Rail Signals Maintenance Training Content and Standards

Abstract: This Recommended Practice establishes standards for a program of rail signals maintenance training.

Keywords: rail signals, training

Summary: The safe and efficient operation of transit rail systems is highly dependent on reliable rail signals to control train operations. Rail signals maintenance has been identified by APTA and unions representing transit workers as a craft with a shortage of practitioners. In response to the need for rail signals maintenance training, the Transportation Learning Center has partnered with APTA, transit agencies and unions representing transit workers to develop joint labor-management training guidelines and recommended training practices.

Scope and purpose: The labor-management subject matter experts on the Signal Training Joint Steering Committee developed the training curriculum and guidelines with the expectation that training would be instructor-led and include on-the-job training under the supervision of an experienced and qualified journeyman or technician. Completion of level 100 to 300 learning objectives would typically require a three-year period, though these guidelines do not include instructional hour and on-the-job hours recommendations.
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1. Objective of this standard

Public transportation faces a technical skills shortage driven by changing technologies, shifting workforce demographics, record-breaking growth in ridership and the continuing expansion of transit systems and users. Industry leaders acknowledge that the pace of technological change has surpassed the capacity of most agencies to train skilled technicians and new entrants/employees in the effective diagnosis, repair and maintenance of advanced capital equipment. To address many of these issues, labor-management partnerships have been advocated in a number of blue-ribbon reports (see References) from the Transportation Research Board and its Transit Cooperative Research Program (TCRP) as well as from the American Public Transportation Association (APTA).

The safe and efficient operation of transit rail systems is highly dependent on reliable rail signals to control train operations. Rail signals maintenance has been identified by APTA and unions representing transit workers as a craft with a shortage of practitioners. The inadequate numbers of rail signals maintainers is attributed to several factors, including the pending retirement of incumbent workers, the continued expansion of rail transit systems nationwide and inadequate recruitment and training of signal maintainers. The difficulty in recruiting new entrants into the field is exacerbated by sometimes unfavorable outdoor and confined working conditions and changes in signal technology.

In response to the need for rail signals maintenance training, the Transportation Learning Center has partnered with APTA, transit agencies and unions representing transit workers to develop joint labor-management training guidelines and recommended training practices. The development of these training guidelines was supported through grants from the U.S. Department of Labor, the Federal Transit Administration and the TCRP. In addition, APTA is supporting programs to develop computer-based short courses of study using the recommended training guidelines developed with the Center.

1.1 The Steering Committee

The development of recommended training guidelines was coordinated through a joint labor-management steering committee of subject matter experts drawn from rail transit agencies across the country. Table 1 lists the agencies and unions involved.

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*Other participants: Brotherhood of Rail Road Signalmen, GE Transportation, Washington Group*
Meeting over a period of two and one-half years, this committee of management and labor subject matter experts:

- Determined the job responsibilities and related tasks required of signals maintainers.
- Determined the skills, knowledge and abilities required to successfully execute the job responsibilities and tasks of the signals maintenance craft.
- Developed a program of training and order of instruction for classroom and on the job training for signals maintainers.
- Determined the learning objectives associated with each phase of the training process to develop signals maintainers.

1.1.1 Meeting dates
The Signal Training Joint Steering Committee met on the following dates:

- November 14, 2006
- January 23, 2007
- February 13, 2007
- March 1, 2007
- June 20, 2007
- September 26, 2007
- January 28, 2008
- September 3, 2008
- March 27, 2009

2. Rail Signals Training Guidelines
Rail signals maintenance training guidelines are organized into nine subject areas corresponding to the different job responsibilities of a rail signal maintenance technician. These subject areas:

1. Comprehensive overview of rail train operations and safety
2. Train detection and control
3. Switches
4. Grade crossings
5. Power distribution
6. Signals
7. Train stops
8. Interlockings
9. Control panels and human-machine interfaces

The nine areas of the curriculum include content and learning objectives at various levels of difficulty. Level 100 training modules are introductory content and may overlap with other crafts that share a core of basic mechanical, electrical and electronic knowledge. Level 200 training areas are specific to rail signal maintenance and build on the foundation technical knowledge, skills and abilities developed in the level 100 training areas. Level 300 training modules are the more advanced learning objectives imparting skills, knowledge and abilities required for signal technicians and journeyman to execute all of the job responsibilities required of a typical signal maintainer. The training guideline also includes an advanced 400-level component that would apply to the maintenance and troubleshooting skills of an advanced technician.

The labor-management subject matter experts on the Signal Training Joint Steering Committee developed the training curriculum and guidelines with the expectation that training would be instructor-led and include on-the-job training under the supervision of an experienced and qualified journeyman or technician. Completion
of level 100 to 300 learning objectives would typically require a three-year period, though these guidelines do not include instructional hour and on-the-job hours recommendations.

2.1 Signals Overview (two modules, levels 100 and 200)

100. Overview

- **100-1. History and Purpose of Signal Systems**
  100-1-1. Describe how signals are used to maximize capacity of limited track safely
  100-1-2. Describe different failures that caused something to be done to improve the system
  100-1-3. Describe different systems that have been used throughout history

- **100-2. Fail safe Principles of Signals**
  100-2-1. Describe the importance of train order/time tables
  100-2-2. Describe how continuous refinements make the system more fail safe
  100-2-3. Explain why system has to fail in a safe manner

- **100-3. Introduction to Track Circuits**
  100-3-1. Describe normally energized relays on track circuits
  100-3-2. Describe normally de-energized relays on track circuits
  100-3-3. Explain how most restrictive aspects/a signal set at “danger”
  100-3-4. Define and describe the uses of vital relays
  100-3-5. Explain reasons for regular inspection and testing of vital relays
  100-3-6. Inspect/test vital relays
  100-3-7. Perform vital relay testing

- **100-4. Safety Principles**
  100-4-1. Describe process of moving people safely
  100-4-2. Explain the how the purpose of system is to keep trains from colliding

- **100-5. Rail Roadway Worker Protection**

- **100-6. Safe Train Operation/Expedited Train Movement**
  100-6-1. Demonstrate ability to coordinate track related activities with central dispatch
  100-6-2. Describe how individuals responsible for own safety
  100-6-3. Describe importance of maintaining awareness of your environment
  100-6-4. Describe that human communication is a *vital* part of the process; cannot lose sight of those working on the tracks
  100-6-5. Describe the importance of human communications to central control to train mechanics to operators and all staff
  100-6-6. Describe the overall layout of your system to reduce your personal risk/injury
  100-6-7. Describe why there is a need for more reliable system to track the whereabouts of those working on the tracks for safety reasons
  100-6-8. Explain function of permissive proceed signal and how it is unique to each system
  100-6-9. Explain purpose of slow zone/work zone
  100-6-10. Explain results of failure to comply (high risks and dangers)
  100-6-11. Explain rules, policy and procedures at your organization
  100-6-12. Explain why there is no room for human error

