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SECTION 1 – GENERAL INFORMATION

1.1.0 PURPOSE

This manual establishes basic criteria to be used in the design of the Regional Transportation District's (RTD) Light Rail Transit (LRT) system. In addition, drafting standards, directive or sample drawings and management procedures have been prepared to standardize and guide the design activities and the preparation of contract documents. See separate design criteria for Commuter Rail.

Design is to be directed toward minimum feasible costs for design, construction, capital facilities and operation; minimum energy consumption and minimum disruption of local businesses and communities. It should be consistent with system reliability, passenger comfort, mode of operation, type of light rail vehicle (LRV) to be used and maintenance. Safety for passengers, workers and the public is of primary importance.

1.2.0 SCOPE

The Design Criteria will take precedence over all other standards referred to herein except those fixed by legislation.

Specific attention should be given to the Americans with Disabilities Act (ADA), the ADA Accessibility Guidelines for Building and Facilities (ADAAG), the ADA Accessibility Guidelines for Transportation Vehicles and to any succeeding modifications that may be issued. The applicability of those documents is noted in several sections of this manual where it appears to be particularly appropriate. However, the regulations must be adhered to in all areas, whether or not mentioned herein.

The Design Criteria in this manual relates to the following elements of the LRT systems:

- Civil and Structural Engineering
- Track Geometry and Trackwork
- Utilities
- Landscaping
- Stations
- Operations Facility
- Traction Electrification System
- Signal System
- Communications and Central Control
- Stray Current/Corrosion Control
- Fare Collection Equipment
- Light Rail Vehicles
- System Safety

1.3.0 PROCEDURES

Design Engineers shall prepare drawings and technical specifications for each contract of the project in accordance with their design contract (if applicable) and the following RTD documents:

- Design Criteria Manuals
- CADD Standards
- Contract Requirements
- All other applicable requirements including codes, regulatory standards and environmental impact statements

Deviations may be made within the framework of the Design Criteria to meet the requirements of a particular problem. However, any deviation, discrepancy or unusual solution must be approved by RTD before it can be included in the design. It is the responsibility of the Design Engineer to identify, explain and justify any deviation from the established criteria and to secure the necessary approvals from RTD. Any variation from these Design Criteria must be submitted to and approved by RTD's Executive Safety and Security Committee.

All proposed deviations to these criteria shall be approved by RTD in writing.

1.4.0 DESIGN CODES AND MANUALS

In addition to this Design Criteria Manual, the Design Engineer must comply with all other applicable engineering codes and standards, including those of the various Federal, State, and local jurisdictions.

If codes and/or manuals are specified herein for the design of an element of the RTD LRT system, then the most recent edition(s) shall be used. Responsibility for design remains with the Design Engineer in accordance with the terms and conditions of their contract with RTD.

Where design codes conflict with each other, the Design Engineer shall notify RTD in writing and recommend a solution. The Design Engineer shall also investigate those codes and manuals that have precedence.

Specific codes and standards include, but are not limited to, the following:

- Americans with Disabilities Act (ADA)
- Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities (ADAAG)
- Americans with Disabilities Act Accessibility Guidelines for Transportation Vehicles
- Colorado Department of Transportation (CDOT) - Standard Specifications for Road and Bridge Construction
- CDOT - Standard Plans (M&S Standards)
- CDOT - Highway Design Manual

- CDOT – Drainage Design Manual
- City and County of Denver - Rules for Street Standards
- City and County of Denver - Standard Construction Specifications
- FHWA - Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD)
- Colorado Public Utilities Commission (PUC)
- RTD - Commuter Rail Design Criteria
- RTD - Design Guidelines and Criteria for Bus Transit Facilities
- RTD - Standard Plans for Bus & Light Rail Transit Facilities
- Uniform Building Code (UBC)
- Uniform Fire Code
- American Association of State Highway and Transportation Officials (AASHTO) - Standard Specifications for Highway Bridges
- AASHTO - Standard Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals
- Transit Cooperative Research Program (TCRP) No. 57 " Track Design Handbook for Light Rail Transit"
- American Railway Engineering and Maintenance Association (AREMA)
- American Institute of Steel Construction (AISC)
- American Welding Society (AWS)
- American Concrete Institute (ACI)
- American Society for the Testing of Materials (ASTM)
- National Bureau of Standards
- National Electric Code (NEC)
- National Electric Safety Code (NESC)
- American National Standards Institute (ANSI)
- National Fire Protection Association (NFPA) including NFPA 130 and 101
- Local jurisdictional codes, requirements and ordinances, as applicable

Individual sections of these criteria may also define additional code requirements.

