Elevator and Escalator Maintenance Training Guidelines Standards

Abstract: This document contains standards for a fully accredited Elevator/Escalator Apprenticeship Program.

Keywords: apprenticeship, elevator, escalator, training

Summary: As of 2007, 25 states have adopted formal elevator and escalator maintenance licensing requirements. The transit agency response correspondingly reflects this regulatory environment, as each agency attempts to develop training specific to their regulating authority. The result is largely an unfunded mandate with which no single transit company can afford to comply. This brief description of the dilemma faced by the industry illustrates the urgent need for national guidelines and related training programs.

Scope and purpose: The curriculum, courseware and training guidelines adopted by the group and contained in this Recommended Practice are designed to meet or exceed the licensing requirements of jurisdictions, which currently or in the future, may legislate professional licensure or certification for elevator and escalator technicians. The apprenticeship program will ultimately be registered by the U.S. Department of Labor’s Office of Apprenticeship.
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APTA greatly appreciates the contributions of the National Elevator/Escalator Maintenance Training Standards Development Committee, which provided the primary effort in the drafting of this Recommended Practice:

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1. Development of this standard
The National Elevator/Escalator Maintenance Training Standards Development Committee was formed in 2005 to create a dialog among transit agencies and unions engaged in in-house conveyance equipment maintenance. Several compelling factors brought this group together:

- **First**, the elevator and escalator industry is incorporating digital control technologies into their designs faster than the incumbent workforce can learn these new systems.
- **Second**, every agency has experienced difficulty recruiting qualified elevator/escalator mechanics. In fact, through 2016 the US Department of Labor projects nine percent growth in the number of escalator/elevator positions, leaving transit agencies to compete with private sector employers over an already scarce labor pool. Coincidentally, some 40 percent of the current transit workforce is eligible to retire.
- **Third**, regulatory and legislative changes have required transit agencies to meet state occupational certification requirements for recently hired elevator and escalator maintainers. This regulatory and occupational certification is expected to become more common.

The committee is comprised of labor union and management representatives from North American public transit providers who continue to perform in-house elevator and escalator maintenance. The American Public Transportation Association and the involved transit unions have sponsored this effort, and the Transportation Learning Center (the Center, formerly, the Community Transportation Center) has supported and facilitated this program with funding provided by the U.S. Department of Labor, the Federal Transit Administration and the Transportation Research Board.

1.1 Objective
This committee’s ultimate objective is to develop a fully accredited Elevator/Escalator Apprenticeship Program certified through a national joint apprenticeship and training committee and continuing education training programs for incumbent technicians. The curriculum, courseware and training guidelines adopted by the group are designed to meet or exceed the licensing requirements of jurisdictions, which currently or in the future, may legislate professional licensure or certification for elevator and escalator technicians. The apprenticeship program will ultimately be registered by the U.S. Department of Labor’s Office of Apprenticeship.

1.2 The committee
1.2.1

<table>
<thead>
<tr>
<th>Participants</th>
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<tbody>
<tr>
<td>State</td>
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<tr>
<td>California</td>
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<td>Illinois</td>
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<td>Georgia</td>
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<td>New York</td>
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<td>Pennsylvania</td>
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<td>DC</td>
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<td>APTA</td>
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<td>Transportation Learning Center</td>
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</tbody>
</table>
1.2.2 Meeting dates

The National Elevator/Escalator Maintenance Training Standards Development Committee met on the following dates:

- November 28, 2006
- April 3, 2007
- September 14, 2007
- November 7-8, 2007
- February 21, 2008
- June 14, 2008
- September 17, 2008
- November 5, 2008
- January 8-9, 2009

1.3 Current mix of licensing requirements

As of 2007, 25 states have adopted formal elevator and escalator maintenance licensing requirements. Table 1 describes the current state of elevator and escalator regulation in the jurisdictions represented by the aforementioned transit agencies. This matrix of state and provincial regulations affects transit agencies’ authority to service and maintain their equipment.

The agency response correspondingly reflects this regulatory environment as each agency attempts to develop training specific to their regulating authority. The result is largely an unfunded mandate with which no single transit company can afford to comply. This brief description of the dilemma faced by the industry illustrates the urgent need for national guidelines and related training programs.

<table>
<thead>
<tr>
<th>State/Province</th>
<th>Certification Requirements for Elevator-Escalator Maintainers</th>
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<tbody>
<tr>
<td>California</td>
<td>State-certified apprenticeship with annual renewal. BART is a certified ELES company.</td>
</tr>
<tr>
<td>Georgia</td>
<td>Four-year training program and annual recertification.</td>
</tr>
<tr>
<td>Illinois</td>
<td>State licensing performed by local constructor unions. Works with two years’ experience grandfathered.</td>
</tr>
<tr>
<td>Maryland/District of Columbia</td>
<td>State-administered exam and apprenticeship graduate, with grandfathering for experience.</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>State equipment inspections; no contractor licensing requirements.</td>
</tr>
<tr>
<td>New York</td>
<td>No state requirement.</td>
</tr>
<tr>
<td>Ontario</td>
<td>Provincial certification testing.</td>
</tr>
<tr>
<td>Virginia</td>
<td>State-required exam for contractors.</td>
</tr>
</tbody>
</table>

The partnership opportunity created by the transit industry makes developing an elevator/escalator apprenticeship and continuing education program, along with the corresponding courseware, far more manageable for the group than for any single agency.
1.4 Process and tasks
The maintenance training guidelines working group is nearing completion of an interagency apprenticeship and incumbent training curriculum. The next critical steps include a formal courseware sharing agreement between participating agencies and the collection and development of specialized courseware. The immediate critical needs of the agencies involved demands that the process be abbreviated for short-term gains, while continuing with the long term solution of developing a national joint apprenticeship and training program. Table 2 describes the group’s process to date. The adopted apprenticeship curriculum is presented in Section 2.