- **100-7. Regulatory/Regulations (Importance of Testing)**
  100-7-1. Demonstrate awareness and comply with rules and regulations
  100-7-2. Describe different levels of rules and regulations (company, FRA, FTA, levels of government) and the jurisdiction of each

- **100-8. Signal System Operation**
100-8-1. Demonstrate ability to refer to glossary of terms/nomenclature

- **100-9. Special Tools**
  100-9-1. Explain the use and purpose of preventive maintenance and standard operating procedures at your agency
  100-9-2. Explain the use of an access vehicle

- **100-10. Test Equipment**
  
  **NOTE:** Generally these will be specific to individual agencies.

  100-10-1. Demonstrate ability to use switch obstruction gauge
  100-10-2. Demonstrate ability to use oscilloscope/spectrum analyzer
  100-10-3. Demonstrate ability to use shunt strap/shunt cord
  100-10-4. Demonstrate ability to use RR volt/ohm meters
  100-10-5. Demonstrate ability to use automatic train stop test equipment
  100-10-6. Demonstrate ability to use frequency specific volt meters
  100-10-7. Demonstrate ability to use IJ checker
  100-10-8. Demonstrate ability to use Megger
  100-10-9. Demonstrate ability to use relay testers
  100-10-10. Demonstrate ability to clamp on amp meter (both AC and DC)
  100-10-11. Demonstrate use of surge coils
  100-10-12. Demonstrate ability to use stopwatches

- **100-11. Function and purpose of signal equipment and defining nomenclature**
  100-11-1. Explain FRA nomenclature
  100-11-2. Explain AREMA nomenclature
  100-11-3. Explain IEEE nomenclature (developing CBTC)
  100-11-4. Explaining the use of barcodes
  100-11-5. Explain signal nomenclature
  100-11-6. Explain access and use of APTA standards and recommended best practices

- **100-12. Advanced Test Equipment**
  100-12-1. Demonstrate ability to maintain, calibrate and care for test equipment
  100-12-2. Maintain laptops, software and PTE (portable test equipment)
  100-12-3. Maintain packet checker
  100-12-4. Demonstrate ability to use clamp-on amp meter (both AC and DC)
  100-12-5. Demonstrate ability to use surge coils

200. Overview

- **200-1. Test Equipment (Specialized Testing Equipment)**
  200-1-1. Demonstrate ability to maintain, calibrate and care for test equipment
  200-1-2. Perform maintenance on test equipment
  200-1-3. Demonstrate ability to use and maintain laptops, software and PTE
  200-1-4. Perform maintenance on laptops, software and PTE
  200-1-5. Perform maintenance on packet checker

- **200-2. Power**
  200-2-1. Verify operation of power supply
  200-2-2. Check and verify power supply
  200-2-3. Check input/output using prints
2.2 Train Control (four modules, levels 100 through 400)

101. Train Control (Intro and Overview)
   • 101-1. The fundamentals of DC track circuits
     101-1-1. Understand circuit principles and operations of a DC track circuit
     101-1-2. Identify track components
     101-1-3. Inspect and perform preventive maintenance on a DC track circuit
   • 101-2. Reading track circuit prints and documentation
     101-2-1. Demonstrate ability to use aspect charts
     101-2-2. Demonstrate ability to use track plans
     101-2-3. Demonstrate ability to use train markers
     101-2-4. Demonstrate ability to use electrical prints
     101-2-5. Identify equipment location (rack)
     101-2-6. Identify control lines
   • 101-3. DC Track Circuits and Related Components
     101-3-1. Describe signals and aspects
     101-3-2. Demonstrate ability to read schematics
     101-3-3. Describe traffic direction
     101-3-4. Identify and understand function of rectifier/battery
     101-3-5. Identify and understand function of the resistor
     101-3-6. Identify and understand function of track fuse
     101-3-7. Identify and understand function of down the rail
     101-3-8. Identify and understand function of fuse on the relay end
     101-3-9. Identify and understand function of 1-to-1 transformer
     101-3-10. Identify and understand function of relay
   • 101-4. Coded Track Circuits
     101-4-1. Describe how code is transmitted to the rail
     101-4-2. Identify components of a coded AC track circuit
     101-4-3. Describe difference between train detection and cab signals

201. Train Control (Inspection and Maintenance)
   • 201-1. DC Track Circuits Inspection and Maintenance
     201-1-1. Understand function of all DC Track circuit components
     201-1-2. Perform an inspection and basic maintenance of full circuit, including:
     201-1-3. Demonstrate ability to do track profiles for AC and DC (performance profiles)
     201-1-4. Perform shunt test
     201-1-5. Demonstrate ability to do polarity check (that polarity is different from one track to the next)
     201-1-6. Set up base reference
     201-1-7. Inspect and maintain rectifier/battery
     201-1-8. Inspect and maintain the resistor
     201-1-9. Inspect and maintain track fuse
     201-1-10. Inspect and maintain down the rail
     201-1-11. Inspect and maintain fuse on the relay end
     201-1-12. Inspect and maintain 1-to-1 transformer
     201-1-13. Inspect and maintain relay
     201-1-14. Inspect and maintain automatic block system
201-1-15. Inspect and maintain switch circuit controllers
201-1-16. Inspect and maintain repair relay and relay logic circuits

• **201-2. DC track Circuits Basic Troubleshooting**
  201-2-1. Identify and correct basic common faults in DC track circuits
  201-2-2. Check track voltage at the receive end in the house
  201-2-3. Check track voltage at feed end, same as in the house
  201-2-4. Inspect for broken rail and wires
  201-2-5. Check integrity of insulated joints