1.5.0 CLIMATIC CONDITIONS FOR SYSTEMS DESIGN

The Denver metropolitan area, within which RTD operates, is situated at the foot of the eastern slope of the Rocky Mountains in central Colorado. The area has a semi-arid climate that is somewhat characteristic of the High Plains, but is modified by the Rocky Mountains to the west. Because of this, Denver lies in a belt where there is a fairly rapid change in climate from the foothills to the plains. This change is largely caused by the increase in elevation as you travel west to the foothills. Denver has an elevation of 5,280 feet.

The average annual temperature is about 50°F at this elevation, though this varies a few degrees as elevation changes. The wide average range in daily temperature of 25° to

30°F in the Denver metropolitan area and a wide average range in annual temperature are typical for the High Plains. Variations in temperature are wide from day to day; extremely hot weather in summer and extremely cold weather in the winter normally do not last long and are followed by much more moderate temperatures.

System equipment including vehicles, electrification power and distribution system, signal system and fare collection/validation equipment along with trackwork, stations and other civil features shall be capable of maintaining operation within the following conditions:

TABLE 1A – CLIMATIC CONDITIONS

Ambient Temperature	-30°F to +110°F
Relative Humidity	8 to 100%
Maximum Rainfall in 24 Hours	1.88 inches
Maximum Snowfall in 24 Hours	10.1 inches
Maximum Wind Speed	54 mph
Average Elevation	5,280 Feet

TABLE 1B – TEMPERATURE AND PRECIPITATION

MONTH	TEMPERATURE				PRECIPITATION			
	AVERAGE DAILY MAXIMUM	AVERAGE DAILY MINIMUM	2 YEARS IN 10 WILL HAVE AT LEAST 4 DAYS WITH		AVG TOTAL	2 YEARS IN 10 WILL HAVE		AVG NO. DAYS WITH SNOW COVER
			MAX TEMP EQUAL OR HIGHER THAN	MIN TEMP EQUAL OR LOWER THAN		LESS THAN	MORE THAN	
	°F	°F	°F	°F	IN	IN	IN	
JAN	43	14	61	-6	0.43	0.1	0.8	8
FEB	47	18	64	-2	0.47	0.2	0.7	9
MARCH	52	23	70	4	0.87	0.4	1.6	7
APRIL	62	33	79	19	1.86	0.7	2.8	3
MAY	71	42	86	32	2.54	0.9	3.7	1
JUNE	84	51	96	40	1.58	0.7	2.6	0
JULY	91	57	99	50	2.01	1.0	3.2	0
AUGUST	89	56	98	49	1.49	0.7	2.1	0

MONTH	TEMPERATURE				PRECIPITATION			
	AVERAGE DAILY MAXIMUM	AVERAGE DAILY MINIMUM	2 YEARS IN 10 WILL HAVE AT LEAST 4 DAYS WITH		AVG TOTAL	2 YEARS IN 10 WILL HAVE		AVG NO. DAYS WITH SNOW COVER
			MAX TEMP EQUAL OR HIGHER THAN	MIN TEMP EQUAL OR LOWER THAN		LESS THAN	MORE THAN	
	°F	°F	°F	°F	IN	IN	IN	
SEPT	80	47	94	35	1.14	0.2	1.7	***
OCT	69	36	83	25	0.72	0.1	1.5	1
NOV	54	23	71	7	0.54	0.2	0.9	5
DEC	46	18	64	2	0.40	0.1	0.6	7
YEAR	66	35	*101	** -14	14.05	9.2	18.3	41

