height, Concourse A is not a high-rise

1.1.1.2.2 Concourse B

For Concourse B, the Grade Plane is located at an elevation of 5,370 feet. The highest roof level is 5,450 at the roof of the atrium for a height at the center core of 80 feet. The highest occupied floor (i.e., Level 5, which is primarily mechanical) is at an elevation of 5,427 feet, which is 57 feet above grade. Based on this height, Concourse B is not a high-rise, excluding the Ground Control tower.

1.1.1.2.3 Concourse C

For Concourse C, the Grade Plane is located at an elevation of 5,352 feet. The highest roof level is 5,413 for a height at the center core of 61 feet. The highest occupied floor is at an elevation of 5,394 feet, which is 42 feet above grade. Based on this height, Concourse C is not a high-rise.

1.1.1.3 Building Area

1.1.1.3.1 Terminal

The Building Area is defined by IBC Section 202 as “The area included within surrounding exterior walls (or exterior walls and fire walls) exclusive of vent shafts and courts. The gross square footage and, thus, the total building area for the Terminal is approximately 2,772,000 square feet currently. The Great Hall Redevelopment project will increase the footprint for levels 5 and 6, resulting in an increase of 131,250 square feet for a total area of 2,902,584 square feet (need to verify this with the Great Hall Team).

1.1.1.4 Building Area – Concourses

The Building Area is defined as “The area included within surrounding exterior walls (or exterior walls and fire walls) exclusive of vent shafts and courts. 3 Buildings of Construction Type IA (other than High Hazard occupancies) are permitted to be of unlimited area. Therefore, the building areas noted below are acceptable for the total structure, and no calculations are required regardless of expansion project area increases.

1.1.1.4.1 Concourse A

The gross square footage and, thus, the total building area for Concourse A is approximately 1,397,800 square feet. Prior to completion of the A-West Expansion project

1.1.1.4.2 Concourse B

The gross square footage and, thus, the total building area for Concourse B is approximately 2,186,000 square feet. Prior to completion of the B-West and B-East Expansion projects.

1.1.1.4.3 Concourse C

The gross square footage and, thus, the total building area for Concourse C is approximately 1,302,700 square feet. Prior to completion of the C-East Expansion project.

1.1.1.5 Occupancy Classifications

1.1.1.5.1 Terminal

The Terminal occupancy classification is to be determined as specified in the current Denver Building Code and IBC. IBC 2015 Section 303.3 defines restaurants, dining facilities, and bars as Assembly Group A-2. IBC Section 303.4 defines waiting areas in transportation terminals as Assembly Group A-3. The primary occupancy for the Great Hall Redevelopment Project will therefore be defined as Assembly. The appropriate occupancy classification based on IBC Chapter 3 for the various uses of the Building are shown in [Table 1.1-1: Terminal Occupancy Classification](#).

Table 1.1-1: Terminal Occupancy Classification

Use	Occupancy Classification
Restaurant	A-2*
Bar	A-2*
Commercial Kitchen	A-2*
Offices	B
Mechanical / Electrical Spaces	F-1
Retail Stores	M

**A building or tenant space used for assembly purposes with an account load of less than 50 persons shall be classified as a Group B occupancy.*

The building has multiple occupancies and is a mixed-use facility. Section 508 of the 2015 IBC identifies two approaches for addressing mixed-use conditions: non-separated and separated. IBC Section 508.1 allows buildings to be designed using a non-separated approach, a separate approach, or a combined approach.

Future renovations may utilize a non-separated occupancy approach as specified in IBC Section 508.3. Non-separated occupancies do not utilize fire barriers to separate occupancies except where the code requires special use separation, such as incidental uses (IBC 509) or residential dwelling units. Each portion of the building is individually classified by use group and function of space. The type of construction required is determined through the application of height and area limitations for each of the applicable use groups to the entire building, and the most restrictive construction type is used for the entire building.

Based on [Table 1.1-1: Terminal Occupancy Classification](#), the building contains Group A-2, A-3, B, F-1, M, and S-1 occupancies. IBC Tables 504.3, 504.4, and 506.2 indicate that buildings of Type IA construction have the same height, area, and the number of story limitations for all applicable occupancies. As such, the non-separated occupancy approach from IBC Section 508.3 may be utilized for these occupancies in the building, provided the

most restrictive applicable provisions of IBC Chapter 9 are applied to the building or portion thereof in which the non-separated occupancies are located.

1.1.1.5.2 Accessory Occupancies

Accessory occupancies will not be utilized based on the non-separated occupancy approach.

1.1.1.6 Construction Type: Existing Building Elements

At the time of original construction, the Terminal was built using Construction Type I, Fire Resistive (Type 1 FR), per the 1988 Uniform Building Code (UBC) with the 1990 Denver Building Code amendments (1990 IBCA), with an exception granted for not rating the Great Hall membrane roof. [Table 1.1-2: Building Elements: Type I, FR](#) defines fire resistance requirements for various building elements.

Table 1.1-2: Building Elements: Type I, FR

Building Elements	Type I, Fire Resistive	Hours
Structural frame (columns and primary beams)		3
Roof construction (Great Hall with room >25')		0
Roof construction, other than Great Hall		2
Floor construction		2
Exterior bearing walls		4
Interior bearing walls		*
Exterior nonbearing walls		0
Nonbearing interior partitions		0
Shafts and exit stair enclosures		2
Public corridor walls		0
Horizontal exit firewalls		2

**New interior bearing walls shall comply with current code*

The fire resistance ratings of existing elements permitted at the time of construction are permitted to be maintained unless they are modified as part of the project. Many specialized construction materials have significantly evolved since the Terminal was originally permitted (e.g., spray-applied fireproofing and through-penetration firestop); in utilizing modern construction materials, the associated requirements will be implemented (e.g., special inspection) in accordance with current building codes.

1.1.1.7 New Building Elements

Type I, Fire Resistive construction, is most closely related to Type IA construction in the International Building Code. Any new building elements constructed as a part of this project (that do not support existing building elements) shall comply with the following table for Type IA construction. All construction materials are to be non-combustible except where complying with IBC Section 603. New building elements shall comply with 2016 IBC for Construction

Type IA, listed in [Table 1.1-3: Building Elements: Type 1A](#). Existing building elements replaced in their entirety shall also comply with the 2016 IBC.

Table 1.1-3: Building Elements: Type 1A

Building Elements Type 1A	Hours
Primary structural frame – including columns, girders, trusses	3a
Tent roof construction (Great Hall with roof > 25') and secondary members (cables, tie-downs, etc.)	0
Roof construction – including secondary beams and joists	1.5b
Floor construction – including secondary beams and joists	2
Bearing exterior walls	3
Bearing interior walls	3a
Nonbearing exterior walls and partitions (Fire separation distance $\geq$ 30')	0
Nonbearing interior walls	0
Shafts and exit stair enclosures (IBC 713 & 1022)	2
Exit access corridors (IBC Table 1020.1)	0
Exit passageways (IBC 1024)	2

a. Roof supports: Fire-resistance ratings of primary structured frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.

b. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.

c. Not less than the fire-resistance rating required by building codes and amendments.

d. Not less than the fire-resistance rating based on fire separation distance.

Per IBC Section 403.2.4, sprayed fire-resistant materials installed throughout shall have a minimum bond strength of 430 psf.

1.1.1.7.1 Seismic Design Criteria

The seismic design criteria shall meet the 2018 IBC and 2019 IBCA Chapter 16 requirements for a risk category III building as specified in IBC Table 1604.5.

1.1.1.8 Interior Finish

New materials in the Great Hall shall meet the requirements for Atrium and Covered Mall Interior Finishes⁹. Class B (or Class A) interior finishes shall be provided for the Great Hall as required by IBC 402.6 and 404.8. For other areas of the Terminal, new interior finishes are to comply with NFPA 415 Section 4.1.2, which allows only Class A or B finishes

Wall and ceiling finishes are classified as follows:

Class A: Flame spread 0-25; smoke-developed index 0-450

Class B: Flame spread 26-75; smoke-developed index 0-450

Class C: Flame spread 76-200; smoke-developed index 0-450

1.1.1.8.1 Combustible Construction Materials

Tenant spaces located in the Great Hall shall meet the requirements of IBC Section 402.6.2 for combustibility of construction, except plastic and aluminum composite materials shall only be permitted on a case-by-case basis with corresponding administrative modifications. Tenant Spaces include walled or unwalled covered areas larger than 200 sf (aggregate) used to display or sell merchandise, for general business functions or services, for dining and drinking, or for similar purposes. Other areas of the Terminal are to comply with IBC Section 603 for combustible materials permitted in buildings of Type I construction.

1.1.1.9 Atrium Combustible Loading Restrictions

IBC Section 404.2 states that the floor of an unsprinklered atrium, such as areas in the HTC, Terminal, and Concourses, shall be used for low-hazard uses only and that materials and decorations are required to comply with the IFC. This restriction will apply to unsprinklered areas of the Great Hall, such as waiting areas, restaurant seating areas, or temporary installations.

1.1.1.10 Storage Use Restrictions

Neither the IBC nor the IFC provides a definition of “low-hazard use.” IFC Chapter 32, the high-piled combustible storage chapter, classifies commodities as Class I through Class IV or high-hazard. It can therefore be inferred that Class I through IV commodities are a low or moderate hazard. NFPA 101 Life Safety Code (2015 Edition) is not an adopted code for the Terminal building but is used as a reference herein as it provides more detailed information. NFPA 101 Section 6.2.1.2 requires the hazard of contents to be classified by the registered design professional and approved by the AHJ. NFPA 101 Section 6.2.2.2 defines low-hazard contents as materials with low combustibility that do not propagate fire.

1.1.1.11 Other Special Uses

The following uses, materials, and decorations are considered low hazard and are permitted:

- A. Waiting areas
- B. Passenger security screening areas and associated equipment
- C. Any structure built of noncombustible materials
- D. Garbage collection bins (trash cans)
- E. Structures, including artwork, with combustible components meeting requirements of DBC Section 603
- F. Seating and associated furniture and floor coverings (i.e., tables, foot stools, rugs, etc.) meeting one of the following:
 - 1. Non-upholstered furniture with a Class A or B flame spread rating per ASTM E84 or equivalent test standard.
 - 2. Upholstered furniture tested in accordance with NFPA 260 or having an Upholstered Furniture Action Council (UFAC) rating.
 - 3. Upholstered furniture that has been tested in accordance with, and passed, California Technical Bulletin 133.
 - 4. Non-upholstered wood furniture constructed of solid wood (excluding particle board) components with a minimum dimension of 1 inch.
 - 5. Floor coverings (i.e., rugs, carpeting, etc.) having a Class II rating per NFPA 253.
 - 6. Furniture having a potential heat of 9,000 Btu per pound or less.

- G. Vending stands [kiosks] less than 200 sq.ft. in area9 constructed primarily of noncombustible materials, fire retardant wood or solid wood materials (excluding particle board) with a minimum dimension of 1 inch and with plastic components meeting DFC Section 807.5.1.1
- H. Decorative vegetation as allowed for Group A occupancies in DFC Section 806
- I. Decorative materials as allowed for Group A occupancies in DFC, Section 807
- J. Single vehicles with fuel removed
- K. Art installations consisting of quantities of plastic equal to or less than identified in DFC Section 807.5.1.1.

1.1.1.11.1 Concession Kiosks

Note that the allowance to leave small kiosks unsprinklered comes with the provision that the kiosk will have beam detection and automatic fire alarm notification to the building upon activation of two detection devices. At this time, it is understood that this approach is not the preference of the airport.

1.1.1.12 References

DEN has the following references available upon request. Submit a request to the DEN Project Manager if the following documents are required for the project:

- A. Administrative modification defining building boundaries
- B. Formal analysis of fire-rated walls and doors in the Terminal

1.1.2 Accessibility

1.1.2.1 Accessible Interior Design Intent

DEN facilities shall be universal and barrier-free, designed and constructed. All designs shall comply with (ICCA117.1, ADA), the latest referenced standard. That being said: The DEN complex shall be designed and constructed to accommodate the user of the future. Statistics confirm that the population is becoming increasingly diverse. Integrating the needs of the entire population - children, the aged, and persons with disabilities, including sensory and/or cognitive challenges - creates design challenges that can be optimized by adopting the concept of universal design. Universal design is a design that works for everyone. It is successfully achieved by integrating the principles of barrier-free design (i.e., handicapped accessibility standards) as an integral component of the design process.

It is paramount that the design of DEN focuses around solutions that give priority to accessibility and thus eliminate architectural barriers confronting persons with disabilities. The objective of barrier-free design or universal design is to afford the same opportunity of mobility and independent movement in the environment to the person with a disability as is available to an able-bodied person. Moreover, the consequence of disability should not deprive people of experiencing their environment with an aesthetically pleasing design.

Accessibility standards shall be followed in all areas used by the public as well as areas intended for employee use. Accessibility shall be provided throughout all buildings and in overall site design for all buildings constructed on the City and County of Denver property.

1.1.2.2 Doors

Maneuvering clearance at all doors shall comply with the requirements for an accessible route. To facilitate movement and circulation where possible, doors shall be one of the following:

- A. Held in open position
- B. Double egress

- C. Push-pull, non-latching
- D. Automatically operated
- E. Eliminated

F. The design, modeling, and analysis process is repeated until a design evolves which approaches design

End of Chapter

Chapter 2 - Interior Environment

1.2.0 General Architectural Information

1.2.0.1 Aesthetic Considerations

Application of the DEN Design Principles will enable the fulfillment of DEN's aspiration that the airports' architecture and interiors become a seamless, unified embodiment of their design value and brand idea. Appropriateness of the approach will ultimately be determined by the Design Review Committee (DRC).

For additional information on the Design Review Committee (DRC) refer to the following site:



[DEN Design Review](#)

1.2.0.2 Elements of Design

Design elements of the existing terminal complex are described below. Deviations from this approach that are based on the DEN Design Principles guidelines are permitted but require approval from the DRC.

1.2.0.2.1 Interior Partitions

The primary interior wall types consist of abuse-resistant gypsum board, stainless steel, or terrazzo base. Generally, partitions go-to structure. Rated walls, smoke zones, and plenums are required to comply with the Life Safety Master Plans found in the Life Safety DSM.

1.2.0.3 Criteria and Guidelines

Table 1.2-1: Definitions

Term	Abbreviation	Definition
Decibel	dB	The unit of sound pressure level as a ratio between a measured sound pressure level and the reference pressure.
Field Sound Transmission Class	FSTC	The difference between the STC and FSTC is that the FSTC is a field performance and includes sound leads and flanking paths. Typically, FSTC = STC-5.
Impact Isolation Class Rating	IIC	The rating of impact noise heard through the floor/ceiling in the space below/above.
Noise Criterion	NC	A rating system based on the octave band sound pressure levels for a given noise spectrum. The NC value is determined when the given noise spectrum does not exceed any sound pressure levels of the lowest possible NC curve. These curves are based on satisfactory speech communication without being annoying.
Reverberation Time	N/A	The time, in seconds, taken for a sound within a space to decrease by 60 dB after the sound source has stopped.
Speech Intelligibility	N/A	The measure of how comprehensible speech is in a given condition, using the STI.
Sound Transmission Class	STC	The STC is an integer rating given to a building partition that denotes how well a building partition attenuates airborne sound. It is based on a laboratory performance of a test sample.
Speech Transmission Index	STI	STI is the objective measurement predictor of speech transmission quality.

Acoustic criteria are provided for the following:

- A. Background noise levels within occupied spaces due to HVAC system and mechanical equipment noise using Noise Criteria Curves (NC).
- B. Exterior noise ingress from aircraft and vehicular traffic operations using Noise Criteria Curves (NC).
- C. Acoustical separation between occupied spaces and between non-occupied mechanical room spaces and occupied spaces using field transmission class (FSTC).
- D. Impact Isolation using impact insulation (IIC).
- E. Reverberation time of occupied spaces to control noise levels within large spaces and achieve acceptable speech intelligibility of public address announcements using reverberation time and speech transmission index (STI).
- F. Minimum exterior building attenuation to reduce noise intrusion from both landside traffic movements and airside aircraft operations.

1.2.0.4 STC Rating Charts

Hotel uses and other tenant design standards for STC ratings, take precedence to DEN's minimum STC Standards in these tables:

Table 1.2-2: Typical STC Rating Expectations

STC	What can be heard at this level
25	Soft speech can be heard and understood
30	Normal speech can be heard and understood
35	Loud speech can be heard and understood
40	Loud speech can be heard, but not understood
45	The threshold at which privacy begins
50	Loud sounds can be heard; but are very faint
60+	At this level, good soundproofing begins. Neighbors generally are not disturbed by very loud speech from inside.

Table 1.2-3: DEN STC Standards by Room Type and Adjacencies

Target STC		
Adjacencies		STC
Retail	Retail	50
Standard Office	Standard Office	45
Executive Office	Executive Office	50
Conference Room	Conference Room	50
	Administrative	45
	Office	55
Mechanical Room	Occupied area	60
Training Room	Training Room	50
	Restroom	53
Quiet Room	Occupied area	55

1.2.1 Interior Design Features

1.2.1.1 Exposed Concrete Surfaces

The use of exposed concrete surfaces as an architectural element is generally acceptable. Care should be taken in specifying an appropriate finish surface and technique. Samples must be approved by the DRC.

1.2.1.2 Stone Surfaces

The use of stone as an accent to the primary wall and floor surfaces is encouraged. The use of Colorado or Rocky Mountain stone is further encouraged. Samples must be approved by the DRC.

1.2.1.3 Metal Finish

The existing terminal complex utilizes a “Terminal White” metal finish in a complementary color scheme where infill metal panels, spandrel glass, and other opaque surfaces that are a part of the curtain wall are contrasted against the curtain wall grid. Selection of new metal finishes must complement the existing and be thoughtfully implemented.

Where stainless steel is listed as a material option, the finish will not be prescribed in this document. Specific finish selection will be reviewed with the DRC for specific projects.

1.2.1.4 Ceilings

Ceiling planes delineate, define, and provide scale to space. Certain areas will have an exposed structural framework, while other areas will be scaled for a more finished, private space.

For any area of the ceiling where access is required for maintenance, material selection that facilitates easy access is required.

1.2.1.5 Diffusers

Diffusers shall be coordinated and selected per the Mechanical DSM. Modifications to the standard diffusers as an architectural feature will be required to not only be an element presented to the Design Review Committee (DRC) but are subject to revision by the DEN Mechanical Engineer. In general, hidden diffusers are the preferred approach.

1.2.1.6 Glare

Reflective surfaces, such as reflective glass, are not permitted. This requirement is intended to control glare.

Requirements regarding the Building Envelope should be considered by designers.

1.2.1.7 Exposed Conduit

Generally, all conduits shall be concealed. Exposed conduit is not considered a design element. In open ceiling public areas, where conduits are exposed, conduits shall be painted to match adjacent surface or structure to conceal conduit to greatest extent possible.

1.2.1.8 Cameras/Monitors

Placement and location of cameras and monitors must be integral with the aesthetic design of all public spaces. Number and approval of location(s) will be determined specific to each project.

1.2.1.9 IECC Compliance

Building must be designed in conformance with the currently applicable version of the International Energy Conservation Code.

1.2.1.10 Window Treatments

Window treatments are generally not permitted. Special conditional use must be approved by the DRC. Potential options are listed below.

- A. Window tinting
- B. Window film - high-performance low-e coatings
- C. Decorative coatings - digitally printed frit with ceramic ink on glass (including heat-treated, insulated glass units and laminated glass).
- D. Operable solutions are acceptable in Concessions and office areas but not holdrooms, etc.

1.2.1.11 Sustainability

Sustainability is an important objective of all DEN projects. Sustainable design shall be an integral part of all projects. The incorporation of educational sustainability experiences is encouraged as a LEED point we like to pursue. The Designer of Record may be required to supply graphic design.

Gas appliances are not allowed at DEN, including but not limited to gas fireplaces, in accordance with the City and County of Denver's Office of Climate Action, Sustainability and Resiliency (CASR), **Energize Denver Ordinance**.

1.2.1.12 Application and Use of Materials

Materials are intended to be used in a fashion that is representative of their natural state. Unauthentic or faux use of materials are prohibited. DRC approval is required for any materials that do not meet this guideline. Sufficient backstock for all materials should be readily available for ongoing maintenance activities.

1.2.1.13 Millwork

Sales and transaction counters shall be a maximum of 34" AFF.

Trash receptacles shall be a maximum of 34" high and may not include shelves or racks above the receptacle.

1.2.2 Food Courts, Concession Common Areas, and Common Seating Areas

Concession Common Areas are a waypoint for many passengers before or after travel or between flights. Tenant spaces shall meet all requirements in the Tenant Development Guidelines.

1.2.2.1 Food Courts/Concession Common Areas/Common Seating Areas

Conditions unique to this use are addressed below.

1.2.2.1.1 Additional Approved Flooring Materials

- A. Terrazzo Tile
- B. Dyed/Polished Concrete

1.2.2.1.2 Additional Prohibited Flooring Materials

- A. Stained Concrete where stain is surface applied, and a wax/polish wear coat is required.

1.2.2.1.3 Walls

For use of Metal Panel products, vandal resistant product must be used at contact areas, heavier gauge, and more scratch/scuff resistant.

1.2.2.1.4 Wall Base

- A. Six-inch-high minimum - Dimensional base is required 1/2" minimum depth to protect against the floor cleaning machines; other thickness may be acceptable based on the actual material being used but requires DEN approval.

- B. Base-to-floor transition detail is required to be conducive towards food use/cleaning.
- C. Coved base is preferred.

1.2.2.1.5 Column Cladding

- A. Additional approved material:
- B. Thru-body tile: porcelain, glass, epoxy, natural or engineered stone.
 - a. Tile may only be used with integral/engineered corner protection treatments. Exposed tile at corners is prohibited.

1.2.2.1.6 Corner Guards

Full Height – 8'-0" AFF minimum

- A. Additional approved material
Integral/engineered corner protection treatments associated with approved wall materials.

1.2.2.1.7 Ceilings/Acoustics

- A. Additional Prohibited Materials
 - a. Completely Exposed

1.2.2.1.8 Approved Seating/Furniture/Fixtures Materials

- A. Solid Surface Tops are required.
- B. All seating must be Slip/Tip Resistant, including resistance to tipping forward.
- C. Waste/Recycling Receptacles: Match DEN standard

1.2.2.1.9 Prohibited Seating/Furniture/Fixture Materials

- A. Painted Metal Finishes
- B. Plastic Laminate Tops
- C. Compressed/Pressed fiber board or foam

1.2.2.1.10 Approved Food Courts/Concession Common Areas/Common Seating Areas Materials

The following materials have been approved by DEN for use in this area. Method/implementation of use requires DRC approval. Additional materials will be allowed as approved by the DRC.

- A. Epoxy
- B. Thru-Body Tile
- C. Granite
- D. Concrete Tile
- E. Decorative Polymor Flooring
- F. Terrazzo Tile
- G. Dyed Polished Concrete
- H. Porcelain Panels (floors or walls)
- I. Porcelain Panels (walls only)
- J. Engineered Stone (floors or walls)
- K. Engineered Stone (walls only)

- L. High Pressure Laminate Panels
- M. Metal Paneling
- N. Glass
- O. Resin
- P. Glass Tile
- Q. Ceramic Mosaic Tile
- R. Perforated Imaging Metal Paneling
- S. Laminated MDF Panels
- T. Fiber Cement Panels
- U. Translucent Honeycomb Panels
- V. Heavy Duty Water Based Urethane Paint
- W. Metal Column Cladding
- X. Solid Surface
- Y. Acoustical Lay-In Tile
- Z. Acoustical Wood Ceiling
- AA. Acoustical Metal Ceiling

1.2.2.2 Concession Back of House Areas

All Materials used must be durable, abuse resistant, and cleanable.

1.2.2.2.1 Walls

Stainless steel panels or zinc coated tear plate provide full height (8'-0" AFF) or to 4'-0" AFF with a dimensional heavy-duty chair rail (8"h x 2"d minimum).

1.2.2.2.2 Floor

Slip-resistant seamless floor with an integral base. Poured/troweled epoxy resinous flooring is preferred.

All kitchens, bars, food preparation areas, and similar spaces shall incorporate a waterproof flooring system that ensures complete water resistance, suitable for these high-moisture environments. The assembly must comply with all relevant building codes, industry standards, and manufacturer specifications to guarantee durability and performance.

The installation of the waterproof flooring assembly must be inspected by a qualified subject matter expert (SME) at critical stages during the installation process and upon completion. The SME shall verify that the installation adheres strictly to the approved design documents and the manufacturer's installation confirming that the flooring assembly has been installed correctly and meets all specified standards. This certification shall be submitted to the project manager for inclusion in the project documentation.

1.2.2.2.3 Ceiling

- A. Vinyl faced acoustical ceiling tiles/in suspended ceiling grid system
- B. Epoxy painted gypsum board

1.2.2.2.4 Doors

- A. Approved Materials
 - a. Stainless steel clad doors (heavy gauge), fully welded frames.

- B. Prohibited Materials
 - a. Knockdown frames

1.2.3 Concessions

1.2.3.1 Introduction

The concessions located throughout the terminal and concourses are intended to contribute heavily to the DEN passenger experience. These spaces must be engaging, enjoyable, and informal and are important components to place-making. The retail design elements must embody the DEN Design Principles and activate the DEN brand strategy.

Refer to Concourse Concession Design Guidelines for Concession standards and DEN Design Principles for a road map to reach the design goals and aspirations of DEN.

Note: The design team shall contact the BIM group to establish BIM Room Numbers on all drawing submittals.

1.2.3.2 Stairs

1.2.3.2.1 Interior Public Stairs (Open)

- A. Handrail
 - a. Approved Materials
 - 1. Stainless Steel
 - 2. Wood/Engineered Wood
 - b. Prohibited Materials
 - 1. Powder coated steel
- B. Railing Panel (Balustrade Panel)
 - a. Tempered/Safety Glass
 - b. Metal Panel
 - c. Edge-It LED Panel
 - d. Cable Ties
 - e. Stainless Steel
 - f. Resin/Plastic
- C. Stair Tread/Riser
 - a. Terrazzo
 - b. Thru-Body Tile with metal edges
 - c. Stone/Engineered
 - d. Sealed/Stained Concrete
 - e. Epoxy Terrazzo (Hotel Stair Material)
 - Must utilize standardized universal colors (RAL, pantone, or other definable colors only.) Specific aggregate mix must be included. "Match existing" designation is prohibited for future projects. All new terrazzo floors must have definable features that can be easily reproduced.
 - f. Precast Concrete (Hotel Staircase)
 - g. Concrete Tile

- D. Approved Materials

The following materials have been approved by DEN for use in this area. Method/implementation of use requires DRC approval. Additional materials will be allowed as approved by the DRC.

- a. Epoxy Terrazzo

- b. Thru-Body Tile
- c. Granite
- d. Concrete Tile
- e. Engineered S

E. Resin

1.2.4 Non-Passenger Restrooms

1.2.4.1 Introduction

This section deals with non-passenger restrooms or non-public restrooms. A restroom should provide privacy and functionality for the most valuable resource, staff, and tenants. With airports becoming used around-the-clock more than ever, durability is a major concern. DEN wants to provide non-passenger restrooms that are utilitarian, functional, accessible, durable, clean, and bright.

- A. Every single user toilet room shall be designed accessible.
- B. Lavatories shall be of universal design. There shall be no distinction between accessible lavatories and standard lavatories.
- C. Mirrors shall be mounted with the bottom edge at 40" AFF if mounted over the counter or lavatory.
- D. Restroom accessories (paper towel dispenser, hand dryer, soap dispenser, etc.) will be mounted 44"-48" AFF. When determining the mounting location of restroom accessories, the operable parts (start buttons, dispensing mechanisms, sensors, etc.) will be located no more than 48 inches AFF.
- E. Entry Portals Accessibility standards should be carefully studied. Meeting or exceeding the minimum maneuvering clearances at doorways is an important aspect in design to ensure proper access.

These back-of-house spaces should be durable and utilitarian but also pleasant, clean, and accessible. The universal design approach includes improved usability characteristics to ensure they are usable to the greatest extent possible by people of all ages and abilities, even if a particular feature has a more limited target group.

1.2.4.2 Non-Public (service/ back of house)

- A. Flooring
 - a. Tile - Through body porcelain
 - b. Resinous flooring
- B. Wall Finishes
 - a. Tile - through body porcelain
 - b. Porcelain panel
- C. Counter Tops
 - a. Solid Surface
- A. Ceiling
 - a. Acoustical Metal Ceilings
 - b. Painted Gypsum Board
 - c. Painted Gypsum Board
- B. Approved Materials
 - a. Resinous Flooring
 - b. Thru-Body Tile
 - c. Porcelain Panels
 - d. Heavy Duty Water Based Urethane Paint

- e. Acoustical Metal Ceiling
- f. Solid Surface

End of Chapter

Volume 2 - Communications and Electronic Systems

Chapter 1 - General System Information

2.1.0 Communication and Electronic System Information

2.1.0.1 System Information and Requirements

This chapter provides engineers and designers performing design work for DEN with systems overviews, configurations, and specific design requirements. Communications and Electronic Systems addressed in this Design Standards Manual include:

- A. Premise Wiring Communication System (PWCS)
- B. Telecommunication, Local Area networks (LAN), and Networking Systems
- C. DEN Television
- D. Voice Paging System (VPS) - ECS
- E. Radio Frequency (RF) Systems
- F. Energy Management and Control Systems
- G. Wireless Local Area Networks (WLAN) and Wi-Fi
- H. Wireless Communication Systems

2.1.1 Drawing Requirements

2.1.1.1 Drawings

The communications and electronic systems described in this chapter shall be designed and drawings shall be prepared as applicable, based upon the characteristics, and complexity of the projects involved and as determined by each system narrative contained in these design standards. Drawings shall be provided when essential in the planning, procurement, construction, evaluation, recording, and use of the projects. All drawings shall indicate the complete design.

2.1.1.2 Definition

Facility communications and electronic systems drawings are graphic representations of the facility's design requirements.

2.1.1.3 Completeness

Facility communications and electronic systems drawings, when interpreted in association with the construction specifications, shall:

- A. Furnish sufficient information for the contractor to facilitate permit drawings installation of manufactured equipment that satisfies the design requirements.
- B. Furnish sufficient information to manufacture equipment that is of special design, made exclusively to meet the requirement of the project. Components, assemblies, and systems shall be UL listed.
- C. Describe items so that they may be procured. If PMT is on the project, PMT is to procure a responsibility matrix and asset schedule.

- D. Furnish sufficient information to permit planning, construction, evaluation, recording, repair, and maintenance of facilities.

2.1.1.4 Drawing Sequence

Construction documents are divided into specific groups per NCS. The group number shall always remain the same, no matter how large the project is. Refer to the DFI DSM.

Numbered sheets for areas for plan views shall remain consistent across disciplines. For example, sheets A2.01, S2.01, M2.01, P2.01, F2.01, E2.01, and T2.01 shall all show work in the same area.

2.1.1.5 General Notes, Drawing Index, Symbols, and Abbreviations

These sheets shall contain Notes that are applicable (or general) to all sheets in the set of drawings and, in addition, contain the drawing symbology as required in [2.1.1.13. Communications and Electronic Systems](#). These sheets shall also contain a complete drawing index for the document set.

2.1.1.6 Site Plan

The site plan shall identify, where applicable, all site facilities required in support of the specified communications and electronic systems, including conduits and their interconnection to existing conduits (duct banks), resources, and cabling systems. In addition, the site plan shall indicate all existing utilities and all communications and electronic systems devices and conduits that are located external to the building and indicate connections (penetrations methods) to internal systems. Where applicable, external devices and equipment, e.g., towers, antennas, etc., shall be shown, including all internal and external connections. Keyed symbology shall be shown, which directs the contractor to specific installation, provisioning, and configuration details that shall be included in the detail sheets. All required connections to the grounding system shall be indicated.

2.1.1.7 Floor, Roof, and Reflected Ceiling Plans

Plan drawings shall be provided which indicate all communications and electronic systems devices and equipment locations and include conduit interconnection between devices. All device locations shall be coordinated with all disciplines, including architectural finishes and features. Keyed symbology shall be shown, which directs the contractor to specific installation, provisioning, and configuration details which shall be included in the detail sheets.

When more than one system is shown on a plan, each shall be made clearly discernible by the system. Conduits indicated on the plans shall either be shown as routed to their specific termination location (Equipment or Terminal cabinet) or be indicated by a schedule for the termination location. All conduits shall be coordinated with the requirements of the conduit riser diagram. Devices indicated on plans shall be coordinated with the requirements as indicated in point-to-point diagrams.

2.1.1.8 Equipment Room Layouts and Elevations (DEN and Tenant)

Coordinated equipment room layouts, rack elevations, and wall elevations shall be provided, which indicate the scaled layout of the equipment room and all Communications and Electronic Systems and facilities co-located within the equipment room. Equipment rooms and layouts shall provide sufficient detail that permits coordinated construction and include the following elements:

- A. Interconnection between equipment
- B. Conduit terminations
- C. Grounding and bonding connections
- D. Electrical connections, bonding bus bars, and grounding bars

- E. Floor-mounted and wall-hung equipment placement, including equipment racks
- F. Cable tray configurations
- G. All penetration and fire sealant/safing details
- H. Clearance zones for servicing equipment
- I. Locations and sizing of cooling equipment required and shall be coordinated with the mechanical designer
- J. Coordinate electrical requirements with the electrical designer

Where new equipment and/or facilities are specified/required for installation in an existing equipment room, layouts shall be provided that coordinate the placement of new equipment with existing equipment. The detail provided shall be as indicated above. New equipment shall be delineated by a different line type from existing equipment so that positive identification between new and existing equipment is assured.

2.1.1.9 Point-to Point Wiring Diagrams

Point-to-point wiring diagrams describe the detailed wiring configuration and arrangement of the specific system utilizing lines connected to specific equipment terminals and equipment pieces. Point-to-point wiring diagrams indicate the required system color-coded interconnection details at the component level. Point-to-point wiring diagrams shall be required at the design level only for those electronic and communications systems where interconnection to existing equipment is required. Point-to-point shall be provided only for the specific interface location and configuration. In the cases where new systems are designed and do not require interconnection to existing systems, system concepts and intent shall be conveyed through the functional block diagram, riser diagrams, floor plans, elevations, and project specifications. When required, point-to-point wiring diagrams shall contain the following detail

- A. All wiring by type and size required between all system components
- B. Indicate wire color coding
- C. Indicate terminal strip numbers and positions
- D. Indicate current, signal, and data flow
- E. Diagram should reflect door in a secured state with normally open or normally closed circuit clearly indicated

2.1.1.10 System Riser Diagrams

Communications and electronic systems riser diagrams indicate the distribution of major systems components, wiring systems, and their interconnection requirements. Riser diagrams shall always be provided for cabling systems and indicate the following:

- A. Equipment rooms
- B. Cable quantities
- C. Cable types
- D. Termination locations
- E. Keyed reference to related details

F. In multi-floor facilities, riser diagrams shall be organized by level

2.1.1.11 Conduit/Cable Tray Riser Diagrams

Conduit riser diagrams are provided to indicate the configuration, location, quantity, and size of the conduit/cable tray infrastructure required in support of the specified communications or electronic system. In multi-level facilities, conduit riser diagrams shall be organized by level. All conduit riser diagrams shall indicate the following information:

- A. Equipment rooms (or conduit termination locations)
- B. Conduit quantities
- C. Conduit sizes
- D. Conduit identification schemes
- E. Interfaces to cable trays
- F. Grounding and bonding requirements
- G. Cable tray systems

Conduits that are specified or scheduled for installation of fiber optic cables shall be a minimum of 1" in size and configured with appropriate bending radii and bend requirements. All conduit shall have not more than 180 degrees of bend between pull locations. All conduits and cable tray systems shall be installed in compliance with applicable codes and DEN Standards. Review sizing and bends with Project Manager at Design Development Phase.

Terminal cabinets, equipment backboards, and other conduit termination facilities and locations are considered part of an integrated conduit riser diagram and shall be shown on the conduit riser diagram. Branch conduits installed in support of devices need not be shown on the conduit riser diagram.

The conduit riser diagram shall be coordinated with the system riser diagram, such that cross-reference between systems cables and conduit/tray infrastructure are achievable. Minimum height requirements of the cable tray and conduit systems will be included in the Architectural section so the building may be built to accommodate them. All conduit and cable tray systems shall be configured and suitably sized to permit the segregation of cables by conduit/tray segment by signal level as follows:

- A. Less than 10V
- B. 10V - 70.7V
- C. Greater than 70.7 volts
- D. Telecommunications cabling (voice and data) cables shall never be mixed with dissimilar resources.

2.1.1.12 System Details

Systems details are provided to indicate specific installation techniques and systems configurations. System details shall be provided in support of the design and installation intent indicated on other sheets and call attention to the specific conditions and requirements necessary to ensure that the installed system configuration is compliant with the design intent and requirements. Details shall be provided for all conditions where specific direction can not be properly conveyed or is indicated on other sheets.

2.1.1.13 Communications and Electronic Systems

Communications and Electronic Systems and electronic symbols, when used, shall be in accordance with ANSI standards in accordance with this section. Other symbols, if devised by the consultant, shall be shown in the **ITEM** column and explained in the **DESCRIPTION** column of the **LEGEND** with an indication **FOR THIS PROJECT ONLY**.

2.1.1.14 Symbols for Other Functional Disciplines

Symbols for functional disciplines other than Communications and Electronic Systems shall be as specified in the respective sub-sections of this manual.

2.1.1.15 Functional Designations

Functional designations, when used, shall be in accordance with the appropriate functional designations.

2.1.1.16 Drawing Delineation Types

Communications and Electronic Systems drawings shall generally include the following types of delineations:

- A. Block diagrams
- B. One-line diagrams
- C. Schematic diagrams
- D. Connection diagrams
- E. Facility communications and electronic systems power requirements plans
- F. Facility communications plans and risers
- G. Fire alarm plans and risers
- H. Panel, circuit, security system, data outlets, and other schedules
- I. Detail drawings

The number of delineation drawings for a project shall be adequate to describe the entire system, including existing system and device locations, demolition of systems, reuse of systems or devices, and new work.

2.1.1.17 Delineation Drawings

Subject to the Project Manager's acceptance, the drawings for projects need not contain all delineation types. For example, projects consisting only of a single building and relatively simple communications and electronic systems may not need block diagrams or single-line diagrams if the information normally found in them is effectively conveyed by other delineation types. Each delineation shall be identified by its type below the area where it is displayed, e.g., SCHEMATIC DIAGRAM. These delineations shall not be included in architectural, structural, civil, mechanical, or electrical drawings. If delineation drawings are different from those outlined herein, then the Drawing Index shall clearly show a combination of delineation.

2.1.1.18 Specification Relationship

Specifications that are a portion of a contract package shall include communications and electronic systems technical specifications sections. Each communication or electronic system section shall have its own General Requirements section, which is specifically tailored to the requirements of the electronic and communications system requirements. The communications and electronic systems drawings, together with the specifications, shall describe specifically and adequately all the communications and electronic systems design requirements of the project. Vendor information drawings may be included as reference drawings subject to written approval from the manufacturer. Communications and electronic systems drawings that may form a part of a purchase specification drawing may be included as reference drawings. Prior written acceptance is required for any design-build component.

This Design Standards Manual will be the governing and order of precedent document where discrepancies exist between the relevant Division Specification and this DSM. Designers are encouraged to identify and resolve any discovered discrepancies with the DEN Project Manager, with input from the DEN Subject Matter Experts, as they undertake their design efforts on a given project.

End of Chapter

This page is intentionally blank.

Chapter 2 - Premise Wire and Communications

2.2.0 System Overview

2.2.0.1 Description

The Premise Wire and Communications System (PWCS) at DEN is a universal structured wiring system consisting of multiple cable types that are service location oriented and transmission electronics, including Optical and 802.3 compliant networks. For new or remodeled installations, the PWCS predominantly utilizes Category 6 and Category 6A Unshielded Twisted Pair (UTP), Category 6 Shielded Twisted Pairs (STP), single and multimode fiber optic strands, composite Category 6 STP/UTP copper and fiber optic cable construction types, and coaxial cable for broadband video applications. Services that cannot be extended on the copper facility may be injected into the DEN Optical transport solution for delivery over fiber-based solutions between endpoints.

All cables are extended to their end locations via conduit and/or cable trays. All structured wiring system cables are terminated on universal wall plates (Panduit MiniCom) that support modular connectivity of all cable types identified above.

All cabling additions (provisioning, configuration, and installation) to the existing infrastructure to satisfy local, site, and inter-building connectivity requirements must be performed by the DEN PWCS Technicians or their Inside/Outside Plant Maintenance contractor. A tenant requiring cable installation is directed to contact the DEN Service Desk to order services for any cabling needs outside of their leasehold space.

Tenants are not permitted to install their own copper or fiber cabling between leasehold locations or utilize DEN-managed PWCS pathways for their own cabling. Tenants should coordinate copper and fiber cabling requirements for their leasehold space and connectivity between spaces with DEN Business Technologies at the time of design and throughout the term of their contract. Only DEN PWCS copper and fiber cabling is allowed to be installed in DEN pathways and spaces. Airlines that require their own Communications Room shall utilize a unique pathway when traversing other leasehold spaces and pass horizontal cabling through the DEN communications room such that horizontal cabling could be re-terminated in the DEN communications room if the space is reconfigured for different tenants.

2.2.0.2 Addition of Telecommunications Facilities

When a consultant's scope requires the addition of telecommunications outlets as part of a design, the consultant's scope shall include the following elements.

- A. Location and specification of the outlet locations and quantities.
- B. Specification of conduit and outlet box size with pull string.
- C. Extension of outlet conduit to the nearest communications room or cable tray providing access to the nearest communications room.

NOTE: This room may vary depending on the available resources within the nearest communications room. The consultant is required to coordinate with DEN Planning and Development to establish the proper conduit termination location.

- D. Proper sealing of all openings (penetrations) created or resulting from the installation of telecommunications conduits.
- E. Use of approved products as reviewed by subject matter expert prior to design completion.

2.2.1 Conduit Requirements

The following text includes the minimum requirements for conduit sizing and configuration to be utilized in the installation of telecommunications facilities.

2.2.1.1 Telecommunications Outlet

A telecommunications outlet is defined as a voice, data, fiber, or television outlet. The telecommunications outlet is wall mounted, typically at the same height as an electrical outlet, and serves desktop devices.

- A. Conduit size: 1" minimum
- B. Outlet box size: 4-11/16" x 2-1/2" deep equipped with a 2-gang device ring. This conduit shall be extended to the nearest telecommunications cable tray. Where a tray is not present, the addition of a tray shall be required, or an extension of the conduit to the nearest Intermediate Distribution Frame (IDF) (Communications Room).
- C. Junction boxes in a conduit run shall be a minimum of 6" square.
- D. Looping between telecommunications outlets shall not be permitted.
- E. Gathering of telecommunications conduits to an intermediate (Large) box and extending a single larger conduit to the nearest communications room shall not be permitted unless submitted to and approved by DEN telecommunications.
- F. When a conduit is extended to an existing cable tray, it shall be secured (clamped) and properly bonded (grounded) to the tray system.
- G. All conduit ends shall be equipped with a plastic bushing.
- H. The DEN cable tray system, which is utilized for telecommunications, is subdivided into segments, where services are subdivided by service type and signal level. In those cases where telecommunications facilities include a cable tray segment between the outlet and the serving telecommunications room, the consultant shall be mindful of and coordinate the conduit termination requirements into the proper cable tray segment to ensure code, signal level, and service type compliance.
- I. Installation of a conduit to the cable tray system shall be made so as not to interfere with the future installation of cabling systems.
- J. All conduit installation shall comply with applicable requirements in this and other Manuals, as well as the National Electric Code (NEC) for the number of bends (in degrees) between pull boxes and distances between pull boxes.
- K. Telecommunications conduits may contain fiber optic cable; therefore, the specified bending radius of a telecommunications conduit shall be 2" ID minimum.
- L. Any deviation from these requirements is not acceptable without the written approval of the DEN telecommunication department.

2.2.1.2 Telecommunications Outlet - Wall-Mounted Telephones

- M. Outlet box size: Single-gang x 1-7/8 D with a single-gang device ring. This conduit shall be extended to the nearest telecommunications cable tray. Where a tray is not present, the addition of a tray or an extension of the conduit to the nearest Intermediate Distribution Frame (IDF) (Communications Room) may be required.
- N. Junction boxes in a conduit run shall be a minimum of 4" square.

2.2.1.3 System Color Coding

ECS conduits installed to serve systems specified in Section 275123, "Emergency Communications System," shall have "GREEN" bands, 5' on centers for the entire length of a conduit run, or be continuously painted green. All

junction or pull boxes shall have the cover painted green with the associated zone number written neatly on the box cover with a permanent marker.

EMCS conduits serving temperature control, metering data cabling, lighting control BACnet cabling, and other EMCS integration cabling systems shall have "BROWN" bands, 5' on centers for the entire length, or be continuously painted brown. All junction or pull boxes shall have the cover painted brown.

End of Chapter

This page is intentionally blank.

Chapter 3 - Telecommunication and Networking

2.3.0 System Overview

2.3.0.1 Scope

This chapter provides guidance to the Design Consultant in telecommunication and network systems design for specific DEN use.

2.3.0.2 Criteria

General criteria are set forth below, as well as drawing and design requirements. Options available to the Design Consultant are also indicated. In addition to the requirements set forth herein, all telecommunications designs shall meet the requirements of accepted industry standards, as well as the following reference standards:

- A. IEEE
 - a. C62.41: Recommended Practice on Surge Voltage in Low-Voltage AC Power Circuits
 - b. 802.3: Information Technology – Local and Metropolitan Area Networks
- B. Telecommunications Industry Association/Electronics Industry Association (TIA/EIA)
 - a. EIA-310-D: Cabinets, Racks, Panels, and Associated Equipment
 - b. TIA/EIA-568-B: Commercial Building Telecommunications Cabling Standard
- C. NFPA
 - a. 70: NEC
 - b. 70E: Standard for Electrical Safety in the Workplace

2.3.1 Networks and Services

2.3.1.1 Telecommunication Service

Basic telecommunications service is currently provided to the airport by the regulated provider CenturyLink. These services are delivered to the airport from multiple feeds. These services are extended over the airport Premise Wiring and Communications System (PWCS) to demarcations at airport locations and tenant leasehold spaces throughout the airport. These services range from basic 1FB business lines, frame relay, and data circuits to higher capacity DS-1 (T1) – DS-3 level services.

2.3.1.2 Local Area Networks

DEN operates three Local Area Networks (LANs).

2.3.1.2.1 Enterprise Network

This is the largest network, supporting services ranging from DEN-managed desktops, flight information displays, common-use departure control equipment, building automation systems, and in some cases, tenant networks. The enterprise network is a large, layer three network consisting of core switches, pairs of distribution switches in each major building, and access layer switches located in Intermediate Distribution Frame (IDF) rooms throughout DEN.

2.3.1.2.2 Emergency Communication System

The Emergency Communications System (ECS) is a standalone network that supports PA communications and audible emergency notification. It utilizes switches in a three-layer configuration (core, distribution, and access) that allows public address CobraNet audio to traverse locally in each network region while allowing client-server

and audio communications to traverse between buildings to reach the system servers. The ECS network utilizes Real-time Transport Protocol (RTP) to allow inter-building audio to traverse between buildings, including the Hotel and Transit Center (HTC), Main Terminal, Airport Office Building (AOB), and Concourses.

The ECS loudspeakers serve as the audible portion of the Fire and Emergency Notification System. These loudspeakers must be installed in all tenant spaces. Coordinate with DEN Life Safety to obtain information on the ECS system and proposal submittals for any new equipment.

2.3.1.3 Wireless Networking

DEN operates a wireless 802.11a/b/g/n LAN system throughout all public areas of the airport for public use. The existing network is integrated with the DEN enterprise network and consists of a distributed system of Wi-Fi controllers, access points, and antennas.

DEN does not require or prohibit tenant Wi-Fi networks. However, any proposed private Wi-Fi networks to be installed in tenant spaces are subject to the review and approval of DEN Business Technologies.

2.3.2 Design Criteria

2.3.2.1 Telecommunications Service

Telecommunications shall be provided in each facility to serve the specific communications needs of that facility. This would include the special communications needs of the building or system function as well as the needs of tenants and users of the facility and may include voice, data, and/or video communications services. Space allocations and design, mechanical and electrical services, and premises wiring system shall all meet the requirements of the telecommunications system installed. Raceways to accommodate the required premises wiring shall be installed as part of the construction of the facility and shall meet the requirements called out here-in or within other Design Standards Manuals or Division Specifications. The power requirements of the system and power requirements of all pay telephone credit card readers shall be coordinated with the telephone supplier.

The DEN-managed PABX system provides telephony services to DEN offices and facilities across the entire DEN campus. It can provide both analog and Voice over IP service to endpoints. In addition, some tenants are served telephony service from this system under the DEN Business Technologies Tenant Services program.

Power requirements for all communications rooms at DEN are addressed in the Electrical DSM, Chapter 2.

2.3.2.2 Local Area Networks

In new construction areas, Intermediate Distribution Frame (IDF) rooms are normally constructed in directly adjacent pairs. One room is dedicated for DEN communications equipment. The second room is dedicated for tenant equipment. Horizontal cabling shall be routed through the DEN room to the tenant IDF room to allow cabling to be pulled back and re-terminated in the DEN room if the tenant vacates the tenant room.

Designers are required to meet with the DEN Business Technologies PWCS group to define copper and fiber backbone cabling requirements for any new IDF facility. DEN will provide pair and strand count information as well as tie points in the existing PWCS system for any new cabling.

2.3.2.3 Public Wi-Fi Network

Designers shall coordinate the specific location and configuration of Wi-Fi access points and pods with the DEN Business Technologies Wi-Fi group during the design development phase of each project. Contact the DEN Project Manager to coordinate a meeting after a preliminary layout is selected.

All public areas shall be fully covered by the public Wi-Fi network. In addition, Wi-Fi is provided on the roof or side of buildings for the working side of aircraft. Back office spaces on all building levels shall also have Wi-Fi coverage.

Each access point requires two (2) CAT 6A-rated cables to be extended from the nearest DEN communications room when within a 90-meter distance. Single-mode fiber and 120VAC power shall be available at Access Point locations that are beyond a 90-meter distance from the nearest DEN communications room. External antennas may be utilized to keep the install clean aesthetically. Extensions to the existing airport public wireless LAN system shall be physically complete and fully functional. All new equipment shall fully integrate with the DEN Enterprise Network and the existing Wi-Fi controllers.

2.3.3 Design Requirements

2.3.3.1 Design Development Coordination

NOTE: All communications with DEN personnel shall be routed via the DEN Project Manager unless the Project Manager gives explicit permission to do otherwise.

During design development, consultants shall coordinate their designs with DEN Business Technologies.

Designers are required to produce a spreadsheet for each of the three networks that include the following information for each item of network-connected equipment:

- A. Item number
- B. System name
- C. Device type
- D. Device name, adhering to DEN Business Technologies naming standard
- E. Room number
- F. Outlet and jack number
- G. Serving IDF room
- H. Network (Enterprise, ECS, or SACN)
- I. Power over Ethernet required in Watts

After the information above is compiled, designers are required to meet with the DEN Business Technologies network staff. The DEN staff will compile a detailed bill of materials (BOM) for inclusion in the project specifications based on the equipment that is currently being procured. Designers shall include this bill of material in the network specifications for each of the three networks.

DEN Business Technologies will also complete the network spreadsheet for each of the three networks, including the following for each item of network-connected equipment:

- A. Circuit ID number
- B. Switch name, adhering to DEN Business Technologies naming standard
- C. Switch port assignment
- D. VLAN ID
- E. IP address
- F. Subnet mask
- G. Default gateway
- H. Port speed and duplex

I. Circuit cut sheet

With this information, the Designer may then produce a completed BOM for the project to be included in the design drawings.

2.3.3.2 Design Analysis Report

The Design Consultant shall include in the design analysis report a high-level description of the network design, including the following:

- A. A single-line diagram showing the proposed network topology, including points of connection to the existing networks.
- B. A listing of existing networks affected by the project, as well as an analysis of the effects and required support equipment.
- C. Bandwidth requirements for new equipment.

2.3.3.3 Design Drawings

The Design Consultant shall show all telecommunications system requirements in the contract documents. As a minimum, the drawing shall show the following:

- A. A single-line diagram to depict the network switching equipment, telephone instruments, network outlets, terminal cabinets, premises wiring, and other system components.
- B. Each system component shall be identified as to its type and location. Floor plan drawings shall include a unique numerical identifier adjacent to each outlet to associate drawings with PWCS equipment spreadsheets.
- C. A completed, project-specific BOM, as coordinated with DEN Business Technologies.
- D. Floor plan drawings shall show the location of each system component, outlet, instrument, and distribution wiring.

End of Chapter

Chapter 4 - DEN Television

2.4.0 System Overview

2.4.0.1 Scope

This chapter provides guidance to the Design Consultant in the area of television system design for DEN.

2.4.0.2 Criteria

General criteria are set forth, as well as drawing and design requirements. Options available to the Design Consultant are also indicated. All communications with DEN personnel such as DEN Business Technologies shall be routed via the DEN Project Manager unless the Project Manager gives explicit permission to do otherwise.

During design development, DEN Business Technologies will provide specific guidance to designers relevant to each project. Depending on the scope of the project, designers may only be required to provide simple drop cable. On larger projects, designers shall request a coordination meeting with the DEN Project Manager, DEN Business Technologies, and relevant stakeholders to determine project requirements. Depending on the scope, designers may be required to specify new optical nodes, RF splitters, and optical dividing networks located in DEN comm rooms to provide support for DEN and tenants television drops.

Optical nodes may be required to be shunted in the event of an Emergency Communication System (ECS) announcement. Designers shall coordinate this feature with the subject matter expert of the ECS system at the time of design.

In addition to the requirements set forth herein, all television systems shall meet the requirements of accepted industry standards, as well as the following reference standards:

- A. IEEE – C62.41: Recommended practice on Surge Voltage in Low-Voltage AC Power Circuits
- B. TIA/EIA – EIA-310-D: Cabinets, Racks, Panels, and Associated Equipment

NFPA – 70: NEC

2.4.1 Television Service

2.4.1.1 Tenant Drops

Subscription-based television service is available to all tenants. Tenant locations include, but are not limited to, the following:

- A. Bars and restaurants
- B. Retail establishments
- C. Any non-public tenant-leased locations
- D. Airline-leased spaces such as break rooms and offices

Drops to all tenants shall be equipped with 450MHz high-pass filters at the DEN IDF rooms to block the unencrypted lower-tier service. The standard receiver required to view Dish Network content is the VIP222k or the Wally. Coordinate exact equipment requirements with DEN Business Technologies. (Dish Network may change the receiver model at any time.)

Termination locations and details of tenant drops are dependent on the number of drops required and facilities available in the area. For multiple drops, such as in bars and restaurants, additional equipment required to support

the drops shall be included in the project. Coordinate the exact requirements for each project with the DEN Project Manager. Tenants are not allowed to insert splitters into the drops provided by the transport system. Drops are to be installed by a DEN PWCS-approved contractor.

Tenants may utilize mounts for their television receivers that accommodate a Dish VIP222k or Wally receiver behind each television receiver, or they may elect to centralize these receivers at a back-of-house location. In the latter case, HDMI video extenders will be required from the centralized receivers to the television receivers. The Dish VIP 222k receivers operate with either an infrared remote control or a UHF RF control, allowing remotes to be used with centralized receiver configurations.

2.4.2 Design Criteria

2.4.2.1 Cabling and Conduit

All horizontal television cabling shall be contained within an accepted raceway or cable tray.

2.4.2.2 Fiber

Fiber connectivity to new nodes will need to be coordinated with DEN Business Technologies.

2.4.3 Drawing Requirements

The Design Consultant shall show all entertainment television system requirements in the contract documents. As a minimum, the drawings shall show the following:

- A. A single-line diagram to depict the entertainment television system, including all optical and RF components with RF and optical level calculations. DEN Technologies will utilize this information to update the master DEN Television System diagrams.
- B. Each system component shall be identified with its type and location.
- C. Floor plan drawings to show the location of each system component, outlet, and the distribution raceways.

End of Chapter

Chapter 5 - Radio Frequency

5.0 General

Any tenant RF installation must comply with Chapter 11 of the Communication and Electronic Systems DSM.

End of Chapter

This page is intentionally blank.

Chapter 6 - Energy Management and Control

2.6.0 System Overview

2.6.0.1 Scope

This chapter provides guidance to the Design Consultant in the area of design of the Energy Management & Control System (EMCS) at DEN.

2.6.0.2 Criteria

General criteria are set forth below. Drawing and design requirements are contained in this chapter.

- A. Applicable City and County of Denver building codes
- B. NFPA 70: National Electrical Code
- C. TIA/EIA – TIA-485 / RS-485: Recommended Standard for drivers and receivers used in serial communications systems.

2.6.0.3 Definitions

Table 2.6-1: EMCS Definitions

Term/Abbreviation	Definition
BACNet	A data communication protocol for building automation and control networks, as defined and maintained by AHSRAE Standing Standard Project Committee 135.
BBMD	BACNet/IP Broadcast Management Device
DDC	Direct Digital Controls in a centralized network-oriented approach to control systems that are integrated into the EMCS including HVAC, Electrical Metering, Lighting, and others.
EMCS	Energy Management and Control System
GUI	Graphical User Interface
HMI	Human-Machine Interface
IP	Internet Protocol
MSTP	Master-Slave, Token-Passing

2.6.1 Networks and Services

2.6.1.1 Basic EMCS Network Architecture

The DEN EMCS is a comprehensive network of electrical and mechanical systems and system components that shall provide the ability to monitor, control, and alarm equipment connected to the EMCS and is scoped to be available in all buildings on the DEN campus. The EMCS is primarily used for HVAC and lighting control, data analysis, utility metering, and billing.

The standard communication at the DEN Enterprise Network level is BACnet/IP. The standard communication at the field bus level is BACnet MSTP at a baud rate of 38.4. All addresses, including IP addresses, MSTP Network numbers, BACnet instances, and MAC addresses, are managed and assigned by DEN, and assigned addressing must be strictly adhered to at all times.

The standard communication at the DEN Enterprise Network level is BACnet/IP. The standard communication at the field bus level is BACnet MSTP at a baud rate of 38.4. All addresses, including IP addresses, MSTP Network numbers, BACnet instances, and MAC addresses, are managed and assigned by DEN, and assigned addressing must be strictly adhered to at all times.

2.6.1.2 BACNet IP Networks

All DEN Enterprise Network-connected equipment is to be statically assigned from the DEN EMCS Administrator. BBMDs are installed and maintained by DEN- no device shall be installed and configured as a BBMD by any contractor, and care shall be taken to ensure devices that may have BBMD enabled by default are configured with this feature turned off.

2.6.1.3 BACNet MS/TP Networks

All MSTP networks shall follow BACnet architecture standards, and specific care must be taken to ensure common installation errors such as total length of MSTP runs, Starred networks, T-tapped networks, and incorrectly installed/ not installed End of Line (EOL) resistors are avoided. Network shop drawings shall indicate accurate architecture and include any and all EOL devices and resistors. Routers shall always be the first device of an MSTP BUS. MSTP networks shall be equipment group specific. DEN standard color and polarity shall be: Black Wire to BACnet MSTP (+) and White Wire to BACnet MSTP (-).

2.6.1.4 Physical Integration with DEN

Networks Tenants shall run controls conduit, for Tenant metering in compliance with the Tenant DSM section 3.2.1.5 to the nearest DEN Communications Room. Through the DEN Tenant Project Manager, coordinate with DEN Controls Administrator to controls are connected correctly to the physical components of DEN's controls systems. A sign reading "Tenant Controls and Metering Conduit. Do not demolish outside of tenant lease space." shall be attached at the penetration into the tenant space. If conduit as described above already exists in a Tenant's space, the Tenant is not responsible for installing a new conduit; however, the Tenant is responsible for pulling any necessary controls cabling/conductor through the conduit in compliance with the Tenant DSM Section 3.2.1.5 to the DEN Comms room. Tenants shall not demolish any controls conduit outside of the tenant lease space. Tenants may reuse any controls cabling/conductors, provided they are still functional. Tenants shall not run any controls conduit through the lease space of another tenant except with the express permission from DEN Mechanical or Electrical Engineer. Controls cabling/conductors shall not be run in cable trays, and shall not share conduit with any other cables, wires, conductors, etc.

2.6.2 Design Criteria

2.6.2.1 General Network Requirements

Design each network of the DDC system to include at least 30 percent available spare bandwidth with the DDC system operating under normal and heavy load conditions. Calculate bandwidth usage and apply a safety factor to ensure that this requirement is satisfied when subjected to testing under worst-case conditions. Do not use an existing network controller that is at 80 percent capacity or greater. If DDC equipment is added to a piece of controls equipment (e.g. a FEC, NAE, SNE, etc.) which is below 80 percent capacity, it must not exceed 70 percent capacity once the equipment is installed.

Projects that add points and sequences to DEN Network Automation Engines (NAEs) or System Network Engines (SNEs) must add a new DEN NAE or SNE should the extra controls load cause the NAE to reach 80 percent capacity in hardware points, software points, memory, and/or processing capacity. If a network engine is required, it is to be located in the closest DEN COMM room.

Additionally, any project or program that adds over 500 thousand (500,000) new building square feet to DEN shall require a new controls integration server to be installed. This server shall have at minimum, processing, memory, and network performance requirements capable of operating all mechanical, electrical, and plumbing controls and meters for the new space, as well as any white spaces, future tenant spaces, and/or office buildouts, plus extra hardware and software for an extra 25% performance (i.e., no newly installed controls integration server shall be loaded more than 80 percent in either hardware points, software points, memory, or processing capacity for a full build-out of said space).

Include spare processing memory for each new or replacement controller. RAM, PROM, or EEPROM will implement requirements indicated with the following spare memory:

- A. Network Controllers: Not less than 30 percent spare capacity.
- B. Programmable Application Controllers: Not less than 30 percent spare capacity.
- C. Application-Specific Controllers: Not less than 30 percent spare capacity.

D.HVAC Controls Networks are to remain independent of all other networks. Tenant BACNet devices such as electrical, water, and BTU meters are to be on an IE dedicated Engine. Extend a temperature controls color coded conduit and pull string to nearest DEN Comm room and cap. Label conduit at both ends with location served. A single conduit is allowed to go from the tenant space to the COMM room and carry all three sets of conductors.

2.6.2.2 Electrical Metering Networks

All Electrical meters shall have BACnet Native connectivity, either via BACnet/IP or BACnet/MSTP, and shall be determined by the specific installation. BACnet/MSTP meters shall be on a dedicated BACnet/MSTP trunk. All devices shall be Revenue Grade devices. All billable meters shall be integrated in both DEN GUI and DEN billing application. Refer to the Electrical DSM for electrical metering requirements. Integration points shall be as defined

[Table 2.6-2: Metering EMCS Integration Points](#)

Table 2.6-2: Metering EMCS Integration Points

Integration Point	Point Name	Units	Status	Command	Trend
Total Energy Consumed (3 phases combined)	Total Energy	kWh	Yes	No	Yes
Total demand (3 phases combined)	Current Demand (3 phases)	kW	Yes	No	Yes
Total demand (per phase)	A Phase Current Demand	kW	Yes	No	Yes
Voltage (per phase)	A Phase Voltage	V	Yes	No	Yes
Current (per phase)	A Phase Current	A	Yes	No	Yes
Peak demand (3 phases combined)	Peak Demand (3 phases)	kW	Yes	No	Yes

2.6.3 Design Requirements

2.6.3.1 Drawing Requirements

Designer shall include, at a minimum, the following elements in their design drawings:

- A. EMCS riser diagram, including existing and new components in the project area
- B. Floor plans indicating locations of all EMCS devices

NOTE: Device locations may be shown on individual discipline floor plans (e.g., HVAC control devices on HVAC plans, metering on electrical plans, etc.)

2.6.4 EMCS Graphics

2.6.4.1 General

An HMI is any interface allowing for an operator to monitor or control a machine. A GUI is a type of HMI that provides a digital, graphical user interface generated on a display screen.

All equipment integrated into the EMCS shall be provided with a GUI for monitoring and control. All graphics must be designed to prioritize ease of use for the intended end user. Graphic screens should be intuitive, easy to navigate, use consistent labeling and iconography, and shall be designed to minimize eye strain for operators.

2.6.4.2 Metasys UI Graphics

All graphics developed shall be developed for the current Metasys UI environment.

2.6.4.3 Integration with Existing Systems

All new graphics and modifications to the existing graphics must be carefully reviewed by DEN stakeholders, including any impacted operations and maintenance groups. The EMCS is implemented at DEN through multiple software platforms, and any new graphics must be incorporated into the appropriate software platform based on the location and type of equipment affected. New software platforms shall be prohibited unless specifically approved in writing by the DEN Project Manager and DEN Maintenance.

All entities working within the existing EMCS software environments shall possess adequate training for programming and modification of those systems. Contractor access to the EMCS must be formally requested and approved by DEN Maintenance prior to the start of work. Any programming errors, device conflicts, or other issues introduced by a contractor shall be expeditiously resolved by the contractor at the direction of the DEN Project Manager and DEN Maintenance.

2.6.4.4 Equipment Page Design

A dedicated equipment graphic page is required for all mechanical equipment and any other equipment with more than (1) associated control point.

2.6.4.4.1 Blocks and Templates

There are many existing graphics in the EMCS, including interactive symbols for pumps, fans, lights, piping, duct-work, etc. Existing graphics are also laid out with standardized page arrangements for ease of use. New graphics pages for equipment that is similar to existing equipment shall utilize symbology and page layouts to match the existing graphics. For equipment types with no existing equivalent, the contractor may propose a new layout and submit it to DEN for review and approval.

2.6.4.4.2 Equipment Values and Status

Analog readouts and equipment statuses should be clearly labeled, with appropriate units of measure indicated, and placed as close to the associated graphical item as possible. All analog values should include two decimal point precision.

End of Chapter

This page is intentionally blank.

Volume 3 - Electrical

Chapter 1 - General

3.1.0 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.

3.1.0.1 Definitions

The definitions shown in [Table 3.1-1: Definitions](#).

Table 3.1-1: Definitions

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

3.1.1 Design Parameters

3.1.1.1 Electrical Equipment Ratings

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

A.Low Voltage = 0 – 1000 volts phase-to-phase

3.1.1.2 Voltage Drop

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

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

3.1.1.3 Short Circuit Current

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

3.1.1.4 Utility Coordination

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

3.1.2 Design Document Requirements

3.1.2.1 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
- E. 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.

Provide conduit routing on drawings for main electrical services, power distribution, and power feeders to equipment with single conduits larger than 1" or where any sized conduit is grouped together in a bank or grouping. Refer to the Digital Facilities and Infrastructure DSM for detailed conduit modeling and depiction requirements. Conduit and circuiting for lighting and small power apparatus are shown schematically. Locations of conduit runs are provided by notations and legend symbols. All conduit runs are identified by the scheduled circuit number on the plans. Conduit runs through other leasable tenant spaces should be avoided where possible. Where unavoidable, proposed conduit routings shall be coordinated with DEN Tenant Concessions teams and SME's to ensure coordination with existing conditions and other projects.

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 showing all equipment utilizing DEN Standard Revit diagrams, available from DEN DFI team, in all construction drawing sets.

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

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

End of Chapter

Chapter 2 - Interior Electrical Power Distribution Systems

3.2.0 Interior Electrical Power Distribution Systems

3.2.0.1 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.

3.2.1 Materials and Equipment

3.2.1.1 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 system:
 - Grounded neutral: Bare

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

3.2.1.2 Raceways

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

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

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

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

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

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

Provide a pull rope in all conduits left empty.

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

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

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

2.2.2 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.

Branch circuit breakers should be of the bolt-on, thermal magnetic, molded case type, with a minimum trip rating of 15 amperes and a minimum interrupting rating of 10,000 amperes (and larger as required by the application).

The use of molded case circuit breakers in panelboards should be limited to no greater than the 1,200-ampere trip-rating size.

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. Disconnects (including fused, non-fused, or enclosed circuit breaker) shall be names based on the equipment served with a prefix “D-”.

Table 3.2-1: Panelboard Naming Conventions

Concourse Buildings and Tunnel System Example: B AW1TDEL1A	
B-	Concourse letter. Choices: A through C (South to North)
A	Floor level. Choices: T [tunnel] or B [basement] or A [apron] or C [concourse] or M [mezzanine] or 4 [fourth floor] or 5 [fifth floor] or R [roof].
W1	Core Area. Choices: CE [center core east side] or CW [center core west side] or E1 ... E3 [sub-core number east of center core] or W1 ... W3 [sub-core number west of center core]
T	Indicates CONCESSIONS TENANT panel if appropriate. Choices: T [TENANT] or blank [no space] if DEN
D	Indicates distribution panel if appropriate. Choices: D [DISTRIBUTION] or blank [no space] if NOT DISTRIBUTION
E	Indicates panel feeder function. Choices: E [EMERGENCY/ESSENTIAL POWER], U [UPS origin], EU [EMERGENCY/ESSENTIAL POWER AND UPS ORIGIN], or blank [no space] for normal power.
L	Indicates Panel voltage. Choices: H = 600 or 480Y/277 or L = 208Y/120 or 240/120
1	Sequence number of this panel supplied from this source. Choices: 1...N
A	Sub-fed panel suffix, if appropriate. Choices: A... as required.

Note: In naming transformers and disconnects, dash between concourse and floor level should be removed. Example for transformer feeding example panel T-BAW1TDEL1-A.

AOB, Terminal and Parking Structures Example: 6 11CTDEL2A	
6-	Floor level. Choices: T [tunnel] or 1 through 11 , depending on building.
11D	Module designation (See Architectural designation). Choices: 01 through 15 and A through D .
T	Indicates CONCESSIONS TENANT panel if appropriate. Choices: T [TENANT] or blank [no space] if DEN

AOB, Terminal and Parking Structures Example: 6 11CTDEL2A	
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], VC [VEHICLE CHARGING] 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.

Note: Example for transformer feeding example panel: T-6-11AL1.

3.2.2.1 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. A minimum of 5' clearance free of equipment in front and rear of switchgear shall be maintained for maintenance equipment.

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.

3.2.2.2 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 newly specified or installed electrical panels, and various loads in accordance with the facility design descriptions contained in this Manual.

For installations with a tenant provided 480V panel or a 208V panel directly from a low-voltage distribution board, the meter CT's should be located line side of the panel. Where a transformer is being provided from a 480V distribution board to feed the tenant space, meter CT's should be located on the line side of the tenant transformer.

For installations with a tenant provided 480V panel or a 208V panel directly from a low-voltage distribution board, the meter CT's should be located line side of the panel. Where a transformer is being provided from a 480V distribution board to feed the tenant space, meter CT's should be located on the line side of the tenant transformer.

Meters will be tracked as assets by asset management. Each should be provided with a unique name for tracking. Meters shall be named according to the panelboard being served, with a "M-" prefix added to indicate that it is a meter. Meters installed ahead of transformers or disconnects should be named only for the downstream panel.

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

A. Single-Load External Submeters

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

B. Branch Circuit Monitoring

All submetering equipment shall be integrated, via standards-based communication protocol (BACnet MS/TP or BACnet IP), to the DEN Energy Management Control System (EMCS). All submetering equipment must be capable of reporting, at a minimum, kWh usage information as well as peak kW demand. Metering equipment shall be equipped with a local display system on the unit capable of displaying peak demand kW and kWh usage for each metered load. The designer shall specify labeling requirements such that all external metering equipment clearly identifies the metered loads. Refer to Communications and Electronic Systems DSM Chapter 13 for more information and additional requirements for EMCS integration.

Minimum 1" conduit with pull string shall be routed from meter installation location to the nearest metering termination point, typically located in DEN Communication Rooms. Conduit to be labeled at both ends of room/tenant served by the raceway for future integration.

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 final connections all required hardware modifications, graphics, labeling, programming, and address assignments are performed as part of each project where new metering equipment is installed or where a new tenant takes over an existing space, as directed by the DEN Project Manager.

3.2.2.3 Receptacles

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

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

Refer to specifications for color coding requirements of receptacles.

3.2.2.4 Signage

Each tenant is to provide a sign fed from an individual branch circuit rated for at least 20 amps at the store entrance and shall be placed on the lighting control panel with a dedicated on/off switch. Typical programming for signage zone is 24 hour operation and manually switched by tenant.

Tenant Water Meters

Tenant BTU Meters

3.2.2.5 Floor Devices

DEN has specific requirements for floor devices providing power and/or data service that must be adhered to concerning the type of material used, shape, height above the floor, and different finishes for specific areas.

Specific box characteristics have been chosen based on employee and passenger safety and to maintain consistency throughout the airport. R

3.2.3 Installations

3.2.3.1 Design

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

Electrical panels should be located outside of the public view and in dedicated electrical rooms whenever possible.

Transformers do not need to be installed in fire rated rooms unless specifically required by code.

3.2.3.1.1 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:

C. Emergency Communication Systems

D. Emergency Fuel Shutoff System (EFSO)

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

3.2.3.2 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 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 sub-station terminals and 15 percent at motor terminals.

3.2.3.3 Branch Circuit Requirements

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

3.2.3.3.1 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.

All Variable Air Volume air terminal units (VAV) are to have a local disconnect mounted on the unit.

3.2.3.3.2 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.

3.2.3.3.3 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.

3.2.3.3.4 Powered Seating

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

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

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

3.2.3.3.5 Controlled Receptacles

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

3.2.3.4 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."

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).

3.2.3.5 Electrical Safety

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

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

3.2.3.6 Energy Conservation Measures

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

- A. Use higher distribution voltages, consistent with code and other safety requirements.
- B. Increase feeder and branch circuit conductor sizes to reduce energy losses in service lines to utilization equipment (where cost-effective).
- C. Reduce the length of branch circuit runs by locating power distribution centers as close as practical to the loads.
- D. Provide three-phase utilization equipment rather than single-phase equipment.
- E. Install electrical service entrance equipment as near as possible to the epicenter of the electrical load.
- F. Design for balanced loads in three-phase systems (and correct experienced unbalances during preoperational inspection and tests).
- G. Design for an overall facility load power factor of 95 percent (90 percent minimum). Provide capacitors on motors and other inductive loads that require power factor correction. Provide power factor controllers for motors with widely varying loads.
- H. Motor-driven equipment should be designed to start in an unloaded condition to reduce starting power requirements. Two-speed or variable-speed motors should be considered for HVAC applications to reduce energy consumption during non-peak or off-duty hours.
- I. Provide the highest practical standard voltage motors (e.g., 460-volt instead of 230 or 200-volt).
- J. Provide high-efficiency electric motors and power and distribution transformers.

- K. The Design Consultant shall perform a life cycle cost analysis on all proposed energy-conserving measures. The Design Consultant shall review the cost analysis and the payback period with the Project Management Team for possible inclusion of the energy-conserving measure into the project.
- L. Design ventilation and cooling systems for the required maximum ambient temperature of sensitive electronic and electrical equipment.
- M. All appliances shall be EnergyStar rated.

3.2.3.7 Tenants and Concessions

Existing normal electrical power for systems and equipment is provided at 480Y/277 volts and 208Y/120 volts. Tenants should feed their space from a distribution switchboard that is located on the same level. Public area HVAC equipment, lighting systems, elevators, escalators, and general convenience power shall be from DEN's metered service. Separate, individually metered tenant electric service shall be provided at 480Y/277 volts or 208Y/120 volts for all tenant spaces requiring more than (2) 120 volt, 20A circuits. For 208Y/120 volt installations originating from a 480Y/277 volt distribution panel, tenants should provide a disconnecting means on the primary side of the transformer located in their space for servicing tenant equipment. Tenant meter should be provided on the primary side of the transformer. Tenant vending machines will not be required to be metered. Power requirements are to be coordinated with DEN PM at the design stage.

The tenant's electrical distribution equipment should be installed within the tenant space and cannot be located in any other DEN area or DEN electrical room. The tenant's electrical distribution equipment must be located out of the site of public view and located in such a way that NEC clearance can always be maintained. Tenant panelboards cannot be located behind doors or in any area that would pose a danger to anyone working on the equipment. Transformers 45kVA and below may be installed above an accessible drop ceiling where space allows, and shall be provided with smoke detection.

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

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

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

Tenants shall provide 120V and 20A receptacles throughout the space for general maintenance. Tenants are to provide a minimum of (1) 20A outlet per hallway. Tenants are to provide a minimum of (1) 20A outlet per enclosed space. Tenants are to provide (1) 20A outlet next to each electrical panel installed. All circuits should be provided from panels located on the same level unless approved by DEN Electrical SME's.

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

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

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

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

3.2.3.7.1 Basic Tenants

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

3.2.3.7.2 Concession Tenants

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

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

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

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

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

End of Chapter

Chapter 3 - Grounding Systems

3.3.0 Grounding Systems

3.3.0.1 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.

3.3.0.2 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. Underwriters' Laboratories, Inc. (UL)
 - a. 467 – Electrical Grounding and Bonding Equipment
- E. Institute of Electrical and Electronic Engineers (IEEE)
 - a. 142 – Recommended Practice for Grounding Industrial and Commercial Power Systems

3.3.0.3 Design Approach

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.

3.3.0.4 Design Task Categories

Design tasks require four basic attentions:

- F.Ensuring continuity of the equipment grounding system throughout the facility.

3.3.0.5 Design Analysis Requirements

- A. Uniform presentation of grounding methods and materials.
- B.Selection of equipment grounding conductors for each segment of the system based on the requirements of the NEC.
- C.Provision for adequately grounding equipment requiring flexible conduit or cord connections.