### TABLE 2
Process to Date

<table>
<thead>
<tr>
<th>Task</th>
<th>Status</th>
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</thead>
<tbody>
<tr>
<td>1. Job task and maintenance program comparison among participant agencies.</td>
<td>Complete</td>
</tr>
<tr>
<td>2. Workforce skills assessment and training evaluation of each agency.</td>
<td>Complete</td>
</tr>
<tr>
<td>3. Interagency curriculum and training program comparison.</td>
<td>Complete</td>
</tr>
<tr>
<td>4. Comparison of state and provincial training, licensing and certification requirements.</td>
<td>Complete</td>
</tr>
<tr>
<td>5. Curriculum development and adoption.</td>
<td>Complete</td>
</tr>
</tbody>
</table>

2. Adopted Elevator/Escalator Apprenticeship Program
The following pages contain the adopted training content for transit elevator and escalator technicians

2.1 100-level courses
Property-specific orientation (including track safety, flagging, emergency evacuation)

101. Orientation and background
   • 101-1. General Safety Overview
      Name the agencies and organizations that make and enforce safety regulations
      Name several electrical shock hazards and the techniques used to prevent those hazards
      Name the four classes of fire and how to extinguish them
      Describe the technique used to lift a heavy load
      Explain the importance of personal protective equipment (PPE) and name several types
      Explain what MSDS stands for and how it applies to them (RtK)
      Confined space training
   • 101-2. Customer Service
      Crowd control
      Operational signage
   • 101-3. System Security
      Presentation by jurisdiction security force
   • 101-4. Station Orientation
      Explain how to use the transit system and locate all stations
   • 101-5. Safety and emergency procedures
      Explain how to reach both internal and external emergency service personnel
   • 101-6. Public Safety
      Demonstrate the proper barricade setup for both elevators and escalators
102. Electrical and Job Safety
   • 102-1. Developing a Safe Attitude
      Safety overview, personal responsibility
   • 102-2. Using personal protective equipment
      Discuss safety rules concerning PPE
      Determine when and what PPE is required for a job
      Demonstrate the proper use of various PPE
      Explain the proper care and storage of PPE
   • 102-3. Understanding Electrical Safety
      State (by jurisdiction) electrical safety rules
      Explain basic electrical concepts of current, voltage, resistance and insulation
      Discuss the hazards of electricity
      Discuss methods used to prevent electrical accidents
      Use scientific notation and metric measurements
• 102-4. Lockout/Tagout
   Discuss the importance of using correct lockout/tagout procedures
   Identify various types of lockout and tagout devices
   Explain how to use lockout/tagout devices
• 102-5. MSDS (right to know)
   Recognize the importance of safety and its priority
   Discuss OSHA laws and their relation to authority
   Explain how chemicals in the workplace can be a hazard
   Obtain and use Material Safety Data Sheets
   Properly label, store and dispose of hazardous chemicals
   Discuss methods used to determine exposure to hazardous substances, and how to minimize harmful effects

103 Tools and Material Handling
   • 103-1. Basic Hand Tools
      Measuring Tools
      - Explain how to hold a rigid rule correctly when measuring an object and show from which point the measurement begins
      - Describe how to set lock joint transfer-type calipers
      - Identify vernier calipers
      - Explain how to take a measurement with a micrometer caliper
      - Name the parts of a combination square
      Wrenches and Screwdrivers
      - Identify types of materials used for making wrenches
      - Identify open-end, box-end, socket, socket-head, adjustable, torque and striking-face wrenches
      - Describe two sizes that are important in identifying a socket wrench
      - Identify standard, Phillips, offset, and spiral-ratchet screwdrivers
      - List the steps to follow when driving a screw
      Pipefitting Tools
      - Identify a straight pipe wrench, a Stillson wrench, a chain pipe wrench, a strap wrench, and a compound-leverage wrench
      - Explain how to use a pipe wrench
      - Explain why a machinist’s vise should not be used for holding pipe
      - Explain how to thread pipe
      - Explain how to clean a pipe tool
- Explain how to cut and flare tubing
- Explain procedures for brazing
- Demonstrate the ability to braze a section of pipe

**Plumbing Tools**
- Explain how to use a mechanical tubing bender
- List the steps in joining hubless pipe
- Explain why the drain pipe should be completely covered by the force cup
- Name the criteria used in selecting line-clearing tools
- List the steps in measuring pipe when using the center-to-center measuring systems

**Electrician’s Tools**
- Explain how to use an EMT bender
- Explain and demonstrate the use of an analog and digital meter
- Name the uses of the all-purpose tool
- Demonstrate the use of the all-purpose tool
- Explain the use of a knockout punch

**Sheet Metalworking Tools**
- Identify the different types of snips and punches
- List six safety practices to follow when working with sheet metal
- Describe different types of sheet metal
- Demonstrate the ability to measure the thicknesses of sheet metal

**Metalworking Tools**
- Demonstrate the ability to select the proper hacksaw blades for cutting various materials
- Explain the difference between single-cut and double-cut files
- List the types of taps usually found in a tap set
- Explain how to cut an external thread on a bolt, screw, or stud
- Explain how to remove a reamer from a hole

**Hoisting and Pulling Tools**
- Explain how to prevent synthetic and fiber rope from unraveling
- Explain how individual wires and strands of wire are formed into wire rope
- Identify the most appropriate sling for use near-corrosive chemicals
- Identify a slide-hammer puller
- Describe the different kinds of slings and loads

**103-2. Basic Power Tools**

**Electric Drills**
- Name four parts that are common to both the light-duty drill and the heavy-duty drill
- Name the parts of a drill bit
- Explain how to drill a blind hole
- List the safety rules to follow when using electric power tools

**Electric Hammers**
- Explain the difference in hammering action between a percussion hammer and a rotary hammer
- Select the proper chisel to use for each of the following jobs: brick cleaning; general demolition work; edging, chipping and channeling; and removing floor tile
- List the precautions that should be taken to ensure electrical safety when using an electric hammer
- Name two safety items to use when operating an electric hammer in damp or wet areas