* Average annual highest temperature

** Average annual lowest temperature

*** Less than one-half day

Data for long periods indicate that the average annual precipitation ranges from 13.5 to 14.5 inches, with the highest precipitation occurring at the western edge of the metropolitan area. Particularly in summer and spring, precipitation may vary from year to year and in different areas in the same year. Precipitation in the winter is more in the western part of the Denver metropolitan area than it is in other parts. These differences are small but consistent from October to May. The annual snowfall is about 59 inches. The eastern part of the metropolitan area, however, usually receives more rainfall in summer than the west, but local rainfall varies widely from year to year.

The relative humidity averages 39% during the day and 62% at night, but these averages are slightly higher in winter than in summer. In an average year, the percentage of sunshine is about 69%.

Hailstorms cause some local damage almost every year. The hail usually falls in strips 1 mile wide and 6 miles long. These storms are more common in the eastern part of the Denver metropolitan area than the western part and they generally occur from about May 15 to September 1 but are most common in June and July.

Requirements for climatic conditions defined in other sections of these Design Criteria take precedence.

1.6.0 ACRONYMS AND ABBREVIATIONS

The following acronyms and abbreviations appear in this document. They are defined as indicated:

AAR	Association of American Railroads
AASHTO	American Association of State Highways and Transportation Officials
ABS	Automatic Block Signals
AC	Alternating Current
ACI	American Concrete Institute
ACOE	Army Corps of Engineers
ADA	Americans with Disabilities Act
ADAAG	Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities
AFC	Automatic Fare Collection
AFI	Air Filter Institute
AFO	Audio Frequency Overlay
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
AMCA	Air Moving and Conditioning Association, Inc.
ANSI	American National Standard Institute
APTA	American Public Transit Association
AREMA	American Railway Engineering and Maintenance Association
ARI	Air Conditioning and Refrigeration Institute
ASA	Acoustical Society of America
ASCII	American Standard Code for Information Interchange
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
ASIC	Application Specific Integrated Circuit
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATP	Automatic Train Protection
ATS	Automatic Train Stop
AWO	Maximum empty vehicle operating weight: 97,000 lb
AW1	Full seated load of 77 persons (passengers plus operator), plus AWO: 108,858 lb
AW2	Standees at 4 persons per m ² suitable standing space per passenger, 90 persons minimum, plus AW1: 122,718 lb
AW3	Standees at 6 persons per m ² of suitable standing space per passenger, minimum 136 persons, plus AW1: 129,802 lb
AW4	Standees at 8 person per m ² suitable standing space per passenger, minimum 180 persons, plus AW1: 136,578 lb

AWG	American Wire Gauge
AWS	American Welding Society
BLS	Bureau of Labor Statistics
CCC	Central Control Center
CCD	City and County of Denver
CCH	Communication Control Head
CCIR	International Radio Consultation Committee
CCITT	Consultative Committee for International Telephone and Telegraphs
CCTV	Closed Circuit Television
CDA	Copper Development Association
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CFR	Code of Federal Regulations
CMOS	Complementary Metal Oxide Semiconductor
CPM	Critical Path Method
CRB	Columbia River Basalt
CRT	Cathode-Ray Tube
CTS	Cable Transmission System
DB	Dry Bulb
DBE	Disadvantaged Business Enterprise
DC	Direct Current
DF	Direct Fixation
DIN	Deutsche Industry Norm (German Industrial Standard)
DOGAMI	Department of Geology and Mineral Industries
DWG	Drawing
ECS	Environmental Control System
ECU	Electronic Control Unit
EIA	Electronic Industries Association
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPABX	Electronic Private Automatic Branch Exchange
FAA	Federal Aviation Administration
FACP	Fire Alarm Control Panel
FCC	Federal Communications Commission
FOB	Fahrenheit Dry Bulb
FHWA	Federal Highway Administration
FEA	Finite Elements Analysis
FMP	Fire Management Plan
FRA	Federal Railroad Administration

