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Train Control

Infrastructure Design Criteria Manual (IDCM)

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CHAPTER 11-TRAIN CONTROL

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11.7.6 All parts of the design and its implementation that potentially affect the safe operation of the system as a whole shall be analyzed and verified to be safe.

11.7.7 All components and systems affecting safe operation shall be built to the standards set forth for Class I hardware in AREMA Communication and Signals Manual of Recommended Practices section 17.3.

11.7.8 System hazard analysis and Failure Modes, Effects, and Criticality Analysis (FMECA), when required, shall follow guidelines found within the Department of Defense Standard Practice of System Safety (MIL-STD-882E), AREMA C&S Manual 17.3.3 and 17.3.5, and the APTA Standard Guidelines for FMECA.

11.7.9 FMECA documents and system hazard analysis, when required, shall be independently validated by a 3rd party reviewer not employed by or associated with the system integrator.

11.8 ATC (ATP) TRAIN DETECTION SUBSYSTEM

11.8.1 Vital track circuits shall be used for train detection where detection is necessary for vital ATC functions.

11.8.2 Train detection shall be achieved through use of distinct track circuit segments that shall rely on shunting of the running rails to achieve train detection.

11.8.3 Double rail audio frequency-type track circuits that do not require insulated joints shall be the preferred method used between interlocking boundaries. Insulated joints may be used at non-interlocked locations where greater precision is needed for train detection.

11.8.4 Single rail 60 Hz power frequency (PF) track circuits shall be the preferred method for train detection used within interlockings.

11.8.5 Power frequency track circuits may be used in non-interlocked locations as agreed by CTA.

11.8.6 The track circuit layout at complex interlockings shall be configured to allow for parallel routes wherever possible.

11.8.7 Power frequency track circuits with multiple track segments shall be arranged in a series configuration, whereby a broken transposition wire will cause the track circuit to de-energize.

11.9 ATC (ATP) TRAIN DETECTION BLOCK DESIGN REQUIREMENTS AND CHARACTERISTICS

11.9.1 The minimum block design headway at a maximum performance speed shall be as specified in the project scoping documents.

11.9.2 Potential speed / headway combinations may include:

11.9.2.1 Block design for 35mph maximum speed operation with the headway front-to-front interval at 90 seconds apart or less for single rail line service segments with station spacing approximately one mile apart.

11.9.2.2 Block design for 25mph maximum speed operation with the headway front-to-front interval at 75 seconds apart or less for multiple rail line service segments (corridors) with station spacing approximately one half mile apart.

11.9.2.3 Block design for 15mph maximum speed operation with the headway front-to-front interval at 70 seconds apart or less for multiple rail line service segments with station spacing under approximately one half mile apart.

11.9.3 Block design shall support safe braking requirements for following trains without cab signal degradation for sustained operations.

11.9.4 Block design shall also support safe braking requirements, for following trains, without cab signal degradation, for sustained repeating operations of lead trains making movements past signals that must re-clear.

11.9.5 Block design shall take into account additional reductions in speed and increases back to the maximum speed in areas with civil speed restrictions. This shall allow the net headway interval to be maintained for trains entering and leaving the line segment.

11.9.6 The length of platforms and station dwell time shall be considered in determining the number and location of block limits in approach to and within station limits.

11.9.7 The nominal station dwell time shall be 15 seconds for block design unless otherwise indicated in the design scope. For purposes of block design simulation, actual data from the specific station locations shall be utilized where available. Dwell time duration for simulations shall be based on rush hour period dwell time data.[1]

11.9.8 Block design headway time constraint shall include station dwell time as part of the time interval.

11.9.9 Block design shall be optimized in the normal direction of traffic for eight-car train consist operation, unless otherwise specified. Block design may be required to accommodate migration to longer train operation, when specified.

11.9.10 Headway in the reverse direction of traffic shall be the minimum obtainable with block design optimized for the normal direction of traffic. Reverse running headway shall be for trains running with a minimum cab signal speed

[1] CTA shall furnish this data as an attachment to the design criteria.

of 35MPH and in interval of 120 seconds or less from the front of the first train passing to the front of the second train passing a given point. It may be "as-it-falls" if this 120 second minimum is met.

11.9.11 Block design shall consider the distance between passenger stations and how it affects maximum and average train speeds. Use of intermittent station stops ("A" and "B" stop sequence) also affects such maximum and average speeds. The speeds, in turn, affect the location of block limits. In general, longer blocks may be employed as the distance between stations increases. "Skip-stop" operation shall only be used to determine the signal block layout in sections where "skip-stop" stations are provided and identified in the contract requirements.