• **201-3. AC Track Circuits Inspection and Maintenance**
  201-3-1. Understand function of all AC track circuit components
  201-3-2. Perform an inspection and basic maintenance of full circuit
  201-3-3. Inspect and maintain fuse
  201-3-4. Inspect and maintain transformer
  201-3-5. Inspect and maintain primary fuse
  201-3-6. Inspect and maintain secondary fuse
  201-3-7. Inspect and maintain variable resistor
  201-3-8. Inspect and maintain track fuse
  201-3-9. Inspect and maintain rail
  201-3-10. Inspect and maintain bond wires
  201-3-11. Inspect and maintain track leads
  201-3-12. Inspect and maintain insulated joints
  201-3-13. Inspect and maintain fuse on the relay end
  201-3-14. Inspect and maintain adjustable resistor
  201-3-15. Inspect and maintain isolation transformer (on single-rail track circuits)
  201-3-16. Inspect and maintain frequency (60 Hz/100 Hz)
  201-3-17. Inspect and maintain impedance bonds
  201-3-18. Inspect and maintain narrow and broad band shunts
  201-3-19. Inspect and maintain single rail/double rail
  201-3-20. Inspect and maintain AC vane relays
  201-3-21. Inspect and maintain DC-to-AC code converters
  201-3-22. Inspect negative return bonds

• **201-4. AC Track Circuits Basic Troubleshooting**
  201-4-1. Identify and correct basic common faults in AC track circuits
  201-4-2. Check track voltage at the receive end in the house
  201-4-3. Check track voltage at feed end, same as in the house
  201-4-4. Inspect rail bonds and for broken rail and wires
  201-4-5. Check integrity of insulated joints
  201-4-6. Determine whether phase angles are correct
  201-4-7. Determine whether a problem is due to a ground or DC propulsion current

• **201-5. Track Circuit Protective Devices Inspection and Maintenance**
  201-5-1. Inspect and maintain surge suppressors
  201-5-2. Inspect and maintain ground fault detectors
  201-5-3. Inspect and maintain lightning arrestors
  201-5-4. Inspect and maintain equalizers
  201-5-5. Inspect and maintain fuses
• 201-6. Audio Frequency Overlay (AFO) Train Detection Systems Inspection and Maintenance
  201-6-1. Inspect and maintain carrier frequency
  201-6-2. Inspect and maintain track frequency
  201-6-3. Inspect and maintain power levels
  201-6-4. Inspect and maintain transmitters, receivers, transceivers
  201-6-5. Inspect and maintain frequency compatibility “for harmonics”
  201-6-6. Inspect and maintain common usage areas for overrun circuits
  201-6-7. Inspect and maintain transmitter
  201-6-8. Inspect and maintain audio frequency overlay
  201-6-9. Inspect and maintain phase shift overlay
  201-6-10. Inspect and maintain modulated track frequency
  201-6-11. Inspect and maintain indicating track occupancy (no train means the relay is up)
  201-6-12. Inspect and maintain modulated train/cab frequency (transmitted only when train is present)
  201-6-13. Demonstrate ability to transmit speed information
  201-6-14. Inspect and maintain twisted pair
  201-6-15. Inspect and maintain transmitting mini bond
  201-6-16. Inspect and maintain running rail
  201-6-17. Inspect and maintain receiving mini bond (tuned to receive signal from the transmitter [frequency selective])
  201-6-18. Inspect and maintain receiver
  201-6-19. Put out DC voltage to energize the relay
  201-6-20. Inspect and maintain track relay (vital relay)

• 201-7. AFO Train Detection Systems Basic Troubleshooting
  201-7-1. Check transmit voltage at test points
  201-7-2. Check train transmit voltage and frequency
  201-7-3. Check receive voltage at test points
  201-7-4. Check track receive voltage
  201-7-5. Check voltage input to receive board
  201-7-6. Check receive level
  201-7-7. Check rail and components
  201-7-8. Check track frequency

• 201-8. Coded Track Circuits Inspection and Maintenance
  201-8-1. Inspect and maintain coded track circuit
  201-8-2. Inspect and maintain code transmitting and following relays
  201-8-3. Inspect and maintain AC coded track

301. Train Control (Troubleshooting and Repair)
  • 301-1. DC Track Circuits Troubleshooting
    301-1-1. Follow general troubleshooting process including:
      - Check status; is it working or not?
      - Check for presence of a grounded circuit
      - Check voltage in/out
      - Check relays
      - Check insulated joints
      - Check bonds
- Understand and check track schematics
- Verify rail integrity
- Check feed and relay resistors
- Check feed and relay fuse
- Check track connections and terminations
- Check fouling wires
- Check train transmit voltage and frequency

301-1-2. Troubleshoot, adjust or repair 1-to-1 transformer
301-1-3. Troubleshoot, adjust or repair fuse on the relay end
301-1-4. Troubleshoot, adjust or repair relay
301-1-5. Troubleshoot, adjust or repair the rectifier/battery
301-1-6. Troubleshoot, adjust or repair the resistor
301-1-7. Troubleshoot and repair interlocking (verify request/response)
301-1-8. Troubleshoot and repair automatic block system
301-1-9. Troubleshoot and repair switch circuit controllers
301-1-10. Troubleshoot and repair relay and relay logic circuits
301-1-11. Troubleshoot and repair track circuit
301-1-12. Troubleshoot and repair a circuit ground

• **301-2. AC Track Circuits Troubleshooting**

301-2-1. Troubleshoot, adjust or repair adjustable resistor
301-2-2. Troubleshoot, adjust or repair frequency (60 Hz/100 Hz)
301-2-3. Troubleshoot, adjust or repair fuse on the relay end
301-2-4. Troubleshoot, adjust or repair insulated joints
301-2-5. Troubleshoot, adjust or repair isolation transformer (on single-rail track circuits)
301-2-6. Troubleshoot, adjust or repair track leads
301-2-7. Troubleshoot, adjust or repair bond wires
301-2-8. Troubleshoot, adjust or repair fuse
301-2-9. Troubleshoot, adjust or repair primary fuse
301-2-10. Troubleshoot, adjust or repair secondary fuse
301-2-11. Troubleshoot, adjust or repair track fuse
301-2-12. Troubleshoot, adjust or repair transformer
301-2-13. Troubleshoot, adjust or repair variable resistor
301-2-14. Troubleshoot, adjust or repair AC vane relays
301-2-15. Troubleshoot, adjust or repair DC-to-AC code converters
301-2-16. Troubleshoot, adjust or repair impedance bonds
301-2-17. Troubleshoot, adjust or repair narrow and broad band shunts
301-2-18. Troubleshoot, adjust or repair single rail/double rail
301-2-19. Test voltage on secondary transformer
301-2-20. Troubleshoot and repair a circuit ground