**Pneumatic Drills and Hammers**
- Explain how drill size is determined
- Describe the chiseling action of a bull point chisel when it is used to clean masonry seams
- Describe how to use a rivet buster
- Explain drill speed requirements
- Identify various types of drill bits used in pneumatic hammers

**Screwdrivers, Nutrunners, and Wrenches**
- Identify the operating advantages of pneumatic tools
- Define stalling torque
- Describe the clutch action of direct drive, positive drive, and adjustable torque drive
- Explain how to install a bit in an electric screwdriver
- Describe how to install multiple fasteners correctly in a circular pattern
- List safety rules to follow when using power screwdrivers and wrenches
- Describe the difference between pneumatic and electric nutrunners

**Linear-Motion Saws**
- List other names for both the saber saw and the reciprocating saw
- Describe the cutting action of a saber saw
- Explain how to draw a saw blade with regular set teeth and one with wavy set teeth
- Explain how to plunge cut a rectangular opening
- List the types of band saw blades described in this lesson and a few characteristics of each

**Circular Saws**
- Name the major parts of a circular saw
- Describe the cutting action of a circular saw
- List the factors that determine feed speed
- State the definition of an arbor
- Identify different types of blades

**Electric Sanders**
- Explain how to install a sanding belt
- Identify different types of sanding belts
- Explain how to flush the gear chamber of a belt sander
- Discuss the assembly of a sanding disk
- List the safety rules to follow when using a disk sander

**Grinders and Shears**
- State the meaning of each symbol in the six-symbol standard marking system for grinding wheels
- Explain the correct procedure for mounting a grinding wheel
- List safety rules to follow when using a grinder
- Discuss how to maintain grinders

**Tool Sharpening**
- State the reasons for sharpening tools
- Explain the use of whetstones
- Identify a bench stone
- Explain how to sharpen taps, dies, screwdrivers, and chisels

**103-3. Moving Machinery Using a Dolly**
Identify the different types of dollies and their use
Describe the safe procedure of using dollies

**103-4. Moving Machinery Using Roller Pipes**
Explain the difference between wood and steel pipes
Determine the proper number of rollers required
Explain roller friction
Describe the use of shoes and skids with rollers

**103-5. Assembly of Gantry Crane**
Describe the proper use of and limits of a gantry crane
Identify the parts of and inspection procedures for each
Properly assemble using correct steps and procedures
Understand the proper use, inspection and assembly of a gantry crane

- **103-6. Rigging and hoisting**
  - Describe the theoretical principles of the seven basics of mechanisms
  - Solve basic mechanism problems using concepts of mechanical advantage and friction loss
  - Identify the types of rigging jobs in which load equalization or load distribution are necessary
  - Identify the basic rigging safety guidelines
  - Perform necessary calculations for load equalization and distribution
  - Describe and classify the various type of wire rope, fiber rope and chains
  - Properly inspect wire rope and chain
  - Identify various types of slings and their proper use
  - Describe the common types of sling hardware and their proper use
  - Demonstrate how to calculate the efficiency of reeving system

**104. Basic Mathematics**

**NOTE:** Committee discussed integrating content of this module throughout other 100-level modules. Content was agreed to in committee, but method for presenting alone or integrating with other modules was not resolved.

- **104-1. Whole Numbers and Arithmetic Operations**
  - Demonstrate the ability to add, subtract, multiply and divide whole numbers with an accuracy of 75 percent or greater
  - Identify the place value of digits in a whole number
  - Identify and list the prime numbers between 0 and 100
  - Demonstrate the ability to round whole numbers and approximate whole numbers
  - Demonstrate the ability to solve application (word) problems

- **104-2. Integers and Order of Operations**
  - Demonstrate the ability to add, subtract, multiply and divide signed numbers and integers with an accuracy of 75 percent or greater
  - Identify exponential notation
  - Identify a radical
  - Demonstrate the ability to work with positive and negative numbers on a calculator
  - Demonstrate the ability to solve problems observing the order of operations

- **104-3. Decimals and Percents**
  - Demonstrate the ability to add, subtract, multiply and divide decimals and percentages with an accuracy of 75 percent or greater
  - Demonstrate the ability to read, order, and round decimals
  - Demonstrate the ability to multiply and divide by the powers of 10
  - Demonstrate the ability to convert from percent to decimal and decimal to percent
  - Demonstrate the ability to calculate percentages

- **104-4. Fractions**
  - Demonstrate the ability to add, subtract, multiply and divide fractions with an accuracy of 75 percent or greater
  - Demonstrate the ability to change improper fractions into mixed numbers and mixed numbers into fractions
  - Demonstrate the ability to reduce a fraction to its lowest terms
  - Demonstrate the ability to convert fractions to decimals and decimals to fractions
  - Demonstrate the ability to determine equivalent fractions

- **104-5. Measurements and Applications**
  - Demonstrate the ability to work with operations of powers of 10
Demonstrate the ability to work with zeros as an exponent, negative exponents and scientific notation
Demonstrate the ability to work with applications of length, weight, area, and volume
Demonstrate the ability to convert between the customary and metric systems

- 104-6. Algebra, Basic Operations
  Demonstrate how to calculate the value of an expression by performing mixed operations in the correct order
  Demonstrate how to write an algebraic equation, based on a relationship stated in words
  Demonstrate how to solve an algebraic equation for a specific variable

105. Introduction to Electricity
  - 105-1. Review Electrical Safety
  - 105-2. Fundamentals of Electricity
    Power supply, distribution and usage
  - 105-3. Introduction to Electrical Symbols, Schematics and Print Reading
  - 105-4. Motors Transformers and Switches

106. Electrical Meters
  - 106-1. Multimeter basics
    Explain how meters are used to measure current, voltage, and resistance
  - 106-2. Use of meter to measure
  - 106-3. Meter safety
  - 106-4. Understanding meter types

