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National Elevator/Escalator
Maintenance Training Standards
Development Committee

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.

This Recommended Practice represents a common viewpoint of those parties concerned with its provisions, namely, transit operating/planning agencies, manufacturers, consultants, engineers and general interest groups. The application of any standards, practices or guidelines contained herein is voluntary. In some cases, federal and/or state regulations govern portions of a rail transit system's operations. In those cases, the government regulations take precedence over this standard. APTA recognizes that for certain applications, the standards or practices, as implemented by individual rail transit agencies, may be either more or less restrictive than those given in this document.



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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

Participants

State	City	Agency	Union
California	San Francisco	BART	SEIU Local 1132
Illinois	Chicago	CTA	IBEW Local 137
Georgia	Atlanta	MARTA	ATU Local 732
New York	New York	MTA, NYCT	TWU Local 100
Pennsylvania	Philadelphia	SEPTA	TWU Local 234
DC	Washington	WMATA	ATU Local 68
APTA			
Transportation Learning Center			

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 1
Guidelines and Related Training Programs

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

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

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

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

- Splice insulation
- **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 solder 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

- **108-4. Circuit Materials, Energy and Source of Electricity**

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 series 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 an 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 trouble shooting 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**
- **202-2. Meters and Terminology 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 an 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 Accessibility (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**
- **214-4. Wiring Systems (NEC Code Compliance)**
- **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

Drive Systems
Control Systems
Hoistway
Troubleshooting
Maintenance Requirements
Code Compliance

- **220-2. Dumbwaiters**

Safety Procedures
Drive Systems
Control Systems
Hoistway
Troubleshooting
Maintenance Requirements
Code Compliance

- **220-3. Wheelchair lifts**

Safety Procedures
Drive Systems
Control Systems
Hoistway
Troubleshooting
Maintenance Requirements
Code Compliance

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

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