3.3.1 Materials

3.3.1.1 General

Grounding materials shall be selected from the following types:

3.3.1.1.1 Grounding Conductors

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

3.3.2 Installations

3.3.2.1 General

- A. Grounding systems installation requirements shall be described and delineated in detail.
- B. 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.
- C. Provide for grounding of metallic raceway systems, where utilized as the grounding conductor of the system.
- D. 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.
- E. The Design Consultant shall evaluate the length of all other feeder and branch circuit conduits, the conduit impedance, and the short-circuit protection to determine if an equipment ground conductor is required for safe operation during a ground fault.

3.3.2.2 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.

3.3.2.3 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 shall be of flat tinned copper in one piece.
- E. Connection and splices shall be of the pressure-connector type.

3.3.2.4 Other Grounding System Requirements

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

3.3.2.4.1 Computer and Telephone Equipment

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

End of Chapter

Chapter 4 - Lighting Systems

3.4.0 Lighting Systems

3.4.0.1 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.

3.4.0.2 Criteria

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

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

3.4.0.3 Design Approach

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

3.4.0.4 Design Task Categories

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

3.4.0.4.1 Interior

Environmentally controlled spaces within buildings.

3.4.0.5 Design Standards Nomenclature

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

3.4.0.5.1 General Area Lighting

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

3.4.0.5.2 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.

3.4.0.5.3 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.

3.4.0.5.4 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.

3.4.0.5.5 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.)

3.4.0.5.6 Low-Bay Area

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

3.4.0.5.7 High-Bay Area

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

3.4.0.5.8 Photometrics

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

3.4.0.5.9 Light Source Acronyms

Table 3.4-1: 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

Table 3.4-1: Light Source Acronyms (Continued)

Light Source	Abbreviation
Light Emitting Diode	LED
Metal Halide A type of HID source	MH

3.4.0.6 Design Analysis Requirements

Design illuminance levels shall generally conform to the recommendations of the IES. However, the contribution of all light sources present in a particular area of design shall be appreciated. Refer to [4.1.1 Main Terminal Complex](#).

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

3.4.1 Equipment

3.4.1.1 General Requirements

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

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

3.4.1.2 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 [4.1 Facility Design Guidelines](#) for color temperature requirements. Where no requirement is listed for the specific application, comply with the color temperature requirements listed as follows.

- A. Artwork: May vary from different color temperatures to color-changing LED as designed by the artist.
- B. Warehouse repair, maintenance, baggage areas and tunnels: 4000K

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

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

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

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

3.4.1.3 Lighting Control Requirements

3.4.1.3.1 Controller Locations

Do not provide manual lighting controls in public spaces. All lighting controls for public circulation spaces shall be readily accessible without the use of lifts, and shall be located in access controlled spaces, typically DEN electrical rooms.

3.4.1.3.2 Tenant Lighting Controls

Lighting control systems within tenant spaces shall not be connected to DEN central lighting control systems except where required by the DEN Electrical Engineer. All tenant systems shall comply with current building code regarding lighting controls, including required automatic light-level reduction, zoning, daylight controls, etc.

3.4.2 Installations

3.4.2.1 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:

3.4.2.2 Emergency Lighting

Emergency lighting systems shall be provided in accordance with NFPA 101, Life Safety Code. Emergency lighting should be provided throughout all areas of the airport, especially in sections where occupants are not familiar with the area they are in. In addition, limited emergency lighting shall be provided for outdoor walkways and parking structures. All emergency lighting systems shall be connected to the emergency power distribution system, where available.

Emergency lighting shall be switched with area lighting and configured to automatically activate upon loss of power.,

3.4.2.3 Efficiency Considerations

- A. Provide more energy-efficient light sources (e.g., LED) for lamp selections.

3.4.2.4 Tenants and Concessions

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

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

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

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

Refer to [3.2.3.7 Tenants and Concessions](#) for lighting electrical power consumption charts.

End of Chapter

This page is intentionally blank.

Volume 4 - Life Safety

Chapter 1 - General

4.1.0 Overview

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

If there is a conflict between this document and the Adopted Codes, Codes shall always take precedence. However, there are situations where this document may contain a more stringent requirement, exceeding the code. In this case, the more stringent requirement shall apply.

4.1.1 General

All occupied buildings on DEN property shall be sprinklered.

All Life Safety System circuits shall be installed in conduit. The color of the conduit is determined by the specific system of which it is a part.

4.1.2 Common Terms

The following terms are used throughout this DSM:

Table 4.1-1: Common Terms

Term	Abbr	Definition
City		City of Denver
City and County of Denver	CCD	City and County of Denver
Concourse	CCx	Refers to the buildings where all passenger boarding and deplaning activities take place. DEN has three concourses: A, B, and C.
Fixed Walkway, Passenger Loading Bridges	PLB	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.
Hotel and Transit Center	HTC	The HTC is located at the south end of the Jeppesen Terminal. The HTC consists of the following three areas: - The Westin hotel and conference center. - The outdoor plaza connecting the hotel to the Jeppesen Terminal on Level 5. The RTD train platform and public transit center.

Table 4.1-1: Common Terms (Continued)

Term	Abbr	Definition
Jet Bridge, Jetway, or Passenger Loading Bridge	PLB	An enclosed, movable connector that extends from an airport concourse gate or fixed walkway to an aircraft allowing passengers.
Modules	Mods	Both the Jeppesen Terminal and the Concourse Buildings are segmented into building modules for the purposes of systems organization.
Node		A fire alarm panel, graphic workstation, ECS rack equipment or RES rack equipment or other device on the Life Safety networks that is responsible for network communication.
Tenant		A retail establishment, airline, or other entity which has a space lease agreement with DEN.
Concession Tenant		A retail establishment, not an airline, which has space agreement with DEN.
Terminal Complex	TML	The Terminal Complex is the main complex of buildings at DEN. The Terminal Complex includes, including: • The Jeppesen Terminal, north terminal, and parking garages. (Great Hall) • The Airport Office Building (AOB) • The Central Utility Plant (CUP) • Concourses A, B, and C • Automated Guideway Transit System (AGTS) and baggage tunnels • HTC • PLB

4.1.3 System Definitions

This section describes the different life safety systems detailed in this DSM.

4.1.3.1 Fire Protection Systems

Fire protection (FP) systems are sprinkler systems installed within facilities to mitigate the extent of fire damage and to maximize occupant survivability during emergency events. Many DEN facilities and specialty areas are provided with various types of fire protection systems.

4.1.3.2 Fire Alarm and Detection System

Fire alarm and detection (FA) systems are utilized to provide automatic smoke and fire detection, as well as mass visual notification during emergency events. The Terminal Complex utilizes a networked Fire Alarm System with central controls and operates in conjunction with the other systems as needed. DEN facilities that are outside the Terminal Complex are typically furnished with independent Fire Alarm and Detection Systems.

4.1.3.3 Emergency Communication System

The emergency communication system (ECS) is installed throughout the Terminal Complex and is comprised of a network of audio loudspeakers, as well as visual and textual notification systems. The ECS, together with the Fire Alarm and Detection System, provides audible and visual mass notification during emergency events.

4.1.3.4 Smoke Control System

Smoke control (SC) systems are installed within the Terminal Complex to remove smoke from occupied areas, to enable occupants to exit to a safe area, and minimize smoke-related hazards during emergency events.

4.1.3.5 Emergency Alarm System

Emergency alarm systems (EAS) are utilized to provide indications and warnings of emergency situations involving hazardous materials. DEN uses these systems for beverage dispensing, inert gas applications, and in certain compressed gas storage applications.

4.1.4 System Design

Life safety systems are an integral part of DEN operations. When modifying existing spaces or constructing new spaces, the designer shall consider the impact of all aspects of the design on life safety systems. The designer shall consider indirect impacts to the systems listed in [4.1.3. System Definitions](#), including, but not limited to, the following:

- A. Changes in occupancy type.
- B. Reconfiguration of walls and/or spaces.
- C. Installation of bulky or noisy equipment that may affect visual or audible notification
- D. Multimedia installations in public areas, such as dynamic advertising displays.

4.1.5 Design

For ease of understanding and submittal, drawings have been split into three categories, A/E Construction, Shop, and Interim. All portions of Life Safety Systems contained within this manual shall be fully designed, detailed, and specified in the Contract Documents. Below is the breakout of those drawings to comply with Code requirements.'

4.1.5.1 A/E Construction Drawings

These drawings are submitted to the City Building Department and receive a *LOG* number and, upon approval, obtain a *CommCon* number for approved construction. These drawings shall have a Life Safety design level to include all devices that either initiate an emergency situation or notify the public of an emergency situation. The design shall be code compliant to the appropriate codes adopted by the City at the time the drawings are completed.

In accordance with current adopted code.

4.1.5.2 Shop Drawings (Installer)

These drawings are submitted to the City as a deferred submittal, per Denver Building Code Amendments, to obtain the appropriate Fire permit for construction. These drawings shall take the design of the A/E team and apply the appropriate technical information to provide an appropriate and complete installation of the submitted system. Drawings shall contain all information needed to comply with Denver Fire Department (DFD) requirements as listed in Appendix N.

In accordance with current adopted code.

4.1.5.3 Interim Drawings

These drawings are done by the contractors as part of their means and methods to final construction. This drawing details a level of protection during the demolition and construction of the work area while progressing to the final

product. Since the Airport is an open-for-business facility, a minimum level of protection is required for all areas and systems affected by construction.

4.1.5.4 More Stringent Document Requirements

If there is a conflict among the requirements of this document, the International Building Code (IBC), International Fire Code (IFC), National Fire Protection Association Standards (NFPA), and Denver Building Code Amendments (DBCA) documents referenced above, the Design Consultant shall comply with the more stringent requirements.

4.1.5.5 Reviews

All levels of drawings shall be reviewed by the DEN Life Safety Engineer prior to issuance as a “Construction Drawing” or submitted to the Permit Counter.

4.1.5.6 Drawing Format

All design submittals shall be developed in BIM. Comply with all applicable requirements in the Standards and Criteria and Digital Facilities and Infrastructure (DFI) DSMs.

4.1.5.7 Zone Designation / Nomenclature

All Fire and Smoke Zones shall have a unique equipment designation. As of 2020, DEN modified the original scheme for tagging all Life Safety Zones.

These new naming conventions standardize the naming and numbering of all DEN Life Safety Zones. All DEN Life Safety Zones shall contain a numbering system according to the criteria outlined below. Any deviation from the naming convention must receive written approval from the DEN Life Safety Engineer before implementation. The naming convention outlined below should be fully coordinated with the requirements of tagging in the BIM model. Refer to the DFI DSM. It is expected that the design team presents the proposed names according to this section.

The components used to identify equipment depend on the location and requirements of the project. The DEN naming system consists of five standard components and one optional component, as shown in [Table 4.1-2: Fire and Smoke Zone Designation Level](#).

Table 4.1-2: Fire and Smoke Zone Designation Level

Building	–	Level	–	Core Area	–	Zone Type	–	Zone Name
LLL	–	NN	–	NL	–	LLL	–	NN

L = Alphabetical Character

N = Numerical Character

4.1.5.7.1 Building Abbreviation

The three-character abbreviation for each building shall be used to designate the location of equipment. This abbreviation is assigned by DEN, for example, TML = Terminal, AOB = Airport Office Building, CCx = Concourse x, where x is the alpha designation of the concourse, e.g., A, B, C, etc.

CCB	–	03	–	6E	–	SZ	–	42

4.1.5.7.2 Building Level

The building level is a two-digit indicator used to further refine the location of equipment. This abbreviation is assigned by DEN; for example, 00 is the Basement Level, 02 is the Concourse Level, etc.

CCB	–	03	–	6E	–	SZ	–	42

4.1.5.7.3 Building Section

The building module is a two-digit designator that combines the building module and direction. It shall be used to further refine the location of equipment. This abbreviation is assigned by DEN; for example: 3W is module 3 West.

CCB	–	03	–	6E	–	SZ	–	42

4.1.5.7.4 Zone Type Abbreviation

The two-character abbreviation for each piece of equipment shall be used to designate the type of Zone. Zone abbreviations are. When DEN-designated abbreviations do not fulfill the two or three characters, e.g., SZ = Smoke Zone, FZ = Sprinkler Zone, FZX = Dry Sprinkler Zone, the designator shall omit any additional characters.

CCB	–	03	–	6E	–	SZ	–	42

4.1.5.7.5 Zone Name

This single or multi-character designation identifies the specific device or area within each zone. This takes into account subzones that may exist within a larger zone. Gates shall be designated with Gxx as the gate number.

CCB	–	03	–	6E	–	SZ	–	42

4.1.6 Referenced Codes and Standards

The versions of Codes and Standards are what is adopted by CCD at the time the project submits their drawings for permit.

4.1.6.1 Denver Building Code Amendments

- A. International Building Code
- B. International Mechanical Code
- C. International Fire Code
- D. International Electrical Code
- E. National Fire Protection Association Standards
 - a. NFPA 3 – Standard for Commissioning of Fire Protection and Life Safety Systems
 - b. NFPA 4 – Standard for Integrated Fire Protection and Life Safety System Testing
 - c. NFPA 10 – Standard for Portable Fire Extinguishers
 - d. NFPA 11 – Standard for Low-, Medium-, and High-Expansion Foam
 - e. NFPA 12 – Standard on Carbon Dioxide Extinguishing Systems
 - f. NFPA 13 – Standard for the Installation of Sprinkler Systems
 - g. NFPA 14 – Standard for the installation of Standpipe and Hose Systems
 - h. NFPA 17 – Standard for Dry Chemical Extinguishing Systems
 - i. NFPA 17A – Standard for Wet Chemical Extinguishing Systems
 - j. NFPA 20 – Standard for the Installation of Stationary Pumps for Fire Protection

- k. NFPA 25 – Standard for the Inspection, Testing and Maintenance of Water-Based Fire Protection Systems
- l. NFPA 30 – Flammable and Combustible Liquids
- m. NFPA 30A – Motor Fuel Dispensing Facilities and Repair Garages
- n. NFPA 70 – National Electrical Code
- o. NFPA 72 – National Fire Alarm and Signaling Code
- p. NFPA 90A – Standard for the Installation of Air-Conditioning and Ventilating Systems
- q. NFPA 90B – Standard for the Installation of Warm Air Heating and Air-Conditioning Systems
- r. NFPA 92 – Standard for Smoke Control Systems
- s. NFPA 92A – Standard for Smoke Control Systems Utilizing Barriers and Pressure Differences
- t. NFPA 92B – Standard for Smoke Control Systems in Malls, Atria and Large Spaces
- u. NFPA 96 – Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations
- v. NFPA 101 – Life Safety Code
- w. NFPA 110 – Standard for Emergency and Standby Power Systems
- x. NFPA 111 – Standard on Stored Electrical Energy Emergency & Standby Power Systems
- y. NFPA 130 – Standard for Fixed Guideway Transit and Passenger Rail Systems
- z. NFPA 409 – NFPA 409 – Standard on Aircraft Hangars
- aa. NFPA 415 – Standard on Airport Terminal Buildings, Fueling Ramp Drainage and Loading Walkways
- ab. NFPA 2001 – Standard on Clean Agent Fire Extinguishing Systems

End of Chapter

Chapter 2 - Fire Protection System

4.2.0 General

Fire protection systems shall be provided in accordance with the currently adopted editions of the standards and codes listed in the DSMs and in the IFC as adopted and amended by CCD. IBC Amendments, Appendix S contains additional requirements. It shall represent all the requirements of the agency Insurance Underwriters. The following description of fire protection requirements is based on NFPA codes.

4.2.1 Scope

This chapter provides design guidance to the Engineer in the area of Fire Protection Systems, which is utilized for all systems that extinguish a fire by activating a sprinkler or detector, or a combination of both.

4.2.2 System Description

These systems provide immediate suppression to a detected fire. The suppressant may include more than one medium. The typical medium used is water and may be activated by several different methods.

4.2.3 Criteria

Fire Protection Systems shall meet CCD requirements. Fire Protection Systems shall be provided in accordance with the latest adopted editions of the codes and standards listed in the DSM. Note that in the Denver Amendments to IBC, Appendix S has specific requirements for airports, which are in addition to all other referenced standards.

These systems shall have a means and method of detecting a fire product and, upon a specific setting of the detection devices or series of devices, resulting in a fire retardant applied in the area. These systems shall operate automatically and independently of any other detection or suppressant system in the area.

4.2.4 Tenant Spaces

Tenant spaces of 5,000 square feet in gross area or more are required to be served by an independent sprinkler zone. The tenant sprinkler zone shall be a single zone, originating back to the supply pipe, and shall not be part of another zone for annunciation.

4.2.5 Drawing Requirements

Refer to [4.1.5.1.A/E Construction Drawings](#) to [4.1.5.6.Drawing Format](#)

4.2.5.1 A/E 30% Drawings

The A/E 30% drawing should contain the design density of the areas identified by room or area, as well as the required Architectural drawings.

4.2.5.2 A/E 60% Drawings

The A/E 60% drawings should contain the information in [4.2.5.1.A/E 30% Drawings](#) and the following information:

- A. The identification of the Fire Zone.
- B. The new layout area or the new zone that is created for the remodeled area.
- C. The locations of sprinklers for the NFPA 13 required layout.

D. Cross sectional views at tenant openings detailing the configuration of the smoke curtain, closely spaced sprinklers, etc, especially when considering bulkheads greater than 2 feet in width or stepped ceiling configurations.

4.2.5.3 A/E 90% Drawings

The A/E 90% drawings should contain the information in [4.2.5.1.A/E 30% Drawings](#), [4.2.5.2.A/E 60% Drawings](#) and the following information:

- A. The identification of sprinklers in the locations they are presented with details to the type, pendant, upright, or sidewall.
- B. A note from the EoR that they are confident that the calculations for the area are adequate for supply.

4.2.5.4 Design Documents

Design documents shall be produced using BIM, as set forth in the DFI DSM instructions. All Design Documents shall contain the following at a minimum:

- A. Plans showing an as-built fire-sprinkler layout of existing/new space.
- B. Plans the location of existing and new sprinkler zone control valves.
- C. Building fire protection riser diagram identifying riser for modification to sprinkler zones of project impact.
- D. Building a fire zone diagram identifying the area of work and fire sprinkler zone impacts, including an accurate depiction of sprinkler zone boundaries.
- E. DEN Specifications shall be edited as required for the specific scope of work.
- F. DEN Master Diagrams are available upon request from the DEN Life Safety Engineer. Master diagrams shall be updated and returned to the DEN Electrical Life Safety Engineer at IFC and Record Document phases.

4.2.5.5 Interim System Documents

Sprinklers in the area of construction shall remain operational per 2019 NFPA 13 Chapters 9 and 10. If there is a ceiling, when the ceiling is demolished the, sprinklers in the area are to be turned up to comply with NFPA 13 and flex drops shall be removed back to the branch line or main. The Denver fire suppression permit can be obtained via a Scope of Work letter signed by a NICET III or higher detailing the existing condition and the interim condition. Drawings shall be provided that indicate the area where sprinklers will be turned up. The intent is to have the demolition and interim conditions as a single submittal which is a Fire walkthrough E-permit.

4.2.5.6 Sequence of Operation

For public area sprinkler zones, activation of these zones shall activate the Smoke Control system for the same zone.

4.2.6 Design Analysis Requirements

4.2.6.1 Building Description

Building Descriptions are taken from the A/E drawings to indicate the building this system is being designed for.

- A. Building Name
- B. Construction Type
- C. Occupancy Types
 - If storage, the product expected to be stored in the area.

- D. Area Name (or Tenant)
- E. Level of Hydraulic Design density

4.2.6.2 Applicable Codes

The list of Codes or documents that this system is required to follow for the shop drawings.

4.2.6.3 Design Responsibility

The Engineer of Record for the Shop Drawings shall retain design responsibility. Shop drawings must be signed and sealed by a professional engineer licensed in the state of Colorado, as required by DBCA. National Institute for Certification in Engineering Technologies (NICET) signature is allowed only as applicable per DFD Policy.

4.2.6.4 Sprinkler Design Densities

Spaces at DEN shall adhere to specific sprinkler design densities as indicated in [Table 4.2-1: Sprinkler Design Density Table](#). Remote area adjustments may be acceptable for Quick Response (QR) sprinklers.

Table 4.2-1: Sprinkler Design Density Table

Space	Design Density	Specific Density (GPM/Sq Ft)
Concourse		
Basement	OH2	0.20 / 1,500
Apron	OH2	0.20 / 1,500
Offices	LH	0.10 / 1,500
Retail Services	OH2	0.20 / 2,000
Restaurant Sitting	OH2	0.20 / 1,500
Restaurant Food Prep	OH2	0.20 / 1,500
Terminal		
Lobby / Retail / Service	OH2	0.20 / 2,000
Offices	LH	0.10 / 1,500
Restaurant Sitting	OH2	0.20 / 1,500
Restaurant Food Prep	OH2	0.20 / 1,500

**Including 30% area increase for dry system.*

4.2.6.5 Piping / Valves

Sprinkler piping shall follow:

- A. 2-inch and smaller piping shall be scheduled 40 and threaded.
Note: Ductile Iron Threaded Fittings Shall Not Be Provided
- B. 2.5 inch and larger piping can be scheduled 10 piping. Dry-pipe system piping 2.5" or larger shall be schedule 40 with grooved fittings and cut groove joints. Joints shall not be roll grooved.

- C. Dry-pipe system piping installed on the exterior of the building or in basement areas shall be schedule 40 black steel piping with corrosion-resistant paint.
- D. Dry-pipe valve assembly shall be installed with a dual tamper configuration. One control valve with tamper switch on the incoming wet side of the valve and one installed immediately after the valve on the dry side. Both control valves with tamper switches are to be monitored as a single point on the Fire Alarm System.
- E. Installation locations of proposed sprinkler valves to be coordinated with DEN Life Safety department prior to submittal of documents.
- F. Main Drain, Inspector's Test, and other valve locations, where water is to be discharged, shall have piping installed to route water to the nearest floor drain or sump pump location.
- G. Plumbing or piping chases that are accessible shall be provided with fire sprinkler protection.

4.2.6.6 Pump Water Flow Meter

The flow for the fire pump assembly shall be mounted prior to the input of the jockey pump to avoid any mistaken flow alarms. The jockey pump has the ability to supply enough water to move the meter and cause an inadvertent alarm condition.

4.2.7 Associated Systems

4.2.7.1 Sprinkler System

This system is considered a wet system since the pipes are constantly filled with water, and the system is Hydraulically Calculated.

4.2.7.2 Dry System

This system is similar to the wet system above, except that the pipes are filled with nitrogen until an action charges the system with water. This, too, is hydraulically calculated.

All dry systems shall utilize a nitrogen generation system.

If 50% or more of a dry zone is modified (measured by system volume OR coverage area), the system shall be converted to a nitrogen system. When installing a nitrogen generator, select the total capacity to cover the dry capacity of the existing dry valves in the room where the generator will be installed.

Note: A warning sign stating "Nitrogen present in this space. Ventilate thoroughly before entering" must be posted on the entrance door to any space where a nitrogen generator is installed.

4.2.7.3 Kitchen Hood Systems

Kitchen hood suppression systems shall comply with applicable sections of NFPA 17, 17A, and 96, and UL 300.

4.2.7.4 Coordinated with Smoke Control Zones

Where fire sprinklers are installed in an existing or new smoke control zone, the zoning of the fire sprinkler system shall match the smoke control zones. There may be multiple sprinkler zones in a single smoke control zone. In no case shall a fire sprinkler zone cross more than one smoke control zone.

4.2.8 Specific Building Requirements

4.2.8.1 Airport Terminal and Concourse Buildings

A. All areas of the Terminal Complex shall be sprinkled in accordance with applicable codes and standards.

B.Exterior glass partitions surrounding foyer areas shall be protected with closed-head sprinklers on 6-foot centers to provide a water curtain.

C.For tenant equipment and ductwork that may be in the tunnel and/or basement areas, designer is to include 7'-8" clearance for Fire Department access in tunnels and basements. Designer is to include allowances for fire sprinklers that will be located under mechanical duct and equipment. See the Architectural DSM for more information.

End of Chapter

This page is intentionally blank.

Chapter 3 - Fire Alarm and Detection System

4.3.0 General

Per International Codes, our buildings require a minimum amount of smoke detection. Along with these codes, the Denver Building Code Amendments, specifically Appendix S, details the level of detection required and how that detection is placed within the restrictions of NFPA 72.

4.3.1 Scope

This chapter provides guidance to the Design Consultant in the area of Fire Detection and Alarm System design for DEN. General criteria are set forth, as well as drawing and design analysis requirements.

4.3.2 System Description

The Fire Alarm System installed in the DEN Terminal Complex is a Networked Fire Alarm System as supported by Johnson Controls. The system consists of a 50-Node Network connected via a Class A fiber optic backbone. Most nodes are 4100ES fire alarm control units with an integrated and supervised system of initiating and control devices and notification appliances. There are twelve (12) network head-end annunciation units, known as TSW, located throughout the facility in Fire Command Centers and DEN Operation Centers.

The Johnson Controls Fire Alarm System was progressively installed from 2010 through 2017. The system was integrated with the airport's IED paging/PA system in 2014-15 to form an integrated ECS.

4.3.3 Criteria

Fire Detection and Alarm Systems are required to meet CCD requirements. Fire Detection and Alarm Systems shall be provided in accordance with the latest editions of the standards and codes listed in this DSM, as well as the IBC and IFC as currently adopted and amended by the CCD. Note that in the current edition of the Denver Amendments to IBC, Appendix S has specific requirements for airports, which are in addition to all other referenced standards.

4.3.4 Drawing Requirements

Refer to [4.1.5.1.A/E Construction Drawings](#) to [4.1.5.6.Drawing Format](#).

4.3.4.1 A/E 30% Drawings

The A/E 30% drawing should determine if any detection will be required, as well as the required Architectural drawings

4.3.4.2 A/E 60% Drawings

The A/E 60% drawings should contain the information in [4.3.4.1.A/E 30% Drawings](#) and the following information:

- A. Initial placements of the detection.
- B. Fire alarm notification.
- C. Emergency communication devices.
- D. If there are any other life safety systems, they need to be identified, as well as their future locations.
- E. The preliminary sequence of operations.
- F. Identification of the Fire/Smoke Zone the equipment is part of.

4.3.4.3 A/E 90% Drawings

The A/E 90% drawings should contain the information in [4.3.4.1.A/E 30% Drawings](#), [4.3.4.2.A/E 60% Drawings](#), and the following information:

- A. Final locations of all detection, fire alarm notification, and emergency communication devices. Fire Alarm Terminal Cabinets in concession tenant spaces.
Terminal Cabinets for both FA and ECS may be unnecessary if deemed appropriate by DEN Life Safety.
- B. Final tap settings of strobes.
- C. If there are any other life safety systems, they shall indicate any monitoring or controlling of those devices.
- D. The Sequence of Operation is the responsibility of the Engineer of Record.

4.3.4.4 Fire Alarm System Interim Drawings

Documentation shall be provided for the Interim fire alarm plan during construction, including temporary visual notification coverage and the removal of any fire alarm components. Documentation shall also identify any existing Fire Alarm devices in the area of construction which shall remain operational. The minimum documentation required on shop drawings will be based on the scope of work scenarios below. The intent is to have the demolition and interim condition as a single submittal that is a Fire walk-through E-permit.

- A. Scenario 1 - Existing fire alarm notification appliances will remain for temporary coverage during construction.
 - 1. Existing fire alarm devices to remain.
 - 2. Existing fire alarm appliances (strobes) to be used as temporary visual coverage of the area of work during construction.
 - 3. Temporary strobes may be located on the wall or the ceiling to accommodate construction activities and to maximize visual coverage.
 - 4. Prescriptive Code visual coverage is not required for temporary strobes.
 - 5. Notations shall be provided stating whether the temporary strobes will be removed and/or replaced upon successful pretest of the final alarm system scope, or if they will be re-installed in their original locations.
 - 6. Fire alarm conduit in the area of work may be removed or relocated and the existing fire alarm circuit wire may be “free run” to the temporary strobes.
 - 7. Notations shall be provided stating that all existing fire alarm circuits passing through the construction area will be protected and the circuit integrity maintained.
 - 8. For Retail/Concession Tenants, a Fire Alarm Terminal Cabinet (FATC) shall be provided outside of the tenant space to provide a single point of tie-in for fire alarm circuits serving the tenant.
 - 9. The tentative location of the FATC shall be shown on the floor plan and noted that it is to be mounted no higher than 9’ a.f.f. in a location to be field verified by DEN Life Safety prior to installation.
 - 10. All Temporary, existing, and new Fire alarm circuits serving the tenant shall be re-routed through the FATC.
 - 11. Demolition of architectural assets may be shown for that work to commence once the fire alarm and other applicable permits have been issued.
 - 12. The location and layout of any temporary construction walls.
 - 13. A scope narrative shall be provided identifying the intended work and the quantity of fire alarm strobes that will be used for temporary coverage during construction.

14. As required by Denver Fire Department (DFD), all documents must be signed by a minimum NICET III certified fire alarm technician, or stamped by a Professional Engineer, before being submitted to Denver Fire Department for a walk-through permit.
15. Documents are also to be submitted to DEN Life Safety Engineering for reference only.
- B. Scenario 2 - Existing fire alarm notification appliances will remain for temporary coverage during construction and some fire alarm devices and/or appliances in the construction area will be removed.
 1. In addition to the minimum required documentation in Scenario 1, additional documentation shall be provided showing:
 - a. The location, quantity and addressing of any fire alarm device, appliance or circuit that will be removed.
 - b. Documentation shall be submitted to DEN Life Safety Engineering for approval prior to signing/stamping for DFD submittal. Once written approval has been issued by a DEN representative then the signed documents (with corrections if applicable) may be submitted for permitting.
 - c. The signed document shall also be submitted to the current fire alarm system manufacturer's representative for updates to the master DEN fire alarm Revit environment.
- C. Scenario 3 - Temporary fire alarm strobes will be added in the construction area and/or on the exterior of the temporary construction walls to maintain existing visual coverage in the public space.
 1. In addition to the minimum required documentation in Scenario 1 or 2, whichever applies, documentation shall be provided showing:
 - a. The location, quantity, candela setting, addressing and circuiting for the new appliances, as well as any new circuits or power supplies.
 - b. Note that existing visual coverage in areas outside the construction zone that obstructed by temporary construction walls is required to meet prescriptive Code requirements.
 - c. Strobes may also be added inside the construction zone if there is not an existing strobe already covering the space.
 - d. Updated appliance device lists, battery calculations and voltage drop calculations showing the existing appliances and noting the new appliances and the effect of the added current draw and wire length to the fire alarm system's batteries and circuiting.
 - e. This information must be coordinated with the current fire alarm system manufacturer's representative to determine that adequate power, voltage drop, and battery capacity are available.
 - f. Updated riser diagram showing the existing and new appliances and circuiting.
 - g. Updated calculations and riser diagrams must be coordinated with the current fire alarm system manufacturer's representative to determine that adequate power, voltage drop, and battery capacity are available and to update master DEN records.
 - h. Wiring details showing terminal connections for each new appliance type added.
 - i. The submittal procedure for Scenario 3 shall be the same as Scenario 2 unless: The quantity of added strobes will exceed the number allowed by DFD for NICET signatures. In this case, the documents must be stamped by a Professional Engineer.

4.3.5 Design Analysis Requirements

The Design Consultant shall provide a Fire Alarm System Basis of Design to substantiate the Fire Detection and Alarm System design. At a minimum, the Fire Alarm System Basis of Design shall include the following categories:

- A. Building description
- B. Fire alarm system type
- C. Design methodology
- D. Testing and inspection
- E. Equipment and tools

- F. Requirements for submittals
- G. End of job closeout

4.3.5.1 Applicable Code

The list of Codes that this system is required to follow for the shop drawings.

4.3.5.2 Design Responsibility

The Engineer of Record for the Shop Drawings. PE Seal applied to the drawings as required by DBCA. The entity creating the shop drawings shall be certified by the manufacturer for designing their system.

4.3.6 Initiating Devices

4.3.6.1 Heat Detectors

Heat detection shall be provided as determined by the Design Analysis Report (DAR). The Design Consultant shall make appropriate accommodations in accordance with NFPA 72 when applying heat detectors to de-rate for ceiling heights and consider unusual ceiling configurations.

4.3.6.2 Smoke Detectors

Smoke detectors shall be provided as determined by the DAR. Smoke detectors shall be the addressable type and compatible with the Fire Alarm System. Conventional smoke detectors may be used in special conditions where addressable detectors are not compatible with the environmental or hazard condition present. Where required, combination smoke/heat detectors may be installed.

4.3.6.2.1 Combination Smoke/Heat Detectors

- A. Combination smoke/heat detectors shall be provided when a transformer is located above the ceiling.
- B. In sprinklered areas subject to high probability of false alarms such as kitchens, smoke detectors are not required at a transformer, provided the transformer is 112.5 KVA or less dry-type and therefore does not require a dedicated room as defined by the NEC.

4.3.6.3 Carbon Monoxide Detectors

Detectors designed and listed for the detection of carbon monoxide, which is a product of incomplete combustion.

4.3.6.4 Duct Detectors

Smoke detectors are designed and listed for the detection of smoke within a duct of an Air Handling system. This device may include the ability to interface with the Air Handling Unit.

4.3.6.5 Pull Stations

Manual stations shall be provided as determined by the DAR. Manual stations shall be double-action type devices with key-operated reset and shall be addressable where permitted by ambient conditions. Where ambient conditions do not allow the use of addressable stations, use non-addressable stations that are tied back to an I/O panel in a conditioned space where monitoring can take place.

4.3.6.6 Water Flow Switches

Provide monitor devices for non-addressable water flow indicators. Water flow indicators include paddle-type flow switches, pressure switches, and other types. Ensure the sequence of operations associated with water flow

indication is consistent with protected areas (e.g., initiation of smoke control zones, limited area notification, elevator shunt trip, etc.).

4.3.6.7 Kitchen Hood

Provide monitoring devices for the non-addressable kitchen hood suppression system. A minimum of two points of monitoring are disabled/trouble and activation.

4.3.6.8 Dry System Pressure Switch

For all dry-pipe systems, pre-action, and deluge systems, monitor alarm pressure switch for individual system annunciation.

4.3.6.9 Other System Alarm Monitoring

Fire system alarm devices not associated with sprinkler systems include, but are not limited to, gaseous fire extinguishing systems, dry and wet chemical systems (including kitchen hood systems), foam systems, and other fire suppression or extinguishing systems. Provide a means to monitor individually each non-addressable alarm devices.

4.3.7 Monitoring

4.3.7.1 Tamper Switches

Provide monitor devices for non-addressable valve tamper switches. Supervise the valve position as defined by the fire suppression system design (i.e., either open or closed position). Each valve tamper switch shall be individually monitored.

4.3.7.2 Pressure Switches

For all dry-pipe and pre-action systems, provide piping supervision by means of low-air pressure switches. Low air pressure switches shall be monitored by the Fire Alarm System.

4.3.8 Control

4.3.8.1 Elevator Recall

Where elevators are installed, modified, or replaced, the Fire Alarm System shall provide elevator recall and shunt trip functions as applicable, per NFPA 72. Elevator interfaces shall be achieved by addressable fire alarm relays.

4.3.8.2 Door Holder Release

Fire alarm system shall interrupt power to magnetic door holders to close the doors and establish release for required controlled exit doors.

Doors shall be released consistent with the smoke control zones, and security door release sequences may be considered Security Sensitive Information (SSI).

Door release shall be achieved by addressable fire alarm relays.

4.3.8.3 Media Shunt

In Tenants with private audio/visual systems or other visual advertising, a media shunt shall be provided during emergency messaging activation. Media shunt shall be achieved by addressable fire alarm relays.

4.3.9 Notification Devices

4.3.9.1 Strobes

Strobes with ALERT shall be installed on walls or ceilings as indicated on the Fire Alarm System drawings. All new work shall be designed and installed to the prescriptive requirements of NFPA 72. Activation shall be per the approved Sequence of Operation for the building. All storage rooms, coolers and work rooms greater than 500 sf shall have a strobe for visual notification.

Activation of the strobes shall be per the approved Sequence of Operation.



Figure 4.3-1: Typical ALERT Strobes

In the AOB, CUP, Concourse A, AGTS Maintenance Facility, and in certain AGTS spaces between the AGTS tunnels, standard (non-addressable) visual notification appliances are utilized as manufactured by Eaton Cooper Notification (i.e., Wheelock). In the Terminal, Concourse B, Concourse C, and HTC, addressable visual notification appliances are utilized as manufactured by Johnson Controls.

4.3.9.1.1 Terminal Complex (Jeppesen Terminal, Concourses, HTC)

- A. Visual appliances shall be provided in all areas in accordance with NFPA 72.
 - B. Visual notification devices installed in public spaces, including Tenant spaces, shall be white with red letters that read ALERT.
 - C. Visual notification devices installed in back-of-house spaces shall be red with white letters that read, ALERT.
- A. Candela rating shall be included on the design drawings.

4.3.9.2 Speakers

4.3.9.2.1 Terminal Complex (Jeppesen Terminal, Concourses, AOB, CUP, and HTC)

A. Audible alarm devices shall be used in all areas as required by applicable codes.

B. All public spaces, including Tenant and Airline spaces, shall have audible coverage through the ECS. Tone notifications (i.e., fire alarm audible devices) may be provided in non-public areas with high ambient noise levels.

4.3.9.3 Supervision

Circuit supervision shall be provided consistent with NFPA 72.

4.3.10 Survivability

4.3.10.1 Extended System

To provide a higher level of survivability from fire and physical damage, a level of protection consistent with Level 1 pathway survivability per NFPA 72 shall be provided for visual notification circuits to fire alarm visual appliances (strobes).

All circuits shall be Class B as defined by NFPA 72, and ‘T-taps’ are not allowed.

Table 4.3-1: Fire Alarm Systems Wiring Requirements

Circuit Type	Circuit Class	Survivability Level
Signaling Line Circuit (SLC)	Class B	Level 1
Initiating Device Circuit (IDC)	Class B	Level 1
Notification Appliance Circuit (NAC)	Class B	Level 1
Remote Unit Interface (RUI)	Class A	Level 1
Network Communications	Class X	Level 1

4.3.10.2 Signaling Line Circuits

Signaling line circuits (SLCs) shall follow the requirements as dictated in NFPA 72, Chapter 23.

All circuits shall be Class B as defined by NFPA 72, and ‘T-taps’ are not allowed.

4.3.11 Graphic Annunciation

4.3.11.1 Terminal Complex (Jeppesen Terminal, Concourses, HTC)

Graphic annunciation shall be provided at all the Fire Command Centers via the TSW that shall indicate the location of the actuated detection or protection device. All additions or modifications to the system, including floor plan changes, shall be incorporated into the workstation graphics.

End of Chapter

This page is intentionally blank.

Chapter 4 - Emergency Communication System

4.4.0 General

The Airport is equipped with an Emergency Voice Communication System (ECS), which acts as the facility's paging system. The zoning of the paging system shall correlate with the established Fire Zones as defined by the IFC and NFPA 72. Refer to [Chapter 1- General](#).

4.4.1 Scope

This chapter provides design guidance to the Engineer in the area of the Emergency Communication System (ECS), which is utilized for both emergency communication and public address (PA) messaging at DEN. The ECS is designed, operated, and maintained as a life safety system at DEN. General criteria are set forth, as well as drawing and design analysis requirements.

4.4.2 System Description

4.4.2.1 The ECS Audio

- A. The ECS audio system shall have the following required operational capabilities:
 - B. In all Public Areas, the system has the capability of sensing ambient noise sound levels and adjusting loudspeaker zone signal levels up or down accordingly to maintain good speech intelligibility.
 - C. All inputs and outputs shall be monitored for correct operation. Audio levels of each logical system parameter shall be monitored, including but not limited to Microphone Stations, DSP, Amplifiers, loudspeaker lines with impedance and ground faults, and ambient noise system. Other data information of equipment and power monitoring shall be included in monitoring when available. All detected faults shall be displayed on the ECS standard and remote CPUs.

4.4.2.2 Manufacturer Limitation

- A. Manufacturer Limitation:
 - a. Components provided under this Contract shall be compatible with and connected to the existing Innovative Electronic Designs, Inc. (IED, Inc.) IED IP108 vACS is located in the center core of each concourse, the Hotel and Transit Center, and Room TML_04_2E_010 in the Terminal.
- B. The Emergency Communications System (ECS) provides paging and background music to all public areas of the airport facilities. Voice paging must be provided to all non-public support areas and parking areas. The system is used for general announcements and emergency announcements throughout Concourses A, B, and C, Terminal, Hotel, Transit Center, AGTS Tunnel, Office Tower, and Central Utility Plant.
- C. Most loudspeakers operate on a 70 Volt distributed system. Powered loudspeaker arrays are permitted. The loudspeakers shall be grouped in modular zones allowing maximum flexibility for paging area assignment. Loudspeaker types shall match DEN's current standards to the greatest extent possible. All Gate Podiums, Ticket Counters, Baggage Claim podiums and offices, Fire Command Centers, and Operations Communications Centers must be equipped with microphone stations manufactured by IED, Inc. Match existing configurations for operator continuity between areas.

4.4.3 Drawing Requirements

Refer to [4.1.5.1.A/E Construction Drawings](#) to [4.1.5.6.Drawing Format](#).

4.4.3.1 A/E 30% Drawings

The A/E 30% drawing should determine if any audio notifications will be required, as well as the required Architectural drawings.

4.4.3.2 A/E 60% Drawings

The A/E 60% drawings should contain the information in [4.4.3.1.A/E 30% Drawings](#) and the following information:

- A. Initial placements of the speakers.
- B. Preliminary sequence of operations.
- C. Identification of the associated notification Zone for each piece of equipment.

4.4.3.3 A/E 90% Drawings

The A/E 90% drawings should contain the information in [4.4.3.1.A/E 30% Drawings](#), [4.4.3.2.A/E 60% Drawings](#), and the following information:

- A. Final locations of all emergency communication devices. Concession Tenant Terminal cabinet included.
- B. Final tap settings of speakers.
- C. Audio Model indicating the speaker layout meets the initial dB levels and Intelligibility of the spaces. In Tenant spaces smaller than 2000 SF, an acoustic model is not required.
- D. The detailed Acoustically Distinguishable Spaces (ADS) Plan as required by NFPA 72 7.3.3.5.
- E. Notation of video displays/signs that will capture textual ECS notification or shunt, if applicable.

4.4.4 Conduit and Wire

4.4.0.1 Loudspeaker Cable

4.4.4.0.1 Homerun

- A. Manufacturer: WestPenn 25227 or Equal
- B. Size: #12 AWG, stranded
- C. Type: Unshielded twisted pair
- D. Insulation Color: Red (positive), black (negative)
- E. Jacket Color: Dark green
- F. Cable shall be plenum rated
- G. All cable shall be installed in conduit
- H. Loudspeaker circuits shall not contain T-Tap or star configurations.

4.4.4.0.2 Circuit Loudspeaker Cable

- A. Manufacturer: WestPenn 25226 or Equal
- B. Size: #14 AWG, stranded

- C. Type: Unshielded twisted pair
- D. Insulation Color: Red (positive), black (negative)
- E. Jacket Color: Dark green
- F. Cable shall be plenum rated
- G. All cable shall be installed in conduit
- H. Loudspeaker circuits shall not contain T-Tap or star configurations.
- I. Ambient Noise Sensor wire shall be in a separate conduit from speaker wire.

4.4.4.0.3 Whip to Speaker Cable

- A. Manufacturer: Smartwire, #MC-007960-11BR-GB or Equal
- B. Size: #14 AWG, stranded
- C. Type: Unshielded twisted pair
- D. Insulation Color: Red (positive), black (negative)
- E. Metal Cladding Color: Dark green or White with Dark green stripe
- F. Cable shall be plenum rated
- G. Loudspeaker circuits shall not contain T-Tap or star configurations.
- H. Whip not to exceed 6' in length.
- I. Control cable shall be installed in conduit and shall be low capacitance 22 AWG stranded four twisted pair with 100% aluminum polyester overall shield and drain wire.
 - a. The nominal O.D. shall be 0.325" with a green outer jacket nominal conductor D.C.R. shall be 24 ohm/1000 ft.; the nominal capacitance shall be 15.5 pF/ft. between conductors and the nominal capacitance shall be 27.5 pF/ft. between one conductor and other conductors connected to shield.
- J. The installation may involve localized conditions in which metallic-conductor cable systems will transition from conduit to tray installation for limited lengths of run.
 - a. If a cable is transitioning from a room via tray into a conduit for the remaining distance of the run, the wiring should be the type rated for use in the conduit.
 - b. If the majority of the cable run is in conduit, use cable rated for such use.
 - c. If the majority of the cable run is in a cable tray, use cable rated for use in a tray.

4.4.4.1 Conduit Color & Wire Integrity

All conduits shall be green in color from the manufacturer or done in the field.

All wiring shall be continuous from device to device. No circuit splicing allowed.

4.4.5 Criteria

Emergency Communications Systems are required to meet CCD requirements. Emergency Communications Systems shall be provided in accordance with the latest editions of the standards and codes listed in the DSM, as well as the IBC and IFC as currently adopted and amended by the CCD. Note that in the Denver Amendments to IBC, Appendix S has specific requirements for airports, which are in addition to all other referenced standards.

All public and non-public ADS (Acoustically Distinguishable Space) shall have a measured Speech Transmission index (STI) not less than 0.45 and an average STI of not less than 0.50 STI.

4.4.6 ECS Interim Documents

Emergency Communications System (ECS) coverage is not required in active construction areas. Visual notification shall be maintained. As ECS devices are removed, circuit integrity shall be maintained such that all public facing areas continue to receive full ECS coverage. A Denver fire alarm permit for demolition can be obtained via a Scope of Work letter and a sketch or drawing detailing the existing condition and the proposed demolition work.

4.4.7 Design Analysis Requirements

The Design Consultant shall provide an Emergency Alarm System Basis of Design to substantiate the Alarm System design. At a minimum, the Emergency Alarm System Basis of Design shall include the following categories:

- A. Building/Tenant description
- B. Emergency alarm system type
- C. Fire alarm system type
- D. Design methodology
- E. Acoustical models
- F. Testing and inspection
- G. Equipment and tools
- H. Requirements for submittals
- I. End of job closeout

4.4.7.1 Applicable Codes

The list of Codes that this system is required to follow for the shop drawings.

4.4.7.2 Design Responsibility

The Engineer of Record for the Shop Drawings. PE Seal applied to the drawings as required by DBCA.

4.4.7.3 Ambient Noise Levels

Any areas with an ambient noise level exceeding the maximum sound level, as specified by NFPA 72, shall be provided with supplemental means of notification (i.e., visual). The Designer shall perform SPL measurements within the work area during normal occupancy to determine the actual ambient noise level. The following table of approximate ambient noise levels shall be used as a reference in PA system design.

Table 4.4-1: Measured Average Ambient Noise Level

Measured Average Ambient Noise Levels	
Application	Sound Level
AGTS Tunnel	80 dBA
Baggage Tunnel	80 dBA
Mechanical Room	78 dBA

Table 4.4-1: Measured Average Ambient Noise Level (Continued)

Measured Average Ambient Noise Levels	
Application	Sound Level
Holding areas	63 dBA
Retail Space	63 dBA
Computer Room	70 dBA
Office	52 dBA
Restaurant	71 dBA
Lobbies	60 dBA
Hotel room	52 dBA

4.4.8 Loudspeakers

The Design Consultant shall ensure that:

- A. Loudspeaker circuits shall be grouped in zones for the sterile area, restricted area, tenant spaces, and public area. Each individual stairwell shall be a unique circuit.
- B. Loudspeakers shall be grouped by building floors. No circuit shall feed speakers on more than one building level or stairwell circuits excepted.
- C. To the extent possible, loudspeakers on the same circuit shall be installed within no more than one smoke zone.
- D. The contract provides an elevation view showing loudspeaker mounting height, spacing, and the angle of dispersion; shows calculations to verify the power delivered to the loudspeakers; and provides catalog cuts of the typical manufacturers' data that shall be provided in the DAR.
- E. The ECS design uses a distributed loudspeaker system or line array layout as determined by the acoustical design.
- F. Designers are encouraged to creatively select speaker types, makes, models, and loudspeaker placement to optimize speech intelligibility in all airport building locations. The STI levels specified within this document are only the minimum requirements.
- G. The design hearing height shall be 5 feet above the floor in general areas and 4 feet above the floor where permanent seating is provided.
- H. The ECS shall be designed to deliver PA announcements at 10 dBA above the design ambient noise level and emergency announcements at the level specified in NFPA 72.
- I. PLBs containing fixed walkways in excess of 20 feet in length shall be provided with intelligible ECS loudspeaker coverage, in its own zone and may be combined with up to three (3,) adjacent PLBs, throughout the entire fixed walkway.
- J. DEN Approved Speaker List Matrix: Contact DEN's Life Safety Team for approved speaker information.
- K. If it is necessary to install nonstandard, custom-made or hard-to-procure speakers, spare units should be provided in coordination with the Life Safety Team
- L. Line Level (8 ohm) speakers that are independently powered and used for ECS shall follow the UPS requirements in NFPA 72 and in section 4.2.1.

4.4.9 Fire Alarm System Interface

4.4.9.1 ECS

NOTE: Emergency Live-Voice and Fire alarm announcements shall always take precedence over PA announcements.

4.4.10 ECS Operational Plan

4.4.10.1 Introduction

DEN has implemented a robust and comprehensive Emergency Communication System (ECS) throughout the major buildings on the DEN campus. This includes the HTC, Jeppesen Terminal (Main and North Terminal), AOB, CUP, Concourse A, Concourse B, Concourse C, and the AGTS Maintenance Facility. This system has been progressively implemented from 2011 – 2016 in conjunction with the airport's Public Safety Notification Upgrade (PSNU) and Fire Alarm Replacement Projects. Simultaneously, the HTC was built, and appropriate system interfaces were designed and implemented.

This plan provides a detailed review of system operation, infrastructure, interfaces, messages, and maintenance requirements. This document is based on previously issued documents, including the "Emergency Communication System Migration Plan" (Revision 1 dated March 14, 2012) and the "Emergency Communication System Implementation Plan" (Revision 6.4 dated September 13, 2013). The information contained herein is considered ancillary to the "Fire Alarm Replacement Project Design Analysis Report" (Revision 2.0, dated June 22, 2011, Final revision pending) and supplements the findings of the "Emergency Communication System Risk Analysis," Revision 1.0, dated September 21, 2011.

1Exception: Non-DEN-controlled video displays exceeding 60" (25.4mm) measured diagonally shall display ECS messages when required by the fire code official.

4.4.11 Operational Sequences

4.4.0.1.1 Live Voice Activation

For live voice announcements, the user shall utilize the ECS Paging Microphone Station.

4.4.11.0.1 Alarm Silence

- A. Selecting the Cancel Message button on the TSW (AOB only) shall deactivate the playing of the prerecorded message. This shall deactivate all strobes and textual messages.
- B. Alternatively, selecting the Alarm Silence button on the FACP or TSW shall deactivate the playing of the prerecorded message and all strobes and textual messages.

4.4.0.2 Media Shunt

The Fire Alarm System provides media shunt function in Tenant spaces throughout the complex, as well as select visual displays throughout the public space. When a Tenant has a private hard-wired audio and/or video system, the system shall be shunted (i.e., power removed, black screen, silenced tenant speakers) to allow the emergency audible message to be heard over the ECS loudspeakers and any significant visual distractions removed. The fire alarm control module that provides media shunt shall activate anytime an emergency message sequence is activated.

4.4.11.0.2 Audio Shunt

Tenant audio systems shall be capable of accepting a contact closure to mute their system. The mute input shall be wired to an audio sensing relay on the local ECS loudspeaker circuit that closes anytime an emergency message is active.

4.4.11.0.3 Visual Shunt

The Fire Alarm System provides a shunt of all public cable television (CATV) feeds at key CATV distribution points in the Terminal, Concourse A, Concourse B, Concourse C, and the City portions of the HTC (i.e., Level 1-5). The fire alarm control module shall remove the CATV feed during an active emergency message sequence by removing power from the central distribution hub in the area.

Select advertising video displays and digital directory displays shall shunt anytime an emergency message is activated. This is accomplished using a fire alarm control module that removes power or through other means (i.e. programming, video switching components, etc.) to the select device or devices.

4.4.12 Fire Alarm System Notification Appliances

4.4.0.3 ECS/ Paging System Notification Appliances

The Fire Alarm System relies entirely on the IED Paging System for audible ECS notification in all but a select few locations.

The IED Paging System uses commercial-grade loudspeakers to provide adequate audibility and intelligibility throughout all spaces with paging system coverage. Paging loudspeakers and circuits are zoned for routine airport paging as well as emergency paging consistent with the ECS sequence of operation. Loudspeakers placed in Tenant finish areas and non-public areas are provided with a sticker on the front surface of the loudspeaker that states Fire Alarm Do Not Disconnect to prevent tampering. Refer to [Figure 4.4-1: Typical Ceiling Loudspeaker with ECS Indicator](#).



Figure 4.4-1: Typical Ceiling Loudspeaker with ECS Indicator

Notification devices (i.e., loudspeakers) are in each of the main complex buildings in areas where intelligible audio reproduction can be accomplished. There are loudspeakers in some parking structures and passenger pickup/drop-off areas (i.e., curbside), AGTS tunnels, most mechanical and electrical rooms, as well as all office and public spaces. These devices range from small coaxial in-ceiling loudspeakers, industrial horn-type loudspeakers used in harsh environments, and large-format line array-type loudspeaker units used in the Terminal Great Hall, Concourses, and HTC RTD train platform to achieve intelligibility in difficult acoustic environments.

4.4.13 ECS Operation

4.4.13.1 System Description

The ECS system consists of the IED Globalcom Suite of hardware and software providing audible voice coverage throughout the DEN Complex. The system relies on a distributed data network of controllers, digital microphones, and amplifiers. The system uses industry-hardened network standards for audio transmission over TCP/IP networks utilizing both RTP (Real Time Protocol) and Cirrus Logic Cobranet audio transport. The integrity of the network is maintained by the DEN Technologies/Life Safety department. There is a dedicated backbone and distribution system of switches for the IED audio traffic separate from the typical users' network (enterprise). This data network is a redundant class A network. This network model allows greater control, monitoring, and notification both for

fault notifications as well as emergency messaging. The system can reproduce a single audio input source to every loudspeaker in the network, approximately 15,000 loudspeakers simultaneously. There is some control of the zoning available to the user allowing the selection of a part of the building, most of the building, or all buildings for live voice announcements.

IED titan amplifier frames have eight (8) available amplifier card slots with a ninth automatic failover backup amplifier card. Each card is capable of two channels of 300W of 70.7V audio or Line Level audio. The redundant amplifier switches over automatically upon amplifier card failure providing a redundant backup.

The IED system receives via a dry contact closure signal from the Johnson Controls Fire Alarm System to capture all zones of loudspeakers and accepts audio from the Johnson Controls Fire Alarm System to play over all zones in the local building. This happens in five buildings during an emergency weather message, as each building has separate activation into the IED system. The IED system also provides a fault relay into the Johnson Controls Fire Alarm System to notify of any large system outages that substantially affect the operation of the paging system.

4.4.13.1.1 IED Globalcom System

The IED Globalcom system is also responsible for the normal voice reproduction functions for the airport, including courtesy announcements, regulated prerecorded messages for airport security, and Airline daily operations. The fire alarm audio feed and live voice announcements from the FCC microphone station take priority, interrupting any other audio playing through the system.

The microphone stations in Fire Command Centers and Operations Centers have special authority to allow emergency-level paging.

Globalcom provides an ambient sound analysis system that monitors the ambient level of the sound in a space, and if it is outside of the threshold, the system automatically increases or decreases the level of the loudspeakers in that zone accordingly. This system allows better intelligibility in space by providing accurate SPLs during normal activities as well as abnormal activities by actively attenuating the level. These sensors are provided in all public spaces in the Terminal Complex. The system has been equalized and set up to provide a minimum of 10dB over ambient levels for normal use and 15dB over ambient levels for emergency levels within public spaces per NFPA 72. This system is limited in the amount of gain allowed to keep overall levels within acceptable ranges.

Amadeus

4.4.0.3.1 Textual Message Code Considerations

The textual messaging at DEN is utilized to improve notification for the hearing impaired and in support of the overall emergency communication approach, including pre-signal implementation.

Textual visual information should be of a size and visual quality that is easily read. Many factors influence the readability of textual visual appliances, including the following:

- A. Size and color of the text or graphic
- B. Distance from the point of observation
- C. Observation time
- D. Contrast
- E. Background luminance
- F. Lighting
- G. Stray lighting (glare)
- H. Shadows
- I. Physiological factors

NFPA 72, 1020 edition provides guidance for font size based on viewing distance and mounting height of the display, as does the ADA. The information in the following tables is extracted from NFPA 72, which has been harmonized with the requirements of ADA.

Table 4.4-2: NFPA, 72 ADA Sign Requirement

NFPA 72 Number	Guidance
24.4.2.21.10	Textual visible appliance messages shall be permitted to be static, flashing, or scrolling, depending on the message being delivered.
24.4.2.21.11	The message text shall be permitted to be any color, as long as it is clearly legible in the environment in which it is located.
24.4.2.21.12	Emergency textual messages shall override non-emergency textual messages.
24.4.2.21.14.1*	Characters shall contrast with the background using either light characters on a dark background or dark characters on a light background.
24.4.2.21.14.2	Characters shall be permitted to be uppercase or lowercase, or a combination of both.
24.4.2.21.14.3	Characters shall be conventional in form and not italic, oblique, script, highly decorative, or of other unusual form.

Table 24.4.2.21.14.5 Visual Character Height		
Height to Finished Floor or Ground from Baseline of Character	Horizontal Viewing Distance	Minimum Character Height
>70 in. (1780 mm)–≤10 ft (3050 mm)	<15 ft (4570 mm)	2 in. (51 mm)
>70 in. (1780 mm)–≤10 ft (3050 mm)	≥15 ft (4570 mm)	2 in. (51 mm), + ¼ in. (3.2 mm)/12 in. (305 mm) of viewing distance above 15 ft (4570 mm)
>10 ft (3050 mm)	<21 ft (6400 mm)	3 in. (77 mm)
>10 ft (3050 mm)	≥21 ft (6400 mm)	3 in. (77 mm), + ¼ in. (3.2 mm)/12 in. (305 mm) of viewing distance above 21 ft (6400 mm)

Figure 4.4-2: NFPA Visual Character Height Resources

For purposes of utilizing FIDs/BIDs/GIDs, a 3-inch Sans Serif font is recommended. Smaller font sizes might be acceptable for displays where the viewing distance is less than 30 ft. In the case of larger video displays (e.g., Jumbotron™-type displays), the suggested visual message should be scaled larger as needed to provide legibility from greater distances. The following figure shows an example of emergency messaging on a large video display.



Figure 4.4-3: Example of Large Video Advertising Displays

4.4.14 ECS Screens

A fundamental recommendation should maintain simplicity in the interface screens. This simplicity should extend to both the number of possible screens and to the simplicity and ease of use of each screen. Control of the screen is recommended to be via touch screen, but mouse control is acceptable. TSWs shall utilize a dedicated ECS Control Screen.

4.4.14.1 TSW Prerecorded Message Screen

The TSW has a single ECS Control Screen, which contains selection buttons for all the various messages. Refer to [Figure 4.4-4: TSW ECS Control Screen](#). The screen is separated into six main sections:

- A. Master Control Buttons to enable and cancel/disable the screen.
- B. Help / Legend section to explain colors and operation.
- C. Play the Emergency Messages section to activate emergency messages for each of the buildings.
- D. Play the Test Messages section to activate the test message for each of the buildings.
- E. Play Tornado Messages to activate tornado-related messages site wide (not including the HTC).
- F. Hotel and PTC section to activate tornado-related messages within the HTC.
- G. Selection buttons are toggle-type buttons with a feedback color change indicating a change of state if the button has been selected. Travel/navigation, cancel/reset, and similar buttons shall not require a change of state indications but shall simply perform the intended operation.

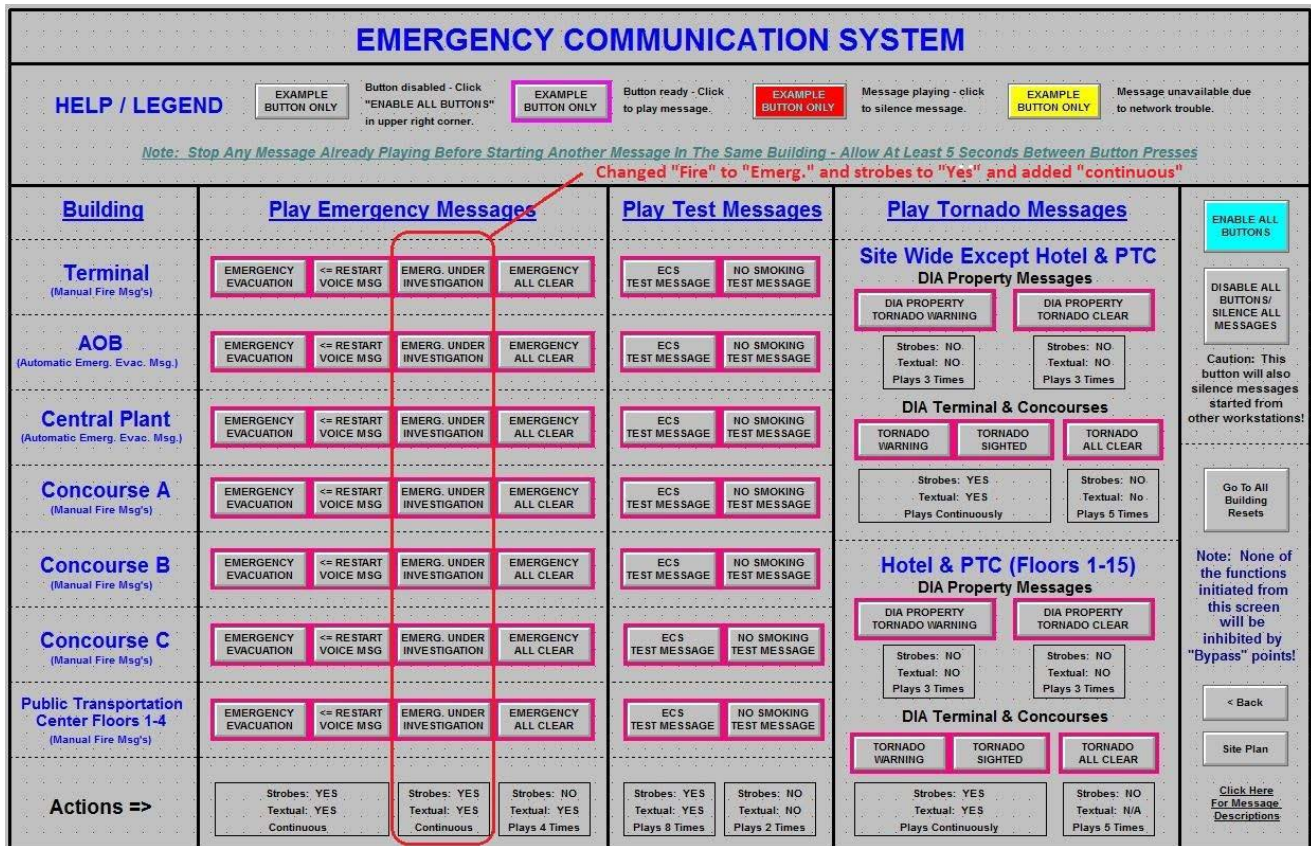


Figure 4.4-4: TSW ECS Control Screen

To activate the ECS Control Screen, an Enable Button shall act as a confirming prompt message (e.g., Are You Sure? message). This enable button shall provide a final reminder to the authorized user that they are about to initiate the selected message. Cancel message, clear all, and navigate screen buttons shall not include a confirmation pop-up message.

The Restart Voice Message button is provided to allow an authorized user to re-initiate the emergency evacuation prerecorded message. This button shall not be active unless/until the Emergency Evacuation button (or equivalent) has been previously activated, and the Evac message is still playing. This button shall immediately activate the Evac message to play five times, followed by a Slow Whoop signal until canceled or silenced. This button shall not include a confirming prompt message since the Evac signals are already active.

4.4.14.2 ECS System Live Voice Selection

Live voice announcements shall continue to be made from the IED Microphone Station and IED Touch Screen. This screen is also called the A-Panel. The operator shall select the area (zone) and key the microphone to conduct an announcement.

As an operational recommendation, it is recommended that live voice messages be made on a building-wide basis due to the transient nature of the occupants. Selective zone paging should only be done when there is a specific reason to do so to avoid occupant confusion.



Figure 4.4-5: IED Paging Panel (Director Panel) and Digital Microphone Station

4.4.14.2.1 ECS/Fire Alarm Interface

As a rule, the Johnson Controls Fire Alarm System shall provide the prerecorded messages as detailed in this operational plan and the IED System shall provide the live voice capability, except as noted herein. The Johnson Controls Fire Alarm System shall provide a dry contact to notify the ECS to accept the audio messages. The ECS shall accept the audio messages as well as providing live voice override.

For other required operations, the Johnson Controls Fire Alarm System and PA/ECS and MUFID systems shall be interconnected via dry contacts. This interface, for both audio and video capture, is housed in the Textual ECS Interface/Fire Alarm Interface Panel (FA/ECS) located in the PA Communications Room in the North Terminal, Concourse A, Concourse B, and Concourse C and in the MDF room of the HTC. Contacts shall be maintained (i.e., latching), unless otherwise noted, so that visual displays are directly controlled by the Fire Alarm System to the extent possible. An All Clear message shall deactivate its associated message latched contacts. ECS messages shall be allowed to override fire alarm messages. Johnson Controls Fire Alarm System custom control programming shall be used to activate and latch (or deactivate) dry contacts.



Figure 4.4-6: Fire Alarm/Textual ECS Interface Cabinet

End of Chapter

Chapter 5 - Smoke Control System

4.5.0 General

The Airport is equipped with a Smoke Control Systems, which provides a tenable space within the facility if smoke is developed because of a fire. The zoning of this system is zoned per the adopted codes and functions accordingly. Any new or alterations occurring to the facility shall follow the existing methodology and codes adopted at the time of construction.

4.5.1 Scope

This chapter outlines specific requirements to be included in the overall mechanical system designs and specifications for the issuance of construction documents suitable for bidding and permitting. These designs and specifications shall include engineered smoke control systems where applicable for specific locations. This chapter describes the smoke control system design requirements and criteria for specific locations and the scope of participation that is required by Design Professionals of Record.

4.5.2 System Description

The purpose of this system is to remove smoke from the facility in such a manner as to have a tenable space for the occupants as they exit the facility in an orderly manner.

4.5.3 Criteria

The Smoke Control System shall meet CCD requirements. The Smoke Control System shall be provided in accordance with the latest editions of the standards and codes listed in the DSM, as well as the IBC and IFC as currently adopted and amended by the CCD. Note that in the Denver Amendments to IBC, Appendix S has specific requirements for airports, which are in addition to all other referenced standards. In addition, the design shall comply with all applicable Contract Documents.

4.5.4 Tenant Spaces

Tenant spaces 5,000 square feet in gross area, or more are required to have their own dedicated, automatic smoke control zone. Cross sectional views at tenant openings detailing the configuration of the smoke curtain, closely spaced sprinklers, etc., especially when considering bulkheads greater than 2 feet in width or stepped ceiling configurations shall be provided on the drawings.

4.5.5 Drawing Requirements

Refer to [4.1.5.1.A/E Construction Drawings](#) to [4.1.5.6.Drawing Format](#).

4.5.5.1 A/E 60% Drawings

A preliminary sequence of operations. The identification of the Smoke Zone the equipment is part of.

4.5.5.2 A/E 90% Drawings

The A/E 90% drawings should contain the information in [4.5.5.1.A/E 60% Drawings](#). The final Sequence of Operation is the responsibility of the Engineer of Record.

4.5.5.3 Preparation

Design documents shall be prepared by or under the direct supervision of a Fire Protection Engineer Licensed in the State of Colorado (Engineer). The Engineer shall be regularly engaged in the design and installation of smoke control systems of the type and complexity required for the application.

4.5.6 Design Analysis Requirements

The Design Consultant shall provide a Fire Alarm System Basis of Design to substantiate the Smoke Control System Design. At a minimum, the Fire Alarm System Basis of Design shall include the following categories:

- A. Building description
- B. Fire Alarm system type
- C. Design methodology
- D. Testing and inspection
- E. Equipment and tools
- F. Requirements for submittals
- G. End of job closeout
- H. All items required by Appendix N of the DBCA

4.5.6.1 Applicable Codes

The list of Codes that this system is required to follow for the shop drawings.

4.5.6.2 Design Responsibility

Each discipline shall have their section with the appropriate PE Seal applied to the drawings as required by DBFCA.

4.5.7 Equipment

All new smoke control system designs shall provide dedicated smoke control equipment for providing pressurization or exhaust. HVAC systems associated with new facilities shall not be used for smoke control. Duct materials and ductwork shall be designed, in accordance with the adopted codes and standards, to convey smoke and withstand the maximum pressure (both positive and negative) provided by the smoke control pressurization or exhaust fans when operating in a smoke control mode. Pressurization and exhaust ductwork shall maintain structural integrity during the entire period required for the system to operate.

Equipment including, but not limited to, fans, ductwork, balancing dampers, damper actuators, motors, etc., utilized for smoke control shall be suitable for the intended operating temperatures. Materials used for systems providing smoke control shall conform to applicable codes and DEN Specifications. Smoke control system components (e.g., fans and dampers) shall be UL listed for use in smoke control systems. Other components and accessories (e.g., starters, drives, variable frequency drives (VFDs), actuators, etc.) shall be UL-listed for their intended purpose.

Renovation work in existing areas shall maintain the existing smoke control equipment and sequence unless directed otherwise by the DEN Project Manager. Design requirements shall include evaluation and testing of existing smoke control equipment and sequence. Testing reports shall be submitted to the DEN Project Manager prior to proceeding with the design. Where existing HVAC equipment is utilized as a component of the smoke control system, the Engineer shall investigate alternatives to provide dedicated smoke control equipment with the DEN Mechanical and Life Safety Engineers and the DEN Life Safety Team.

4.5.8 Equipment / Zone Identification

The Engineer shall obtain equipment and zone identification from the DEN Mechanical Engineer.

In general, new smoke control equipment is identified as follows:

Table 4.5-1: Smoke Control Equipment Identification

Smoke Control Equipment Identification Example: SEF 2 W5S	
SEF-	Equipment Type: SEF for Smoke Exhaust Fan, SPF for Smoke Pressurization Fan, FSD for Fire/Smoke Damper, and SD for Smoke Damper.
2-	Alpha/Numerical Identifier for Fan or Damper Number. (Obtain from DEN Mechanical Engineer)
W5S	Alpha/Numerical Identifier for Fan or Damper Location. (Obtain from DEN Mechanical Engineer)

The addition of smoke control equipment to an existing building shall follow the fan and damper naming convention for the existing smoke control system. Smoke pressurization and exhaust fans serving the same area shall have the same numerical sequence. Smoke control equipment shall not be identified by any other method. The designer shall coordinate with other disciplines for naming conventions associated with fans and peripheral equipment, such as starters and disconnects, to ensure that a single system of identification is being applied to Smoke Control, HVAC, Electrical, and Fire Alarm drawings.

4.5.8.1 Transfer Air

Sizing of smoke exhaust transfer air openings shall include smoke exhaust air quantities as required by applicable codes and design criteria. Coordinate requirements for security grilles or barriers with DEN Mechanical Engineer.

4.5.8.2 Smoke Zone and Airflow Diagrams

Existing smoke control zone diagrams, operating sequences, and airflow diagrams are available upon request from the DEN Life Safety Engineer. These diagrams and matrices shall be used whenever a smoke test is required. These files shall only be modified when smoke control zones or equipment are added or modified. The Engineer shall update the DEN Smoke control diagrams and the smoke control matrix for the building of design and submit the updated electronic file to the DEN Mechanical Engineer, separate from the Contract Documents.

Building airflow diagrams are available for limited areas only and are in the process of being created for all areas. When the airflow diagram is available, the Mechanical Systems Design Engineer shall update the DEN airflow diagram for the building or area of design and submit the updated file to the DEN Mechanical Engineer as a separate submittal.

4.5.8.3 System Initiation

The sequence of operations provided on Fire Alarm Record Drawings includes all initiation and operational requirements, including whether one or two initiation devices are required to activate automatic smoke control sequences for the associated smoke zone. Only automatic and/or water flow initiating devices dictate the area smoke control zone of operation. For area smoke control sequencing, manual pull stations act as confirming devices but do not dictate the smoke control zone activated. Smoke control sequences that include vertical pressurization activate from a single automatic or manual fire alarm initiating device. Refer to the fire alarm sequence of operation in the Fire Alarm Record Drawings for specific requirements to initiate building smoke control.

The firefighters' smoke control panel (FSCP) located in each Fire Command Center (FCC) shall provide manual control of all smoke control system equipment and sequencing. Manipulation of the FSCP shall override any automatic smoke control function. The FSCP is graphically depicted and controlled through computer-based graphics display interfaces (TSW) provided throughout the Main Complex. Manual smoke control panels are provided for the AGTS smoke control system in both AGTS control centers.

4.5.9 Terminal Smoke Control Operation Overview

4.5.9.1 Great Hall

Sixty (60) dedicated, direct-drive exhaust fans located at the top of the great hall tent near the tent support columns are used to exhaust the Great Hall. A hatch is located above the exhaust fans to protect the Great Hall from the outside environment. The exhaust fan hatches are automatically opened upon fan activation but must be manually reset. Manually resetting or closing the hatch requires a man lift to access each exhaust fan hatch and requires a considerable amount of time to perform. As a result, exhausting the Great Hall is achieved by manual operation only.

4.5.9.2 Levels 5 and 6 Ticketing, Baggage Claim and Tenant Areas

Sixty (60) dedicated, direct-drive exhaust fans located at the top of the great hall tent near the tent support columns are used to exhaust the Great Hall. A hatch is located above the exhaust fans to protect the Great Hall from the outside environment. The exhaust fan hatches are automatically opened upon fan activation but must be manually reset. Manually resetting or closing the hatch requires a man lift to access each exhaust fan hatch and requires a considerable amount of time to perform. As a result, exhausting the Great Hall is achieved by manual operation only.

4.5.9.3 Level 1 Offices

Return air fans located in the Level 1 mechanical rooms are used to provide smoke exhaust capabilities, with relief air fans used to pressurize the adjacent space. The smoke control system design intent is to exhaust the area with a minimum of four (4) air changes per hour.

4.5.9.4 Water Flow Activation in Public Areas

In areas commonly occupied by the public, the Smoke Zone of that area shall activate upon activation of the Water Flow Alarm from the same zone.

4.5.10 North Terminal Smoke Control Operation Overview

4.5.10.1 Level 4 Offices and Communications Area

The smoke control system serving Level 4 areas utilizes return fans located in the Mechanical Rooms on Level 4. The communications rooms located on the North end of Level 4 are provided with a clean agent fire extinguishing system. As a result, dampers located at the room boundary are closed on activation of an alarm device within the room to minimize the leakage rate for these rooms.

4.5.11 Concourse A Smoke Control Operation Overview

The following is a general description of the smoke control systems installed for specific areas in Concourse A. Refer to Fire Alarm Record Drawings for smoke control sequence of operations, fire alarm sequence of operation, and smoke zone information. The existing smoke control design approach for Concourse A includes exhausting the zone in an alarm with a minimum of four air changes per hour or 20,000 cfm (except the control tower) and, as required,

pressurizing vertical enclosures. Adjacent zones are not pressurized unless make-up air is determined to be necessary to prevent excessive negative pressure within the building. Make-up/supply air fans are modified for each smoke zone to attempt to create a slightly negative condition (i.e., more exhaust than make-up air). This approach is an attempt to contain the smoke in the original zone and to avoid the smoke being pushed into other building areas or even other buildings. Maintaining a slightly negative condition credits the large volume of the building to allow make-up from other areas and through normal building leakage. Smoke control exhaust for Concourse A starts automatically with the activation of two initiating devices in public areas and a single initiating device in non-public areas.

4.5.11.1 Center-core and International Smoke Control Zones

This section does not pertain to the passenger bridge or the Level 3 International Walkway located between the Center-core and Sub-cores. Tenant areas less than 5,000 sf in area, located on the Concourse and Mezzanine Levels of the Center-core, are considered a part of the Center-core smoke zone (SZ-CC). Manual, dedicated smoke exhaust for these Tenants is provided and shall be maintained. Draft curtains or equivalents are provided between the Tenant areas and the Center-core. If no ceiling is planned in a Tenant space or adjacent spaces, ducted return must be designed connecting the adjacent Tenant plenums. Provide return air registers within the ductwork sized to accommodate the smoke exhaust air quantity. Provide balancing dampers as required to balance the system. Refer to [Chapter 3- Fire Alarm and Detection System](#), for required return air grille specifications.

The Center-core smoke control zone utilizes dedicated rooftop exhaust fans at the Center-core ceiling. Center-core egress stairwells and elevator hoistways are pressurized.

4.5.11.2 Sub-core, Holdroom, and International Walkway Smoke Control Zones

Exhaust for smoke zones located on the Concourse and Mezzanine Levels are provided via the rooftop direct drive exhaust fans. Level 4 and International walkways utilize a ceiling plenum or return air plenum with dedicated smoke exhaust fans for smoke evacuation. The retail Tenant areas located in the Sub-core of the Concourse and Mezzanine Levels are not dedicated smoke control zone.

4.5.11.3 Tenant Space Smoke Control Zones

Tenant space smoke control zones shall comply with IBC Amendments, Appendix S.

