

DESIGN CHARACTERISTICS OF SELECTED RAIL RAPID TRANSIT SYSTEMS

This appendix is a tabulation of the ATC design characteristics and engineering features of five operating rail rapid transit systems:

Bay Area Rapid Transit (BART)

Chicago Transit Authority (CTA)

Massachusetts Bay Transportation Authority (MBTA)

New York City Transit Authority (NYCTA)

Port Authority Transit Corporation (PATCO)

Listed vertically at the left of the tables are the generic functions which must be accomplished to provide train protection, train operation, train supervision, and system communications.¹⁰¹ Arrayed beside these functions are descriptions of the equipment and techniques employed in the five transit systems. The major distinction is between manual and automated techniques, with supplementary material to indicate specific engineering and operational features.

None of the rail rapid transit systems described here is completely manual or completely automatic.

¹⁰¹See appendix A for a definition and description of these functions.

All represent various combinations of manual and automatic train control—the particular mixture being determined by local needs and conditions, the history of engineering development in each locale, and (for the newer systems, at least) the fundamental design philosophy. Generally speaking, NYCTA and CTA are the least automated of the five transit systems, although both have a considerable amount of automation of train protection functions. The Red Line of MBTA represents a higher level of automation, incorporating some automatic train operation features in addition to basic automatic train protection. The other MBTA lines are equivalent to NYCTA or CTA in the extent of automation, PATCO is still more automated, with virtually all train protection and operation functions assigned to machine components. On the other hand, PATCO has almost completely manual means of train supervision. BART is the most highly automated of the five systems. Train protection and operation are fully automatic, but monitored by an onboard operator. Train supervision is also largely automated, with extensive use made of central computers to accomplish functions that are performed by dispatchers and towermen in other transit systems. The order of listing in the table indicates progressive increase in the general level of train control system automation.

TRAIN CONTROL SYSTEM CHARACTERISTICS

TRAIN PROTECTION FUNCTIONS	NYCTA	CTA
Train Detection		
Monitoring of track occupancy	Conventional voltage level track circuits of two types: single rail, power frequency, hardwired double rail, power frequency, hardwired	Conventional voltage level track circuit of three types: single rail, power frequency, hardwired double rail, power frequency, hardwired double rail, audio frequency, hardwired
Train Separation		
Collision prevention, primarily by blocks to ensure safe separation and speed limits to ensure safe stopping distance	Fixed blocks (length: 40-1200 ft.) Relay logic Minimum design headway: 1 1/2 min.	Fixed blocks (length: 300-2000 ft.) Relay logic Minimum design headway: 1 1/2 min.
Movement Commands		
Speed and stopping commands to trains	Wayside signals Three-aspect block signal system (Proposed cab signal system will have 70,50, 35, 25, 15, and 3 mph speed commands and a cab signal cutout. Absence of a positive command is interpreted as 0 mph.)	Mixture of wayside and cab signals Three-aspect block signal system Five cab signal speed commands (70, 35,25, 15,0 mph)
Overspeed Protection		
Comparison of command and actual speed to ensure that civil speed limits are not violated	Wayside signals with timers and trip stops	Mixture of cab signals with automatic overspeed protection and wayside signals with timers and trip stops
Speed Determination		
Sensing and display of actual train speed	Estimated by motorman, no speedometer in cab except on new R 44 and R-46 cars.	Tachometer, with speedometer in cab
Interlocking		
Prevention of conflicting train movement through switches and along routes	Mixture of electro-mechanical and all-relay	Mixture of mechanical, electro - mechanical, electro-pneumatic, and all-relay
Train and Track Surveillance		
Monitoring the right-of-way for obstructions, persons on track, broken rails, etc.	Visual track surveillance (primarily by motorman with some assistance from conductor)	Visual track surveillance (primarily by motorman with some assistance from conductor); cab signal for broken rail protection
Monitoring condition of train systems.	Status of some carborne systems is monitored automatically and displayed by annunciator placards in the cab.	Status of some carborne systems is monitored automatically and displayed by annunciator placards in the cab.