107. Wiring Technologies and Equipment
  - 107-1. Safety Rules in Power Electronics
    Discuss and list the safety rules for avoiding electrical shock
    Describe several causes of electrical burns
    Know the reason for grounding of electrical equipment
    Determine dangerous levels of electrical current as it relates to the human body
      - Physiological effects of electric current on the human body
      - Rules for safe practice and avoiding electric shock
      - Avoiding burns and avoiding equipment related injuries
  - 107-2. Wiring Tools and Insulation Removal
    Discuss and identify by name the different types of hand tools associated with wire
    Demonstrate the ability to strip various types of insulation materials from different gauges of wire
      - Hand tools
      - Stripping techniques
      - Demonstration and practice
  - 107-3. Hand Splicing Techniques
    Demonstrate the ability to make each of the splice types discussed and demonstrated
      - Western Union
      - Twisted pair
      - Fixture joint
      - Knotted tap
  - 107-4. Mechanical Terminals
    Know the maximum allowable temperature for heat shrink tubing
    Demonstrate the ability to make several wire splice connections utilizing wirenuts
    Demonstrate the ability to install heat shrink tubing on various wire connections
      - Wire nuts and bolt splices
      - Snap-lock splices
• 107-5. Electrical Wiring, Connector and Terminal Repair
Discuss the advantage of crimped terminal repairs vs. soldering
Demonstrate the ability to install various sizes of crimp-on wiring terminals both insulated and non-insulated
Explain the difference in terminals and splices used on aluminum wiring as compared to other wiring materials
Discuss why pre-insulated terminals and lugs are color-coded
- Non-insulated terminals and splices
- Specialized terminals for aluminum wire
- Preinsulated terminals lugs and splices
- Specialized crimping techniques

• 107-6. Solder and Soldering Process
Discuss the advantages of using soldering to join two pieces of metal together as an electrical path
Discuss the nature of solder and the wetting action
Explain the proper technique for applying solder and handling the soldering iron during the soldering process
Demonstrate the ability to correctly tin various sizes of stranded wire
Identify the correct tolerances allowed for insulation clearance when soldering to different types of terminals
Explain the various wrapping techniques
Review and discuss the steps of the soldering process
Explain why flux is used in the soldering process
Demonstrate the ability to properly wrap and solder various types of electrical terminations
Identify the characteristics of both acceptable and unacceptable solder connections

108. DC Fundamentals

• 108-1. Safety Rules in Power Electronics
Discuss and list the safety rules for avoiding electrical shock
Describe several causes of electrical burns
Know the reason for grounding of electrical equipment
Determine dangerous levels of electrical current as it relates to the human body
- Physiological effects of electric current on the human body
- Rules for safe practice and avoiding electric shock
- Avoiding burns and avoiding equipment related injuries

• 108-2. Science of Electricity and Electronics
Identify the relationship between elements and compounds
Diagram a model of an atom
Discuss the concepts of atomic weight and atomic number
State the law of charges and explain it using examples
Explain what is meant by electric current, voltage and resistance
Describe the two theories of current direction
Distinguish between conductors, insulators and semiconductors
State and explain Ohm’s law

• 108-3. Basic Instruments and Measurements
Explain and demonstrate the correct procedure for using an ammeter, a voltmeter, and an ohmmeter
Discuss the difference between a DMM and a VOM
Interpret a linear scale
Interpret a nonlinear scale
Calculate the values of shunt resistors and multiplier
Discuss the concept of meter sensitivity
Understand basic electrical diagrams

  Identify different conductor and insulator materials
  Discuss the factors that affect resistance in a conductor
  Identify different types of switching devices
  Identify different types of resistors
  Determine the value of color coded resistors
  Calculate electrical power in watts
  Convert horsepower to watts
  Define polarization as it relates to an electrical circuit
  Determine efficiency of an electrical circuit
  Combine Ohm’s law and Watt’s law to find unknown values in a given circuit
  Discuss different sources of electrical energy
  Explain the difference between primary and secondary
  Calculate the outputs of batteries connected in series and parallel

- **108-5. Series Circuits**
  Determine the total resistance of a series circuit
  Determine the voltage drops in a series circuit
  Determine the current values of a series circuit
  Determine the wattage values of a series circuit
  Apply Ohm’s law to solve for unknown voltage, current, and resistance in a series circuit
  Apply series circuit theory to assist in troubleshooting a series circuit

- **108-6. Parallel Circuits**
  Determine the total resistance of a parallel circuit
  Determine the voltage drops in a parallel circuit
  Determine the current values of a parallel circuit
  Determine the wattage values of a parallel circuit
  Apply Ohm’s law to solve for unknown voltage, current, and resistance in a parallel circuit
  Apply parallel circuit theory to assist in troubleshooting a parallel circuit

- **108-7. Combination (Series-Parallel) Circuits**
  Determine the equivalent circuit resistance for a given combination circuit
  Determine the voltage drops in a combination circuit
  Determine the current values of a combination circuit
  Determine the wattage values of a combination circuit
  Apply combination circuit theory to troubleshoot a combination circuit

**109. AC Fundamentals**

- **109-1. Alternating Current Principles**
  Explain how a generator is used to produce alternating current using a graph to show a typical AC wave
  Define and calculate average (avg), effective (rms), instantaneous voltage (vinst) and voltage peak to peak (vpp)
  Demonstrate the ability to operate an oscilloscope while performing typical circuit measurements
  (amplitude, frequency, time, phase, etc.)
  Determine voltage both AC and DC using an oscilloscope
  Determine the frequency of a waveform using an oscilloscope

- **109-2. Transformers**
  Explain and demonstrate important operating characteristics of single-phase transformers
  Connect transformer windings in series-aiding or series-opposing configurations
Calculate the current and voltage ratios for a given transformer
Determine the phase relationship of a transformer primary to secondary
Determine the frequency of a waveform using an oscilloscope