4.5.12 Concourse B Smoke Control Operation Overview

The following is a general description of the smoke control systems installed for specific areas in Concourse B. Refer to Fire Alarm Record Drawings for smoke control sequence of operations, fire alarm sequence of operation, and smoke zone information. The existing smoke control design approach for Concourse B includes exhausting the zone in an alarm with four air changes per hour or 20,000 cfm minimum and, as required, pressurizing vertical enclosures. Adjacent zones are not pressurized unless make-up air is determined to be necessary to prevent excessive negative pressure within the building. Make-up/supply air fans are modified for each smoke zone to attempt to create a slightly negative condition (i.e., more exhaust than make-up air). Maintaining a slightly negative condition credits the large volume of the building to allow make-up from other areas and through normal building leakage. Smoke control exhaust for Concourse B starts automatically with the activation of two initiating devices in public areas and a single automatic initiating device in non-public areas.

4.5.12.1 Center Core Smoke Control Zones

Tenant areas less than 5,000 sf located on the Concourse and Mezzanine Levels of the Center-core are considered a part of the Center-core smoke zone (SZ-CC). Although the Tenant areas on the Concourse and Mezzanine levels are not separate smoke zones, manual, dedicated exhaust for these Tenants are provided and shall be maintained. Draft curtains or equivalents are provided between the Tenant areas and the Center-core. In general, Center-core smoke control systems utilize a ceiling plenum or return air plenum with dedicated smoke exhaust fans for smoke

evacuation, with the exception of the atrium smoke control zone (SZ-CC). Air plenum openings shall be designed to ensure adequate smoke removal from the Tenant space. The sizing of openings shall not exceed a face velocity of 200 fpm. If no ceiling is planned in a Tenant space or adjacent spaces, a ducted return must be designed connecting the adjacent Tenant plenums. Provide return air registers within the ductwork sized to accommodate the smoke exhaust air quantity. Provide balancing dampers as required to balance the system. Refer to [Chapter 3 - Fire Alarm and Detection System](#), for required return air grille specifications.

The Center-core smoke control zone utilizes dedicated rooftop exhaust fans at the Center-core ceiling. Center-core egress stairwells and elevator hoistways are pressurized.

4.5.12.2 Sub-core and Holdroom Smoke Control Zones

Exhaust for smoke zones located on the Concourse and Mezzanine Levels are provided via rooftop, direct drive exhaust fans. Level 4 smoke zones utilize a ceiling plenum or return air plenum with dedicated smoke exhaust fans for smoke evacuation. The retail Tenant areas located in the Sub-core of the Concourse and Mezzanine Levels are not part of the smoke control zone.

4.5.12.3 Ventilation/Smoke Control Fans (VSCFs)

VSCFs are a legacy system used exclusively in the basement of Concourse B. The VSCFs at DEN are being phased out, and new VSCFs shall not be installed. VSCFs work by using dampers to reverse the flow of air through ventilation ductwork, changing their function from providing ventilation to smoke exhaust.

No new VSCFs shall be installed at DEN. All fans used for smoke exhaust or smoke pressurization shall be used exclusively in these functions and shall be labeled as Smoke Exhaust Fans (SEFs) or Smoke Pressurization Fans (SPFs), respectively. Refer to [Chapter 5 - Smoke Control System](#) for smoke control requirements.

4.5.12.4 Tenant Space Smoke Control Zones

Tenant space smoke control zones shall comply with IBC Amendments, Appendix S.

4.5.13 Concourse C Smoke Control Operation Overview

The following is a general description of the smoke control systems installed for specific areas in Concourse C. Refer to Fire Alarm Record Drawings for smoke control sequence of operations, fire alarm sequence of operation, and smoke zone information. The existing smoke control design approach for Concourse C includes exhausting the zone in an alarm with a minimum of four air changes per hour or 20,000 cfm and, as required, pressurizing vertical enclosures. Adjacent zones are not pressurized unless make-up air is determined to be necessary to prevent excessive negative pressure within the building. Make-up/supply air fans are modified for each smoke zone to attempt to create a slightly negative condition (i.e., more exhaust than make-up air). Maintaining a slightly negative condition credits the large volume of the building to allow make-up from other areas and through normal building leakage. Smoke control exhaust for Concourse C starts automatically with the activation of two initiating devices in public areas and a single automatic initiating device in non-public areas.

4.5.13.1 Center Core Smoke Control Zones

Tenant areas located on the Concourse and Mezzanine Levels of the Center-core are considered a part of the Center-core smoke zone (SZ-CC). Although the Tenant areas on the Concourse and Mezzanine levels are not a separate smoke zone, manual, dedicated exhaust for these Tenants are provided and shall be maintained. Draft curtain or equivalent is provided between the Tenant areas and the Center-core. In general, Center-core smoke control systems utilize a ceiling plenum or return air plenum with dedicated smoke exhaust fans for smoke evacuation, with the exception of the atrium smoke control zone (SZ-CC). Air plenum openings shall be designed to ensure adequate smoke removal from the Tenant space. If no ceiling is planned in a Tenant space or adjacent spaces, a ducted return must be designed connecting the adjacent Tenant plenums. Provide return air registers

within the ductwork sized to accommodate the smoke exhaust air quantity. Provide balancing dampers as required to balance the system. Refer to [Chapter 3 - Fire Alarm and Detection System](#), for required return air grille specifications.

The Center-core smoke control zone utilizes dedicated rooftop exhaust fans at the Center-core ceiling. Center- core egress stairwells and elevator hoistways are pressurized.

4.5.13.2 Sub-core Smoke Control Zones

Exhaust for smoke zones located on the Concourse and Mezzanine Levels are provided via rooftop, direct drive exhaust fans. Level 4 smoke zones utilize a ceiling plenum or return air plenum with dedicated smoke exhaust fans for smoke evacuation. The retail Tenant areas located in the Sub-core of the Concourse and Mezzanine Levels are not part of the smoke control zone.

4.5.13.3 Tenant Space Smoke Control Zones

Tenant space smoke control zones shall comply with IBC Amendments, Appendix S.

4.5.14 Tenant Spaces

- A. Tenant spaces less than 5,000 sq. ft. and open to the terminal or concourse shall be incorporated into the terminal and concourse smoke control exhaust operating sequence and shall be separated by an 18-inch draft curtain/draft stop with closely spaced sprinklers in accordance with Section 9.3.5 of NFPA 13 and smoke detectors in accordance with Section 4.5.2 in the tenant space. Cross sectional views at tenant openings detailing the configuration of the smoke curtain, closely spaced sprinklers, etc., especially when considering bulkheads greater than 2 feet in width or stepped ceiling configurations shall be provided on drawings.
- B. Tenant Spaces and similar rooms adjoining the airport terminal and concourse buildings. All continuous tenant spaces adjoining the airport terminal and concourse buildings that exceed 5,000 sq. ft. shall be a separate smoke control zone per Section 4.6.1. Separate smoke zones must be separated by a smoke partition or an 18-inch draft curtain/draft stop with closely spaced sprinklers installed in accordance with Section 9.3.5 of NFPA 13 and smoke detectors in accordance with Section 4.5.2 in the tenant space.

4.5.15 Construction Documents

The Contract Documents for smoke control systems shall include, as a minimum:

- A. Drawings showing the smoke zones for all spaces of design and surrounding the area of design. Fire alarm system drawings to include: a matrix identifying the sequence of operation of all equipment in the smoke control zones. This matrix and existing smoke zone drawings are available from the DEN Mechanical Engineer.
- B. A written sequence of operations describing how the smoke control and HVAC system integration is to function during smoke control pressurization and exhaust sequence of operations.
- C. The drawings shall indicate all mechanical and electrical as-built conditions for areas of renovation work. The Engineer should perform a site observation confirming all existing conditions and equipment to be utilized for smoke control operations.
- D. Schedules of all smoke control equipment.
- E. DEN Technical Specification sections are required to adequately define the smoke control equipment products and installation.
- F. Deferred smoke control shop drawing and Design Documentation submission in accordance with IFC Amendments, Appendix N and S. Only for submitting for the DFD Permit.

- G. The design team shall include a comprehensive design for the smoke draft stop at the storefront in all applicable projects. The design must fully address fire safety and smoke control requirements as per relevant building codes and standards. To ensure clarity and accuracy, the design team shall be provided detailed drawings, including a reflected ceiling plan, sections, and elevation drawings as necessary to completely depict the proposed smoke draft stop assembly.
- H. All drawings should include precise dimensions, annotations, and specifications for the smoke draft stop, clearly illustrating its integration with the storefront system. The drawings must also indicate the exact locations of code-required smoke detectors and closely spaced sprinkler heads, ensuring compliance with fire safety regulations and manufacturer guidelines. These elements shall be coordinated with the overall design to maintain functionality, accessibility, and aesthetic alignment with the project requirements.

4.5.16 Smoke Control System Testing

Smoke Control System Testing is required whenever any of the following conditions occur:

- A. Smoke Control Zone boundary is altered.
- B. Smoke removal route path has been altered (interior walls removed or added, ceilings modified, etc.).
- C. The smoke control equipment and/or devices has been altered, installed, or replaced.

Smoke Control Testing shall be performed by the Contractor and witnessed by design Engineer of Record (EoR) in accordance with the adopted Denver Fire Code Amendments, Denver Building Department, DFD, and DEN requirements. The Contractor shall utilize a Colorado Licensed Fire Protection Engineer for witnessed certification testing.

Smoke control tests will not be performed if outdoor temperatures are expected to drop below 40 degrees Fahrenheit at any time during the test. It is the tenant's responsibility to coordinate with DEN and DFD to schedule testing at appropriate times.

4.5.17 Renovation Work

When any portion of a smoke control zone is modified by a Tenant or Base Building Contract (new/removed equipment, new/removed walls, new/removed ceilings, etc.), the smoke control zones affected, and the immediately adjacent zones are required to be tested and certified by the EoR upon completion of the work.

End of Chapter

Chapter 6 - Emergency Alarm Systems

4.6.0 General

The Airport is equipped with various systems that are essential to the well-being of all personnel who occupy any of our facilities. The zoning of these systems is specific to the area in which they are utilized. They shall also report the Facility Fire Alarm System and specifically identified as to the area and the hazard which is being monitored.

4.6.1 Scope

This chapter provides design guidance to the Engineer in the area of Emergency Alarm Systems, which is utilized for all systems that require a notification of the Fire Department and Operations for the Safety of the occupants.

4.6.2 System Description

These include a variety of systems that are not part of the Fire Alarm System or any components of the Fire Alarm System. They are, however, required by Code to be monitored and relayed to the Fire Department and Operations for Emergency Response. These systems include but are not limited to:

- A. Carbon Dioxide Detection
- B. Refrigerant detection
- C. Emergency fuel shut off
- D. Inert gas monitoring

4.6.3 Criteria

These systems do not follow under any of the specific systems detailed in this DSM but are essential to the Health and Well-being of all persons working and traveling through our facilities. Each system, as identified in [4.6.2.System Description](#), has its own set of Code and Amendments requirements that must be followed.

These systems shall meet CCD requirements. Emergency Alarm Systems shall be provided in accordance with the latest editions of the standards and codes listed in the DSM, as well as the IBC and IFC as currently adopted and amended by the CCD. Note the Denver Amendments to IBC, Appendix S has specific requirements for airports, which are in addition to all other referenced standards.

4.6.4 Drawing Requirements

Refer to [4.1.5.1.A/E Construction Drawings](#) to [4.1.5.6.Drawing Format](#).

4.6.4.1 A/E 30% Drawings

On top of what is expected from the Architects, the drawings shall indicate if any system detection shall be required.

4.6.4.2 A/E 60% Drawings

All of what is expected for the 30% and initial placements of the system detection and fire alarm monitoring points. A preliminary sequence of operations. The identification of the Fire/Smoke Zone the equipment is part of.

4.6.4.3 A/E 90% Drawings

All of what is expected for the 60% and the final locations of all monitoring detection and fire alarm monitoring points. The final Sequence of Operation is the responsibility of the Engineer of Record.

4.6.5 Design Analysis Requirements

The Design Consultant shall provide a Fire Alarm System Basis of Design to substantiate the Fire Detection and Alarm System design. At a minimum, the Fire Alarm System Basis of Design shall include the following categories:

- A. Building description
- B. Fire alarm system type
- C. Design methodology
- D. Testing and inspection
- E. Equipment and tools
- F. Requirements for submittals
- G. End of job closeout

4.6.5.1 Applicable Codes

The list of Codes that this system is required to follow for the shop drawings.

4.6.5.2 Design Responsibility

The Engineer of Record for the Shop Drawings. PE Seal applied to the drawings as required by DBCA.

4.6.6 System Requirements

4.6.6.1 Inert Gas

Inert Gas systems with more than 100 pounds (45.4 kg) of inert gas or any system using any amount of an inert gas below grade used in a commercial, manufacturing, or industrial application, such as water treatment with pH balancing, food processing or laboratories shall comply with this Manual. Inert gases include but are not limited to argon, helium, nitrogen, and carbon dioxide.

Excessive storage amounts of inert gases shall be required to comply with this Manual. Excessive storage amounts shall be 6,000ft³ of the inert gas or a combination of multiple inert gases stored together. The table below outlines the maximum storage amounts for common inert gases as a reference. However, it is up to the Design Engineer to correctly calculate the total storage amounts per scenario.

Table 4.6-1: Inert Gas Maximum Storage Amounts

Inert Gas	Maximum Storage Amount (lbs)
Argon	612
Carbon Dioxide	686
Helium	61
Nitrogen	429

Where inert gas storage tanks, cylinders, piping, and equipment are located indoors, rooms or areas containing inert gas storage tanks, cylinders, piping, and fittings and other areas where a leak of inert gas can collect shall be provided with either ventilation in accordance with [4.4.9.Fire Alarm System Interface](#) or an emergency alarm system in accordance with [4.4.8.Loudspeakers](#).

4.6.7 Beverage Dispensing Carbon Dioxide Emergency Alarm Systems

Continuous gas detection shall be provided to monitor areas where carbon dioxide may accumulate, including any areas where detection is required by code. Detection equipment shall be provided to indicate carbon dioxide levels at each point of use and in each storage area/room. For other code information see Denver Fire Code Amendments Section 916 & 5307.

4.6.7.1 Alarm Set Points

Alarm set points shall be set at:

- A. 5,000 PPM (TWA) Time Weighted Average – Self Re-Setting (Non-Latching) Alarm
 - a. Notification for employees only in approved locations with instructional signage.
- B. 15,000 PPM (TWA) – Latching Alarm
 - a. Notification for employees only in approved locations.
 - b. Requires a service company or approved.
- C. 30,000 PPM – Latching Alarm
 - a. Initiate amber strobes and audible horns provided in the vicinity of each interior storage container, cylinder, or tank and at each point of use. Additional amber strobes and audible horns shall be placed at the entrances to below-grade locations, confined spaces, and walk-in coolers. The notification devices shall be rated a minimum of 80cd for a visible effect and 75 dBA for an audible effect and shall be mounted in accordance with NFPA 72 requirements.
 - b. Activation of the automatic system shutoff valve.
 - c. Evacuate the room/area and call 4211.
 - d. Alarm Signal to the fire alarm system and transmitted as a “HAZMAT Alarm” through the AES.

4.6.8 Inert Gas Emergency Alarm Systems

4.6.8.1 Alarm Set Points

- A. Alarm set points shall be set at:
 - a. Oxygen levels below 19.5%-Self-re-setting (non-latching) Alarm.
 - b. Visual notification only in approved locations.
- B. Oxygen levels below 17%-Latching Alarm
 - a. Visual and audible notifications in approved locations.
 - b. Activation of the automatic system shutoff valve.
 - c. Evacuate room/area and call 4211.
 - d. Alarm Signal on the fire alarm system and transmitted as a “HAZMAT Alarm” through the AES.

4.6.9 Mechanical Ventilation

Mechanical ventilation shall be in accordance with the International Mechanical Code and shall comply with all the following:

- A. Mechanical ventilation in the room or area shall be at a rate of not less than 1 cubic foot per minute per square foot [$0.00508 \text{ m}^3/(\text{s} \cdot \text{m}^2)$].
- B. Exhaust shall be taken from a point within 12 inches (305 mm) of the floor.
- C. The ventilation system shall be designed to operate at a negative pressure in relation to the surrounding area.
- D. Ventilation shall run continuously or be activated by a sensor or detector to maintain an atmosphere of less than 5,000 PPM.
- E. A mechanical permit is required in accordance with the Denver Building Code.

4.6.10 UPS Backup

Battery/UPS backup for the equipment shall be 24-hours quiescent operation and 15 minutes of alarm. Calculations shall mirror that of a Fire Alarm System.

End of Chapter

Chapter 7 - Two-Way Communication System

4.7.0 General

This section specifies unique situations based upon the building and its unique features. Every attempt is made to follow current code.

4.7.1 System Description

This system provides communications for ADA-defined people who are either located in an Area of Rescue or an Elevator Lobby that does not have direct access to an Exit outside.

4.7.2 Criteria

The requirements of this chapter are specific to the building feature noted.

4.7.3 Tenant Spaces

Tenant Spaces over 5,000 square feet are required to have their own Smoke Control Zone and Sprinkler Zone. These subsystems shall be monitored and controlled by the facility Fire Alarm System.

End of Chapter

This page is intentionally blank.

Chapter 8 - Area Specific Life Safety Systems

4.8.0 Scope

This section specifies unique situations based on the building and its unique features. Every attempt is made to follow the current code.

4.8.1 System Description

The requirements of this chapter are specific to the building feature noted.

4.8.2 Criteria

The design shall comply with the applicable Codes as adopted by the CCD.

4.8.3 Tenant Spaces

Tenant Spaces over 5,000 square feet are required to have their own Smoke Control Zone and Sprinkler Zone. These subsystems shall be monitored and controlled by the facility's Fire Alarm System.

End of Chapter

This page is intentionally blank.

Chapter 9 - Systems Testing and Commissioning

4.9.0 General

This chapter provides guidance on the Inspection and Testing of the previously mentioned systems and their associated sub-systems.

4.9.1 Scope

The testing of Life Safety Systems individually and as a full building system.

4.9.2 System Description

Each system has its unique testing criteria as dictated by the appropriate Codes that are adopted for that system. Since the Fire Alarm System is the focal point of all the information for the Fire Department and Operations, all related systems shall have their signals verified at the Fire Alarm System.

The following list shows the systems and their respective codes for Commissioning. Refer to the Sustainability DSM for information related to the DEN Commissioning Process.

- A. Sprinkler Systems - NFPA 25, Chapter 5
- B. Standpipe - NFPA 25 Chapter 6
- C. Fire Pumps - NFPA 25, Chapter 8
- D. Clean Agent - NFPA 2001 Chapter 7, NFPA 72 Chapter 14, NEC 760, 780
- E. Fire Alarm and Detection Systems - NFPA 72 Chapter 14, NEC 760, 780
- F. Emergency Communication System - NFPA 72 Chapter 14, NEC 760, 780
- G. Emergency Alarm Systems - NFPA 72 Chapter 14, NEC 760, 780
- H. Smoke Control - NFPA 72 Chapter 14, NEC 760, 780
- I. Radio Enhancement System - IBC 510, DFCA 510 & 916, NEC 780
- J. Two-way Communications - IBC 1009.8, DFCA 1009.8, NEC 760, 780
- K. Kitchen Hoods - IFC 904, 906, NFPA 17A
- L. Emergency Fuel Shut Off - NFPA 72 Chapter 14, NEC 760, 780

When an area is complete, testing of all the systems, integrated shall be performed to ensure that all Alarms are noted and recorded in the Fire Command Center as well as reported to the Airport Fire Department.

4.9.3 Criteria

As a large, complicated complex, it is advised to follow the dictation of NFPA 3 and 4 for commissioning of systems as they are installed, repaired, and replaced. This ranges from each individual system to its interaction with other Life Safety Systems.

4.9.4 Documentation

Documentation shall be from the system's corresponding NFPA Codes and written per NFPA 4, Chapter 7.

End of Chapter

This page is intentionally blank.

Chapter 10 - Other Life Safety Systems

4.10.0 Design Review

The following listed systems shall have their drawings created and submitted to DEN for review prior to submitting them for the permit with the Building/Fire Departments. Refer to the Standards and Criteria DSM for general submittal requirements.

- A. Media cutoff
- B. Security – Access control
- C. Video security
- D. Video advertisements
- E. Carbon dioxide detection
- F. Carbon monoxide detection
- G. Hazardous gas detection
- H. Refrigerant leak detection
- I. AES transmitters
- J. Generators, normal and emergency power
- K. Fire pumps
- L. Oxygen sensors
- M. Temperature sensors
- N. Low-frequency notification system

4.10.1 Code Requirements

The above systems are required to be logged and permitted by the City and County of Denver prior to any installation or testing.

The above systems may or may not interact with the site Fire Alarm System; each installation is unique and requires the Engineer of Record/Designer of Record to review the design conditions with the DEN Life Safety Engineer.

The International Codes (I-Codes), as adopted and amended by the City and County of Denver, contain the information required to create an acceptable set of shop drawings for permitting and construction.

4.10.2 Fire Pump

- A. The following needs to be added to the specifications as a required means and methods.
 - 1. The tank fuel level settings, low and high shall be set prior to filling the tank with any fuel.
 - 2. The fire pump needs to be run and final tested before the insulation for the exhaust is installed.

End of Chapter

This page is intentionally blank.

Volume 5 - Mechanical

Chapter 1 - General

5.1.0 General

5.1.0.1 Intent

The Mechanical systems consist of HVAC, plumbing, fire protection, automatic controls, and process systems located in the terminal building, the Airport Office Building, concourses, and outlying support buildings. The goals and objectives are to develop a Mechanical design to achieve an efficient, economical, maintainable, and reliable installation consistent with the goals and objectives of the Denver International Airport/City and County of Denver.

The space environment shall be designed to be controllable within an acceptable year around comfort and health levels. The Design Engineer shall utilize the latest state-of-the-art, energy-conservative, readily available equipment and components based on proven design techniques.

5.1.0.2 Definitions

For Mechanical Airport Definitions, refer to the Mechanical DSM.

5.1.0.3 General

The Designer shall prepare the design, construction documents, drawing, and specifications for HVAC equipment, ductwork and piping, exhaust equipment, controls, insulation, structural, plumbing, fire protection, automatic control systems, energy management systems, and operational services such as aircraft and vehicle fuel and glycol systems. The Designer shall coordinate the mechanical design with the applicable sections of the architectural, electrical, structural, civil, and DEN standards and criteria.

All construction documents shall be developed by the designer and reflect a complete engineered design. The installing contractor may perform certain engineering tasks, such as fire protection, but the designer is responsible for the total overall design.

The designer is responsible for including aspects of this Mechanical DSM and other pertinent DSM divisions into the design documents. An example of this can be found in [Section 5.3.3.5.Food and Beverage Tenant Equipment](#) where the designer is to add a note to the drawings regarding the cleaning of grease duct or notes on removal of existing equipment and control points in [Section 5.5.0.2.Existing Base Building HVAC Control Systems](#).

DEN items to be included (or excluded) from the designer specifications are included throughout Chapter 12 of the Mechanical DSM. The intent of these items are to be included in the tenant's Mechanical and Plumbing Specifications. Examples include the prohibition of PEX piping, push-on or press on pipe fittings, powder actuated fasteners, cable supports, etc.

Designers are to add to the Construction Drawing's general notes itemizing materials and methods that are not allowed at DEN. Examples include push-on or press-on piping connectors, grooved piping or piping connections, powder actuated supports, cable duct/pipe supports, etc.

Designers are to add to the Construction Drawing's general notes for the contractor to hold a mandatory meeting with DEN Stakeholders prior to connections to any piping (DEN Utilities). Tie-in to Plumbing systems to coordinate with DEN Plumbing and tie-in into Mechanical systems (duct or piping) to coordinate with DEN HVAC. Meetings are to be scheduled through the DEN PM and are to indicate the location of the tie-in, how the tie-in is to be made, size

of the tie-in, and any factors that require deviance from the construction documents. Meetings with Stakeholders is necessary to avoid delays and additional costs to the project.

DEN Mechanical Engineer requires that designers perform at least two project site inspections during the construction of a project that they have designed; more complex projects will require additional site visits. Designer is to submit this as a construction observation report to DEN PM for tracking the adherence to project drawings and specifications as well as the quality of workmanship opinions. Designers are to include the date and time of the observation, items being observed and excluded from the observation and photographs of the items noted in the observation report. See the Standards and Criteria DSM Chapter 8 for additional information.

5.1.0.4 Mechanical Engineer

All references in this document to the DEN Mechanical Engineer refer to the individual listed below. For questions, updates, or requests for deviations to this document, contact:

Manager of Systems Engineering
Design, Engineering, and Construction
26100 E 68th Ave.
Aurora, CO 80019

5.1.0.5 Regulatory Requirements

Designers shall specify that work shall be per underwriters; public utility; local; state, and federal codes; ordinances; and applicable regulations. Work shall also comply with the latest editions of all applicable codes, ordinances, and regulations in effect as of the date of the contract documents. If discrepancies occur between the contract documents and any applicable codes, ordinances, acts, or standards, the most stringent requirements shall apply. Where hourly fire ratings are indicated or required, designs shall provide for components and assemblies meeting the requirements of the American Insurance Association, Industrial Risk Insurers, Factory Mutual Insurance Association, and listed by Underwriters Laboratories, Inc.

5.1.0.6 Work Sequence, Coordination, and Installation

Project documents shall be developed so that work is furnished and installed in a logical sequence and performed in an expeditious manner for an efficient flow of work. Attention is to be given to the positioning of large equipment items and tie-ins to existing systems that will require system shutdowns. Progress of mechanical work shall be coordinated with other trades.

All site conditions and dimensions shall be verified by field measurements. Chases, slots, and openings shall be verified and designed to allow for mechanical installation. When mounting heights are not specifically detailed or dimensioned, systems, materials, and equipment are to be installed to provide the maximum headroom possible with minimum headroom of 7'-6" above the finished floor (AFF). If there are spaces with finished ceilings, the systems shall be of adequate height above the ceiling.

All systems that require periodic servicing or equipment replacement shall be readily accessible from the space. Coordinate connection of mechanical systems with exterior underground and utility services.

Contract drawings shall indicate the general arrangement of mechanical systems. Information shown may be schematic. Field verification by the designer of all existing architectural, mechanical, electrical, civil, and structural system locations is required.

Drawings and specifications are to complement each other. The designer shall clearly identify any work, materials, or equipment indicated on the drawings but not described by the specifications or described by the specifications but not shown on the drawings. In case of a conflict, the Contractor shall obtain clarification from the designer through the DEN PM in writing prior to bidding the job. After the job is bid, the conflict shall be resolved at the sole discretion of the DEN PM.

Although the general criteria may not be specifically indicated, Designers shall design and specify all supplementary or miscellaneous items, appurtenances, and devices incidental to or necessary for a complete mechanical system. Designers are to coordinate with devices being installed to prevent duplication of appurtenances internal to the device.

The designer shall fully detail all demolition drawings, and all unused mechanical and plumbing systems shall be demolished. No mechanical or plumbing systems, including equipment, ductwork, piping, supports, controls, power conduit, etc., shall be abandoned in place.

5.1.0.7 Site Conditions

The designer shall field verify the site location and availability of existing mechanical and electrical systems and the building structure. The designer shall examine site premises and utilities to become familiar with existing local conditions affecting work, such as obstructions, levels, necessary cutting, and any other existing services, before submitting the design. Designer shall research and coordinate with the appropriate stakeholders until a thorough understanding of how existing systems and equipment operate. Construction documents are to include the integration of new and existing equipment services with any upgrades in existing equipment or service necessary for proper operation. No allowance will subsequently be made due to any misunderstanding with respect to existing site conditions. All possible interferences inhibiting the routing of services shall be verified.

5.1.1 Design Criteria

5.1.1.1 System Criteria

The mechanical systems for all facilities at DEN are to be based on straightforward, proven design techniques utilizing the latest state-of-the-art development in readily available equipment and hardware. The overriding criteria for the use of systems and equipment shall be the safety, convenience of maintenance, simplicity, and comfort of the traveling public.

It is most important that the systems installed serve the public well, are readily serviceable and maintainable, are stable and direct in their operation, and provide flexibility for future change and development. All equipment, appurtenances, and hardware shall be accessible for adjustment and maintenance. Suitable access is required to permit the removal and replacement of equipment items. Maintenance clearances for existing equipment, even if said equipment is not in project scope shall be maintained. Special care shall be taken in areas with high ceilings, such as Concourse holdrooms, where DEN Maintenance personnel require the use of scissor lifts to perform maintenance on equipment a level above the finished floor. Provisions are to be made for the centralization of operating and maintenance diagnostics.

5.1.1.2 Mechanical Design Criteria — Flexibility

Special provisions are to be made in determining terminal and concourse building heating and air conditioning load requirements to properly allow for the dynamic nature of the application of these loads. During normal operation, these loads can vary dramatically from zone to zone, and the peak load can fluctuate significantly within each zone. This is due to the rapid mass movement of people within the building, as well as the shifting solar load on glass walls, infiltration loads associated with people and baggage movement in and out of the building, and out-side air ventilation requirements.

Heating and air conditioning system controls must provide system flexibility to satisfy the shifting internal cooling loads. The HVAC system must be able to handle varying perimeter loads during heating and cooling seasons while the internal and other loads fluctuate between no load and peak conditions. In addition, appropriate air quality conditions must be maintained in the spaces while the natural/nearby ambient (outside) conditions are very often of less than ideal quality.

5.1.1.2.1 Design Parameters

All new systems or major modifications to existing systems shall be designed and selected based on the latest ASHRAE Standards 90.1 and 55 requirements. Design conditions for DEN according to the latest version of *ASHRAE Standard 169 - Climatic Data for Building Design Standards*

Historical Reference: Many existing base building systems were designed and selected based on the following design conditions:

5.1.1.2.2 Design Conditions Prior to 2022

Design conditions for DEN according to *ASHRAE Handbook- Fundamentals 2013* are as follows (rounding to the nearest degree F):

- A. Cooling at the 1% level: 92°F (DB)/60°F (MCWB)
- B. Evaporation at the 1% level: 64°F (WB)/81°F (MCDB)
- C. Heating at the 99.6% level: 1°F (DB)

5.1.1.2.3 Indoor Design Temperatures

It is intended that the mechanical systems (in general) maintain indoor design conditions in all occupied spaces normally accessible to the public as follows (unless specified otherwise):

- A. Summer: 75°F, 50% maximum relative humidity
- B. Winter: 72°F

5.1.1.2.4 Outdoor Design Temperatures

Original outdoor design conditions used for system designs are as follows:

- A. Summer: 92°F dry bulb/59°F wet bulb (coincident conditions)
96°F air-cooled condensing temperature
63°F wet bulb design condition.
- B. Winter: -5°F

These design criteria conditions are based on the recommended conditions listed for areas near Denver in the *1987 ASHRAE Fundamentals Handbook* at the 2-1/2% summer condition and the 99% winter condition. That is, based on historical data, the outdoor temperatures can be expected to exceed the summer design conditions 2-1/2% of the time and exceed the winter design conditions 1% of the time.

The more stringent design condition is required for winter criteria due to the inherent outdoor air infiltration condition present in most airport situations. The design wet bulb condition is based on the 2- 1/2% mean coincident wet-bulb condition.

5.1.1.3 Ventilation Standards

All new systems or major modifications to existing systems shall be designed and selected based on the latest version of ASHRAE standard 62.1 or the IMC, including CCD amendments; whichever is more stringent.

Historical Reference: Many existing base building systems were designed and selected to meet the following:

Ventilation Standards for occupied spaces are to be based upon ASHRAE standard 62-1989, *Ventilation for Acceptable Indoor Air Quality*. The minimum required ventilation rate of outdoor air per person is to be 15 CFM per person, with several special-use areas in the buildings having significantly higher requirements. The distinction between smoking permitted and smoking prohibited has been abandoned in the revised standard; Denver Executive Order No. 99 prohibits smoking in all indoor public places, including bars, restaurants, and food courts.

5.1.1.4 Energy Efficiency Requirements

Energy efficiency is an important consideration in the design of mechanical systems for all DEN facilities. Heating, ventilating, and air conditioning systems are to be designed to meet or exceed the requirements of the latest version of ASHRAE standard 90.1 - *Energy Efficient Design of New Buildings except for Low-Rise Residential Buildings* and the CCD building code. Projects seeking LEED certification must meet all requirements to achieve LEED Gold certification or higher as defined by CCD Executive Order 123.

Equipment selections must be specified to meet or exceed these standards. The equipment and systems described herein must be selected to obtain the optimum in conserving life cycle owning and operating costs considering energy efficiency, initial costs, maintainability, and comfort.

5.1.1.5 Noise Criteria

The mechanical (HVAC) system shall be designed to minimize noise in the occupied space. The system and components shall be designed so as not to transmit or generate sound above a specified noise level in the space. Sound attenuators, duct liner, lower duct velocities and appropriate ductwork fittings and components shall be utilized as required to attain acceptable sound levels. Vibration isolation shall also be evaluated and utilized. Sound attenuators shall be isolated from the building structure.

For all HVAC and sound attenuation equipment provide schedules defining sound pressure levels in all 8-octave bands in dBA and calculated Noise Criteria (NC).

Sound tests shall be conducted in accordance with accepted procedural standards in and around all major sound-producing equipment either to confirm adequate attenuation or to identify problem areas requiring additional modifications as required by the DEN PM.

Maximum noise levels in the occupied space produced by HVAC equipment shall be in accordance with the NC curves listed in [Table 5.1-2: NC Criteria by Space](#).

Table 5.1-1: NC Criteria by Space

Occupied Space	NC Curve
Main Terminal	40
Concourse	40
Baggage Handling Areas	45
Restaurant and Food Service	40
Retail	40
Private Lounges	35
Offices	35
Conference Room	30
Control Tower Offices	35
AARF Station	35
Maintenance Work Area	45
Hotel Rooms	30
Mechanical Equipment Room	50

Notes:

- For NC curves, the lower number, the quieter the background noise
- Noise is to be free of tonality.
- Noise is to be free of low frequency time modulations (fluctuations).
- For any additional spaces not listed in the table above, refer to the NC Curves in the latest
- AHRAE Handbook - HVAC applications or other applicable standards.

Where mechanical noise is to be utilized for sound masking, RC (room criteria) curves shall be utilized as described in Chapter 8, Sound and Vibration of the most recent *ASHRAE Handbook, Fundamentals*.

Equipment and ductwork noise levels to permit attaining sound pressure levels in all 8-octave bands in Tenant occupied spaces shall conform to noise criteria NC-35 curves. Motor drives for pumps or any equipment shall operate with noise levels not exceeding OSHA 8-hour 90dBA Time Weighted Average (TWA). Noise levels shall be determined in accordance with IEEE Standard #85, Test Procedure for Air-Borne Noise Measurements on Rotating Electric Equipment.

5.1.1.5.1 Horn and Strobe Systems in Mechanical Equipment Rooms

Mechanical equipment room NC curves may exceed the levels listed above with written permission from DEN Mechanical Engineer. To obtain written permission from DEN Mechanical Engineer, the Consultant must provide a comparison of all different equipment and strategies for reducing NC curves to the DEN Mechanical Engineer by the 60% Contract Document Submittal and a written explanation of why these alternatives were rejected. Cost premiums on more quiet equipment or sound masking shall not constitute a reason for rejection. If DEN accepts deviation from the above standards, a horn and strobe system may be used in mechanical equipment rooms only. The horn and strobe shall be installed per the most recent edition of NFPA 72.

5.1.1.6 Altitude Correction

The design of all air systems, gas-fired equipment, and other affected mechanical equipment shall incorporate an adjustment for the altitude at DEN of 5,400 feet above sea level. The following parameters for altitude conditions are:

- A. Relative density correction factor = 0.819
- B. Air density = 0.0614 lbs/cu.ft
- C. CFM transfer factor = 0.884

5.1.1.7 Supports and Penetrations

All supports and anchors for mechanical and plumbing equipment shall be designed, detailed, and specified by a Colorado-licensed Structural Engineer. Provide detail including how attachment is to be made, i.e., between roof curb and equipment as well as roof curb and roof structure. A specification section is not sufficient for detailing any connections. Support sizing by the contractor is prohibited.

In general, cable and/or wire supports are not allowed.

Penetrations and reinforcement of penetrations through structural floors and/or walls shall be designed, detailed, and specified by a Colorado-licensed Structural Engineer.

5.1.2 Equipment Identification

5.1.2.1 General

All mechanical and plumbing equipment shall have a unique equipment designation. As of 2014, DEN modified the original scheme for tagging all assets.

These new naming conventions standardize the naming and numbering of all DEN mechanical and plumbing equipment. All DEN mechanical and plumbing equipment shall contain a numbering system according to the criteria out-lined below. Any deviation from the naming convention must receive written approval from the DEN mechanical engineer before implementation. The naming convention outlined below should be fully coordinated with the requirements of tagging in the BIM model. Refer to the DFI DSM.

5.1.2.2 Air Handling Unit, Unitary Equipment, and Hydronic Equipment Identification

The components used to identify large equipment, such as Air Handling Units (AHUs), and unitary equipment, such as Unit Heaters (UHs), Cabinet Unit Heaters (CUHs), and Fan Coil Units (FCUs), depend on the location and requirements of the project. The DEN naming system consists of five standard components and one optional component, as follows. Use an underscore character to separate components as shown in the examples below.

LLL	_	NN	_	NL	_	LLL	_	L	_	NN
(1)		(2)		(3)		(4)		(5*)		(6**)

L = Alphabetical character

N = Numerical character

** = Only used for AHUs*

*** = Only used for Unitary Equipment*

5.1.2.2.1 Building Abbreviation

The three-character abbreviation for each building shall be used to designate the location of equipment. This abbreviation is assigned by DEN, for example: TML = Terminal, AOB = Airport Office Building, CCx = Concourse x, where x is the alpha designation of the concourse, e.g., A, B, C, etc.

CCB	_	04	_	7W	_	AHU	_	A	_

5.1.2.2.2 Building Level

The building level is a two-digit indicator used to further refine the location of equipment. This abbreviation is assigned by DEN, for example: 00 is the Basement Level, 02 is the Concourse Level, etc.

CCB	_	04	_	7W	_	AHU	_	A	_

5.1.2.2.3 Building Module

The building module is a two-digit designator that combines the building module and direction. It shall be used to further refine the location of equipment. This abbreviation is assigned by DEN, for example: 3W is module 3 West.

CCB	_	04	_	7W	_	AHU	_	A	_

5.1.2.2.4 Equipment Abbreviation

Equipment abbreviations are assigned by DEN and are listed in Table 5.1-3: Equipment Abbreviation.

CCB	_	04	_	7W	_	AHU	_	A	_

5.1.2.2.5 Concourse AHU Alphabetical Designator

AHUs in the Concourses are identified by an alphabetical designator (a letter). Generally, AHU-As serve holdroom, subcore, and center core perimeter zones, AHU-Bs serve holdroom, subcore, and center core interior zones, AHU-

Cs serve holdroom conveyances, and letters beyond C are used for other various zones. Refer to Concourse AHU zoning details for zones existing AHUs serve. In general, Designers should try to replicate existing AHU zones when designing new buildings or expansions.

Each building module must only have one AHU of each designation (e.g., module 7W cannot have two AHU-As in it).

CCB	–	04	–	7W	–	AHU	–	A	–

5.1.2.2.6 Numeric Designator

The numeric designator shall produce a unique identifier that belongs to only one piece of equipment. The numeric designator ranges from 01 – 99, where a placeholder of zero will be utilized for values less than 10. This is to be unique for each room unless replicated somewhere else. In the Concourses, this designation is only used for non-AHU unitary and hydronic equipment at DEN, such as FCUs and pumps. In the Terminal, Hotel, AOB, and outlying buildings, AHUs are also designated numerically 01 – 99 within the building (e.g. in the Terminal, there is only one AHU with the Equipment Abbreviation and Numeric Designator combination AHU_01).

CCB	–	04	–	7W	–	AHU	–	A	–	09

5.1.2.3 Dependent Unit Equipment Identifier

Due to the sheer number of terminal units at DEN (e.g., terminal devices such as VAVs, ATs, and FPBs), additional information must be included to ensure each equipment name is unique. Points for terminal equipment will have a naming component identifying the equipment that serves them inserted as follows. This naming convention shall also be used for split-system DX cooling and heat pumps where applicable. Any split system air conditioner and/or heat pump shall include the dependency identifier for both pieces of equipment.

LLL	–	NN	–	NL	–	LLL	–	XXXLLL (LL)	–	NN
(1)		(2)		(3)		(4)		(5)		(6)

5.1.2.3.1 Building Abbreviations

The three-character abbreviation for each building shall be used to designate the location of equipment. This abbreviation is assigned by DEN, for example: TML = Terminal, AOB = Airport Office Building, CCx = Concourse x, where x is the alpha designation of the concourse, e.g., A, B, C, etc.

CCB	–	03	–	6E	–	VAV	–	0401WAB	–	05H

5.1.2.3.2 Building Level

The building level is a two-digit indicator used to further refine the location of equipment. This abbreviation is assigned by DEN, for example: 00 is the Basement Level, 02 is the Concourse Level, etc.

CCB	–	03	–	6E	–	VAV	–	0401WAB	–	05H

5.1.2.3.3 Building Module

The building module is a two-digit designator that combines the building module and direction. It shall be used to further refine the location of equipment. This abbreviation is assigned by DEN, for example: 3W is module 3 West.

CCB	–	03	–	6E	–	VAV	–	0401WAB	–	05H

5.1.2.3.4 Equipment Abbreviation

Equipment abbreviations are assigned by DEN and are listed in Table 5.1-3: Equipment Abbreviation.

CCB	–	03	–	6E	–	VAV	–	0401WAB	–	05H

5.1.2.3.5 Dependency Identifier

This series of numbers and letters is an abbreviated version of the parent unit's equipment name and represents the AHU, coil section, or condensing unit that serves the terminal unit or the other half of the split system. The first two numbers in the abbreviation represent the floor the AHU is on (in the example below, 04 represents the fourth floor). The third and fourth number and the first letter represent the building module where the AHU is located (in the example below, 07W represents holdroom 7 west). The final letters represent the equipment type and equipment identifier (in the example below, AB represents AHU-B). For a make up air unit, use the shortened abbreviation M instead of MAU. For an air-cooled condensing unit, these last letters would be ACU##. For a fan coil unit that includes the DX cooling coils, the last letters would be FCU##. Thus, an ACU as the parent equipment would have the FCU as a dependent, and an FCU as the parent equipment would have the ACU as a dependent.

CCB	–	03	–	6E	–	VAV	–	0401WAB	–	05H

5.1.2.3.6 Numeric Designator

The numeric designator shall produce a unique identifier that belongs to only one piece of equipment. The numeric designator ranges from 01 – 99, where a placeholder of zero will be utilized for values less than 10. This is to be unique for each room unless replicated somewhere else. For terminal units with heating (e.g., a VAV box with reheat), an H shall be added to the end of the numeric designator.

CCB	–	03	–	6E	–	VAV	–	0401WAB	–	05H

5.1.3 DEN Mechanical/Plumbing Equipment Naming Components — Identifiers

The following table provides the identifiers and their descriptions for use in equipment naming conventions.

Table 5.1-2: Equipment Abbreviations

Identifier	Description	Identifier	Description
AC	Air Compressor	GWH	Gas Water Heater
ACT	Actuator	ACUH	Air Curtain
ACU	Air-Cooled Condensing Unit	HRC	Heat Recovery Coil
ADS	Air/Solid Separator	HRP	High Resolution Pump
AHU	Air Handling Unit	HSC	Horizontal Split Case Pump
AS	Air Separator	HWP	Heating Water Pump

Table 5.1-2: Equipment Abbreviations (Continued)

Identifier	Description	Identifier	Description
BFP	Backflow Preventor		
B	Boiler	HX	Heat Exchanger
C	Chiller	IRH	Gas Infrared Heater
CRAC	Computer Room Air Conditioner*	MAU	Makeup Air Handling Unit
CT	Cooling Tower	P	Pump
CUH	Cabinet Unit Heater	PCA	Pre-conditioned Air Handler
CHWP	Chilled Water Pump	PWC	Potable Water Closet
CV	Control Valve	PCU	Pollution Control Unit (Scrubber)
DSS	Ductless Split System	RAF	Return Air Fan
DWP	Domestic Water Pump	RHC	Reheat Coil Unit
EBB	Electric Baseboard Heater	RTU	Roof-Top Air Handling Unit
EF	Exhaust Fan	SF	Supply Fan
EIH	Electric Infrared Heater	SG	Slide Gate
EMCS	Energy Management Control System	SP	Sump Pump
ET	Expansion Tank	TP	Transfer Pump
EUH	Electric Unit Heater	UH	Unit Heater
EWB	Electric Water Heater	VAV or AT	Variable Air Volume Box (Terminal Unit). Note that AT is for historical reference only, no new units shall be called AT
FCU	Fan Coil Unit with Heating and Cooling Coil*	VAV-H or ATH	Variable Air Volume Box with Heating Coil (Terminal Unit with Heating). Note that ATH is for historical reference only, no new units shall be called ATH
FCU-H	Fan Coil Unit with Heating Coil*	VFD	Variable Frequency Drive
FPVAV	Fan-Powered Variable Air Volume Box	VLT	Vault Supply Fan System
F-SE	Smoke Exhaust Fan	VSCF	Ventilation Smoke Control Fan (Historical Reference Only)
FTR	Fin-tube Radiator	WG	Waste Disposal Grinder (Triturator)
GR	Open Channel Grinder	WH	Water Heater
GV	Gate Valve		

* DX Units are to be paired with an ACU condensing unit abbreviation.

5.1.4 Submittals

5.1.4.1 Design Submittals

Regardless of the requirements outlined by the Design Analysis Report, or lack of, the Designer shall submit the following electronic files at the 100% phase of the project to the DEN Project Manager:

D.Ventilation calculations defined by the latest version of ASHRAE 62.1

E.Tenant airflow requirements (if required)

Each item shall be included as a single, book-marked PDF file. No paper copies are required or will be accepted. All equipment shall be labeled as identified on the contract drawings. Each filename should include the contract number

Refer to the Digital Facilities and Infrastructure Design Standards Manual and the Standards and Criteria Design Standards Manual for additional design submittal requirements.

5.1.4.2 As-Built Submittals

The Designer shall submit electronically through the DEN Project Manager the information outlined in [5.1.4.Submittals](#) with corrections made due to field changes in construction.

Refer to the Digital Facilities and Infrastructure Design Standards Manual for additional as-built submittal requirements.

5.1.5 Equipment Supports and Thermal Expansion Compensations

5.1.5.1 Design

All equipment supports and thermal expansion compensation shall be manufactured systems or designed and detailed by a Colorado Registered Professional Engineer. Supports shall be coordinated with Architectural and Structural disciplines. Under no circumstances shall the construction documents direct a Contractor to provide supports without detailed performance specifications outlining the criteria and requirements of supports and their design and installation.

Wire and cable hangers are not allowed to support equipment, piping or ductwork. Powder-actuated fasteners are not allowed at the DEN Terminal Complex.

5.1.6 Workmanship

Designer to include in the contract documents wording to convey a high quality of workmanship.

Only quality workmanship will be accepted. Poor workmanship, improper layout of work and lack of coordination of work, as determined by the DEN Project Manager, are not acceptable and shall be connected at the contractor's cost.

Any changes or deviations from the drawing and specifications must be accepted in writing by the DEN Project Manager. All errors in installation shall be corrected at the expense of the Contractor. All specialties shall be installed as detailed on the drawings. Where details or specific installation requirements are not provided, manufacturer's recommendation shall be followed.

Upon completion of Work, all equipment and materials shall be installed complete, thoroughly tested, checked, correctly adjusted, and left ready for intended use or operation. All Work shall be thoroughly cleaned, and all

residue shall be removed from surfaces. Exterior surfaces of all material and equipment shall be left in a new and unblemished condition.

Contractor shall provide a complete installation, including all required labor, material, cartage, testing, insurance, permits, and taxes.

End of Chapter

Chapter 2 - Central Utility Plant

5.2.0 Equipment

5.2.0.1 Piping and Valves

The hydronic systems design shall be based upon the following criteria.

- A. Piping shall be designed in accordance with specified technical criteria. Water pipe sizing shall be based on the stricter of the two following parameters:

Table 5.2-1: Water Piping Sizing

Pipe Size	Max Velocity (fps)	Max Pressure Drop* (ft per 100 ft pipe)
up to 2"	4	8.5
2-1/2" thru 6"	6	4
8" thru 12"	8.5	2.5
14" thru 20"	10.5 (14)**	2.5
24" thru 42"	11.0 (14)**	1.5

* Based on new, clean steel pipe

** Number in parentheses is velocity limit applicable to long straight runs where noise is not critical (such as pipe tunnels, etc.). Maximum pressure drop still applies.

- B. Pressure drops in piping systems shall be calculated to allow for aging and corrosion of the interior surface. Therefore, all water piping systems shall be designed with the following friction factors (C values) based on the Hazen Williams Friction Factor formula.

Table 5.2-2: Water Piping Friction Factors

System Type	C Value
Closed Water	120
Closed, treated water	130
Open water	100
(New clean steel pipe)	(140)

- C. Hydronic systems should be designed for the widest practical ΔT and the closest possible approach of the return water temperature to the terminal equipment supply air temperature.
- D. The terminal equipment must be selected not only for its full load capacity but also for its performance over the full range of partial loads. Laminar fluid flow in the coils shall be avoided.
- E. Coils subject to 100% outside air at winter design conditions shall be protected by one of the following methods:
- Provide propylene glycol in the water loop serving the AHU coils for those units arranged for smoke removal - automatic 100% outside air capacity. These units must not be equipped with protective

- override controls to shut off the fan if a freezing condition is determined when operating for smoke removal. The glycol-water loop for this system is to be linked to the main heating hot water system through a plate and frame-type heat exchanger.
- b. For those units not arranged for smoke removal use, provide freeze protection thermostats on the coil face to shut down the unit fan if a freezing condition is detected.
- F. Control valves in hydronic systems must not be oversized. The flow characteristics and pressure drops are to be selected for the appropriate Cv value corresponding to the design flow to be controlled.
- G. Provide automatic air vents at all coils and at the high points of all piping. Provide drains at the low points of all piping.
- H. Hydronic systems controls shall be automatic and adjustable to optimize pumping and thermal efficiency.
- a. As of 2012, three-way valves are no longer allowed at DEN at the terminal complex.
 - b. Use pressure-independent two-way valves at coils in variable flow systems.
 - c. Hot water coil valves shall fail to the open position.
 - d. All valves in the heating water system shall be specified with components that are rated for 230°F continuous operations.

The CUP facilities include toilets, equipment operator areas, maintenance personnel offices, a control room, CUP EMCS/legacy EMCS control stations, and spare parts tool and inventory areas. The CUP houses:

5.2.0.1.1 As-Built Drawing Chilled Water Abbreviation

Existing drawings for much of DEN denote the Chilled Water Supply and Chilled Water Return abbreviations as CWS and CWR, respectively. New drawing sets shall use industry-standard abbreviations for Chilled Water Supply and Chilled Water Return: CHWS and CHWR, respectively. CWS and CWR shall be used to denote Condenser Water Supply and Condenser Water Return, respectively.

End of Chapter

Chapter 3 - HVAC Systems

5.3.0 HVAC Systems

5.3.0.1 Air Handling Systems

The air handling systems, including fans, motors, and duct static pressure losses, shall be adjusted for the high altitude at the airport site.

5.3.0.2 Roof-Mounted HVAC Systems

Rooftop HVAC equipment shall not be incorporated into the designs for the DEN terminal, its concourses, or other airside buildings without written approval from DEN Mechanical Engineer. However, this equipment does have applications for some of the support facilities. These shall be in accordance with FAA standards. Rooftop equipment is not to interfere or hinder the use of existing fall protection systems. Whenever a rooftop unit is utilized in the mechanical design of a building, the following concerns should be addressed in detail:

NOTE: All roof-mounted equipment surfaces shall be a dull, non-reflective white or gray finish to prevent sun reflection from obstructing control tower operations.

5.3.0.2.1 Maintenance

Equipment shall be readily accessible.

NOTE: Certain weather conditions (e.g., lightning, high wind speeds, etc.) can restrict access to roofs. Air- port Operations can also restrict access to roofs at their discretion. Designers should be aware of these possible restrictions and consult the PM about risks and other options.

New roof-mounted equipment shall maintain clear space for required service areas, and new reinforced roof walkway pads shall be installed from the nearest roof access to the equipment. Walkways shall extend around the entire equipment.

5.3.0.2.2 Energy Efficiency

This equipment is normally air-cooled and is often not designed to be energy efficient.

5.3.0.2.3 Thermal Performance

Thermal performance shall comply with the requirements in the latest edition of ANSI/AHRAE/IES 90.1. Effects of metal-to-metal contact and thermal bridges shall be included in the calculations.

5.3.0.2.4 Surface Condensation

Unit cabinets shall have additional insulation and vapor seals if required to prevent condensation on the interior and exterior of the cabinet. Portions of cabinets located downstream from the cooling coil shall have a thermal break at each thermal bridge between the exterior and interior casing to prevent condensation from occurring on the interior and exterior surfaces. The thermal break shall not compromise the structural integrity of the cabinet.

5.3.0.2.5 Maximum Leakage

Unit cabinets shall have a maximum leakage of 0.5 percent of the total supply-air flow at a pressure rating equal to the fan shut-off pressure.

5.3.0.2.6 Deflection Performance

Unit cabinet wall and roof deflection shall be within 1/240 of the span at the design working pressure equal to the fan shut-off pressure. Deflection limits shall be measured at any point on the surface.

Cabinet floor deflections shall be within 1/360 of the span considering the worst-case condition caused by the following:

- A. Service personnel
- B. Internal components
- C. Design working pressure defined for the walls and roof

5.3.0.2.7 Wind-Restraint Performance

All wind restraints shall be designed by Colorado Licensed Structural Engineer. Wind-restraint design shall not be delegated to the contractor.

5.3.0.2.8 Noise and Vibration

Proper vibration isolation is usually not provided unless special requirements are specified.

5.3.0.2.9 Aesthetics

This equipment can have a negative impact on the appearance of a building, depending on the elevation of other buildings or facilities in the vicinity. An architectural enclosure shall be provided around roof-mounted mechanical equipment. Any mechanical equipment or architectural enclosure that can be seen from a public area requires coordination with PM or Design Review Committee approval.

5.3.0.2.10 Fall Protection

Rooftops at DEN do not have built-in fall protection with the exception of Concourse C East and Concourse A West expansions. Maintenance for any equipment located within 10 feet of the edge of a rooftop will require additional fall protection installed. Any forms of fall protection visible from public areas (e.g., railings) require coordination with PM for Design Review Committee approval.

5.3.0.2.11 Rooftop Penetrations

Any rooftop penetrations shall be detailed by Colorado licensed Structural Engineer. Penetration design by the contractor is prohibited. Penetrations shall be designed in a manner that does not void the roof warranty.

5.3.0.3 HVAC for Unfinished (Tenant) Areas

HVAC systems for unfinished future Tenant areas shall be designed to provide for heating and cooling in accordance with the same criteria as for the systems described previously. The interior spaces (defined as that space 12+/- feet from the exterior wall) shall be designed for VAV with only cooling primary air ductwork routed to the terminal units. The VAV units shall be sized to deliver approximately 1.25 CFM of supply air per square foot. Prior to setting airflows, the anticipated use of Tenant areas shall be reviewed for functions that may require airflow rates above this amount (i.e., kitchens, bars, etc.). Additional CFM shall then be built into the air handling system design to easily handle these special areas. Controls will be connected to the VAV terminal unit only if some cooling or ventilation is required in the space.

The exterior glass walls shall utilize a perimeter forced air system as described previously. The perimeter system shall be complete in the unfinished area. The interior system shall be complete only to the VAV terminal system components.

5.3.0.3.1 Concourse C West Expansion - Tenant Areas

Existing VAV systems serving exclusively perimeter loads shall not be demolished or modified to include interior space loads. A separate VAV or makeup air system shall address interior loads as required.

When tenant spaces are designed for future use (e.g., grey box) with no terminal equipment installed, the final contract documents shall indicate the minimum and maximum allocated airflows for each space.

5.3.1 Ventilation Systems

5.3.1.1 Outdoor Air Requirements

Outside air shall be brought in through the air handling systems to satisfy minimum ventilation requirements plus provide building pressurization and minimize air infiltration at building entrance door areas.

Existing outdoor air requirements on air handling equipment in the terminal complex Facilities were designed around ASHRAE standard 62-1989. Outside air ventilation amounts shall be provided in accordance with the latest edition of ASHRAE standard 62 or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. The Engineer shall coordinate those requirements with the DDS and provide electronic copies of correspondence and documentation of the final design direction to the DEN PM. The Engineer is responsible for providing documentation that states the existing equipment can comply with any modifications in outdoor air.

Outside air intakes shall be located high and away from landside vehicle traffic and airside jet exhaust to the greatest extent possible, a minimum of ten feet above grade. All ventilation air will be brought in through air intakes in the mechanical penthouses. If additional ventilation air is required, consideration should be given to using indirect-fired gas make-up air units or heat pump make-up air units with electric reheat with roof-mounted intakes. If heat pump make up air units with reheat are selected. In some locations, National Fire Protection Agency (NFPA) 415 may have requirements that are more prohibitive and shall be followed.

5.3.1.2 Air Economizer Control

All air-handling units used for comfort cooling with a design capacity greater than or equal to 54,000 Btu/hr shall be equipped with airside, dry-bulb economizer cycle operation. The control system for this operation must be arranged to modulate outside and return air dampers to maintain a mixed air setpoint temperature. Outside air dampers will close to the minimum position and return air dampers open when the O.A. is 75°F (adjustable).

It may not be appropriate to provide AHUs to be located on the apron level and similar areas with 100% outdoor air capability due to the air quality in these areas. Therefore, some air handlers shall be provided with continuous minimum outside air levels. All units with minimum outdoor air requirements shall have freeze protection. Upon restarting supply fans after freeze protection has tripped, outdoor air dampers shall remain closed for 5 minutes (adjustable) to allow supply air temperature sensors or freeze stats to reheat to avoid re-tripping freeze protection.

These units shall utilize waterside economizer cycles (if applicable).

5.3.1.3 Return Air/Transfer Air

Eggcrate grilles shall be used in return air plenums that are used for smoke control. Perforated face grilles shall not be used.

5.3.1.4 Ventilation Rates

As described earlier in this document, the outside air ventilation rate shall be as recommended in the latest edition of ASHRAE standard 62.1. Careful consideration shall be given to these new recommended rates, particularly considering recent attention in the HVAC industry to indoor air quality. Applicable ventilation rates are published in ASHRAE standard 62.1.

Outside air requirements, unless otherwise specified, shall be as follows for normal occupancy levels.

The occupancy load in many public areas of the airport (i.e., concourses, hold rooms, ticketing areas, baggage claim, etc.) is highly variable. As an alternate to the ventilation air flows indicated as based on normal occupancy levels, it is acceptable to calculate the minimum ventilation rate of 10 CFM per person, based on peak load occupancy, unless exhaust requirements override this amount.

5.3.2 Existing Systems

5.3.2.1 General

The following is a general overview of the HVAC systems used in the base buildings at DEN. This narrative is general in nature and should not be used as the basis for sizing of equipment in tenant spaces, general specifications, and/or control sequence modifications.

5.3.2.2 Existing Air Handling Systems

In the present designated Tenant areas of the Terminal building, Concourses, and AOB, the HVAC systems consist of variable air volume air handling units with heating and cooling capability. The VAV systems provide the flexibility required to maintain comfort during shifting cooling loads. The holdrooms in the Concourses are supplied by both VAV and constant-volume air handling units. The exterior walls are supplied by heating-cooling VAV boxes that discharge out perimeter slot diffusers. The interior areas are supplied by constant-speed fans.

The air handling units in the Concourses and Terminal are located on the fourth level. The air handling units supplying the AOB are located on the roof. In the North Terminal, the air handling units are in the third-level mechanical equipment rooms. The first and second levels of the terminal have hot water only. The third-level has a constant volume of air and access to both hot and chilled water. Verify the locations and available quantities for Tenant usage with the PM.

The Concourse basement levels have a limited amount of Central Plant heating water available for Tenant development. Most heating will have to be provided by electrical heat or gas-fired equipment. Presently the basements have four (4) air changes per hour of tempered air. In the Concourse B basement, the Ventilation/Smoke Control Fans (VSCFs) serve both ventilation and smoke exhaust. VSCFs are a legacy system and are being phased out. No new VSCFs shall be installed; new ventilation systems shall not serve double duty as smoke exhaust systems. For smoke control requirements, refer to the Smoke Control chapter in the Life Safety DSM. This smoke and ventilation air is not available to the Tenant for comfort heating or cooling.

The air handling units are dedicated to distinct zones with overlapping airflows via a common return/relief fan system. The perimeter zones are VAV and fan-powered units with heating water heating at the terminal unit. The interior concourse holdrooms and subcore areas are cooling only VAV units. The central circulation zone is served by a constant volume system. The VAV perimeter air handling unit discharge temperature will be reset based on the "worst space load." All VAV heat terminals have double-ended control to increase air temperature and volume in unison.

The air handling units were sized based on normal heating and cooling loads for the public levels. The airflows are governed by the sensible cooling and winter heating load. There is no provision for latent loads. Air supply was based on the following:

Table 5.3-1: Basis for Existing Air Handling System Air Supply

Space	Minimum Occupancy
Bars	7 SF per person
Concession Areas	30 SF per person
Dining Rooms	15 SF per person

Table 5.3-1: Basis for Existing Air Handling System Air Supply (Continued)

Space	Minimum Occupancy
Holdrooms	100 SF per person
Offices	100 SF per person

Due to the large glassed area curtain wall configuration of the south perimeter zones of the Concourse and Terminal, large airflows were required by the South perimeter zone. To minimize the size of the South perimeter air handling units, a portion of the load was shared by the VAV air handling units serving interior zones.

Air handling unit airside economizer controls utilize free cooling when possible during mild weather. Outside and return air dampers modulate to maintain $55^{\circ}\pm$ mixed air temperature. At the minimum mixed air temperature of $45^{\circ}\text{F}\pm$ or on a temperature rise over $75^{\circ}\text{F}\pm$, the outside air damper goes to a minimum position. Space temperature modulates hot and chilled water coil valves.

5.3.2.3 Existing HVAC Air Distribution

The existing perimeter supply air system in the Terminal, AOB, and Concourses consists of in-place heating-cooling VAV terminal air units complete with supply ducts and slot diffusers. The amount of perimeter air per linear foot of the outside wall varies with the location. The interior supply air system generally consists of a SMACNA Class 4" WG primary duct that is supplied from the existing building supply system. The duct is routed in the ceiling of the Tenant spaces.

5.3.3 Tenant Remodel Requirements

5.3.3.1 Tenant Design Parameters

The Tenant shall provide adequate cooling to provide comfort conditions. Tenant shall not exceed the maximum amount of Lighting and Connected loads as defined in the Electrical DSM. If the allowable electrical load exceeds the following cooling capabilities, the Tenant shall provide additional cooling. The Tenant shall provide heat load calculations to confirm adequate cooling is being provided.

The Tenant shall provide a complete HVAC system to meet loads that exceed the requirements listed below. The Tenant shall verify the heating and cooling loads from the perimeter, adjoining structures, and adjacent spaces affecting the Tenant area. All Tenant areas in the Terminal are in the interior spaces and are unaffected by the perimeter heating/cooling loads. Tenant Designers shall provide DEN with heating and cooling load calculations.

Reference the Tenant DSM for Tenant Remodel Requirements.

5.3.3.1.1 Existing Base Building Mechanical Design Capabilities

The base building air handling system in the Concourses has been designed to accommodate the following loads for Restaurants, Food Courts, Offices, and Concession Spaces (aka ALLOWABLE LOAD):

- A. Basic Office, Retail, Airline Tenant: Exterior Load + 1.00 CFM/SF
- B. Restaurant Tenant: Exterior + 1.25 CFM/SF for the seating area. Kitchen is to be conditioned with a tenant-supplied mechanical make-up air system.
- C. Bar Tenant: Exterior load + 1.25 CFM/SF
- D. Food Court Tenant: Exterior load + 1.25 CFM/SF for seating areas. Source of make-up air will be by each tenant and coordinated between DEN and each tenant.

- E. Concourse C West expansion & Concourse B South Regional Jet Facility: No Tenant HVAC (hydronic on airside) accommodations have been made. Tenant shall provide a complete stand-alone HVAC system.
- F. Concourse A West Expansion (MOD 6W and 9W). See [DEN Concourse A West Expansion Concessions Matrix](#).
- G. Concourse B West Expansion (MOD 8W and 9w). See [DEN CEP Concourse B West Expansion Concessions Matrix](#).
- H. Concourse C East Expansion (MOD 6E and 9E). See [DEN Concourse C East Expansion Concessions Matrix](#).

The Tenant shall provide adequate cooling for occupant comfort conditions with the Base Building supply air. When the Tenant's defined load cooling load exceeds the allowable load listed above, the Tenant shall provide a separate HVAC system to meet the load difference. If the allowable electrical load exceeds the allowable load, the Tenant shall provide additional cooling equipment. This may be accomplished with air conditioning units utilizing the DEN chilled water system or with a make-up air unit with DX cooling and an air-cooled condenser. Heating may be supplied by the DEN heating water system, direct or indirect-fired natural gas heat, or electric heat. The designer shall verify the availability of the existing system capacity. No system shall be assumed to have sufficient capacity without supporting calculations.

5.3.3.2 VAV Terminal Air Units

The interior Tenant VAV boxes and controls shall be furnished and installed by the Tenant. All variable air volume (VAV) units shall be pressure independent with normally closed, electronic damper actuators that have a minimum air flow rate adjustment to zero (fully closed). Heating coils shall be sized for heating the maximum air flow rate of each unit. All heating coil control valves shall fail open. All VAV terminal boxes shall have native BACnet communication and connect directly to the DEN EMCS. Refer to [Chapter 5- Controls](#) for additional requirements.

Perimeter VAV boxes are the property of the DEN and shall not be altered from original design. These systems are designed specifically for the curtain wall load. Tenants shall not use perimeter VAV systems for supplemental conditioning due to new Tenant loads. In some cases, VAV boxes, controls, and diffusers will need to be moved to meet Tenant architectural cases. Relocated equipment shall perform in the exact manner of the original installation. Refer to other chapters for operation and accessibility requirements of DEN systems.

Designer shall ensure all components of DEN VAV terminals are completely accessible for maintenance and no additional HVAC or Tenant equipment is required to be removed from operation to complete maintenance activities. Control modules shall have a minimum twenty-four (24 x 24) inches of clear space in front of the controls and an area directly to floor below to allow for maintenance activities.

5.3.3.3 New Tenant HVAC Systems

Most Curtain Walls areas on the Concourses and the Terminals are served by existing base building heating-cooling VAV and/or Fan-powered terminal air conditioning units. The exterior space is defined as that space from the exterior wall to 8 feet in from the exterior wall.

The Tenant shall provide terminal air units and appropriate ductwork if required for the perimeter areas. The system shall consist of heating-cooling VAV boxes.

The use of light-troffer diffusers is not allowed.

Interior spaces are designed for VAV terminal air units with 55°F± cooling-only air available from the existing primary duct supplied from the existing system. The Tenant shall connect to the primary duct to supply perimeter or interior areas and route to the VAV terminal units.

5.3.3.4 New Tenant Air Handling Units

All roof-mounted equipment surfaces shall be a dull, non-reflective white or gray finish to prevent sun reflection from obstructing control tower operations. These shall be in accordance with FAA standards. New roof-mounted equipment shall maintain clear space for required service areas, and new reinforced roof walkway pads shall be installed from the nearest roof access to the equipment. Walkways shall extend around the entire equipment.

5.3.3.5 Food and Beverage Tenant Equipment

All kitchens shall be air-conditioned. The exhaust requirements will be determined by the cooking exhaust hoods installed within the facility. All cooking and food reheating equipment, including ovens, fryers, grilles, conveyor toasters, and similar, shall have dedicated exhaust hoods serving the equipment. The kitchen exhaust system shall be designed in accordance with the latest version of NFPA 96, "Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations," and the latest editions of the International Mechanical and International Energy Conservation Codes, including City amendments. Re-circulating hoods are not allowed.

Tenant shall furnish and install, if applicable, a complete kitchen exhaust system and mechanical make-up air system. In the Concourses and Terminal, each Food and Beverage Tenant shall provide their own mechanical make-up air system. Kitchen grease exhaust hoods shall be UL listed. UV systems may be used in type 1 hoods with the exceptions of heavy-duty and extra heavy-duty cooking appliances as defined by the currently adopted version of the Denver Building Code. In heavy-duty and extra-heavy-duty applications, UV hoods may be used in combination with another approved grease, smoke, and odor control system.

Exhaust and make-up air quantities shall be determined per food service Tenant. The system shall be complete with a hood, grease removal system, exhaust fan, and control panel. Roof-mounted exhaust fans shall be utility-set type and arranged in an upblast configuration.

Locations with roof mounted exhaust systems shall include the installation of Frost-Free Hose Bib or Hydrant for Kitchen Exhaust System Cleaning.

The design team shall include a frost-free hose bib or hydrant on the roof within 50 feet of the roof-mounted kitchen exhaust system to facilitate cleaning. It shall be connected to the project's water supply, meet local plumbing codes, and include backflow prevention.

Wherever food service has the potential for odor propagation outside of tenant areas, the tenant shall provide exhaust and make-up air.

The exhaust air from kitchen hoods shall be free from grease, vapor, and smoke. Installation of a water wash scrubber with filters shall be the preferred method. In the Terminal Building, the air scrubber shall be mounted on the roof. In the Concourses, the Tenant shall provide space for the exhaust fan and air scrubber within the Tenant's return air plenum space. Tenant air scrubbers may only be mounted on Concourse roofs with written permission obtained from DEN Mechanical Engineer. All roof-mounted tenant equipment in the Terminal and Concourses must conform with standards in [5.3.0.2.Roof-Mounted HVAC Systems](#). All clean-outs for grease-laden exhaust ducts must be located in Tenant space.

Designer to include a note on the drawing that upon completion of construction, general contractor is to provide an inspection report to DEN from a qualified kitchen exhaust cleaning contractor, confirming that sufficient access to clean the entire kitchen grease exhaust system has been provided. Any required modifications to allow complete system cleaning shall be installed prior to DEN acceptance.

Locations with roof mounted kitchen grease exhaust equipment shall include the installation of a frost-free roof hydrant for cleaning within 50 feet of the equipment. It shall be connected to the tenant's water supply, and include dedicated backflow prevention. Drains from the hydrant shall be routed into an approved receptor within the tenant's space.

Heat recovery from kitchen hood exhaust should be considered in the final design if grease buildup or collection can be avoided. Make-up air should be heated to 70°F or cooled via evaporative cooling equipment and supplied at the kitchen hoods. Packaged, factory-designed, and NFPA-approved kitchen exhaust hoods with make-up air systems are acceptable. To reduce cross-contamination and odors, no air from active cooking commercial kitchens shall return to the DEN base building air handling systems. Under no circumstance shall a positively pressurized kitchen or hood exhaust duct run through a return air plenum or occupied space.

Makeup air for kitchens shall be provided by a dedicated makeup air unit designed for a minimum of 100% of exhaust airflow. In no instance shall makeup air be taken from HVAC systems adjacent to the kitchen. All kitchens shall maintain a negative air balance in respect to adjacent spaces during active cooking operations.

See [Chapter 5- Controls](#) for additional tenant controls requirements.

5.3.4 Sustainability

As part of the City and County of Denver's Office of Climate Action, Sustainability, and Resiliency (CASR), the [Energize Denver Ordinance](#), which establishes energy use intensity targets for buildings over 25,000 sq. ft., DEN is working to reduce our carbon emissions impact. As such, gas-fired HVAC equipment or fixtures, except for kitchen cooking equipment (stoves, ovens, etc.), needs to be evaluated by the consultant for alternate energy sources. Evaluation needs to include available electrical and heating water capacities as a replacement for natural gas. Also, areas in the Terminal Complex that need heating for any type of heating load shall be connected to the existing heating water system unless there is not enough capacity available. Remodeling of spaces may not replace the existing hydronic heating systems as a heating source with electric heat without an evaluation and justification. Equipment heating source evaluations shall be presented and accepted in writing by the DEN Mechanical Engineer prior to proceeding with the design.

End of Chapter

Chapter 4 - Air Distribution Systems

5.4.0 Air Distribution Systems

5.4.0.1 Ductwork Design

Ductwork layout and sizing shall be performed using the best practices to ensure minimum energy loss by thermal transfer and friction. Design shall ensure that the minimal duct length is achieved and that no unnecessary loops or branches are used. Ductwork shall be routed in the most direct route feasible. Ductwork fittings shall be selected based on best practices for optimal performance in energy (friction and thermal) and sound transmission.

Ductwork shall generally be designed for low pressure, i.e., 2.0" WG or less, positive or negative. All medium-pressure ductwork (operating pressures in excess of 2" WG, positive or negative) shall be sized based on the static regain method. All low-pressure ductwork shall be sized using either the static regain method or the equal friction method. The existing main ductwork upstream of VAV boxes is considered medium pressure. All ductwork systems shall be designed to minimize noise transmission through the ductwork and avoid noise generation from components or fittings. Ductwork air velocities shall not exceed the following limits:

Table 5.4-1: Ductwork Air Velocity Limits

Area	Velocity Limits
Mains - Equipment rooms and non-occupied spaces	3400 fpm
Mains - Occupied spaces	2200 fpm
Branch or mains with diffuser connection	600 fpm
Branch with diffusers	1200 fpm

Aspect ratios shall not exceed 4:1 for mains

5.4.0.2 Ductwork Requirements

Ductwork shall be either rectangular or round (spiral) as appropriate for the specific application. All designs shall be in accordance with SMACNA HVAC Duct Construction Standards and the technical criteria in this manual. All supply air distribution ductwork shall be galvanized sheet metal with flanges, seams, supports, etc., to match the appropriate duct classification as defined by SMACNA unless moisture in the system dictates the use of aluminum or stainless-steel materials. Kitchen exhaust ductwork shall be welded stainless steel.

Although SMACNA allows spin-in fitting for medium-pressure ductwork, because they are difficult to differentiate in field inspections from low-pressure fittings, spin-in fittings are not allowed at DEN. Spin-in fittings shall not be represented on plans or sketches for medium-pressure systems. Spin-in fittings are allowed on low-pressure systems.

Exposed ductwork used as an architectural feature shall be round and constructed of sufficient gauge metal to prevent dings or dents. Ductwork material shall be either aluminum finish or suitable for painting. No external insulation shall be provided on architecturally exposed ductwork. Lined ductwork shall be used in exposed areas when radiated sound level exceeds that required in [Chapter 1- General](#).

All 90-degree elbows in both medium and low-pressure ductwork shall contain double-walled, airfoil-type turning vanes unless long-radius elbows are used.

Ductwork near air-handling units and outside air ductwork will be lined, as required, for thermal performance, noise control, and condensation control.

The Design Consultant shall designate the calculated duct static pressure on the drawings to establish duct construction classification. Changes in duct pressure classifications shall be called out via note or symbol.

Flexible round duct shall be a maximum of 5 feet in length and be of material acceptable by the Denver Building Code.

In general, no ductwork shall be run underground.

No ductwork shall be routed through/across the AGTS tunnel.

5.4.0.3 Dampers

All control dampers shall be the parallel-blade type.

- A. Outside air intake, dampers shall have air-tight seals at both the edges and ends of the blades. The seals shall be of a material that will not disintegrate with exposure to jet exhaust fumes.
- B. Control dampers shall be provided on all main branch take-offs and on the main ductwork downstream of a branch take-off.
- C. Fire and combination fire/smoke dampers shall be UL listed and conform to the standards and requirements of the International Building Code and CCD building code amendments. To limit fire alarm addressing and maintenance of combination fire/smoke dampers, these dampers are only to be installed where required by code; use fire dampers to the greatest extent possible. Fire and combination fire/smoke dampers shall have access doors provided for service and maintenance no more than 12" away from the damper. Access doors shall be 12" x 12" or larger.

Due to long intervals of typical operational modes and various system pressure changes, all backdraft dampers shall have motorized actuators. No barometric-type dampers shall be specified on any system without written permission from DEN mechanical engineer. Tenant projects shall not use barometric-type dampers. Motorized dampers shall fail in a condition that provides maximum protection to occupants and equipment.

5.4.0.4 Diffusers

Various types of diffusers are to be considered based on architectural input. Consideration shall be given to quality, durability, capacity, aesthetics, throw, and noise level. Coordinate with the architect all diffuser types and locations. Linear slot diffusers shall be individual, 4-foot maximum sections with individual supply boots. Perforated face diffusers are not to be used. Diffusers with face-adjustable dampers/throw blades shall not be used.

5.4.0.5 Grilles

Standard core 1/2" x 1/2" x 1/2" eggcrate grilles shall be used in return, air plenums/systems. Eggcrate grilles shall have a minimum free area of 90%. Perforated face, louvered face, or other face types shall not be used in return air systems in smoke control areas.

5.4.0.6 Transfer Air

Transfer air openings are required in all walls to structure, in return, air plenums and smoke control zones. Transfer air openings shall be sized for a maximum velocity of 200 fpm in smoke zones and 500 fpm in return air plenums that are not used for smoke control. Sizing shall accommodate the entire return air/smoke control system to the point of installation. Refer to the Life Safety DSM for additional requirements.