MBTA	PATCO	BART
Conventional voltage level track circuits of three types: single rail, power frequency, h a r d w i r e d double rail, power frequency, hardwired double rail, audio frequency, hardwired	Conventional voltage level track circuits of two types: single rail, power frequency, hardwired (yard only) double rail, power frequency, hardwired (revenue tracks)	Low voltage level track circuits: double rail, audio frequency, multiplex one rail; power frequency track circuits in yards
Fixed blocks (length: 425-2100 ft.) Relay logic Minimum design headway: 1 1/2 min.	Fixed blocks (length: 295-3400 ft.) Relay logic Minimum design headway: 2 min.	Fixed blocks (length 75-1100 ft.) Solid-state logic Minimum design headway: 1 1/2 min. (With sequential Occupancy Release system, headways are restricted to 2 min.)
Mixture of wayside and cab signals Three-aspect block signal system Eight cab signal speed commands (70, 65,50,40,25, 10,0 mph and yard speed)	Cab signals Five speed commands (75, 40,30, 20, 0 mph) to ATO system which controls speed	Cab signals Eight speed commands (80, 70,50, 36, 27, 18,6, 0 mph) to ATO system which controls speed
Mixture of cab signals with automatic overspeed protection and wayside signals with timers and trip stops	Cab signals with automatic overspeed protection	Cab signals with automatic overspeed protection
Estimated by motorman, no speedometer in cab except for Silverbird cars on Red Line	Tachometer, with speedometer in cab	Tachometer, with speedometer in cab
Mixture of electro-mechanical and all-relay	All-relay	All -relay
Visual surveillance (primarily by motorman with some assistance from train guards); cab signal for broken rail protection (Red Line only)	Visual surveillance by train operator cab signal for broken rail protection	Visual surveillance by train operator cab signal for broken rail protection
Status of some carborne systems is monitored automatically and displayed by annunciator placards in the cab.	Status of some carborne systems is monitored automatically and displayed by annunciator placards in the cab.	Status of some carborne systems is monitored automatically and displayed by annunciator lights in the cab.

TRAIN CONTROL SYSTEM CHARACTERISTICS--Continued

TRAIN SUPERVISION FUNCTIONS	NYCTA	CTA
Schedule Design and Implementation		
Planning of service in light of anticipated demand, available equipment, and environmental conditions (includes orders to execute the plan)	Manual	Manual
Train Identification		
Determination of the route and destination of a train	Mixture of manual and automatic (Automatic only on R-44 and R-46 cars, where passive unit on train resonates when excited by wayside equipment)	Mixture of manual (by train operator or towerman) and automatic (passive unit on train resonates when excited by wayside equipment or optical scanning of identity panel on train by wayside equipment)
Train Dispatching		
Control of train departures from terminals (or waypoints) in accordance with schedule	Mixture of manual and automatic (electro-mechanical clock)	Mixture of manual and automatic (electro-mechanical clock)
Route Assignment and Control		
Selection and assignment of routes to be followed by trains, including periodic update reports by trains as to identity, location, and destination	Mixture of manual methods (by central control remotely or by towerman locally) and automatic control based on train identity information or track circuit occupancy	Mixture of manual control by local towerman and automatic control based on train identity information or track circuit occupancy
Performance Monitoring		
Following the progress of trains against the schedule	Visual observation (model boards in towers and central control) Also manual check-off at towers	Visual observation (model boards in towers and pen graph recorders at central control)
Performance Modification		
Adjustment of movement commands or revision of schedule in response to traffic conditions	Verbal instructions to adjust running speed or station stops; remotely controlled starting signals to delay departure from terminals and control points	Verbal instructions to adjust running speed or station stops; remotely controlled starting signals to delay departure from terminals and control points
Alarms and Malfunctions Recording		
Alerting to malfunctions and problems and recording of time, location, and nature	Manually activated electrical alarming and manual recording based on verbal reports	Manual alarming and recording based on verbal reports
Yard Train Control		
Train assembly, routing, and movement with in yards and to and from revenue tracks	Manual train operation and a mixture of manual and automated switching	Manual