• **301-3. Track Circuit Protective Devices Troubleshooting**

301-3-1. Troubleshoot, adjust or repair equalizers
301-3-2. Troubleshoot, adjust or repair fuses
301-3-3. Troubleshoot, adjust or repair ground fault detectors
301-3-4. Troubleshoot, adjust or repair lightning arrestors
301-3-5. Troubleshoot, adjust or repair surge suppressors

• **301-4. AFO Train Detection Systems Troubleshooting**
301-4-1. Follow general troubleshooting process including:
   - Adjust transmit voltage and receive voltage
   - Use of frequency selective (or specific) voltmeter
301-4-2. Troubleshoot, adjust or repair carrier frequency
301-4-3. Troubleshoot, adjust or repair common usage areas for overrun circuits
301-4-4. Troubleshoot, adjust or repair frequency compatibility “for harmonics”
301-4-5. Troubleshoot, adjust or repair power levels
301-4-6. Troubleshoot, adjust or repair track frequency
301-4-7. Troubleshoot, adjust or repair transmitter
301-4-8. Troubleshoot, adjust or repair transmitters, receivers, transceivers
301-4-9. Troubleshoot, adjust or repair modulated train/cab frequency
301-4-10. Troubleshoot, adjust or repair audio frequency overlay
301-4-11. Troubleshoot, adjust or repair indicating track occupancy
301-4-12. Troubleshoot, adjust or repair modulated track frequency
301-4-13. Troubleshoot, adjust or repair phase shift overlay
301-4-14. Troubleshoot, adjust or repair receiver
301-4-15. Troubleshoot, adjust or repair receiving mini bond
301-4-16. Troubleshoot, adjust or repair track relay (vital relay)
301-4-17. Troubleshoot, adjust or repair transmitting mini bond
301-4-18. Troubleshoot, adjust or repair twisted pair
301-4-19. Put out DC voltage to energize the relay
301-4-20. Replace circuit board with proper frequency

• 301-5. Interlocking Troubleshooting
  301-5-1. Describe how interlocking may be controlled by automatic, remote or local control
  301-5-2. Describe how interlocking may be controlled by all three, one at a time
  301-5-3. Troubleshoot and repair event recorders

• 301-6. Using Frequency Shift Key (FSK)

• 301-7. Coded Track Circuit Troubleshooting
  301-7-1. Troubleshoot, adjust or repair AC coded track
  301-7-2. Troubleshoot, adjust or repair code transmitting and following relays
  301-7-3. Troubleshoot, adjust or repair coded track circuit

• 301-8. Advanced Track Circuit and Transmission/Receiving Troubleshooting
  301-8-1. Check train transmit voltage and frequency

401. Train Control (Installation, Rebuild, Setup and Testing)
• 401-1. DC Track Circuits Installation, Rebuild and Testing
  401-1-1. Install, replace, rebuild, set up or test 1-to-1 transformer
  401-1-2. Install, replace, rebuild, set up or test fuse on the relay end
  401-1-3. Install, replace, rebuild, set up or test relay
  401-1-4. Install, replace, rebuild, set up or test the rectifier/battery
  401-1-5. Install, replace, rebuild, set up or test the resistor

• 401-2. AC Track Circuits Installation, Rebuild and Testing
  401-2-1. Install, replace, rebuild, set up or test AC vane relays
  401-2-2. Install, replace, rebuild, set up or test DC-to-AC code converters
  401-2-3. Install, replace, rebuild, set up or test impedance bonds
  401-2-4. Install, replace, rebuild, set up or test narrow and broad band shunts
  401-2-5. Install, replace, rebuild, set up or test single rail/double rail
401-2-6. Install, replace, rebuild, set up or test adjustable resistor
401-2-7. Install, replace, rebuild, set up or test frequency (60 Hz/100 Hz)
401-2-8. Install, replace, rebuild, set up or test fuse on the relay end
401-2-9. Install, replace, rebuild, set up or test insulated joints
401-2-10. Install, replace, rebuild, set up or test isolation transformer (on single-rail track circuits)
401-2-11. Install, replace, rebuild, set up or test track leads
401-2-12. Install, replace, rebuild, set up or test bond wires
401-2-13. Install, replace, rebuild, set up or test fuse
401-2-14. Install, replace, rebuild, set up or test primary fuse
401-2-15. Install, replace, rebuild, set up or test secondary fuse
401-2-16. Install, replace, rebuild, set up or test track fuse
401-2-17. Install, replace, rebuild, set up or test transformer
401-2-18. Install, replace, rebuild, set up or test variable resistor

• 401-3. Audio Frequency Overlay Installation, Rebuild and Testing
  401-3-1. Install, replace, rebuild, set up or test modulated train/cab frequency
  401-3-2. Install, replace, rebuild, set up or test audio frequency overlay
  401-3-3. Install, replace, rebuild, set up or test indicating track occupancy
  401-3-4. Install, replace, rebuild, set up or test modulated track frequency
  401-3-5. Install, replace, rebuild, set up or test phase shift overlay
  401-3-6. Install, replace, rebuild, set up or test receiver
  401-3-7. Install, replace, rebuild, set up or test receiving mini bond
  401-3-8. Install, replace, rebuild, set up or test track relay (vital relay)
  401-3-9. Install, replace, rebuild, set up or test transmitting mini bond
  401-3-10. Install, replace, rebuild, set up or test twisted pair
  401-3-11. Put out DC voltage to energize the relay
    - Install DC voltage to energize the relay
  401-3-12. Install, replace, rebuild, set up or test carrier frequency
  401-3-13. Install, replace, rebuild, set up or test common usage areas for overrun circuits
  401-3-14. Install, replace, rebuild, set up or test frequency compatibility “for harmonics”
  401-3-15. Install, replace, rebuild, set up or test power levels
  401-3-16. Install, replace, rebuild, set up or test track frequency
  401-3-17. Install, replace, rebuild, set up or test transmitter
  401-3-18. Install, replace, rebuild, set up or test transmitters, receivers, transceivers

• 401-4. Coded Track Circuits Installation, Rebuild and Testing
  401-4-1. Install, replace, rebuild, set up or test AC coded track
  401-4-2. Install, replace, rebuild, set up or test code transmitting and following relays
  401-4-3. Install, replace, rebuild, set up or test coded track circuit

• 401-5. Track Circuit Protective Devices Installation, Rebuild and Testing
  401-5-1. Install, replace, rebuild, set up or test equalizers
  401-5-2. Install, replace, rebuild, set up or test fuses
  401-5-3. Install, replace, rebuild, set up or test ground fault detectors
  401-5-4. Install, replace, rebuild, set up or test lightning arrestors
  401-5-5. Install, replace, rebuild, set up or test surge suppressors
2.3 Turnouts/Switches (four modules, levels 100 through 400)