5.4.0.7 VAV Terminal Air Units

Designer shall ensure all components of VAV terminals are completely accessible for maintenance, and no additional HVAC or Tenant equipment is required to be moved or removed from operation in order to complete maintenance activities. Control modules shall have a minimum of twenty-four (24) inches of clear space to allow for

maintenance activities. Each VAV Terminal Air Unit is to have its own method of disconnecting the controls for maintenance. Clear space shall be defined to mean the space directly in front of the device. Access to the clear space shall also be unobstructed. VAV controls shall be of the direct digital control (DDC) type and shall be able to interface with the Johnson Controls MetaSys control front end.

5.4.0.8 Security Gates

Security grates shall be installed on all ductwork and transfer air openings larger than 144 square inches between public spaces and private/security spaces. All roof penetrations larger than 144 square inches with a direct path of access indoors shall be required to have a security grate.

5.4.0.9 Ductwork Supports

Cable or wire ductwork supports shall not be used.

5.4.0.10 Presentation of Ductwork Systems

All ductwork shall be shown on construction documents as double lines, regardless of the drawing scale and pressure classification. Round ductwork shall be indicated with a centerline. Limits of all lined ductwork shall be identified clearly by double-line symbology. The Design Consultant shall detail all ductwork fittings and connection types.

Single line ductwork can be shown on Schematic Design, Design Development, 30%, and limited portions, 60% submittals only.

All ductwork shall be identified by system type (exhaust, supply, return, etc.). All callouts for ductwork continuations off the plan shall identify its termination/origin. All callouts shall be in the direction of airflow. General notes of direction are not allowed.

Table 5.4-2: Allowable Direction Callouts

Not Allowed	Allowed
24 x 24 up	24 x 24 SA up to mezzanine tenant service
24 x 84 SA from below	24 x 84 SA from AHU-D
22 x 36	22 x 36 EX
84 x 36 up	84 x 36 RA to REF-4

Designers shall indicate on plans all changes in SMACNA duct static pressure classifications. Changes shall be represented with a double diamond symbol containing the static pressure of each section. For example:

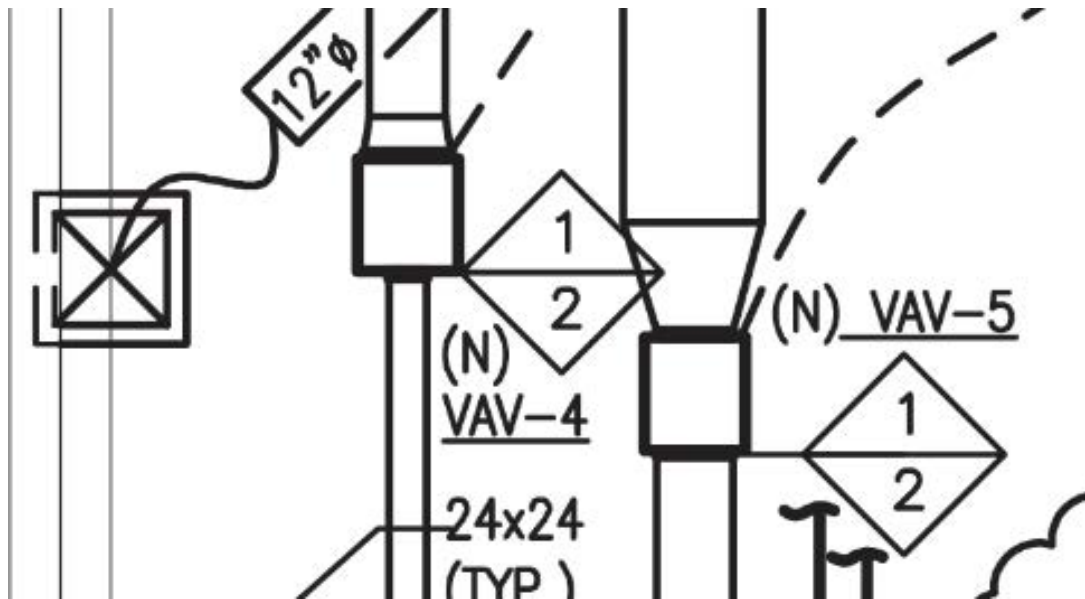


Figure 5.4-1: Allowable Duct Static Pressure Callouts Examples

End of Chapter

Chapter 5 - Controls

5.5.0 Controls

5.5.0.1 General

A complete system of automatic controls shall be provided to maintain space conditions within allowable limits. When heating and cooling are incorporated into one system for personnel comfort, the automatic temperature controls shall not be capable of simultaneous heating and cooling and shall provide a deadband. Automatic temperature control devices for personnel comfort shall have a heating control range between 65°F and 74°F and a cooling control range between 72°F and 85°F.

Designers are responsible for indicating in the construction documents (construction drawings and specifications) any aspects of Controls requirements for any project at DEN. Designers are not to refer to the DSM's directly, but include the relevant aspects of these DSM's into the construction documents.

Not all controls are for HVAC systems. Designer to coordinate with DEN for requirements for plumbing and other systems. Plumbing systems will include electric water heaters not used in Tenant spaces, sump pump status and alarms, emergency drainage flow switches and domestic booster pumps. Water detector alarms at water entry and mechanical rooms are to be included near backflow preventors and around each air-handling unit. Water detector alarms are to close the source of water that may be leaking at the room's boundary.

The system shall consist of all necessary control devices, control valves, control dampers, damper motors, pneumatic and electric switches, relays, gages, panel boards, tubing, and fittings, including all necessary accessories required for a complete and operative control system. All control wiring and control system electric power is to be furnished to provide complete environmental control and central panel functions. Products are to be of the latest design to avoid becoming untimely obsolete.

Control systems shall be electronic, digital systems controlling all HVAC equipment utilizing local microprocessor field panels located in the applicable adjacent equipment rooms. The field panels shall be capable of interfacing with the Energy Management Control System (EMCS) outlined in Volume 2, Chapter 6 of the Tenant DSM. Field panels located in the CUP shall be housed in NEMA 4X cabinets. Electric motor operators shall be used for all new valve and damper actuators; pneumatic operators are used for many existing valve and damper actuators. The existing pneumatic control systems located throughout the concourses and terminal are largely undocumented and should not be used for new projects.

Equipment utilizing manufacturer's controls system shall control all elements of their equipment and not rely on external controls for part of its operation. As an example, equipment such as a DOAS unit with heat recovery to control freeze protection and not rely on an additional controls system for that function. Intent is to not have three different controls system for a single system.

The local field panels shall be tied to the Facilities EMCS for equipment outside of the CUP or the CUP EMCS (for CUP equipment) located at the CUP but capable of standalone operation. If a network engine is required, it is to be located in a DEN COMM room.

Projects integrating DDC controls, or other non-HVAC related controls systems, shall be completely independent of the HVAC controls' MS/TP networks and controllers. The intent is that non-HVAC controls cannot affect the HVAC systems during a loss of continuity in the controlling system's network.

Tenants that utilize their own HVAC systems and subsequently the maintenance of those systems, must have controls that indicate alarms and equipment shutdowns from a local control panel. Tenant controls systems are not to be integrated into the DEN EMCS without DEN Facilities Maintenance and DEN Mechanical Engineer approval. Where there are DEN building systems used by the tenant, additional critical alarms must be sent to the EMCS for response by DEN. Such critical alarms would include those found in Section 5.5.4 for equipment utilizing

base building heating or chilled water systems. The intent is to give an indication of a failure of tenant equipment such that DEN Maintenance will be notified that a DEN maintained system may be in danger of being compromised. Tenant is responsible for integration of the critical alarms into the JCI Metasys system including integration into the graphics. Tenant is to route communications conduit from Electric metering and HVAC/Plumbing Meters back to the nearest DEN controlled COMM room. In addition, tenant is to provide a pull string in each of the conduits to the COMM room for future use of metered systems according to Volume 3 Section 3.2.1.5 Low Voltage4 DEN Submetering.

Airline tenant HVAC equipment status is to be integrated into the DEN EMCS system including modifications to the graphic interface. If a BACnet interface does not exist from the manufacturer for the particular equipment, then current monitoring in addition to space temperature could be included to give an indication of status when the equipment is supposed to be operating and isn't. Alarming will be similar to other stand alone equipment in the Concourses and Terminal. Other requirements for connecting equipment to the DEN EMCS are included in the DSM's (Mechanical, Electrical, and the Communication and Electronic Systems). For a list of alarms to include in the EMCS front end, refer to the Mechanical DSM Table 5-1.

Any new HVAC equipment must be coordinated with DEN through the project manager even though DEN will not be operating or maintaining the equipment. In general, if airline tenants attach HVAC equipment in their space and connect it into a DEN utility (i.e., electrical, HVAC or Plumbing) then it will need to be added to the DEN EMCS system. The extent if the addition will be through a BACnet interface to monitor the equipment. Metering for the HVAC equipment will not be required for airline tenants.

Designer is responsible for locating sensors where external influences will not affect the sensor (i.e., don't locate space temperature sensors where sunlight can hit them or near heat producing equipment).

Designer to include Control Points Abbreviations located in Appendix A in their construction documents (Construction drawings or Specifications). Designer must include the control points naming examples from 5.5.3 in the Construction Documents. All tenants are to follow this naming convention even if using their own HVAC systems.

Reference the Communication and Electronic Systems DSM for more information and requirements.

Tenant shall contact Johnson Controls, Inc (JCI) to design control scheme for buildout, unless otherwise directed by DEN Mechanical Engineer.

5.5.0.2 Existing Base Building HVAC Control Systems

The HVAC host control system consists of a network of fully independent direct digital control (DDC) controllers that are interconnected via a multiplexed digital data trunk. Data available to any one direct digital controller is available to all DDC controllers. Each macro controller may supervise a sub-network of micro-level DDC controllers. Sensor input devices and output devices shall be connected to either the macro or the micro-level DDC controllers. Each room with macro controllers has a local operator interface using an English language format. The control system interfaces over a phone modem or Ethernet connection with a main server in the Network Operations Center and can be accessed remotely. Each macro in the system is connected together by a Local Area Net- work (LAN) for peer-to-peer communication, multiple-user programming, and data gathering.

Existing building control system manufacturers and integration requirements shall be verified with the DEN Mechanical Engineer during project design. The following listing is subject to change as ongoing projects are implemented:

- A. Terminal: Honeywell and Johnson Controls. Transitions to Johnson Controls as Great Hall work is progressing through the terminal.
- B. Concourse A: Honeywell and Automated Logic (West Concourse Exapnsion). Transitioning from Honeywell to Johnson Controls and Automated Logic.

- C. Concourse B: Johnson Controls BACnet
- D. Concourse C: Honeywell. Transitioning from Honeywell to Johnson Controls, except for Concourse Expansion Program C-East (Building Modules 5E-10E), which will remain Honeywell.

As of 2016, all new controls shall use the BACnet communication protocol to connect to the existing Johnson Controls Inc. Metasys Control System (EMCS). In many locations, routers exist for connections for new controls. In most locations, these routers are LonMark-certified devices that will need to be replaced with any new control work. Contact the DEN Mechanical Engineer for a copy of the latest router location map.

Currently, the Terminal, AOB, Concourse A, Concourse C, and various outlying buildings use an aging Honeywell CNAP controls system. CNAP controls are no longer supported by Honeywell, and new and replacement parts are not available. Additionally, Honeywell will not support connecting additional CNAP VAV/FPB controllers (mcels) to the CNAP AHU controllers (xl-plus boards). Due to their volatility and lack of replacement parts, DEN will not allow additional VAVs or FPBs to be added to AHU systems that still use the xl-plus controllers. When designing mechanical systems in these areas, designers should re-use existing mcels already connected to the xl-plus boards. If additional VAVs or FPBs are required, the xl-plus board must be replaced with new BACnet-compatible controllers. Wherever xl-plus boards are replaced, all VAV controllers (mcels) and any other devices connected to the xl-plus boards and associated controls cabling must also be replaced with new BACnet-compatible controllers and cables. All associated terminal control devices (temperature sensors, thermostats, duct static pressure sensors, etc.) must also be replaced with BACnet-compatible devices. Equipment removed must be tracked by the contractor performing the system upgrade and point removal coordinated with the controls vendor that was previously in the space. All controls points no longer used must be removed from the project by the temperature controls contractor, regardless of the manufacturer. All graphics in the EMCS or outdated Honeywell system must reflect the removal of the points. Designer is to include these requirements in the design documents. Contact the DEN Mechanical Engineer when designing mechanical systems in the areas listed above for current controls-based restrictions.

The fire and security automation systems are independent and separate systems from the HVAC automation system.

5.5.0.3 New and Replacement HVAC Control Systems

For continuity of operation of the controls systems at DEN, HVAC DDC controls systems are limited to systems manufactured by Johnson Controls, Inc., Automated Logic Corporation, and Alerton. New devices connected to AHU's must use the same controls manufacturer as the AHU for communication with the AHU. Designer is to include the requirements in the design documents. Consult DEN PM and DEN Mechanical Engineer for existing controls system in the area of work.

Design each network of the DDC system to include at least 30 percent available spare bandwidth with the DDC system operating under normal and heavy load conditions. Calculate bandwidth usage and apply a safety factor to ensure that this requirement is satisfied when subjected to testing under worst-case conditions. Do not use an existing network controller that is at 70 percent capacity or greater. If DDC equipment is added to a controller which is below 70 percent capacity, it must not exceed 70 percent capacity once the equipment is installed. Reference the Communication & Electronic Systems DSM for more information.

Include spare processing memory for each new or replacement controller. RAM, PROM, or EEPROM will implement requirements indicated with the following spare memory:

- A. Network Controllers: Not less than 30 percent spare capacity.
- B. Programmable Application Controllers: Not less than 30 percent spare capacity.
- C. Application-Specific Controllers: Not less than 30 percent spare capacity.

New and replacement DDC Controllers shall include 20 percent spare I/O point capacity of each AI, AO, BI, and BO point. The minimum spare I/O Points per controller shall be:

- A. AIs: Three

- B. AOs: Three
- C. BIs: Five
- D. BOs: Five

All trend data shall be stored on an SQL database accessible by DEN staff.

When DEN maintained equipment is being removed by the tenant, designer is to provide DEN a matrix of which equipment and subsequent control points have been removed from the project, what is remaining to be re-used and what is new. **ASHRAE Guideline 36**

All EMCS front-end Graphics shall be MUI (MetaSys UI) compatible. Views and points for all areas shall be imported into MetaSys. All controls points no longer used, no matter the manufacturer, must be removed from the project by the temperature controls contractor. Designer is to include these requirements in the design documents.

High Performance Sequences of Operation for HVAC Systems provides designers with an industry-standard basis of design for implementing sequences of operation. Consultants are encouraged to consult the latest version of this document when designing sequences of operation. However, sequences designed by consultants shall be modified to take the unique project and site conditions into account, as well as legacy systems and controls at DEN. DEN Mechanical Engineers are available to answer questions and provide information about existing systems and controls sequences.

5.5.1 Sample Control Components and Requirements

5.5.1.1 VAV Terminal Unit Controls

- A. Zone temperature controls shall be designed to have a 5°F space temperature setpoint deadband between heating and cooling operation.
- B. In general, VAV controls shall be selected and configured for proportional control and not floating point control. Designers shall discuss any concerns (e.g., first cost impacts) or recommended deviations with a DEN Mechanical Engineer.
- C. VAV boxes with heating coils control shall be provided with a discharge air temperature sensor to be located downstream of the VAV box for temperature setpoint reset control.
- D. VAV box controls shall prohibit reheat or simultaneous heating and cooling operations per ASHRAE 90.1.
- E. Where reheat is required due to existing system limitations, the system may be designed to comply with the exceptions to ASHRAE 90.1 reheat restrictions. In these cases, reheat shall be minimized to the extent possible. Refer to [5.5.1.6.HVAC Control Functions](#).
- F. New devices must use the same controls manufacturer as the AHU for communication with the AHU. Designer to specify the controls manufacturer in the design documents.
- G. Terminal boxes must be included into existing logic sequence (voting for pressure, temperature, CO2, building pressure etc).

5.5.1.2 Unit Heaters Controls

Small unit heaters shall be controlled by cycling the fan on and off and controlling a two-way valve on the hot water coil. Large unit heaters, cabinet unit heaters and air curtains with heating coils shall run continuously while heating is required, and water flow to the coil shall be modulated to maintain the set space temperature. All modulating control valves shall be pressure-independent type.

- a. Split Systems- Fan Coil Units (FCU)

Where split systems are installed in critical spaces such as telecommunications and electrical rooms, the Facilities EMCS shall monitor the status of the fan coil unit fan and air-cooled condensing unit with the use of a current transformer and shall alarm the system in the event of a fan or compressor failure. The EMCS shall also monitor the room temperature. The fire alarm system shall stop fans. The split system shall run through factory controls based on the room thermostat.

Hydronic FCUs shall be utilized where design conditions permit. Small unitary FCU installations shall use 2-position control valves for hydronic coil control. Larger or multi-zone FCUs, or designs requiring finer flow control (e.g., for discharge temperature setpoint control) shall use modulating control valves. All modulating control valves shall be pressure-independent type. Hydronic control valves shall be located on the downstream side of cooling/heating coils.

In the event of a power loss, the FCU outside air dampers shall fail to the fully closed position. Return Air dampers shall fail to the fully open position. Heating Hot Water control valves shall fail to the fully open position, and Cooling Water control valves shall fail to the fully closed position.

5.5.1.3 Exhaust Fan

In general, exhaust fans should be interlocked with the building AHU and run continuously.

Exceptions include exhaust fans interlocked with MAUs, kitchen hoods, or point-of-generation exhaust for specific pollutants.

5.5.1.4 Pump Controls

Heating and cooling coils shall not utilize pumped coil loops for freeze protection.

5.5.1.5 Monitoring

Fire system monitoring or security provisions are not incorporated into the EMCS initially; however, provisions should be made to allow these features to be added should this requirement change.

Tenant controls system for HVAC and plumbing equipment need to have audio and visual alarms with placard reading "NOTIFY TENANT MAINTENANCE OF AN ALARM" or some other approved method for maintaining equipment in proper working order. Alarming would need to include but not limited to freeze protection, clogged filters, water detection, fan failure or equipment being shut-off when not in maintenance mode.

5.5.1.6 HVAC Control Functions

The AHUs and the spaces they condition shall be controlled by standalone, remote, automation control systems. These systems shall be located directly in areas of equipment. The microprocessor-based control system shall communicate with the EMCS through an Ethernet port interface via BACnet communication protocol and all other necessary equipment for proper signal-level reception and transmission. New devices must use the same controls manufacturer as the AHU for communication with the AHU. Designer to specify the controls manufacturer in the design documents.

The following control functions shall be programmed into the control system:

- A. Provide airside economizer controls to utilize free cooling when possible on all AHUs with a design capacity greater than 54,000 Btu/h (or current ASHRAE 90.1/IECC requirements, whichever is more stringent).
- B. VAV boxes are to be controlled by the temperature control system. The controller shall adjust the box's damper position based on the space temperature. VAV boxes with heating coils shall also reset discharge air temperature in a heating mode based on the space temperature signal.

- C. Variable air systems that have heating coils at the VAV terminal units shall be designed to control to the following sequences/reset schedules unless a clear need is demonstrated and alternate control sequence is approved by DEN Mechanical Engineer. Reset control examples are presented below. The engineer shall review the validity of the examples for use in design on a unit-by-unit basis.
- D. New VAV Boxes connected to a DEN AHU are to have the controls fully integrated into the Sequence of Operation and the EMCS including modifications to the Graphic screens.

5.5.1.6.1 AHUs

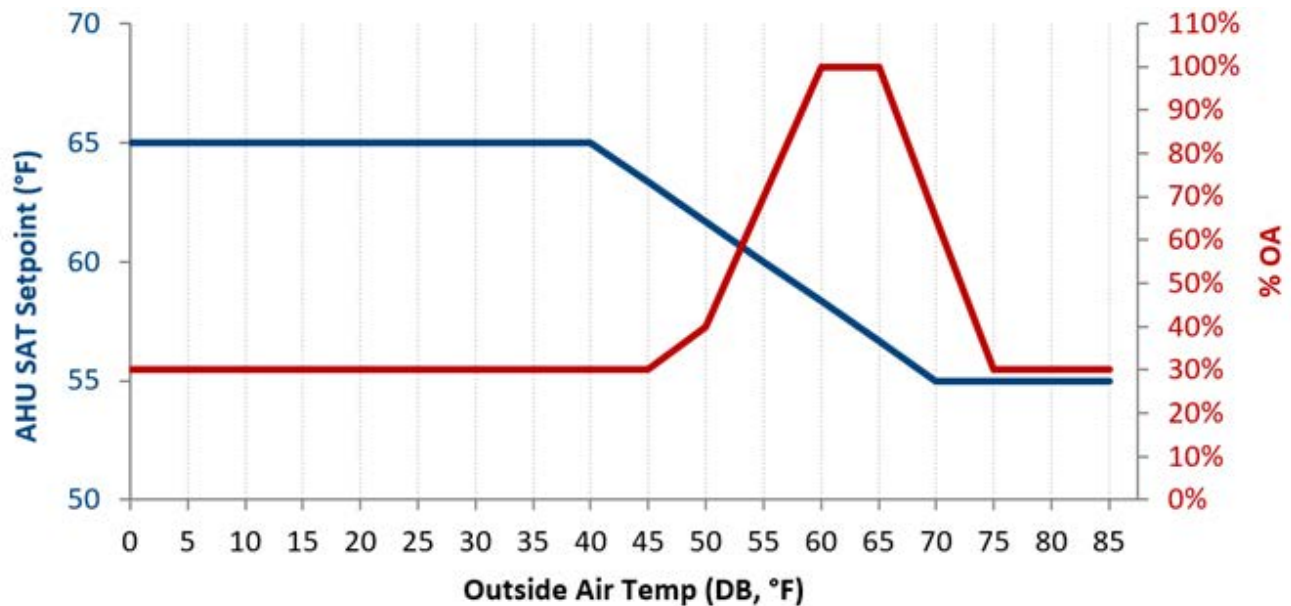


Figure 5.5-1: AHU Control

5.5.1.6.2 VAV Boxes

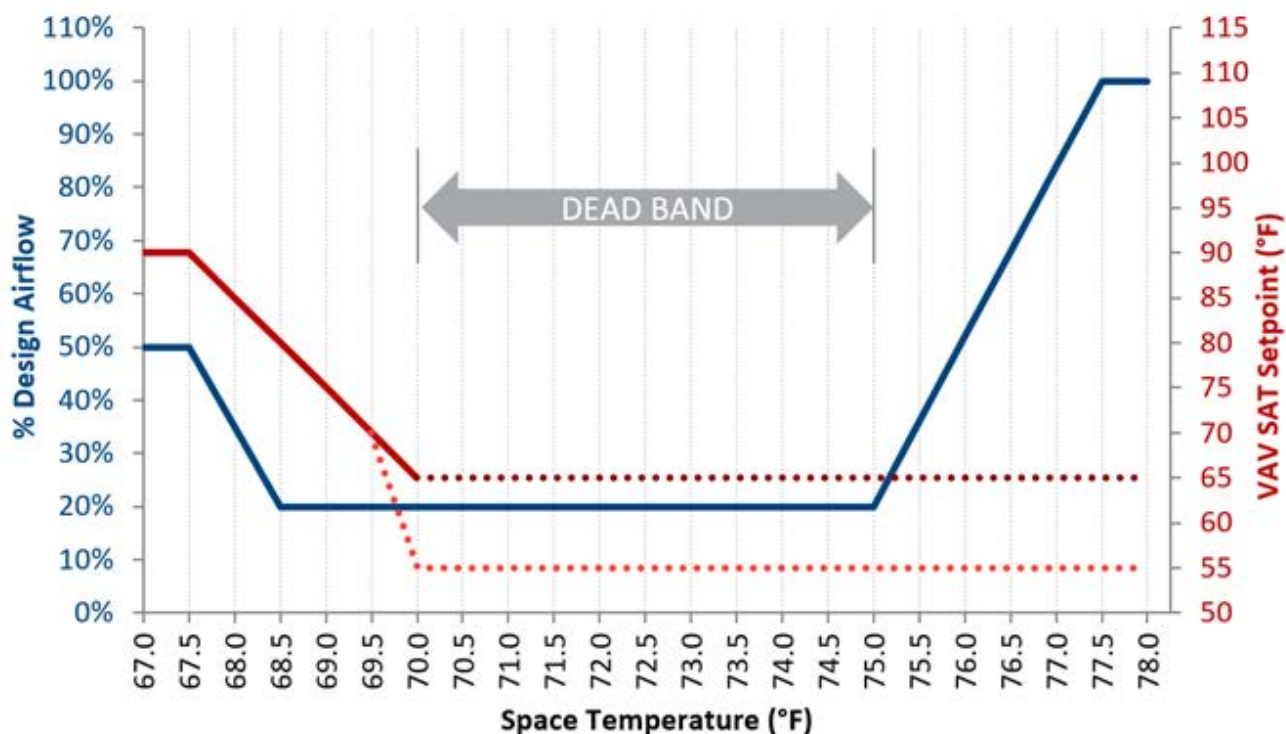


Figure 5.5-2: VAV Control

NOTE: Designs may require alteration of the minimum percent Design Airflow and/or percent OA setpoints shown above (indicated as 20% and 30%, respectively) for zones or AHUs to meet code-required minimum ventilation rates. Conversely, designs utilizing Demand Control Ventilation may warrant a reduction of these minimum setpoints.

5.5.1.7 Thermostats and Temperature Sensors

Thermostats are only allowed on unitary equipment that is not connected to the EMCS. Temperature sensors shall be provided in all other locations. All new temperature sensors shall be furnished with a service port for remote laptop connection to the unit controller and EMCS.

In areas of the airport accessible to passengers, thermostats and temperature sensors shall not have displays.

Thermostats and temperature sensors shall be mounted in accordance with all codes and standards adopted by the City and County of Denver. Additionally, thermostats and temperature sensors shall be located on surfaces that do not receive any direct sunlight, are not obstructed by furniture or other appliances, and are away from sources of heating or cooling which might impinge on their ability to accurately measure zone temperature. Designers shall use industry best practices when locating all sensors.

5.5.2 Sequence of Operation

The startup, operation, and shutdown of systems shall be sequenced in accordance with the general control sequences outlined in the Technical Specifications of the Mechanical Design Standards. Prior to the installation of a specific system, a specific and more detailed sequence of operations shall be developed for each type of HVAC, HV, or ventilation system. In these sequences of operation, specific points of measurement of temperature, humidity, pressure, etc., shall be designated.

Designer is to ensure accuracy of the Sequence of Operation and coordinate with any existing systems and equipment. Designer shall research and coordinate with the appropriate stakeholders until a thorough understanding of how existing systems and equipment operate. Construction documents are to include the integration of new and existing equipment operation into the Sequence of Operation.

5.5.2.1 Emergency Shutdown

Operating facilities with potentially explosive, toxic, or otherwise hazardous processes shall be equipped with emergency process shutdown panic buttons located at the main control panel and at all exits to the affected areas. Each HVAC system shall have a manual shutdown button per National Fire Protection Agency (NFPA) 90A located at a firefighter's emergency shutdown station.

5.5.2.2 Automatic Shutdown

Each HVAC system with 2,000 cfm or more capacity shall be equipped and arranged to automatically shut down fans (and close dampers on units larger than 15,000 cfm) in accordance with NFPA 90A, Denver Building Code Amendments, and initiate the fire alarm. Smoke detectors installed in HVAC ductwork shall be tested prior to acceptance for proper airflow and voltage sensitivity in the presence of the Engineer of Record. The shutdown circuit shall prevent the AHU from restarting until the smoke detectors have been reset by DEN's fire protection personnel. This test for proper operation shall be made with the AHU in all modes of operation.

Those units that are to be used for smoke removal shall be arranged such that no control function can shut down the unit fan and override the smoke removal function when activated.

5.5.2.3 Automatic System Restart

Equipment and associated factory-installed controls, field-installed controls, electrical equipment, and power supply connected to building normal and backup power shall automatically return equipment and associated controls to the operating state occurring immediately before the loss of normal power, without the need for manual intervention by an operator when power is restored either through a backup power source or through normal power if restored before backup power is brought online.

5.5.3 Controls Points Naming

5.5.3.1 General

Controls points in the EMCS front end shall be named in a consistent and informative way. Every point name shall indicate the equipment it is associated with and the function of the point itself. Each point name shall consist of the entire equipment tag, described in [5.1.2.Equipment Identification](#), and a standard abbreviation describing the function of the point. A list of all standard abbreviations used by DEN can be found in non-standard abbreviations must be approved in writing by DEN Mechanical Engineer.

Each point name must be unique. Because of this, smaller terminal equipment with non-supervisory controllers must include the abbreviated equipment name from their supervisory controller in their point names. Refer to [5.5.4.Non-supervisory Controller Point Numbering](#).

IP addresses for BACnet and LonWorks routers are not available to the public. Written approval from the DEN PM, DEN Mechanical Engineer, DEN Manager of Systems, and DEN Information Security is required to access this information.

Points for Tenant equipment shall be flagged in Metasys metadata as tenant points. Coordinate flagging requirements with the DEN EMCS administrator.

Designer must include the complete control points list along with naming from [5.5.3.2. Supervisory Controller Point Naming](#) and [5.5.4. Non-supervisory Controller Point Numbering](#) in the Construction Documents.

5.5.3.2 Supervisory Controller Point Naming

Naming for supervisory controller points shall include the name of the equipment associated with the point, followed by an abbreviation of the function of the point. A period shall separate the equipment name from the function abbreviation.

LLL_XX_LX_LLL_L (L)(_XX)	—	LLL	—	Abbreviation
(1)		(2)		(3)

L = Alphabetical character

N = Numerical character

For example, the point name for the discharge air temperature for AHU-B in the 4th floor mechanical room of Holdroom 7 West of Concourse B would be CCB_04_7W_AHU_B_TCP.DA-T. The effective discharge air temperature setpoint for the same unit would be CCB_04_7W_AHU_B_TCP.DAT-EFF-SP.

5.5.3.2.1 Equipment Tag

The first component of the point name shall be the equipment tag, as defined in [5.1.2. Equipment Identification](#).

CCB_04_7W_ AHU_B	—	TCP	.	DA-T

5.5.3.2.2 TCP Extension

AHU control panels are all tracked as separate sub-assets in the DEN Asset Management Program from the AHUs they control. Because of this, the abbreviation _TCP shall be added to the end of the equipment name when naming AHU control points.

CCB_04_7W_ AHU_B	—	TCP	.	DA-T

5.5.3.2.3 Function Abbreviation

The third component of the point name shall be the function abbreviation. A period shall separate the first three components of the point name from the function abbreviation. Abbreviations can be found in [Appendix A- Controls Points Abbreviations](#).

CCB_04_7W_ AHU_B	—	TCP	.	DA T

5.5.4 Non-supervisory Controller Point Numbering

Due to the sheer number of non-supervisory controllers at DEN (e.g., terminal device controllers such as VAV or UH controllers), additional information must be included to ensure each control point name is unique. Points for non-supervisory controllers will have four components as follows.

LLL_XX_LX_LLL	_	XXXLLL(L)	_	XX(L)	.	Abbreviation
(1)		(2)		(3)		(4)

L = Alphabetical character

N = Numerical character

For example, the point name for the occupied heating setpoint for ATH-05, located on the Mezzanine Level of Sub-core 6 West of Concourse B, served by AHU-B in the 4th floor mechanical room of Holdroom 7 West would be CCB_03_6W_VAV_047WAB_05H.OCC-HTG_SP. The discharge air temperature for the same unit would be CCB_03_6W_VAV_047WAB_05H.DA-T.

5.5.4.1 Equipment Tag

The first component of the point name shall be the equipment tag, as defined in [5.1.2.Equipment Identification](#). The numeric designator shall be removed from the equipment identification.

CCB_03_6W_VAV	_	047WAB	_	05H	.	OCC-HTG-SP

5.5.4.2 Equipment Controlled

The second component of the point name shall identify the equipment that the supervisory controller controls. This shall be an abbreviated version of the equipment tag for the supervisory controller's equipment. The building identifier shall be removed, along with all the underscores. The equipment abbreviation shall be shortened to the first letter of the abbreviation.

For example, the shortened abbreviation for AHU B located in the 4th floor mechanical room of Holdroom 7W of Concourse B would be shortened from CCB_04_7W_AHU_B to 047WAB.

CCB_03_6W_VAV	_	047WAB	_	05H	.	OCC-HTG-SP

5.5.4.3 Numeric Designator

The third component of the point name shall be the numeric designator of the equipment. The first 3 components of the point name shall be separated by underscores. In instances where there would be two sequential underscores, only a single underscore shall be used.

CCB_03_6W_VAV	_	047WAB	_	05H	.	OCC-HTG-SP

5.5.4.4 Function Abbreviation

The fourth component of the point name shall be the function abbreviation. A period shall separate the first three components of the point name from the function abbreviation. Abbreviations can be found in [Appendix A-Controls Points Abbreviations](#)

CCB_03_6W_VAV	_	047WAB	_	_	.	OCC HTG SP

5.5.5 Equipment Alarming

DEN has thousands of pieces of mechanical equipment controlled by the EMCS. Most of these pieces of equipment have alarms for various failure states in the EMCS. Because the EMCS software requires each individual alarm to be acknowledged each time it occurs, having every failure state alarm in the EMCS is not useful.

Only critical alarms that notify DEN maintenance users of situations which need to be addressed immediately shall be programmed into the EMCS. Critical alarms are at a minimum: controller communication error, low air temperature or freezestat trip alarms at make-up air units utilizing base building heating or chilled water systems, low heating water return temperature, device or sensor failure for any critical alarm point, etc. All critical alarms are to be trended in the EMCS. Designer to list out critical alarms in the construction documents. All other alarm states shall be trended in DEN's Fault Detection and Diagnostic (FDD) and Monitoring-Based Commissioning Software, SkySpark.

Alarms shall be designed and tuned to minimize nuisance alarming in both the EMCS and SkySpark. Alarms with latching components shall be designed and implemented such that the latching component of the alarm does not occur on a false positive tripping of the alarm. Industry-standard alarm sequences that are known to cause nuisance alarms and false positives at DEN include, but are not limited to Command/Status Mismatch alarms. Because ASHRAE Guideline 36 recommends these alarms latch, care should be taken while designing and implementing these alarms, in order to not lock out equipment unnecessarily.

The lists below indicate whether an alarm shall be programmed to alarm in the EMCS, or trended in SkySpark.

Note: to be trended in SkySpark, an alarm point needs to be trended in the EMCS software. However, any alarm points that are trended in SkySpark must also be trended in the EMCS software. DEN simply does not want nor need these points to alarm in the EMCS.

5.5.5.1 Alarms in the EMCS

The following alarms shall Alarm the EMCS front-end software. They should also be trended in SkySpark.

Table 5.5-1: Alarms in the EMCS

Air Curtain

Point Description	Occurrence	SkySpark	BAS
Controller	Communication Failure		X
Controller	Diagnostics		X
Air Curtain Fan	Device Failure		X
Room Temperature	Sensor Failure/Unreliable		X

Air Handling Unit - VAV, SZVAV, MAU or VSCF

Point Description	Occurrence	SkySpark	BAS
Controller	Communication Failure		X
Controller	Diagnostics		X
Outside Air Temperature	Sensor Failure/Unreliable		X
Pre-Filter	Sensor Failure/Unreliable		X
Filter	Sensor Failure/Unreliable		X
Mixed Air Temperature	Sensor Failure/Unreliable		X
Chilled Water Coil Water Pipes (EWT & LWT)	Sensor Failure/Unreliable		X
Hot Water Coil Water Pipes (EWT & LWT)	Sensor Failure/Unreliable		X
Supply Fan Array	Device Failure		X
Supply Fan Array	Communication Failure		X
Supply Air (Temperature)	Sensor Failure/Unreliable		X
Return Air Smoke Detector	Smoke		X
Supply Air Smoke Detector	Smoke		X
Duct Static Pressure	Switch Trip		X
Freezestat	Switch Trip		X
Carbon Monoxide (CO)*	Sensor		X
Natural Gas*	Sensor		X
Smoke Pressurization*	Life Safety Override		X

*For VSCF units only. Edit on a per-unit basis, depending on unit configuration and coordination with life safety systems.

Booster Pump

Point Description	Occurrence	SkySpark	BAS
Panel Power Loss	Device Failure		X
Pump Failure (qty. 3)	Device Failure		X
Pump Run Failure (qty. 3)	Device Failure		X
Pump VFD Fault (qty. 3)	Device Failure		X
Pump VFD Comm Fault (qty. 3)			

Fan Coil Unit

Point Description	Occurrence	SkySpark	BAS
Controller	Communication Failure		X

Fan Coil Unit

Point Description	Occurrence	SkySpark	BAS
Controller	Diagnostics		X
Condensate Overflow (as applicable)	Switch Trip		X
Supply Fan	Device Failure		X
Offline	Device Failure		X

VAV - Cooling Only

Point Description	Occurrence	SkySpark	BAS
Controller	Communications Failure		X
Controller	Diagnostics		X
Room Temperature	Communications Failure		X

VAV - Reheat

Point Description	Occurrence	SkySpark	BAS
Controller	Communications Failure		X
Controller	Diagnostics		X
Temperature Air Discharge	Sensor Failure/Unreliable		X
Room Temperature	Communications Failure		X

Relief Fan

Point Description	Occurrence	SkySpark	BAS
Relief Fan	Device Failure		X

5.5.5.2 Alarm Points Only Trended in SkySpark

The following alarms shall only be trended in SkySpark. None of the following alarms shall alarm in the EMCS Front-End software:

Table 5.5-2: Alarm Points Only Trended in SkySpark

Air Curtain

Point Description	Occurrence	SkySpark	BAS
Hot Water Water Control Valve	Device Failure	X	
Room Temperature	High Analog	X	
Room Temperature	Low Analog	X	

Air Handling Unit - VAV, SZVAV, MAU or VSCF

Point Description	Occurrence	SkySpark	BAS
Outside Air Temperature	High Analog	X	
Outside Air Temperature	Low Analog	X	
(Outside) Air Inlet Damper	Device Failure	X	
Air Return Damper	Device Failure	X	
Pre-Filter	High Analog	X	
Filter	High Analog	X	
Mixed Air Temperature	High Analog	X	
Mixed Air Temperature	Low Analog	X	
Chilled Water Control Valve	Device Failure	X	
Chilled Water Coil Water Pipes (EWT & LWT)	High Analog	X	
Chilled Water Coil Water Pipes (EWT & LWT)	Low Analog	X	
Supply Air (Temperature)	High Analog	X	
Supply Air (Temperature)	Low Analog	X	
Discharge Air Temperature Setpoint	High Analog	X	

Booster Pump

Point Description	Occurrence	SkySpark	BAS
Suction Pressure	High Analog	X	
Suction Pressure	Low Analog	X	
Suction Pressure	Sensor Failure	X	
System Pressure	High Analog	X	
System Pressure (3" & 6" Transducer)	Sensor Failure	X	

Reduced Pressure Backflow Preventer

Point Description	Occurrence	SkySpark	BAS
Valve Battery Alarm (qty. 2)		X	
RPBP General Alarm (qty. 3)		X	

Fan Coil Unit

Point Description	Occurrence	SkySpark	BAS
Chilled Water Control Valve	Device Failure	X	
Room Temperature	High Analog	X	
Room Temperature	Low Analog	X	

VAV - Cooling Only

Point Description	Occurrence	SkySpark	BAS
Room Temperature	High Analog	X	
Room Temperature	Low Analog	X	
Air Flow CFM	High Analog	X	
Air Flow CFM	Low Analog	X	
Damper Position (as applicable)	Device Failure	X	

VAV - Reheat

Point Description	Occurrence	SkySpark	BAS
Temperature Air Discharge	High Analog	X	
Temperature Air Discharge	Low Analog	X	
Room Temperature	High Analog	X	
Room Temperature	Low Analog	X	
Hot Water Control Valve	Device Failure	X	
Air Flow CFM	High Analog	X	
Air Flow CFM	Low Analog	X	
Damper Position (as applicable)	Device Failure	X	

Relief Fan

Point Description	Occurrence	SkySpark	BAS
Relief Damper	Device Failure	X	

Domestic Water Heater

Point Description	Occurrence	SkySpark	BAS
Recirculation Water Temperature	Low Analog	X	
Tank Temperature (as applicable)	Low Analog	X	

Exhaust Fan

Point Description	Occurrence	SkySpark	BAS
Fan Status	Device Failure	X	

End of Chapter

Chapter 6 - Hydronic Systems

5.6.0 Hydronic Systems

5.6.0.1 Existing Campus Heating/Cooling Systems Operation

Chilled water and heating water for the HVAC systems in the terminal buildings, AOB, and concourses are supplied from the CUP. Refer to [Chapter 2- Central Utility Plant](#) for overall systems and additional requirements.

5.6.1 Equipment

5.6.1.1 Chilled Water System

The DEN chilled water system shall not be used as condenser water for direct-expansion-unitary-type HVAC or refrigeration equipment without written approval from the Manager of DEC Systems Group. The only exception not requiring approval is low-temperature systems serving the PCA glycol system.

5.6.1.2 Hydronic Requirements

Chilled or heating water shall be sized for a maximum of 10 feet pressure drop per 100 feet of equivalent pipe for any run, but no more than an average of 4 feet pressure drop per 100 feet of equivalent pipe for the entire connected system. Circuit setters or balancing valves shall not be used for equipment isolation. Chilled Water coils shall be selected for a 16°F ΔT and Heating Water coils for a 40°F ΔT , at the following conditions:

- A. Hydronic design temperatures for primary loop (Central Utility Plant):
 - a. Chilled water supply temperature: 42°F with reset controls in cooler conditions potentially allowing up to 50°F
 - b. Chilled water return temperature: 58°F (will vary)
 - c. Heating water supply temperature: 220°F
 - d. Heating water return temperature: 170°F (will vary)
 - e. No glycol is used in the DEN primary loops
- B. Hydronic design temperatures for secondary loops (Terminal, AOB, Hotel and the Concourses):
 - a. Chilled water supply temperature: 42°F with reset controls in cooler conditions potentially allowing up to 50°F
 - b. Chilled water return temperature: 58°F (will vary)
 - c. Heating water supply temperature: 190°F
 - d. Heating water return temperature: 170°F (will vary)
 - e. No glycol is used in DEN secondary loops. Glycol systems only exist on secondary or tertiary loops when used in conjunction with a heat exchanger.

Design Consultant shall review system designs to ensure chilled water temperatures in secondary systems do not exceed 58°F. Temperatures in excess of 58°F cause problems with the operation of PCA plant equipment.

Design shall ensure that the minimal pipe length is achieved, and no unnecessary loops or branches are used. Piping shall be routed in the most direct route feasible.

Designs including flow meters or other devices requiring servicing shall be located such that access to these devices is below 10'-0" AFF.

Flexible hydronic piping shall not be used in heating and chilled water hydronic systems.

5.6.1.3 Tenant Loops

When not defined in the record documents, no more than 20 GPM of chilled or heating water shall be used for any Tenant in the existing Concourses. Connections shall only be made to the base building Tenant hydronic loops when they exist. Tenant loop connections are located at each central core and concourse subcore on the apron level. Other locations will be approved in writing by the DEN Mechanical Engineer on a case-by-case basis with supporting system flow analysis. Systems shall not be deemed to have adequate capacity for connections at any location there is not an existing valved connection.

When tenant spaces are designed for future use (e.g., grey box) with no terminal equipment installed and connections for future systems are provided, the final contract documents shall indicate the maximum allocated water flow (gpm) and design pressure (PSIG) for each connection in each space.

For any new Tenant service, a digital BTU meter on each hydronic service entrance to the Tenant lease area shall be installed. The meter shall be in an accessible area within the Tenant lease area. The meter shall have native BACnet communication for future connection directly to the DEN EMCS.

5.6.1.4 Piping and Valves

Control valves shall be sized for the correct and appropriate Cv value at the design flow rate. All valves shall be suitable for extended service operation without extensive requirements for lubrication or servicing. Control valves shall be pressure-independent valves manufactured by either Flow Control Industries Delta-P Valves or Johnson Controls VP140 series valves. Valves and actuators used on the CUP distribution side (230°F heating water temperature) are to be rated for a minimum of 250°F; valves and actuators on the building side (190°F heating water temperature) are to be rated for a minimum of 212°F.

Many of the existing butterfly and ball valves no longer positively close and seal. Designer to anticipate that valves 2-1/2" and larger that are original will need to have line stops installed and the defective valves replaced. Verify location with the DEN Mechanical Engineer.

Mechanical grooved piping and fittings shall not be used for hydronic systems and should not be considered for value engineering options. Due to the operating system temperatures and system movement, mechanical grooved connections have been problematic for maintenance.

Press-fit, or push-on types of piping systems and connectors shall not be used for any hydronic or plumbing system.

Flanged connections are allowed only at valves and connections to equipment (pumps, coils, etc.). Flanged connections shall not be used in other locations.

No piping shall be routed through/across the AGTS tunnel.

Isolation valves are required at all equipment and branches. Ball valves, gate valves, or butterfly valves should be rated for the temperature and pressure of the line. Valves shall be added before and after any control valves, strainers, air vents, coils, etc., for service. Equipment in series with no branches may all be isolated by a single pair of isolation valves.

5.6.2 Design Criteria

5.6.2.1 General Requirements

Piping layout and sizing shall be done using the best practices to ensure minimum energy loss by thermal transfer and friction. The hydronic systems design shall be based on the following criteria:

- A. Piping shall be designed in accordance with the technical criteria in other sections of this DSM. Water pipe sizing shall be based on the stricter of the two following parameters unless code requirements overrule:

Table 5.6-1: Water Piping Sizing

Pipe Size	Max. Velocity (fps)	Max. Pressure Drop* (ft per 100 ft pipe)
up to 2"	4	8.5
2-1/2" thru 6"	6	4.5
8" thru 12"	8.5	2.5
14" thru 20"	10.5 (14)**	2.5
24" thru 42"	11.0 (14)**	1.5

**Based on new, clean steel pipe*

***Number in parenthesis is velocity limit applicable to long straight runs where noise is not critical (such as pipe tunnels, etc.). Maximum pressure drop still applies.*

- B. Due to availability issues and relative cost, 5-inch piping and valves shall not be used.
- C. Pressure drops in piping systems shall be calculated to allow for aging and corrosion of the interior surface. Therefore, all water piping systems shall be designed with the following friction factors (C values) based on the Hazen-Williams Friction Factor formula.

Table 5.6-2: Water Piping Friction Factors

System Type	C Value
Closed water	120
Closed, treated	130
Open water	100
(New clean steel pipe)	(140)

- D. Hot and chilled water distribution systems should be designed for variable volume flow.
- E. Hydronic systems should be designed for the widest practical ΔT and the closest possible approach of the return water temperature to the terminal equipment supply air temperature, but not exceed temperatures listed in this section.
- F. The terminal equipment must be selected not only for its full load capacity but also for its performance over the full range of partial loads. Laminar fluid flow in the coils shall be avoided.
- G. Integral face and bypass coils should be utilized with preheat coils.
- H. Coils subject to 100% outside air at winter design conditions shall be protected by one of the following methods:
- Provide propylene glycol in the water loop serving the AHU coils for any unit with 100% outside air capacity at winter conditions. These units must not be equipped with protective override controls to shut off the fan if the freezing condition is determined when operating for smoke removal. The glycol-water loop for this system is to be linked to the main heating hot water system through a plate and frame-type heat exchanger.
 - For those units not arranged for smoke removal use, provide freeze protection thermostats on the coil face to shut down the unit fan and close any Outdoor Air dampers if a freezing condition is detected. Outdoor Air dampers shall fail closed. Outdoor Air dampers typically used for HVAC can't

- fully restrict all of the freezing air coming into the equipment even with the fan shut off. The designer is to include sequences of operation needing to take place during freeze protection operation such as flowing water through the heating and cooling coils.
- c. DEN has the following recommendation for Tenants: Tenants with hydronic coils subject to 100% outdoor air are at a higher risk of freezing these coils. DEN recommends more robust methods of freeze protection to be used. This could include DX for cooling. If there is electrical capacity, DEN recommends using heat pumps for heating with supplementary electric resistance coils for extremely low outdoor air temps. Another option is to use a secondary hydronic loop with glycol, connected to the primary hydronic systems via heat exchanger. Tenants may opt to use DEN's hydronic system for 100% outdoor air heating and cooling, provided they accept the extra risk this entails. Pumped coils shall not be used as a means of freeze protection.
 - I. The impact of the change in volume due to the thermal expansion of the distribution system fluids during all operations must be addressed in the design process. Expansion loops shall be used to compensate for the impact of thermal expansion. Other methods of thermal expansion compensation shall only be allowed with written permission from DEN Mechanical Engineer.
 - J. Control valves in hydronic systems must not be oversized. The flow characteristics and pressure drops are to be selected for the appropriate Cv value corresponding to the design flow to be controlled.
 - K. Provide automatic air vents at all coils and at the high points of all piping. Provide drains at the low points of all piping.
 - L. Hydronic systems controls shall be automatic and adjustable to optimize pumping and thermal efficiency.
 - a. When close control is essential, use two-way pressure-independent control valves.
 - b. Three-way valves shall not be used on any system directly connecting the CUP hydronic system.
 - c. When using three-way valves for throttling, avoid pressure under one port being significantly higher than under the other.
 - d. Use mixing three-way valves with caution for flow diversion or diverting valves for mixing since the valves have tendencies to slam shut at reduced flows.
 - e. Use two-way valves at terminal coils in variable flow systems.
 - f. Hot water coil valves shall fail to the open position.
 - g. No coil or heat exchange device shall be run wild or without a control valve.
 - M. When designing piping supports, roller hangars, and supports shall only be used with written permission from DEN Mechanical Engineer.

5.6.3 Piping Supports

5.6.3.1 Design

All piping supports shall be manufactured systems or designed and detailed by a Colorado Registered Professional Engineer. Supports shall be coordinated with Architectural and Structural disciplines and completely detailed for connection to the structure.

Under no circumstances shall the construction documents direct a Contractor to provide supports without detailed performance specifications outlining the criteria and requirements of supports and their design and installation.

5.6.3.2 Products

Cable or wire piping supports and/or anchors shall not be used.

5.6.4 Existing Systems

5.6.4.1 Hydronic Requirements

Hydronic heating and cooling availability varies from area to area in the concourse and Terminal. Many concourse sub-core locations contain tenant hydronic loops within the lease area. In general, these systems are sized for 20 gpm (heating and cooling) for each original lease area.

Existing heating water loops for perimeter VAV shall not be used for Tenant space conditioning without a complete heating water system analysis and verification of capacity. The analysis shall be accepted in writing by the DEN Mechanical Engineer.

The Tenant shall furnish and install a digital BTU meter on each hydronic service entrance to the Tenant lease area. The meter shall be in an accessible area within the Tenant lease area. The meter shall have native BACnet communication to connect directly to the DEN EMCS. Tenant is to route communications conduit from Electric metering and HVAC/Plumbing Meters back to the nearest DEN controlled COMM room. Tenant is to provide a pull string to nearest DEN comm room and cap according to the Tenant DSM Volume 3 Section 3.2.1.5 Low Voltage DEN Submetering. Label conduit at both ends with location served.

Provide isolation valves on the supply and return of each hydronic system serving the Tenant lease area. The valves shall be in an accessible area within the Tenant lease area.

5.6.5 Update of Standard Diagrams

5.6.5.1 Flow Diagrams

DEN currently maintains hydronic flow diagrams of all buildings, which shall be used on any project that modifies the hydronic arrangements in these facilities. These diagrams are being updated and may not be complete but are available from the DEN Mechanical Engineer. Consultants shall submit any modifications to these diagrams directly to the DEN Mechanical Engineer at the Issue for Construction and Record Documents phases of the project independently of any other required submittal.

All new flow diagrams shall be developed using the existing diagrams as guidelines. Consultants shall submit any new diagrams to the DEN Mechanical Engineer at the Issue for Construction and Record Documents phases of the project independently of any other required submittal. Submittals are to be in Revit; refer to the Digital and Facilities Design Standards Manual for specific BIM requirements.

End of Chapter

This page is intentionally blank.

Chapter 7 - Space Requirements and Maintainability

5.7.0 Space Requirements and Maintainability

5.7.0.1 General

All DEN equipment in Tenant Spaces (generally just perimeter VAV boxes) must conform with Mechanical DSM Chapter 7- Space Requirements and Maintainability. Designer is to include a clear visual representation of areas of clearance and accessibility around all equipment. Tenant Equipment is encouraged to follow these design principles but is not required to.

In general, for DEN Perimeter VAVs, Tenant must provide and model maintenance access down to finished floor. Where DEN Perimeter VAVs are installed above hard ceilings, a 24-inch x 24-inch access panel or larger is required in the ceiling. DEN personnel shall not be required to move or modify tenant equipment or furnishings to access DEN equipment. All elevated DEN-equipment must be ladder-accessible.

For tenant equipment and ductwork that may be in the tunnel and/or basement areas, designer it to include 7'-8' clearance for Fire Department access in tunnels and basements. Designer is to include allowances for fire sprinklers that will be located under mechanical duct and equipment. See the Architectural DSM for more information.

End of Chapter

This page is intentionally blank.

Chapter 8 - Plumbing Requirements

5.8.0 Plumbing Requirements

5.8.0.1 General

This section applies to the systems used to receive, transport, or discharge liquid waste or sewerage; the systems used to receive and distribute potable water; the systems used to receive and distribute fuel gas; and the systems used for the collection and transport of rainwater and cooling coil condensate drains, etc.

5.8.0.2 System Requirements

Facilities for the physically disabled shall be provided in all public building restrooms.

- A. All domestic hot and cold water piping and designated storm drainage piping within conditioned areas shall be insulated. The Design Consultant shall use the best practices to ensure pipes do not freeze. Heat trace systems are not considered best practices and shall only be considered when no other option exists.

5.8.1 Plumbing Design Parameters

5.8.1.1 General

Projects required to have a Sewer Use and Drainage Permit (SUDP) require the engineer of record to perform site inspections and obtain photographic documentation necessary to verify installation conformance to the approved plans and specifications. Engineer is to submit documentation along with a cover letter signed and sealed from the engineer of record attesting to the installation and submit to the DEN Project Manager for Contract Director approval and submission to the Authority Having Jurisdiction.

5.8.1.2 Calculations

Design calculations shall be based on the latest editions of the ASPE Data Book, ASHRAE 90.1, and the Denver Amendments to the International Code Series. Recognized acceptable engineering practices shall be applied for areas where design criteria have not been established specifically by these codes and standards.

When using the International Plumbing Code (IPC) water fixture unit calculation method, only the flushometer table for conversion to flow rate shall be used since all concourse and terminal domestic water mains ultimately connect to public restrooms.

Several areas of the terminal and concourses experience dramatic pressure fluctuations. The engineer shall make every effort to ensure that new designs do not amplify current conditions. In these areas, static and dynamic pressure calculations shall be performed and submitted.

To avoid excessive system noise and the possibility of erosion-corrosion, flowrates shall not exceed flow velocities of 8 fps for cold water and 5 fps in hot water up to 140°F.

No assumptions shall be made on plumbing system capacities. All connections to existing plumbing systems shall have capacity calculations proving capacity. The design consultant shall submit all calculations directly to the DEN Mechanical Engineer in PDF format.

As of 2014, Denver Water maintains a domestic water supply pressure of 65 psi. This is 5 psi lower than the original airport system design.

5.8.1.3 Grease Traps

Grease traps shall be required from fixtures and equipment with grease-laden waste located in food preparation areas. Grease traps are installed at all subcore of the concourses and many of the quadrants of the center cores. Two grease traps exist in the terminal, one serving each side of the facility.

As of 2014, the capacities are:

Table 5.8-1: Grease Trap Capacities

Tag	Building	Max Flow (gpm)	Capacity (gal)
A-18	Concourse A	100	2,500
A-24	Concourse A	100	2,500
A-31	Concourse A	100	3,000
A-38	Concourse A	100	2,500
A-39	Concourse A	100	2,500
A-40	Concourse A	100	2,500
A-41	Concourse A	100	2,500
A-49	Concourse A	100	3,000
A-71	Concourse A	100	2,500
B-12	Concourse B	100	2,500
B-22	Concourse B	100	2,500
B-28	Concourse B	100	2,500
B-29	Concourse B	100	2,500
B-37	Concourse B	100	2,500
B-39	Concourse B	100	2,500
B-44	Concourse B	100	2,500
B-45	Concourse B	100	2,500
B-52	Concourse B	100	2,500
B-53	Concourse B	100	2,500
B-80	Concourse B	75	1,500
B-88	Concourse B	75	1,500
B-63	Concourse B	100	2,500
C-27	Concourse C	100	2,500
C-30	Concourse C	100	2,500
C-31	Concourse C	100	2,500
C-39	Concourse C	100	2,500

Table 5.8-1: Grease Trap Capacities (Continued)

Tag	Building	Max Flow (gpm)	Capacity (gal)
C-38	Concourse C	100	2,500
C-41	Concourse C	100	2,500
C-40	Concourse C	100	2,500
C-48	Concourse C	100	2,500
C-49	Concourse C	100	2,500
C-54	Concourse C	100	2,500
C-57	Concourse C	100	2,500
C-62	Concourse C	100	2,500
C-63	Concourse C	100	2,500
T-East	Terminal	75	1,500
T-West	Terminal	75	1,500

As of 2016, flow/capacity diagrams have been developed to track system usage. These diagrams are available from the DEN Mechanical Engineer but are to be verified in the field for discrepancies in the area of work. Design Consultants shall submit any modifications to these diagrams directly to the DEN Mechanical Engineer at the Issue for Construction and Record Documents phases of the project independently of any other required submittal.

All new flow diagrams shall be developed using the existing diagrams as guidelines. Consultants shall submit any new diagrams to the DEN Mechanical Engineer at the Issue for Construction and Record Documents phases of the project independently of any other required submittal. Submittals are to be in Revit; refer to the Digital and Facilities Design Standards Manual for specific BIM requirements.

Grease interceptors shall be sized in accordance with the procedures established by the Denver Wastewater Management Division.

Undersink/counter interceptors are not allowed when a grease waste line exists within a reasonable distance from the appliance. Undersink/counter interceptors shall only be used with written approval from the DEN Mechanical Engineer.

All grease interceptors (excluding allowed under sink/counter-type grease interceptors) shall be installed below grade. All manhole and cleanout covers shall be located at the grade or finished floor.

All grease interceptors shall be installed outdoors, except with written permission from DEN Mechanical Engineer. Any grease interceptors installed indoors (excluding allowed undersink/counter-type grease interceptors) shall be installed in rooms with exterior access doors.

Parking for interceptor grease removal vehicles shall be no more than twenty (20) feet from the furthest grease interceptor manhole. Vertical distance from the bottom of the grease interceptor to the grade level of the parking space shall be no more than twenty (20) feet.

Grease waste removal hose drag route shall not be through any public area except parking lots. Hose drag route may be through no more than one (1) door.

5.8.1.4 Floor Drains

Buildings shall be provided with floor drains that have traps and cleanouts.

Mechanical rooms shall contain general area floor drains and equipment drains for condensate and other miscellaneous drainage. Equipment drains shall not serve dual duty. Equipment drains shall be located to minimize pipe runs to the drain and minimize potential tripping hazards due to floor-supported piping.

All floor drains in chases, basement areas, restrooms, mechanical rooms, and entry vestibules shall have trap primers.

5.8.1.5 Cleanouts

Where a horizontal drainage pipe, a building drain, or a building sewer has a change of horizontal direction greater than 45 degrees (0.79 rad), a cleanout shall be installed at the change of direction. Where more than one change of horizontal direction greater than 45 degrees (0.79 rad) occurs within 40 feet of the developed length of piping, the cleanout installed for the first change of direction shall serve as the cleanout for all changes in direction within that 40 feet of developed length of piping.

The location and types of all cleanouts shall be noted on the drawing. All drains exiting the building shall have a double cleanout so that the drain line may be cleaned into and out of the building.

All cleanouts for Tenant waste piping shall be located within the Tenant lease area.

5.8.1.6 Industrial Waste

Industrial waste sewer shall be provided for areas where fueling of aircraft and vehicles takes place.

5.8.1.7 Backflow Prevention

The potable water supply system shall be designed, installed, and maintained in such a manner as to prevent contamination from non-potable liquids, solids, or gases being introduced into the potable water system through cross-connections or any other connections to the system. Protective measures and the requirement for backflow prevention devices shall meet or exceed the requirements of the IPC, Denver Building Code Amendments, and the requirements of the water utility, Denver Water. If there is any conflict between these requirements, the most stringent requirement shall apply in the design and/or modification to the existing potable water system. Should existing systems be found that do not comply with the latest backflow prevention requirements, the design will include upgrading the backflow prevention of that system being renovated, added to, and/or constructed. All domestic water connections to mechanical, plumbing, and fire protection systems, including lawn sprinkling systems, shall be protected from backflow by use of backflow preventers installed in the piping. Plumbing designs shall meet best management practices for cross-connection control.

At building or building zone main service entrances, provide two backflow preventers in parallel with lockable shutoff valves for primary and backup operations. Each backflow preventer shall be sized for full-service flow.

Separate backflow prevention is required on all potable water piping inside tenant spaces. Backflow prevention shall meet the requirements of IPC for backflow prevention. Single check valves shall not be used. Provide an isolation valve upstream of the backflow prevention device.

5.8.1.8 HVAC Coil Condensate Drains

Coil condensate drains shall have properly sized condensate traps and shall be fully detailed in the contract documents. Condensate pumps shall only be used with written permission from the DEN Mechanical Engineer. General condensate drain trap details without a schedule of sizing are prohibited. Trap sizing by the contractor is also prohibited.

Condensate discharge to be routed to a code approved place of disposal. Discharge of HVAC coil condensate to the exterior is not allowed without written permission from the DEN Mechanical Engineer.

When Code requires a secondary method of condensate drain protection, manufacturer-furnished overflow drains with properly sized condensate traps shall be fully detailed in the contract documents. Pumped condensate and water level detection alternatives are prohibited. Secondary Condensate Drain pans may only be used when a manufacturer overflow is not available.

Wherever units equipped for cooling service are installed above facilities, such as electrical power equipment, computer equipment, data server or telecommunications equipment, or other electrical or electronic equipment susceptible to malfunction if exposed to water, Contractor shall provide a supplemental drain pan to serve as additional protection against leakage, overflow, or other failure of the primary drain pan normally comprising a part of the air conditioning equipment. Supplemental drain pans are to be constructed of 20 gauge (minimum) galvanized steel, with a minimum depth of 2 inches, fabricated, braced, and supported so as to ensure stability. Secondary condensate drain pans shall not interfere with other maintenance and access requirements detailed in this Design Standards Manual.

All overflow drains that are required to terminate with an open site shall have signs with directions on procedures for notification of maintenance control.

5.8.1.9 Secondary Condensate Drains

When the code requires a secondary condensate drain from HVAC equipment coil drain pans, manufacturer-furnished overflow drains should be used. Secondary drain pans shall only be used when no option exists from the manufacturer.

Secondary drain pans shall be fully design and detailed on the contract documents. No component of the drain pan shall be left to the contractor's discretion. Details shall accommodate the following:

- A. Easy removal of the secondary pan for maintenance of equipment.
- B. Secondary pans shall be supported independently of HVAC equipment.
- C. Structural supports and connections to the building structure.
- D. Dedicated piping from the drain pan to an open site location. Open site termination shall include signage defining procedures in the event of a leak. Sign shall read, "If water is observed from the pipe below, immediately contact Maintenance Control at (303) 342-2800".
- E. Drain pan shall not block or inhibit access to surrounding systems.

Pumped primary or secondary pans and leak detection alternatives are prohibited.

5.8.2 Plumbing System Components

5.8.2.1 General

- A. Electric (instantaneous type or small storage tank) domestic water heaters shall be provided at each toilet room. No central domestic hot water system is provided in the Terminal Building Complex or in the Concourses.
- B. All potable water piping to Tenant lease areas shall be furnished with a digital water meter on the potable water service entrance to the Tenant lease area. The meter shall be in an accessible area within the Tenant lease area. The meter shall have native BACnet communication to be able to connect directly to the DEN EMCS.
- C. Exterior grease traps shall be provided for fixtures in kitchen and food service concessions areas as these facilities may require.

- D. All water supply to fixtures shall be protected by an approved vacuum breaker.
- E. A detailed area chart/plan shall be prominently displayed in the main equipment rooms showing the locations of all main piping and valves. The Design Consultant is to include this as a Contractor requirement.

All domestic hot and cold water and storm drainage piping within conditioned areas shall be insulated. All piping subjected to freezing temperatures shall be insulated and protected from freezing as appropriate.

5.8.2.2 Plumbing Fixtures and Equipment

- F. Stop valves shall be provided on all fixtures, including water coolers.
- G. All fixture types shall be in the design documents and called out on the contract drawings.
- H. All water coolers in public areas shall be barrier-free bi-level type and include a bottle fill station on the lower cooler.
- I. Roof vents (DWV) shall be of 3-inch diameter minimum.
- J. Drains from service and slop sinks shall be a minimum of 3-inch diameter.
- K. Minimum potable water line size shall be 3/4-inch except for branch to fixture, which may be 1/2-inch.
- L. Air admittance valves shall not be used unless approved in writing by the DEN Mechanical Engineer. Only continuously piping island fixture vents (aka, foot vents) as described by the IPC shall be used.
- M. All traps shall be protected in accordance with the IPC. Trap protection products are allowed but require written permission of the DEN Mechanical Engineer before inclusion into design. Sure Seal and similar products may be provisionally allowed, Trap Guard and similar products are prohibited.
- N. Due to availability issues and relative cost, 5-inch piping and valves shall not be used.

5.8.2.3 Piping

Refer to the specifications for pipe material types. Due to continuing issues with cast iron waste piping degrading and leaking, all sanitary and grease waste piping above grade is to be epoxy coated cast iron. See Chapter 12, Section 221316. PVC shall not be used inside the building above grade without written permission of the DEN Mechanical Engineer. Cast iron shall not be used for underground piping.

All sanitary sewer piping shall slope at no less than 1/4" per linear foot (2.08%) for allowance of future low-flow fixtures.

Design shall ensure that the minimal pipe length is achieved and that no unnecessary loops or branches are used. Piping shall be routed in the most direct route feasible. No piping shall be routed through/across the AGTS tunnel.

Minimum size of piping is 2" in diameter for sanitary and grease waste and vents.

Press-fit, or push-on types of piping systems and connectors shall not be used for any hydronic or plumbing system.

5.8.2.4 Plumbing Pumps

All plumbing pumps shall have manual isolation on each side of the pump. An electrical disconnect shall be located within fifteen feet of the pump unless dictated otherwise by Code.

5.8.2.5 Plumbing Sumps

Plumbing sumps larger than three (3) feet in diameter and two feet deep shall be constructed of cast-in-place or precast concrete. Plastic or FRP sumps shall not be used in below-ground sumps due to the highly expansive nature of DEN soils. All sumps shall be fully detailed and coordinated with structural and civil engineers.

5.8.2.6 Heat Trace Systems

Electric heat trace is not a preferred method of thermal protection of piping. When heat trace is required and approved in writing by the DEN Mechanical Engineer, the entire system limits shall be detailed on the contract drawings, completely specified in the contract documents, and completely coordinated with other disciplines for electrical load and maintenance access. No portion of system design shall be left to the Contractor.

Plumbing Drawings shall include the following:

- A. Location of heat trace control panel and audible/visual alarm.
- B. Location of alarm signage and detailed requirements of alarm procedures.
- C. Limits of piping to be heat traced.
- D. Control diagram showing interface with DEN EMCS, sequence of operation including all devices, and complete points list.

5.8.2.6.1 Tenant Use of Heat Trace Systems

No tenant domestic water shall be exposed to freezing temperatures, even with heat trace systems.

5.8.3 Energy Conservation in Plumbing System Design

5.8.3.1 Domestic Hot Water

Hot water for domestic water use shall be designed in accordance with ASHRAE 90.1-2010 Section 7 and OSHA requirements. ASHRAE 90.1 establishes minimum requirements for hot water generator recovery efficiency, storage tank insulation, pipe insulation, temperature controls, pump operation, equipment automatic shutdown, and conservation of hot water.

5.8.3.2 Temperature

The domestic hot water serving five (5) or more fixtures or the furthest fixture is more than 30 feet from the water heater shall have a circulation loop with a temperature-controlled circulation pump. Domestic hot water shall be circulated to maintain a temperature of 122°F.

5.8.3.3 Safety Devices

Safety devices shall be provided on the hot water generators and storage devices. Safety devices shall be as required by code and, as a minimum, shall include energy cut-off devices, relief valves, and/or temperature or combination temperature and pressure relief valves.

All water heaters, regardless of size, shall have an expansion tank on the domestic cold water inlet.

5.8.4 Natural Gas

5.8.4.1 Sizing

Gas piping shall be sized per the requirements of the International Fuel Gas Code, CCD Amendments to the code, and local Gas Utility. Additional criteria:

- A. Gas specific gravity: 0.65
- B. Gas thermal capacity: 834 BTU per cubic foot

5.8.4.2 Metering

Metering and pressure regulation for all buildings shall comply with the requirements of Xcel Energy. Contact the DEN PM to coordinate the current requirements.

Natural gas service for concourse Tenants will be connected from the metered area designated by DEN. The Designer shall coordinate gas and meter requirements with the local gas utility. Historically, tenants in the Terminal connect to a DEN provided gas line close by and sub-metered/billed by DEN to the tenant. Verify with the DEN Mechanical Engineer prior to design.

All gas requirements (demand and pressure) shall be shown on the drawings.

5.8.4.3 Gas Systems Protection

Architect and Engineer of Record for design of facilities shall design protective measures for all gas piping systems at DEN. All gas piping above grade, both upstream and downstream of meters, shall be protected. Protection and access for all utility equipment shall be coordinated with Xcel Energy.

All gas piping, meters, pressure regulators, appurtenances, and systems shall be fully protected from possible collisions with vehicles, baggage cart tugs, support equipment, etc. To the greatest extent possible, gas systems shall be located away from areas where it is possible for vehicles and/or equipment to strike it directly and/or indirectly through adjacent walls that offer inadequate protection from such vehicle strikes. Standard CMU walls and concrete curbs do not provide adequate protection, as can be seen from the photos below. In addition, gas systems shall be protected from grade level to ceiling, as strikes can occur at nearly all elevations that are not either protected and/or concealed in ceilings.

Gas piping, meters, pressure regulators, appurtenances, and systems exposed to aircraft apron areas shall be fully protected all the way from grade level to the bottom of the soffit level.



Figure 5.8-1: Concourse B: Tug Damage to Wall



Figure 5.8-2: Gas Piping Strike: Side and Front Views

5.8.4.4 Sustainability

As a part of the City and County of Denver’s Office of Climate Action, Sustainability, and Resiliency (CASR), the Energize Denver Ordinance, which establishes energy use intensity targets for buildings over 25,000 sq. ft. DEN is working to reduce our carbon emissions impact. As such, no new gas-fired equipment or fixtures, except for kitchen cooking equipment (stoves, ovens, etc.), shall be installed at DEN without written permission from the DEN Mechanical Engineer.

Gas fireplaces are not allowed at DEN.

5.8.5 Tenant Remodel Requirements

5.8.5.1 Plumbing Requirements

Tenant plumbing fixtures and piping systems, including all rough-in and final connections, shall be furnished and installed by the Tenant. Plumbing fixtures and accessories shall be of commercial quality and shall use best practices in water conservation. All plumbing systems shall be installed in accordance with the IPC and local plumbing codes. No plastic piping is permitted above the Tenant’s ceiling, in a return air plenum, or below a floor. Plastic Piping is only allowed in below-ground applications and as indicated in section [5.8.2.3.Piping](#).

Indicate on floor plans the routing and size of beer and soda conduits.

Domestic water shall be sized by fixture units and the curve for flush valves per the DDS. The Tenant shall provide a domestic cold-water branch from the main located in the pump/water service entry room when service is not available in the lease area.

5.8.5.2 Grease Waste

Food Service Tenants shall connect all grease waste to designated grease waste lines. Flow and capacity diagrams of all existing grease interceptors are available from the DEN Mechanical Engineer but are to be verified in the field for discrepancies in the area of work. Refer to the Standards and Criteria DSM for master diagram requirements. All new flow diagrams shall be developed using the existing diagrams as guidelines. Consultants shall submit any new diagrams to the DEN Mechanical Engineer at the Issue for Construction and Record Documents phases of the project independently of any other required submittal. Submittals are to be in Revit; refer to the Digital and Facilities Design Standards Manual for specific BIM requirements.

5.8.5.3 Water Heaters

Provide electric water heaters when water heaters are required. Gas-fired water heaters may be used *only* with written acceptance of the DEN Mechanical Engineer and verification there is the adequate volume in space for combustion air and an accessible route for the flue. See [5.8.4.4.Sustainability](#) for reducing carbon emissions at DEN.

All water heaters shall have an expansion tank, regardless of the water heater size.

For increased efficiency, heat-pump water heaters shall be considered.

5.8.5.4 Water Meters

The Tenant shall furnish and install a digital flow meter on the water service entrance to the Tenant lease area. The meter shall be in an accessible area within the Tenant lease area. The water meter shall have native BACnet communication to be able to connect directly to the DEN EMCS. See DEN Communications & Electronic DSM for more information on the requirements. Extend temperature controls conduit and pull string to nearest DEN comm room and cap. Label conduit at both ends with location served.

Provide a lockable isolation valve directly upstream of the meter.

Domestic cold-water service to the Tenant lease area will not need to be metered if Tenant has only a single hand sink.

5.8.5.5 Backflow Prevention

Backflow prevention is required on all Tenant connections to the building's domestic water main, including service to a single hand sink. The backflow preventer shall be in an accessible area within the Tenant lease area.

5.8.5.6 Roof Water

Tenant locations with roof mounted exhaust systems shall include the installation of Frost-Free Hose Bib or Hydrant for Kitchen Exhaust System Cleaning. The design team shall include a frost-free hose bib or hydrant on the roof within 50 feet of the roof-mounted kitchen exhaust system to facilitate cleaning. It shall be connected to the project's water supply, meet local plumbing codes, and include backflow prevention. Include a set of valves to drain the water during the winter months. Valves shall be clearly labeled with a permanent sign noting that the valves are for winterization.

End of Chapter

Chapter 9 - Facility Design

5.9.0 Passenger Terminal — Concessions and Services

5.9.0.1 Design Conditions

- A. Cooling: 74°F (50% RH Max) No Humidity Control
- B. Heating: 70°F No Humidity Control

DEN AHUs are not designed to handle the heating and cooling loads of less energy-efficient setpoints. Refer to [5.9.0.2.Air Handling Systems](#) for Tenant airflow allocations. In previous projects, many tenants have found that these energy efficiency requirements are uncomfortable, and have requested DEN change their zone temperature setpoints. This causes problems for DEN HVAC systems, as modifying zone temperature setpoints without adding supplemental heating or cooling equipment often causes tenants to exceed their allotted airflow, and strains DEN HVAC systems and equipment. If a tenant requires zone temperatures that are not feasible with their allotted airflow, the tenant must install additional mechanical equipment to make up the difference in heating or cooling loads. This equipment could include, but is not limited to fan coil units that recirculate air in the space, air or water source heat pumps, or other mechanical solutions. Care should be taken when selecting equipment and designing sequences of operation to ensure that no simultaneous heating and cooling of zones occurs.

5.9.0.2 Air Handling Systems

The base building air handling system has been designed to accommodate the following loads for Restaurant, Food Courts, Office, and Concession Spaces:

- A. Basic Office, Retail, Airline Tenant: Exterior Load + 1.00 CFM/SF
- B. Restaurant Tenant: Exterior + 1.25 CFM/SF for seating area. Kitchen to be conditioned with Tenant supplied makeup air system.
- C. Bar Tenant: Exterior load + 1.25 CFM/SF
- D. Food Court Tenant: Exterior load + 1.25 CFM/SF for seating areas. Source of makeup air shall be by each Tenant and coordinated between DEN and each Tenant.

The Tenant shall provide a complete HVAC system to meet loads that exceed the requirements listed above. The Tenant shall verify the heating and cooling loads from the perimeter, adjoining structures and adjacent spaces affecting the Tenant area. All Tenant areas in the terminal are in the interior spaces and are unaffected by the perimeter heating /cooling loads.

5.9.0.3 Outdoor Air Requirements

In general, outside air shall be brought in through the base building AHU and/or the kitchen ventilation system. Refer to [5.3.1.Ventilation Systems](#) for ventilation requirements. The Tenant HVAC shall makeup a minimum of 100% of what is exhausted from the space.

5.9.0.4 Kitchen Exhaust

All kitchens shall be air conditioned. The exhaust requirements shall be determined by the cooking exhaust hoods installed within the facility. The kitchen exhaust system shall be designed in accordance with [5.3.3.5.Food and Beverage Tenant Equipment](#).

5.9.0.5 Ventilation Rates

The existing system ventilation was designed in accordance with American Society of Heating, Refrigeration, and Air Conditioning Engineers Standard (ASHRAE) 62-1989, Ventilation for Acceptable Indoor Air Quality. All new design for proper ventilation shall be in accordance with the recommendations of the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent. Filtration.

5.9.0.6 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13 and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

5.9.1 Domestic Concourse — Tenant Spaces

5.9.1.1 Design Conditions

- A. Cooling: 74°F (50% RH Max) No Humidity Control
- B. Heating: 70°F No Humidity Control

DEN AHUs are not designed to handle the heating and cooling loads of less energy-efficient setpoints. Refer to [5.9.1.2.Air Handling Systems](#) for Tenant airflow allocations. In previous projects, many tenants have found that these energy efficiency requirements are uncomfortable, and have requested DEN change their zone temperature set-points. This causes problems for DEN HVAC systems, as modifying zone temperature setpoints without adding supplemental heating or cooling equipment often causes tenants to exceed their allotted airflow, and strains DEN HVAC systems and equipment. If a tenant requires zone temperatures that are not feasible with their allotted airflow, the tenant must install additional mechanical equipment to make up the difference in heating or cooling loads. This equipment could include, but is not limited to fan coil units that recirculate air in the space, air or water source heat pumps, or other mechanical solutions. Care should be taken when selecting equipment and designing sequences of operation to ensure that no simultaneous heating and cooling of zones occurs.