• 109-3. Series Circuits
• 109-4. Parallel Circuits
• 109-5. Combination (Series-Parallel) Circuits
• 109-6. Basic troubleshooting theory (AC-DC)

110. Basic Hydraulic and Pneumatic Theory & Applications
• 110-1. Safety Rules in Power Hydraulics and Pneumatics
• 110-2. Basic Hydraulic Principles
  Hydraulic pumps, valves, actuators
• 110-3. Basic Pneumatic Principles
  Pneumatic Pumps – Valves – Actuators
• 110-4. Basic Hydraulic and Pneumatic Symbols, Schematics and Print Reading

111. Basic Mechanical Theory & Application
• 111-1. Mechanical Power Transmission
  Discuss the different styles of belts that are used in industry
  Discuss the benefits of a positive-drive belt
  Discuss the benefits of a chain drive system
  Discuss the use of gears and gearboxes
  Define pitch diameter, circular pitch, pitch line and gear ratio
  Perform speed calculations for belt drives, gear drives, and chain drives
  Assemble and perform alignments on belt drives, gear drives, and chain drives
  Properly tension belts and chains
• 111-2. Pumps and Compressors
  List types of pumps in use today
  Explain and calculate volumetric efficiency
  Explain and calculate the delivery of a pump
  Discuss some of the common problems that may be encountered while troubleshooting a pump
• 111-3. Fluid Power
  Discuss some fluid power fundamentals
  Explain psi, psig, psia, and inches of mercury ("Hg)
  Understand how force is transmitted through a hydraulic system
  Understand the effects of compressing air for a fluid power system
  Learn how to recognize the different valves that may be used in a fluid power system
  List and explain at least eight methods of valve actuation
  Discuss the operation of different actuators
  Use a hydraulics/pneumatics trainer to construct fluid systems for various operations
• 111-4. Lubrication
  Explain some basic terms that are used when referring to lubrication
  Discuss the necessity for lubrication
  Discuss the different forms of lubrication
  List the types of lubricants used in industry
  Discuss application of lubrication
  Discuss the importance of a lubrication schedule
  Demonstrate the proper use of a viscometer
  Lubricate equipment using a grease gun and chain oiler
• 111-5. Bearings
  Define radial, axial, and radial-axial loads
  List the different parts of a bearing
  List the different types of antifriction bearings and the different types of plain bearings
  Correctly install and remove a bearing
  List several reasons for bearing failure

• 111-6. Coupled Shaft Alignment
  Discuss the fundamentals of shaft coupling alignment
  Demonstrate how to correctly use the dial indicator to align coupling shafts
  Demonstrate the use of the reverse dial indicator method to correct coupling shaft misalignments
  Demonstrate how to use the feeler gauge, taper gauge and dial caliper to detect and correct coupling shaft
  Explain the advantages and disadvantages of using a laser alignment kit to detect and correct coupling shaft misalignments

• 111-7. Seals and Packing
  Discuss the different styles of belts that are used in industry
  Discuss the benefits of a positive-drive belt
  Discuss the benefits of a chain drive system
  Discuss the use of gears and gearboxes
  Define pitch diameter, circular pitch, pitch line and gear ratio
  List different types of gears
  Perform speed calculations for belt drives, gear drives and chain drives
  Assemble and perform alignments on belt drives, gear drives and chain drives
  Properly tension belts and chains

2.2 200-level courses

200. Overview of vertical transportation
  • 200-1. Elevator/Escalator Types and Styles
  • 200-2. Elevator/Escalator Components and Controls
  • 200-3. Simulator Orientation
  • 200-4. Hydraulic and Pneumatic Diagrams
  • 200-5. Elevator and Escalator as-built drawing review

201. AC Motors, DC Motors and Generators
  • 201-1. Magnetism
    Explain the basic magnetic principles
    State the three laws of magnetism
    Describe the link between electric current and magnetism
    Explain Roland’s law
    Discuss various types of relays and the manner in which they work
    Describe the use of magnetic shields
  • 201-2. Fundamentals of Rotating Machines
  • 201-3. DC Motors and Generators
    Explain the operating principles of a DC motor
    Explain counter-electromotive force
    Identify various DC motors
    Discuss the purpose for, and operation of, motor starting circuits
    Identify and explain the operation of various DC motors
    State the function of the field windings in a DC generator or motor
State the function of the armature in a DC generator or motor

- **201-4. AC Motors**
  - Discuss the operation of an induction motor
  - Identify and explain the operation of various three-phase motors
  - Explain how a split-phase condition is created
  - Discuss the purpose of AC motor protection circuits
  - List the common causes of motor failure
  - Explain basic troubleshooting techniques for AC motors

- **201-5. Motor Controls**
- **201-6. AC Induction Motors**
  - Describe the operation of an induction motor

- **201-7. Synchronous Motors**
  - Describe the operation of a synchronous motor

- **201-8. Three Phase Synchronous Operation**

202. Troubleshooting Electrical/Electronic Systems

- **202-1. Symbols and Circuits Review**
- **202-3. Introduction to troubleshooting DC and AC systems**
- **202-4. Introduction to troubleshooting digital systems**
- **202-5. Circuits Measurement**

203. Introduction to Electrical Ladder Drawings

- **203-1. Ladder Logic vs. Ladder Diagrams**
- **203-2. Reading and interpreting schematics and circuits**
- **203-3. Understanding International diagrams and symbols**
- **203-4. Interpreting blueprints and flow charts**
- **203-5. Concepts of relay logic**
- **203-6. Understanding terminology**
- **203-7. Interpreting logic gates and diagrams**

204. AC Circuit Analysis

- **204-1. Inductance and RL Circuits**
  - Define the terms inductor and inductance
  - Explain how inductance affects current
  - Calculate the transient response time for an RL circuit
  - Define mutual inductance
  - Use various measuring and computing methods to determine the values of currents and voltages in an inductive circuit
  - Determine inductive reactance by using measurements of circuit currents and voltages
  - Calculate the equivalent inductance in both series and parallel circuit arrangements