11.9.12 Block design shall maximize the availability of a valid cab signal based on available braking distance, and minimize STOP or 0mph speed command sections.

11.9.13 Block limits shall be arranged to minimize the possibility of trains receiving a STOP command that requires a train to complete a safe braking stop short of berthing locations in stations. Additional track circuits or block signals may be required to facilitate minimizing this in high density corridors.

11.9.14 Track block limits shall be no closer than 50 feet from the entering or leaving end of a station, except where the block boundaries are defined by insulated joints or high definition bridging receivers (receive points) adjacent to the station.

11.9.15 Track block boundaries at interlockings shall include a distance for a buffer rail to separate the insulated joints at the signal from the special work rail joints. The minimum buffer rail length shall be 19.5 feet unless otherwise reduced by CTA.

11.9.16 Block design boundaries for signals with automatic train stop devices shall be located with sufficient braking distance that a train approaching the red signal at the CSS+1mph and getting tripped will come to a stop so as to not foul another train operating through the interlocking. Similarly there shall be sufficient braking distance that a train approaching at the same speed and getting tripped will come to a stop so as to not collide with a train just beyond the exit of the interlocking.

11.9.17 All track circuit design should strive for complete and continuous vital detection throughout. However, at no time shall any area of non-detection be greater than 20 feet.

11.9.18 Overlaps in "signal rails" when used as part of a Power Frequency (PF) track circuit, without a corresponding negative rail, shall be minimized, and shall not exceed 5.5 feet in length.

11.9.19 Track circuit design lengths shall not exceed 90% of the maximum length according to the track circuit manufacturer's requirements. The track circuit length shall be at least 10% greater than the manufacturer's minimum requirements.

11.9.20 Track circuits comprised of multiple segments shall not include a segment shorter than the inner wheel-base dimensions of CTA trains, unless at least one axle from the truck will occupy the adjacent segment of the same track circuit.

11.9.21 Block design train detection resolution shall not preclude the use of single car trains.

11.9.22 Train detection on all station platform areas should[2] be designed to provide sufficient track circuit resolution to positively confirm that the entire train is berthed within the station limits.

11.9.23 The block design may also utilize block signals with train stops and interlocking signals with train stops to shorten up braking distances. All circuit designs shall positively affirm the train stop is in the tripping position if it is being used to shorten up control line distances. This shall be clearly noted on the control line drawings.

11.9.24 The cab signal system may be supplemented with wayside block signals with automatic train stops to accommodate a closer headway as necessary.

11.9.25 Block design boundaries shall take into account the ability to install the necessary equipment and shall be adjusted to compensate for field conditions and installation constraints. Note that constraints may include buildings, walls, middle-third structure occupancy restrictions at elevated locations preventing platform installation and available air-rights or property rights.

11.9.26 Block design shall include control points to release trains from speed restrictions as soon as practical. Speeds shall upgrade not more than 50 feet after the rear of the train exits the restriction.

11.9.27 Block design shall include the development of scaled time-distance (time vs. distance) curves based on trains operating within the specified headway design constraints. Curves shall be based on trains obeying all civil and operational speed restrictions, not exceeding the headway design speed, while following nominally loaded car acceleration and nominal service braking profiles. Curves shall include station dwell time for each train. These shall demonstrate the relationships between the rear of a lead train, the front of a following train and the time for each cab signal speed command to be available for the following train at each block entry point. Separate graphical

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[2] Individual contracts shall determine if the final track circuit configuration that supports positive berthing identification is mandatory.

representations of the track and profile shall also be shown below each distance segment. Track representation shall include all station limits, berthing points, curve limits, curve data, switches, signals, track circuit boundaries and any other factors which might require restricted speeds.

11.9.28 Provide a Block Design Report. The report shall include a statement of the operational and safe braking criteria used. Description of the modeling software used. Validation that the braking model was properly applied. Safe braking validation for each speed in each control line to be performed by an entity completely independent of the block design modeler.

11.9.29 Provide simulation model at maximum speed to demonstrate headway.

11.10 CONTROL LINE DEVELOPMENT FROM BLOCK DESIGN

11.10.1 Home signal and block signal control lines shall be developed from the block design.

11.10.2 Cab signal control lines shall be developed from the block design.

11.10.3 Control line design shall be based on safe braking requirements for each block segment.

11.10.4 The maximum authorized design speed shall be 70mph, except where otherwise designated.

11.10.5 The Restricted speed command should not be utilized for mainline block design unless specifically indicated otherwise.

11.10.6 The Restricted speed command shall be utilized in approach to terminals where the end of track or bumping post is less than 150 ft from the head car berthing location.