102. Turnouts (Intro and Overview)
- 102-1. Turnout Layout and Components
  - 102-1-1. Describe theory of operation and purpose of turnouts
  - 102-1-2. Overview of turnout prints
  - 102-1-3. Describe turnout components: rail, frogs, points, etc.
  - 102-1-4. Describe purpose and components of point detection
  - 102-1-5. Describe purpose and components of electric/mechanical locks
- 102-2. Types of Switches
  - 102-2-1. Describe theory of operation; how do switches work?
  - 102-2-2. Describe main features of various types of switches

202. Turnouts (Inspection and Maintenance)
- 202-1. Understanding Layout prints
  - 202-1-1. Demonstrate ability to read switch layout prints (specs, dimensions and tolerances)
  - 202-1-2. Demonstrate ability to read and understand diagrams, prints and schematics
- 202-2. Switch Layout and Components, Inspection and Maintenance
  - 202-2-1. Perform inspection (maintenance and adjustment)
  - 202-2-2. Perform obstruction tests
  - 202-2-3. Inspect/test and maintain detector rods (indication rod)
  - 202-2-4. Inspect/test and maintain electric switch lock
  - 202-2-5. Inspect/test and maintain lock rod
  - 202-2-6. Inspect/test and maintain switch circuit controller and/or external circuit controller
  - 202-2-7. Inspect/test and maintain switch layout
  - 202-2-8. Inspect/test and maintain throw rod
  - 202-2-9. Inspect/test and maintain track components (rail, frogs, points)
  - 202-2-10. Reference fouling wires and circuits (from other modules)
  - 202-2-11. Explain relationship between various turnout components
  - 202-2-12. Inspect/test and maintain bonds
  - 202-2-13. Inspect/test and maintain fouling wires and circuits
  - 202-2-14. Perform preventive maintenance tasks according to regulations or manufacturer’s specifications
- 202-3. Power Switch Inspection and Maintenance
  - 202-3-1. Perform inspection (maintenance and adjustment)
  - 202-3-2. Inspect/test and maintain air source
  - 202-3-3. Inspect/test and maintain hydraulic switch
  - 202-3-4. Inspect/test and maintain electric (AC/DC) switch machines
  - 202-3-5. Inspect/test and maintain pneumatic switch
  - 202-3-6. Inspect/test and maintain solenoid switch
  - 202-3-7. Inspect/test and maintain switch heaters/snow melters
- 202-4. Hand Throw Switches Inspection and Maintenance
  - 202-4-1. Inspect/test and maintain electric/mechanical locks
  - 202-4-2. Inspect/test and maintain spring switch
  - 202-4-3. Inspect/test and maintain slap switch or variable point switch

302. Turnouts (Troubleshooting and Repair)
- 302-1. Switch Layout and Components Troubleshooting
302-1-1. Troubleshoot, adjust or repair connecting rods
302-1-2. Troubleshoot, adjust or repair detector rods (indication rod)
302-1-3. Troubleshoot, adjust or repair electric switch lock
302-1-4. Troubleshoot, adjust or repair lock rod
302-1-5. Troubleshoot, adjust or repair switch circuit controller
302-1-6. Troubleshoot, adjust or repair switch layout
302-1-7. Troubleshoot, adjust or repair throw rod
302-1-8. Troubleshoot, adjust or repair track components (rail, frogs, points)

- **302-2. Power Switch Troubleshooting**
  302-2-1. Troubleshoot, adjust or repair electric/mechanical locks
  302-2-2. Troubleshoot, adjust or repair hydraulic switch
  302-2-3. Troubleshoot, adjust or repair motor AC/DC
  302-2-4. Troubleshoot, adjust or repair pneumatic switch
  302-2-5. Troubleshoot, adjust or repair power (electric) switch
  302-2-6. Troubleshoot, adjust or repair solenoid switch
  302-2-7. Troubleshoot, adjust or repair spring switch
  302-2-8. Troubleshoot, adjust or repair switch circuit controller
  302-2-9. Troubleshoot, adjust or repair switch heaters/snow melters

402. Turnouts (Installation, Rebuild, Setup and Advanced Testing)
- **402-1. Switch Layout and Components Installation, Rebuild and Testing**
  402-1-1. Install, replace, rebuild, set up and/or test connecting rods
  402-1-2. Install, replace, rebuild, set up and/or test detector rods (indication rod)
  402-1-3. Install, replace, rebuild, set up and/or test electric switch lock
  402-1-4. Install, replace, rebuild, set up and/or test hydraulic switch
  402-1-5. Install, replace, rebuild, set up and/or test lock rod
  402-1-6. Install, replace, rebuild, set up and/or test switch circuit controller
  402-1-7. Install, replace, rebuild, set up and/or test switch layout
  402-1-8. Install, replace, rebuild, set up and/or test throw rod
  402-1-9. Install, replace, rebuild, set up and/or test track components (rail, frogs, points)

- **402-2. Power Switch Installation, Rebuild and Testing**
  402-2-1. Install, replace, rebuild, set up and/or test electric/mechanical locks
  402-2-2. Install, replace, rebuild, set up and/or test hydraulic switch
  402-2-3. Install, replace, rebuild, set up and/or test motor AC/DC
  402-2-4. Install, replace, rebuild, set up and/or test pneumatic switch
  402-2-5. Install, replace, rebuild, set up and/or test power (electric) switch
  402-2-6. Install, replace, rebuild, set up and/or test solenoid switch
  402-2-7. Install, replace, rebuild, set up and/or test spring switch
  402-2-8. Install, replace, rebuild, set up and/or test switch heaters/snow melters

2.4 Grade Crossing (four modules, levels 100 through 400)

103. Grade Crossing (Intro and Overview)
- **103-1. Grade Crossing Warning System Theory and Operation**
  103-1-1. Describe grade crossing warning systems history
  103-1-2. Describe equipment, circuits and warning devices
  103-1-3. Describe grade crossing types, (gated and non-gated) and levels of protection
103-1-4. Describe types of warning systems, constant warning time vs. fixed distance warning
103-1-5. Describe regulations pertaining to grade crossings
103-1-6. Describe types and operation of gate mechanisms