- **204-2. Capacitance and RC Circuits**
  - Define the terms “capacitor” and “capacitance”
  - Explain how capacitance affects current
  - Calculate the transient response time for an RC circuit
  - Use various measuring and computing methods to determine the values of currents and voltages in a capacitive circuit
  - Determine capacitive reactance by using measurements of circuit currents and voltages
  - Calculate the equivalent capacitance in both series and parallel circuit arrangements

- **204-3. Tuned Circuits and RLC Networks**
Explain resonant frequency and how it affects various RCL circuits
Calculate a resonant frequency
Discuss the characteristics of a series RCL circuit at its resonant frequency
Discuss the characteristics of a parallel RCL circuit at its resonant frequency
List four types of filters and explain their action

205. Semiconductor Fundamentals

- **205-1. Safety Review**
  Discuss and list the safety rules for avoiding electrical shock
  Describe several causes of electrical burns
  Know the reason for grounding of electrical equipment
  Determine dangerous levels of electrical current as it relates to the human body
  - Physiological effects of electric current on the human body
  - Rules for safe practice and avoiding electric shock
  - Avoiding burns and avoiding equipment related injuries

- **205-2. Semiconductors, diodes**
  Explain and demonstrate important operating characteristics of single-phase transformers
  Connect transformer windings in series-aiding or series-opposing configurations
  Calculate the current and voltage ratios for a given transformer
  Determine the phase relationship of a transformer primary to secondary
  Determine the frequency of a waveform using an oscilloscope

- **205-3. DC Power Supplies – Single Phase**
  Draw and describe the basic operation of a half-wave rectifier circuit
  Draw and describe the basic operation of a full-wave rectifier circuit
  Draw and describe the basic operation of a full-wave bridge rectifier circuit
  Describe the basic action of a filter using a simple schematic diagram
  Explain the methods used for improving filtering action
  Construct and test a simple DC power supply circuit

- **205-4. Solid-State Transducers**
  Describe the purpose of a transducer
  List various types of transducers
  Describe the operation of a PTC and NTC thermistor
  Identify typical applications of common transducers
  Describe the operation of a Hall effect transducer

- **205-5. Transistor theory**
  Identify PNP and NPN transistor symbols and their respective component leads
  Explain the operation of a bipolar transistor
  Identify key factors on a transistor operation curve
  Identify common base, common collector and common emitter circuit configurations
  Explain the methods used for testing a bipolar transistor
  Demonstrate the ability to properly test a bipolar transistor
  Silicon-controlled rectifiers (SCRs)
    - Identify and label the schematic diagram of an SCR
    - Explain the operation of an SCR
    - Describe how an SCR operates using a simple circuit
    - Describe how an SCR can be used as a switch to control a simple lamp circuit
    - Describe how an SCR can be used to vary the current in a simple lamp circuit
    - Demonstrate the ability to properly test and SCR
  Triacs, diacs and unijunction transistors
    - Draw the schematic symbol and describe the basic operation of a triac
- Draw the schematic symbol and describe the basic operation of a diac
- Draw the schematic symbol and describe the basic operation of a UJT
- Describe the typical applications of a triac
- Describe the typical applications of a diac
- Describe the typical applications of a UJT

The transistor as an amplifier
- Describe amplifier concepts using a typical circuit for illustration
- Describe the three main classes of amplification using typical circuits

206. Digital Fundamentals

- 206-1. Digital Technology
  Describe the characteristics of industrial and electronic revolutions
  List the members of the technical team in electronics and describe their typical educational backgrounds
  Define such terms as “analog,” “signal,” “digital signal,” “bus,” “MSB,” “LSB,” “DIP,” “IC,” “TTL,” and “CMOS”
  Count to at least 20 in the binary system and convert binary numbers to decimal
  List names given to the two logic levels

- 206-2. Logic Elements
  Recognize switch-based AND, OR and NOT circuits and explain their actions in terms of truth tables and Boolean algebra expressions
  Recognize symbols for integrated circuit AND, OR and NOT logic elements and explain their actions in terms of truth tables, Boolean expressions and timing diagrams
  Describe the actions of multi-input logic elements
  Predict logic levels at all points in circuits containing AND, OR and NOT elements

- 206-3. Combination Logic
  Construct truth tables for combinational logic circuits containing AND, OR and NOT elements based on their logic diagrams
  Construct truth tables for such circuits based on their Boolean expressions
  Write Boolean expressions for combinational logic circuits composed of AND, OR and NOT elements based on their logic diagrams
  Draw logic diagrams for such circuits based on their Boolean expressions
  Write Boolean expressions for combinational logic circuits composed of AND, OR and NOT elements based on their truth tables using sum-of-products and product-of-sums methods

- 206-4. NAND, NOR, XOR Elements
  Construct truth tables for combinational logic circuits containing AND, OR and NOT elements based on their logic diagrams
  Construct truth tables for such circuits based on their Boolean expressions
  Write Boolean expressions for combinational logic circuits composed of AND, OR and NOT elements based on their logic diagrams
  Draw logic diagrams for such circuits based on their Boolean expressions
  Write Boolean expressions for combinational logic circuits composed of AND, OR and NOT elements based on their truth tables using sum-of-products and product-of-sums methods

- 206-5. Binary Number Shortcuts
  Count using the binary numbering system
  Compare place values for the digits of binary numbers
  Convert binary numbers to decimal and decimal numbers to binary
  Add unsigned binary numbers
  Determine the twos complement of binary numbers and use the twos complement method to do binary subtraction
Add signed binary numbers
Determine if overflows have occurred when binary numbers have been added