11.10.7 Maximum permitted cab signal speeds shall not be designed to exceed the civil speed limits associated with curves or special track work.

11.10.8 Maximum speed limits for elevated steel guide ways shall be 55mph.

11.10.9 The cab signal system control line speeds shall allow a train utilizing the nominal (service) braking to slow down to the comfort civil speed. The cab signal speeds shall not be required to enforce safe braking down to the "comfort"/civil speed for curves. The cab signal speeds shall be required to ensure "safe" braking to a speed which is less than 58% of the overturning speed prior to entering a curve or spiral.

11.10.10 Control lines shall identify speed reductions based on status of signals passed by the control lines.

11.10.11 Control lines shall identify speed reductions due to diverging routes at interlockings.

movements, and when the train occupies the combination of either the island or the mainline detector track for crossover movements.

11.13.1.2 For movements entering interlockings, the cab signal loop shall be enabled to turn on ahead of the train of crossing the insulated joint when the wayside signal is clear.

11.13.1.3 For other movements the cab signals shall be enabled when the train occupies the approach track.

11.13.2 The design shall provide cab signal transmission for an interlocking facing movement in the track circuit adjacent to interlockings regardless of the traffic alignment to allow for turn-back moves without disruption of cab signal. The design should also provide for reverse cab signal transmissions back to the interlocking in second or third track circuits from a platform that is not immediately adjacent, when a turn-back is likely or identified as a design requirement.

11.13.3 The ATP system shall provide safe spacing between trains and shall be arranged so that a train control command to reduce speed or stop shall provide ample time and distance for the train to brake within the calculated safe braking distance.

11.13.4 The ATP system shall provide for broken rail detection by simulating occupancy in a track circuit where there is a broken rail.

11.13.5 Where cab speed control lines are based in part on the increased side trip emergency mechanism (STEM) braking rate, that train stop shall be positively confirmed to be in the tripping position unless the associated signal is clear. The train stop shall be verified to be in the tripping position in the cab signal controls for the track circuit immediately in approach to that train stop, unless the signal is clear (i.e. not displaying a STOP or “Call-On” aspect) for that move.

11.13.6 Cab signals in approach to a signal shall reduce to 0mph if a train stop is “pinned” or driven down by an opposing route. Cab signals in approach to a signal shall reduce to 0mph if the facing point switch is not indicating. Cab signal shall also reduce to 0mph after a “call-on” is accepted (by operating the track-trip-manual-release) and the trip is driven down, so the train may not be required to make a second penalty stop after passing the signal.

11.14 ATC NOMINAL (SERVICE) BRAKING CALCULATIONS

11.14.1 Nominal braking shall be utilized for determination of the time-distance braking profile of trains making station stops in headway design and shall be used for design of speed reductions in approach to curves. Control lines shall be designed such that the command for a speed reduction occurs at a sufficient distance to allow a decelerating train to be at or below the Comfort Speed for the curve prior to entering the curve. The Nominal Command Distance (NCD) shall take into account the combination of the Nominal Reaction Distance (NRD) and the Nominal Braking Distance (NBD).

11.14.2 The base Nominal Service Brake Rate (seated passenger load rate) used for Nominal Braking Distance calculations shall be as identified in Table 1 of Appendix A, modified to take into account the grade effects over the distance traveled. No additional safety factor shall be used for nominal braking calculations.

11.14.3 The Nominal Service Braking Reaction Time shall be as identified in Table 1 of Appendix A. Nominal Reaction Distance shall be calculated as the distance a train travels at the cab signal speed for the Nominal Service Braking Reaction Time.

11.14.4 The Nominal Command Distance (NCD) = (Nominal Reaction Distance (NRD) + Nominal Braking Distance (NBD)).[5]

11.15 ATP SAFE BRAKING DISTANCE CALCULATIONS

11.15.1 Cab signal safe braking distances shall be based on the following combination of distances associated with ATP equipment or system reaction times and physical constraints:

11.15.1.1 Command Reaction Distance (D_C): Distance traveled during ATP reaction/recognition time.

11.15.1.2 Acknowledgement/Response Distance (D_A): Distance traveled during rail operator acknowledgement / propulsion system response time.

11.15.1.3 Dead Time/Brake Build up Distance (D_{BB}): Distance traveled during dead (coast) time combined with brake build up time.

11.15.1.4 Brake Distance (D_B): Distance traveled during train braking from maximum over-speed velocity to stop, including a safety factor.

11.15.1.5 Net Overhang Distance (D_{OH}): Distance associated with car body overhangs from lead axle to front of train (5 feet per car).