203. Grade Crossing (Inspection and Maintenance)
   - 203-1. Grade Crossing Inspection and Maintenance
     203-1-1. Perform preventive maintenance tasks according to regulations or manufacturer’s specs, including items below:
     203-1-2. Inspect and maintain warning devices (gates, warning lights, signage, bells and grade)
     203-1-3. Inspect and maintain grade crossing controls (prediction/protection)
     203-1-4. Inspect and maintain crossing structures
     203-1-5. Inspect and maintain crossing signage
     203-1-6. Inspect and maintain barriers/gate arm
     203-1-7. Inspect and maintain gate mechanisms
     203-1-8. Inspect and maintain approach and island circuits
     203-1-9. Inspect and maintain non-gated grade crossing
     203-1-10. Inspect and maintain event recorders/monitoring equipment
     203-1-11. Inspect and maintain quad gates
     203-1-12. Inspect and maintain traffic signal interface (preemption)
     203-1-13. Perform a post accident inspection

303. Grade Crossing (Troubleshooting and Repair)
   - 303-1. Grade Crossing Warning System Troubleshooting and Repair
     303-1-1. Troubleshoot causes of false activations and activation failures
     303-1-2. Explain processes for if a warning system cannot be repaired promptly
     303-1-3. Troubleshoot, adjust or repair warning devices (gates, warning lights, signage, bells and grade)
     303-1-4. Troubleshoot, adjust or repair grade crossing controls (prediction/protection)
     303-1-5. Troubleshoot, adjust or repair crossing structures
     303-1-6. Troubleshoot, adjust or repair crossing signage
     303-1-7. Troubleshoot, adjust or repair barriers/gate arm
     303-1-8. Troubleshoot, adjust or repair gate mechanisms
     303-1-9. Troubleshoot, adjust or repair approach and island circuits
     303-1-10. Troubleshoot, adjust or repair non gated grade crossing
     303-1-11. Troubleshoot, adjust or repair event recorders/monitoring equipment
     303-1-12. Troubleshoot, adjust or repair quad gates
     303-1-13. Troubleshoot, adjust or repair traffic signal interface (preemption)

403. Grade Crossing (Installation, Rebuild, Setup and Testing)
   - 403-1. Grade Crossing Warning System Installation, Rebuild, Setup and Testing
     403-1-1. Explain how to safely disable a crossing to facilitate emergency repairs
     403-1-2. Demonstrate track circuit frequency selection for grade crossing repairs
     403-1-3. Install, replace, set up or test warning devices (gates, warning lights, signage, bells and grade)
     403-1-4. Install, replace, set up or test grade crossing controls (prediction/protection)
403-1-5. Install, replace, set up or test crossing structures
403-1-6. Install, replace, set up or test crossing signage
403-1-7. Install, replace, set up or test barriers/gate arm
403-1-8. Install, replace, set up or test gate mechanisms
403-1-9. Install, replace, set up or test approach and island circuits
403-1-10. Install, replace, set up or test non gated grade crossing
403-1-11. Install, replace, set up or test event recorders/monitoring equipment
403-1-12. Install, replace, set up or test quad gates

2.5 Power Distribution (four modules, levels 100 through 400)

104. Power Distribution (Intro and Overview)
   • 104-1. Power Distribution Theory and Operation
      104-1-1. Describe theory of operation of local power distribution system
   • 104-2. Primary Power Sources and System Components
      104-2-1. Demonstrate ability to read schematics
      104-2-2. Describe how incoming power comes from utilities, the types of power and its uses for signaling systems
      104-2-3. Describe operation of breakers
      104-2-4. Describe power source
      104-2-5. Explain how to sectionalize power sources for testing and troubleshooting and repair on low and high tension
      104-2-6. Explain how to properly phase different power sources
      104-2-7. Explain how to use voltage tester and phasing tester
      104-2-8. Explain how to perform insulation testing and cable fault testing on low and high tension sources
      104-2-9. Describe theory of operation of pneumatic power distribution system
      104-2-10. Explain how to sectionalize power sources for testing and troubleshooting and repair on pneumatic systems

204. Power Distribution (Inspection and Maintenance)
   • 204-1. Primary Power Sources, Inspection and Maintenance
      204-1-1. Demonstrate ability to troubleshoot using a meter
      204-1-2. Inspect and maintain DC power rectified
      204-1-3. Inspect and maintain frequency converters
      204-1-4. Inspect and maintain rectifiers
      204-1-5. Inspect and maintain solar panels
      204-1-6. Inspect and maintain Transfer switches
      204-1-7. Inspect and maintain transformer, circuit breakers, cables
      204-1-8. Inspect and maintain pneumatic supplies and allied equipment
   • 204-2. Secondary power sources inspection and maintenance
      204-2-1. Demonstrate ability to troubleshoot using a meter
      204-2-2. Inspect and maintain batteries
      204-2-3. Inspect and maintain chargers
      204-2-4. Inspect and maintain inverters
      204-2-5. Inspect and maintain rectifiers
      204-2-6. Inspect and maintain secondary power
204-2-7. Inspect and maintain solar panels
204-2-8. Inspect and maintain UPS (emergency or standby power)

- **204-3. Power Distribution System Inspection and Maintenance**
  204-3-1. Demonstrate ability to troubleshoot using a meter
  204-3-2. Inspect and maintain AC power
  204-3-3. Inspect and maintain batteries
  204-3-4. Inspect and maintain chargers
  204-3-5. Inspect and maintain DC power rectified
  204-3-6. Inspect and maintain primary power
  204-3-7. Inspect and maintain rectifiers
  204-3-8. Inspect and maintain solar panels
  204-3-9. Inspect and maintain transfer switches
  204-3-10. Inspect and maintain transformer, circuit breakers, cables
  204-3-11. Inspect and maintain UPS (emergency or standby power)