- **206-6. Numbering Systems and Codes**
  Count using the octal and hexadecimal numbering systems
  Convert between binary and octal numbers and between binary and hexadecimal numbers
  Convert between decimal and octal numbers and between decimal and hexadecimal numbers
  Convert between decimal and binary-coded decimal numbers
  Describe the nature of the gray code and its most important application
  State the meaning of the term “ASCII”

207. Hydraulic and Pneumatic Applications
- 207-1. Practical Hydraulics
- 207-2. Practical Pneumatics
- 207-3. Hydraulic and Pneumatic drawings (review, troubleshooting applications)
- 207-4. Applications of Hydraulics and Pneumatics for ELES
- 207-5. Hydraulic and Pneumatic logical troubleshooting

208. Escalator-Specific: Principles of Operation
- 208-1. Safety Procedures
- 208-2. Principles of Escalator Operation
- 208-3. Escalator Structural Overview
- 208-4. Main Drive Systems
- 208-5. Handrail Drive Systems
- 208-6. Braking Systems
- 208-7. Control Systems

209. Escalator-Specific: Electrical Systems
- 209-1. Safety Procedures
- 209-2. Electrical Systems Sequence of operation
- 209-3. Power Supplies
- 209-4. Wiring Supplies (NEC Code Compliance)
- 209-5. Safety Circuits
- 209-6. Control Circuits
- 209-7. Drive Motor Inspection and Maintenance
- 209-8. Troubleshooting escalator electrical

210. Escalator-Specific: Step Installation and Maintenance
- 210-1. Safety Procedures
- 210-2. Inspection and Troubleshooting
- 210-3. Step Removal and Replacement
- 210-4. Roller Removal and Replacement
- 210-5. Rack Maintenance
- 210-6. Alignment and Adjustment

211. Escalator-Specific: Handrail Installation & Maintenance
- 211-1. General Safety Procedures
- 211-2. Handrail Drive Systems
- 211-3. Inspection and Troubleshooting
- 211-4. Handrail Removal and Replacement
212. Escalator-Specific: Inspection and Basic Maintenance
- 212-1. Lighting
- 212-2. Steps
- 212-3. Handrails
- 212-4. Safety devices
- 212-5. Drive systems
- 212-6. Brakes
- 212-7. Controllers
- 212-8. General Housekeeping procedures
- 212-9. Operational Test
- 212-10. Code Compliance Overview / Jurisdictional testing
- 212-11. Internal communications (authority specific learning objectives)
  Glossary of local terms and language
  Reporting requirements and forms
  Communication procedures

213. Elevator-Specific: Principles of Operation
- 213-1. Safety Procedures
  Entrapment response, evacuation
- 213-2. Traction (Electrical) Elevators & MRL Elevators
- 213-3. Hydraulic Elevators
- 213-4. Rack & Pinion Elevators
- 213-5. ADA Accessibillity (Wheelchair Lifts)
- 213-6. Door Systems
- 213-7. Control Systems
  Understand relay logic
  Understand programmable logic
- 213-8. Authority Specific Entrapment Guidelines
- 213-9. Introduction to Code Specifications (ASME 17.1A)

214. Elevator-Specific: Electrical Systems
- 214-1. Safety Procedures
- 214-2. Electrical Systems sequence of operations
- 214-3. Power Supplies
- 214-5. Safety Circuits
- 214-6. Control Circuits

215. Elevator-Specific: Drive System Maintenance & Repair
- 215-1. General Safety Procedures
- 215-2. Troubleshooting
- 215-3. Gear Drive Systems
- 215-4. Gearless Drive Systems
- 215-5. Hydraulic Drive Systems
- 215-6. Component Removal and Replacement
- 215-7. Lubrication Requirements and Adjustments

216. Elevator-Specific: Principles of Door Operation & Maintenance
- 216-1. Safety Procedures
- 216-2. Principles of Elevator Door Operation
• 216-3. Troubleshooting
• 216-4. Lubrication and Adjustments
• 216-5. Component Removal and Replacement
• 216-6. Alignment and Testing
• 216-7. Code Compliance

217. Elevator-Specific: Traction (Electric) Elevators/MRL
• 217-1. Safety Procedures
• 217-2. Drive Systems
• 217-3. General traction and MRL systems
• 217-4. Control Systems
  Selector
• 217-5. Roping
  Maintaining Sheaves
• 217-6. Hoistway
• 217-7. Troubleshooting
• 217-8. Maintenance Requirements
  Lubrication
• 217-9. Code Compliance

218. Elevator-Specific: Hydraulic Elevators
• 218-1. Safety Procedures
• 218-2. Drive Systems
• 218-3. Control Systems
  Selector
• 218-4. Hoistway
• 218-5. Troubleshooting
• 218-6. Maintenance Requirements
  Lubrication
• 218-7. Code Compliance

219. Elevator-Specific: Inspection and Basic Maintenance
• 219-1. Elevator Car
• 219-2. Lighting
• 219-3. Safety Devices
• 219-4. Machine room & Drive Systems
  Valve system
  Piston seals and jack
  Oil
• 219-5. Brakes
• 219-6. Controllers
• 219-7. Hoistway
• 219-8. Hall / Landing devices
• 219-9. General Housekeeping procedures
• 219-10. Emergency Equipment
• 219-11. Code compliance review

220: Elevator-Specific: Other Systems
• 220-1. Rack & Pinion Elevators
  Safety Procedures
2.3 300-level courses

300. Electrical/Electronic Systems
   • 300-1. Electric Motor Drives
   • 300-2. Mechanical and Solid State Switches
   • 300-3. Testing Diodes, Transistors and Thyristors
   • 300-4. Troubleshooting electronic systems

301. Advanced Electrical Ladder Drawings
   • 301-1. Multiple Page Prints
   • 301-2. Electronic Sensors
   • 301-3. International Drawings
   • 301-4. PLC Prints
   • 301-5. Troubleshooting Exercises

302. Automated Equipment
   • 302-1. Understanding Control Devices
   • 302-2. Sensors – Primary Purposes
   • 302-3. Digital control Devices
   • 302-4. Variable Control Devices
   • 302-5. Applications
   • 302-6. Troubleshooting Exercises