11.15.2 The design shall include adjustments of the acceleration rate and safe braking rate for grade effects.

[5] Car body overhang distance is not included in calculating distance.

11.15.3 For purposes of calculating the safe braking distance (SBD), the entry speed for a signal block shall be assumed to be 1mph over the cab signal speed (CSS+1).

11.15.4 Command Reaction Distance (D_C): The ATP (cab signal command) reaction/recognition distance shall be calculated based on a train traveling at the block entry speed for the cab signal command detection time. Command detection time shall be as identified in Table 1 of Appendix A. No additional safety factor shall be applied to this distance.

11.15.5 Acknowledgement/Response Distance (D_A): Prior to receiving an ATC penalty brake application, the train may be in an acceleration mode and remain in a state of acceleration during ATC Over-speed Recognition and Operator Acknowledgement time. In addition, it may remain in a state of acceleration during the Propulsion Relay Response time until the end of the Propulsion Removal time. The Propulsion Removal Response time will vary at a given speed based on the jerk limiting of the rate of change from acceleration to deceleration. Times for these responses are as identified in Table 1 of Appendix A. Acceleration rates shall be based on the values in Table 1 of Appendix A. The reaction distance for this component shall be calculated based on the average speed of the train as it accelerates to a maximum over-speed velocity, for the combined time duration of the ATC Over-speed Recognition, Propulsion Relay Response and Propulsion Removal times. No additional safety factor shall be applied to this distance.

11.15.6 Dead Time/Brake Build-up Distance (D_{BB}): Dead time and brake build up time shall be as identified in Table 1 of Appendix A. The distance travelled shall be calculated based on the train travelling at the maximum over-speed velocity for this time. No additional safety factor shall be applied to this distance.

11.15.7 Brake Distance (D_B): The loaded car brake rate identified in Table 1 of Appendix A shall be adjusted for grade effects before being used for braking calculations. The distance travelled during train braking shall be based on the train reaching maximum over-speed velocity and braking at the grade-adjusted, loaded car rate. This distance shall be increased by multiplying it by the Safe Braking Distance Safety factor.

11.15.8 The Safe Braking Distance Safety Factor (SBDSF) for cab signal penalty braking shall be 1.20.

11.15.9 The Safe Braking Distance (SBD) = (D_C + D_A + D_{BB} + (SF * D_{BR}) + D_{OH}).

11.16 SIDE TRIP EMERGENCY MECHANISM (STEM) BRAKING CALCULATIONS

11.16.1 Side trip emergency mechanism (STEM) safe braking distances (STEMSBD) shall be based on the following combination of distances associated with STEM equipment or system reaction times and physical constraints:

11.16.1.1 Dead Time/Brake Build-up Distance: Distance traveled during brake build up time at maximum over-speed velocity.

11.16.1.2 Braking Distance: Distance traveled during train braking from maximum over-speed velocity to stop, including a safety factor.

11.16.1.3 Net Overhang Distance: Distance associated with car body overhangs from lead axle to front of train.

11.16.2 The design shall include adjustments of the safe braking rate for grade effects.

11.16.3 For purposes of calculating the SBD, the approach speed prior to engaging the side trip shall be the maximum over-speed velocity that a train may be traveling at when it encounters the train stop. If the train is expected to encounter the train stop under normal cab signal conditions, the maximum over-speed shall 1mph over the cab signal speed (CSS+1).

11.16.4 Dead Time/Brake Build-up Distance: The calculation of the brake build up reaction distance shall use the STEM Dead Time and Brake Build-up Time at maximum over-speed velocity. Reaction distance calculations shall not include any additional safety factor. The STEM Dead Time and Brake Build-up Time shall be as identified in Table 1 of Appendix A.

11.16.5 The calculation of the braking distance shall be based on the application of the brakes, at the fully de-rated rate, with the rate adjusted for the average negative grade (GR) over the segment of track. Brake distance calculation shall be increased by multiplying the distance by the safety factor STEMBDSF.

11.16.6 The STEM Braking Distance Safety Factor (STEMBDSF) shall be 1.1.

11.16.7 The STEM Safe Braking Distance (STEMSBD) = (Dead Time/Brake Build-up Distance + (STEMBDSF * Braking Distance) + Net Overhang distance (for 2 cars)).

11.16.8 Consideration may be given to reduce the applied safety factor to 1.10 on side trip braking calculations under limited circumstances for end of track locations.