304. Power Distribution (Troubleshooting and Repair)
- **304-1. Primary Power Sources, Troubleshooting**
  304-1-1. Troubleshoot, adjust or repair AC power
  304-1-2. Troubleshoot, adjust or repair DC power rectified
  304-1-3. Troubleshoot, adjust or repair rectifiers
  304-1-4. Troubleshoot, adjust or repair transformer, circuit breakers, cables
  304-1-5. Troubleshoot, adjust or repair grounds; determine what type of ground is present
  304-1-6. Replace a rectifier
- **304-2. Secondary Power Sources Troubleshooting**
  304-2-1. Troubleshoot and replace batteries
  304-2-2. Troubleshoot and replace chargers
  304-2-3. Troubleshoot and replace inverters
  304-2-4. Troubleshoot, adjust or repair secondary power
  304-2-5. Troubleshoot, adjust or repair UPS (emergency or standby power)
- **304-3. Power Distribution System Troubleshooting**
  304-3-1. Troubleshoot, adjust or repair AC power
  304-3-2. Troubleshoot and replace batteries
  304-3-3. Troubleshoot and replace chargers
  304-3-4. Troubleshoot and replace frequency converters
  304-3-5. Troubleshoot and replace inverters
  304-3-6. Troubleshoot, adjust or repair primary power
  304-3-7. Troubleshoot, adjust or repair rectifiers
  304-3-8. Troubleshoot, adjust or repair transfer switches
  304-3-9. Troubleshoot, adjust or repair transformer, circuit breakers, cables
  304-3-10. Troubleshoot, adjust or repair UPS (emergency or standby power)
  304-3-11. Troubleshoot, adjust, or repair air equipment, such as pneumatic train stops and switches. Sectionalize air mains
  304-3-12. Perform ground detection testing

404. Power Distribution (Installation, Rebuild, Setup and Testing)
- **404-1. Primary Power Sources Installation**
  404-1-1. Install, replace, rebuild, set up or test AC power
404-1-2. Install, replace, rebuild, set up or test batteries
404-1-3. Install, replace, rebuild, set up or test chargers
404-1-4. Install, replace, rebuild, set up or test DC power rectified
404-1-5. Install, replace, rebuild, set up or test frequency converters
404-1-6. Install, replace, rebuild, or set up inverters
404-1-7. Install, replace, rebuild, set up or test primary power
404-1-8. Install, replace, rebuild, set up or test rectifiers
404-1-9. Install, replace, rebuild, set up or test transfer switches
404-1-10. Install, replace, rebuild, set up or test transformer, circuit breakers, cables
404-1-11 Install, replace, rebuild, set up or test UPS (emergency or standby power)

• 404-2. Secondary Power Source Installation
404-2-1. Install, replace, rebuild, set up or test AC power
404-2-2. Install, replace, rebuild, set up or test frequency converters
404-2-3. Install, replace, rebuild, set up or test meter
404-2-4. Install, replace, rebuild, set up or test transfer switches
404-2-5. Install, replace, rebuild, set up or test transformer, circuit breakers, cables

• 404-3. Power Distribution System Installation
404-3-1. Install, replace, rebuild, set up or test batteries
404-3-2. Install, replace, rebuild, set up or test chargers
404-3-3. Install, replace, rebuild, set up or test inverters
404-3-4. Install, replace, rebuild, set up or test secondary power
404-3-5. Install, replace, rebuild, set up or test UPS (emergency or standby power)

2.6 Signals (three modules, levels 200 through 400)

205. Signals (Inspection and Maintenance)

• 205-1. Signaling Systems Inspection and Maintenance
205-1-1. Inspect/test and maintain automatic train protection (ATP)
205-1-2. Inspect/test and maintain automatic train operation (ATO)
205-1-3. Inspect/test and maintain automatic train supervision (ATS)

• 205-2. Wayside Signaling Inspection and Maintenance
205-2-1. Inspect/test and maintain automatic block system (ABS)
205-2-2. Inspect/test and maintain wayside signaling
205-2-3. Inspect/test and maintain interlocking signal system

• 205-3. Train Wayside Communication (TWC) Inspection and Maintenance
205-3-1. Inspect/test and maintain movable block
205-3-2. Inspect/test and maintain communication-based train control (CBTC)
205-3-3. Inspect/test and maintain positive train separation (PTS)
205-3-4. Inspect/test and maintain automatic train control (ATC)

305. Signals (Troubleshooting and Repair)

• 305-1. Signaling Systems Troubleshooting
305-1-1. Troubleshoot, adjust and/or repair automatic train protection (ATP)
305-1-2. Troubleshoot, adjust and/or repair automatic train operation (ATO)
305-1-3. Troubleshoot, adjust and/or repair automatic train supervision (ATS)
305-1-4. Troubleshoot, adjust and/or repair centralized traffic control
305-1-5. Troubleshoot, adjust and/or repair advanced train control system (ATCS)
305-1-6. Troubleshoot, adjust and/or repair advanced automatic train control (AATC)
• **305-2. Wayside Signaling Troubleshooting**
  305-2-1. Troubleshoot, adjust and/or repair automatic block system (ABS)
  305-2-2. Troubleshoot, adjust and/or repair wayside signaling
  305-2-3. Troubleshoot, adjust and/or repair interlocking signal system

• **305-3. Train Wayside Communication (TWC) Troubleshooting**
  305-3-1. Troubleshoot, adjust and/or repair movable block
  305-3-2. Troubleshoot, adjust and/or repair communication-based train control (CBTC)
  305-3-3. Troubleshoot, adjust and/or repair positive train separation (PTS)
  305-3-4. Troubleshoot, adjust and/or repair automatic train control (ATC)

405. Signals (Installation, Rebuild, Setup and Advanced Testing)

• **405-1. Signaling Systems Installation, Rebuild and Setup**
  405-1-1. Install, rebuild, set up and/or test automatic train protection (ATP)
  405-1-2. Install, rebuild, set up and/or test automatic train operation (ATO)
  405-1-3. Install, rebuild, set up and/or test automatic train supervision (ATS)
  405-1-4. Install, rebuild, set up and/or test centralized traffic control
  405-1-5. Install, rebuild, set up and/or test advanced train control system (ATCS)
  405-1-6. Install, rebuild, set up and/or test advanced automatic train control (AATC)

• **405-2. Wayside Signaling Installation, Rebuild and Setup**
  405-2-1. Install, rebuild, set up and/or test automatic block system (ABS)
  405-2-2. Install, rebuild, set up and/or test interlocking signal system

• **405-3. Train Wayside Communication (TWC) Installation, Rebuild and Setup**
  405-3-1. Install, rebuild, set up and/or test movable block
  405-3-2. Install, rebuild, set up and/or test communication-based train control (CBTC)
  405-3-3. Install, rebuild, set up and/or test positive train separation (PTS)
  405-3-4. Install, rebuild, set up and/or test automatic train control (ATC)

2.7 Train Stops (three modules, levels 200 through 400)

206. Train Stops (Inspection and Maintenance)

• **206-1. Mechanical**
  206-1-1. Demonstrate ability to understand electrical prints and ground equipment diagrams
  206-1-2. Explain operation of train stops
  206-1-3. Inspect/test and maintain mechanical parts
  206-1-4. Inspect/test/maintain speed enforcement system (wheel detector)