303. Elevator-Specific Courses by Manufacturer and/or Model
   • 303-1. Elevator-Specific: Principles of Operation
   • 303-2. Elevator-Specific: Electrical/Control Systems
   • 303-3. Elevator-Specific: Troubleshooting
   • 303-4. Elevator-Specific: Drive System Maintenance & Repair
• 303-5. Elevator-Specific: Principles of Door Operation & Maintenance
• 303-6. Elevator-Specific: Inspection and Maintenance
• 303-7. Elevator-Specific: Safety Devices

304. Escalator Specific Courses by Manufacturer and/or Model (e.g., Kone, Fujitec, Schindler, Otis)
• 304-1. Escalator Specific - Principles of Operation
• 304-2. Escalator Specific - Electrical / Control Systems
• 304-3. Escalator Specific - Troubleshooting
• 304-4. Escalator Specific - Drive System Maintenance & Repair
• 304-5. Escalator Specific - Step Installation & Maintenance
• 304-6. Escalator Specific - Handrail Installation & Maintenance
• 304-7. Escalator Specific - Inspection and Maintenance
• 304-8. Escalator Specific - Safety Devices

2.4 400-level courses

400. Advanced Controllers
• 400-1. Controller functions and Components
• 400-2. Relay Logic
  Interpretation of Relay-type Instructions
• 400-3. Solid state controllers
• 400-4. Programmable Controller Systems
• 400-5. Troubleshooting I/O Devices and Processors
  Controller Diagnostics
  Diagnostic use of laptop or handheld device
• 400-6. Controller Programming / Reprogramming / Upgrading
  Programming Terminology

401. Manufacturer-Specific Controllers
• 401-1. SLC500 Processor Operation
• 401-2. Introduction to RSLogic Software

402. Advanced Equipment Inspections
• 402-1. Use of human senses to identify problems

403. Root Cause Failure Analysis
• 403-1. Review of OEM Service Bulletins (Find Connections to Local Failures)
• 403-2. Information gathering
• 403-2. Component analysis
• 403-3. Interpretation of statistics (e.g. MTBF, etc.)

404. Predictive Maintenance
• 404-1. Introduction to vibration analysis
• 404-2. Lubrication sampling
• 404-3. Thermal imaging scans
• 404-4. Engineering or vendor discussion / consultation
### Abbreviations and acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AC</td>
<td>alternating current</td>
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<tr>
<td>APTA</td>
<td>American Public Transportation Association</td>
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<tr>
<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
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<tr>
<td>ATU</td>
<td>Amalgamated Transit Union</td>
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<tr>
<td>avg</td>
<td>average</td>
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<tr>
<td>BART</td>
<td>Bay Area Rapid Transit</td>
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<tr>
<td>CMOS</td>
<td>complementary metal–oxide–semiconductor</td>
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<tr>
<td>CTA</td>
<td>Chicago Transit Authority</td>
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<td>DC</td>
<td>direct current</td>
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<tr>
<td>DIP</td>
<td>dual inline package</td>
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<tr>
<td>DMM</td>
<td>digital multimeter</td>
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<tr>
<td>ELES</td>
<td>elevator/escalator</td>
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<tr>
<td>EMT</td>
<td>electrical metallic tubing</td>
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<tr>
<td>Hg</td>
<td>mercury</td>
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<tr>
<td>IBEW</td>
<td>International Brotherhood of Electrical Workers</td>
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<tr>
<td>IC</td>
<td>integrated circuit</td>
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<tr>
<td>LSB</td>
<td>least significant bit</td>
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<tr>
<td>MARTA</td>
<td>Metropolitan Area Rapid Transit Authority (Atlanta)</td>
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<tr>
<td>MRL</td>
<td>machine room-less (elevators)</td>
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<tr>
<td>MSB</td>
<td>most significant bit</td>
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<td>MSDS</td>
<td>material safety data sheets</td>
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<td>MTBF</td>
<td>mean time between failures</td>
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<tr>
<td>NEC</td>
<td>National Electrical Code</td>
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<tr>
<td>NTC</td>
<td>negative temperature coefficient</td>
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<td>NYCT</td>
<td>New York City Transit</td>
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<tr>
<td>PLC</td>
<td>programmable logic controller</td>
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<tr>
<td>PPE</td>
<td>personal protective equipment</td>
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<tr>
<td>psi</td>
<td>pounds per square inch</td>
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<tr>
<td>psia</td>
<td>psi absolute</td>
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<tr>
<td>psig</td>
<td>psi gauge</td>
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<tr>
<td>PTC</td>
<td>positive temperature coefficient</td>
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<tr>
<td>RC</td>
<td>resistor-capacitor</td>
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<tr>
<td>RCL</td>
<td>resistor-capacitor-inductor</td>
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<tr>
<td>RL</td>
<td>resistor-inductor</td>
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<tr>
<td>rms</td>
<td>root mean square</td>
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<tr>
<td>RtK</td>
<td>right to know</td>
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<tr>
<td>SCR</td>
<td>silicon-controlled rectifiers</td>
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<tr>
<td>SEIU</td>
<td>Service Employees International Union</td>
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<tr>
<td>SEPTA</td>
<td>Southeastern Pennsylvania Transit Authority</td>
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<tr>
<td>TTL</td>
<td>transistor-transistor logic</td>
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<tr>
<td>TWU</td>
<td>Transport Workers Union</td>
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<tr>
<td>UJT</td>
<td>unijunction transistor</td>
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<tr>
<td>VOM</td>
<td>volt/ohm meter</td>
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<tr>
<td>vinst</td>
<td>instantaneous voltage</td>
</tr>
<tr>
<td>vpp</td>
<td>voltage peak to peak</td>
</tr>
<tr>
<td>WMATA</td>
<td>Washington Metropolitan Area Transit Authority</td>
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