APPENDIX A - CTA CAR PERFORMANCE CHARACTERISTICS

TABLE 1: ATC AND PROPULSION SYSTEM CHARACTERISTICS			
Item	Symbol	Standard Value	Unit
Cab Signal Command Detection Time	T_C	2.60	sec
ATC Over-speed Recognition and Operator Acknowledgement Time	T_A	4.10	sec
Dead Time (coast) and Brake Build-up Time	T_{BB}	1.00	sec
Acceleration Rate Up to 30mph (for purposes of safe braking)	$A_{[<30MPH]}$	1.30	mphps
Acceleration Rate Between 31mph & 50mph (for purposes of safe braking)	$A_{[31MPH-50MPH]}$	0.65	mphps
Acceleration Rate above 50mph (for purposes of safe braking)	$A_{[>50MPH]}$	0.35	mphps
Cab Signal Speed	CSS	15, 25, 35, 45, 55, or 70	mph
Cab Signal Brake Rate for Level Grade	BR_{CS}	1.92	mphps
Cab Signal Brake Rate Safety Factor	SF_{CS}	1.2	N/A
Net Overhang Distance of two cars (use half of this for distances to bumping post or fouling point)	D_{OH}	10	ft
Nominal Service Brake Rate	BR_{NOM}	2.225	mphps
Nominal Service Braking Reaction Time	T_{NSB}	7.4	sec
Side Trip Emergency (STEM) Dead Time and Brake Build-up Time	T_{STEM}	1.5	sec
Side Trip Emergency (STEM) Brake Rate for Level Grade	BR_{STEM}	3.5	mphps
Side Trip Emergency (STEM) Brake Rate Safety Factor	SF_{STEM}	1.1	N/A

TABLE 2: NOMINALLY LOADED CAR TRACTIVE EFFORT (FOR TIME DISTANCE CURVE DEVELOPMENT ONLY)

SPEED [mph]	TRACTIVE EFFORT [lbs/ton]		SPEED [mph]	TRACTIVE EFFORT [lbs/ton]		SPEED [mph]	TRACTIVE EFFORT [lbs/ton]
1	250.00		26	156.00		51	53.00
2	250.00		27	156.00		52	51.00
3	250.00		28	156.00		53	48.00
4	250.00		29	156.00		54	44.00
5	250.00		30	155.00		55	42.00
6	250.00		31	150.00		56	40.00
7	250.00		32	145.00		57	37.00
8	249.00		33	140.00		58	34.00
9	249.00		34	136.00		59	32.00
10	249.00		35	132.00		60	30.00
11	249.00		36	128.00		61	27.00
12	249.00		37	122.00		62	25.00
13	244.00		38	118.00		63	23.00
14	229.00		39	114.00		64	21.00
15	214.00		40	108.00		65	20.00
16	199.00		41	102.00		66	18.00
17	167.00		42	95.00		67	16.00
18	157.00		43	89.00		68	14.00
19	157.00		44	83.00		69	12.00
20	157.00		45	77.00		70	10.00
21	157.00		46	73.00		71	8.00
22	157.00		47	68.00		72	8.00
23	157.00		48	65.00		73	8.00
24	157.00		49	60.00			
25	156.00		50	57.00			

APPENDIX B – SAFE BRAKING CALCULATIONS

CAB SIGNAL SAFE BRAKING FORMULAS

$$\left(\frac{5280}{3600}\right) * (CSS + 1) * T_C = D_C$$

$$\left(\frac{5280}{3600}\right) * \left[T_A * (CSS + 1) + \frac{1}{2} A * T_A^2\right] = D_A$$

$$\left(\frac{5280}{3600}\right) * T_{BB} * \left[(CSS + 1) + A_{[CSS]} * T_A\right] = D_{BB}$$

$$\frac{\left(\frac{5280}{3600}\right) * \left[(CSS + 1) + A_{[CSS]} * T_A\right]^2}{2 * BR_{CS[\%GR]}} = D_{BR}$$

$$D_C + D_A + D_{BB} + (SF * D_{BR}) + D_{OH} = SBD_{CS}$$

SIDE TRIP EMERGENCY SAFE BRAKING FORMULAS

$$\frac{5280}{3600}(CSS + 1) * T_{STEM} = D_{STEM\ DELAY}$$

$$\frac{\left[\frac{5280}{3600}(CSS + 1)^2\right]}{2 * BR_{STEM}} = D_{STEM\ BR}$$

$$D_{STEM\ DELAY} + (SF_{STEM} * D_{STEM\ BR}) + D_{OH} = SBD_{STEM}$$

CURVE SPEED CALCULATIONS

$$V_{MPH} = \sqrt{0.25 * R * (E_A + E_u)}$$

$$R = Curve\ Radius\ (feet)$$

$$E_A = Curve\ Superelevation\ (inches)$$

$$E_u = Allowable\ unbalance\ (inches) = 4.5''$$