MBTA	PATCO	BART
Manual	Manual	Schedule prepared manually and fed into central computer
Mixture of manual and automatic (optical scanning of identity panel on train by wayside equipment)	Automatic (passive unit on train resonates when excited by wayside equipment)	Automatic (active unit on train transmits identity to wayside transceiver for relay to terminals, stations, and central control)
Mixture of manual and automatic (electro-mechanical clock)	Automatic (electro-mechanical clock)	Automatic (computer controlled)
Mixture of manual methods (by central control remotely or by towerman locally) and automatic control based on train identity information or track circuit occupancy.	Mixture of manual control by central control remotely and automatic control based on train identity information or track circuit occupancy	Automatic (trainborne destination information transmitted to wayside equipment which automatically sets route); manual control (by central or local controllers) available as an alternative or back-up mode
Visual observation (model boards in towers and central control)	Visual observation (model board at central control)	Visual observation (model boards at central control and towers) with computer-aided display and alerting
Verbal instructions to adjust running speed or station stops; remotely controlled starting signals to delay departure from terminals and control points	Verbal instructions to adjust running speed or station stops; remotely controlled starting signals to delay departure from terminals and control points	Automatic, station dwell time and train performance mode (speed and/or acceleration) controlled by central computer (can be selected by computer automatically or by manual input)
Manual alarming and recording based on verbal reports	Manual alarming and recording based on verbal reports	Automatic alarming and recording for some events; manual inputs to computer record also possible
Manual	Manual	Manual (special hostling control panel)

TRAIN CONTROL SYSTEM CHARACTERISTICS—Continued

TRAIN OPERATION FUNCTIONS	NYCTA	CTA
Velocity Regulation		
Control of actual speed in relation to command (civil) speed	Manual	Manual
Station Stopping		
Stopping train in alignment with station platform	Manual	Manual
Door Control		
Opening and closing of doors at stations	Manual, by conductor	Manual, by conductor (or operator on single-car trains)
Train Starting		
Departure from station	Manual, by operation of propulsion control	Manual, by operation of propulsion control
COMMUNICATION SYSTEMS	NYCTA	CTA
Train – Central	Radio	Train phone
Train – Station	No direct link, relayed through central control	No direct link, relayed through central control
Train – Wayside	Radio	No direct link, relayed through central control
Central - Station	Telephone; also public address system on platform at some stations and automatic train departure signs at some terminals	Telephone; also public address system on platform at some stations and automatic train departure signs at some terminals
Central – Wayside	Radio and dial telephone	Dial telephone; also public address to certain key towers and terminal supervisors
Station – Wayside	Dial telephone	Dial telephone
Station – Station	Dial telephone	Dial telephone
Wayside - Wayside	Radio and dial telephone	Dial telephone
Outside Emergency Assistance	Walkie-talkie radio net for police, central control and key dispatchers, other assistance summoned through central control	Dial or direct-line telephone

MBTA	PATCO	BART
Automatic on Red Line, with manual operation (at full speed) available as alternative mode. Manual on other lines	Automatic, with manual operation (at, full speed) available as alternative mode.	Automatic, with manual operation (at reduced speed) available as a back-up mode or if track conditions dictate
Manual	Automatic Stop command triggered when train passes fixed wayside point; braking effort to stop in required distance reckoned from wheel revolution	Automatic Continuous stop command generated by wayside equipment; braking effort to stop in required distance reckoned from wayside measuring points.
Manual by train guard (conductor)	Manual by train guard (motorman)	Automatic, with manual override
Manual, by operation of propulsion control	Manual, by depressing start button	Automatic
MBTA	PATCO	BART
Radio No direct link, relayed through central control Radio	Train phone No direct link, relayed through central control No direct link, relayed through central control	Radio No direct link, relayed through central control Radio
Telephone and public address system on station platforms; some startees equipped with walkie-talkie radios	Telephone, public address, closed-circuit TV, and call-for-aid phones at automatic fare collection gates	Telephone and public address system; automatic signs on station platforms indicating train arrival and destination
Radio and dial telephone	Dial telephone, radio in trucks and work trains, walkie-talkie for trackside workers	Radio and dial telephone
Dial telephone	Dial telephone	Dial telephone
Dial telephone	Dial telephone	Dial telephone
Dial telephone	Radio and dial telephone	Radio and dial telephone
Police and fire each on separate radio network; utilities contacted by telephone	PATCO police on system radio network; outside police on separate network or contacted by telephone; fire and utilities contacted by telephone	BART police on system radio network; fire and utilities contacted by phone