• **206-2. Magnetics**
  206-2-1. Inspect/test and maintain magnetic stops

• **206-3. Wheel Pickups**
  206-3-1. Inspect/test and maintain wheel pickups

• **206-4. De-rail**
  206-4-1. Inspect/test and maintain de-rail

306. Train Stops (Troubleshooting and Repair)

• **306-1. Mechanical**
  306-1-1. Troubleshoot, adjust or repair mechanical parts
  306-1-2. Identify which modules interface with the trip stop

• **306-2. Magnetics**
  306-2-1. Troubleshoot, adjust or repair magnetic stops
• **306-3. Wheel Pickups**
  306-3-1. Troubleshoot, adjust or repair wheel pickups

• **306-4. De-rail**
  306-4-1. Troubleshoot, adjust or repair de-rail

406. Train Stops (Installation, Rebuild, Setup and Advanced Testing)
• **406-1. De-rail**
  406-1-1. Install, rebuild, or set up de-rail

• **406-2. Magnetics**
  406-2-1. Install, rebuild, or set up magnetic stops

• **406-3. Mechanical**
  406-3-1. Use track install diagram
  406-3-2. Install, replace, rebuild, or set up mechanical parts

• **406-4. Wheel Pickups**
  406-4-1. Install, rebuild or set up wheel pickups

2.8 Interlocking (two modules, levels 100 and 200)
107. Interlocking (Intro and Overview)
• **107-1. Explain Concepts of Interlocking Operation**

207. Interlocking (Inspection and Maintenance)
• **207-1 Interlocking**
  207-1-1. Inspect and maintain manual interlocking
  207-1-2. Inspect and maintain automatic interlocking

307. Interlocking (Troubleshooting and Repair)
• **307-1. Troubleshooting Interlocks**
  307-1-1. Perform route locking test
  307-1-2. Perform approach locking test
  307-1-3. Perform time locking test
  307-1-4. Perform traffic locking test
  307-1-5. Perform indication locking test
  307-1-6. Download and read event reports

2.9 Control Panels (three modules, levels 200 through 400)
208. Control Panels (Inspection and Maintenance)
• **208-1. Local Control Panels/Human-Machine Interfaces (HMI)**
  208-1-1. Inspect and maintain components
  208-1-2. Inspect and maintain safety tool
  208-1-3. Inspect and maintain communication-based train control (GPS)
  208-1-4. Demonstrate ability to read control panel schematics
  208-1-5. Identify functions of each light, button or key
  208-1-6. Explain each panels function as it relates to interlocking
  208-1-7. Replace light indicators and switches

• **208-2. New Technology**
  208-2-1. Inspect and maintain electronic track circuit
  208-2-2. Inspect and maintain programmable logic controllers
208-2-3. Inspect and maintain solid state interlocking
208-2-4. Inspect and maintain computer based interlocking

308 Control Panels (Troubleshooting and Repair)
• 308-1. Local Control Panels/Human-Machine Interfaces (HMI)
  308-1-1. Troubleshoot, adjust or repair control panel components
  308-1-2. Use control panel to troubleshoot the interlocking
  308-1-3. Troubleshoot, adjust or repair communication-based train control (GPS)
• 308-2. New Technology
  308-2-1. Troubleshoot, adjust or repair electronic track circuit
  308-2-2. Troubleshoot and repair PLCs (programmable logic controllers)
  308-2-3. Troubleshoot and repair solid state interlocking
  308-2-4. Troubleshoot and repair solid computer based interlocking

408 Control Panels (Installation, Rebuild, Setup and Testing)
• 408-1. Local Control Panels/Human-Machine Interfaces (HMI)
  408-1-1. Fulfilling testing requirements
  408-1-2. Install or replace control panels
  408-1-3. Perform simulations to test interlocking
• 408-2. New Technology
  408-2-1. Install, replace, rebuild, set up or test electronic track circuit
References
Transportation Learning Center, “People Make the Hardware Work: Transit Experts Call for Labor-

Abbreviations and acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AATC</td>
<td>advanced automatic train control</td>
</tr>
<tr>
<td>APTA</td>
<td>American Public Transportation Association</td>
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<tr>
<td>ABS</td>
<td>automatic block system</td>
</tr>
<tr>
<td>AC</td>
<td>alternating current</td>
</tr>
<tr>
<td>AFO</td>
<td>audio frequency overlay</td>
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<tr>
<td>AREMA</td>
<td>American Railway Engineering and Maintenance-of-Way Association</td>
</tr>
<tr>
<td>ATC</td>
<td>automatic train control</td>
</tr>
<tr>
<td>ATCS</td>
<td>advanced train control system</td>
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<tr>
<td>ATO</td>
<td>automatic train operation</td>
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<tr>
<td>ATP</td>
<td>automatic train protection</td>
</tr>
<tr>
<td>ATS</td>
<td>Automatic Train Supervision</td>
</tr>
<tr>
<td>ATU</td>
<td>Amalgamated Transit Union</td>
</tr>
<tr>
<td>CBTC</td>
<td>communication-based train control</td>
</tr>
<tr>
<td>CTA</td>
<td>Chicago Transit Authority</td>
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<tr>
<td>DC</td>
<td>direct current</td>
</tr>
<tr>
<td>FRA</td>
<td>Federal Railroad Administration</td>
</tr>
<tr>
<td>FSK</td>
<td>frequency shift key</td>
</tr>
<tr>
<td>FTA</td>
<td>Federal Transit Administration</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
</tr>
<tr>
<td>HMI</td>
<td>human-machine interfaces</td>
</tr>
<tr>
<td>Hz</td>
<td>hertz</td>
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<tr>
<td>IBEW</td>
<td>International Brotherhood of Electrical Workers</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers</td>
</tr>
<tr>
<td>LACMTA</td>
<td>Los Angeles County Metropolitan Transportation Authority</td>
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<tr>
<td>MTS</td>
<td>Metropolitan Transit System (San Diego)</td>
</tr>
<tr>
<td>PLC</td>
<td>programmable logic controllers</td>
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<tr>
<td>PTE</td>
<td>portable test equipment</td>
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<tr>
<td>PTS</td>
<td>positive train separation</td>
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<tr>
<td>TCRP</td>
<td>Transit Cooperative Research Program</td>
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<tr>
<td>TWC</td>
<td>train wayside communication</td>
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<tr>
<td>UPS</td>
<td>uninterruptable power supply</td>
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