5.9.1.2 Air Handling Systems

The base building air handling system has been designed to accommodate the following loads for Restaurant, Food Courts, Office, and Concession Spaces:

- A. Basic Office, Retail, Airline Tenant: Exterior Load + 1.00 CFM/SF
- B. Restaurant Tenant: Exterior + 1.25 CFM/SF for seating area. Kitchen to be conditioned with Tenant supplied makeup air system.
- C. Bar Tenant: Exterior load + 1.25 CFM/SF
- D. Food Court Tenant: Exterior load + 1.25 CFM/SF for seating areas. Source of makeup air shall be by each Tenant and coordinated between DEN and each Tenant.
- E. Concourse B Regional Jet Facility: No Tenant HVAC (hydronic on airside) accommodations have been made. Tenant shall provide a complete stand-alone HVAC system.

The Tenant shall provide a complete HVAC system to meet loads that exceed the requirements listed above. The Tenant shall verify the heating and cooling loads from the perimeter, adjoining structures and adjacent spaces affecting the Tenant area.

5.9.1.3 Perimeter Systems

The glass wall in the area shall be conditioned by the base building system.

5.9.1.4 Outdoor Air Requirements

In general, outside air shall be brought in through the base building AHU and/or the kitchen ventilation system. Refer to [5.3.1.Ventilation Systems](#) for ventilation requirements. The Tenant HVAC shall makeup a minimum of 100% of what is exhausted from the space.

5.9.1.5 Ventilation Rates

The existing base building system ventilation was designed in accordance with American Society of Heating, Refrigeration, and Air Conditioning Engineers Standard (ASHRAE) 62-1989, Ventilation for Acceptable Indoor Air Quality. All new design for proper ventilation shall be in accordance with the latest edition of ASHRAE standard 62, Ventilation for Acceptable Indoor Air Quality, or the currently enforced International Mechanical Code with City amendments, whichever is more stringent.

5.9.1.6 Kitchen Exhaust

All kitchens shall be air conditioned. The exhaust requirements shall be determined by the cooking exhaust hoods installed within the facility. The kitchen exhaust system shall be designed in accordance with [5.3.3.5.Food and Beverage Tenant Equipment](#).

5.9.1.7 Filtration

Outside air shall be filtered, as a minimum, using 2" dry type pre-filter section having a minimum rating of MERV 7, 12" dry type filter section having a minimum rating of MERV 13 and a 12" filter section for future removable mixed media (i.e., carbon/potassium permanganate) filter section.

5.9.1.8 AHU Controls

Refer to [5.5.1.Sample Control Components and Requirements](#).

5.9.1.9 Central Utility Plant

Chilled water and hot water connections are not available for Tenants in this area.

5.9.1.10 Plumbing Requirements

All plumbing systems shall conform to the requirements of the International Plumbing Code (IPC) as adopted and modified by the CCD building code.

Plumbing design shall consider impact of future terminal expansion.

Provide plumbing fixtures for the physically disabled.

Refer to [Chapter 8- Plumbing Requirements](#) for plumbing design parameters and basis of occupancy.

5.9.1.11 Fire Protection

The fire protection system shall be provided in accordance with the latest editions of National Fire Protection Agency (NFPA) Standards and the building code of the CCD. The following description of fire protection requirements is based on NFPA and FM Global the current agency insurance underwriter.

- A. Provide wet-pipe and dry-pipe sprinkler systems for this area.

- B. Provide Class I standpipe system.
- C. Provide an extinguisher at each station in the enclosed areas.
- D. Provide manual pull-type fire alarm stations at exits.
- E. All escalator and stair opening perimeters shall be provided with closely spaced sprinkler heads providing a water curtain.

5.9.1.12 Smoke Control

All public and Tenant areas shall be served by a separate smoke control system. Refer to the Life Safety DSM for requirements.

5.9.1.13 Simplicity of Systems

Where possible, Consultants shall reduce or eliminate redundant systems and equipment, or sequences of operation. DEN staff understand that certain provisions in the Design Standards Manuals, codes and regulations, and project specific requirements or constraints may necessitate the use of redundant systems, equipment, or sequences of operation. In instances where redundant equipment is located outside of tenant lease bounds, the Consultant shall provide a narrative describing what requirement necessitates the use of the redundant systems, equipment, or sequences of operation on the mechanical notes or plumbing notes sheet of the drawings.

For any food service tenant space with an exhaust air quantity over 5000 CFM, there shall be one (1) make-up air unit for every one (1) kitchen exhaust fan.

End of Chapter

Appendix A - Controls Points Abbreviations

Below is a list of DEN approved standard controls points abbreviations. Non-standard abbreviations must be approved in writing by DEN Mechanical Engineer.

Appendix A - Control Point Abbreviations

Identifiers	Description
AF-OFST	Return Airflow Offset from Total Supply
AHU-MODE	AHU Mode
BYPD-C	Bypass Damper Command
CHWE-F	Chilled Water Entering Flow
CHWE-T	Chilled Water Entering Temp
CHWL-T	Chilled Water Leaving Temp
CHWR-T	Chilled Water Return Temperature
CHWS-T	Chilled Water Supply Temperature
CLG-FB	Cooling Valve Feedback
CLG-M	Cooling Mode
CLG-O	Cooling Output
CLG-O-BTU	Cooling Valve BTU
CLG-O-FLOW	Cooling Flow
CLG-VLV-FAIL	Chilled Water Valve Failure
CO2-RESET	DCV Reset Enable
CW-ALM-DLY	Chilled Water Coil Alarm Time Delay
CW-ALM-SP	Chilled Water Coil Alarm Threshold
DA-F	Discharge Air Flow
DA-P	Discharge Air Static Pressure
DAP-EFF-SP	Effective Discharge Air Press Setpoint
DAP-IGN	DA Pressure Ignore Requests
DAP-ITSP	Initial Discharge Air Pressure Setpoint
DAP-MAX-SP	Maximum DA Pressure Setpoint
DAP-MIN-SP	Minimum DA Pressure Setpoint
DAP-REQS	DA Pressure Requests
DAP-RES	Setpoint Response DA Pressure Reset
DAP-RES-MAX	Setpoint Maximum Response DA Reset

Appendix A - Control Point Abbreviations (Continued)

Identifiers	Description
DAPR-MODE	DA Pressure Reset Mode
DAP-STRT-RP	Static Pressure Setpoint Ramp Time
DAP-T-D	Time Delay DA Pressure Reset
DAP-T-INT	Time Interval DA Pressure Reset
DAP-TRIM	Setpoint Trim DA Pressure Reset
DA-T	Discharge Air Temperature
DA-T-ALM	Discharge Air Temp Setpoint Alarm
DAT-ALM-DB	AHU DAT Alarm Deadband
DAT-ALM-DLY	AHU DAT Alarm Delay Time
DAT-ALM-TM	AHU DAT Alarm Time Threshold
DAT-EFF-SP	Effective Discharge Air Temp Setpoint
DAT-HI-OAT	High OAT for DAT Reset
DAT-IGN	DAT Ignore Requests
DAT-ITSP	Initial Discharge Air Temp Setpoint
DAT-LO-OAT	Low OAT for DAT Reset
DAT-MAX-SP	Maximum DA Temp Setpoint
DAT-MIN-SP	Minimum DA Temp Setpoint
DAT-MRN-CLG	Morning Pre-Cool Discharge Temp Setpoint
DAT-MRN-WRM	Morning Warmup Discharge Temp Setpoint
DAT-REQS	DA Temperature Requests
DAT-RES	Setpoint Response DA Temp Reset
DAT-RES-MAX	Setpoint Maximum Response DA Reset
DATR-MODE	DA Temperature Reset Mode
DAT-STBK	Unoccupied Setback Disch Temp Setpoint
DAT-STUP	Unoccupied Setup Discharge Temp Setpoint
DAT-T-D	Time Delay DA Temp Reset
DAT-T-INT	Time Interval DA Temp Reset
DAT-TRIM	Setpoint Trim DA Temp Reset
DA-VP	Discharge Air Velocity Pressure
DESIGN-DA-F	Design Discharge Flow
DHC-FB	Defrost Heating Valve Feedback

Appendix A - Control Point Abbreviations (Continued)

Identifiers	Description
DHCL-T	Defrost Leaving Temp
DHC-O	Defrost Heating Output
DHWE-F	Defrost Hot Water Entering Flow
DHWE-T	Defrost Hot Water Entering Temp
DHWL-T	Defrost Hot Water Leaving Temp
DHWT-SP	Defrost Temp Setpoint
EAD-FB	Exhaust Air Damper Feedback
EAD-O	Exhaust Air Damper Output
EA-EW-T	Exhaust Air Entering Wheel Temp
EA-F	Exhaust Air Flow
EA-FILT-DP	EA Filter Diff Pressure
EA-LW-T	Exhaust Air Leaving Wheel Temp
ECON-DB	Economizer Deadband
ECON-ENA	Economizer Mode Enable
EF-AF	Exhaust Fan Associated with AHU Airflow
EF-C	Exhaust Fan Command
EFF-CDAT-SP	Effective Cooling DAT Setpoint
EFF-HDAT-SP	Effective Heating DAT Setpoint
EFF-OA-T	Effective Outside Air Temperature
EF-HP	Exhaust Fan High Pressure
EF-HSP	EF High Static Pressure Alarm
EF-O	Exhaust Fan Output
EF-S	Exhaust Fan Status
EF-VP	Exhaust Fan Velocity Pressure
ERW-C	Energy Recovery Wheel Command
ERW-O	Energy Recovery Wheel Output
ERW-S	Energy Recovery Wheel Status
ERW-ALM	Energy Recovery Wheel Alarm
FLTR-DP	Filter Differential Pressure
FIRE-ALM	Fire Alarm
FLTR-WRN	Filter Warning

Appendix A - Control Point Abbreviations (Continued)

Identifiers	Description
FLTR-WRN-SP	Filter Warning Setpoint
HI-DAT-ALM	High Discharge Temp Alarm
HI-DAT-SP	High Discharge Setpoint
HP-ALM	DA High Duct Pressure Alarm
HTG-EN	Global Heating Enable
HTG-M	Heating Mode
HW-ALM-DLY	Hot water Coil Alarm Time Delay
HW-ALM-SP	Hot water Coil Alarm Threshold
LDAT-ALM	Low Discharge Air Temp Alarm
LDAT-SP	Low DA Temp Setpoint
LTA-R	Low Temp Alarm Reset
LT-SP	Low Limit Setpoint
LP-ALM	Low Duct Pressure Alarm
LT-ALM	Low Temperature Alarm
LT-S1-ALM	Low Limit Stage 1 Alarm
LT-S2-ALM	Low Limit Stage 2 Alarm
MA-LT-ALM	Mixed Air Low Limit Alarm
MA-T	Mixed Air Temperature
MAT-LL	Mixed Air Temp Low Limit
MAT-LL-DLY	Mixed Air Temp Low Limit Release Delay
MECH-CLG-DLY	Mechanical Cooling Time Delay
MOA-CO2RSTA	CO2 Low Range
MOA-CO2RSTB	CO2 High Range
MPC-END	Morning Pre-Cool End Month
MPC-OAT	Morning Pre-Cool OAT Enable Temp
MPC-STPT	Morning Pre-Cool Space Setpoint
MPC-STRT	Morning Pre-Cool Start Month
MRN-CLG	Morning Cool-down Mode
MRN-WRM	Morning Warm-up Mode
OAD-FB	Outdoor Air Damper Feedback
OAD-O	Outdoor Air Damper Output

Appendix A - Control Point Abbreviations (Continued)

Identifiers	Description
OA-F	Outside Air Flow
OA-FILT-DP	OA Filter Diff Pressure
OA-F-SP	Outside Air Flow Setpoint
OAG-DAT-SP	OAT Greater DA Temp Setpoint
OAL-DAT-SP	OAT Less DA Temp Setpoint
OA-T	Global Outside Temperature
OCC-C	Occupied Mode
OCC-M	Occupied Mode
PFILT-DP-ALM-DLY	PreFilter Alarm Delay
PH-FB	Preheat Valve Feedback
PH-O	Preheat Output
PH-O-BTU	Preheat Valve BTU
PH-O-F	Preheat Flow
PH-T	Preheat Temp
PH-VLV-FAIL	Hot Water Valve Failure
PHW-F	Preheat Water Entering Flow
PHWR-T	Hot Water Return Temperature
PHWS-T	Hot Water Supply Temperature
PID-TMP-DB	PID Deadband Heating Econ Cooling
PWR-FAIL-DLY	Power Failure Restart Delay Time
PWR-FAIL-INT-UNIT- DLY	Power Fail Interstage Unit Delay
RAD-FB	Return Air Damper Feedback
RAD-O	Return Air Damper Output
RA-F	Return Air Flow
RAF-AF-SP	Return Airflow Setpoint
RAF-C	Return Air Fan Command
RAF-MM-ALM	Return Fan Mismatch Alarm
RAF-O	Return Air Fan Output
RAF-S	Return Air Fan Status
RA-H	Return Air Humidity
RA-SD-ALM	Return Air Smoke Detector Alarm

Appendix A - Control Point Abbreviations (Continued)

Identifiers	Description
RA-T	Return Air Temperature
RA-T	Return Air Temp
SA-F	Supply Air Flow
SA-SD-ALM	Supply Air Smoke Detector Alarm
SD-CMD	Shutdown Command
SF-C	Supply Fan Command
SF-MM-ALM	Supply Fan Mismatch Alarm
SF-O	Supply Fan Output
SF-S	Supply Fan Status
SYS-OFF	System Off Mode
SYS-RESET	System Reset
T-MIN	DAT Minimum at High OAT
TUNING-RESET	Tuning Reset
UNIT-CNT	Device No for Interstage Unit Delay
UNIT-RESET	Unit Reset
UNOCC-CLG-DB	Unoccupied Cooling Deadband
UNOCC-CLG-SP	Unoccupied Cooling Setpoint
UNOCC-HTG-DB	Unoccupied Heating Deadband
UNOCC-HTG-SP	Unoccupied Heating Setpoint
UNOCC-STATE	Unoccupied State
UNOCC-STBK	Unoccupied Setback Mode
UNOCC-STUP	Unoccupied Setup Mode
V_OT	Minimum Outside Air Setpoint -Non-DCV
V_OT-MIN	DCV Minimum Outside Air Setpoint
VAV-CO2-MAX	Maximum Zone CO2
VAV-T-AVG	VAVs Temp Average
VAV-T-MAX	VAVs Temp Maximum
VAV-T-MIN	VAVs Temp Minimum

Appendix A - VAV Points Abbreviations

Identifier	Description
AHU-SA-T	Supply Air Temperature
AHU-SF-S	AHU Supply Air Fan Status
AUTOCAL-C	Autocalibrate
AVG-MAX-CALC-ZN-T	ZN-T FOR Maximum & Average Calculation
HTG-ENA	Global Heating Enable
CLG-C	Cooling Command
CLG-MAXFLOW	Cooling Max Flow
CLGOCC-MINFLOW	Occ Cooling Min Flow
CLG-REQ	Discharge Temperature Request
DA-T	Discharge Air Temperature
DATHTGMAX-SP	Discharge Air Setpoint Heating Max
DA-VP	Discharge Air Velocity Pressure
DPR-O	Supply Air Damper Output
EFFCLG-SP	Effective Cooling Setpoint
EFFDAT-SP	Effective Discharge Setpoint
EFFHTG-SP	Effective Heating Setpoint
EFF-OCC	Effective Occupancy
EFF-SETPOINT	Active Setpoint
HTG-C	Heating Command
HTG-MAXFLOW	Heating Max Flow
HTG-O	Heating Output
HTGOCC-MINFLOW	Occ Heating Min Airflow
HTGSTBY-SP	Standby Heating Setpoint
IMP-V	Importance Factor
IRH-C	IRH Command
MIN-CALC-ZN-T	ZN-T for Minimum Calculation
NET-OCC	Supervisor Occupancy
OCC-CLG-SP	Occupied Cooling Setpoint
OCC-HTG-SP	Occupied Heating Setpoint
OCC-SCHEDULE	Occupancy Schedule
SA-F	Airflow Rate

Appendix A - VAV Points Abbreviations (Continued)

Identifier	Description
SAFLOW-SP	Flow Setpoint
SF-C	Supply Fan Command
SF-S	Supply Fan Status
SYSTEM-MODE	System/Control Mode
UNITEN-ENA	Unit Enable
UNIT-S	Unit Status
UNNOC-CLG-SP	Unoccupied Cooling Setpoint
UNNOC-DB	Unoccupied Deadband
UNNOC-HTG-SP	Unoccupied Heating Setpoint
UNNOC-STATE	Unoccupied Status
VAV-IGN-CAL	VAV Box Ignore for Calculation
WC-ADJ	Setpoint Offset
WC-C	Warmup/Cooldown
ZN-T	Zone Temperature
VFD Points	
FAULT	Fault Status
HOA	Hand/Off/ Auto Status
SPD-FBK	Speed Feedback
AMPS	Amperage/ Motor Current
HZ	Hertz/ Frequency
kWh	Kilowatt Hours
HRS	Run Hours
S	Running/ Stopped Status
C	Start/ Stop Command
O	Output
ALM	Alarm
Floating Point Valves	
OPN-C	Open Command
OPN-S	Open Status
CLO-C	Close Command
CLO-S	Close Status

Appendix A - VAV Points Abbreviations (Continued)

Identifier	Description
Equipment Control	
C	On/ Off Command
S	On/Off Status
ALM	Alarm
ENA	Enable/Disable
MS	Normal/Maintenance mode
DP	Differential Pressure
RT	Run Time
Hydronic Elements	
HWS-T	Heating Water Supply Temperature
HWR-T	Heating Water Return Temperature
HWS-F	Heating Water Supply Flow
HWR-F	Heating Water Return Flow
HWS-P	Heating Water Supply Pressure
HWR-P	Heating Water Return Pressure
CWS-T	Condenser Water Supply Temperature
CWR-T	Condenser Water Return Temperature
CWS-F	Condenser Water Supply Flow
CWR-F	Condenser Water Return Flow
CWS-P	Condenser Water Supply Pressure
CWR-P	Condenser Water Return Pressure
CHWS-T	Chilled Water Supply Temperature
CHWR-T	Chilled Water Return Temperature
CHWS-F	Chilled Water Supply Flow
CHWR-F	Chilled Water Return Flow
CHWS-P	Chilled Water Supply Pressure
CHWR-P	Chilled Water Return Pressure
GLWS-T	Glycol Supply Temperature
GLYR-T	Glycol Return Temperature
GLYS-F	Glycol Supply Flow
GLYR-F	Glycol Return Flow

Appendix A - VAV Points Abbreviations (Continued)

Identifier	Description
GLYS-P	Glycol Supply Pressure
GLYR-P	Glycol Return Pressure
DP	Differential PressureS

End of Appendix

Matrix A: DEN Concourse A West Expansion Concessions

DEN Concourse A West Expansion Concessions Matrix

Space		Plan Name					Mechanical									Plumbing								Electrical				
Location	Category	Room Number	Plan Tag	Seating Internal for F & B Operation	Dumb Waiter Shaft	Floor Area	Cooling Load		Chilled Water Flow Allowance (GPM)	Heating Hot Water Flow Allowance (GPM)	Cooking			Ventilation (CFM)		Domestic Cold Water		Domestic Hot Water		San. Sewer)	Grease Waste)	Vent		Gas		Maximum Load (AMPS)	Design Load (AMPS)	Connect Supported (VOLTS)
							Alloance (SF/TON)	Total (Tons)			(Y/N)	Type: Gas, Elect, G/E	Grease Exhaust	Diswasher Exhaust	Hood Makeup from Outside	Service	Size (IN.)	Service	Size (IN.)	Size (IN.)	Size (IN.)	Size (IN.)	Size (IN.)					
Subcore 6W Concourse Level ¹	Food & Beverage	CCA_02_6W_020	Concessions Seating	Y	Y	4,681	300	15.6	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	2	CW, Metered Up from Apron	Tenant-provided Electric Water Heater in the Space		4	N/A	N/A	3	400	424	277/480,3PH	
Subcore 6W Concourse Level ¹	Back of House	CCA_02_6W_CR51	Circulation	N/A	Y	354	500	0.7	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Subcore 6W Apron Level ²	Kitchen	CCA_01_6W_014	Concessions Kitchen	N/A	Y	1,786	300	6.0	16.7	29.3	Y	G/E	8800	700	9,500	CW, Metered	2	Tenant-provided Electric Water Heater in the Space		4	4	3	By Tenant (2400 CFH Allowance)	100	85	277/480,3PH		
Subcore 6W Apron Level ²	Storage	CCA_01_6W_013	Concessions Loading/ Storage	N/A	N	1,162	1200	1.0	3	3.7	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	3	277/480,3PH		
Subcore 6W Base-ment Level ³	Storage	N/A	N/A	N/A	N	3,290	N/A	N/A	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	8	277/480,3PH		
Holdroom 7W ¹	Travel & Convenience	CCA_02_7W_037	Concessions	TBD	N	1,468	1000	1.5	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	200	124	277/480,3PH		
Subcore 9W Concourse Level ¹	Food & Beverage	CCA_02_9W_020	Concessions Seating	Y	Y	4,681	300	15.6	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	2	CW, Metered Up From Apron	Tenant-provided Electric Water Heater in the Space		4	N/A	3	N/A	400	424	277/480,3PH	
Subcore 9W Concourse Level ¹	Back of House	CCA_02_9W_CR06	Circulation	N/A	Y	354	500	0.7	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	2	CW, Metered Up From Apron	Tenant-provided Electric Water Heater in the Space		4	N/A	3	N/A	100	89	277/480,3PH	
Subcore 9W Apron Level ²	Storage/ Future Kitchen	CCA_01_9W_025	Concessions Storage	N/A	Y	954	300	3.3	9.9	17.3	Y	G/E	5200	425	5,600	CW, Metered	2	Tenant-provided Electric Water Heater in the Space		4	4	3	By Tenant (2400 CFH Allowance)	100	47	277/480,3PH		
Subcore 9W Apron Level ²	Loading/ Storage	CCA_01_9W_008	Loading/ Storage	N/A	N	627	1200	0.5	1.5	1.9	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	1.1	277/480,3PH		

DEN Concourse A West Expansion Concessions Matrix (Continued)

Space		Plan Name					Mechanical								Plumbing								Electrical			
Subcore 9W Basement Level ¹	Storage	N/A	N/A	N/A	N	2,936	N/A	N/A	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	7	277/480,3PH
Holdroom 10W ³	Travel & Convenience	CCA_02_10W_050	Concessions	TBD	N	1,054	1000	1.1	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	58	277/480,3PH

Notes:

¹ If required natural gas is provided by XCEL Energy during Tenant Design. Space air conditioning is from the Concourse VAV Air Handling Systems.

²If required natural gas is provided by XCEL Energy during Tenant Design. Space air conditioning is from the Apron VAV Air Handling Systems.

³If required natural gas is provided by XCEL Energy during Tenant Design. No Air handling systems exist in the basement for conditioning Tenant spaces.

Matrix B: DEN CEP Concourse B West Expansion Concessions

DEN CEP Concourse B West Expansion Concessions Matrix

Space		Plan Name					Mechanical									Plumbing								Electrical		
Location	Category	Room Number	Plan Tag	Seating Internal for F & B Operation	Dumb Waiter Shaft	Floor Area	Cooling Load		Chilled Water Flow Allowance (GPM)	Heating Hot Water Flow Allowance (GPM)	Cooking			Ventilation (CFM)		Domestic Cold Water		Domestic Hot Water		San. Sewer)	Grease Waste)	Vent	Gas	Maxmum Load (AMPS)	Design Load (AMPS)	Connect Supported (VOLTS)
							Alloance (SF/TON)	Total (Tons)			(Y/N)	Type: Gas, Elect, G/E	Grease Exhaust	Diswasher Exhaust	Hood Makeup from Outside	Service	Size (IN.)	Service	Size (IN.)	Size (IN.)	Size (IN.)	Size (IN.)	Size (IN.)			
Holdroom 8W Concourse Level	Travel & Convenience	CCB_02_8W_010	Travel & Convenience	TBD	N	754	600	1.3	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	64	277/480,3PH
Subcore 9W Concourse Level	Food & Beverage	CCB_02_9W_015	Concessions	Y	Y	3,784	150	25.2	N/A	N/A	N	N/A	N/A	N/A	N/A	CW, Metered Up From Apron	2	Tenant-provided Electric Water Heater in the Space		4	N/A	3	N/A	400	312	277/480,3PH
Subcore 9W Concourse Level	Back of House	CCB_02_9W_CR14	Corridor	N/A	Y	544	N/A	N/A	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Subcore 9W Apron Level	Kitchen	CCB_01_9W_023	Concesions Storage	N/A	Y	1,484	300	4.9	21	33	Y	G/E	8,800	700	9,500	CW, Metered	2	Tenant-provided Electric Water Heater in the Space		4	4	3	By Tenant (2400 CFH Allowance)	100	71	277/480,3PH
Subcore 9W Apron Level ³	Storage	CCB_01_9W_020	Concesions Storage	N/A	N	1,031	N/A	N/A	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	50	277/480,3PH
Storage Apron Level	Storage	CCB_01_9W_022	Loading	N/A	N	571	N/A	N/A	N/A	N/A	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	100	64	277/480,3PH

Notes:

If required natural gas is provided by XCEL Energy during Tenant Design. Space air conditioning is from the Concourse VAV Air Handling Systems.

This page is intentionally blank.

Matrix C: DEN Concourse C East Expansion Concessions

DEN Concourse C East Expansion Concessions Matrix

Space		Plan Name						Mechanical																	Electrical			
Location	Category	Room Number	Plan Tag	Seating Internal for to Restaurant (Y/N)	Trash Chute Access (Y/N)	Dumb Waiter Shaft	Floor Area (S/F)	Cooling Load		Chilled Water Flow Allowance (GPM)	Heating Hot Water Flow Allowance (GPM)	Cooking		Kitchen/ Dishwasher Exhaust		Ventilation (CFM)			Domestic Cold Water		Domestic Hot Water	San. Sewer)	Grease Waste)	Vent	Gas	Allow-ance (AMPS)	Calculated Load (AMPS)	Voltage
								Allowance (SF/TON)	Total (Tons)				Type: Gas, Elect, G/E	(Y/N)	Air Flow (CFM)	Dishwasher Exhaust	Hood Makeup from Outside	Makeup Air from Terminal	Service	Size (IN.)	Service	Size (IN.)	Size (IN.)	Size (IN.)	Size (IN.)			
Subcore 6E Concourse Level ¹	Concession Space	CCC_02_6E_025	Restaurant 1	Y	Y	Y	3200	300	10.7	20	15	Y	E/G	Y	4500/1400	2980	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	77	480/277V
Subcore 6E Concourse Level ¹	Concession Space	CCC_02_6E_026	Restaurant 2	Y	Y	Y	3200	300	10.7	20	15	Y	E/G	Y	4500/1400	2980	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	77	480/277V
Subcore 6E Concourse Level ²	Retail	CCC_02_6E_023	Travel & Convenience	N	N	N	1000	300	3.3	5	1.25	N	N/A	N	N/A	235	N/A	N/A	Concourse CW Loop, Metered	0.75	Local Electric Water Heater in Space	4	N/A	3	N/A	100	6	480/277V
Subcore 6E Concourse Level ²	Concession Space		Gourmet Coffee Kiosk	N	N	N	1000	300	3.3	5	1.25	N	N/A	N	N/A	930	N/A	N/A	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	3	3	N/A	100	24	480/277V
Subcore 6E Apron Level ¹	Kitchen	CCC_02_6E_023	Kitchen 1	N	N	Y	1400	300	4.7	15	10	Y	E/G	Y	4500/1400	N/A	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	67	480/277V
Subcore 6E Apron Level ¹	Kitchen	CCC_02_6E_023	Kitchen 2	N	N	Y	1400	300	4.7	15	10	Y	E/G	Y	4500/1400	N/A	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	67	480/277V
Subcore 6E Basement Level ³	Concession Storage	CCC_00_6E_007	Storage	N	N	N	3858	1200	3.2	5	5	N	N/A	N	N/A	465	N/A	N/A	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	3	N/A	2	N/A	125	9	480/277V

DEN Concourse C East Expansion Concessions Matrix (Continued)

Space		Plan Name						Mechanical																	Electrical					
Subcore 9E Concourse Level ¹	Concession Space	CCC_02_9E_025	Restaurant 1	Y	Y	Y	3200	300	10.7	20	15	Y	E/G	Y	4500/1400	2980	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	77	480/277V		
Subcore 9E Concourse Level ¹	Concession Space	CCC_02_9E_027	Restaurant 2	Y	Y	Y	3200	300	10.7	20	15	Y	E/G	Y	4500/1400	2980	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	77	480/277V		
Subcore 9E Concourse Level ²	Retail	CCC_02_9E_023	Travel & Convenience	N	N	N	1000	300	3.3	5	1.25	N	N/A	N	N/A	235	N/A	N/A	Concourse CW Loop, Metered	0.75	Local Electric Water Heater in Space	4	N/A	3	N/A	100	6	480/277V		
Subcore 9E Concourse Level ²	Concession Space		Gourmet Coffee Kiosk	N	N	N	1000	300	3.3	5	1.25	N	N/A	N	N/A	930	N/A	N/A	Concourse CW Loop, Metered	0.75	Local Electric Water Heater in Space	4	3	3	N/A	100	24	480/277V		
Subcore 9E Apron Level ¹	Kitchen	CCC_01_9E_015	Kitchen 1	N	N	Y	1400	300	4.7	15	10	Y	E/G	Y	4500/1400	N/A	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	67	480/277V		
Subcore 9E Apron Level ¹	Kitchen	CCC_01_9E_015	Kitchen 2	N	N	Y	1400	300	4.7	15	10	Y	E/G	Y	4500/1400	N/A	2700	1800	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	4	4	3	By Tenant (2400 CFH Allowance)	100	67	480/277V		
Subcore 9E Basement Level ³	Concession Storage	CCC_00_9E_005	Storage	N	N	N	3589	1200	3	5	5	N	N/A	N	N/A	430	N/A	N/A	Concourse CW Loop, Metered	1.5	Local Electric Water Heater in Space	3	N/A	2	N/A	100	9	480/277V		

Notes:

¹If required natural gas is provided by XCEL Energy during Tenant Design. Cooling and heating are provided by the Concourse air conditioning systems.

²Cooling and heating are provided by the Concourse air conditioning systems.

³Apron secure storage.

Volume 6 - Standards and Criteria

Chapter 1 - Administration

6.1.0 Administration

6.1.0.1 References

The DEN Design Standards may be cited as such and are referred to herein as the Standards. The Design Standards Manuals are referred to herein as DSMs.

City and County of Denver is referred to herein as the City or CCD.

Denver International Airport is referred to herein as DEN.

DEN is operated by the Department of Aviation of the City and County of Denver. More information about the organization and administration of DEN can be found at:



[Denver Government Website](#)

6.1.0.2 Purpose

The DSMs define a precise architectural and engineering vocabulary that serves as a basis for making decisions throughout the design and construction process. The DSMs provide direction without limiting the creative abilities of those who are governed by them.

6.1.0.3 Scope

The provisions of the DSMs apply to the design of any building, structure, infrastructure, or improvement on DEN property.

6.1.0.4 Format

Where specific formats are provided or referenced, those formats shall be used by the consultant.

6.1.0.5 Procedures

The procedural guidelines contained in these manuals are intended to supplement existing consultants' procedures and to establish a uniform basis for program control for DEN. Where the manuals are silent on a procedural matter, it is incumbent on the consultant to request specific direction from the DEN Project Manager. If no guideline is available, the consultant shall propose its existing corporate guidelines.

6.1.0.6 Exclusions

The DSMs are not all-inclusive, and there are areas of the DSMs that do not address design requirements. In these instances, the consultant shall use professional design judgment and expertise in preparing a proposed system design for those areas within the consultant's Scope of Work (SOW).

6.1.1 Compliance with Codes and Regulations

The DSMs are not to be used in lieu of codes or regulations that may be applicable to design or construction work. The user of the DSMs shall be solely responsible for the design product compliance with all codes and regulations. In some cases, the DSMs contain requirements that are more stringent than codes or regulations. The user shall comply with the more stringent requirement unless the requirement conflicts with any code requirements.

6.1.2 Variance and Interpretation

It is recognized that these DSMs may not always contain the newest developments in technology. While airport construction is not to serve as an experiment for new, untested systems and technologies, the consultant should present to DEN any proven new developments in systems and alternate methods of technology which the consultant thinks are worthy and beneficial for consideration.

6.1.2.1 Request Submittals

Variance and interpretation requests must meet at least one of the following criteria:

- A. Improvement to design
- B. Improvement to public safety
- C. Improvement to construction schedule
- D. Construction cost savings
- E. Operation and maintenance cost savings
- F. Resolution of conflict of established standards
- G. Design condition not covered by the DSMs
- H. Lifecycle cost-benefit

Consultant shall submit the appropriate form to the Project Manager for approval. Consultant shall not proceed with any variance in design without written approval from DEN.

6.1.2.2 Request Format

Tenant shall submit variance requests to the DEN Tenant Project Manager for review.

- I.

6.1.2.3 Consultant Notification

Variance requests shall be reviewed by DEN Design, Engineering, and Construction (DEC). The consultant shall allow a minimum of 14-day review time by DEC. The consultant shall be notified in writing of interpretations and/or the acceptance/non-acceptance of the submittal.

6.1.3 Progress Meeting

Progress meetings will be scheduled weekly or as deemed necessary by the DEN Project Manager to promote the competent and timely execution of the contract. The meetings will be held at DEN and will be chaired by the DEN Project Manager. The consultant shall be available in person at DEN or, subject to the approval of the DEN Project Manager, be available via telephone and/or web conference. The consultant, critical personnel, and/or sub-consultants shall be present to assure timely transfer of information.

6.1.4 Coordination and Administration

6.1.4.1 Procedures

The consultant shall follow DEN's procedures for coordinating and administering activities and for communicating among the consultant, subconsultants, tenants, City, and other consultants; payment submittals; reporting requirements; and consultant and City reviews and acceptances. To facilitate this coordination, consultant shall serialize all correspondence associated with the work it performs and shall maintain correspondence logs in accordance with instructions received from the Project Manager.

6.1.4.2 Coordination

The consultant shall coordinate the services and work provided by all its subconsultants working on the project. The consultant shall have primary responsibility of the program and processes utilized to eliminate any conflicts and inconsistencies within the final design packages prepared by the consultant and its subconsultants.

6.1.4.3 Design Standards

The consultant incorporates in design and construction documents, the applicable DEN design standards, and City criteria. If the consultant determines that an element of the design should be covered by a Design Standard, but one does not exist for that element, it shall notify DEN in writing and proceed as directed. If the consultant finds that deviation from any Design Standard may be appropriate, the consultant shall submit in a timely manner any proposed deviations in writing, accompanied by graphic information to DEN for review and/or acceptance. Design development of design for which a Standard modification or a new design is required shall not be considered an additional cost to DEN. The consultant shall fully cooperate with other consultants working at DEN, particularly those consultants whose work connects or interfaces with the consultant's SOW.

6.1.4.4 Communication with Consultant

DEN will transmit written instructions, responses, or other communications to the consultant. The consultant shall, by a letter to DEN, designate (by name) one or more assistant managers to receive oral and written communications when the consultant's manager is away from the worksite and to act as the consultant's designated representative. During the times that the consultant's manager may be temporarily absent, an assistant consultant manager shall be authorized to act immediately on orders or instructions issued by DEN.

6.1.4.5 Design Review Committee

The Project Manager will provide Design Review Committee (DRC) process document that outlines requirements for making presentations for design review as applicable. Projects in public view generally require DRC review. More information on the DRC can be found on the Flydenver.com website,



[DEN Design Review](#)

6.1.4.6 Design Project Closeout

The consultant shall plan for project closeout from day one. By law and General Conditions of the contract, DEN requires any set of drawings and specifications in PDF form used to establish pricing or contract for work be delivered to the Project Manager. Additionally, as a part of the design project closeout, the Design consultant shall provide model information outlined in the BXP as generated per the DFI DSM. The contract documents and models will be stored in DEN's common data environment and archived by the Project Manager.

6.1.5 Field Verification

Field verification by the designer of all existing architectural, mechanical, electrical, civil, structural, and other systems that are impacted by the project scope, or are part of the project scope, is required.

End of Chapter

Chapter 2 - Design Phases

6.2.0 Design Phases

6.2.0.1 Tenant Project Design Phases

Coordinate required design phase submittals with the DEN Project Manager. DEN review is required at minimum at the 100% Contract document milestone. Additional milestone reviews (at 30%, 60%, and 90%) may be required to help identify compliance issues prior to design completion, per Chapter 32 of the Standards and Criteria DSM.

For each deliverable, coordinate with DEN for requirements regarding quantities of documents and quantities of sealed and signed documents to be submitted.

End of Chapter

This page is intentionally blank.

Chapter 3 - Contract Documents

6.3.0 Contract Documents

6.3.0.1 Intent

The intent of the contract documents is to include all items necessary for the proper execution and completion of the construction work. Prior to beginning the contract documents phase, the consultant shall completely familiarize all team members with the most current version of the DEN Design Standards Manuals (DSMs), and the most recent versions of the General Contract Conditions (GCC) published by DEN and the City and County of Denver if applicable, or other documents which fill a similar contractual role. This document shall become part of the construction contract and the document identifies responsibility of the contractor, DEN, and the consultant. The work (GCC 121 Work and 1801 contractor's Warranties, Guarantees and Correction of Work) provided by the contractor shall be ultimately governed by this document. The individual documents comprising the contract documents are all essential parts of the contract and a requirement occurring in one is binding as though occurring in all. They are complementary and indicate the construction and completion of the work. Anything mentioned in the technical specifications and not shown on the contract drawings or shown on the contract drawings and not mentioned in the technical specifications, shall be of like effect as if shown or mentioned in both.

6.3.0.2 Referenced Standards

Material and workmanship specified by the number, symbol, or title of a referenced standard shall comply with the latest edition or revision and amendments and supplements thereto in effect on the date the bid is received except where a particular issue or edition of a publication is indicated. In case of a conflict between the technical specifications and the referenced standard, the more stringent shall govern.

6.3.0.3 Precedence of Contract Documents

6.3.0.3.1 Special Conditions

Special Conditions shall be given precedence over General Conditions. Special conditions are authored by Airport Legal Services with input from DEN and the consultant. Special conditions typically address the following:

- A. Schedule of work and sequence (milestones)
- B. Liquidated damages for each milestone and overall project
- C. Special security requirements
- D. Others

6.3.0.3.2 General Contract Conditions

These conditions are established by DEN. The consultant shall obtain a copy of GCC 2011 from DEN's website:



[Denver Government Website](#)

GCCs shall be given precedence over DEN standard technical specifications except that if, and to the extent that, the DEN standard technical specifications provide for a higher standard or for more stringent requirements than the General Conditions do, the DEN standard technical specifications shall be given precedence in such respects.

6.3.0.3.3 DEN Standard Technical Specifications

DEN Standard technical specifications shall be given precedence over contract drawings. This condition dictates that the consultant not repeat in the drawings, annotations in the specifications. This condition also does NOT relieve the consultant from completely and accurately coordinating dimensional and product profiles/illustration on the drawings. If alternate products are specified, the larger of the acceptable products shall be illustrated on the drawings.

6.3.0.3.4 Larger Scale Drawings

Large-scale drawings shall be given precedence over smaller scale drawings, for example: 1" =1' is larger scale than 1"=40' and 1"=1' is larger scale than 1/8"=1'. This requirement in no way relieves the consultant from the liability of accurate coordination of dimensions between small and large-scale drawings.

6.3.0.3.5 Conflict or Inconsistency

In the event of conflict or inconsistency between provisions of the technical specifications, the more stringent shall be given precedence over the less stringent. This requirement in no way relieves the consultant from the liability of coordinating all aspects of the specifications, including Division 01 - General Requirements.

6.3.0.4 Scope of Work

The contract documents contain the SOW for the contractor.

Not all the following will necessarily be included in every project. Actual scope of work contract documents will be based on project requirements. If DEN PM determines that project has different requirements for SOW contract documents, DEN PM will set up a meeting with DEN stakeholders and consultant to determine which SOW contract documents are required for the contractor prior to the submittal of 100% contract documents by the consultant.

6.3.0.4.1 Obtain Notice to Proceed (NTP)

The following is the current list of documents required to obtain Notice to Proceed (NTP) from DEN for concession projects that exceed \$15,000:

- A. Copy of contract between tenant and contractor.
- B. Original tenant payment bond, for full contract amount, on DEN form.
- C. Original contractor performance bond, labor and material payment bond, and dual obligee rider. For full contract amounts, and on DEN forms.
- D. Establish a goal through DSBO if one for the initial concession buildout isn't identified in the concession agreement. Contact dsbo@flydenver.com. Copy your assigned DEN Project Manager on all correspondence with DSBO. Once a goal is assigned, you will need to submit appropriate documents to DSBO to prove how you will obtain the minimum required participation. Provide a copy of DSBO's approval on how participation will be obtained.
- E. Indication from the Auditor's Office of Prevailing Wage that the project is set up in LCP tracker, and statement from general contractor that all subcontractors have been set up in LCP tracker (for prevailing wages).
- F. Copy of contractor's evidence of insurance.
- G. Copy of concessionaire's evidence of insurance.
- H. Copy of 1C building permit (or demo permit for partial NTPs)
- I. Copy of building department approved construction drawings.
- J. Copy of contractors safety plan, including site specific job hazard analysis (JHA).
- K. Construction schedule

- L. Copy of concession agreement with the City and County of Denver.
- M. Indication that drawings and specifications have been approved by DEN.
- N. Copy of report from ADA consultant confirming there are no ADA issues with the design.
- O. Copy of the contractor's Equity, Diversity, and Inclusion (EDI) plan. If the team has questions on the EDI plan, contact your assigned DEN Project Manager.

Projects that are under \$15,000, but more than \$2,000 have the following NTP requirements.

Indication from the Auditor's Office that the project is set up in LCP tracker, and statement from general contractor that all subcontractors have been set up in LCP tracker (for prevailing wages).

6.3.0.4.2 Part II — Technical Specifications

The following technical documents are also included in the SOW, subject to contractual requirements:

- A. Division 01, DEN Standard Technical Specifications
Prepared by design team, reviewed by DEN
- B. Divisions 02 – 14, 21 – 23, 26 – 28, and 31 – 33, DEN Standard Technical Specifications
Prepared by consultant, as required
- C. Schedules
Prepared by consultant
- D. Contract drawings
Prepared by consultant)
- E. Accepted shop drawings, approved change directives, and change orders

6.3.1 Contract Documents, Technical Specifications, and Technical Reports

6.3.1.1 Construction Documents

Based upon design development documents that have been reviewed and accepted by DEN, the consultant shall prepare complete construction documents and shall provide the following:

- A. Agency and utilities permits
- B. Final DARs, if applicable
- C. Geotechnical study, if applicable

6.3.2 Submittal Requirements

The consultant shall comply with [Chapter 20- Submittals](#).

6.3.3 System Compatibility

As project systems are refined and operational requirements are defined that require interface between the project and DEN systems. The consultant shall specify system controls that are compatible with existing DEN control systems, including, but not limited to: electrical, lighting controls, mechanical controls, fire protection and detection, surveillance, and security. This system compatibility shall include, but not be limited to any and all upgrades to existing systems to handle the increased existing control system responsibilities created by the addition of the systems installed with the project or task. The consultant shall identify all necessary upgrades to

existing systems and provide the necessary documentation to accomplish those upgrades within the construction contract documents. The consultant shall identify the requirements for equipment and software compatibility and specify project equipment and software that will facilitate that interface.

End of Chapter

Chapter 4 - Record Documents

6.4.0 Record Documents

All documents shall be dated with the date of project Final Completion and shall be noted as Project Record in the title block or footer. Cover sheets of specifications and drawings shall be titled Project Record. The consultant is responsible for creating a final reconciled Revit/Civil 3D model. Refer to the DFI DSM.

6.4.0.1 Record Drawings

Incorporate in Revit/Civil 3D format all changes in the projects and any deviations between the drawings and the work performed, no matter how insignificant, including all clarifications made during construction based on marked-up prints, change directives, change orders, request for information, drawings, and other data furnished to the consultant by DEN. Refer to the DFI DSM. The consultant shall maintain on an ongoing basis from contractor NTP to construction contract Final Completion the record drawing information based upon information provided by DEN. Annotations in the title block shall be removed and Project Record and date of final construction contract completion shall be entered in the title block.

6.4.0.2 Specifications

Incorporate all changes in e-SPECS format in the projects and any deviations between the specifications and the work actually performed, no matter how insignificant, including all clarifications made during construction based on marked-up specifications, change directives, change orders, RFI, cut sheets, submittals, other data furnished to the consultant by DEN. The consultant shall maintain record specification information based upon information provided by DEN.

6.4.0.3 Final Design Analysis Report (Conformed)

Provide update and any modifications to the final DAR, if applicable. Submit PDF files in accordance with [Chapter 20 - Submittals](#).

6.4.0.4 Certification

Include a certification on the cover sheet of drawings and specifications stating that to the best of the consultant's knowledge and belief, the consultant certifies that all construction shown in these record drawings has been completed in substantial conformance with the contract documents, and that all changes from the contract documents as bid have been noted to the best of its knowledge and belief. The consultant shall include its full business address, phone numbers, and a statement of disclaimers where appropriate.

6.4.0.5 Submittal

Refer to [Chapter 20- Submittals](#).

End of Chapter

This page is intentionally blank.

Chapter 5 - Design Contract Closeout/Task Closeout

6.5.0 Design Contract Closeout/Task Closeout

Work specified in this chapter includes procedures required prior to acceptance of the consultant's work.

6.5.0.1 Document Inspection

The consultant shall inspect records of all submittals completed to assure that all deliverables required by the contract have been completed. Inspection shall include inspection of each submittal to assure that each submittal is complete and in compliance with the consultant contract including the DEN DSMs.

6.5.0.2 Final Review

The consultant shall meet with DEN to review the status of work completed prior to submittal for project or task closeout. When the consultant considers that the work is complete, they shall submit written certification that:

- A. Work has been completed in compliance with the contract and all submittals have been received by DEN.
- B. Work has been completed in accordance with the assigned project or task.
- C. \Review of all contractor submittals is complete and third-party inspections required by code agencies have been completed, submitted, and accepted.
- D. If the project or task required installation or construction, the record documents have been submitted and accepted by DEN.
- E. All damaged or destroyed real, personal, public, or private property has been repaired or replaced.
- F. All personnel badges and vehicle permits have been returned (contract closeout only), if applicable.

6.5.0.3 City Review

DEN and authorized staff will inspect to verify status of completion with reasonable promptness after receipt of such certifications. If DEN finds incomplete or defective work:

- A. DEN, at DEN's sole discretion, will either terminate the inspection or prepare a list and notify the consultant in writing, listing incomplete or defective work.
- B. The consultant shall take immediate steps to remedy stated deficiencies and send second written certification to DEN that work is complete.
- C. DEN will then re-inspect work.

End of Chapter

This page is intentionally blank.

Chapter 6 - Specification Requirements

6.6.0 Specification Requirements

6.6.0.1 Consultant Requirements

The consultant shall provide complete specifications for all projects and/or tasks. Specifications include tables and schedules arranged as noted in this Chapter.

6.6.0.2 Compliance

The Specifications are part of the contract documents and shall comply with requirements of [Chapter 3 - Contract Documents](#).

6.6.0.3 Location

Specifications are to be in Part II of the Construction contract. Part II of the Specifications shall include all general requirements, product data sheets (if required), finish/room schedules, door schedules, equipment schedules, hardware schedules, fixture schedules, other appropriate schedules and the Technical Specifications and criteria required to construct or prepare design/build proposals to construct the projects. Part II of the Specifications shall be prepared by the consultant based upon the consultant's previously accepted preliminary technical specifications. Division 01 - General Requirements technical specifications shall be prepared by the design team, reviewed by DEN.

6.6.0.4 Consultant Preparation

The consultant shall be responsible for preparation of the Technical Specifications listed in [Table 6.6-1: Part II Specifications](#) are available from DEN in draft stage.

Table 6.6-1: Part II Specifications

Section	Title
011100	Summary of Work**
011400	Work Sequence and Constraints**
011420	Security Requirements & Sensitive Security Information (SSI)*
011430	Vehicle and Equipment Permitting**
011810	Utilities Interface**
012300	Alternates**
012510	Substitutions*
012910	Schedule of Values*
013100	Project Management and Coordination**
013119	Project Meetings*
013210	Schedule*
013223.11	Construction Layout and As-Built Surveys**

Table 6.6-1: Part II Specifications (Continued)

Section	Title
013223.15	Survey Information**
013223.15	Quantity Survey**
013233	Photographic Documentation**
013300	Submittal Procedures*
013325	Shop and Working Drawings, Product Data and Samples*
013510	Construction Safety*
013516	Alteration Project Procedures
013520	Construction Safety-Airside
014100	Regulatory Requirements***
014210	Referenced Material**
014220	Abbreviations and Symbols***
014225	Reference Standards**
014230	Definitions and Conventions**
014320	DEN Quality Assurance for FAA Funded Projects*
014510	Contractor Quality Control**
014520	Contractor Quality Control Program–FAA
014525	Material Testing Agency**
014545	Special Inspection Agency and Owner Testing Agencies**
015050	Mobilization*
015210	Temporary Facilities*
015215	Field Offices**
015525	Traffic Control**
015719	Temporary Environmental Controls**
015810	Temporary Signs**
016000	Product Requirements
016610	Storage and Protection**
017330	Cutting and Patching**
017419	Construction Waste Management and Disposal**
017420	Cleaning**
017515	System Startup, Testing and Training**
017720	Contract Closeout*

Table 6.6-1: Part II Specifications (Continued)

Section	Title
017825	Operation and Maintenance Data**
017835	Warranties and Bonds*
017840	Contract Record Documents*
017900	Demonstration and Training**
018113.13	Sustainable Design Requirements– LEED for New Construction and Major Renovations***
018113.16	Sustainable Design Requirements– LEED for Commercial Interiors***
018113.19	Sustainable Design Requirements– LEED for Core and Shell Development***
019113	General Commissioning Requirements**

**Provided by DEN*

***Shared responsibility of DEN and Design Consultant*

****Provided by Consultant*

Divisions 02 – 14, 21 – 23, 26 – 28, and 31 – 33	The consultant shall prepare Divisions 02 – 14, 21 – 23, 26 – 28, and 31 – 33 specifications, construction drawings, schedules, allowances, and bid forms in compliance with DEN Technical Requirements.

Notes:

- The formatting requirements apply to the DEN Standard Technical Specifications, which follow the Construction Specifications Institute (CSI) Masterformat layout.
- If the project requires CDOT and/or FAA specifications in addition to the DEN Standard Technical Specifications, the consultant must work with the DEN Project Manager to properly format at the CDOT and/or FAA specifications.

6.6.0.5 DEN Technical Requirements

The DEN technical requirements provide DEN-specific requirements that must be included in nonstandard specifications for all DEN projects. For each specification division, an itemized list of DEN-specific technical specification requirements is provided, which may include general requirements, product requirements, and execution requirements. The designer shall incorporate these requirements into their project specification content as appropriate for the project scope. Requirements are provided in an outline format, similar to construction specifications, for ease of incorporation. Content may be copied directly, with article/paragraph numbering and structure modifications as needed to ensure a cohesive specification document. Care must be taken to avoid introducing conflicting information.

6.6.0.6 Coversheet, Index and Certification Page

All specifications shall contain a standard coversheet. The standard coversheet is available as a template file from DEN. All specifications shall contain an Index and Certification page between the coversheet and first page of the Table of Contents. The certification page shall be used to document the number of pages per Division. A space shall be provided below the Index for Professional Seals per Division or group of Divisions.

6.6.1 Format

6.6.1.1 Style

Use *The Associated Press Stylebook* (available in most bookstores) as a companion writing style guide. It alphabetically lists preferred spelling, standard abbreviations, and numbering styles.

6.6.1.2 Construction Specification Institute Divisions

The formatting requirements apply to the DEN standard and nonstandard technical specifications, which follow the Construction Specifications Institute (CSI) MasterFormat layout. If the project requires CDOT and/or FAA specifications in addition to the DEN standard technical specifications, the consultant must work with the Project Manager to properly format the CDOT and/or FAA specifications.

The general CSI division breakdown of divisions 01 – 14, 21 – 23, 26 – 28, and 31 – 33 will be followed. The general CSI section format will be followed as the basis for the content and arrangement of the specification sections. Appropriate articles will be utilized to expand on these headings.

- Part 1 General
- Part 2 Products
- Part 3 Execution

The following Part 4 and Part 5 shall be included, if applicable:

- Part 4 Measurement for Payment
- Part 5 Method of Payment

NOTE: Method of payment for each specification section may vary, depending on the inclusion or exclusion of unit pricing, owner allowances, sequencing, etc.

6.6.2 Standard Text Elements

6.6.2.1 General

A Microsoft Word template for creating specifications with all DEN styles outlined in this chapter is available from the DEN Project Manager upon request.

6.6.2.2 Margins

- A. Top and bottom margin, 0.5 inches, 0.0 Gutter, 0.5 inches Header and Footer margins
- B. Left and Right Margins are each 1.0-inch

6.6.2.3 Typeface and Line Spacing

Print text in 10 pt. Arial normal type with 10 pt. Bold Section Titles in uppercase, Line spacing is single space unless specified otherwise.

6.6.2.4 Tab Set

Text formatting will be done by tab spaces. The standard tab is one tab equals 0.5 inches unless otherwise specified.

6.6.2.5 Header

At the top of each text page is a six-line, flush right and flush left header. Border them on top and bottom. Set three returns below the bottom border. Set margins at standard 1" left and right. Typeface shall be 8 pt. upper case Arial.

Table 6.6-2: Technical Specification Header Layout

Line #	Alignment	Description
Line 1	Flush left	TECHNICAL SPECIFICATIONS
	Flush right	DENVER INTERNATIONAL AIRPORT
Line 2	Flush left	Enter Division number and name
	Flush right	DEN STANDARD TECHNICAL SPECIFICATIONS - 2017
Line 3	1 Space from Left:	Enter CSI Section Number
	Flush right	Enter Construction Contract Number (as provided by City
Line 4	Flush left	Enter Section Name

6.6.2.6 Footer

At the bottom of each text page is a six-line flush right and flush left header and Section/Page Number Centered. Border them on top. Set three returns above the border. Set margins at standard 1" left and right. All typefaces in the footer shall be 8 pt. lowercase Arial bold.

Table 6.6-3: Technical Specification Footer Layout

Line #	Alignment	Description
Line 1	Flush Left:	ISSUED FOR: . During the Design Phases and before Issue for Bid, Indicate the Phase such as Issue for DD Review:13 March 2019 . At IFC, enter Issue for Construction and the date of the bid opening. At record drawing phase, enter Project Record and the date of Final Completion of the Construction or Installation
Line 4	Centered	Enter consultant's Name
Line 4	Flush Right:	Enter Revision Number. At Issue for Bid and IFC, the number shall be 000. Thereafter, any changes will be sequential in number.
Line 5	Flush Left	Enter Date of Baseline Specification
Line 5	Centered:	Enter Section Number. Microsoft Word will automatically update the page number

6.6.3 Table of Contents Page and Paragraph Numbering System

6.6.3.1 Location

Table of Contents shall be at the beginning of each manual and volume and will be designated Table of Contents in the left header and in the footer (TOC). TOC title shall be immediately below the header

6.6.3.2 Line Spacing

All line spacing shall be Single space.

6.6.3.3 Line Numbering

Line numbering is not used at DEN. Upon request of the Project Manager, line numbering shall be incorporated into the specifications. The individual pages for the technical shall use automatic line numbering function of the word processing program. In the case of one side or two-sided printing of the specification document, the line numbering must be shown on the right margin.

6.6.3.4 Page Numbers

Number the pages in each section beginning with a section number, followed by a hyphen (-), and then the page number. Repeat for each section.

6.6.3.5 Section Title

10 pt. Arial Bold centered at the top of the page. No returns prior to title entry are required in that the header carries three returns to allow visual spacing in the print out. Section titles correspond to the CSI Master Format. Division and number are flush left, followed by a hyphen and division title. If the technical specifications are provided by CDOT or the FAA, the numbering/naming must follow the current CDOT/FAA specifications, as appropriate.

6.6.4 Text Pages

Text pages follow many of the same rules as the Table of Contents page. The exceptions are detailed in the following section.

6.6.4.1 Exceptions

Figure 6.6-1: [Technical Specification General Format](#) displays the general format utilizing hanging indents.

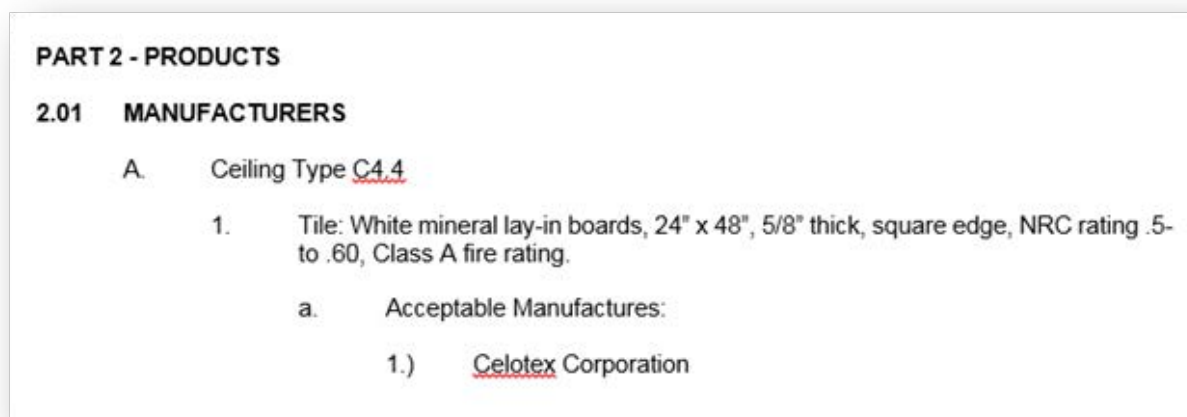


Figure 6.6-1: Technical Specification General Format

6.6.5 Table and Figure Indexes

6.6.5.1 Location

These indexes appear immediately after the Table of Contents and are designated List of Figures and List of Tables under the volume number and title in the page header. In the text, figures and tables are located as closely as possible to the narrative they illustrate.

6.6.5.2 Titles

Titles are centered above the table or charts and printed in 10 pt. uppercase bold.

6.6.5.3 Format

- A. Divide each index into division. Place division numbers flush left, tab once and begin title.
- B. Identify each table or figure by section, part or division and number in series.
- C. Table or figure number should be flush with section title.
- D. Indent one tab (1/4") and begin graphic title.
- E. Print section numbers and title in 10 pt. uppercase bold.
- F. Print chart or figure number and title in 10 pt. uppercase normal.
- G. Include section numeral along with page number and place flush left.

6.6.6 Tables and Charts

6.6.6.1 Location

Tables and charts are located as closely as possible to the narrative they illustrate. The tables and charts may be incorporated into the text in Microsoft Word format. Note that tables and charts used in the specifications must be submitted in magnetic media. Full-page charts or tables immediately follow the page they illustrate. They may be either horizontal or vertical. Always allow 1 inch along the binding edge to assure legibility after reproduction and 3-hole punch.

6.6.6.2 Numbering

Table and chart numbering are by section, part or CSI division and table number (i.e., Division 2, Section 024119, part 8, table number 3 would become Table 024119.8.3) Print in 10 pt., uppercase/lowercase bold.

6.6.6.3 Title

Like the Table of Contents, the titles for these indexes are located 1/2" below the header and centered between the margins. In each case, the title is in 10 pt. uppercase bold.

6.6.6.4 Typeface

Print section title 10 pt. uppercase bold. Print abbreviations in 10 pt., uppercase, bold and descriptions in 10 pt. uppercase/lowercase, normal.

6.6.7 Nomenclature

6.6.7.1 Terminology

Terminology used in all documents shall be in accordance with the terms established in the DEN standard technical specifications, be generally accepted throughout the industry, and must be consistent throughout the documents.

6.6.7.2 Abbreviations

Abbreviations shall be avoided unless listed and fully explained in Division 01 - General Requirements or within the specification section in which the abbreviation occurs.

6.6.7.3 Generic Terms

Generic terms shall be used throughout the documents, except that the names of manufacturers, trade names, and model numbers may be specified as described in [6.6.8.Detail Specifications](#).

6.6.8 Detail Specifications

6.6.8.1 General Requirements

This portion of the specifications will describe specific project requirements and quality of materials, processes, and workmanship. The detail specifications will include the following items, when applicable:

- A. Names of manufacturers - minimum of three (3)
- B. Trade names and model numbers of products
- C. Type, grade, and quality of materials
- D. Alloy of metals
- E. Type and grade of finishes
- F. Physical properties
- G. Required performance, tests, and submittal
- H. Methods of fabrication
- I. Methods of installation
- J. Tolerances
- K. Warranties

6.6.8.2 DEN Standard Technical Specifications

DEN provides and maintains a standard set of DEN specific boilerplate specifications for Division 01 as well as a small number of key sections in Divisions 02-33. Refer to [Table 6.6-1: Part II Specifications](#) and [Table 6.6-4: DEN Standard Specifications: Division 02-33](#) for a listing of all available DEN standard specifications. DEN does not maintain a comprehensive set of specifications. These Division 01 specifications are to be used on all projects in the Terminal, Concourses, and adjoining areas. Division 02-33 DEN standard specifications shall be selected for use on all projects where the applicable product, system, or process described by the section is included in the project. The consultant shall obtain the most current DEN standard technical specifications from the Project Manager at the start of each project. **IN NO CASE, SHALL DEN STANDARD TECHNICAL SPECIFICATIONS BE RE-USED ON PROJECTS.**

Before preparing red-lined specifications, Consultants shall obtain the most recent copy of DEN boilerplate specification Table of Contents (TOC). The Consultant shall strike-through any unneeded specification sections from

the TOC and submit the red-lined TOC to the DEN PM to request the specifications needed for the project. The Consultant shall include the red-lined TOC in all future red-line specification submittals.

Table 6.6-4: DEN Standard Specifications: Division 02-33

Section	Title
087100	Door Hardware
129300	Site Furnishings
147300	Over the Wing Passenger Loading Bridges
147310	Apron Drive Passenger Loading Bridges
147320	Radial Drive Passenger Loading Bridges
221226	Potable Water Cabinets
230130.51	HVAC Air-Distribution System Cleaning
230596	HVAC Smoke Control Testing
230993	Sequence of Operations for HVAC Controls
236600	Preconditioned Air Hydronic Air Handling Units – Aviation
236611	Preconditioned Air DX Air Handling Units – Aviation
236614	Preconditioned Air Ductwork and Accessories – Aviation
236616	Preconditioned Air Electric Control Systems – Aviation
236619	Preconditioned Air Sequence of Operation - Aviation
238126	Split-System Air Conditioners
263544	Aircraft Ground Power Units
265650	Exterior Lighting – Airside
272100	Local Area Networks (LANs)
272101	Public Wireless LAN (WiFi)
273200	Telephone System
274111	Video Surveillance and Environmental Monitoring System (VSEMS)
274133	Master Antenna Television System
274219	Multi-User Flight Information Display System (MUFIDS)
274220	Common Use Passenger Processing Systems (CUPPS)
275123	Emergency Communications System
275313	DEN Standards for Time Synchronization
275319	Public Safety Distributed Antenna System (DAS)
281300	Access Control
282300	Video Surveillance

Table 6.6-4: DEN Standard Specifications: Division 02-33 (Continued)

Section	Title
283300	Compressed Gases
283801	Emergency Fuel Shutoff System (EFSO)

If a DEN standard technical specification does not exist, the consultant shall develop a technical specification based on MasterSpec or other industry standard technical specification content source. Project specifications must include all DEN technical requirements identified in discipline DSMs.

Consultant-supplied MasterSpec sections shall be based on content no older than 2 years old.

Include a specification source matrix in each design submittal which lists all sections included in the project, along with their source (DEN boilerplate, MasterSpec, manufacturer's guide specification, etc) and revision date. The specification source matrix is available upon request via the DEN Project Manager. Nonstandard technical specifications shall be submitted to the DEN Project Manager as part of the standard contract document reviews. Any sections added to the project following the 60% design submittal shall be submitted for an independent internal review and acceptance by DEN SMEs and Stakeholders, separate from the standard contract document reviews.

6.6.8.3 DEN Technical Requirements

The DEN technical requirements can be found in discipline DSMs.

6.6.8.4 Products and Materials

Specific products or materials required by these DEN standard technical specifications shall be specified on each project to maintain design continuity, engineering efficiency, and ease of maintenance. The *required* products or materials must be confirmed in writing by DEN. DEN standard technical specifications shall be used for all projects. The consultant shall obtain a set of the most current DEN standard technical specifications from the Project Manager at the start of each project. **IN NO CASE, SHALL DEN STANDARD TECHNICAL SPECIFICATIONS BE RE-USED ON PROJECTS.**

6.6.8.5 Specifying and Reviewing Products and Material Submittals

All products, materials, process, etc., which the consultant deems necessary to specify within the project specification, to identify contractor requirements for quality of materials, procedures and processes, and workmanship must require a contractor submittal that must be reviewed by the consultant in accordance with the requirements. At no time, shall any contractor submittals not undergo a consultant review for compliance with the project specifications. Using the DEN standard technical specification formats and protocols for preparation of the project specification, should the consultant believe that a contractor submittal for a product, material, or workmanship issue not require a submittal, written approval from DEN must be obtained; to delete any requirement for the deletion of a submittal requirement of the specifications or the consultant not reviewing the contractor submittal for compliance to the specification requirements. If a specification does not exist, the consultant may develop specifications based on MasterSpec or other industry standard specification. Specifications used in this manner shall be submitted separately from the contract documents for a separate review.

6.6.9 Redundancy

Care must be taken to assure that information contained in any section is not redundant, in conflict or at variance with the General Conditions, Special Conditions, Detail Specifications, or Drawings.

6.6.10 Reference

Each section of the Detail Specifications must list a cross-reference to related work specified in other sections of the detail specifications, to define the limits of the work described in each section.

6.6.11 Industry Codes and Standards

Industry codes and standards may be referenced in the detail specifications to require compliance with these codes and standards. Such references shall not be used to supersede the design indicated on the project drawings, or to take the place of a complete design.

6.6.12 Design Standards

The specifications shall not contain any reference to compliance with the DSMs by name. The DSMs are to be used as a guide to the design of a project and not as a contract document for construction. The DEN technical requirements outlined in [6.6.0.5.DEN Technical Requirements](#) must be incorporated in consultant specifications and cannot be referenced.

6.6.13 FAA Requirements

The consultant shall produce a report, which details the specific FAA requirements for contractor activities during construction on operating airports. This report shall contain copies of the rules, regulations, and advisory circulars that specify contractor activities while constructing the project. Following the review and acceptance of the report, the consultant shall prepare or modify a contract document section, which specifically details contractor requirements for compliance with the FAA rules and regulations.

6.6.14 Redline DEN Standard Technical Specifications

All DEN standard technical specifications are required to be submitted in redline format at all intermediate submittals of the contract documents (DD, 30%, 60%, 90%, 100%, etc.). DEN standard technical specifications shall be edited in Microsoft Word with the track changes tool enabled (striking out deleted items and adding comment bubbles or bold text of new items). The intent of this step is to identify quickly to DEN Review Staff DEN standard technical specification items that are being removed and non-standard items that are being added to the specification. This requirement shall not be waived for any project.

6.6.15 Submittal Register

During the process of preparing the technical specifications, the Consultant shall also prepare and keep a register of submittals to be delivered by the construction Contractor according to the technical specifications. Prior to the commencement of design, the DEN PM shall provide the Consultant with an outline for this submittal register. The Consultant shall submit the completed submittal register to DEN with the 100% Contract Documents.

6.6.16 Overstock Materials

DEN does not require overstock materials for concessions projects.

End of Chapter

This page is intentionally blank.

Chapter 7 - Architectural Drawings

6.7.0 Architectural Drawings

6.7.0.1 Contents

The drawings shall present all information relative to the size, form, location, and arrangement of the project components. The drawings shall indicate complete design. Prior written acceptance from DEN is required for any design-build component. The following items shall be included on the architectural drawings, when applicable to the specific project:

- A. Location of materials, assemblies, products, and accessories.
- B. Size, thickness, and significant dimensions of all building elements.
- C. Gauges, except for prefabricated and assembled units.
- D. Diagrams of specially fabricated connections.
- E. Relationships of adjacent dissimilar materials.
- F. Soil boring or test pit logs including locations.

6.7.0.2 Design Requirements

Refer to Architectural DSM for detailed requirements of architectural design, details, and specifications.

6.7.0.3 Sequence

Construction documents are divided into specific groups per NCS. The group number shall always remain the same no matter how large the project. Refer to DFI DSM.

- A. Numbered sheets for areas for plan views shall remain consistent across disciplines. For example, sheets A2 01, S2 01, M2 01, P2 01, F2 01, E2 01, and T2 01 shall all show work in the same area.

6.7.1 Plans

6.7.1.1 Floor Plans

Plan view drawings shall present the following minimum information:

- A. North direction arrow located in accordance to drawing requirements and at top of drawing where feasible.
- B. Floor elevation - The floor elevation shall be keyed to DEN NAVD-88 Datum in at least one location on each floor plan. The elevation shall be clearly defined as finish floor or elevation of structural floor.
- C. Identify and indicate the correct horizontal relationship, size, and location of all component. Avoid repeating dimensions that are to be found on large-scale drawings.
- D. Cross-reference symbols or notations to sections, elevations, insert plans, larger scale plans, diagrams, and other drawing details so these drawing elements can be readily located.
- E. Include column lines, graphic scale, show the space in the context with the surrounding area, include BIM room numbers.

6.7.1.2 Reflected Ceiling Plans

Reflected ceiling plan drawings shall clearly delineate all systems including but not limited to materials, soffits, ceilings, partitions, exterior walls, columns, lighting, sprinklers, monitoring devices, diffusers, grilles, registers, signage, and furring elements. The reflected ceiling plans shall carry the same minimum information as itemized above.

6.7.1.3 Large Scale Plans

Where large-scale plans are presented, critical dimensions for code compliance shall be identified. Enlarged plans are required at each gate and shall accurately depict all equipment (PCA, GPU, PWC, etc.) with required access n clearances and the relationship to aircraft and airline ground support equipment (GSE).

Sections shall be included when loading bridges serve multiple sizes of aircraft to ensure loading sill height does not negatively affect gate equipment.

6.7.1.4 Precedence

There is no precedence; plan drawings of the same areas that are presented at different scales shall not deviate.

6.7.1.5 Roof Plans

Provide roof plans that indicate all components of other disciplines including, but not limited to lightning protection, mechanical, electrical, plumbing, access systems and communications systems. Indicate traffic pads from all access points to and around roof mounted equipment or areas requiring maintenance and access. Show storm water flow directions, crickets, flashings, and materials.

All roof penetrations shall conform with roof manufacturer's requirements and shall not void roof warranties.

6.7.2 Sections

6.7.2.1 Precedence

There is no precedence; section drawings of the same areas that are presented at different scales shall not deviate.

6.7.2.2 Sections

Sections shall be provided to define completely the character of construction elements. Above or below grade elevations shall be keyed to the DEN NAVD-88 Datum. Notes such as similar to shall not be acceptable. consultant shall provide design of each type of detail.

6.7.3 Elevations

6.7.3.1 Exterior Elevations

Exterior elevations shall be provided for all exterior planes of new or modified construction, and shall include all other systems including, but not limited to civil, mechanical, electrical, plumbing, fire protection, lighting, communications, lightning protection, fences, and access systems. Indicate the correct vertical relationships, size, and location of the components.

6.7.3.2 Interior Elevations

Interior elevations shall be provided for all interior planes of new or modified construction and shall include all other systems installed in or on the surfaces.

6.7.3.3 Material Definitions

Different materials shall be delineated to define separation of materials.

6.7.4 Demolition Drawings

6.7.4.1 General

Demolition drawings shall be prepared which clearly indicate altered, discontinued, and removed work where extensive removal and/or demolition operations are required. Demolition drawings shall indicate, but not be limited to, the following pertinent information:

- A. Location and size of structural members.
- B. Methods of closing openings.
- C. Other information to clearly indicate the extent of known materials and conditions to be removed.
- D. Symbols that are used for the demolition work shall be the same as those used on the drawings for new construction.
- E. Complete design and detailing of systems interruptions and protection of adjacent or affected systems and operations from damage due to interruptions and/or construction activities.

6.7.5 Composite Drawings

The consultant shall coordinate and prepare composite drawings showing all disciplines on one drawing. Each discipline shall be identified by a specific color. One set of plots shall be submitted to DEN as indicated in [Chapter 20 - Submittals](#) indicating ceiling cavity spaces and utility/structural drawings. The consultant shall ensure that the project systems are completely coordinated and that no designed interference exists. This includes conduit routings, drain lines, sprinkler systems, etc.

6.7.5.1 Egress Plans

The consultant shall provide floor plans indicating safety egress from the facilities that shall include blocks of occupancy types, calculated quantity of occupants, and calculated egress widths. This shall include block diagrams indicating the egress schemes.

End of Chapter

This page is intentionally blank.

Chapter 8 - Structural Drawings

6.8.0 Structural Drawings

6.8.0.1 Definition

A structural drawing delineates the various portions of the overall structural system. All construction materials shall be defined with dimensions, sizes, and locations in the structure. The drawings shall indicate complete design. Prior written acceptance from DEN is required for any design-build component. Structural drawings shall be coordinated with other disciplines and shall include penetrations and other accommodations required.

6.8.0.2 Sequence

Construction documents are divided into specific groups per NCS. The group number shall always remain the same no matter how large the project. Refer to DFI DSM.

- A. Numbered sheets for areas for plan views shall remain consistent across disciplines. For example, sheets A2 01, S2 01, M2 01, P2 01, F2 01, E2 01, and T2 01 shall all show work in the same area.

6.8.1 Floor Plans

6.8.1.1 Structural Steel Framing

Show framing for each floor level, and elevations (top of steel) for all members. Locate all beams with respect to column lines and give sizes. Locate all support points for equipment, posts, hangars, stairs, etc. Sections referring to structural steel details shall be required.

Define by notes all grades of steel used, types and sizes of connections (with details as required) and refer to all standard drawings, charts, tables, notes, etc., for information required to construct a safe and complete floor system.

6.8.1.2 Floor Plans

Show all plan dimensions of floor. Define outer limits, location, and size of openings, elevations for all areas, floor types (concrete, grating, floor plate, etc.) and thickness, equipment supports, and any other items to be incorporated in the floor construction. Cut sections and indicate details shown on same or other sheets to show edge details, equipment pedestals, reinforcement, anchor bolts, and miscellaneous embedments.

Define reinforcement grades and sizes, bar grating or floor plate sizes, and details; locate all floor construction joints, reinforcement lap/splices as required. Define and locate all penetrations. Define steel decking wherever used as concrete form or otherwise shall be defined. Define material properties required for all concrete, steel, floor topping, or other materials used.

6.8.1.3 Roof Plans

Define all plan dimensions and openings as for floors. Define top of steel elevations, sizes, and locations of all beams, purlins, and joists. Define roof type (concrete, steel deck, etc.) Provide framing as required around openings. Define loading requirements for steel deck roofs, such as live load, wind uplift, and attachment to framing for diaphragm action. Define roof slope and locate drains. Locate support points for all roof-mounted equipment such as HVAC equipment, tanks, etc.

All roof penetrations shall conform with roof manufacturer's requirements and shall not void roof warranties.

6.8.2 Elevations and Wall Sections

6.8.2.1 General

Show all columns, beams, bracing on column lines. Size all columns and bracing. Define connections or show loads for connections to be designed by contractor. Give size for all struts and beams not shown on floor plans. Show framing at doors, windows, etc. Provide details for any non-standard connections.

On exterior walls, show girt system. Show sizes, spacing, and locate sag rods. Detail special girts, parapet construction, framing around openings, etc. Types and sizes of siding shall be coordinated with architectural drawings.

6.8.3 Standard Drawings, Schedules, Tables and Details

6.8.3.1 Drawings

In lieu of detailing repeated identical items on all views where they occur, detail on standard drawings and refer to them by letter or number designations. The drawings include, but are not limited to, the following:

6.8.3.1.1 General Notes and Details

Include references to pertinent codes and standards. Give design criteria and loads as required. Show standard details for treatment of concrete edges, joints, penetrations, and anchor bolts. Detail standard handrails and ladders and their anchorage to structure.

6.8.3.1.2 Column Schedules

Show location and size of columns used. Detail splices and base plates, showing shear bars, anchor bolts, grout, and any other required features.

6.8.3.1.3 Bracing Connections

Show typical details for diagonal bracing. List all combinations of vertical, horizontal, and diagonal connections between braces, beams and columns and reference by letter or number designations to plans and elevations.

6.8.3.1.4 Standard Beam and Joist End Connections

Detail typical connections, showing required tolerances, edge distances, pitch, gage, etc. Show manner of designating connections on plans. If standard connections are used for given beam sizes, list.