FTA	Federal Transit Administration
FWB	Fahrenheit Wet Bulb
GSA	General Services Administration
HPCU	Hydraulic Pressure Control Unit
HSCB	High Speed Circuit Breaker
HVAC	Heating, Ventilating and Air Conditioning
IBC	International Building Code
ICEA	Insulated Cable Engineers Association
IEC	International Electro-technical Committee
IEEE	Institute of Electrical and Electronic Engineers
IES	Illuminating Engineering Society
ISO	International Organization for Standards
JEDEC	Joint Electronic Device Engineering Council
JIG	Joint Industrial Council
LAHT	Low Alloy High Tensile Strength (Steel)
LED	Light Emitting Diode
LOS	Level of Service
LRT	Light Rail Transit
LRV	Light Rail Vehicle
LVPS	Low Voltage Power Supply
MB	Maximum Brake
MCE	Maximum Credible Earthquake
MDBF	Mean Distance Between Failure
MIL	Military Specification
MIS	Management Information System
MOV	Metal Oxide Varistor
MOW	Maintenance-of-Way
MSB	Maximum Service Brake
MSS	Manufacturers Standardization Society of the Valve and Fitting Industry
MTTR	Mean Time to Repair
NBS	National Bureau of Standards
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NESC	National Electrical Safety Code
NETA	National Electrical Testing Association
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
OCS	Overhead Contact System
OSI	Open System Interconnect

OSHA	Occupational Safety and Health Administration
PA	Public Announcement
PABX	Private Automatic Branch Exchange
PE	Preliminary Engineering
PIV	Peak Inverse Voltage
PUC	Public Utilities Commission
RMS	Root Mean Square
ROW	Right-of-Way
RTU	Remote Terminal Unit
SAE	Society of Automotive Engineers
SCADA	Supervisory Control and Data Acquisition
SES	Subway Environment Simulation
SIC	Standard Industrial Code, U.S. Department of Labor
SMAC	Sheet Metal and Air Conditioning Contractor's National Association
SSP	System Safety Program
TES	Traction Electrification System
TIG	Tungsten Inert Gas
TIR	Total Indicated Runout
TOR	Top of Rail
TPSS	Traction Power Substation
TVM	Ticket Vending Machine
TWC	Train to Wayside Communication
UBC	Uniform Building Code
UDFCD	Urban Drainage and Flood Control District
UFC	Uniform Fire Code
UL	Underwriters Laboratories, Inc
UPS	Uninterruptible Power Supply
USASI	United States of America Standards Institute
USDCCM	Urban Storm Drainage Criteria Manual
USDOT	United States Department of Transportation
VPI	Vacuum Pressure Impregnation
VSWR	Voltage Standing Wave Ratio
WB	Wet Bulb

1.7.0 UNITS OF MEASURE

A	Ampere
Amp	Ampere
BTU	British Thermal Unit
CFS	Cubic feet per second

dB	Decibel
dBA	Decibel on the 'A' weighted scale
FC	Foot-candles
ft	Foot or feet
ft/min	Foot per minute
ft ³ /mi	Cubic feet per minute (or cfm)
ft ³ /sec	Cubic feet per second (or cfs)
g	Acceleration due to Gravity (32.2 ft/s ² = 9.81 m/s ²)
gpm	Gallons per minute
H	Hour
Hz	Hertz
In	Inch
J	Joule
kg	Kilogram
kHz	Kilohertz
km	Kilometer
km/h	Kilometer per hour
kWh	Kilowatt hour
l	Liter
lb	Pound
lbf	Pound force
m	Meter
MHz	Mega Hertz
mi	Mile
mph	Miles per hour
mphps	Miles per hour per second
min	Minute
mm	Millimeter
mV	Millivolt
μV	Microvolt
N	Newton
oz	Ounce
pcf	Pound per cubic foot
plf	Pound per linear foot
psf	Pound per square foot
psi	Pound force per square inch
s	Second
sec	Second
sq ft	Square Feet (or sf)

V	Volt
V _{ac}	Volt alternating current
V _{dc}	Volt direct current
°C	Degree Celsius
°F	Degree Fahrenheit