6.8.3.1.5 Non-standard Connections

Detail as required except where shown on plan or elevation drawings.

6.8.3.1.6 Stair Details

Show plan and elevations for all stairs, with riser and tread dimensions. Show reinforcing for concrete stairs. For steel stairs, show all member sizes, connections, bracing and supports.

6.8.3.1.7 Girt Details

Show all girt bracket types, sag rods, and joints between girt sections and all connections. Detail special built-up girt sections.

6.8.3.1.8 Miscellaneous Details

Show details for all welded girders, trusses, built-up members, and assemblies used. Show all necessary views of crane girders, crane columns, and brackets and attachment to building, crane stops, clearance requirements, and dimensions relative to building column lines and elevations. Provide details for fabrication of floor plates, floor bracing, and all other miscellaneous items to be installed by the contractor.

End of Chapter

This page is intentionally blank.

Chapter 9 - Mechanical Drawings

6.9.0 Mechanical Drawings

6.9.0.1 Definitions

A mechanical drawing delineates equipment, materials, components, ductwork, piping, and accessories to convey liquids, and gases for the construction of mechanical systems. Mechanical systems include HVAC, plumbing, fire protection, building automation and any process system requirements. The drawings shall indicate complete design. Prior written acceptance is required for any design-build component.

6.9.0.2 General Requirements

These drawings establish the requirements for construction of the facility design, including pertinent services, equipment, and other features required for the performance of the mechanical equipment. These drawings shall incorporate dimensions, symbols, reference to codes, conventions, schedules, diagrams, etc., in describing the size and routing of pipes, material to be used, equipment criteria, duct sizes and shapes, amount of flow and the temperature of material in pipes and ducts, valve types and location, floor and wall penetrations, tank construction, equipment, piping insulation, and other facets of mechanical design as are required.

6.9.0.3 Design Requirements

Refer to Mechanical DSM for detailed requirements of mechanical design, details, and specifications.

6.9.1 Sequence

6.9.1.1 Numbering

Construction documents are divided into specific groups per NCS. The group number shall always remain the same no matter how large the project. Refer to DFI DSM.

- A. Numbered sheets for areas for plan views shall remain consistent across disciplines. For example, sheets A2 01, S2 01, M2 01, P2 01, F2 01, E2 01, and T2 01 shall all show work in the same area.

6.9.1.2 Demolition

Demolition drawings of mechanical systems shall call out all ductwork, insulation, piping, and associated controls to be removed. Controls shall be called out to be removed in the programming of that system. Abandoned-in- place equipment, piping, and ductwork is not allowed unless authorization is obtained in writing from the Project Manager.

6.9.2 Flow Diagrams

6.9.2.1 Schematic Illustrations

Flow diagrams are schematic illustrations of piping or duct circuits including equipment, components, and instruments involved in the mechanical system. The purpose of flow diagrams shall be to define a mechanical system with respect to flow directions, component sizes, control functions, operational and flow balances.

6.9.2.2 Key Drawings

Flow diagrams are key drawings, which form a basis for detail design drawings, maintenance, operator training, and construction. Because of the definitive nature of flow diagrams, they shall be developed prior to the commencement of construction document phase piping drawings or any detail design drawings, which may be affected by the flow diagrams.

6.9.2.3 Flow Diagrams

Flow diagrams shall be required to illustrate the following:

- A. HVAC airflow of all HVAC systems and relative pressurization of spaces
- B. Chilled water piping systems
- C. Process systems; chemical feed systems
- D. Heating water piping systems
- E. Automation; temperature controls, process controls, life safety controls, etc. Diagram shall depict all components in control of equipment and interface with DEN EMCS systems.

Existing flow diagrams shall be modified to show new work and modifications to any equipment represented in the diagram. The need for additional flow diagrams shall be determined on a project-by-project basis by the Design Engineer, the DEN Mechanical Engineer, and the DEN Project Manager. The need for additional flow diagrams shall be based on the complexity of piping in the mechanical system. Flow diagrams shall define all contributory loads and demand loads of existing systems or systems to be provided by others

6.9.3 Flow and Control Diagram Requirements

6.9.3.1 General Requirements

All piping, ductwork, and equipment shall be represented on flow diagrams in schematic form. Accurate depiction of physical relationships is essential for clarity, e.g., a pressure vessel with nozzles located on top, bottom, and sides should appear on the flow diagram with nozzles shown in approximately the same relationship. Piping specialties and special features shall bear a reasonable resemblance to the actual items or installations.

Flow and controls may be shown on a single diagram. For complex or very large control and flow diagrams, they may be requested to be separate by the DEN Mechanical Engineer.

6.9.3.2 Flow Direction

A flow direction arrow shall appear at each line junction or change of direction to illustrate the flow direction.

6.9.3.3 Limits of Construction

Purchased equipment packages, which are pre-assembled or pre-piped, shall be so designated with a dashed line to outline the limits of the vendor-supplied portion.

6.9.3.4 Instruments and Controls

Instrument Society of America (ISA) symbols shall be used to represent instruments and control loops. Instruments shall be identified by a tag number inside a circular balloon, in accordance with ISA standards. Tag numbers shall be permanently affixed to each instrument. Typical industry Process and Instrumentation Diagram (P&ID) standard level of detail is preferred.

Flow diagram shall completely identify all devices, mechanisms of control (i.e., pneumatic, electric) and interface points. Level of detail documents can be provided upon request through the DEN Mechanical Engineer.

6.9.3.5 Set Points

Set points for relief valves, limit switches, control valves, dampers, and operating temperatures shall be indicated. Normal and failure positions shall be called out for control valves and dampers (fail open, fail closed, normal open, normal closed, etc.). Other instrument set points or operating control points shall be called out as appropriate to aid design and construction.

6.9.3.6 Logic/Control

For complex systems and/or those systems controlled by Direct Digital Control (DDC), or those connecting to the DEN EMCS, a written logic description shall be added to the flow diagrams or included in the project technical provisions of the Specifications.

- A. Instrument Society of America (ISA) symbols shall be used to represent control devices, instruments, and control loops.
- B. All components shall be identified by a tag number inside a circular balloon, in accordance with ISA standards. Tag numbers shall be permanently affixed to each instrument.

6.9.3.7 Operating Controls

Consideration shall be given to all anticipated operating conditions, including start-up and shutdown. Flow diagrams shall show bypasses, start-up lines, shutdown lines, and any valves, controls, etc., required for any anticipated operating condition.

6.9.3.8 Identification Tags

Facilities management identification tag numbers and basic design parameters shall be shown on the flow diagrams. The Engineer shall obtain equipment tag numbering from the DEN Project Manager

6.9.3.9 Existing System Tie-In

When new mechanical systems are to be connected to existing systems or systems being designed by others, each tie-in shall be identified on the drawings by a hexagon symbol bearing a unique tie-in number. The designer shall include a list of tie-ins on the drawings as required for a project. The tie-in schedule shall note the tie-in number, piping, ductwork, or other service, and the extent of interruption required to affect each tie-in. This schedule shall be used to help coordinate construction with normal operations to minimize unscheduled down time.

6.9.3.10 Symbols

Symbols used on flow diagrams for valves, instruments, and accessories shall conform to standards established by the legend.

6.9.3.11 Gravity Drainage

When a specific service requires positive gravity drainage, arrows and notes on the flow diagram shall illustrate the slope required. Plans shall indicate starting and ending invert elevations.

6.9.3.12 Space Pressurization Diagrams

Space pressurization diagrams are required to show how air is intended to move throughout the facility and required pressurization aspects of many space types (i.e., restrooms under negative pressure). Diagrams shall be in block form and depict as clearly and simply as possible all HVAC & Life Safety systems. Diagrams shall show:

- A. All equipment (AHU, EF, VAV, FCU, etc.) serving each space/area with appropriate unit tags.
- B. Total airflow rates of pressurized systems in each space (each diffuser is not required unless a VAV serves many individual spaces).
- C. Paths of transfer air in each space with anticipated airflow rate.
- D. Path of return air in each space with anticipated airflow rate.
- E. Path of smoke control and airflows in each space.
- F. Room names of each space.
- G. Single- or double-line presentation of ductwork system flow.

6.9.4 Drawings for Mechanical Systems

6.9.4.1 General

Piping drawings shall delineate the components required to convey the fluids. Drawings shall be completely coordinated with other disciplines and existing systems to ensure no conflicts occur in the documents. Drawings shall include but not be limited to such items as the supply and distribution of potable water, sanitary water and waste, storm waste, chilled water, systems for fire protection, drainage, fuel supply to boilers and heating water. Piping drawings shall delineate the material, system, size, and routing of pipe, hose and tubing, the associated vessels and equipment, and other facets of mechanical design by incorporating dimensions, symbols, codes, conventions, schedules, and diagrams.

Floor plans, flow diagrams and isometrics for systems in the Terminal Complex shall not use a single drawing that references different areas of the project, e.g., a single "typical" pump room to represent multiple pump rooms. Each room and diagram is unique and must be represented independent of other rooms.

6.9.4.2 Flow Diagrams

When flow diagrams are required, they shall be completed prior to commencement of detail piping drawings.

6.9.4.3 Enlarged Plans

When adequate detail cannot be shown on arrangement plans, enlarged plans shall be provided.

Enlarged plans are required at each gate and shall accurately depict all equipment (PCA, GPU, PWC, etc.) with required access clearances, movement requirements, and the relationship to aircraft and airlines ground support equipment (GSE).

Sections shall be included when loading bridges serve multiple sizes of aircraft to ensure loading sill height does not negatively affect gate equipment. Sections shall show minimum clearances to ground for loading bridge mounted equipment.

6.9.4.4 Drawing Delineation

The following rules shall be followed in the delineation of ductwork and piping drawings.

Exposed pipe shall be shown as a single thick line, and hidden or buried pipe shall be shown as a thick dashed (hidden) line; however, to delineate clearances and special conditions, 6" and larger pipe shall be shown using a double line, drawn to scale shown, the actual pipe dimensions, and pipe centerline.

When new and existing piping, ductwork and/or equipment are shown on the same drawing, existing pipe, ductwork, and equipment shall be shown using a light or shaded lineweight. New equipment shall be drawn with heavier

lineweights than main piping. Hidden lines shall be reserved for hidden equipment, ductwork, or piping below and not used to represent existing systems.

All ductwork shown on plans shall be shown using a double line, drawn to scale shown, the actual duct dimensions, and round duct centerline. Single line representation shall only be used for flexible ductwork to diffusers/grilles. For food and beverage tenant projects, ductwork is to be color coded for each system type. Grease exhaust shall be shown in a different color than any other system type and so on. Refer to the Digital Facilities and Infrastructure (DFI) DSM for color legend and additional requirements.

Pipe shall be identified as to size, service code (fluid in pipe), and flow direction. Flow direction shall be clearly identified with arrows indicating the direction of flow on the centerline of the pipe.

Valve stems, hand wheels, etc., even though shown symbolically, shall be drawn to scale where a clearance problem may exist or where removal or operation may be critical.

- A. General site routing plans – 1/10" to 1/20" = 1'-0"
- B. Piping plans (including double line piping) – 1/8" to 1/4" = 1'-0"
- C. Enlarged plans, sections and details – 1/4" to 3/4" = 1'-0"

Pipe and ductwork mains and branches shall be dimensionally located from the facilities structure, such as column lines, walls, ceiling, equipment, supports, etc., or from recognized benchmarks; as required or justified by complexity or space constraints.

Pipes and ductwork shown in elevation or section shall have their centerline or bottom of pipe/duct elevations given above or below grade or floor elevation to a reference datum plane. All pipe/duct elevations shall be identified on the drawings and coordinated with other items vertically.

When draining of horizontal piping is required or drip stations are called for, the slope in lines shall be called out by an arrow placed adjacent to the applicable line.

The slope shall be indicated in fraction of an inch per foot or the elevation given at both ends of the slope. Invert elevations shall be given at the start point of the first bend, and obstruction clearance, at tie-ins to existing piping and/or when the continuation of the piping is covered by another discipline.

When more than one system or service is delineated on the drawing, line designations shall be used.

When pipe or tubing runs are grouped close together, the line designations shall be called out.

Guides, anchors, and expansion compensators shall be located and described. Show all dampers (balancing, control, fire, smoke, etc.) and location of maintenance access.

All new and existing diffusers, registers, and grilles shall be called out with a minimum face size or neck size, design airflow, specification type, and maximum pressure drop or maximum throw at 100 fpm. Presentation shall be identified with a single callout. [Figure 6.9-1: Air Distribution Device Identification](#) shows the correct callout identification method.

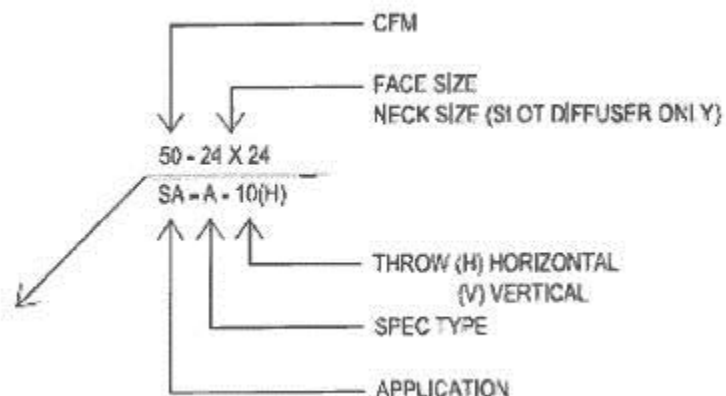


Figure 6.9-1: Air Distribution Device Identification

Ductwork sizing shall be called out W x H. No symbols for measurement units are required. All dimensions shall be in inches.

- A. Correct: 24 x 36
- B. Incorrect: 24"/36"

Round ductwork shall be identified in inches followed by the diameter symbol. No symbols for measurement units are required, i.e., 24.

Ductwork and piping callouts shall be labeled in the direction of fluid flow and indicate equipment service. [Figure 6.9-2: Exhaust Air Callout Diagram](#) is labeled incorrectly. It should read 34x16 from AHU-CX above:

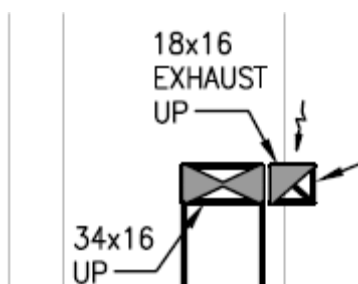


Figure 6.9-2: Exhaust Air Callout Diagram

The piping abbreviations shown in from the DEN Revit Template are to be used for drawing consistency. Designers shall use the line type designation illustrated when single line drawings are used.

MECHANICAL			
PIPING		AIR CONDITIONING AND REFRIGERATION	
GRAPHIC	DESCRIPTION	GRAPHIC	DESCRIPTION
———LPS———	LOW PRESSURE STEAM	———RD———	REFRIGERANT DISCHARGE
———MPS———	MEDIUM PRESSURE STEAM	———RS———	REFRIGERANT SUCTION
———HPS———	HIGH PRESSURE STEAM	———RL———	REFRIGERANT LIQUID
———HPC———	HIGH PRESSURE CONDENSATE	———CWS———	CONDENSER WATER SUPPLY
———MPC———	MEDIUM PRESSURE CONDENSATE	———CWR———	CONDENSER WATER RETURN
———LPC———	LOW PRESSURE CONDENSATE	———CHWS———	CHILLED WATER SUPPLY
———BBD———	BOILER BLOWDOWN	———CHWR———	CHILLED WATER RETURN
———PC———	PUMPED CONDENSATE	———GLCS———	GLYCOL SOLUTION CHILLED SUPPLY
———MU———	MAKEUP WATER	———GLCR———	GLYCOL SOLUTION CHILLED RETURN
-----ATV-----	ATMOSPHERIC VENT	———GLH/CS———	GLYCOL SOLUTION HOT/CHILLED SUPPLY
———FOD———	FUEL OIL DISCHARGE	———GLH/CR———	GLYCOL SOLUTION HOT/CHILLED RETURN
———FOG———	FUEL OIL GAUGE	———FILL———	FILL LINE
———FOS———	FUEL OIL SUCTION	———H———	HUMIDIFICATION LINE
———FOR———	FUEL OIL RETURN	———D———	DRAIN
———FOV———	FUEL OIL TANK VENT	———HPWS———	HEAT PUMP WATER SUPPLY
———HWS———	LOW TEMP HOT WATER SUPPLY	———HPWR———	HEAT PUMP WATER RETURN
———HWR———	LOW TEMP HOT WATER RETURN		
———MTWS———	MEDIUM TEMP HOT WATER SUPPLY		
———MTWR———	MEDIUM TEMP HOT WATER RETURN		
———HTWS———	HIGH TEMP HOT WATER SUPPLY		
———HTWR———	HIGH TEMP HOT WATER RETURN		
———GLHS———	GLYCOL SOLUTION HEATED SUPPLY		
———GLHR———	GLYCOL SOLUTION HEATED RETURN		
———CA———	COMPRESSED AIR		
———VAC———	VACUUM (AIR)		
———VPD———	VACUUM PUMP DISCHARGE		
———(NAME)E———	EXISTING PIPING		
~~———X-X-X(NAME)-X-X-X———~~	PIPE TO BE REMOVED		

Figure 6.9-3: Mechanical Piping Abbreviations and Line Types

6.9.4.5 Demolition Drawings

- Demolition drawings shall completely identify limits of demolition and items to remain for each system.
- Define the requirements for maintaining system operation in critical operational spaces where HVAC systems cannot be interrupted.
- Drawings shall identify locations of all existing piping isolation valves and drain points required to perform the scope of work indicated and shall not direct the contractor to locate them in the field. Include additional floor plans if required to indicate the locations of the piping isolation valves. Verify locations of valves and drain points at the project site; do not rely on as-built drawings.
- Drawings shall be fully coordinated with other life safety systems for removal.

6.9.4.6 Mechanical Details

- All roof penetrations shall be fully detailed and conform with roof manufacturer's requirements. Roof penetrations shall not void roof manufacturer's warranty.

6.9.5 Update of Standard Diagrams

DEN currently maintains standard diagrams for most buildings, which shall be used in any project that modifies these listed systems:

- A. HVAC control router location map
- B. Heating and chilled water flow diagrams
- C. PCA flow diagram for Concourses A and C

These diagrams should be included in the base building Revit model. If not, they are available from the DEN Mechanical Engineer in AutoCAD format. All new flow/location diagrams shall be developed using the existing diagrams in the guidelines.

6.9.6 Heating, Ventilating, Air Conditioning

6.9.6.1 General

Heating, ventilating, and air conditioning drawings delineate the components required to supply or move air by natural or mechanical means. Such air may or may not be conditioned (i.e., filtered, tempered, and/or humidified). These drawings shall establish procedures for construction of the facility design, including pertinent services, equipment, and utilities. The delineation for these drawings shall incorporate dimensions, symbols, codes, conventions, schedules, diagrams, etc., in describing the ducts blowers, filters, heating or cooling coils, roof exhausts, grilles, dampers, air conditioning units, pumps, controls, ducts, and equipment. The drawings shall be completely coordinated with all other design disciplines to assure that there are no designed conflicts and that the systems can be installed as delineated.

6.9.6.2 Combined Drawings

HVAC Systems and piping systems for HVAC systems may be combined on the same set of drawings where practical and prior written acceptance from DEN has been issued.

6.9.6.3 Drawing Delineation

The following rules shall apply when detailing these drawings:

- A. Drawings shall be prepared showing routing of ducts and piping and location of ducts, grilles, and required ventilation, exhaust, and/or air conditioning equipment. The preferred scale for arrangements is 1/4" = 1'-0" (To aid in checking drawings and resolving potential interferences among other components, such as piping, electrical, architectural, etc., the heating, ventilation, and air conditioning drawing shall be prepared to the same scale as these other drawings, where feasible).
- B. Duct layouts shall include grille sizes, CFM, splitters, outlet control dampers, elbows, access doors, branches, volume control dampers, louver openings, booster heating equipment, test holes, and other miscellaneous components equipment and controls.
- C. When duct sizes are given, the first dimension is the side shown, for example, 20x12. The 20" dimension is the width and the 12" dimension is the depth where the duct is shown in plan.
- D. Material for ducts, gage of metal, type and spacing of joints and reinforcements, type and spacing of hangers, angle, or change in size transitions, and cross bracing shall be covered in specifications.
- E. Direction of flow shall be indicated by an arrow.
- F. In multiple level facilities, piping shall be fully detailed on the level where the work occurs. Piping on the floor level below shall not be shown as hidden line as the only method of presentation.

- G. All parts such as coils, fans, dampers, filters, housings, compressors, and miscellaneous items shall be called out on the drawing. A schedule may be employed for this purpose. A schedule lists the type, size, capacity, speed, pressure, type enclosure, fins per inch and rows, and other pertinent components in tabular form. Deviations from the standard schedules shall be approved by the Project Manager prior to use.
- H. Clearly define dedicated maintenance access areas for all equipment on plans and details. Presentation shall indicate clear space from area of maintenance of equipment and include a dedicated area directly below to the operational floor. Maintenance areas shall include but not be limited to:
 - a. Filter pull areas
 - b. Coil pull areas
 - c. Dedicated control panel access (24" clear)
 - d. Door swings (duct and equipment)
 - e. Valve and damper handle/actuator access
 - f. Motor service space
 - g. Major component removal
 - h. Life safety devices
 - i. Specialized expansion fittings
 - j. P/T ports
- I. Automatic control diagrams for ventilation, heating, and air conditioning systems shall show:
 - a. All controllers, sensors, thermocouples, valve and damper operators, relays, and accessories necessary to illustrate the functions and sequence of operation of all principal components in the system.
 - b. The set point and throttling range of all controllers.
 - c. The normally open or closed position of all valves and dampers.
 - d. A list or matrix of inputs and outputs.
 - e. The sequence of operation of the system through a complete winter-summer cycle, including the off and fire alarm conditions shall be provided in the specifications.
- J. On existing mechanical piping systems, detail location of nearest shut-off valve and system drain for all tie-ins. Design shall not direct the contractor to locate them in the field.

6.9.7 Mechanical Design Submittal Requirements

6.9.7.1 General

This section addresses the minimum requirements for the submittal of mechanical discipline construction or RFP documents during the progress of design. Unless otherwise stated in the consultant's contract or approved task, at a minimum, the consultant shall deliver the following content in the submittal packages to DEN. These requirements are in addition to the requirements detailed in [Chapter 20- Submittals](#) of this DSM.

The information and requirements in this section are in addition to the requirements laid out in [Chapter 2- Design Phases](#) and [Chapter 3- Contract Documents](#).

The following are the minimum requirements for each submittal phase, and are required in all projects, except for written exemptions from the PM and approval of DEN Mechanical Engineer (defined in the Mechanical DSM). In general, mechanical system designers should focus on large equipment locations and clearances, controls and

sequences of operations, and mechanical diagrams in earlier submittals, and work on smaller details such as branch ductwork, selection of smaller equipment, and mechanical details in later submittal packages.

Table 6.9-1: Submittal Requirements

Submission Type	Description	30% Design	60% Design	90% Design	100% Design
General Mechanical Notes					
	Boilerplate Notes ^{A,C}		X	X	
	Project-Specific Notes ^{A,B,C}				X
Symbols Legend					
	General Symbols ^{A,C}	X	X		
	Project-Specific Symbols ^{A,B,C}			X	X
Demolition Phasing Plans					
	General Area of Demolition	X			
	Phasing Plan ^D	X ^P	X ^F	X ^F	
	Tie-In Points and Schedule	X ^P	X ^U	X ^F	X ^F
Floor Plans					
	General Equipment Layout	X			
	Large Equipment Placement	X ^P	X ^U	X ^F	X ^F
	Small Equipment Placement		X ^P	X ^U	X ^F
	Phasing Plan ^D	X ^P	X ^F	X ^F	X ^F
	Tie-In Points and Schedule	X ^P	X ^F	X ^F	X ^F
	Duct Pressure Classifications		X ^U	X ^U	X ^F
	Transfer/Return/Exhaust Opening Sizing		X	X	X
	Control Device Locations		X ^U	X ^U	X ^F
	Life Safety Airflow Coordination		X ^F	X ^F	X ^F
Equipment Placement					
	Large Equipment Placement	X	X	X	X
	Large Equipment Coordination		X	X	X
	Large Equipment Maintenance Areas		X	X	X

Table 6.9-1: Submittal Requirements (Continued)

Submission Type	Description	30% Design	60% Design	90% Design	100% Design
	Small Equipment Placement		x	x	x
	Small Equipment Coordination			x	x
	Small Equipment Maintenance Areas			x	x
Ductwork Layouts					
	Single-Line New Medium Pressure Ductwork or Duct Zones	x			
	Double-Line New Medium Pressure Ductwork		x	x	x
	Single-Line New Low Pressure Ductwork		x		
	Double-Line Low Pressure Ductwork			x	x
	Single-Line Existing Piping			x	
	Double-Line Existing Piping				x
	Existing Shut-Off Valve Locations		x	x	x
	Tie-In Points and Schedule	x ^P	x ^U	x ^F	x ^F
Enlarged Plans					
	Dimensional General Arrangements for Large Equipment	x			
	Enlarged Plans for Mechanically Intensive Areas		x ^P	x ^U	x ^F
	Tie-In Points and Schedule		x ^P	x ^U	x ^F
Section Views					
	Section Views for Mechanically Intensive Areas		x ^P	x ^U	x ^F
	Section Views for Dimensionally Sensitive Areas		x ^P	x ^U	x ^F
	Section Views for Critical Structure Crossings		x ^P	x ^U	x ^F
	Tie-In Points and Schedule	x ^P	x ^U	x ^F	x ^F

Table 6.9-1: Submittal Requirements (Continued)

Submission Type	Description	30% Design	60% Design	90% Design	100% Design
Controls and Sequence of Operations					
	Sequences for Large Equipment	x ^P	x ^U	x ^F	x ^F
	Sequences for Small Equipment		x ^P	x ^U	x ^F
	P&ID for Large Equipment		x	x	x
	P&ID for Small Equipment			x	x
	Points Lists for Large Equipment		x ^P	x ^F	x ^F
	Points Lists for Small Equipment			x ^P	x ^F
Mechanical Details					
	General Details ^{A,B}		x ^P	x ^U	x ^F
	Non-Standard Details ^C	x ^P	x ^U	x ^F	x ^F
Equipment Schedules					
	Equipment Schedules	x ^P	x ^U	x ^F	x ^F
Specifications					
	Specifications Table of Contents	x ^P	x ^U	x ^F	x ^F
	Red-lined Specifications		x ^P	x ^U	x ^F
	Clean Specifications				x ^F

P- Preliminary: Preliminary denotes some work has been done, but much of the detail is missing. Consultant shall focus more on difficult work first, such as large equipment placement, maintenance clearances, and sequences of operations. Routing of low-pressure ductwork and mechanical piping are not desired for preliminary work.

U- Updated: Updated denotes work has been submitted to DEN before review, and DEN's comments have been taken into account and feedback incorporated into Construction Documents. More detail and revisions may still be required.

F- Finalized: Finalized denotes work that needs little if any more updated before being submitted for permits. All DEN comments shall be taken into account and feedback incorporated into Construction Documents.

A Use DEN=provided symbols, general notes, and details.

B Remove any symbols, notes, and details not used in project for final submittal.

C Non-standard symbols, notes, and details, where required by the project, shall be submitted in earlier sets of Construction Documents

D Phasing Plans, when required by the project, shall be finished by the 60% submittal.

End of Chapter

Chapter 10 - Plumbing Drawings

6.10.0 Plumbing Drawings

6.10.0.1 Definitions

A plumbing drawing delineates equipment, materials, components, ductwork, piping, and accessories to convey liquids, and gases for the construction of mechanical systems. Mechanical systems include HVAC, plumbing, fire protection, building automation and any process system requirements. The drawings shall indicate complete design. Prior written acceptance is required for any design-build component.

6.10.0.2 General Requirements

The drawings establish the requirements for construction of the facility design, including pertinent services, equipment, and other features required for the performance of the mechanical equipment. These drawings incorporate dimensions, symbols, reference to codes, conventions, schedules, diagrams, etc., in describing the size and routing of pipes, the kind of material to be used, equipment criteria, duct sizes and shapes, amount of flow and the temperature of material in pipes and ducts, valve types and location, floor and wall penetrations, tank construction, equipment, piping insulation, and other facets of mechanical design as are required. Drawings shall be completely coordinated with other disciplines to ensure there are no conflicts and that the systems can be installed as delineated

Provide a legend sheet indicating all symbols, line types, and abbreviations used in the contract drawings. Legend shall be project specific. General legends encompassing symbols and abbreviations not part of work are prohibited.

6.10.0.3 Design Requirements

Refer to Mechanical DSM for detailed requirements of plumbing design, details, and specifications.

6.10.1 Sequence

6.10.1.1 Numbering

Construction documents are divided into specific groups per NCS. The group number shall always remain the same no matter how large the project. Refer to DFI DSM.

- A. Numbered sheets for areas for plan views shall remain consistent across disciplines. For example, sheets A2 01, S2 01, M2 01, P2 01, F2 01, E2 01, and T2 01 shall all show work in the same area.

6.10.1.2 Demolition

Demolition drawings of plumbing systems shall call out all insulation, piping and associated controls to be removed. Controls shall be called out to be removed in the programming of that system. Abandoned-in-place piping is not allowed unless written authorization is obtained in writing from the Project Manager.

6.10.2 Flow Diagrams

6.10.2.1 Schematic Illustrations

Flow diagrams are schematic illustrations of piping or duct circuits including equipment, components, and instruments involved in the mechanical system. The purpose of flow diagrams shall be to define a mechanical system with respect to flow directions, component sizes, control functions, operational and flow balances.

6.10.2.2 Key Drawings

Flow diagrams are key drawings, which form a basis for detailed design drawings, maintenance, operator training, and construction. Due to the definitive nature of flow diagrams, they shall be developed prior to the commencement of construction document phase piping drawings or any detailed design drawings, which may be affected by the flow diagrams.

6.10.2.3 Requirements

Flow diagrams shall be required to illustrate the following:

- A. Process drain/sewer systems; chemical feed systems.
- B. Hot water piping systems
- C. Plumbing waste and storm drainage systems: diagrams shall be provided and show calculated fixture unit counts or GPM on all sections and equipment.
- D. Plumbing hot and cold-water supply systems: diagrams shall be provided and show calculated fixture unit counts or GPM on all sections and equipment.
- E. Automation; temperature controls related to plumbing equipment.
- F. Natural gas piping systems. Natural gas piping systems shall include calculations of inches of water and shall note the demand loads of all equipment to be connected to the gas system.
- G. Fuel systems

The need for additional flow diagrams shall be determined on a project-by-project basis by the Design Engineer and Project Manager. The need for additional flow diagrams shall be based on the complexity of piping the mechanical system.

6.10.3 Flow Diagram Requirements

6.10.3.1 General

Piping and equipment shall be represented on flow diagrams in schematic form. Accurate depiction of physical relationships is essential for clarity (i.e., a pressure vessel with nozzles located on top, bottom, and sides should appear on the flow diagram with nozzles shown in approximately the same relationship). Indicate direction of fluid flow with flow arrows. Piping specialties and special features shall bear a reasonable resemblance to the actual items or installations.

6.10.3.2 Flow

A flow direction arrow shall appear at each line junction or change of direction to illustrate the flow direction.

6.10.3.3 Limits of Construction

Purchased equipment packages, which are pre-assembled or pre-piped, shall be so designated with a dashed line to outline the limits of the vendor-supplied portion.

6.10.3.4 Instruments

Instrument Society of America (ISA) symbols shall be used to represent instruments and control loops. Instruments shall be identified by a tag number inside a circular balloon, in accordance with ISA standards. Tag numbers shall be permanently affixed to each instrument.

6.10.3.5 Set Points

Set points for relief valves, limit switches, control valves, dampers, and operating temperatures shall be indicated. Failure positions shall be called out for control valves and dampers (fail open, fail closed). Other instrument set points or operating control points shall be called out as appropriate to aid design and construction.

6.10.3.6 Controls

For complex systems or those systems controlled by Direct Digital Control (DDC), a written logic description shall be added to the flow diagrams or included in the project technical provisions of the Specifications.

6.10.3.7 Operating Conditions

Consideration shall be given to all anticipated operating conditions, including start-up and shutdown. Flow diagrams shall show bypasses, start-up lines, shutdown lines, and any valves, controls, etc., required for any anticipated operating condition.

6.10.3.8 Identification Tags

Facilities management identification tag numbers and basic design parameters shall be shown on the flow diagrams in a neat format along the top or bottom of each drawing.

6.10.3.9 Exiting System Tie-In

When new plumbing systems are to be tied into existing systems or systems being designed by others, each tie-in shall be identified on the drawings by a hexagon symbol. The designer shall include a list of tie-ins on the drawings as required for a project. The tie-in schedule shall note the tie-in number, piping, ductwork, or other service, and the extent of interruption required to affect each tie-in. This schedule shall be used to help coordinate construction with normal operations to minimize unscheduled down time.

6.10.3.10 Symbols

Symbols used on flow diagrams for valves, instruments, and accessories shall conform to standards established by the legend.

6.10.3.11 Gravity Drainage

When a specific service requires positive gravity drainage, arrows and notes on the flow diagram shall illustrate the slope required.

6.10.4 Drawings for Piping

6.10.4.1 General

Piping drawings shall delineate the components required to convey the fluids. Included shall be such items as the supply and distribution of potable water, sanitary water and waste, storm waste, chilled water, systems for fire protection, drainage, fuel supply to boilers and heating water. Piping drawings, or a set of piping drawings, delineate the kind, size, and routing of pipe, hose and tubing, the associated vessels and equipment, and other facets of mechanical design by incorporating dimensions, symbols, codes, conventions, schedules, and diagrams.

Floor plans, flow diagrams and isometrics shall not use a single drawing that references different areas of the project, e.g., piping for a single or "typical" toilet room to represent multiple toilet rooms. Each room and diagram is unique and must be represented independent of other rooms.

6.10.4.2 Drawing Delineation

The following rules shall be followed in the delineation of piping drawings:

- A. Exposed pipe shall be shown as a single thick line, and hidden or buried pipe shall be shown as a thick dashed (hidden) line; however, to delineate clearances and special conditions, 6" and larger pipe shall be shown using a double line, drawn to scale shown, the actual pipe dimensions, and pipe centerline.
- B. When new and existing pipe and/or equipment are shown on the same drawing, existing pipe and equipment shall be shown using a lighter or shaded lineweight. New equipment shall be drawn with heavier lineweights than main piping.
- C. Pipe shall be identified as to size and service code (fluid in pipe).
- D. Valve stems, hand wheels, etc., even though shown symbolically, shall be drawn to scale where a clearance problem may exist or where removal or operation may be critical.
- E. The scale used for piping drawings shall be as follows:
 - a. General site routing plans – 1/10" to 1/20" = 1'-0"
 - b. Piping plans (including double line piping) – 1/8" to 1/4" = 1'-0"
 - c. Enlarged Plans, Sections and details – 1/4" to 3/4" = 1'-0"
- F. Pipe mains and branches shall be dimensionally located from the facilities structure, such as column lines, walls, ceiling, equipment, supports, etc., or from recognized benchmarks; as required or justified by complexity or space constraints.
- G. Pipes shown in elevation or section shall have their centerline or bottom of pipe elevations given above or below grade or floor elevation to a reference datum plane. All pipe elevations shall be identified on the drawings and piping coordinated with other items vertically.
- H. Piping callouts shall be labeled in the direction of fluid flow and indicate equipment service. Indicate direction of fluid low with flow arrows.
- I. When draining of horizontal lines is required or drip stations are called for, the slope in lines shall be called out by an arrow placed adjacent to the applicable line.
- J. The slope shall be indicated in fraction of an inch per foot or the elevation given at both ends of the slope.
- K. When more than one system or service is delineated on the drawing, line designations shall be used.
- L. When pipe or tubing runs are grouped close together, the line designations shall be called out.
- M. Guides, anchors, and expansion compensators shall be located and described.

6.10.4.3 Plumbing Details

- A. All roof penetrations shall be fully detailed and conform with roof manufacturer's requirements. Roof penetrations shall not void roof manufacturer's warranty.

6.10.5 Plumbing

6.10.5.1 General

Plumbing drawings delineate the components required to supply domestic hot and cold water to plumbing fixtures and then to remove this water after use through a sanitary drainage and vent system. These drawings shall establish procedures for construction of the plumbing system design, including pertinent utility connections, plumbing fixtures, and piping. The delineation for these drawings shall incorporate dimensions, symbols, codes, conventions, schedules, diagrams, etc., in describing the plumbing system design.

6.10.5.2 Detailing Requirements

The following rules shall apply when detailing these drawings:

- A. Drawings shall be prepared showing routing of domestic cold, hot, and re-circulating hot water piping. Sanitary drainage and vent piping shall also be shown. The preferred scale for arrangements is $1/4" = 1' - 0"$. (To aid in checking drawings and resolving potential interferences among other components, such as ductwork, electrical equipment, etc.) The plumbing drawing shall be prepared to the same scale as the drawings of the other disciplines, where feasible.
- B. Plumbing drawings shall include pipe sizes and routing, design fixture unit counts or design flow rates, direction of flow, clean-out locations, plumbing fixture schedule, invert elevations for sanitary drainage piping, and locations for vent piping roof penetrations. Design fixture unit counts, or design flow rates shall be identified on all main piping between branch connections.
- C. In multiple level facilities, piping shall be fully detailed on the level where the work occurs. Piping on the floor level below shall not be shown as hidden line as the only method of presentation.
- D. Materials for piping, insulation, and equipment such as water meters, water heaters, water hammer arresters, infrared sensing devices for automatic valve control and plumbing fixtures, shall be covered in the technical specifications.
- E. An isometric diagram to five feet outside the buildings shall be provided for the domestic hot and cold-water piping, with re-circulation hot water piping included on the isometric where applicable. Indicate water heater location, valves, and tie-in location for connection to water utility service. Indicate all water meters as necessary.
- F. An isometric diagram shall be provided for the sanitary drainage and vent piping to five feet outside the building, with pertinent invert elevations indicated.
- G. An isometric diagram shall be provided for the following additional plumbing systems:
 - a. Gas piping systems
 - b. Storm water systems (primary and secondary)
 - c. Grease waste and vent systems
 - d. Acid waste and vent systems
- H. All plumbing fixtures shall be itemized in schedules on the drawings. The schedule shall list the type of fixture, and connection sizes of hot, cold, sanitary and vent piping. Water heaters may be scheduled in cases where several are required.
- I. Automatic (infrared) lavatory valve operators and flush valves shall be coordinated with the electrical engineer/electrical drawings and shown on the plumbing drawings.
- J. On existing plumbing systems, detail location of nearest shut-off valve and system drain for all tie-ins. Design shall not direct the contractor to locate them in the field.
- K. The following abbreviations in from the DEN Revit Template are to be used for drawing consistency. Use the line type designation illustrated when single line drawings are used.

PLUMBING

<u>GRAPHIC</u>	<u>DESCRIPTION</u>
———SAN———	SANITARY DRAIN ABOVE FLOOR OR GRADE
- - - - -SAN- - - - -	SANITARY DRAIN BELOW GRADE
- - - - -SSD- - - - -	SUB SOIL DRAIN, FOOTING DRAIN
———IW———	INDUSTRIAL WASTE ABOVE FLOOR OR GRADE
- - - - -IW- - - - -	INDUSTRIAL WASTE BELOW GRADE
———ST———	STORM DRAIN ABOVE FLOOR OR GRADE
- - - - -ST- - - - -	STORM DRAIN BELOW GRADE
———OST———	OVERFLOW STORM DRAIN ABOVE FLOOR OR GRADE
———GW———	GREASE WASTE ABOVE FLOOR OR GRADE
- - - - -GW- - - - -	GREASE WASTE BELOW GRADE
- - - - -V- - - - -	VENT
———D———	DRAIN
———OD———	OVERFLOW DRAIN
- - - - -CW- - - - -	COLD WATER
- - - - -HW- - - - -	HOT WATER
- - - - -HW (X °F)- - - - -	HOT WATER (X DESIGNATES TEMP °F)
- - - - -HWR- - - - -	HOT WATER RECIRCULATION
- - - - -HWR (X °F)- - - - -	HOT WATER RECIRCULATION (X DESIGNATES TEMP °F)
———G———	GAS, NATURAL LOW PRESSURE (LESS THAN 14" W.C.)
———G (X PSI)———	GAS, (X INDICATES PRESSURE)
———ACID———	ACID WASTE
- - - - -AV- - - - -	ACID VENT
———(NAME)E———	EXISTING PIPING
X X X X X (NAME) X X X X X	PIPE TO BE REMOVED

Figure 6.10-1: Plumbing Piping Abbreviations and Line Types

6.10.5.3 Demolition Drawings

Demolition drawings shall completely identify limits of demolition and items to remain for each system. Drawings shall identify locations of all existing piping isolation valves and drain points required to perform the scope of work indicated and shall not direct the contractor to locate them in the field. Include additional floor plans if required to indicate the locations of the piping isolation valves. Verify locations of valves and drain points at the project site; do not rely on as-built drawings. Drawings shall be fully coordinated with other life safety systems for removal.

6.10.5.4 Service Diagrams

On all projects requiring natural gas service, compressed air, or other types of pressured systems, provide as part of the construction documents flow diagrams indicating demand loads. An example may be a flow diagram indicating gas service with regulator size, and inches of water demand calculations for each element or devices to be served by the gas service. Include identification at each device the range of pressures acceptable for start-up, testing, and operation of the device.

6.10.6 Update of Standard Diagrams

DEN currently maintains standard diagrams for most buildings, which shall be used in any project that modifies these listed systems:

- A. Grease trap flow diagram for all Concourses and Terminal

These diagrams should be included in the base building Revit model. If not, they are available from the DEN Mechanical engineer in Auto CAD format. All new flow/location diagrams shall be developed using the existing diagrams as guidelines.

6.10.7 Plumbing Design Submittal Requirements

6.10.7.1 General

This section addresses the minimum requirements for submittal of plumbing discipline construction or RFP documents during the progress of design. Unless otherwise stated in the consultant's contract or approved task, at a minimum, the consultant shall deliver the following content in the submittal packages to DEN. These requirements are in addition to the requirements detailed in [Chapter 20 - Submittals](#) of this DSM.

The information and requirements in this section are in addition to the requirements laid out in [Chapter 2 - Design Phases](#) and [Chapter 3 - Contract Documents](#).

The following are the minimum requirements for each submittal phase, and are required in all projects, except for written exemptions from the PM and approval of DEN Mechanical Engineer (defined in the Mechanical DSM). In general, mechanical system designers should focus on restroom, kitchen, and water entry room layouts and clearances, locations of interceptors, and plumbing diagrams in earlier submittals, and work on smaller details such as branch piping runs, selection of smaller equipment, and plumbing details in later submittal packages.

Table 6.10.1: Submittals

Submission Type	Description	30% Design	60% Design	90% Design	100% Design
General Mechanical Notes					
	Boilerplate Notes ^{A,C}		X	X	
	Project-Specific Notes ^{A,B,C}				X
Symbols Legend					
	General Symbols ^{A,C}	X	X		
	Project-Specific Symbols ^{A,B,C}			X	X
Demolition Phasing Plans					
	General Area of Demolition	X			
	Demolition Plans		X ^P	X ^U	X ^F
	Phasing Plan ^P	X ^P	X ^F	X ^F	
	Tie-In Points and Schedule		X ^P	X ^U	X ^F

Table 6.10.1: Submittals (Continued)

Submission Type	Description	30% Design	60% Design	90% Design	100% Design
Floor Plans					
	General Plumbing Equipment and Fixtures Layout	X			
	Plumbing Equipment and Fixtures Layout		X ^P	X ^F	X ^F
	Phasing Plan ^P	X ^P	X ^F	X ^F	X ^F
	Tie-In Points and Schedule	X ^P	X ^F	X ^F	X ^F
	Control Device Locations		X ^P	X ^U	X ^F
Equipment Placement					
	Plumbing Equipment and Fixtures Placement		X	X	X
	Plumbing Equipment and Fixtures Coordination			X	X
	Plumbing Equipment and Fixtures Maintenance Areas			X	X
Plumbing Piping Layouts					
	General Connections for new/modified systems	X			
	Single-Line New Piping		X		
	Double-Line New Piping			X	X
	Single-Line Existing Piping			X	
	Double-Line Existing Piping				X
	Existing Shut-Off Valve Locations		X	X	X
	Tie-In Points and Schedule		X ^P	X ^U	X ^F
Enlarged Plans					
	Dimensional General Arrangements for Plumbing Equipment and Fixtures	X			
	Enlarged Plans for Plumbing Intensive Areas ^F		X ^P	X ^U	X ^F
	Tie-In Points and Schedule		X ^P	X ^U	X ^F
Section Views					

Table 6.10.1: Submittals (Continued)

Submission Type	Description	30% Design	60% Design	90% Design	100% Design
	Section Views for Plumbing Intensive Areas ^E		X ^P	X ^U	X ^F
	Section Views for Dimensionally Sensitive Areas		X ^P	X ^U	X ^F
	Section Views for Critical Structure Crossings		X ^P	X ^U	X ^F
	Tie-In Points and Schedule	X ^P	X ^U	X ^F	X ^F
Controls and Sequence of Operations					
	Sequences for Plumbing Equipment		X ^P	X ^U	X ^F
	P&ID for Plumbing Equipment			X	X
	Points Lists for Plumbing Equipment			X ^P	X ^F
Plumbing Diagrams					
	Grease Waste Riser Diagram and Interceptor Location		X ^P	X ^U	X ^F
	Isometric Diagrams for Plumbing Intensive Areas ^{E,G}		X ^P	X ^U	X ^F
Plumbing Details					
	General Details ^{A,B}		X ^P	X ^U	X ^F
	Non-Standard Details ^C	X ^P	X ^U	X ^F	X ^F
Plumbing Schedules					
	Plumbing Equipment and Fixture Schedules	X ^P	X ^U	X ^F	X ^F
Specifications					
	Specifications Table of Contents	X ^P	X ^U	X ^F	X ^F
	Red-lined Specifications		X ^P	X ^U	X ^F
	Clean Specifications				X ^F

P- Preliminary: Preliminary denotes some work has been done, but much of the detail is missing. Consultant shall focus more on difficult work first, such as large equipment placement, maintenance clearances, and sequences of operations. Routing of low-pressure ductwork and mechanical piping are not desired for preliminary work.

U- Updated: Updated denotes work has been submitted to DEN before review, and DEN's comments have been taken into account and feedback incorporated into Construction Documents. More detail and revisions may still be required.

- F- Finalized: Finalized denotes work that needs little if any more updated before being submitted for permits. All DEN comments shall be taken into account and feedback incorporated into Construction Documents.*
- A Use DEN=provided symbols, general notes, and details.*
- B Remove any symbols, notes, and details not used in project for final submittal.*
- C Non-standard symbols, notes, and details, where required by the project, shall be submitted in earlier sets of Construction Documents*
- D Phasing Plans, when required by the project, shall be finished by the 60% submittal.*
- E Plumbing-intensive areas are areas with many pieces of plumbing fixtures and/or equipment, such as restroom groups, kitchen groups, water entry rooms. pump stations, etc.*
- G Consultant shall use their best judgment to determine where isometric diagrams will best aid the constructibility and maintainability of the project. All plumbing-intensive areas shall have isometric diagrams.*

End of Chapter

Chapter 11 - Fire Protection Drawings

6.11.0 Fire Protection Drawings

6.11.0.1 Definitions

A fire protection drawing delineates equipment, materials, components, piping and accessories to convey liquids, and gases for the construction of fire protection systems. The drawings shall indicate complete design. Prior written acceptance from the Project Manager is required for any design-build component. These drawings establish the requirements for construction of the facility design, including pertinent services, equipment, and other features required for the performance of the mechanical equipment. These drawings incorporate dimensions, symbols, reference to codes, conventions, schedules, diagrams, etc., in describing the size and routing of pipes, the kind of material to be used, equipment criteria, duct sizes and shapes, amount of flow and the temperature of material in pipes and ducts, valve types and location, floor and wall penetrations, tank construction, equipment, piping insulation, and other facets of mechanical design as are required. Drawings shall be complete and coordinated with other disciplines to ensure there are not conflicts and that the systems can be installed as delineated.

6.11.0.2 Design Requirements

Refer to Life Safety DSM for detailed requirements of fire protection design, details, and specifications

6.11.1 Sequence

6.11.1.1 General

Construction documents are divided into specific groups per NCS. The group number shall always remain the same no matter how large the project. Refer to DFI DSM.

- A. Numbered sheets for areas for plan views shall remain consistent across disciplines. For example, sheets A2 01, S2 01, M2 01, P2 01, F2 01, E2 01, and T2 01 shall all show work in the same area.

6.11.2 Flow Diagrams

6.11.2.1 Schematic

One-line diagrams are schematic illustrations of piping including equipment, components, and instruments involved in the sprinkler system. The purpose of one-line diagram shall be to define the sprinkler system with respect to flow directions, component sizes, control functions and operational.

6.11.2.2 Key Drawings

One-line diagrams are key drawings, which form a basis for detail design drawings, maintenance, operator training, and construction. Because of the definitive nature of one-line diagrams, they shall be developed prior to the commencement of construction document phase piping drawings or any detail design drawings, which may be affected by the one-line diagrams.

6.11.2.3 Requirements

One-line diagrams shall be required to illustrate the following:

- A. Standpipe systems and fire risers

- B. Sprinkler System
- C. Fuel systems
- D. Fire Alarm System
- E. Emergency Fuel Shutoff System

The need for additional one-line diagrams shall be determined on a project-by-project basis by the Design Engineer and Project Manager. The need for additional one-Line diagrams shall be based on the complexity for piping of the fire protection system.

6.11.3 Flow Diagram Requirements

One-line diagram requirements shall conform to requirements in this DSM and the guiding NFPA standard.

6.11.4 Drawings for Piping

6.11.4.1 General

Fire Protection Drawings shall delineate the components required to convey the fluids. Piping drawings shall delineate the material, size, and routing of pipe, hose and tubing, the associated vessels and equipment, and other facets of mechanical design by incorporating dimensions, symbols, codes, conventions, schedules, and diagrams.

Systems shall never be shown to be supported by slab on grade without flex connections.

Where systems require structural penetration for clearances of other project elements, provide a complete design including required penetration sizes. Completely coordinate with the Structural Engineer all penetrations sizes and locations.

6.11.4.2 One-line Diagrams

When one-line diagrams are required, they shall be completed prior to commencement of detail piping drawings.

6.11.4.3 Demolition

Demolition drawings of Fire Protection systems shall call out all piping, and associated controls to be removed. Controls shall be called out to be removed in the programming of that system. Demolition drawings shall include phasing plans identifying how the area and life safety systems will remain operational throughout all phases of the scope of work. Abandoned-in place systems are not allowed unless authorization is obtained in writing from the DEN Project Manager.

6.11.4.4 Existing System Tie-In

When new fire protection systems are to be tied into existing systems or systems being designed by others, each tie-in shall be identified on the drawings by a hexagon symbol. The designer shall include a list of tie-ins on the drawings as required for a project. The tie-in schedule shall note the tie-in number, piping, or other service, and the extent of interruption required to affect each tie-in. This schedule shall be used to help coordinate construction with normal operations to minimize unscheduled down time.

6.11.4.5 Delineation

The following rules shall be followed in the delineation of piping drawings:

- A. Exposed pipe shall be shown as a single thick line and hidden, or buried pipe shall be shown as a thick dashed (hidden) line; however, to delineate clearances and special conditions, 6" and larger pipe shall be shown using a double line, drawn to scale shown, the actual pipe dimensions.

- B. When new and existing pipe and/or equipment are shown on the same drawing, existing pipe and equipment shall be shown using a hidden line. New equipment shall be drawn with lighter lines than main piping.
- C. Pipe shall be identified as to size and service code (fluid in pipe).
- D. Valve stems, hand wheels, etc., even though shown symbolically, shall be drawn to scale where a clearance problem may exist or where removal or operation may be critical.
- E. The scale used for piping drawings shall be as follows:
 - a. General site routing plans – $1/10"$ to $1/20" = 1'-0"$
 - b. Piping plans (including double line piping) – $1/8"$ to $1/4" = 1'-0"$
 - c. Sections and details – $1/4"$ to $3/4" = 1'-0"$
- F. Pipe mains and branches shall be dimensionally located from the facilities structure, such as column lines, walls, ceiling, equipment, supports, etc., or from recognized benchmarks; as required or justified by complexity or space constraints.
- G. Pipes shown in elevation or section shall have their centerline or bottom of pipe elevations given above or below grade or floor elevation to a reference datum plane. All pipe elevations shall be identified on the drawings and piping coordinated with other items vertically.
- H. When draining of horizontal lines is required or drip stations are called for, the slope in lines shall be called out by an arrow placed adjacent to the applicable line.
- I. The slope shall be indicated in fraction of an inch per foot or the elevation given at both ends of the slope.
- J. When more than one system or service is delineated on the drawing, line designations shall be used.
- K. When pipe or tubing runs are grouped close together, the line designations shall be called out.
- L. Guides, anchors, and expansion compensators shall be located and described.

6.11.4.6 Detailing

The following rules shall apply when detailing these drawings:

- A. Drawings shall be prepared showing routing of fire protection piping. The preferred scale for arrangements is $1/4" = 1'-0"$.
- B. To aid in checking drawings and resolving potential interferences among other components, such as ductwork, electrical equipment, etc. The fire protection drawings shall be prepared to the same scale as the drawings of the other disciplines.
- C. Fire protection drawings shall include pipe sizes and routing, direction of flow, test connection points, riser diagrams showing valves and alarms, fire extinguisher and hose locations.
- D. Materials for piping, valves, sprinkler heads, alarm devices, and fire department connections shall be covered in the technical specifications.
- E. Identify space hazard classification for all fire sprinkler systems.
- F. Density and remote square footage requirements shall also be indicated.
- G. Designs modifying existing Fire Sprinkler Systems shall clearly indicate location of the existing zone control valves, locations of system drains, locations of all existing devices and all existing fire protection zones.
- H. All roof penetrations shall be fully detailed and conform with roof manufacture's requirements. Roof penetrations shall not void roof manufacturer's warranty.

6.11.5 Update of Standard Diagrams

DEN currently maintains standard diagrams for most buildings, which shall be used in any project that modifies these listed systems:

- A. Fire Protection Riser diagram for all Concourses
- B. Fire Protection Zone diagram for all Concourses, AOB, Terminal, HTC/PTC
- C. Smoke Control Zone diagram for all Concourses, AOB, Terminal, HTC/PTC

These diagrams should be included in the base building Revit Model. If not, they are available through the DEN Life Safety Engineer in AutoCAD format. All new flow/location diagrams shall be developed using the existing diagrams as guidelines.

6.11.6 Life Safety Design Submittal Requirements

6.11.6.1 Sprinkler System

6.11.6.1.1 A/E 30% Drawings

The A/E 30% drawing should contain the design density of the areas identified by room or area, as well as the required Architectural drawing backgrounds.

6.11.6.1.2 A/E 60% Drawings

The A/E 60% drawings should contain the information in [6.11.6.1.1.A/E 30% Drawings](#) and the following information:

- A. The identification of the Fire Zone.
- B. The new layout area or the new zone that is created for the remodeled area.
- C. The locations of sprinkler for the NFPA 13 required layout.

6.11.6.1.3 A/E 90% Drawings

The A/E 90% drawings should contain the information in [6.11.6.1.1.A/E 30% Drawings](#), [6.11.6.1.2.A/E 60% Drawings](#), and the following information:

- A. The identification of the sprinklers in the locations they are presented with details to the type, pendant, upright or sidewall.
- B. A note from the EoR that they are confident that the calculations for the area are adequate for supply.

6.11.6.2 Fire Alarm Systems

6.11.6.2.1 A/E 30% Drawings

The A/E 30% drawings should indicate if any detection will be required, as well as the required Architectural drawing backgrounds.

6.11.6.2.2 A/E 60% Drawings

The A/E 60% drawings should contain the information in [6.11.6.2.1.A/E 30% Drawings](#) and the following information:

- A. Initial placements of the detection
- B. Fire alarm notification.
- C. Emergency communication devices.
- D. If there are any other life safety systems, they need to be identified, as well as their future locations.

- E. Preliminary sequence of operations.
- F. Identification of the Fire/Smoke Zone the equipment is part of.

6.11.6.2.3 A/E 90% Drawings

The A/E 90% drawings should contain the information in [6.11.6.2.1.A/E 30% Drawings](#), [6.11.6.2.2.A/E 60% Drawings](#), and the following information:

- A. Final locations of all detection, fire alarm notification and emergency communication devices. Fire Alarm Terminal Cabinets included.
- B. Final tap settings of strobes.
- C. If there are any other life safety systems, they shall indicate any monitoring or controlling of those devices.
- D. The Sequence of Operation is the responsibility of the Engineer of Record.

6.11.6.3 Emergency Communication System

6.11.6.3.1 A/E 30% Drawings

The A/E 30% drawings should indicate if any intelligibility will be required, as well as the required Architectural drawing back-grounds.

6.11.6.3.2 A/E 60% Drawings

The A/E 60% drawings should contain the information in [6.11.6.3.1.A/E 30% Drawings](#) and the following information:

- A. Initial placements of speakers.
- B. If there are any other ECS, connections they need to be identified, as well as their future locations..
- C. Preliminary sequence of operations.
- D. Identification of the Speaker Zone the equipment is part of.

6.11.6.3.3 A/E 90% Drawings

The A/E 90% drawings should contain the information in [6.11.6.3.1.A/E 30% Drawings](#), [6.11.6.3.2.A/E 60% Drawings](#) and the following information:

- A. Final locations of all emergency communication devices. Emergency Communication System Terminal Cabinets included.
- B. Final tap settings of speakers
- C. If there are any other life safety systems, they shall indicate any monitoring or controlling of those devices.
- D. The Sequence of Operation shall follow the sequence identified in the Life Safety Design Standards Manual Chapter 4.
- E. An audio model shall be provided for all areas open to the public to provide an indication if the dBA levels would be met as well as the intelligibility of the area.

End of Chapter

This page is intentionally blank.

Chapter 12 - Electrical Drawings

6.12.0 Electrical Drawings

6.12.0.1 General Information and Requirements

The electrical drawings described in this chapter shall be prepared as applicable, depending upon the characteristics and complexity of the projects involved. These drawings shall be provided when essential in planning, procurement, construction, evaluation, recording, and use of the projects. The drawings shall indicate complete design. Prior written acceptance is required for any design-build component.

6.12.0.2 Definition

Facility electrical drawings are graphic representations of facilities electrical design requirements.

6.12.0.3 Design Requirements

Refer to Electrical DSM for detailed requirements of electrical design, details, and specifications.

Refer to DFI DSM.

6.12.0.4 Completeness

Facility electrical drawings, when interpreted in association with the construction specifications, shall:

- A. Furnish sufficient information to permit installation of manufactured equipment that requires electrical service **WITHOUT CONFLICT WITH WORK OF OTHER DISCIPLINES**.
- B. Furnish sufficient information to manufacture equipment that is of special design, made exclusively to meet the requirement of the project. Components and systems shall be UL listed.
- C. Describe items so that they may be procured.
- D. Furnish sufficient information to permit planning, construction, evaluation, recording, repair, and maintenance of facilities.
- E. Furnish the above in sufficient completeness for accomplishment without the need of assistance from the consultant.

6.12.0.5 Sequence

Construction documents are divided into specific groups per NCS. The group number shall always remain the same no matter how large the project. Refer to DFI DSM.

- A. Numbered sheets for areas for plan views shall remain consistent across disciplines. For example, sheets A2 01, S2 01, M2 01, P2 01, F2 01, E2 01, and T2 01 shall all show work in the same area.

6.12.0.6 Electrical and Electronic Symbols

Electrical and electronic symbols, when used, shall be in accordance with American National Standards Institute (ANSI). Other symbols, if devised by the consultant, shall be shown in the **ITEM** column, and explained in the **DESCRIPTION** column of the **LEGEND** with indication **FOR THIS PROJECT ONLY**.

6.12.0.7 Delineation Types

Electrical drawings shall generally include, as required, the following types of delineations:

- B. One-line diagrams
- C. Facility electrical power distribution plans
- D. Facility lighting plans. (Outdoor and indoor)
- E. Fire alarm plans and risers
- F. Panel, circuit, and other schedules
- G. Detail drawings

The number of delineation drawings for a project shall be kept to a minimum, consistent with clarity for constructibility.

6.12.0.8 Delineation Drawings

Different and various combinations of delineation types may be shown on the same drawing, except that lighting, power, and life safety systems shall always be on separate plans. Each delineation shall be identified by its type below the area where it is displayed, e.g., SCHEMATIC DIAGRAM. These delineations shall not be included on architectural, structural, civil, or mechanical drawings.

6.12.0.9 Legend

Electrical drawings shall contain a legend of symbols. The symbols as used in accordance with Section Symbols for Electrical Drawings shall be considered standard for application to electrical drawings. Refer to [12.13.Symbols for Electrical Drawings](#). If a nonstandard symbol is not fully described by supplementary notation where it is shown, it should be:

- A. Contained in the **LEGEND**.
- B. Explained in the notes to eliminate possibility of misinterpretation if paragraph (a) is insufficient.
- C. **Noted: FOR THIS PROJECT ONLY.**

6.12.0.10 Specification Relationship

Specifications, which are a portion of a contract package, shall include an electrical section. The electrical drawings, together with the specifications shall specifically describe all the electrical design requirements of the project. Vendor information drawings may be included as reference drawings subject to written approval from the Manufacturer. Electrical drawings, which may form a part of a purchase specification drawing, may be included as reference drawings. The consultant by submitting the documents for Bid ensures that space allocations for equipment specified is adequate and compliant with all code requirements, including clearance requirements and free of conflicting space requirements of all other trades.

6.12.1 Electrical Plans

6.12.1.1 Definition

Electrical plans consist of scaled delineations and line symbology arranged to depict circuits and electrical equipment installation. Diagrams and the specifications supplement the plans to present the required information for facilities. The following types of plans are included:

- A. Electrical equipment arrangement
- B. Facility electrical power distribution, including underground distribution
- C. Facility grounding

- D. Facility lighting, indoor and outdoor
- E. Facility security
- F. Facility lightning protection
- G. Facility communications
- H. Fire alarm

6.12.1.2 Symbols

Electrical symbols used shall be in accordance with Section - Symbols for Electrical Drawings. Electrical items such as wire, conduit, cable, electrical equipment, etc., shall be delineated by line work distinguishable from line work used to depict items shown for reference or orientation. Lines between boxes on power and lighting circuit plans shall indicate cable, conduit, duct, and wire runs. Separate lines for wires within these carriers are generally not shown except by symbol. Conduit runs shall generally be indicated by straight lines run parallel to building lines, walls, floors, ceilings, etc.

It is the consultant's responsibility to design the project, not the contractors. Assuming the contractor *will figure it out* is not responsible Professional Design. When a specific routing of conduit, wire, and cable run is required, the routing of these runs shall be dimensioned and/or covered by note. Specific routing location run shall be required when routing is buried, to be placed in concrete, or to be routed through penetrations to prevent conflict or to assure clearances. Dimensional locations of routing shall be shown.

Circuit designation shall be shown for feeders, such as:

- A = Alarm Circuit
- C = Control Circuit
- L = Lighting Circuit
- D = DC Circuit

6.12.1.3 Arrows on Wires

The use of arrowheads on lines, which depict wire, cable, or conduits, shall be limited to the indication of *home runs* (home runs are those returning, without interruption, to the local panel board). Location and elevation of wire ways, electrical bus, and cable trays shall be shown.

6.12.1.4 Views

More than one plan view of the same area may be required to show different electrical systems, such as communications on one, power on another, and lighting on another. The plan views shall be supplemented, as required, by sections, elevations, and details.

6.12.1.5 Details

Details depict features, which require delineation in addition to that provided on the basic plan or elevation.

6.12.1.6 Devices

Devices, which have different energized and de-energized appearance, shall be shown in the de-energized condition.

6.12.1.7 Scale

Scales 1/8"=1'0" and larger shall generally be used. Drawings shall be the same scale as the architect's drawings, unless a larger scale is required. Drawing North orientation shall be the same as the architect's drawings. Building areas shall be the same as the architect's drawings and presented in the same order.

6.12.2 Facility Electrical Power Distribution Plans

6.12.2.1 Definition

Facility electrical power distribution plans depict primary and secondary power distribution, control, and grounding, excluding lighting, and communications. Plans shall show equipment arrangements, configuration, and information to locate, position, and mount electrical equipment.

6.12.2.2 Panelboard Schedules

Power panelboard schedules shall be shown. The total connected load (KVA) and the estimated demand load (KVA), including the demand factor used, and shall be shown on the schedule with phases balanced. All panelboard schedules included in project documents shall be noted as new - "NEW" or existing - "EX" near panel name.

Existing circuits on new or existing panelboards shall be indicated with a "(E)" prior to load served on the circuit description to differentiate from new loads added in project scope.

6.12.2.3 Panelboard Drawings

Panelboards, existing and new, shall be delineated in plan and elevation, showing all equipment adjacent to the installation dimensionally. New and existing equipment shall be indicated to scale. If optional panelboard manufacturers are specified, the LARGEST panel shall be shown, and the code-required clearances shall be indicated on the drawings.

6.12.3 Facility Lighting Plans

6.12.3.1 Definition

Facility lighting plans are electrical plans, which depict the lighting circuits, lighting control circuits, fixtures, and accessories within a facility. Facility lighting plans delineate the installation of the lighting system beginning with the power source at the service entrance equipment or the lighting transformer and panelboards and extending to the light fixtures.

6.12.3.2 Emergency Lighting

Emergency battery-powered lighting units, which are activated by power failures, shall clearly indicate the lighting circuits to which they are connected and that they are connected on the line side of all switches per applicable code.

6.12.4 One-Line Diagrams

6.12.4.1 Definition

A single-line diagram shows, by means of single lines and graphic symbols, the course of an electrical/electronic circuit or system of circuits and the component devices or parts used therein. The principal objective of the single-line diagram is to record a maximum of significant information in a minimum of space. Facilities single-line diagrams are most useful in representing power distribution and communication systems. It may be used in the study and explanation of the facilities. A single-line diagram conveys basic information about the operation of a circuit or system of circuits. It omits much of the detailed information usually shown on schematic or connection diagrams. A single-line diagram delineates, in more detail than a block diagram, information, which will subsequently be shown on other diagrams.

6.12.4.2 Requirements

- I. Complete one-line diagrams are required, except with written permission from DEN PM.
- J. Only one phase of a multiphase system and one polarity of a dc system shall be used to simplify the circuit and to include the necessary essentials.
- K. Descriptive nomenclature, when used, shall be placed above or to the right of the subject element or connecting line unless other placement has a distinct advantage for the particular application.
- L. All symbols shall be of the single-line type. Halftone all existing to remain equipment/wiring. New equipment shall be bold.
- M. A single-line diagram is termed functional if various line widths are used to separate categories of circuits. When this type of diagram is made, the line widths shall be defined. No more than two widths of lines shall be used. Heavy-width lines represent power circuits and medium-width lines represent control and measurement circuits.
- N. Nominal voltages shall be used for supplementary information in the designations of systems.
- O. Power transformer impedance shall be indicated on the drawing.
- P. Transformer voltage representation shall use the symbols dash (-) and slant (/) as follows:
- The dash (-) separates the voltage ratings of separate windings on a transformer, e.g., 13 8 KV - 480V.
 - The slant (/) separates multiple voltages or indicate taps of the same winding, e.g., 208Y/120
 - Transformation ratios shall use the slant (/) as the separation between the values.
- Q. A one-line diagram may show only the power circuits or be extended to include secondary and control circuits in the simplified form.
- R. The one-line diagram may include pertinent rating information about its items; for example, voltages of potential transformers, ampere rating of current transformers, fault current, interrupting capacity, breaker frame and trip ratings of circuit breakers, motor horsepower ratings, load estimates, bus ampere and voltage rating.
- S. A one-line diagram may also include wire and cable information, and further descriptions of elements; i.e., element categories, models, drawing numbers, functional designations, length of cable.
- T. Indicate distribution equipment, power, control, and metering, and protective relay circuits from the incoming feeder to ultimate motor lighting panel or other load, including item names.
- U. Winding connection symbols shall be used adjacent to the symbols for the transformer windings.
- V. The quantity of a device may be indicated on a single-line symbol when it is necessary to define its quantity in relation to the graphical symbol. The numeral indicating quantity is placed adjacent to the symbol. The number 3 adjacent to the magnetic overload device indicates that there are three circuits like the one shown.
- W. A note shall be included with the legend or notes indicating the function of the quantity numeral, e.g., **THE NUMERAL ADJACENT TO RELAYS DENOTES QUANTITY.**
- X. Device lists shall be incorporated on the drawings and included as part of the legend, when functional designations per [12.5.Connection Diagrams](#) are used. In addition, the meaning of each suffix used with a device function number should be listed if it is not included with a complete device function number. The following illustrates a device list:
- 1A - Master Element
 - 1M - Master Element
 - 23 - Temperature Control Device
 - 38 - Bearing Protective Device
 - 43 - Manual Transfer Switch

- f. 47 - Phase Sequence Voltage Relay
 - g. 49 - Machine Thermal Relay
 - h. 51 - AC Time Overcurrent Relay
 - i. 51N - AC Time Overcurrent Relay (Neutral)
 - j. 52 - AC Circuit Breaker
 - k. 52X - Auxiliary Relay for 52
 - l. 86 - Locking-out Relay
- Y. Protective relays may be included along with an indication by operator dash lines on the device upon which the relay acts.
- Z. Electrical values and other functional information shall be included as necessary to allow analysis of the circuit. Examples of some types of information that may apply are as follows:
 - a. Current, voltage, and interrupting rating of circuit breakers
 - b. Primary and secondary voltages and kVA ratings of power transformers
 - c. Voltage and kVA or kW rating of generators
 - d. Voltage and HP rating and type of motors
 - e. Rating and type of load on feeder circuits
 - f. Ratings of power and control sources
 - g. Circuit breaker frame trip and interrupting current
 - h. Switches ampere rating
 - i. Ratings of instrument transformers, fuses, resistors, capacitors, and contractors, motor starters
 - j. Resistance to ground, inductance, and temperature ratings
 - k. Voltage and current waveforms
 - l. Bus amperage, voltage, and fault current capacity

12.13 Symbols for Electrical Drawings

12.13.1 Definition

Electrical/Electronic Symbols for Diagrams are graphical symbols providing coverage for electrical and electronic diagrams. Correlation of symbols with parts lists, descriptions, or instructions may be established by means of reference and functional designations. Symbols shall be in accordance with ANSI Y32.2, Graphical Symbols for Electrical and Electronics Diagrams. Notify DEN of any inconsistency between the DEN Design Standard Symbols and the ANSI Standards.

It should be noted that letter combinations used as part of graphical symbols are not abbreviations. Functional designations shall be assigned in accordance [12.0.2.Functional Designations](#).

12.13.2 Symbols

Symbols for Electrical Plans are graphical symbols that provide coverage for architectural and electrical layout drawings. Functional electrical and electronic symbols should be used to provide full coverage for these drawings. Symbols shall be in accordance with ANSI Y32.9, Graphic Symbols for Electrical Wiring and Layout Diagrams used in Architecture and Building Construction.

12.13.3 Labels

Labels for panelboards and electrical equipment shall designate the source location (fed from), voltage, and ampacity. The prefixes to be used for panelboard numbers shall be compliant with those designated in the Electrical DSM.

6.12.4 Electrical Design Submittal Requirements

6.12.4.1 General

This section addresses the minimum requirements for submittal of Electrical discipline construction or RFP documents during the progress of design. Unless otherwise stated in the consultant's contract or approved task, at a minimum, the consultant shall deliver the following content in the submittal packages to DEN. These requirements are in addition to the requirements detailed in [Chapter 20- Submittals](#) of this DSM.

6.12.4.2 90% Submittal Requirements

The goal of the 90% Electrical submittal is to finalize the progression of design from the previous submittal. The detail levels shall build upon all requirements of the previous design submittal and be at a nearly complete phase. All comments from the previous submittals shall be addressed and adequately incorporated into this submittal. All components of Electrical systems shall be in their final form.

6.12.4.2.1 General Electrical Notes

Consultant Standard general Electrical notes may be used but must fully comply with all DEN Design Standards and contract requirements.

6.12.4.2.2 Symbols Legend

DEN Standard symbols shall be used. DEN provides consultants with standard symbols in a Revit family, which shall be used in all contract documents.

6.12.4.2.3 Demo Plans

Show all existing electrical equipment, systems, lighting, controls, etc. and accessories (supports, enclosures, etc.) to remain including and all equipment, systems, and accessories to be demolished.

6.12.4.2.4 Site Plan

A site plan must be provided showing the project location and any associated site work including but not limited to utility transformers and equipment, site lighting, EV charging stations, and security.

6.12.4.2.5 Floor Plans

Provide floor plans for entire area of construction. The following shall be shown on floor plans:

- A. Room names on every plan showing each area and its purpose.
- B. Coordination with Architectural and all other drawings for any items that require the installation of electrical power.
- C. A keymap showing the specific location of the of the project.

6.12.4.2.6 Electrical Single Line Diagram

Provide a complete single line diagram showing all electrical equipment that is to be added to the project including conduit and wiring between equipment. Voltage drop should be taken into consideration at this point to ensure all wiring is sized correctly. Fault current calculations should be completed at this point and shown at each point. Utilize DEN standard REVIT one-lines available from DEN DFI group. See Digital Facilities and Infrastructure DSM for more information. Relevant information from project (Fault Current, AIC Rating, Main Rating, Voltage Drop) should be placed in DEN Revit families on single line and 1L schedules displayed on plan.

6.12.4.2.7 Emergency and Backup Power

Show all components of the emergency power distribution system in single-line diagrams and floor plans. Equipment sizing and load calculations must be nearly finalized and shown in the drawings.

6.12.4.2.8 Power and Telecommunication

All receptacle layouts must be shown along with any phone/data outlets including any special systems being installed. Security doors should be shown and labeled. Circuiting should be provided on plans for this equipment.

6.12.4.2.9 Lighting

A light fixture schedule must be provided along with a lighting layout for the entire project. Switch locations should be shown including any occupancy sensors and/or lighting controls being installed. Circuiting should be provided on plans. Developed sequence of operations for lighting control devices based on IECC room type requirements to be provided indicating control devices and how room will operate.

6.12.4.2.10 Load Calculations

Load calculations must be provided at all switchgear/switchboards and panelboards.

6.12.4.2.11 Equipment Schedules

Provide schedules for all mechanical and plumbing equipment to be used in the project. Schedules are not required to be completely detailed at this phase, but all ID tags must be populated and be coordinated with other disciplines.

6.12.4.2.12 Specifications

Provide a redline of all specification sections.

6.12.4.3 100% Submittal Requirements

The goal of the 100% Electrical submittal is to validate compliance of the previous submittal. The detail levels shall build upon all requirements of the previous design submittal. All details, narratives, and components of Electrical systems shall be complete. All comments from the previous submittals shall be addressed and adequately incorporated into this submittal.

6.12.4.3.1 General Electrical Notes

Consultant Standard general Electrical notes may be used but must fully comply with all DEN Design Standards and contract requirements.

6.12.4.3.2 Symbols Legend

DEN Standard symbols shall be used. DEN provides consultants with standard symbols in a Revit family, which shall be used in all contract documents.

6.12.4.3.3 Demo Plans

Show all existing electrical equipment, systems, lighting, controls, etc. and accessories (supports, enclosures, etc.) to remain including and all equipment, systems, and accessories to be demolished.

6.12.4.3.4 Site Plan

A site plan must be provided showing the project location and any associated site work including but not limited to utility transformers and equipment, site lighting, EV charging stations, and security.

6.12.4.3.5 Floor Plans

Provide floor plans for entire area of construction. The following shall be shown on floor plans:

- A. Room names on every plan showing each area and its purpose.
- B. Coordination with Architectural and all other drawings for any items that require electrical power being installed.
- C. A keypad showing the specific location of the project should be provided.

6.12.4.3.6 Electrical Single Line Diagram

Provide a complete single line diagram showing all electrical equipment that is to be added to the project including conduit and wiring between equipment. Voltage drop should be taken into consideration at this point to ensure all wiring is sized correctly. Fault current calculations should be completed at this point and shown at each point. Relevant information from project (Fault Current, AIC Rating, Main Rating, Voltage Drop) should be placed in DEN Revit families on single line and 1L schedules displayed on plan.

6.12.4.3.7 Emergency and Backup Power

Fully identify all components of the emergency power distribution system in single-line diagrams, floor plans and details as necessary. Provide completed load calculations and selective coordination information as required. Identify all emergency power branch circuit home runs and device connections.

6.12.4.3.8 Power and Telecommunication

All receptacle layouts must be shown along with any phone/data outlets including any special systems being installed. Security doors should be shown and labeled. Circuiting should be provided on plans for this equipment.

6.12.4.3.9 Lighting

A complete light fixture schedule must be provided along with a lighting layout for the entire project. Switch locations should be shown including any occupancy sensors and/or lighting controls being installed. Circuiting should be provided on plans. Finalized sequence of operations for lighting control devices based on IECC room type requirements to be provided, indicating control devices and how room will operate.

6.12.4.3.10 Load Calculations

Load calculations must be provided at all switchgear/switchboards and panelboards.

6.12.4.3.11 Panel Schedules

Panel schedules that are completely filled out showing all anticipated circuits and loads should be shown on the plans.

6.12.4.3.12 Enlarged Plans

Provide fully detailed floor plans for new or existing electrical and Telecommunication rooms along with the equipment being installed.

6.12.4.3.13 Equipment Schedules

Provide schedules for all mechanical and plumbing equipment to be used in the project. Schedules are not required to be completely detailed at this phase, but all ID tags must be populated and be coordinated with other disciplines.

6.12.4.3.14 Electrical Diagrams

Electrical Diagrams must be shown for any item that needs detailing on plans.

6.12.4.3.15 Specifications

Provide a redline of all specification sections.

End of Chapter

Chapter 13 - Communications/Electronic Systems

6.13.0 Communications/Electronic Systems

6.13.0.1 General Information and Requirements

This chapter provides engineers and designers performing design work for DEN with systems overviews, configurations, and specific design requirements. Communications and Electronic Systems addressed in this chapter include:

- A. Security Card Access System (SCAS)
- B. Closed Circuit Television System (CCTV)
- C. Fire Alarm System (FAS)
- D. Emergency Communication System (ECS)
- E. Public Affairs Television System (PATV)
- F. Premise Wiring Distribution System (PWCS)
- G. Parking/Ground Transportation Revenue Control System (PGTS)
- H. Flight and Baggage Information Display System (FIDS/BIDS)
- I. Data Acquisition and Control System (DACS)
- J. Two-Way Communication System (2-Way)
- K. Radio Enhancement Systems (RES)

Refer to the Life Safety DSM for additional information about Life Safety Systems.

6.13.1 Drawings

6.13.1.1 Drawings

The communications and electronic systems described in this chapter shall be designed and drawings shall be prepared as applicable, based upon the characteristics and complexity of the projects involved and as determined by each system narrative contained in these DSMs. Drawings shall be provided when essential in planning, procurement, construction, evaluation, recording, and use of the projects. All drawings shall indicate complete design.

6.13.1.2 Definition

Facility communications and electronic systems drawings are graphic representations of facilities design requirements.

6.13.1.3 Completeness

Facility communications and electronic systems drawings, when interpreted in association with the construction specifications, shall:

- A. Furnish sufficient information to permit installation of manufactured equipment that satisfies the design requirements.

- B. Furnish sufficient information to manufacture equipment that is of special design, made exclusively to meet the requirement of the project. Components, assemblies, and systems shall be UL listed.
- C. Describe items so that they may be procured.
- D. Furnish sufficient information to permit planning, construction, evaluation, recording, repair, and maintenance of facilities.
- E. Furnish the above in sufficient completeness for accomplishment without the need of assistance from the consultant.

6.13.1.4 Drawing Sequence

Construction documents are divided into specific groups per NCS. The group number shall always remain the same no matter how large the project. Refer to DFI DSM.

- A. Numbered sheets for areas for plan views shall remain consistent across disciplines. For example, sheets A2 01, S2 01, M2 01, P2 01, F2 01, E2 01, and T2 01 shall all show work in the same area

6.13.1.5 General Notes, Drawing Index, Symbols, and Abbreviations

These sheets shall contain Notes that are applicable (or general) to all sheets in the set of drawings and in addition contain the drawing symbology as required in [6.13.1.4. Drawing Sequence](#). These sheets shall also contain a complete drawing index for the document set.

6.13.1.6 Site Plan

The site plan shall identify, where applicable, all site facilities required in support of the specified communications and electronic systems, including conduits and their interconnection to existing conduits (duct banks), resources, and cabling systems. In addition, the site plan shall indicate all existing utilities and all communications and electronic systems devices and conduits that are located external to the building and indicate connections (penetrations methods) to internal systems. Where applicable, external devices and equipment, e.g., towers, antennas, etc., shall be shown, including all internal and external connections. Keyed symbology shall be shown, which directs the contractor to specific installation, provisioning, and configuration details that shall be included in the detail sheets. All required connections to the grounding system shall be indicated.

6.13.1.7 Floor Plans/Roof Plans

Plan drawings shall be provided which indicate all communications and electronic systems devices and equipment locations and include conduit interconnection between devices. All device locations shall be coordinated with all disciplines including architectural finishes and features. Keyed symbology shall be shown which directs the contractor to specific installation, provisioning and configuration details which shall be included in the detail sheets.

When more than one system is shown on a plan, each shall be made clearly discernible by system. Conduits indicated on the plans shall either be shown as routed to their specific termination location (Equipment or Terminal cabinet) or be indicated by schedule for termination location. All conduits shall be coordinated with the requirements of the conduit riser diagram. Devices indicated on plans shall be coordinated with the requirements as indicated in point-to-point diagrams.

6.13.1.8 Equipment Rooms Layouts and Elevations

Coordinated equipment room layouts and wall elevations shall be provided which indicate scaled layout of the equipment room and all Communications and Electronic Systems and facilities co-located within the equipment room. Equipment rooms and layouts shall provide sufficient detail that permit coordinated construction and include the following elements:

- A. Interconnection between equipment
- B. Conduit terminations
- C. Grounding connections
- D. Electrical connections and grounding bars
- E. Floor mounted and wall hung equipment placement
- F. Cable tray configurations
- G. All penetration and fire sealant details
- H. Clearance zones for servicing equipment
- I. Locations and sizing of cooling equipment required

Where new equipment and/or facilities are specified/required for installation in an existing equipment room, layouts shall be provided that coordinate the placement of new equipment with existing equipment. Detail provided shall be as indicated above. New equipment shall be delineated by a different line type from existing equipment so that positive identification between new and existing equipment is assured.

6.13.0.1 Functional Block Interconnection Diagrams

A block diagram describes the concepts and/or organization of an equipment or facility using rectangular blocks, representing functions or groups of functions. Interconnecting lines establish the relationships between blocks and indicate the direction of information flow. A block diagram is used to give a quick over-all picture of a system and the general interrelationships between components of that system. It may be used for general arrangement studies, functional explanations, systematization of facilities, or for design discussion purposes.

6.13.0.1.1 Diagrams

- A. A block diagram shall be presented in as simple a form as possible. Rectangular blocks shall be used to represent functional electrical systems or parts thereof and/or major elements of an electrical system or circuit. Various other symbols may be used as supplementary information to increase the utility of the diagram.
- B. Identifying nomenclature shall be included within the blocks.
- C. Block diagrams may be made for any level of project activity. For example, a block diagram at the highest level may be made for a complete project, or any lower-order stage.
- D. Related mechanical, electro-mechanical, or optional apparatus may be included on block diagrams in rectangular form.
- E. Mechanical connections between such elements shall be illustrated with dashed lines connecting the applicable blocks.
- F. If the form of the circuit involves multiple sources and common or similar circuits, or variations thereof, tabulations may be used.
- G. If a block diagram must be divided and placed on more than one drawing, the division of the circuit should be made in a logical manner, that will eliminate confusion and at a point of minimum information transfer.
- H. When abbreviations or symbols are used on any drawing, provide on that same drawing keynote, abbreviation, and symbol legend.

6.13.0.1.2 Connecting Lines

- A. Lines connecting blocks shall indicate relationships, direction of flow of the system, sequence of operation, etc. The arrangement of lines and blocks shall show action or energy flow in functional sequence from top to bottom and/or left to right of the diagram, starting at the top left or top center, and ending at the bottom right of the diagram.

- B. Connection lines shall be labeled, where necessary, to make the meaning clear and unmistakable. When dashed lines are used for more than one purpose on a block diagram, these purposes shall be made clear by label, legend, or note.
- C. Connecting lines shall include arrows to further define the circuit flow.

6.13.0.2 Point-to-Point Wiring Diagrams

Point-to-point wiring diagrams describe the detailed wiring configuration and arrangement of the specific system utilizing lines connected to specific equipment terminals and equipment pieces. Point-to-point wiring diagrams indicate the required system color-coded interconnection details at the component level. Point-to-point wiring diagrams shall be required at the design level only for those electronic and communications systems where interconnection to existing equipment is required. Point-to-point shall be provided only for the specific interface location and configuration. In the cases where new systems are designed and do not require interconnection to existing systems, system concepts and intent shall be conveyed through the functional block diagram, riser diagrams, floor plans, elevations, and the project specifications. When required, point-to-point wiring diagrams shall contain the following detail.

- A. All wiring by type and size required between all system components
- B. Indicate wire color coding
- C. Indicate terminal strip numbers and positions
- D. Indicate current, signal, and data flow

6.13.0.3 System Riser Diagrams

Communications and electronic systems riser diagrams indicate the distribution of major systems components, wiring systems, and their interconnection requirements. Riser diagrams shall always be provided for cabling systems and indicate:

- A. Equipment rooms
- B. Cable quantities
- C. Cable types
- D. Termination locations
- E. Keyed reference to related details
- F. In multi-floor facilities, riser diagrams shall be organized by level

For simpler designs not containing cabling distribution systems specific riser diagram information, (e.g., major component location information may be incorporated into the Functional Block Diagram).

6.13.0.4 Conduit/Cable Tray Riser Diagrams

Conduit riser diagrams are provided to indicate the configuration, location, quantity, and size of the conduit/cable tray infrastructure required in support of the specified communications or electronic system. In multi-level facilities, conduit riser diagrams shall be organized by level. All conduit riser diagrams shall indicate the following information:

- A. Equipment rooms (or conduit termination locations)
- B. Conduit quantities
- C. Conduit sizes
- D. Conduit identification schemes
- E. Interfaces to cable trays
- F. Grounding and bonding requirements

G. Cable tray systems

Conduits, which are specified or scheduled for installation of fiber optic cables, shall be configured with appropriate bending radii and bend requirements. All conduit and cable tray systems shall be installed in compliance with applicable codes and DEN DSMs. Conduit shall have not more than 270 degrees of bend between pull locations and shall have a minimum of 1" size. Review sizing and bends with Project Manager at Design Development Phase.

Terminal cabinets, equipment backboards, and other conduit termination facilities and locations are considered part of an integrated conduit riser diagram and shall be shown on the conduit riser diagram. Branch conduits installed in support of devices need not be shown on the conduit riser diagram.

The conduit riser diagram shall be coordinated with the system riser diagram, such that cross-reference between systems cables and conduit/tray infrastructure are achievable. All conduit and cable tray systems shall be configured and suitably sized to permit the segregation of cables by conduit/tray segment by signal level as follows:

- A. Less than 10V
- B. 10V - 70 7V
- C. Greater than 70 7 volts
- D. Telecommunications cabling (voice and data) cables shall never be mixed with dissimilar resources

6.13.0.5 System Details

Systems details are provided to indicate specific installation techniques and systems configurations. System details shall be provided in support of the design and installation intent indicated on other sheets and call attention to the specific conditions and requirements necessary to ensure that the installed system configuration is compliant with the design intent and requirements. Details shall be provided for all conditions where specific direction can- not be properly conveyed or is indicated on other sheets.

6.13.0.6 Communications and Electronic Systems Symbols

Communications and Electronic Systems and electronic symbols, when used, shall be in accordance with ANSI standards, in accordance with [6.13.0.6.Communications and Electronic Systems Symbols](#). Other symbols, if devised by the consultant, shall be shown in the ITEM column and explained in the DESCRIPTION column of the LEGEND with indication FOR THIS PROJECT ONLY.

6.13.0.7 Symbols for Other Functional Disciplines

Symbols for functional disciplines other than Communications and Electronic Systems shall be as specified in the respective sub-sections of this manual.

6.13.0.8 Functional Designations

Functional designations, when used, shall be in accordance with [6.13.0.2.Point-to-Point Wiring Diagrams](#).

6.13.0.9 Drawing Delineation Types

Communications and Electronic Systems drawings shall generally include the following types of delineations:

- A. Block diagrams
- B. One-line diagrams
- C. Schematic diagrams
- D. Connection diagrams
- E. Facility communications and electronic systems power requirements plans

- F. Facility communications plans and risers
- G. Facility grounding plans and risers
- H. Facility security plans and risers
- I. Facility lightning protection plans
- J. Fire alarm plans and risers
- K. Emergency Communication plans and risers
- L. Two-Way Communication plans and risers
- M. Radio Enhancement System plans and risers
- N. Panel, circuit, and other schedules
- O. Detail drawings

The number of delineation drawings for a project shall be adequate to describe the entire system including existing system and device locations, demolition of systems, reuse of systems or devices, and new work.

6.13.1.9 Delineation Drawings

Subject to Project Manager acceptance, the drawings for projects need not contain all delineation types. For example, projects consisting only of a single building and a relatively simple communications and electronic systems may not need block diagrams or single-line diagrams if the information normally found in them is effectively conveyed by other delineation types. Each delineation shall be identified by its type below the area where it is displayed, e.g., SCHEMATIC DIAGRAM. These delineations shall not be included on architectural, structural, civil, mechanical, or electrical drawings. If delineation drawings are different from outlined herein, then the Drawing Index shall clearly show combination of delineation.

6.13.1.9.1 Specification Relationship

Specifications that are a portion of a contract package shall include communications and electronic systems technical specifications sections. Each communications or electronic system section shall have its own General Requirements section, which is specifically tailored to the requirements of the electronic and communications system requirements. The communications and electronic systems drawings, together with the specifications, shall describe specifically and adequately all the communications and electronic systems design requirements of the project. Vendor information drawings may be included as reference drawings subject to written approval from the manufacturer. Communications and electronic systems drawings that may form a part of a purchase specification drawing may be included as reference drawings. Prior written acceptance is required for any design-build component.

End of Chapter

Chapter 14 - Signage and Graphic Drawings

6.14.0 Signage and Graphic Drawings

6.14.0.1 General Design Requirements

Signs shall comply with all federal, state, and local codes and DEN agency requirements.

6.14.0.1.1 Public Area Signage

Each Project Manager must submit all required project signage to the DEN PM at 30%, 60%, and 95% contract document (drawings and specifications) reviews. Approval of signage is required prior to the completion of construction or procurement documents.

6.14.0.1.2 Regulatory Signage

Regulatory signage is typically signage that is required by applicable codes and regulatory agencies. Regulatory signage shall be submitted to the DEN PM for design, message review, and coordination prior to fabrication.

Dynamic FIDS, BIDS, and GIDS monitors are addressed in [Chapter 13- Communications/Electronic Systems](#).

6.14.0.2 Sign Construction

Signs that frequently change must be made of local, readily available materials. All message changes must be streamlined to update changes overnight if necessary. Signs that historically change most frequently at DEN are tenant listings and parking signs.

6.14.1 Drawings

6.14.1.1 Content

The drawings illustrate and provide all necessary sign information relative to the size, form, location, attachment, and arrangement of the static and dynamic signage components and systems. The following shall be included in the static and dynamic signage and graphics drawings, where applicable. Tracing or copies of manufactured drawings is copyright infringement and is not acceptable.

- A. Manufacturer locations of materials, assemblies, products, and accessories
- B. Size, thickness, and significant dimensions of all signage elements
- C. Gauges, except for prefabricated and assembled units
- D. Details of specially fabricated connections
- E. Relationship of adjacent dissimilar materials
- F. Soil boring or test pit logs including locations for foundations supporting exterior signs
- G. Sign location plans shall present all necessary information of all signage system components. Drawings shall indicate, at a minimum, front and back panel designations, sign type, unique sign numbers, and concealed attachment methods.

6.14.1.2 Static and Dynamic

Signage and graphics drawings are divided into two sections identified as, Static Signage and Dynamic Signage. All static signs are required to have a unique sign number identified on all location plans.

6.14.1.3 Static Signage Drawings

Construction documents are divided into specific groups per NCS. The group number shall always remain the same no matter how large the project.

- A. Numbered sheets for areas for plan views shall remain consistent across disciplines. For example, sheets A2 01, S2 01, M2 01, P2 01, F2 01, E2 01, and T2 01 shall all show work in the same area.

6.14.1.4 Dynamic Signage Drawings

Construction documents are divided into specific groups per NCS. The group number shall always remain the same no matter how large the project.

- A. Numbered sheets for areas for plan views shall remain consistent across disciplines. For example, sheets A2 01, S2 01, M2 01, P2 01, F2 01, E2 01, and T2 01 shall all show work in the same area.

6.14.1.5 Minimum Requirements

Sign location plans shall present the following minimum information:

- A. Unique sign number and sign type symbol
- B. Front panel designation
- C. Back panel designation
- D. Sign type

6.14.1.6 Sections and Interior Elevations

Sections and interior elevation drawings show typical sign elevations and their relationship, size, mounting dimensions, and location to interior architectural elements.

6.14.1.7 Details

Detail drawings for both static and dynamic signage showing sign unit elevations, mounting conditions, sizes, graphic layouts, and construction details of each sign and display unit type.

6.14.1.8 Continuation

Drawings shall indicate, where applicable, any continuation from one drawing to another and where plans and system layouts are continued on another drawing. The location of the drawing on which the continuation appears must be noted at the point of break in the plans.

6.14.2 Structural Requirements

Structural requirements shall be designed by a licensed Colorado Structural Engineer. The Structural Engineer shall:

- A. Confirm existing structure can support anticipated signage loads.
- B. Verify imposed loads on signs including seismic, wind, thermal, and impact. For signs designed to be free standing in interior public spaces, the load shall be a minimum of the load required for handrails or guardrails and inclusive of seismic, maintenance, and thermal loads. For exterior sign wind load requirements, refer to current CDOT standards.
- C. Design foundations, beam supports, and attachments.
- D. Document and verify the design accommodates thermal movement from heat sources.

6.14.3 Mechanical Requirements

For sign assemblies not provided by the sign manufacturer, include necessary mechanical requirements designed by a licensed Colorado Mechanical Engineer. The Mechanical Engineer shall:

- A. Confirm heat loads developed by internal and external lighting.
- B. Design ventilation systems both active and passive.
- C. Document and verify heat loads contributed to the surrounding space.
- D. Design any modifications required by fire protection systems.

6.14.4 Electrical Requirements

Electrical requirements shall be designed by a licensed Colorado Electrical Engineer. The Electrical Engineer shall:

- A. Establish load studies for points of connection for new services.
- B. Design raceways, panels, and transformers to support the installation.
- C. Design electrical systems within the sign and assure application for UL listing prior to Bid Advertisement.

6.14.4.1 Building/Structure (Exterior) Numbering

Each building or structure shall have at least one sign located on the exterior structure. Review of the building and site plan must be completed with DFD to confirm location and quantity of the signs. Contact the Project Manager for assignment of the building identifier number.

End of Chapter

This page is intentionally blank.

Chapter 15 - GIS/CADD Requirements

6.15.0 GIS/CADD Requirements

As of 2011, all projects are done using Autodesk Revit and Civil 3D.

End of Chapter

This page is intentionally blank.

Chapter 16 - Surveys

16.0 Field Measurements

Field measurements will be performed by the Consultant to verify existing conditions unless this activity is specifically excluded from the contracted scope of work (SOW).

End of Chapter

This page is intentionally blank.

Chapter 17 - Testing Agency Reports

6.17.0 Testing Agency Reports

6.17.0.1 Testing Requirements

Unless specifically excluded in the consultant's contract, the consultant shall provide testing services and analysis in the locations and quantities to satisfy data and analysis information required so the consultant can provide a complete and accurate design.

These surveys and testing programs shall include but not be limited to all soils tests and any other investigations of surface or subsurface conditions, which would be required to design the projects. The scope of such surveys, tests, and investigations shall be submitted to DEN for its review and acceptance before the surveys or investigations are commenced. The scope shall include consultant's consideration of information, which DEN has provided such as topographic maps, site preparations drawings, and the results of available soils investigations. All surveys shall conform to the DEN LDP Coordinate System established by DEN and shall be coordinated with the DEN Survey Office. The consultant shall perform any and all surveys and soils investigations required by any governmental agencies, regulatory bodies, and authorities having jurisdiction before they will issue construction acceptances for any project. The consultant shall be solely responsible for contact and coordination with all utility companies for establishment of utility locations prior to site investigations.

6.17.0.2 Testing Agency

Laboratory and field-testing will be conducted by an independent testing laboratory retained by the consultant. DEN may request additional testing beyond the minimum requirements of the contract documents.

6.17.1 Testing Agency

6.17.1.1 General

The consultant shall employ the services of an independent testing agency. Prior to performing any tests, the consultant shall submit the following information to DEN:

- A. Evidence of license to operate as a commercial testing laboratory.
- B. Evidence that the laboratory has been inspected by AASHTO Materials Reference Library (AMRL) or Cement and Concrete Reference Library (CCRL) within the last three years.
- C. Copies of the AMRL or CCRL inspections along with documentation showing correction of deficiencies (if any).
- D. AMRL or CCRL reference sample program test results from the previous two (2) years.
- E. Affidavit of compliance with applicable national certification and/or accreditation program stating that the laboratory performing the work is qualified to perform the tests and work in accordance with the technical requirements required by the contract specifications.
- F. Name, registration number, and engineering discipline of the Registered Professional Engineer (Colorado) in charge of the laboratory. The engineer shall be a full-time employee of the laboratory and have a minimum of five (5) years of experience in construction materials testing.
- G. Evidence that the laboratory and field technicians are qualified for performing the work. Qualifications can be demonstrated through certification by LEED, National Institute for Certification in Engineering Technologies (NICET), American Concrete Institute (ACI), National Ready-Mixed Concrete Association (NRMCA), Portland Cement Association (PCA), American Welding Society (AWS), American Society of

Nondestructive Testing (ASNT), or a degree in a related engineering field with construction field experience.

- H. A list of testing equipment proposed for each test procedure.
- I. A copy of the certification and latest calibration data for all laboratory and field equipment to be used for this project verifying their conformance to national standards.
- J. Estimated number of each type of test.

6.17.1.2 Control of Measuring and Test Equipment

The testing laboratory shall select the measuring and test equipment in such a manner as to provide proper type, range, accuracy, calibration, and tolerance for determining compliance with specified requirements. Measuring and test devices shall be calibrated, adjusted, and maintained at prescribed intervals prior to use, based upon equipment stability and other conditions affecting measurement. Provisions shall be made for the proper handling and storage of equipment. Calibration shall be accomplished using certified standards that have a known traceable relationship to the National Institute of Standards and Technology. Every calibrated measuring and test device shall show the current status, date of last calibration, and the due date for the next calibration. Calibration records shall be maintained as quality records and shall be made available for inspection upon request of the Project Manager.

6.17.1.3 Surveillance of Inspections

When the laws, ordinances, rules, regulations, or orders of any public agency having jurisdiction require DEN's surveillance of inspections or tests, the consultant shall notify DEN of the place, date, and time forty-eight (48) hours prior to the inspection/test operation.

6.17.1.4 Retain Tested Materials and Data

The consultant shall be responsible for maintaining tested materials and testing data until Final Completion of the project or construction contract, or at such time as DEN notifies the consultant in writing. Tests and tested materials shall be available at time of Bid and during the Bidding process for review by proposers.

6.17.2 Documentation

6.17.2.1 Submittal

The consultant shall submit reports of testing and testing analysis to DEN.

6.17.2.2 Document Control

All records and documents, which are quality related shall be prepared, identified, and maintained by the consultant and shall be submitted to DEN. Records shall be protected from damage, deterioration, or loss. Retention time for all quality records shall be not less than three (3) years from date of final payment.

6.17.2.3 Test Results

Test results shall be submitted to DEN after completion of inspections/tests and prior to incorporation of the items into the work unless the test or inspection must be done after installation. Field density and moisture tests shall be reported in draft form immediately at the test site with typed/printed final test results given with 48 hours. If the DEN inspector is not present for the actual test, the draft results shall be given to DEN at the end of the shift. All other inspection and test results shall be submitted within forty-eight (48) hours of the inspection or test. Test reports shall include worksheets showing any and all calculations used in obtaining the test results. All test results must be reviewed and signed by a registered licensed engineer in the state of Colorado. The signature represents that the test procedures used are in strict conformance with the applicable testing standard, the calculated data

are true and accurate, the tools and equipment used were in calibration, the sample was not contaminated, and the persons running the test were qualified.

In addition, the testing laboratory shall prepare and submit to DEN a Monthly Summary Report, which summarizes the activities and results for the quality control tests and inspections conducted during that period. The Monthly Summary Report shall consist of both graphics and text and at a minimum shall identify all test types, test locations, testers, test results, any calculations used, specifications, whether the test passed or failed, and the material supplier, installer, and consultant. Material performance trends shall include a statistical evaluation of each type of test, results of which shall be clearly stated in an overview for each Monthly Report. The Monthly Report shall be submitted per requirements.

6.17.2.4 Records

Records (reports) of inspection and test activities are quality records and shall be maintained, in a manner that provides integrity of item identification, acceptability, and traceability. Reports shall identify the following:

- A. Consultant's name
- B. Contract number and title
- C. Testing laboratory name
- D. Name of items inspected/tested including a physical description and as applicable, model and make
- E. Quantity of items
- F. Inspection/test procedure used. If national standards are used, any deviation from these standards
- G. Date the samples were taken and the date the test was made
- H. Where tests were performed including environmental condition where applicable
- I. Name of inspector/tester
- J. Observations/comments
- K. Specified requirements in the contract that the item must meet
- L. Acceptability
- M. Deviations/nonconformance
- N. Corrective action
- O. Evaluation of results
- P. Signature of authorized evaluator
- Q. Where the material was installed

End of Chapter

This page is intentionally blank.

Chapter 18 - Codes and Compliance

6.18.0 Codes and Compliance

6.18.0.1 Consultant Responsibility

The consultant shall be responsible for ensuring that all designs at the time the Issue for Bid are complete and are compliant with all building code regulatory requirements. Design and construction shall be based on the latest edition of the referenced codes, including additions and revisions in effect at the time of project bidding, unless specifically indicated otherwise.

The consultant shall schedule a series of project familiarization meetings with applicable building code and fire prevention officials to review project development. The consultant and all applicable subconsultants shall attend these meetings to discuss code issues and design direction.

The consultant shall submit documents in a timely manner to all required review agencies to ensure that permits are available at the time of bid advertisement. This shall include intergovernmental agreements and acceptances to tap water and sewer lines. The Designer is responsible for submitting the specifications and drawings to Denver's Building Inspection Division for the division's plan review and receiving acceptances thereon sufficient to allow the contractor to obtain the necessary building permits so as not to cause any delay.

6.18.0.2 Compliance

The codes contain specific references that define the Engineer of Record's responsibility for reviewing of contractor submittal for compliance to the code, establishing construction acceptance criteria, special inspections requirements and procedures, and the engineer's review of contractor-engineered items. As a requirement of its contract responsibilities, the consultant is responsible for the development of all code-required items, which are directed by the applicable project regulations and codes and reviewing of all contractor submittals for compliance to the building codes applicable to the project.

6.18.0.3 Variances

All requests for code and compliance variances must be accepted by DEN prior to requesting a formal variance from any code agency.

6.18.1 Agencies

The following is a partial listing of agencies that have jurisdiction over projects at DEN.

6.18.1.1 Building Code

All design and construction work shall be governed by the amendments to the International Building Code for DEN, latest edition. Particular attention shall be directed to Appendix N of this code, which addresses the construction of DEN buildings and structures.

Review and acceptance of all construction documents for compliance to the Denver Building Code as it applies to DEN.

City and County of Denver Denver Development Services
201 West Colfax Avenue, Department 205
Denver, Colorado 80202

6.18.1.2 Denver Fire Department

Review and acceptance of plans for compliance with the DFD's requirements as it applies to DEN.

Denver Fire Department
201 West Colfax Avenue, Department 205
Denver, Colorado 80204

6.18.1.3 Department of Health and Hospitals

The enforcement of the Denver Health Code, latest edition, is under the jurisdiction of:

City and County of Denver
Department of Environment Health
201 West Colfax Avenue, Department 1009
Denver, Colorado 80204

6.18.1.4 Wastewater Management Division

Review and acceptance of plans for compliance with Chapter 56 of the Revised Municipal Code and enforcement of the Rules and Regulations Governing Sewer Charges and Fees and Management of Wastewater.

City and County of Denver
Department of Public Works
Wastewater Management Division
2000 West 3rd
Denver, Colorado 80223

6.18.1.5 Denver Zoning Administration

Review and acceptance of plans for compliance with the Denver Zoning Ordinance as it applies to DEN.

City and County of Denver
Denver Zoning Administration
201 West Colfax Avenue, Department 205
Denver, Colorado 80202

6.18.1.6 FAA Requirements

Design and construction shall be in accordance with the requirements of the FAA Design Standards criteria, as set forth in applicable FAA advisory circulars. The consultant shall submit FAA submittals to DEN Maintenance and Engineering, not directly to the FAA. The following FAA Standards govern the height and location, with respect to runways and taxiways, of all DEN structures:

- A. FAR Part 77, "Objects Affecting Navigable Airspace"
- B. AC 150/5300-13, "Airport Design"
- C. AC 150/5370-2D/E, "Operational Safety on Airports During Construction"
- D. AC 70/7460-1K, "Obstruction Marking and Lighting"
- E. Latest edition Advisory Circulars may be obtained from:

FAA U.S. Department of Transportation
5440 Roslyn Street, Suite 300
Denver, Colorado 80216-6026
(303) 286-5538

U S. Department of Transportation
Subsequent Distribution Section, M-4943
Washington, D C 20590
Superintendent of Documents
U S. Government Printing Office
Washington, D C 20402

6.18.1.7 Public Health Service

The Assistant Secretary for Health, Department of Health and Human Services, is authorized to make and enforce such regulations that are necessary to prevent the introduction, transmission, or spread of communicable diseases from foreign countries into the United States or its possessions (Section 361, Public Law 410, 78th Congress).

Director, Division of Quarantine
Public Health Service
Center for Prevention Services
Centers for Disease Control
Atlanta, Georgia 30333
Attention: Chief, Program Operations Branch
(404) 639-2574

End of Chapter

This page is intentionally blank.

Chapter 19 - Construction Schedule

6.19.0 Construction Schedule

The consultant or contractor, depending on contractual obligations shall provide DEN with a construction schedule for each project. The schedule data and information shall be prepared and submitted in accordance with the following requirements. The construction schedule is an integral part of the design process and serves to edify the design. Staging, sequencing, work constraints, and submittal requirements contained in the technical specifications must be coordinated and integrated into the construction schedule. In some cases, DEN and/or tenants may require completion, sequencing, or work activities during given timeframes. The consultant is responsible for delivery of a design that can be completed and that has been coordinated to assure that work can be prosecuted in given timeframes. Incomplete and poorly coordinated documents may result in project delays

6.19.1 Schedule Requirements

The consultant shall prepare for each project a detailed construction schedule in graphic, Critical Path Method (CPM) precedence diagram, and bar chart format.

The schedule shall show construction phasing and sequencing, the number of days required to complete major construction activities, and the number of days required to complete each construction contract.

- A. Identify any work that will be performed by others which could affect the contractors' ability to meet the schedule in any way including work items or milestones that affect or are affected by DEN, other contractor's work, utilities, and other third parties.
- B. Identify any important interrelationships or dependencies between major construction, design, procurement, and tenant supplied systems and activities performed by others and program milestones.
- C. Identify and show all significant work tasks including planning, mobilization, shop submittals and acceptances, procurement, fabrication, and construction.
- D. Testing and inspection. The schedule shall list major data submittals required by the contract. The total contract time including project milestones shall be identified and incorporated in the construction contract documents.
- E. Work items shall be identified in accordance with the anticipated bid form units, prices, tasks, and/or CSI UniFormat division classifications. The order, sequence, and interdependence of all significant work items including construction; procurement, fabrication, testing, start up, and inspection and delivery of critical or special materials and equipment; submittals and acceptances of critical samples, shop drawings, procedures, or other documents that could have a schedule impact. The work items shall be sorted by float, early start, Subcontractor, or other sorts mutually agreed to. The schedule shall also show the logic ties of successor and predecessor work items.

6.19.2 Submittal Format

Schedule shall be submitted electronically in PDF format.

End of Chapter

This page is intentionally blank.

Chapter 20 - Submittals

6.20.0 Submittals

6.20.0.1 General Information and Requirements

This chapter addresses the minimum requirements for submittal of construction or RFP documents during the progress of design and construction. Unless otherwise stated in the consultant's contract or approved task, at a minimum, the consultant shall deliver the following submittals to DEN. The consultant shall submit to DEN progress review submittals of design and contract documents, cost estimates, design-build phasing plans, and schedules. These submittals shall contain the information that DEN requires to monitor the consultant's progress and to monitor compliance with the applicable DEN DSMs, and the master schedule. DEN will provide the consultant with its written comments, recommendations, instructions, and assistance after it has reviewed these submittals.

6.20.0.2 Submittal Certification

Each required submittal shall be accompanied by written certification by the design contract signatory that the submittal is complete and in compliance with the contract and DEN DSMs. The consultant is solely responsible for completion and coordination of work by subconsultants. Any deviation shall be so noted in the certification and shall be accompanied by a copy of the written authorization

6.20.0.3 Consultant Design Quality Control Program

The consultant shall have in place a quality control program. Quality controls are those actions taken to maintain a level of quality in the work product that is consistent with the project objectives and client requirements. The consultant's principal shall stamp and sign as reviewed and approved as complying with contract requirements, prior to submission to DEN. Preliminary submittals shall be noted as preliminary. Licensing stamp and signature shall be required on submittals to the following: government agencies, DEN for bid set, record set.

6.20.0.3.1 City Review

Submittal documents will be reviewed by DEN for conformance to requirements of the contract drawings and specifications. Review of a separate item will not constitute review of an assembly in which the item functions. DEN will withhold acceptance of submittals, which depend on other submittals not yet submitted. Review and acceptance will not relieve consultant from their responsibility for accuracy of submittals, for conformity of submittal document to requirements of contract drawings and specifications, for compatibility of described product with contiguous products and the rest of the system, or for protection and completion of the contract in accordance with the contract drawings and specifications. The consultant is responsible for the interdisciplinary coordination and communication within their design contracts and with other consultants with whom their work may interface.

6.20.0.3.2 Consultant Design Standards Monitoring

The consultant shall monitor and review all the documents for design integrity and compliance to the appropriate Design DSM criteria, codes, and standards.

6.20.0.4 Review by DEN

Review and comments by DEN do not relieve the consultant from liabilities of providing complete design services and is not an acceptance of any errors or omissions that may be contained in the documents. Review by DEN shall NOT be construed by the consultant as replacing the consultant's quality control program. Submittals by the consultant must be reviewed by the consultant and corrected PRIOR to submittal to DEN.

DEN reserves the right to reject any submittals described below when DEN determines they do not adequately represent the required level of completion, do not include all relevant design disciplines, systems, approved tenant requirements or do not include all the required documents. Partial or incomplete submittals will be accepted by DEN for review purposes only when DEN requires them for a specific purpose or has otherwise authorized their submittal. Such partial submittals to DEN shall not relieve the consultant of its commitments to meet schedule and budget requirements contained in the agreement.

6.20.0.5 Schedule of Review Submittals by DEN

Review timeframes shall be consistent with the agreed upon or contract design schedule. If no timeframes for review are stated, the consultant shall assume the DEN review will be forwarded to the consultant 18 calendar days after delivery to DEN. In the event the submittal is not accepted, DEN shall include specific reasons for the rejection and the consultant shall commit to a date for re-submittal after the necessary corrections, instructions, or changes have been incorporated. If the rejection resulted in part from the consultant's failure to comply with the terms of the consultant's contract or authorized task, the consultant shall also provide at no cost to DEN its plan for recovering any time lost caused by the rejection. During this review period, the consultant will continue with any other work required by this agreement unless it is notified specifically to the contrary by DEN in writing.

6.20.0.6 DEN Review Format

Construction document review comments will be returned to the consultant in the form of electronic mark-up of documents.

6.20.0.7 Consultant Response to Reviews

After DEN has provided the consultant with its review of the submittal, the consultant shall provide DEN with a written reply that states the consultant's disposition, resolution, or action to be taken on each of DEN's or approved tenant's comments, instructions, or recommendations. The consultant shall submit its reply to DEN within seven (7) calendar days after it receives DEN's comments unless a different timeframe is specifically provided in the agreement or as approved by the Project Manager.

Responses shall be in the same format that comments were presented to the consultant. Responses to PDF comments shall be made using the Reply feature of each individual comment. The original PDF with comment replies shall be returned to the Project Manager in the timeframe defined above. In no case shall mixed formats (letter response to PDF comments) be used unless approved by the Project Manager.

6.20.1 Typed Submittals – Specifications, Tables, Estimates, Design Analysis

6.20.1.1 Format

All typed submittals shall be in hard copy form and in Microsoft Word for Windows 10 and all subsequent versions of Windows or other previously authorized format. These electronic submittals shall be via Unifier. The files shall not be protected. Files shall contain the text, illustrations, tables, schedules, and exhibits contained in the document.

6.20.1.2 Specifications

The consultant shall use the uniform format established in these DSMs for all reports, contract documents, and technical specifications. Technical specifications and reports shall be provided on reproducible copy and in Microsoft Word for Windows 10 and all subsequent versions of Window unless otherwise specified in the consultant contract. Electronic submittal shall be via Unifier according to City guidelines. Files shall not contain macro language; nor shall files be protected. The files shall contain the illustrations, tables, and exhibits contained in the document.

Specifications shall be submitted as files containing all specification sections relevant to the project. The Consultant shall, at minimum, submit a single .pdf file containing tracked changes to all specifications included in the project. The Consultant can additionally submit a “clean” file with no tracked changes, but these are not necessary for DEN’s submittal review process.

6.20.1.3 Data and Product Cut Sheets

The consultant shall submit copies of specifications that incorporate behind each specification section sheets cut sheets, product data sheets and back-up materials for the items specified in the respective section. Cut sheets and product data shall identify system or item performance criteria, size, weight, and color. If color selection is requested of DEN, original manufacturer color samples shall be included. Selected products shall be marked or noted in BLACK to facilitate reproduction. This submittal shall be provided at the 60% construction document submittal and at the 100% construction document submittal. Each specification volume shall be submitted electronically.

6.20.2 Submittal Format – Drawings

Drawings shall be submitted in the format and size as required by DEN. The consultant shall contact DEN in writing prior to each submittal for clarification of the drawing size to be submitted (full size, half size, or reduced size).

6.20.3 Building Information Management/Revit

6.20.3.1 Submittal Schedule

Refer to DFI DSM.

6.20.3.2 Labeling of Media

Consultants must label media with the following information:

- A. Consultant name
- B. Contract number
- C. DEN project number
- D. Submittal date
- E. Submittal level
- F. Contact phone number

Additionally, a hard copy file list must accompany the submitted disc.

6.20.4 PDF Submittal Requirements

6.20.4.1 Specifications

In addition to other formats required, specifications shall be submitted as a single PDF file. The file shall be an Adobe Acrobat, PDF file version 6 or later containing all pages in each submittal. This PDF file shall contain all pages rotated to correct orientation. The PDF file shall be delivered to DEN in the unlocked, security-free state. All sections shall have a bookmark. All bookmarks shall be subdivided by discipline and specification number-title. As much as it is possible, documents shall be directly converted to PDF format. Scanning of files to PDF is acceptable only with written permission from the Project Manager. Additionally, all pages within or printed from the PDF file must match the pages submitted. Single PDF files of each separate specification section are only acceptable with written permission of the Project Manager.

6.20.4.2 Drawings

In addition to other formats required an Adobe Acrobat, PDF file version 6 or later containing all sheets in each submittal or Volume submitted together with the CADD files at each submittal level. This PDF file shall contain all sheets rotated to correct orientation and plotted to full extents for to-scale printing. The PDF file shall have and be delivered to DEN in the unlocked state. All bookmarks shall be subdivided by discipline and drawing number-title for drawings, as shown in [Figure 6.20-1: Drawing Bookmark](#). As much as it is possible, be directly converted to PDF format. Scanning of files to PDF is acceptable only with written permission Project Manager. Additionally, all sheets within or printed from the PDF file must match the drawings submitted. Single PDF files of each separate drawing are only acceptable with written permission of the Project Manager.

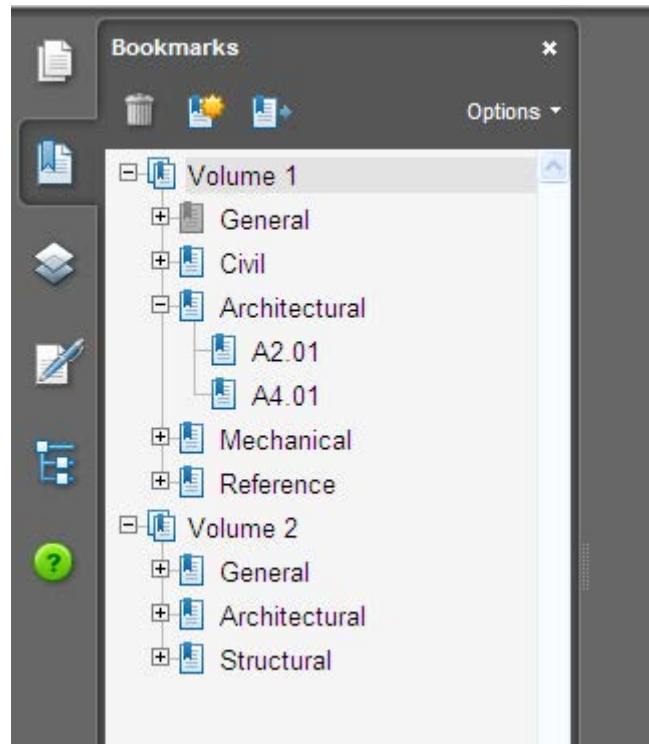


Figure 6.20-1: Drawing Bookmark

6.20.4.3 Reports

In addition to other formats required, reports shall be submitted as a single PDF file. The file shall be an Adobe Acrobat, PDF file version 6 or later containing all pages in each submittal. This PDF file shall contain all pages rotated to correct orientation. The PDF file shall be delivered to DEN in the unlocked, security-free state. All sections shall have a bookmark. All bookmarks shall be subdivided by chapter/title and subchapter numbers/headings. As much as it is possible, documents shall be directly converted to PDF format. Scanning of files to PDF is acceptable only with written permission from the Project Manager. Additionally, all pages within or printed from the PDF file must match the pages submitted.

6.20.4.4 Calculations

In addition to other formats required, calculations shall be submitted as a single PDF file. The file shall be an Adobe Acrobat, PDF file version 6 or later containing all pages in each submittal. This PDF file shall contain all pages rotated to correct orientation. The PDF file shall be delivered to DEN in the unlocked, security-free state. All sections shall have a bookmark. All bookmarks shall be subdivided by discipline and equipment/system number-

title. As much as it is possible, documents shall be directly converted to PDF format. Scanning of files to PDF is acceptable only with written permission from the Project Manager. Additionally, all pages within or printed from the PDF file must match the pages submitted.

6.20.5 Contract Documents Phase. 90% Submittal

6.20.5.1 General

An In-Progress Submittal of the contract documents shall be scheduled by the consultant when the contract documents are approximately 90% complete or substantially complete. If DEN determines that major items of work have been omitted in this submittal, DEN may reject the submittal. The consultant shall provide a separate written report addressing comments and direction provided the consultant by DEN after the 60% submittal.

6.20.5.2 Review by DEN

DEN will schedule a meeting to take place no later than fourteen (14) calendar days after the in-progress submittal is received to review and discuss its comments with the consultant and to resolve any issues, which are identified. All of DEN's and approved tenant's written comments and requirements shall either be incorporated in the contract documents or addressed in some other appropriate written manner satisfactory to DEN within fourteen (14) calendar days after they are received. During this review period the consultant shall continue with any other work required unless is notified specifically to the contrary by DEN in writing.

6.20.5.3 Minimum Submittal Requirements and Quantities

For minimum submittal requirements and quantities, refer to [Table 6.20-1: Minimum Submittal Requirements and Quantities](#).

Refer to the following chapters for discipline specific design submittal requirements:

- [Chapter 9- Mechanical Drawings](#)
- [Chapter 10- Plumbing Drawings](#)
- [Chapter 11- Fire Protection Drawings](#)
- [Chapter 12- Electrical Drawings](#)
- [Chapter 22- Communications/Electronic Systems](#)

6.20.5.4 Construction Documents 90% Submittal

The 90% submittal shall incorporate the comments and information gained from the 60% submittal and is a comprehensive and complete pre-final construction contract document, suitable for public procurement and construction. The documents shall essentially be 100% complete, pending any work for only minor corrections to resolve discrepancies discovered during the final review and for the incorporation of final client comments.

6.20.5.4.1 Drawings

The drawing set shall include all required construction working-drawing sheets completed to practically 100% level of completion. Refer to chapters 14 through 23 for additional 90% drawing submittal requirements for each discipline.

- [Chapter 7- Architectural Drawings](#)
- [Chapter 8- Structural Drawings](#)
- [Chapter 9- Mechanical Drawings](#)
- [Chapter 10- Plumbing Drawings](#)
- [Chapter 11- Fire Protection Drawings](#)
- [Chapter 12- Electrical Drawings](#)

- [Chapter 13- Communications/Electronic Systems](#)
- [Chapter 14- Signage and Graphic Drawings](#)

6.20.5.4.2 Specifications

Specifications shall be complete, comprehensive, and fully coordinated with the working drawings between disciplines and with the contract and special provisions. Consultant shall coordinate with the DEN PM to ensure the contract and special provisions are projects specific. The specifications shall include the following contract requirements:

- A. Supplemental conditions
- B. Division 01 - General Requirements
- C. Division 02 through Division 48: All other technical specification sections

6.20.5.4.3 Schedule

The consultant shall furnish a finalized probable construction schedule for the overall times of procurement, fabrication, delivery, and installation of various systems of the projects, including consideration for phasing the construction work. The finalized probable construction schedule shall contain a level of detail consistent with the requirements of the applicable Construction Specification, as edited by the consultant and included in the construction documents. An electronic medium of a compressed back up shall be provided on CD or DVD with each submittal. As part of the 90% submittal the consultant shall include a draft of the schedule of construction submittals that lists all items, by specification section, that the construction contractor will have to submit for review and approval during the execution of the work. The consultant shall also provide a record *as executed* design schedule, indicating all significant changes from the original design schedule agreed upon at the NTP.

6.20.5.4.4 Spare Parts and Long Lead Items List

At the 90% submittal phase, the consultant shall have finalized the requirements for spare parts and long lead items. DEN shall schedule a meeting prior to submission of 90% submittals with design consultant and other DEN stakeholders to make project specific determination about what spare parts will be required.

6.20.6 Contract Document Phase 100% Final Submittal

6.20.6.1 General

This submittal shall include all the requirements set forth in [Chapter 3- Contract Documents](#).

6.20.6.2 Review by DEN – Final Review Meeting

The consultant shall schedule a meeting to review these documents with DEN. This meeting must be scheduled no later than thirty (30) calendar days prior to the date shown in the master schedule for completing these documents for each project. The consultant shall resubmit the in-progress submittal with all omissions corrected as instructed by DEN.

DEN will schedule a meeting no later than fourteen (14) calendar days after the Final Review meeting referred to above to discuss City questions, comments, or requirements and to resolve any disagreements between the parties. Prior to this meeting, DEN shall provide the consultant with their comments, requirements, approved tenant comments, and specific instructions on data or information that they require be incorporated into the RFP, contract documents, or other deliverables.

6.20.6.2.1 Certification

The consultant shall certify in writing that all the RFP or contract documents are in conformance with the DEN DSMs, all code agency requirements, and that the documents are complete. This certification will be forwarded to

the FAA for acceptance when AIP funding is to be used for the projects. On federally funded projects, these documents will be submitted to the appropriate federal agency for review.

6.20.6.2.2 Documents

Comply with requirements of the DEN DSMs. All contract and RFP documents shall be complete. All design, drafting, coordination, dimensioning and cross references shall be complete, all agency plan comments shall be resolved, and DEN's and approved tenant's comments from all previous reviews must be incorporated into the documents or otherwise be addressed to the satisfaction of DEN. It is necessary that drawings be signed and stamped for this submittal.

6.20.6.3 Construction Document, 100% Submittal

The final submittal of the 100% construction contract documents shall incorporate all client comments developed by the 90% review, with all outstanding actions resolved. Deliverables shall include the following documents:

- A. Consultant annotated responses to the design review comments from the 90% submittal.
- B. Final drawings
- C. Final cost estimate
- D. Final Calculations
- E. Final construction schedule, including phasing considerations.
- F. Spare parts and long lead items list. At the 100% submittal phase, the consultant of record shall have finalized the requirements for spare parts and long lead items.
- G. An original letter signed and sealed by the consultant and addressed to the client providing a list of the special inspections required by the Universal State Building Code (USBC) for the proposed work.
- H. An original letter signed and sealed by the consultant of record and addressed to the client certifying that the design as submitted is in accordance with prevailing and applicable codes. Letter shall include a list of such codes used in the design.
- I. An original letter signed and sealed by the consultant of record and addressed to the client for the temporary Support of Excavation (SOE) system, when applicable.
- J. A complete list of all drawings submitted for final code review.
- K. The final construction submittal schedule, listing all submittals required of the contractor by specification section.
- L. Include a note on the drawings that the contractor shall provide third party inspections for all systems and installations that are not readily available during normal business hours.

6.20.6.4 Final Construction Documents

The final construction documents shall be comprehensive, clear, and suitable for the purposes of procurement, contracting, and construction, and shall incorporate the final, client-approved solicitation provisions, contract provisions, special provisions, conditions of the contract, and general requirements.

Refer to the following chapters for discipline specific design submittal requirements:

- [Chapter 9- Mechanical Drawings](#)
- [Chapter 10- Plumbing Drawings](#)
- [Chapter 11- Fire Protection Drawings](#)
- [Chapter 12- Electrical Drawings](#)

- [Chapter 22- Communications/Electronic Systems](#)

6.20.6.5 Certification Requirements

Final construction documents, including drawings, specifications, and calculations shall be sealed and signed by the appropriate Professional Registered Architect or Engineer-of-Record. Plans and specifications prepared for asbestos abatement, hazardous materials remediation, wetland delineation or other environmental activities shall be signed and sealed in accordance with federal and state regulations.

6.20.7 Submittals Concurrent to Final Contract Document Submittal

6.20.7.1 Agency and Utilities, Applications, and Permits

- A. Identify all design or construction related governmental permits, licenses or other acceptances that are required to complete each project.
- B. Prepare and submit to DEN technical data and information required to prepare any federal grant application and any State of Colorado or federal permit application. These submittals shall include the number of copies of contract drawings and specifications, which any State of Colorado, utility, and/or regulatory body requires in connection with their review and acceptance of the individual applications. DEN shall submit these applications to the appropriate agency, utility, and/or department.
- C. During all phases of work, prepare and submit technical data and information to all government agencies, regulatory bodies, and public utilities necessary to obtain the required permits or acceptances to design and construct each project. A copy of this information shall be sent to DEN. The consultant shall either:
 - a. Obtain, on behalf of DEN, and deliver to DEN's Building Inspection Division prior to publication of the Notice for Invitation to Bid, the permits and acceptances described above, or
 - b. Confirm that these permits and acceptances have been obtained and all other requirements including the Building Division requirements have been satisfied by delivery to DEN, a letter signed by the Building Division and other authorized representatives of each government agency or regulatory body stating that the necessary building and other permits are ready to be issued to successful proposers for each construction contract
 - c. The consultant shall not be responsible for paying any construction permit fee unless the consultant is performing construction work or the activities of the consultant during testing require code agency reviews and permits.
- D. The consultant shall also during the bidding and construction phases of this agreement submit to the government department, agency, regulatory body and/or public utilities technical data or information contained in addenda, change requests, change directives, and/or change orders, which those agencies, departments, regulatory bodies, or utilities need to issue any new or modified permits or acceptances and shall obtain those permits and acceptances on behalf of DEN and deliver them to the Building Division.
- E. Incorporate in the contract documents submitted all revisions necessary to obtain the governmental permits and licenses or other acceptances.
- F. Document all discussions relating to permits, licenses, and acceptances with City, State, and Federal agencies, regulatory bodies, departments, and with public utilities. Within 24 hours of meetings or discussions, provide DEN with copies of all meeting minutes and all serialized correspondence sent to and received from such agencies, departments, and public utilities relating to permits or acceptances, including copies of the permits, licenses, and acceptances.

6.20.8 Other In-Progress Submittals

DEN may require in-progress submittals at any time during the term of this agreement. These submittals may be required to address specific questions or issues related to matters such as interface problems or other issues associated with work performed by other consultants, tenants, design-build contractors, and contractors, and any

special problem areas that are identified by DEN. DEN shall provide the consultant with its requirements for in-progress submittals with reasonable advance notice to allow the consultant to schedule and prepare the submittal.

6.20.9 Building Department Document Review Submittal

6.20.9.1 Building Department Review

Upon completion of the final review submittal and the written acceptance of this submittal by DEN and Senior Director, the consultant shall complete the contract documents and bind them, so they are ready for distribution to the Building Department for plan review. The contract documents shall be completed, reviewed, checked, signed, and sealed by the consultant. DEN's comments and approved tenant comments from previous reviews shall be incorporated in the contract documents and all outstanding issues shall be resolved to the satisfaction of DEN.

The consultant shall then schedule a meeting with the Project Manager for document review by the DEC Director. Upon review, the consultant will receive a letter of payment for plan review to accompany the plan review documents. The consultant shall deliver these documents to the Building Department for review and notify the Project Manager of the Building Department log number and provide a weekly update of the review status. The consultant shall address all Building Department issues at no additional cost to the project.

Immediately after acceptance by the Building Department, the consultant shall prepare the bid documents as indicated in the section below.

6.20.10 Issue for Construction Submittals

6.20.10.1 General

Within fourteen (14) calendar days after bids or proposals are opened, the consultant shall incorporate or bind in all addenda issued by DEN during the bidding or RFP process into the construction or RFP contract documents as directed by DEN.

6.20.10.2 Minimum Submittal Requirements and Quantities

For minimum submittal requirements and quantities, refer to [Table 6.20-1: Minimum Submittal Requirements and Quantities](#).

6.20.11 Record Document Submittal

6.20.11.1 General

Submit in compliance with [Chapter 4- Record Documents](#).

6.20.11.2 Minimum Submittal Requirements and Quantities

For minimum submittal requirements and quantities, refer to [Table 6.20-1: Minimum Submittal Requirements and Quantities](#).

Table-6.20-1: Minimum Submittal Requirements and Quantities

	Contract Documents			Plan Review			Bid Phase	Construction Administration	
	90%	100%	Bid Doc	Addenda	Bid Doc	Addenda	Conformed Document	CR	Record Docs
Reports	1	1	1	1			1	1	1
Soils Report									
PDF File	1	1	1	1	1	1	1	1	1
SPECIFICATIONS									
Cut Sheets/ Specification Set	1	1	1	1			1	1	1
Original Elec File	1	1	1	1			1	1	1
Stamped & Sealed (Hard Copy)			1	1					
PDF File	1	1	1	1			1	1	1
DRAWINGS									
Mylar 6 Mil									
½ Size Drawings									
CADD/3-D Model– Original Elec	1	1	1	1			1	1	1
Navisworks Model	1	1	1	1			1	1	1
Planning Study	1	1	1	1			1	1	1
Composite Drawings	1	1	1	1			1	1	1
Stamped & Sealed (Hard Copy)			2	2					
PDF File	1	1	1	1			1	1	1
REPORTS									
Refer to Requirements of Each Phase	1	1	1	1			1	1	1
Hard Copy	1	1	1	1			1	1	1
Bid Evaluation									
Certificate of Compliance	1	1	1	1			1	1	1
PDF File	1	1	1				1	1	1
ELECTRONIC MEDIA									
Containing all the above Electronic Files	3	3	3	3			3	3	3

End of Chapter

Volume 7 - Structural

Chapter 1 - General

7.1.0 General

This manual establishes minimum criteria by which the structural systems must be designed to provide protection of life, health, and property in the environments provided.

7.1.1 Abbreviations

The abbreviations included in the [Table 7.1-1: Abbreviations](#) are used throughout this manual:

Table 7.1-1: Abbreviations

Abbreviations	Definition
AAE	AA Engineers and Associates, Inc.
AASHTO	American Association of State Highway and Transportation Officials
AMRL	AASHTO Materials Reference Laboratory
ARFF	Aircraft Rescue and Firefighting Facility
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
CCRL	Cement and Concrete Reference Laboratory
CDOH	Colorado Department of Highways
DEN	Denver International Airport
EFP	Equivalent Fluid Pressure
EPA	Environmental Protection Agency
F	Bracing Strut Loads
FSB	Factor of Safety Against Bottom Instability
H	Depth Below Ground Surface
HDPE	High Density Polyethylene
K	Lateral Earth Pressure Coefficient
K _a	Active Earth Pressure Coefficient
K _o	At-rest Earth Pressure Coefficient
K _p	Passive Earth Pressure Coefficient
I	Excavation Strut Spacing
L	Distance between Centers of Spread Footings, the Least Dimension of Mat Foundations, or Shortest Length of a Continuous Footing

Table 7.1-1: Abbreviations (Continued)

Abbreviations	Definition
m	Horizontal Distance Coefficient
n	Vertical Depth Coefficient
No	Cohesive Soil Strength Coefficient
NSP	Non-Swell Potential
NVLAP	National Voluntary Laboratory Accreditation Program
OSHA	Occupational Health and Safety Administration
pcf	Pounds Per Square Foot Per Foot Depth
PDA	Pile Driving Analyzer
P _H	Resultant Horizontal Earth Pressure
psf	Pounds Per Square Foot
PVC	Polyvinyl Chloride
P-Y	Load Versus Deflection, as used in Pile Lateral Load Modeling
q	Surcharge or Areal Load Pressure Intensity
Q ₁	Line Load Intensity
Q _p	Point Load Intensity
R	Distance from Blast Point
SCS	U.S. Department of Agriculture Soil Conservation Service
USDA	United States Department of Agriculture
V _r	Maximum Particle Velocity
W	Weight of Explosive Charge
β	Retaining Wall Backfill Surface Inclination
β	Areal Load to Retaining Wall Inclination
Y	Earth Unit weight
Y _w	Unit Weight of Water
δ	Retaining Wall Roughness Coefficient
σ _h	Horizontal Earth Pressure
σ _H	Horizontal Pressure Due to Uniform Surcharge
φ	Friction Angle
φ'	Friction Angle Based on Effective Stresses

7.1.2 Structural Codes and Standards

Design to most recent adopted Building Codes and City and County of Denver Code Amendments (hereafter referred to as Building Code or Code). In certain cases, this DSM shall have more stringent requirements than building code. Designer will design to the more stringent of the two.

7.1.2.1 Applicable Standards

- A. American Society of Civil Engineers (ASCE) ASCE/SEI 7
- B. American Concrete Institute (ACI) ACI 318
- C. American Institute of Steel Construction (AISC)
 - a. Steel Construction Manual
 - b. Code of Standard Practice
 - c. Specification for Structural Joints Using ASTM A325 or A490 Bolts
 - d. Engineering for Steel Construction, A Source Book on Connections
- D. American National Standards Institute, Inc. (ANSI)
 - a. A58.1 Minimum Design Loads for Buildings and Other Structures
- E. American Welding Society (AWS) D1.1
 - a. Structural Welding Code-Steel
- F. American Water Works Association (AWWA)
 - a. Standard for Steel Tanks, Standpipes, Reservoirs and Elevated Tanks, for Water Storage AWWA D-100-59
- G. American Society of Testing Materials (ASTM)
 - a. Standard properties of miscellaneous building materials
- H. Portland Cement Association (PCA)
 - a. Applicable Standards
- I. Post-Tensioning Institute (PTI)
 - a. Post-Tensioning Manual
- J. Prestressed Concrete Institute (PCI)
 - a. Applicable Standards
- K. AASHTO LRFD Bridge Design Specifications

Miscellaneous standards for properties, manufacture and installation of specific items are not fully covered by the above standards.

7.1.3 Quality Assurance Program

The structural systems design shall be thoroughly coordinated by the Design Consultant with the work of all other trades. The contract drawings shall reflect a design as completely engineered as possible. Provide design loads for any connections that are to be designed by the contractor. Provisions for attachment of equipment to the structure are to be noted, and support points located.

If the design of structural steel elements results in components that require nondestructive testing, that requirement must be indicated on the drawings. Nondestructive testing should only be specified where visual inspection by a certified inspector cannot provide reasonable assurance of structural integrity. Procedures, techniques, acceptance criteria, etc., shall conform to AWS D1.1 structural welding code and the AWS B1.0 guide for nondestructive inspection of welds.

Refer to the Standards and Criteria DSM for the overall project quality control program. Note especially that the Design Consultants must submit a quality control program for review and approval prior to the commencement of the work. There are specific quality assurance procedures required during the preparation of calculations, drawings, and specifications.

7.1.4 References

The following reference sources were used in the creation of this manual:

1. Preliminary Geotechnical Investigation, City and County of Denver, New Denver Airport Site, #8901, AA Engineers and Associates, Inc., February 9, 1989.
2. Soil Survey of Adams County, Colorado, USDA Soil Conservation Service, October 1974.
3. Subsurface Investigation for Design and Construction of Foundations of Buildings, American Society of Civil Engineers (ASCE), 1976.
4. Pile Driving Analyser, Pile Dynamics, Inc., Cleveland, Ohio.
5. Kezdi, Arphad, Lateral Earth Pressure, in Foundation Engineering Handbook, J.F. Winterkorn and H.Y. Fang, editors, 1975.
6. Terzaghi and R.B. Peck, Soil Mechanics in Engineering Practice, 2nd Edition, John Wiley and Sons, NewYork, 1967.
7. Steel Sheet Piling Design Manual, U.S. Steel Corporation, 1970.
8. K. Terzaghi, Anchored Bulkheads, Transactions, ASCE Volume 119, 1954.
9. Foundations and Earth Structures, Design Manual 7.2, NAVFAC DM-7.2, Department of the Navy, Navy Facilities Engineering Command, May 1982.
10. Standard Specifications for Road and Bridge Construction, State of Colorado, State Department of Highways, Division of Highways, 1986.
11. Final Wind Speed Zones and Wind Induced Loads on the Video Board Report, Wind Tunnel Tests for DIA Hotel and Transit Center, CPP, Inc., December 20, 2017.
12. AISC Design Guide 11: Vibrations of Steel-Framed Structural Systems Due to Human Activity.

End of Chapter

Chapter 2 - Task Requirements by Phase

7.2.0 Task Requirements by Phase

During the design phase of new facilities or facility improvements at DEN and after the initial design scope development stage, submittals are required for review by the owner at the following stages of completion. The owner's comments, corrections, notations, etc., shall be revised by the Design Consultant and incorporated into the design before the next stage of completion is submitted. Refer to the Standards and Criteria DSM for the material included in each phase.

7.2.1 Schematic Design Requirements

Refer to the Standards and Criteria DSM.

This phase includes a preliminary one-line schematic design layout of the structural systems, alternative systems if appropriate, and a cost estimate refined to the 15% level. Conduct meetings with owner, facility users, and operators for design input.

7.2.2 Design Development Requirements

Refer to the Standards and Criteria DSM.

Perform design development tasks for the contract that shall include general areas of work for floors and roofs, floor framing, columns, bracing, foundations, and miscellaneous structures.

7.2.2.1 Calculations

Perform definitive structural calculations. They should include sizing for all main components and most secondary members exclusive of bracing and connections.

7.2.2.2 Plans and Elevations

- A. Plans and elevations showing major components; general arrangements; and location of all major framing.
- B. Location of doors, windows, stairs, and other openings.
- C. Lateral force resisting systems. Define systems and locate diaphragms, braces, and moment resisting connections.
- D. Layout of standards, schedules, and details.
- E. Indicate scope of information to be provided in final design drawings.
- F. Standard drawings, schedules, charts, and details.
- G. Layout drawings indicating information to be supplied in subsequent phases. Include any information available currently to show concepts of construction details, materials, and overall structural systems.

7.2.2.3 Coordination Requirements

- A. Coordinate overall plan and elevation views with Architectural Design Consultant.
- B. Coordinate all access openings in floors and walls with Architectural Design Consultant.
- C. Coordinate all floor and wall penetrations for ducts, pipes, conduits, etc. with mechanical and electrical Design Consultants.
- D. Coordinate locations, sizes, and loadings from all equipment to structural system.

- E. Meet with any other consultants at review meetings to verify direction and progress during design development work.

7.2.2.4 Geotechnical Specification Requirements

Outline specifications including brief technical descriptions of all system, members, and materials.

7.2.2.5 Cost Estimates

- A. Prepare preliminary cost estimates on a per square foot or similar basis.
- B. Preliminary cost estimate shall include a list of quantities of materials and unit prices.
- C. Prepare cost estimates for alternative support systems, including schedule impacts of different systems.

7.2.2.6 Documentation Requirements

Design development documents to be completed for the structural systems shall include the following:

- A. Preliminary Design Analysis Report. For information about this report, refer to the Standards and Criteria DSM.
- B. Drawings shall be prepared using the current edition of Revit adopted by DEN. Refer to the Digital Facilities and Infrastructure (DFI) DSM.

Drawings shall include, but not be limited to, the following, if applicable:

- A. Foundation plan showing all footings, grade beams, walls, trenches, etc. Locate and orient columns and equipment foundations.
- B. Structural floor and roof plans.
- C. Types and dimensions of floors, including grating and floor plates. Define all major equipment supports, openings, framing systems.
- D. Elevations and building sections.
- E. Locate all floor levels, beams, columns, struts and framing around openings. Locate braces or moment resisting connections.
- F. Standard drawings, details, schedules, and charts.
- G. Show standard details selected at this phase for bracing, girt system, beam connections, concrete slab edges, handrails, ladders, stairs, etc. Provide format for schedules for columns, connections, foundations, etc.

7.2.3 60% Design Review

Refer to the Standards and Criteria DSM.

Tasks to be completed by the 60% completion level:

- A. Rough draft of specifications.
- B. Drawings - Plans should be at least 80% complete.
- C. Elevations - Should be at least 70% complete.
- D. Details - Should be at least 50% complete.
- E. Schedules - Should be at least 70% complete.
- F. Updated and completed calculations.
- G. All notes, details, schedules and charts shown.

H. Identify, in tabular form, work required to complete drawings.

Note: A Final Design Analysis Report is required. Refer to the Standards and Criteria DSM.

7.2.4 Final (100%) Review

All work complete and checked. Submit for final review.

Refer to the Standards and Criteria DSM.

7.2.5 Bid Document Requirements

All comments and corrections from final review have been incorporated.

Refer to the Standards and Criteria DSM.

7.2.6 Bidding Period Requirements

Once the project is ready for bidding purposes, a complete set of project documents shall be submitted to the Owner along with any addenda.

Refer to the Standards and Criteria DSM for an explanation of the Design Consultant's responsibilities during bidding.

7.2.7 Construction Period Requirements

Refer to the Standards and Criteria DSM.

End of Chapter

This page is intentionally blank.

Chapter 3 - Structural Systems

7.3.0 Structural Systems

The structural system of each building, structure, or portion thereof shall be selected to support its own weight and that of all structural and nonstructural components attached to it. It must also resist all forces applied to it from pedestrian or vehicular traffic, wind, seismic movement, thermal movement, and all loads from equipment or other sources.

The structural systems shall be selected to provide a safe, healthy, and comfortable environment for all persons or equipment occupying or affected by their presence. They shall also be coordinated for a pleasing, unified appearance, efficient circulation of personnel and other traffic, and economical construction.

7.3.1 Foundations

Foundations for all structures are to provide a supporting platform on which to erect the structure. They shall resist all loads from the superstructure and all lateral or swelling forces from the soil without exceeding acceptable limits for bearing pressures, pile capacities, or settlement. Uplift of any part of a structure is also to be resisted by anchorage to the foundation.

A subsurface investigation will be required for each facility, and a report will be prepared that will include a recommended foundation system and design and construction parameters.

7.3.1.1 Shallow Foundations

Shallow foundations are those that are constructed a relatively short distance below grade and derive their support from bearing pressure on the underlying soil. Tops of slabs or mats will be located as required for ground floor or basement floor elevations. Footings subject to outside temperatures are to be located below frost penetration depth, a minimum of 3'-0" below ground surface. Soils investigations will be made to determine permissible bearing pressures.

7.3.1.2 Deep Foundations

Deep foundations shall be employed where shallow foundations do not provide satisfactory bearing capacity or resistance to settlement or heaving. Footings or mats are supported by piles or drilled shafts. Load-carrying capacity is provided by end bearing, skin friction, or a combination of both. Type of pile or shaft will be determined from soils investigation. Select type of deep foundation that will be most capable of supporting the imposed loads efficiently and economically.

7.3.2 Superstructure Types

7.3.2.1 Steel Structures

Steel structures are essentially frames that support floors, roofs, and walls of a building. Vertical loads from floors, roofs, and other structural components are supported on beams, joists, or trusses that are in turn supported by columns. Walls are supported by beams or by girts spanning between columns.

Lateral loads from wind, seismic or temperature movements, etc. are resisted by shear walls, diagonal bracing, or by moment resisting members and connections.

Materials used in steel structure shall be those with proportions and properties that provide the best performance in the overall design. The use of stainless, high strength or corrosion resistant steels may be warranted in special areas.

Members used in fabricating a steel frame may be rolled sections, factory built joists and joist girders, or custom designed and built up sections. Connections may be welded, bolted or a combination of both. Composite design may be used where required or economically advantageous.

Connections both bolted and welded, may be designed by the Design Consultant or the fabricator. If designed by the Design Consultant, they must be thoroughly detailed in the construction documents. If designed by the fabricator, the drawings must clearly define that responsibility and provide all the design loads, restrictions, and special provisions. Connections designed by the fabricator must be under the direct supervision of a professional engineer registered in the State of Colorado. The construction documents must specify that the fabricator furnish documentation, under a licensed professional engineer's seal and signature, that a professional engineer has designed the connections.

In either case, the Design Consultant must review and approve the connection details and retain responsibility for conformance with overall design requirements and information given in the construction documents. However, the review and approval by the Design Consultant do not relieve the fabricator and his professional engineer of their design responsibility.

7.3.2.2 Cast-In-Place Concrete Structures

Cast-in-place structures are essentially frames of reinforced concrete members, cast in their final position at the construction site. The typical structure is a moment resisting frame with connecting members placed to form monolithic joints. Reinforcing steel extends through joints to provide continuity between members.

Cast-in-place members and components may include, but are not limited to, foundations, columns, beams, floors, walls, tunnels, and machinery pedestals.

Construction joints may be used between successive pours. Extend reinforcing bars through joints to splice onto bars following placement.

Where appropriate, post-tensioning may be used with the cast-in-place construction. It may be used to limit deflections of long-span members, to develop frame action, to control cracking in slabs, etc.

Forms for concrete members are to be constructed of materials that have the strength to support the fluid concrete and any loads that may be applied during construction. Form surfaces that are in contact with the concrete must be of a material that will give the concrete a satisfactory finish. Reuse of forms can be achieved by designing members of the same sizes where practical.

Foundations are to be placed on the earth below them. Vertical sides of excavations may be used for forming where the earth can retain its excavated shape. Forming of sides is required for all exposed foundations.

7.3.2.3 Precast Concrete

Precast concrete structures or members are those cast other than in their final position. They may be standard manufactured items or custom designed. Precast members may include, but are not limited to,

- A. Floor and roof deck panels
- B. Wall panels
- C. Columns or posts
- D. Beams
- E. Other precast items are wall copings, door and window frames, stair segments, etc.

Precast members may be prestressed (pre-tensioned or post-tensioned) or non-prestressed. All are to be reinforced to give the members their desired strength and durability.

Attachment to other members of the overall structure is to be made by bolting, welding, anchoring by use of dowels into cast-in-place segments, or other approved methods.

Design of precast elements must include the forces due to removing sections from forms, lifting, transporting, anchoring, etc., in addition to those forces to be resisted after the element is incorporated into the framing system.

7.3.2.4 Tilt-Up Concrete

Tilt-up construction is a special case of pre-cast concrete. Wall panels are poured in beds or on the grade floor slab with embedded devices for attachment to the building frame. After curing, the panels are tilted to a vertical position and connected to the building. Tilt slabs may serve as the building frame or merely as a skin enclosing it.

Design of tilt-up elements must include the forces due to lifting, anchoring, etc., in addition to those forces to be resisted after the element is incorporated into the framing system.

7.3.2.5 Concrete Masonry Units (Concrete Blocks)

Concrete blocks are used for construction of both interior partitions and exterior walls. Depending on the size and use of the buildings, walls may be load bearing and provide the entire means of resisting vertical and lateral loads. Block walls may also be incorporated as shear walls to resist lateral loads in other types of building frames.

Depending on the size or use, concrete block walls may be reinforced or non-reinforced. Special purpose blocks are available for anchorage of various items, spanning openings, etc.

End of Chapter

This page is intentionally blank.

Chapter 4 - Structural Design

7.4.0 Structural Design

The structural systems of each building or portion thereof shall provide a safe environment for all persons and equipment occupying or affected by it. All forces which may be expected to act upon it shall be considered in designing and members proportioned to resist these loads without exceeding stresses, deflections, or other limits defined by the applicable codes and standards. Loads to be used in designing include, but are not limited to the following:

7.4.0.1 Dead Load

Dead load is defined as the weight of structure, supported structures and building components, and all stationary equipment and furnishings. Floor dead load includes ceilings and services hung from the floor.

7.4.0.2 Live Load

- A. Temporary loading imposed by snow, traffic, machines, etc.
- B. Live loads for small spaces, toilet rooms, corridors, etc. should be the same as the live load for the surrounding spaces if the surrounding live load is heavier.
- C. Catwalks and equipment access platforms shall be designed for at least 40 psf live load. Lay-down areas may require substantially heavier loads.
- D. Loads for rigging and construction equipment (lifts, transporting heavy equipment to other areas, etc) for current project.

Airports need to be flexible to accommodate various uses of space throughout the life of airport operations. Therefore, it is the responsibility of the Design Consultant to examine spaces that may be used for something other than for what they were initially intended. Use the higher loading requirement when it is reasonably justifiable. (i.e., airline office space, due to future remodeling, may become circulation corridor space. Therefore, design for 125 psf.) All assumptions should be listed in the Preliminary Analysis Report for comment and/or approval by PM.

7.4.0.3 Snow Load

Design for load specified in the proposed Denver Building Code Amendments. Roof loads shall account for roof slopes and potential accumulation of snow at valleys, parapets, roof structures, and offsets of roofs of uneven configuration.

7.4.0.4 Wind Load

Design for wind speed specified in the proposed Denver Building Code Amendments and exposure category C. Design pressures shall be calculated for individual structures on basis of shape, height, size, and locations as specified by ANSI A58.1, but not less than 30 psf for exterior walls and any interior partitions subject to jet blast.

Design for wind speed on the Hotel Plaza shall be increased by the factors specified in [Figure 7.4-1: Local Design Wind Speed Zones- Hotel Plaza](#). Wind speed zones are presented as a ratio to site design wind speed. Numbers in parenthesis indicate local wind speeds in MPH.

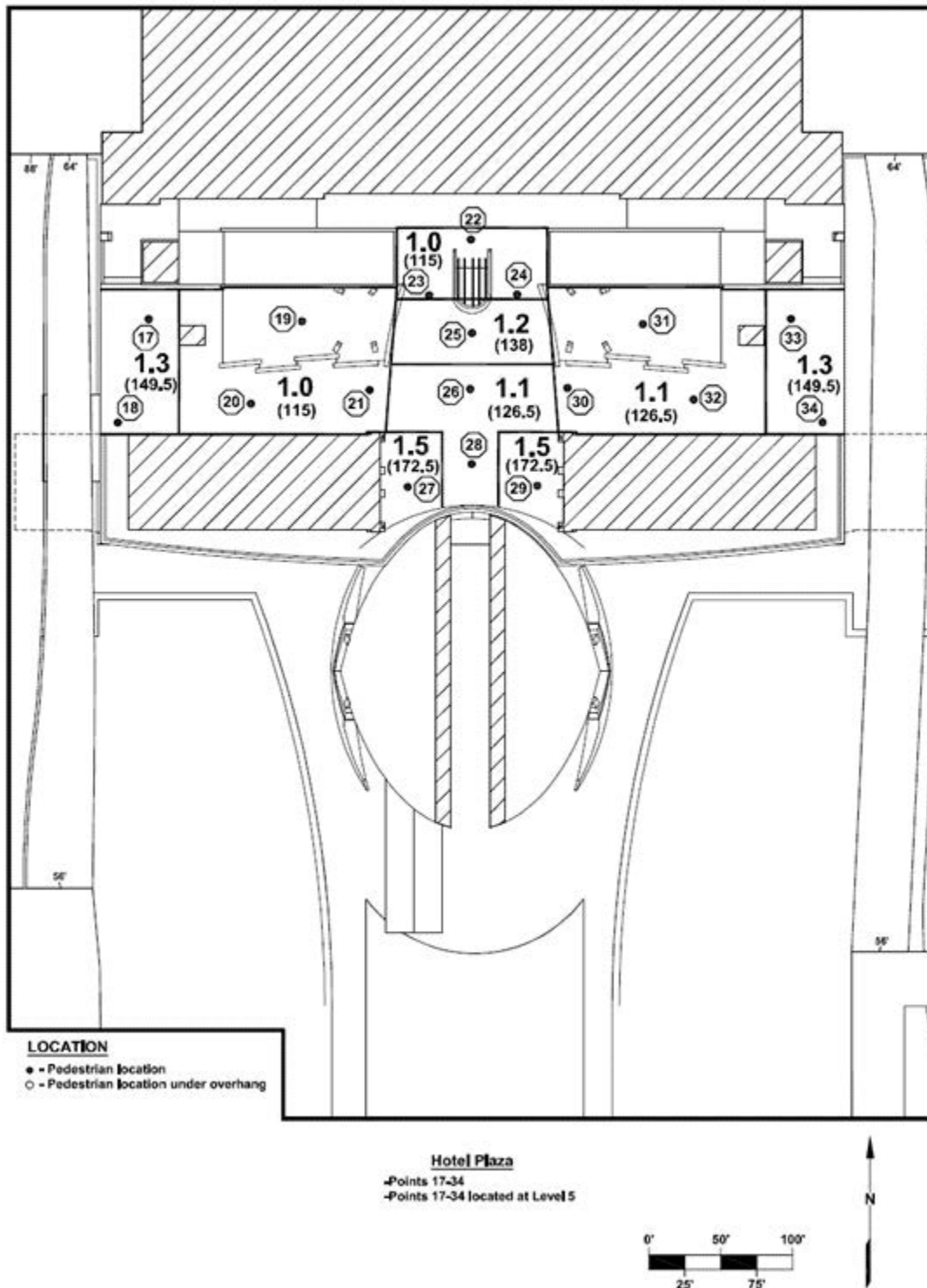


Figure 7.4-1: Local Design Wind Speed Zones - Hotel Plaza

7.4.0.5 Earthquake Load

Design for forces specified by ASCE 7 with minimum Seismic Design Category B.

7.4.0.6 Other Loads

7.4.0.6.1 Fire Lane Loads

Design for worst condition for AASHTO HL-93 or actual firetruck loads including tankers, and outrigger loads. Consult with Denver Fire Department for most current firetruck loads.

7.4.0.6.2 Mechanical Rooms

Design for actual equipment loads, but not less than 125 psf.

7.4.0.6.3 Elevators

Use loading data from manufacturer for specific elevators used with 100% impact.

7.4.0.6.4 Electrical & Communication Rooms

Design for actual equipment loads, but not less than 125 psf.

7.4.0.6.5 Lateral Loads

The Structural Design Consultant shall submit a plan showing the path of resistance for all lateral loads as part of the design development (35%) submittal.

7.4.0.6.6 Handrails and Railing Systems

Require contractor to design, engineer, fabricate, and install handrails and railing systems to withstand the following structural loads without exceeding the allowable design working stress of the materials for handrails, railing systems, anchors, and connections. Apply each load to produce the maximum stress in each of the respective components comprising handrails and railing systems.

7.4.0.6.7 Top Rail of Guardrail System

Capable of withstanding the following loads applied as indicated:

- A. Concentrated load of 200 lbf applied at any point nonconcurrent, in any direction.
- B. Uniform load of 50 lbf per linear foot applied nonconcurrent, in any direction.
- C. Concentrated and uniform loads above need not be assumed to act concurrently.

7.4.0.6.8 Handrails Not Serving as Top Rails

Capable of withstanding the following loads applied as indicated:

- A. Concentrated load of 200 lbf applied at any point nonconcurrent.
- B. Uniform load of 50 lbf per linear foot applied nonconcurrent, vertically downward or horizontally.
- C. Concentrated and uniform loads above need not be assumed to act concurrently.

7.4.0.6.9 Infill Area of Guardrail System

Capable of withstanding a horizontal concentrated load of 200 lbf applied to one square foot at any point in the system including panels, intermediate rails, balusters, or other elements composing the infill area.

Above load need not be assumed to act concurrently with uniform horizontal loads on top rails of railing system in determining stress on guard.

7.4.0.6.10 Glass-Supported Railing Systems

Capable of withstanding loads indicated for top rails and infill area of guardrail systems based on safety factor of 4, with each section of top rail supported by a minimum of 3 glass panels or by another means so that it remains in place should one panel fail.

7.4.0.6.11 Interior Walls and Partitions

Design to resist all loads to which they are subjected but not less than 5 psf applied perpendicular to the walls. Deflection shall not exceed $L/360$ of the span.

When the structural framing members, either concrete or steel, are left exposed as an architectural element, coordinate the finish of these members with the Architectural Design Consultant.

7.4.0.6.12 Vibration Criteria

Design all structural slabs to the following vibration criteria.

Table 7.4-1: Vibration Criteria

Occupancy Type Description	Acceleration Limit (%g)	Number of Walkers
Dining adjacent to general circulation	1.2	4
Dining seated inside formal restaurant	1.2	1
General Circulation	1.2	4
Mechanical	N/A	N/A
Mechanical Workshop	N/A	N/A
Office	0.5	1
Restroom	1.2	1
Retail	1.2	1
Seated Concourse Assembly Area	1.2	1
Storage	N/A	N/A
Vehicle Parking/Dining	N/A	N/A

7.4.0.7 Major Structural Components

7.4.0.7.1 Roofs

Roofs over all enclosed areas shall protect the interiors from the outside environment. Forces acting on the roof include the dead load of the roof and all structure and equipment supported, live loads including snow and traffic or other temporary forces, and wind effects. Any roof that may become a future floor shall be designed for a minimum uniform live load of 100 psf or greater load if required.

7.4.0.7.2 Walls and Partitions

All walls and partitions shall be designed to support their own weight and any building components or equipment supported by them. Lateral loads from wind or earthquake forces shall be applied as well as collision or other forces. Walls to be stiffened or provided with lateral support by girts as indicated.

7.4.0.7.3 Main Structural Framing System

All beams, columns, bracing, and other parts of the main load-resisting frame shall be designed to resist gravity, lateral, and thermal loads applied directly or through floors, roofs, and walls. Reactions from traffic or mechanical systems shall be included. Member types and sizes are to be selected to give a uniform appearance. Lateral loads are to be resisted by shear walls, diagonal bracing, moment-resisting members and connections, or combinations thereof.

7.4.0.7.4 Foundations

Design foundations to support structures on the underlying soil. All gravity and lateral loads are to be resisted without exceeding permissible loading or total or differential settlement limits determined from soils investigations. Uplift of any portion to be resisted by foundation. Foundations may be slabs on grade or piles, individual spread footings, or footings on piles or drilled shafts.

7.4.0.7.5 Floors

Floors are to be designed for the floor dead load plus uniform or concentrated live loads pertinent to given areas. Include loads from all equipment, furnishings, piping, lighting and structures supported upon or suspended from them. Design all stairs, ramps, escalators, and walkways for 100 psf, except as noted for individual zones or buildings.

7.4.0.7.6 Ground Transportation and Parking Lots

Ground transportation and parking lots that are exposed to weather shall be designed for snow removal equipment loads.

7.4.1 Passenger Terminal

7.4.1.1 Minimum Floor Live Loads

The Design Consultant is responsible for verifying all loads.

7.4.1.1.1 Concessions and Service

Design for 100 psf in public areas and 125 psf in storerooms. Consider weights of vending machines, appliances, and miscellaneous equipment and increase live loads as required.

7.4.1.1.2 Vibrating Loads

The Design Consultant shall address the problem of transfer of unacceptable vibrations to the public areas including hold rooms, waiting rooms, concession areas, observation lounge, restaurants, etc. Isolation joints, isolation dampers, absorbers or other means shall be used to control the transfer of vibrations from the baggage system, tug drive, conveyors, moving walkways, trains, or any other source.

7.4.2 Other Buildings – Minimum Floor Live Loads

7.4.2.1 International Concourse

Use same live loads as for corresponding use areas in Terminal. For areas where baggage conveyors could potentially be hung, follow the guidelines for the Terminal Ticketing Level. Comply with the requirements for the baggage system and vibrating loads stated in the Terminal section.

7.4.2.1.1 Concessions and Services

Design for 100 psf in public areas and 125 psf in store rooms.

7.4.2.2 Domestic Concourse

Use same live loads as for corresponding use areas in Terminal. For areas where baggage conveyors could potentially be hung, follow the guidelines for the Terminal Ticketing Level. Comply with requirements for the DCV bag-gage system and vibrating loads stated in the Terminal section.

7.4.2.2.1 Concessions and Services

Design for 100 psf in public areas and 125 psf in storerooms.

7.4.3 Miscellaneous Structures Other Than Buildings

The Design Consultant is responsible for verifying all loads. Check all aircraft loads, tug loads, firefighting, and ARFF equipment, etc.

7.4.3.1 Lighting and Sign Supports

Design lighting and sign supports, including poles, sign bridges, arms, and foundations for loads and criteria from following the latest edition of the AASHTO specification: Standard Specification for Structural Supports for Highway Signs, Luminaries, and Traffic Signals.

7.4.3.2 Metal Structures on Concrete Slab

When design requires detailing of, or modification to metal structures resting on concrete slabs on grade, utilize a detail similar to [Figure 7.4-2: Example of Base Connection Detail- Metal Structure on Concrete Tab](#) at the base connection. All design loading as outlined in applicable codes shall be followed to design and size the members to be used.

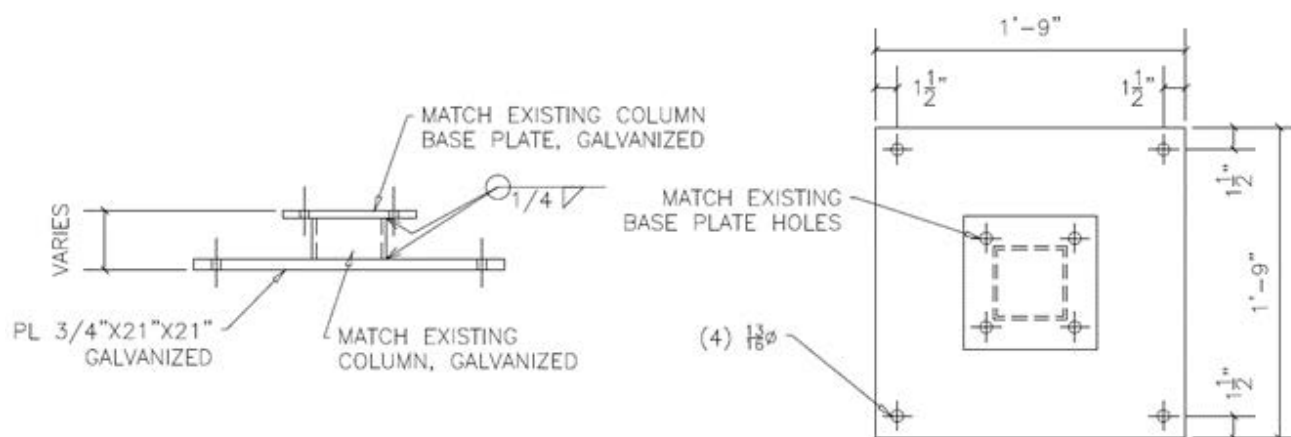


Figure 7.4-2: Example of Base Connection Detail - Metal Structure on Concrete Tab

End of Chapter

Volume 8 - Sustainability

Chapter 1 - Background and Introduction

8.1.0 Purpose and Background

8.1.0.1 Intended User

Airports are designed to exist for generations. The development decisions made today directly impact DEN's viability and success for decades to come. As a process, sustainability is about considering relevant economic, environmental, and social criteria in all decision-making. It does not prescribe a specific outcome or mandate that every project has certain environmental attributes. Understanding that all projects have inherent constraints, sustainable criteria need to be built-in from the earliest stages of design to ensure that decisions are made in a systematic and holistic way to stay within project constraints while meeting the sustainability goals of the airport. The key is to balance short and long-term costs in such a way as to minimize negative impacts and maximize benefits. By achieving this, DEN will continue to be a global leader in airport sustainability and our projects will perform to the highest sustainability standards in the aviation industry.

This DSM assists planning, design, and construction teams with integrating sustainability, certification, and commissioning into their project processes and deliverables. It provides guidelines for project teams to deliver sustainable projects through an integrated stakeholder engagement process. It sets the expectations for sustainable development at DEN.

With new design strategies and technologies becoming available at a rapid pace, it is the expectation of the airport that project teams develop designs and proposals that deliver innovative approaches and maximize the sustainable outcomes of the project. These strategies and their total costs should be included in the base design, clearly indicated in the budget for all project proposals and presented in terms of capital investment as well as total costs over the life of the project.

8.1.0.2 Summary

DEN has a longstanding commitment to advancing sustainability in our facilities and operations and improving the standard for sustainability in the aviation industry. This commitment is rooted in our Strategic Objectives and aligns with other City and County of Denver (CCD) principles, best-practices, and requirements.

This Design Standard Manual reinforces that commitment and formally defines the sustainability requirements that all new building construction, major facility renovation projects, and non-building landside and airside projects shall meet. The manual directly aligns with the CCD Executive Order Number 123 (XO123), Denver Green Building Ordinance, Energize Denver Ordinance, Denver One Water Plan, Net Zero, and DEN's continued commitment to sustainable development and operations.

8.1.0.3 Scope

The scope of coverage of this manual includes all processes related to the certification of any project under various rating and certification bodies; the validation of performance of a project during design, construction, acceptance, turnover, and operation; and the development of high-performance design criteria to support those certification and validation efforts.

8.1.1 Environmental Policy

Denver International Airport (DEN) is dedicated to working with our partners to promote strong environmental performance. Our organization and employees are committed to business practices, policies, actions, and programs that enhance our performance by:

- A. Protecting the environment
- B. Conserving energy and natural resources
- C. Preventing pollution
- D. Meeting or exceeding all compliance obligations and voluntary commitments
- E. Continually improving the Environmental Management System (EMS)

8.1.2 Sustainability Policy

DEN is committed to strategically considering the long-term economic, social, and environmental impacts of all airport activities in order to maximize long-term benefits and ensure that our success strengthens our community stakeholders.

8.1.3 Vision 100

Vision 100 is DEN's strategic plan that will enable DEN to prepare for and reach 100 million annual passengers. The strategic plan will serve as a blueprint to align decision-making and enable accountability so together we can thoughtfully prepare to serve 100 million passengers. This plan will guide our work over the next 3-5 years, the first phase of reaching Vision 100.

DEN's strategic plan is centered around four pillars of Vision 100 and under each pillar are strategic objectives.

8.1.3.1 Empowering Our People

This is about the people who work at DEN and those who want to be part of DEN today or in the future. DEN's success relies on its people and partners.

To ensure we have a strong workforce, we must provide opportunities for employees to develop and grow so we can retain our talent and knowledge. We also need to prepare future employees by providing training and opportunities. We want Denver to become THE place for aviation talent. We will also create more opportunities for minority, women-owned, and veteran-owned businesses to do business at DEN and grow to become prime contractors or full concession owners. By taking care of our people, we can ensure DEN is prepared today and in the future.

8.1.3.2 Growing Our Infrastructure

We must continue to invest and grow our facility by completing key projects such as Great Hall and others, continuing improvements to Peña Boulevard and exploring options- for a 7th and even 8th runway. We will continue to focus on projects in our Capital Improvement Plan to ensure we can build a facility to accommodate 100 million annual passengers.

8.1.3.3 Maintaining What We Have

We must continue to take care of what we currently have. The airport opened in 1995 and is experiencing a great deal of wear and tear due to increasing passenger volumes. Projects such as Concourse Renewal, which will upgrade our restrooms, wayfinding, hold rooms and flooring, will make a tremendous improvement. We will replace aging conveyances, replace and add train cars and ensure our asset management system is efficient and effective. As employees, we help by reporting maintenance or cleanliness issues so they can be resolved quickly.

8.1.3.4 Expanding Our Global Connections

A competitive advantage of DEN includes our vast amount of land and the fact that we are centrally located in the United States with easy access to the coasts. This allows us to expand our air service network and grow our cargo operations. Our DEN Real Estate program will be essential for this pillar as we open up about 16,000 acres for commercial use. This will generate additional revenue, keep costs down for airlines, and lead to more flights, more passengers and more business opportunities.

8.1.4 DEN Community Demographics

Section in development.

8.1.5 Equity, Diversity, and Inclusion

In alignment with the City & County of Denver's Race & Social Justice (RSJ) goals the DEN Equity, Diversity, and Inclusion (EDI) team designed three pillars of focus with interconnected strategies. The three pillars of People (Employees), Operations (Customers), and Community (Internal & External) make up the DEN Equity Plan and have wide-reaching tactics aimed to drive innovative change and build sustainable outcomes.

8.1.6 Codes, Regulations, and Ordinances

This section describes key sustainability regulations and ordinances that apply to DEN projects. Project teams are expected to understand how these apply to their specific projects and include a plan for compliance in their proposals and designs. Refer to the code, regulation, or ordinance language for comprehensive information.

8.1.6.1 City and County of Denver Executive Order 123 (XO123)

XO123 was originally issued in 2013 and has been subsequently amended multiple times. The current version of XO123 is available for review online from CCD, see below. Under XO123, all new City funded building and major building renovation projects over 5,000 square feet are required to achieve a minimum of LEED® Gold certification. Projects under the 5,000 square foot threshold are expected to meet the intent of Gold Certification but are not required to pursue formal certification.

The most current version of the LEED® reference manuals for New Construction, Commercial Interiors, Core and Shell, and Airports shall be used. Where contradictions exist between the LEED® reference manual and any CCD or DEN document or standard, the more stringent requirement shall apply.



[City and County of Denver Executive Orders](#)

8.1.6.2 City and County of Denver Green Building Ordinance

A Green Buildings Ordinance (GBO) was approved by Denver City Council on October 29, 2018, and took effect, November 2, 2018. It is available for review on Denver's Green Buildings Ordinance site from the CCD.



[Denver Green Building Ordinance](#)

The GBO applies to the following:

- A. New buildings 25,000 square feet or larger.
- B. Roof permits for existing buildings 25,000 square feet or larger.
- C. Additions of 25,000 square feet or larger.

8.1.6.3 Building Codes and Amendments

The Denver Building and Fire Code establishes the minimum, mandatory standards for building construction in Denver. Denver's code is based on international standards for safe, habitable structures. It is available for review from CCD:



[Denver Building Codes, Policies, and Guides](#)

8.1.6.4 Environmental Permits & Guidelines

Review relevant DEN Technical Specifications, DEN Environmental Guidelines and local, state and federal permitting requirements. All applicable specifications, guidelines and permits must be adhered to. Refer to the DEN Environmental Management website for additional guidelines.



[DEN Environmental Management System](#)

In accordance with DEN Rule and Regulation 180, the ISO 14001-certified EMS requires that all entities doing business at DEN or on behalf of the airport conform to certain elements of the standard. More specifically, all DEN Business Partners must be aware of the DEN Environmental Policy, identify the significant environmental aspects associated with their operations, develop programs to manage these aspects in a manner that complies with environmental requirements, and further, must ensure the competency of their staff with respect to environmental responsibilities.



[PART 180 ENVIRONMENTAL MANAGEMENT](#)

8.1.6.5 Energize Denver Ordinance

The Energize Denver ordinance establishes energy use intensity targets for buildings over 25,000 sq. ft. It is available online at the Energize Denver Hub from the CCD.



[Energize Denver Ordinance](#)

8.1.6.6 Universal Recycling and Composting Ordinance

This ordinance requires nearly all construction and demolition projects to separate and recycle, at a minimum, all readily recyclable concrete, asphalt, clean wood, scrap metal, and corrugated cardboard. Projects are required to submit a recycling and reuse plan to the city to confirm compliance with the ordinance prior to obtaining a construction or demolition permit. Note that the requirements may increase over time, so check the link for current information. The compliance form can be found on the City's Waste No More C&D webpage.



[Universal Recycling Submittal Requirements](#)

8.1.6.7 Denver One Water Plan

The One Water approach promotes coordination and collaboration among various city departments, organizations, and agencies in charge of managing all aspects of the urban water cycle including: water supply, wastewater, storm and flood protection, water quality, watersheds and waterways. The plan requirements are available for review from CCD.



[Denver One Water Plan](#)

8.1.6.8 Net Zero

DEN is continuously updating the guiding principles for Net Zero implementation at the airport. DEN is pursuing Net Zero strategies on a project by project basis. Contact the DEN project manager or DEN Environmental for current requirements. When pursuing net zero energy at DEN, consider all electric building solutions similar to those that have been implemented in the City and County of Denver in the all electric pilot demonstration at the link below:



[All Electric Pilot Demonstrations](#)

8.1.7 Applicability

DEN is owned and operated by the City and County of Denver and subject to applicable Executive Orders issued by the Mayor, Ordinances and City Policies. For instance, Executive Order 123 (XO 123) directly addresses the sustainability expectations for all City projects. All DEN funded projects must comply with XO 123 requirements in addition to following the expectations outlined in this DSM. For clarification on specific project application, contact the DEN Project Manager.

8.1.7.1 New Construction or Major Renovation – Heavy Civil

All DEN horizontal infrastructure/civil projects over \$1M but less than \$10M total construction cost shall utilize the Envision® sustainability framework and rating system to the extent practicable and complete the Envision self-assessment tool. The self-assessment tool shall be completed at least twice - once at the beginning of design and again near project completion.

All DEN horizontal infrastructure/civil projects over \$10M total construction cost shall utilize the Envision sustainability framework and rating system and achieve, at a minimum, the Verified level using the Envision self-assessment tool, unless otherwise specified. Projects will seek third-party verification and certification through the Institute for Sustainable Infrastructure on a case-by-case basis. The decision to pursue third-party verification will be reached through discussion between the project team and DEN Sustainability.

Non-DEN horizontal infrastructure projects that meet the above construction costs are encouraged to utilize the Envision rating system, including the self-assessment tool and third-party verification.

8.1.7.2 New Construction – Buildings

Any new building construction project which totals over 5,000 square feet of enclosed space is subject to the requirements in this manual.

8.1.7.3 Major Renovation – Buildings

Any major renovation or re-model of an interior space wherein over 50% of the gross floor area is being renovated and mechanical, electrical, plumbing, and life-safety systems are modified, deleted, or added shall comply with the requirements in this manual.

8.1.7.4 Commissioning Projects

Projects of any size that include building systems are subject to the requirements of Commissioning. This includes new systems, modifications to existing systems, and removal of systems. Applicable systems include any of the following:

- A. Mechanical systems
- B. Electrical systems
- C. Plumbing systems
- D. Life safety systems
- E. Building Enclosures/envelope
- F. Other systems, as directed by the DEN Project Manager

8.1.8 Definitions, Abbreviations, and Terminology

Table 8.1-1: Definitions lists common terms associated with this DSM.

Table 8.1-1: Definitions

Term	Definitions
Sustainability	DEN is committed to strategically considering the long-term economic, social, and environmental impacts of all airport activities in order to maximize long- term benefits and ensure that our success strengthens our community stakeholders.
Certification	Third party verification and certification of design and construction practices by an entity approved by DEN.
Validation	The action of making or declaring something legally or officially acceptable.
High-Performance Design	An approach to the design of a project where it is required to meet certain performance requirements, such as energy efficiency, without a specific prescribed method by which to attain those requirements.

Table 8.1-1: Definitions (Continued)

Term	Definitions
Integrative Process	The integrative process engages all stakeholders through an iterative process to design and construct projects that achieve the desired level of high- performance design.
Life Cycle Assessment (LCA)	Framework to quantify the environmental impacts of a product or service across all stages of its life cycle.
Life Cycle Cost Analysis (LCCA)	The process for evaluating the total financial cost of an asset or investment over its service life.
Design Analysis Report (DAR)	A report to present a clear, complete, and concise picture of the design of the facilities and systems. See Chapter 3 of the Standards and Criteria Design Standards Manual for more information.

Table 8.1-2: Abbreviations and Terminology lists abbreviations and terminology used throughout this manual.

Table 8.1-2: Abbreviations and Terminology

Term	Definition
AOB	Airport Office Building
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
BTU	British Thermal Unit
CCD	City and County of Denver
CDE	Common Data Environment
Cx	Building equipment and systems commissioning
CxA	Building equipment and systems commissioning agent
DDS	Denver Development Services. DDS is the Denver Building Department
DEC	Design, Engineering and Construction. DEC is a division within DEN.
DEN	Denver International Airport
DEN PM	DEN Project Manager. The DEN PM is the CCD representative.
DEN PMIS	The DEN Project Management Information System
DFD	Denver Fire Department
ECS	Emergency Communication System
EMCS	Energy Management Control System
HTC	Hotel and Transit Center
HVAC	Heating, Ventilating, Air Conditioning systems
ISI	Institute for Sustainable Infrastructure
LEED®	Leadership in Energy and Environmental Design
NFPA	National Fire Protection Association

Table 8.1-2: Abbreviations and Terminology (Continued)

Term	Definition
OPR	Owner's Project Requirements
SSI	Sensitive Security Information
Tenant	Lessee to CCD and DEN, including the Tenant's Architectural/Engineering Consultants.
XO123	The CCD Executive Order Number 123. This Executive Order and the applicable memoranda establish key sustainability policies for CCD.

Table 8.1-3: Project Personnel lists typical team members and their level of engagement on DEN project teams.

Table 8.1-3: Project Personnel

Personnel	Definition
Core Team Members	Core members typically include the project manager, sponsor, contract administrator, designer, and contractor. This is the team that is ultimately responsible for making final decisions about the project.
DEN Project Stakeholders	A stakeholder is someone who will be affected by the project and who has a vested interest in the project's success. Typical stakeholders include the project sponsor, facilities and operations staff, design consultants, construction vendors, concessionaires, fire safety staff, IT staff, airline representatives, and even travelers who might visit or use the space.
Key Stakeholders	Key stakeholders may include individuals representing both DEN and the customer who have special expertise in certain areas essential to the project, such as fire, life safety, sustainability, airport security, finance, the FAA, and many more.
Periphery Stakeholder	Periphery stakeholders may include design consultants, construction subs, and customer representatives whose expertise is needed at critical points in the project.
Project Teams	Project team members are project dependent. It is essential to think critically about each project and determine who needs to be at the table at these various levels.

Table 8.1-4: Cx Terms provides a list of terms, abbreviations (abbr.) and definitions as they relate to this Cx Program.

Table 8.1-4: Cx Terms

Term	Abbr.	Definition
Basis of Design	BOD	A document that records concepts, calculations, decisions, and product selections used to meet the requirements of the Contract and to satisfy applicable regulatory requirements.
Building Envelope Commissioning	BECx	Quality-based process for evaluating the performance of a facility envelope to determine if a project is meeting the defined objectives, standards, and requirements of the owner.
Commissioning	Cx	The process of assuring that all systems and components of a project are designed, installed, tested, and operated according to the operational requirements of the airport.

Table 8.1-4: Cx Terms (Continued)

Term	Abbr.	Definition
Cx Plan	N/A	The formal document which defines the commissioning process for each project, including key stakeholders, activities, and milestones. A Cx plan shall be developed for each project.
DEN Contract Administrator	CA	The DEN PMO will provide a Contract Administrator to support the execution of all Cx tasks.
DEN Cx Program	N/A	A program within the DEN Systems Group, charged with the mission of providing commissioning services for DEN projects, as further described in this program definition.
DEN Cx Program Manager	Cx PGM	The individual responsible for the overall governance of the DEN Cx Program.
DEN Cx Agent	CxA	The individuals contracted by DEN for the purposes of providing Cx services for DEN projects and programs, or the DEN Systems Commissioning Engineer for in-house commissioning.
DEN Project Manager	PM	The individual responsible for the management and execution of the project being commissioned.
Existing Building Commissioning	EBCx	A systematic process for improving an existing building's performance by identifying and implementing relatively low- cost operational and maintenance improvements, helping to ensure that the building's performance meets owner expectations.
Monitoring Based Commissioning	MBCx	Integration of the components of permanent energy monitoring systems, real-time energy analysis, and ongoing commissioning. This provides the building operator a continual stream of information that helps identify operational issues as they occur to save energy consumption over the life of the building.
New Construction Commissioning	NCCx	A process that ensures that a new building operates initially as the owner intended and that building staff are prepared to operate and maintain its systems and equipment.
Ongoing Commissioning	N/A	This is an extension of NCCx and is a repetition of the functional performance testing and reporting procedures performed during the acceptance phase. The ongoing Cx may occur twice per year to coincide with summer and winter seasons.
Owner's Project Requirements	OPR	A written document that details the requirements of a project and the expectations of how it will function. These include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information. This will be in agreement with the DSMs and may be referred to as DEN's Project Requirements (DPR).
Pre-Functional Checklist	PFC	Checklist(s) executed by the contractor(s) to represent completion of system readiness for functional testing.
Project Management Office	PMO	The DEN Project Management Office defines and maintains standards for project management.

Table 8.1-4: Cx Terms (Continued)

Term	Abbr.	Definition
Subject Matter Expert	SME	Individuals with deep understanding of a discipline, subject or process, assigned to a project to assist the DEN Project Manager with reviews, scoping, problem-solving and decision-making.
TAB	TAB	Testing, adjusting and balancing.

8.1.9 Compliance Paths

There are a range of compliance pathways to achieve Envision and LEED certification. Relevant stakeholders must be engaged early to determine the most feasible path, while considering the project scope, budget and organizational priorities.

End of Chapter

Chapter 2 - Plan

8.2.0 Stakeholder Identification/Engagement

Refer to the ORAT Standards Manual for stakeholder engagement requirements.

For projects utilizing the Envision® framework, please refer to the Envision credit LD1.3 Provide for Stakeholder Involvement for specific guidance and requirements.

8.2.1 Project Charter

Review the applicable credits in the sustainability frameworks to determine the elements to incorporate in the project's charter.

8.2.1.1 Goals/OPR

During the pre-design phase, initial project parameters are being developed. The goal is to set the design intent and Owner Project Requirements (OPR) for the duration of the project. The design intent and OPR's may be developed through engagement of a Sustainability Consultant to conduct a pre-define charrette or other pre-define activities.

8.2.1.2 Energy and Utility Goals

During the pre-design phase, project energy and utilities goals are developed for use in the OPR for the duration of the project. Utilities rebates, energy efficiency, renewable energy, and utilities availability to the project are some of the goals and requirements to be considered.

8.2.1.3 LEED and Envision Credit Assessment

Complete a LEED® Checklist and Envision® Self-Assessment tool to determine the baseline for the project and identify potential gaps.

8.2.2 Sustainability Elements of DEN Projects

8.2.2.1 LCA

A listing of all major materials to be procured for the subject building or construction project should be developed and alternative choices should be identified. The choices should then be ranked based on lifecycle environmental impacts and economic cost. Recommendations should be developed for the optimum material selection to meet technical, environmental, and economic requirements for the project. Examples of such materials include concrete mixes, exterior cladding and roofing, floor coverings, and indoor furniture.

Life Cycle Assessment (LCA) encompasses the evaluation of the potential environmental impacts of a given product, process, or service over the course of its lifetime. Also known as life cycle analysis, eco-balance, cradle-to-grave and cradle-to-cradle analysis, LCA is a technique used to quantify the impacts from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling and reuse. LCA can be applied at the component, process, product, and system scale, including buildings.

DEN recognizes that construction projects create life cycle impacts on the environment by using materials, equipment, energy, and other resources. Therefore, DEN encourages Consultant Teams to incorporate LCA into the planning, design, and construction process with the objective of identifying and then minimizing or eliminating such impacts. This process can assist teams in making informed choices on the selection of a design element, a piece of equipment or construction practice.

8.2.2.2 LCCA

Life-Cycle Cost Analysis (LCCA) takes into account all costs of acquiring, owning, and disposing of infrastructure, building or building systems at DEN. The LCCA is conducted on the whole project to identify the total economic impacts of the project. The business case should include consideration of whether a Life-Cycle Cost Analysis should be completed at the Define Phase.

Refer to Mechanical DSM section for more detail.

8.2.2.3 Envision®

Envision was designed to help infrastructure stakeholders implement more sustainable, resilient, and equitable projects. Envision helps communities cut greenhouse gas (GHG) emissions, create good-paying “green” jobs, address environmental justice, and meet climate-change targets. Infrastructure owners and design teams, community and environmental groups, constructors, regulators, and policymakers can all benefit from using Envision. Download the Envision Brochure or more detailed Envision Packet for more information. Contact the DEN Project Manager or DEN Environmental to request the DEN Envision Resource library. See Envision link below:



[Envision](#)

8.2.2.4 LEED®

Under XO123, all new, DEN-funded building and major building renovation projects over 5,000 square feet are required to achieve a minimum of LEED® Gold certification. Projects under the 5,000 square foot threshold are expected to meet the intent of LEED Gold level but will not be required to pursue formal certification.

8.2.2.5 Project Location

Select locations of the project components to minimize or avoid environmental impacts and maximize efficiency.

8.2.3 Net Zero

CCD is developing guidance for Net Zero development. DEN will follow that guidance for future requirements. Contact DEN PM for guidance.

End of Chapter

Chapter 3 - Define

8.3.0 Stakeholder Engagement

8.3.0.1 Identify Stakeholders

The define phase begins before the designer and contractor are hired. This phase focuses on internal stakeholder engagement to further define the project goals, objectives, and budget. DEN project managers engage a team of stakeholders in the development of the project requirements, which helps to inform the design phase. The stakeholder requirements are outlined in an engagement strategy and/or plans.

8.3.0.1.1 Project Management Team

The DEN project manager will work with the DEN project sponsor, design team, DEC tactical planning, and sustainability to define the stakeholders that should be engaged in the project.

8.3.0.1.2 Envision® Professional

For infrastructure projects, a credentialed ENV SP preferably with airport experience shall be engaged to facilitate the Envision® process. Follow the requirements as outlined in the engagement strategy and/or plans or as defined by the Envision framework (see e.g., Envision credit LD1.3).

8.3.0.1.3 LEED® Professional

For building projects, a credentialed LEED® AP professional shall be engaged to facilitate the LEED® process.

8.3.0.1.4 Commissioning Agent

For building projects, a Commissioning Agent (CxA) is engaged not only as a technical advisor but as an Owners Representative through the define, design, build, and closeout process.

8.3.1 LEED®

8.3.1.1 General

LEED is a widely accepted standard for high performance sustainable buildings that has been vetted and implemented on a global scale. However, it is understood that some LEED criteria are impractical or impossible to implement on certain projects at DEN. For this reason, only certain criteria are required for all projects with all other criteria being left optional. The minimum required criteria were based on lessons learned from previous LEED projects and existing best management practices in place at the airport.

Project managers, designers, and contractors are expected to refer to the current LEED Reference Guide for specific definitions and instructions on compliance and documentation for each of the project criteria. Projects will continue to be required to comply with all local, state, and federal code requirements.

The current version applicable at DEN is LEED v4 for BD-C: New Construction and Major Renovation. The Gold Certification requires 60-79 points.

8.3.1.2 Goals

Development of Owner's Project Requirements (OPR). The OPR includes evaluation of required and optional goals along with the LCA/LCCA for the project.

8.3.1.3 Project Requirements

See [Table 8.3-1: Project Requirements for New Construction and Major Renovations](#) which provides Required (R) and Optional (O) requirements.

Table> 8.3-1: Project Requirements for New Construction and Major Renovations

		New Construction	Major Renovation	Equivalent LEED Points
Credit	Integrative Process	R	R	L
Location and Transportation				
Credit	LEED for Neighborhood Development Location	O	O	16
Credit	Sensitive Land Protection	O	O	1
Credit	High Priority Site	O	O	2
Credit	Surrounding Density and Diverse Uses	O	O	5
Credit	Access to Quality Transit	O	O	5
Credit	Bicycle Facilities	O	O	1
Credit	Reduced Parking Footprint	O	O	1
Credit	Green Vehicles	O	O	1
Sustainable Sites				
Prereq	Construction Activity Pollution Prevention	R	R	req
Credit	Site Assessment	R	R	1
Credit	Site Development - Protect or Restore Habitat	O	O	2
Credit	Open Space	O	O	1
Credit	Rainwater Management	O	O	3
Credit	Heat Island Reduction	R	R	2
Credit	Light Pollution Reduction	R	R	1
Water Efficiency				
Prereq	Outdoor Water Use Reduction	R	R - at least 50%	req
Prereq	Indoor Water Use Reduction	R	R	req
Prereq	Building-Level Water Metering	R	R	req
Credit	Outdoor Water Use Reduction	R	R	2
Credit	Indoor Water Use Reduction	R	R - at least 40%	4-6
Credit	Cooling Tower Water Use	O	O	2

Table> 8.3-1: Project Requirements for New Construction and Major Renovations (Continued)

		New Construction	Major Renovation	Equivalent LEED Points
Credit	Water Metering	R	R	1
Energy and Atmosphere				
Prereq	Fundamental Commissioning and Verification	R	R	req
Prereq	Minimum Energy Performance	R	R	req
Prereq	Building-Level Energy Metering	R	R	req
Prereq	Fundamental Refrigerant Management	R	R	req
Credit	Enhanced Commissioning	R	R	6
Credit	Optimize Energy Performance	R - at least 32%	R - at least 32%	13-18
Credit	Advanced Energy Metering	R	R	1
Credit	Demand Response	O	O	2
Credit	Renewable Energy Production	O	O	3
Credit	Enhanced Refrigerant Management	R	R	1
Credit	Green Power and Carbon Offsets	O	O	2
Materials and Resources				
Prereq	Storage and Collection of Recyclables	R	R	req
Prereq	Construction and Demolition Waste Management Planning	R	R	req
Credit	Building Life-Cycle Impact Reduction	O	O	5
Credit	Building Product Disclosure and Optimization - Environmental Product Declarations	O	O	2
Credit	Building Product Disclosure and Optimization - Sourcing of Raw Materials	O	O	2
Credit	Building Product Disclosure and Optimization - Material Ingredients	O	O	2
Credit	Construction and Demolition Waste Management	R - at least 75%	R - at least 75%	2
Indoor Environmental Quality				

Table> 8.3-1: Project Requirements for New Construction and Major Renovations (Continued)

		New Construction	Major Renovation	Equivalent LEED Points
Prereq	Minimum Indoor Air Quality Performance	R	R	req
Prereq	Environmental Tobacco Smoke Control	R	R	req
Credit	Enhanced Indoor Air Quality Strategies	O	O	2
Credit	Low-Emitting Materials	R	R	3
Credit	Construction Indoor Air Quality Management Plan	R	R	1
Credit	Indoor Air Quality Assessment	O	O	2
Credit	Thermal Comfort	O	O	1
Credit	Interior Lighting	R	R	2
Credit	Daylight	R	O	3
Credit	Quality Views	O	O	1
Credit	Acoustic Performance	O	O	1
Innovation				
Credit	Innovation	O	O	
Credit	LEED Accredited Professional	R	R	
Regional Priority				
Credit	Regional Priority: Specific Credit	R	O	
Credit	Regional Priority: Specific Credit	R	O	
Credit	Regional Priority: Specific Credit	O	O	
Credit	Regional Priority: Specific Credit	O	O	

8.3.2 High-Performance Design Requirements

8.3.2.1 Design Assessment

Designer shall assess the project according to the following procedure:

- A. Design at least two conceptual options, layouts, equipment procedures or design solutions.
- B. Calculate the rough order of magnitude total cost of ownership for all project components, including equipment, operation and maintenance, carbon emissions, and end-of-life deconstruction.
- C. Quantify climate impact of options, including constructability, equipment, and operation and maintenance activities.

- D. Quantify alternatives for building materials with lower impacts, and document the impacts of end-of-life deconstruction/deconstructability.
- E. Select the final design based on conceptual options, and Design-in-a-day priorities.

8.3.2.2 Siting and Orientation

The building should be sited and oriented to support passive energy savings strategies and the use of on-site renewable energy. Reduce solar heat gain to the occupied spaces in the summer and maximize solar thermal heating in southern occupied spaces in the winter. The final design solution should use orientation, shading and glazing types to support the desired energy flows in the building. All buildings and roofs should be designed to be solar ready.

8.3.2.3 Energy Modeling

Building projects in excess of 5,000 square feet and/or where required by the DEN Mechanical Engineer shall have a computer energy model (the Energy Analysis) performed to establish baseline and design energy performance according to the methodology established in the most current version of ASHRAE Standard 90.1 or the CCD energy code requirements, whichever is more stringent.

8.3.2.3.1 Simulation Elements

Energy Analyses shall simulate performance of all relevant building spaces, components, systems, and subsystems and shall produce aggregate building energy performance estimates for both peak demand and consumption of all sources of energy to the designed building (primary and secondary) for a full year. Energy Analyses shall also include economic analyses of energy costs based upon current DEN utility rates and rate structures, and account for expected future rate instability. Energy cost budgets shall be established and shall meet the requirements of ASHRAE 90.1. This standard allows tradeoffs between mechanical and electrical systems and the building envelope. These tradeoffs shall supersede specific requirements presented only with written approval by DEN Mechanical Engineer or Energy Manager.

8.3.2.3.2 Software

The consultant will develop design strategies for maximizing the project's energy efficiency. An energy model shall be used to evaluate the energy performance of building systems. The following software is acceptable. Select the correct tool to meet the project needs:

- A. EnergyPlus is the required platform for the Xcel Energy, Energy Design Assistance (EDA) rebate and incentive program. This is the required modeling platform unless otherwise approved by the DEN Mechanical Engineer.
- B. Trane TRACE
- C. eQUEST

8.3.2.3.3 Criteria

The Energy Analysis will meet the requirements detailed as follows:

- A. International Building Code, as adopted and amended by CCD
- B. International Energy Conservation Code, as adopted and amended by CCD
- C. ASHRAE 90.1 (latest version at time of NTP)
- D. LEED Requirements (latest version at time of NTP)

Where the requirements of this chapter or the Codes and Standards themselves deviate from one another, the more stringent of the two shall apply.

For the purposes of analysis associated with existing facility systems the following sections of the Mechanical DSM shall be used for historical reference of component performance:

- A. Existing Facility Design and Analysis Conditions
- B. Building Envelope Evaluations
- C. U Values
- D. Building Components
- E. Air Leakage – All Buildings
- F. HVAC Systems
- G. HVAC Equipment
- H. Insulation
- I. Plumbing Systems

8.3.2.4 Energy Performance Criteria

The designer should utilize industry resources to identify the Energy Use Intensity (EUI) target for each specific project. Utilize the resource and building type that best fits the project use. The EUI target should exceed any code or LEED requirements, as applicable, and be coordinated with the larger project stakeholder group. The final project target will need to be approved by the DEN Project Manager, Mechanical Engineer and Energy Manager.

The following resources may be useful in identification of an EUI target:

- A. ASHRAE Advanced Energy Design Guidelines (AEDG)
- B. Architecture 2030 Zero Tool (www.zerotool.org)
- C. Energy Star Portfolio Manager

8.3.2.5 Energy Efficiency

Energy efficiency is an important consideration in the design of the mechanical, electrical and plumbing systems for all DEN facilities.

8.3.2.6 Mechanical Equipment

Heating, ventilating, and air conditioning systems are to be designed to meet or exceed the requirements of the latest version of ASHRAE standard 90.1 - Energy Efficient Design of New Buildings except Low-Rise Residential Buildings, and the CCD building code. Projects seeking LEED certification must meet all requirements to achieve LEED Gold certification or higher as defined by CCD Executive Order 123. Heating, Ventilation, and Air Conditioning Systems are a major consumer of energy in buildings, in most cases, and contribute a significant portion of the building's footprint at DEN. Improved design of these systems with emphasis on outside air economizing for cooling purposes or energy recovery, and for controlling the temperature of conditioned air should be thoroughly evaluated at the design stage. Key issues include coordination of the HVAC design with the building envelope, insulation and glazing properties, connection to the Central Utility Plant or alternative sources of heating and cooling, and energy management systems.

System design should favor the use of electric devices or electrically driven prime movers. The reduction of natural gas in favor of electrical appliances is desired by DEN, and integration with renewable energy sources such as on-site photovoltaics is desired where feasible.

Refer to the Mechanical DSM for additional performance requirements for mechanical equipment.

8.3.2.7 Electrical Equipment

Lighting systems shall meet or exceed the power density requirements set forth in ASHRAE 90.1 and the International Energy Conservation Code, as applicable to the project. Electrical appliances shall be Energy Star rated.

Refer to the Electrical DSM for additional performance requirements for electrical equipment.

8.3.2.8 Water Efficiency

In addition to the minimum requirements under the sustainability certification frameworks applicable to each project, the design will also incorporate additional water efficiency measures as outlined in this manual.

8.3.2.9 Water Management Plan

Develop a water plan to evaluate the water and wastewater supply and demand of the project to understand and coordinate any synergistic opportunities to reduce and/or reuse water.

8.3.2.10 Water Metering

Install permanent water meters that measure the total potable water use for the building and associated grounds. Meter data must be compiled into monthly and annual summaries; meter readings can be manual or automated.

8.3.2.11 Indoor Water Use Reduction

Reduce indoor water use by 40% from baseline using low-flow fixtures and water efficient equipment. Follow the process outlined in the US Green Building Council's LEED guidance manual on how to achieve and document compliance.

8.3.2.12 Indoor Environmental Performance

Occupant comfort and health are priorities for DEN. All projects should take measures to ensure the highest level of indoor air quality during and after construction. This should be achieved by focusing on pollutant control by creating and following a construction indoor air quality management plan, specifying low emitting materials for finishes and furnishings, and using low VOC products.

8.3.2.13 Innovation

Project teams are encouraged to propose and pursue innovative solutions to create more sustainable outcomes on DEN projects. These solutions may include advances in technology or the incorporation of art to create a sense of place. Innovative solutions should be clearly described in project proposals and designs and include information on budget implications as well as costs and benefits over the life of the asset.

8.3.3 Commissioning

Commissioning at DEN generally consists of two categories of activities related to vertical construction: New Construction commissioning (NCCx) and Existing Building Commissioning (EBCx). Throughout the project lifecycle, the DEN Cx program reviews, observes, documents and tests systems to ensure that they meet the requirements of the airport. By implementing the commissioning process, DEN can be confident that project results align with operational and sustainability goals, and that DEN assets achieve and maintain consistently high levels of performance and efficiency.

The Commissioning Agent (CxA) shall be retained by DEN to execute commissioning (Cx) activities according to this DSM. In some cases, the General Contractor may be required to designate a Commissioning Coordinator to actively

participate in the planning and execution of Cx activities. All project stakeholders should be familiar with these requirements as they relate to their discipline and understand individual roles and responsibilities.

8.3.3.1 Commissioning Scope of Work

The commissioning scope of work will be developed by the DEN PM, using DEN standard on-call professional services forms and templates. The DEN Cx Program Manager will aid in determining the extent of commissioning scope for the project and shall make recommendations to the DEN PM based on the project scope to maximize the value of the commissioning process. See [Chapter 6-Commissioning Activities](#) for information on the desired DEN best practices that may be included in the scope of work for a given project. Refer to the project scope of work for direction on which activities are included in a particular project.

8.3.3.2 Milestones

Key project milestones will be identified and coordinated with the CxA, DEN PM, and the DEN Cx Program Manager at task kickoff. The milestones will be included in the Cx Plan.

8.3.3.3 NCCx

DEN's NCCx is a process to ensure that systems and equipment are designed, installed, functionally tested, and validated as capable of being operated and maintained according to the DEN's operational needs.

8.3.3.4 EBCx

DEN's EBCx consists of two distinct processes for investigating, analyzing, and optimizing an existing building's performance.

8.3.3.4.1 Retro Commissioning

Retro commissioning is a process similar to NCCx for existing buildings that never completed initial commissioning. It is usually triggered by a change in building use or occupancy, the onset of operational problems, or some other need.

8.3.3.4.2 Re-Commissioning

Similar to Retro-Commissioning, the Re-Commissioning process is applied to existing systems that were previously commissioned. The existing systems may need additional commissioning due to age or desire to enhance energy efficiency,

8.3.3.5 Reporting and Documentation

The project Cx deliverables shall be determined during project scoping. All deliverables shall be submitted in accordance with the DEN standard professional services submittal process.

8.3.3.6 Targeted Audits

By identifying and implementing relatively low-cost operational and maintenance improvements through targeted audits or assessments of building systems and controls, the CxA can help to ensure that the building's performance meets DEN's expectations on previously commissioned facilities or systems (re-commissioning).

8.3.4 Net Zero

8.3.4.1 Goals

Net Zero goals developed as part of the previous phases of the project life-cycle should be incorporated into deliverables as part of this phase.

End of Chapter

This page is intentionally blank.

Chapter 4 - Deliver

8.4.0 Stakeholder Engagement

Follow the requirements as outlined in the engagement strategy and/or plans.

The design phase consists of translating the project requirements into detailed plans and specifications that are incorporated into construction documents. These design documents can be developed in-house or by a consultant. The design phase is the ideal time to align the project with the airport's sustainability goals. The team should evaluate energy efficiency, indoor water efficiency, and outdoor environmental concerns, at a minimum.

8.4.0.1 Initial Project Concept Review Meeting

Through the Initial Project Concept Review meeting and design document reviews, the input from these stakeholders reveals how the project will impact other projects and systems. This is when the team identifies potential risks and opportunities and ensures that the projects stays in-line with its goals. Another key focus is ensuring that the design is maintainable and meets standard operating procedures. As design documents unfold, the team will have a clearer idea of the physical design. For example, using 3D modeling software, the team can see how systems and components overlap, which ideally supports catching oversights.

8.4.0.2 30/60/90 Design Review

Stakeholders should be engaged at 30/60/90 percent design reviews. Early engagement is imperative since it is easier and more cost effective to make changes earlier in the design. Project teams may also have to have page-turn meetings for key design features that impact varied stakeholders to ensure that all participants fully understand the design and its implications.

8.4.1 Envision®

The Envision Sustainability Professional (ENV SP) facilitates the inclusion of project updates and any additional credits discovered during the design. All applicable credits requirements must be incorporated into the design in order to meet the targeted level of achievement. Track credit requirements through construction in order to meet the targeted levels of achievement.

8.4.2 LEED®

Updates discovered from the define phase are updated in the OPR by the LEED® AP. Updates may need to define project submittals for the build phase that the construction phase will need to perform.

Track credit requirements through construction in order to meet the targeted levels of achievement.

8.4.3 Net Zero

Net Zero goals developed as part of the previous phases of the project life-cycle should be incorporated into the design deliverables as part of this phase.

The installation of Net Zero strategies defined in the design documents should be verified by the DOR and the CxA during construction.

End of Chapter

This page is intentionally blank.

Chapter 5 - Closeout

8.5.0 Stakeholder Engagement

Follow the requirements as outlined in the engagement strategy and/or plans.

8.5.1 Envision®

All applicable credit requirements must be incorporated into the closeout phase in order to meet the targeted levels of achievement.

The project team will complete and submit all required Envision templates and documentation through ISI if the project is pursuing Envision certification. Additional information, project support and appropriate contracts will be necessary to achieve third-party verification. Project teams should consider the best approach for continuing support in these areas to completion, including award. Any additional Envision® templates and project support will continue as necessary to achieve third-party verification. Acceptance will be complete upon receipt of final certification.

8.5.2 LEED®

All applicable credits shall be verified to meet the targeted levels of achievement.

The project team will complete and submit all required LEED® documentation for both the design and construction credits to receive the final certification. Any additional LEED templates and project support will continue as necessary to achieve required third-party verification. Acceptance will be complete upon receipt of accreditation.

8.5.3 Net Zero

The functionality of Net Zero strategies installed during the construction stage should be verified and documented by the DOR and the CxA during functional testing as part of this stage prior to asset handover. Also, the outcome of Net Zero system operation should be verified by the DOR and the CxA through any measurement & verification or MBCx protocols defined with the original goals of the project.

End of Chapter

This page is intentionally blank.

Chapter 6 - Commissioning Activities

8.6.0 Pre-Design

8.6.0.1 Owner's Project Requirements

The OPR shall be developed for each specific project per the DSM by the DEN PM with assistance from the CxA. Assistance may include facilitating an OPR workshop or drafting the OPR. The DEN PM shall identify the Project Sponsor and the appropriate stakeholders and include them in the OPR development.

8.6.0.2 Commissioning Plan (Cx Plan)

The Cx Plan shall be developed by the CxA and submitted to the DEN PM and DEN Cx Program Manager for review and approval using DEN standard professional services submittal procedures. The DEN SMEs shall be included in the review process.

Upon review, the DEN PM may direct the CxA to revise and resubmit the Cx Plan to incorporate any comments. The CxA shall revise and resubmit the Cx Plan as needed until it is accepted by the DEN PM. The approved Cx Plan shall be posted to the DEN Common Data Environment (CDE) or another platform approved by the DEN PM.

The standard Cx plan will include a design and construction phase for the project. The Cx Plan should at a minimum contain the following items per the IECC and will likely include more content to meet the expectations for LEED:

- A. A narrative description of the activities that will be accomplished during each phase of commissioning, including the personnel intended to accomplish each of the activities.
- B. A listing of the specific equipment, appliances, or systems to be tested and a description of the tests to be performed (assumptions should be made if specific information is not known at the time of the report).
- C. Functions to be tested including, but not limited to, calibrations and economizer controls.
- D. Conditions under which the test will be performed. Testing shall affirm winter and summer design conditions and full outside air conditions.
- E. Measurable criteria for performance.
- F. Commissioning Schedule (based on Owner or Contractor provided schedule)

For large projects, it may be necessary to develop separate Cx Plans for the design and construction phase of the project, or to develop separate plans for other phases of work as deemed necessary by the DEN PM. The construction phase Cx Plan shall be updated after the completion of construction documents.

8.6.1 Deliver – Design Stage

8.6.1.1 Review Basis of Design

The BOD is represented by the DEN DSMs and the Designer of Record (DOR) Design Analysis Report (DAR). The CxA reviews the OPR and BOD documents to ensure that the BOD reflects the desired outcomes represented in the OPR.

8.6.1.2 Design Reviews

The CxA shall perform design reviews based on milestones defined by the DEN PM. The design packages will be reviewed with respect to completeness in all areas relating to the commissioning process and to confirm compliance with the OPR and DSM. The CxA shall identify any design-related issues that may hinder the commissioning of systems, such as access restrictions, missing test ports, missing devices, etc. The CxA will be expected to back check their previous design review comments at each subsequent design review. The CxA shall attend design review comment resolution meetings as needed for each design package review.

8.6.1.3 Commissioning Meetings – Design

Regular meetings will be held with the DEN Cx Program Manager and CXAs, to maintain consistent application and interaction for commissioning services across multiple contracts and projects.

A project-specific kickoff meeting should be conducted by the CxA to introduce the Cx team to the project team and review the preliminary Cx Plan. The CxA may need to resubmit the Cx Plan with updates based on the kickoff meeting.

Additional project-specific commissioning meetings will be as defined in the scope of work for the project. The CxA will provide recommendations for meeting frequency and agenda, subject to review by the DEN PM. The general recommendation is bi-weekly meetings during design and weekly meetings during construction.

8.6.1.4 Integration Meetings

Additional meetings may be required for integration of controls, MBCx, envelope Cx, etc. and will be coordinated with the DEN PM. These meetings should be conducted by the design team and attended by the CxA.

8.6.1.5 Commissioning Specifications

The CxA will develop commissioning requirements and incorporate them into the construction documents (i.e. specifications). The CxA develops a comprehensive commissioning specification based on the DEN standard specifications and works with the DOR to incorporate into the construction documents.

8.6.1.6 Provide IECC Cx Permit Letter

For compliance with CCD IECC requirements, submit a letter to the electrical or mechanical/plumbing reviewer as part of the permit submission. The letter is drafted by the CxA and executed by DEN. The letter documents the CxA assigned to the project and represents the qualifications required by the code.

Confirm that the letter is required with the specific DEN Project Manager.

8.6.1.7 Develop Systems Manual Scope and Format

The systems manual contains all of the information necessary to operate, maintain, and recommission energy-consuming systems within the project. The systems manual should include, at a minimum, the following to satisfy both IECC and LEED requirements:

- A. Executive summary
- B. Owner's project requirements
- C. Basis of Design
- D. System single-line diagrams
- E. Construction record documents and specifications

- F. Final accepted submittals
- G. Equipment operations and maintenance manuals (O and Ms)
- H. System balancing reports
- I. Final commissioning report

8.6.1.8 Develop Training Requirements

The CxA should confirm the development of training requirements in coordination with the DEN PM.

8.6.1.9 Develop Monitoring Based Commissioning (MBCx) Plan

The CxA will incorporate MBCx requirements and activities into the preliminary Cx Plan previously developed. The DEN PM will work with the DEN Cx Program Manager to determine if MBCx will be part of the project scope. This may be required by LEED depending on the credits pursued by the project.

8.6.2 Deliver - Construction Stage

8.6.2.1 Update Construction-Phase Cx Plan

The CxA will update the Cx Plan to reflect any design changes and update/add any team members that may have occurred during the design phase. If the Cx Plan was not previously developed the CxA shall develop a construction commissioning plan. This document shall outline the commissioning process throughout the construction phase. Include the following for the construction phase:

- A. General project information and overview
- B. Commissioning goals and objectives
- C. Commissioning team information
- D. Construction team information
- E. Roles and responsibilities during construction
- F. Commissioning scope
- G. Commissioning process
 - 1. Meetings
 - 2. Site observation
 - 3. Documentation
 - 4. Pre-functional checklists, tests, and startup
 - 5. Functional testing and verification
 - 6. Owner training
 - 7. O&M manuals & warranties
- H. Commissioning schedule (based on Contractor provided schedule)
- I. Site specific safety plan

The update Cx Plan shall be posted to the DEN CDE or another platform approved by the DEN PM. Components of the Cx Plan shall be implemented through the DEN CDE or the approved platform as it relates to Cx process activities and the associated Cx milestone schedule.

8.6.2.2 Coordinate Cx Activities (Scheduling)

The CxA will work with the contractor to integrate the Cx activities into the master construction schedule as well as the 3-week lookahead schedule. This may include participation in pull planning sessions if that effort is conducted by the GC.

8.6.2.3 Commissioning Meetings – Construction

The CxA is responsible for setting up and facilitating recurring Cx meetings to coordinate construction activities. The CxA will work with the DEN PM to define the frequency of meetings. There should be a construction phase Cx kickoff meeting prior to the start of major construction activities. Meetings should be weekly once commissioned systems are being installed.

8.6.2.4 Review Submittals

The CxA reviews submittals of commissioned systems concurrently with the design team to ensure ongoing compliance with the OPR, BOD and Cx requirements. The CxA review comments should be documented and addressed. Submittal(s) may include but not be limited to:

- A. HVAC sequences of operation
- B. Lighting control sequences
- C. Controls, controls graphics and programming

8.6.2.5 Develop Construction Checklists

The DEN CDE shall be used for this activity unless another platform is approved by the DEN PM.

The CxA prepares construction checklists (also known as pre-functional checklists (PFCs) or installation verification checklists (IVCs)). The checklists should be prepared utilizing the approved submittals and be specific to the installed systems. The checklist is intended to verify that each piece of equipment has been installed, started up, programmed, tested, and balanced, and that functional testing is ready to proceed. PFCs should be provided to the contractor prior to beginning installation to ensure they are completed by the installing contractor.

Note that the PFCs do not take the place of manufacturer's start-up procedures and documentation.

8.6.2.6 Prepare Functional Performance Tests (FPTs)

The DEN CDE shall be used for this activity unless another platform is approved by the DEN PM.

The functional test procedures are developed by the CxA after the submittal review process for commissioned systems is complete (especially the controls and sequence of operations). The FPTs are provided to the contractors and design team for the opportunity to review, verify proper operating modes, and comment on any desired modifications. FPTs should identify parties responsible for carrying out each activity.

8.6.2.7 Identify and Track Issues

The DEN CDE shall be used for this activity unless another platform is approved by the DEN PM.

The CxA will track any deficiencies discovered throughout construction, acceptance, and occupancy/operation phases. The issues will be shared with the design and construction team through a collaborative platform that identifies the responsible party for corrective action. The CxA will work with the DEN PM to verify resolution of all issues.

8.6.2.8 Conduct Site Visits and Issue Site Observation Reports

The DEN CDE shall be used for this activity unless another platform is approved by the DEN PM.

The CxA will conduct regularly scheduled site visits to verify completion of PFCs and review systems installations. Field observation reports will be issued to document observations and issues will be added as needed. When properly executed this effort may identify and prevent early systemic installation issues that will reduce rework by the contractors. The task required quantity of site observation reports will be coordinated with the DEN PM and the reports will be submitted in the DEN PMIS. The site observation reports will be included in the final Cx Report, which is also submitted in DEN PMIS. The following activities would be expected to be included, at a minimum:

- A. Witness sub-contractor pre-testing
- B. Verify/witness point verification testing
- C. Witness equipment startup

8.6.2.9 Review Requests for Information

The CxA will review and provide responses to Requests for Information (RFIs) pertaining to commissioning activities, documentation, and processes. Additional RFIs may be provided to the CxA throughout construction for informational purposes.

8.6.2.10 Coordination and Shop Drawing Review

The CxA will review and comment on the contractor's coordination and shop drawings for conformance with the commissioning plan.

8.6.2.11 Monitoring-Based Commissioning (MBCx) Implementation & Coordination

Per the LEED v4 Enhanced Credit requirements, the CxA will develop monitoring-based commissioning procedures and identify points to be measured and evaluated to assess performance of energy and water consuming systems. Procedures and measurement points will be included in the MBCx section of the Cx Plan.

Currently DEN utilizes an instance of SkySpark as the Energy Management Information System (EMIS) platform for the implementation of MBCx. The DEN MBCx process and requirements are continuously evolving and should be coordinated for each project.

See [Chapter 7- Monitoring-Based Commissioning \(MBCx\)](#) for implementation standards.

8.6.2.12 Integrate SkySpark Points

In lieu of full Monitoring Based Commissioning, all new control points shall be integrated into the DEN SkySpark platform per Chapter 7, Section 7.3 of this DSM. The extent of the referenced activities will be by direction of the DEN PM.

8.6.3 Deliver – Asset Handover Stage

8.6.3.1 Commissioning Meetings – Acceptance

The CxA is responsible for setting up and facilitating recurring Cx meetings to coordinate acceptance phase activities. The CxA will work with the DEN PM to define the frequency of meetings. There should be an acceptance

phase Cx kickoff meeting prior to the start of major acceptance phase activities. Meetings should be weekly once commissioned systems are being installed.

8.6.3.2 Verify Pre-Functional Checklists (PFCs) and Point Verification Tests (PVTs)

The CxA will collect and review the PFCs and PVTs documentation and checks for completeness. Any review comments are recorded as issues and provided to the construction and design team for resolution.

8.6.3.3 Review Completed Start-Up and TAB Reports

The CxA will collect and review the start-up and TAB reporting documentation to confirm readiness of systems for functional testing. Any review comments are recorded as issues and provided to the construction and design team for resolution. The CxA may be asked to perform a sampling of the TAB work to provide on-site verification.

8.6.3.4 Execute Functional Performance Tests

The DEN CDE shall be used for the activity unless another platform is approved by the DEN PM.

The CxA will perform (direct and witness) on-site functional testing of all systems to be commissioned in accordance with the FPTs. The executed functional test reports signed by the CxA will be submitted in DEN PMIS and included in the final Cx Report, which is also submitted to DEN PMIS. The documentation will include the following as appropriate for each piece of equipment:

- A. Basic information (Project name, building, system, equipment ID)
- B. System description
- C. Operational assumptions
- D. Listing of test participants
- E. Listing of test status for each test
- F. System readiness checklist summary
- G. Required testing supplies
- H. Required trend data
- I. Parameters and set points
- J. Functional performance test data and checklist
- K. CxA Signature Line (Sign-Off)
- L. Reference information (as appropriate)

Retesting will be conducted based on sampling rate and failure percentage.

8.6.3.5 Review Operation & Maintenance Manuals

The CxA will conduct a summary review of the operation and maintenance (O&M) manuals for compliance with the project specifications. Any comments are recorded as issues and provided to the construction and design team for resolution.

8.6.3.6 Verify Completion of Training

The CxA will confirm the training program has been completed according to the owner's requirements. The contractor develops, schedules, and conducts the training. The CxA reviews the training agenda and attendance

documentation, and attends a portion of the training sessions per the owner's requirements as directed by the DEN PM.

8.6.3.7 Complete IECC Cx Compliant Checklist

Per IECC, all preliminary commissioning reports must include the commissioning compliance checklist as required by the IECC. Refer to the current version of the City & County of Denver Submittal Requirements for the IECC Commercial Provisions for the checklist.

8.6.3.8 Prepare Preliminary Cx Report

The CxA will prepare a preliminary Cx report after installation inspections and FPT verification, but before final City inspection (per IECC requirements). The preliminary report will detail all commissioning activities carried out during the project and include at a minimum:

- A. Describe all activities performed during pre-design, design, construction, and closeout.
- B. Include projected activities related to ongoing commissioning and seasonal testing of systems included in the project.
- C. Provide any recommendations for future projects which could improve the commissioning process.
- D. IECC Commissioning Compliance Checklist.

8.6.3.9 Compile Systems Manual

The CxA will compile the documents defined in the systems manual scope and format developed during the design phase.

8.6.3.10 Compile Current Facility Requirements and O&M Plan

The CxA will prepare and maintain the CFR and O&M Plan through the completion of the closeout phase. These documents contain the information necessary to operate the building efficiently. Specific information included within the CFR and O&M Plan include sequence of operations, building occupancy schedule, equipment run-time schedule, setpoints for all HVAC equipment, lighting levels throughout the building, minimum outside air requirements, systems narratives, a preventative maintenance plan, and periodic commission requirements.

8.6.3.11 Deliver Post Construction Documents

The CxA will complete and deliver the necessary operating documents and reports to DEN before building occupancy but no later than 90 days of the date of receipt of the certificate of occupancy for IECC compliance. The final package must include the following:

- A. Up-to-date systems manual.
- B. Documentation of operator training.
- C. Complete functional performance test reports.
- D. Up-to-date issues log detailing closed and open issues.
- E. Updated Cx Plan that outlines commissioning completed to date, plan for seasonal testing, plan for 10-month operational/warranty review, and plan for addressing open issues identified after the initial round of commissioning.
- F. For FAA projects, equipment commissioning documents are required as a condition of final payment. See Section 90-11.I of the Standard Specifications for Construction of Airports AC no. 150/5370-10.

8.6.3.12 LEED Submissions

The CxA will complete and submit all required LEED® templates and documentation through LEED® Online if the project is pursuing LEED accreditation.

8.6.4 Closeout Phase

8.6.4.1 Review As-Built Drawings

The CxA will review the as-built drawings received from the contractor. As-built drawings include redline mark-ups, electronic construction models, Revit models, etc. See the Digital Facilities and Infrastructure DSM for DEN as-built model development process.

8.6.4.2 Troubleshooting/Optimization

The CxA will execute a certain number of hours troubleshooting systems as defined by the DEN PM and identify any optimization opportunities.

8.6.4.3 Develop Ongoing Cx Plan

The CxA will develop and issue an ongoing Cx plan before or as part of the 10-month warranty review. The plan should provide the building's operating staff with procedures, blank test scripts, and a schedule for ongoing Cx activities.

8.6.4.4 Finalize Cx Report

The CxA will update the preliminary Cx report issued during the acceptance phase to document additional activities and findings during the occupancy and operations phase. The final report will detail all commissioning activities carried out during the project and will include at a minimum:

- A. Description of all activities performed during pre-design, design, construction, and closeout.
- B. Include projected activities related to ongoing commissioning and seasonal testing of systems included in the project.
- C. Provide any recommendations for future projects which could improve the commissioning process.

The provider should issue the final Cx Report within 30 days of the substantial completion of the total project.

8.6.4.5 Execute Seasonal Testing

The CxA will perform seasonal testing on systems that require testing of loading, staging, and capacities that were not completed during the initial functional testing. The results of seasonal testing and the issues identified must be included in the final commissioning report.

8.6.4.6 Update/Resolve Cx Issues Log

The CxA will continually update and support resolution of issues. Effort should be made to have all issues resolved prior to the 10-month warranty review.

8.6.4.7 Conduct MBCx Quarterly Checks

The CxA will conduct quarterly reviews of metering and trend logs defined in the MBCx Plan. This should also include verification of any alerts that the operator should receive when equipment, systems and the building are not performing to energy expectations. Any issues will be logged in the approved Cx platform.

Submit Quarterly Check-In Reports in DEN PMIS.

8.6.4.8 Conduct Operations and Warranty Review

The CxA will participate in 10-month operations and warranty walkthrough, to ensure that all equipment associated with systems to be commissioned is operating properly. A 22-month operations and warranty walkthrough may be required and should be confirmed by the DEN PM when developing the scope of services.

- A. Not less than four weeks prior to scheduled warranty walkthrough, provide a checklist to the DEN PM for review. The checklist will include any outstanding issues from the (DEN approved Cx platform) that should be checked during the walkthrough.
- B. Checklist will include a section for each individual piece of equipment, expected attendees and responsibilities, and field or checkboxes for each individual inspection procedure or measurement as directed by the DEN PM.
- C. Provide copies of the checklist on-site during the warranty walkthrough for use in inspecting the equipment.

End of Chapter

This page is intentionally blank.

Chapter 7 - Monitoring-Based Commissioning (MBCx)

8.7.0 MBCx Goals and Objectives

- A. Ensure consistent SkySpark deployment across the airport owned and managed by DEN for the long term.
- B. Shift to Design, Engineering, and Construction (DEC) after project turnover completion.
- C. DEC SMEs will provide support to project management during warranty.

8.7.1 MBCx System Description

8.7.1.1 IT and SkySpark Configuration

- A. SkySpark is installed on a DEN virtual machine on the DEN network.
- B. Remote access is through Citrix.
- C. DEN will manage SkySpark user access.
- D. Each Site will use SkySparkConnectors to integrate data on the same network:
 - 1. SQL

Though SkySpark supports multiple connector types, DEN only links its instance of SkySpark to SQL databases. DEN has found that connecting directly to equipment controllers results in bottlenecks when not set up correctly, resulting in slow speeds and crashing for both SkySpark and the connected equipment controllers.

8.7.2 Planning

8.7.2.1 Design Coordination and Reviews

Review design documents to confirm monitoring points, sequences for rules, and integration of systems such as lighting controls.

8.7.2.2 MBCx Plan

- A. Confirm planned equipment for monitoring.
- B. Determine the points to include MBCx.
- C. Review available SkySpark points with DEN.
- D. Plan for the purchase of additional points as needed.

DEN purchases points from vendors in 50,000 point blocks. SkyFoundry recommends adding additional servers for each 50,000 points. If a project is expected to require additional points, the vendor shall work with DEN to purchase additional points, as well as services to set up another SkySpark server.

8.7.2.3 Contractor Coordination

- A. Coordinate with the controls contractor to request and confirm trend setup.
- B. Coordinate integration details such as the server for the trend storage or BACnet controller information.

8.7.2.4 User Access Setup

Remote access through Citrix:

- A. Set up DEN/Citrix account by submitting User Agreement and Cyber Security forms to access DEN's network and SkySpark project.
- B. Send Access request list to DEC and DEN BT.
- C. Citrix Login: Log in using your DEN credentials and multi-factor authentication (MFA) token received by text or other means.



[Citrix](#)

- D. SkySpark Application: From the Citrix home page, double-click the "SkySpark Web Client" Google Chrome icon to open the SkySpark homepage at skyspark/user/login in a new tab. Access to SkySpark requires a username and password.

Note: Once logged in, the URL will show as skyspark/ui/denverIntAirport.

- E. BAS link also available on the Citrix homepage. Login credentials are the same as FlyDenver.

SkySpark user access:

- A. DEN will set up users and manually email passwords.
- B. Reset password on first use.
- C. Include email tag (external access not set up at this time).
External access not available due to security restrictions.
- D. Include custom tag for companies.
- E. Teams may request the inclusion of a funAccessFilter to limit accessible code to code with the respective team's tag.
- F. User template available through Prototype.

8.7.3 Acceptance – Integration and Initial Commissioning

More detailed examples of the descriptions below (i.e. rules, dashboards, etc) are available to implementers upon request.

8.7.3.1 Project/Site Setup

- A. All DEN work will be consolidated under one combined SkySpark "Project" to provide a unified access point for the airport operations team.
- B. "Sites" will be configured within the overall Project, representing specific areas of the airport such as concourses, the terminal, and central plant.
- C. Each provider will focus on the area and equipment they are responsible for configuring.

8.7.3.2 Equipment Setup and Naming

- A. Equipment will be organized by Concourse, Floor, and Module.
- B. SkySpark point will include these elements in the display name (e.g. CCB 04 08W AHU_B displays with each point on this AHU).

8.7.3.3 Points and Tagging

- A. SkySpark Point names will generally follow EMCS names based on DEN standards. Teams can provide feedback if EMCS names don't follow standards.
- B. Tagging will follow consistent Haystack 4 standards, and the names will facilitate automated tagging.
Note: Haystack 4 requires equips to be tagged with the equip point. Points for these equips shall not be tagged with the equip point.
- C. Integrated equipment will be tagged with a key-value tag designating the provider (e.g. team: "CompanyXYZ"). This allows each team's rules and dashboards to only apply to the equipment they are responsible for integrating.
- D. DEN tagging standards will be developed for points and equipment types not covered by Haystack.
- E. Code Repository
- F. Each point and equip brought into SkySpark by a SkySpark vendor shall include the vendor's tag.
- G. Code will be tagged with a marker tag referencing the team name (e.g. "CompanyXYZ"). The funAccessFilter on each User will reference the team name.

8.7.3.4 Rules

- A. MBCx provider will deploy rules to automatically detect issues and opportunities for the monitored equipment.
- B. Rules may be deployed as pods and can be applied to specific equipment in an area of work or across similar types of equipment.
- C. Rules and applications will be separate for each provider.
- D. Rules will be tagged with a key-value tag designating the provider (e.g., team: "CompanyXYZ"). This ensures that each team's rules and dashboards only apply to the equipment they integrated.
- E. Ensure the ruleOn filter is targeting the equipment the rule is meant for, and that the filter is specific enough that it won't unnecessarily grow over time as more points are imported into SkySpark•E.g., tag equipment such as AHUs and VAVs with the "equip" marker but do not tag points belonging to those pieces of equipment with the respective equipment tag (ie "vav" or "ahu").
- F. Set a proper startDate for the rule. Using earlier than needed start dates unnecessarily uses system memory. The default startDate for SkySpark is 90 days; however, consider limiting rule startDates to shorter than that for rules that don't require as much history. Limiting the startDate has a big impact on SkySpark system performance.
- G. SkySpark vendors shall perform QC to ensure their rules execute efficiently. Rule QC shall include, but not be limited to:
 - In Rule: Debug use the callAvgDur column to find rules that take a lot of time to compute
 - In Rule: Debug use the targets column to see how many targets a rule has. This is a good way to determine if rules targets are properly defined, and if points are tagged correctly.

8.7.3.5 Dashboards

- A. Energy dashboards will be configured to monitor the whole building and energy end-uses where applicable. This may include:
 1. Site/meter energy monitoring dashboard to display monthly and annual energy data, costs, EUIs, etc.
 2. Campus-wide energy dashboard to compare energy use across Sites and identify changes.
 3. Energy end-use dashboard to evaluate the breakdown of energy for major loads (greater than 10% of annual energy use).

- B. Operator dashboard will provide equipment operating details and key metrics. Heat maps can visually display data over time. Each integration team will create their own dashboards.

8.7.3.6 Key Performance Indicator (KPIs)

- A. KPIs can be configured at the meter level and/or the equipment level and may include energy use/costs, energy/cost intensities, and equipment-level metrics.
- B. KPIs will be tagged with a key-value tag designating the provider (e.g. team: "CompanyXYZ"). This ensures that each team's rules and dashboards only apply to the equipment they integrated.

8.7.3.7 Automated Tests and TAB Verification

- A. SkySpark will monitor real-time equipment operation to verify the sequence of operations.
- B. Issues found through SkySpark will be added to the construction commissioning issues log.
- C. Automated scripts can be used to drive the operation of devices, and SkySpark can identify issues from the automated test.

8.7.3.8 Contractor Coordination for Issue Resolution

- A. The construction team will generate MBCx or SkySpark issues in the construction commissioning issues log and the construction team will respond accordingly.

8.7.4 Ongoing Monitoring and Maintenance

8.7.4.1 Ongoing Issues Tracking Process

DEN currently has various methods of ongoing issue tracking processes. CxA should coordinate with the DEN PM and DEN SkySpark Super User to verify what is best for their project.

8.7.4.2 Issue Resolution Mapping, Roles, and Responsibilities

Coordinate with DEN PM for issue resolution mapping, roles, and responsibilities.

8.7.4.3 Warranty Management Process

Issues identified by the Commissioning team that were turned over to the owner/GC for warranty review will be monitored over the first year of operation.

8.7.4.4 Quarterly Checkups

CxA shall provide quarterly checkups for two years after substantial completion of the project, unless otherwise specified in contract documents.

At a minimum, the Quarterly Checkup shall include any issues being currently tracked, new issues, seasonal testing reports, and recommendations for issue correction. Any additional issues identified shall be added according to the issue tracking process approved by the DEN PM.

8.7.4.5 Energy Monitoring/Measurement and Verification (M&V)

Section under development.

8.7.5 SkySpark Quality Control

8.7.5.1 Quality Control Submittals

The CxA shall develop, implement, and regularly utilize a document Quality Control Plan (QCP) for SkySpark implementation. The objective of the QCP is to ensure the project's SkySpark deployment is efficient and doesn't impact system performance. The Quality Control Plan may be submitted as an appendix to Quarterly MBCx reports. CxA shall include the following:

- A. Sample Equipment and Point Tagging - For each type of equipment in the project, include a sample tagging scheme for the equip and its points. Include a list of all tags to be applied to the points and equips, and indicate which tags do not conform with Haystack 4 standards. For each tag that does not conform with Haystack 4 standards, indicate why it is being included.
- B. Rules Tuning - after points have been brought into SkySpark and tagged, and rules have been written, the CxA shall tune the rules to ensure their performance. The CxA shall include a list of rules, and include the following information:
 - 1. Number of targets vs number of expected targets. If number of targets is substantially larger than the number of expected targets, the CxA shall identify what is causing the discrepancy, as well as what remedial steps will be taken to address the discrepancy.
 - 2. Number of targets in error. If the number of targets in error is larger than a quarter of the number of expected targets for the rule, the CxA shall identify what is causing the errors, as well as what remedial steps will be taken to address the discrepancy.
 - 3. Average computation time for rules.
- D. Job Tuning - the CxA shall include a list of all jobs deployed as part of the project, what functions they call to run, and how often they should run. Note: multiple CxAs may be working on DEN's deployment of SkySpark at any one time. Please ensure that all points are tagged correctly, and rules and functions are optimized. DEN has noted that the primary cause of excessively large rule targets and targets in error is improper tagging

End of Chapter

This page is intentionally blank.