



# **Electrical Industry Construction Training Criteria**

Commercial

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## **Introduction**

The Electrical Industry Training Committee was charged, by the California Apprenticeship Council, with the task of developing uniform minimum training criteria for the Construction Industry's occupation of Electrician.

The Committee has used the CAC's Industry Training Criteria regulation (California Code of Regulations 212.01) as the basis for our work.

This document represents a consensus of a two-thirds majority of the Electrical Industry Training Committee.

At the first meeting it was unanimous that the Electrical Industry needed to be divided into two groups. This is the Commercial and Industrial segment.

We believe that, based on the data in this document, these are the Knowledge, Skills and Abilities that are required to be successful in a career as a Commercial/Industrial Construction Electrician. We have also included an outline that can be used as a basis for curriculum development.

# CURRICULUM GUIDE

The following curriculum guide has been developed to help curriculum planners and training organizations develop a comprehensive course of study that will encompass the skills necessary for a successful career as an electrical construction worker.

This guide covers the entire set of skills, including core and specialty skills, that have been identified from the occupational standards in the prior section.

Curriculum developers and training organizations are encouraged to utilize this guide in their development process. We believe that this guide will lead to a

successful training program and successful career.

The location or space devoted to any particular topic should not be read as an indicator of the importance of that topic to the occupational fitness of the worker.

The organization of the topics is based, to a degree, on increasing complexity; however, it is important to note that there is a high degree of interrelatedness between topics and in developing a curriculum it may be advisable, even necessary, to break topics into components and present them in a differing order

## **I. SAFETY**

### **A. General jobsite safety awareness**

1. why safety is important
2. key factors involved with safe work practices
3. develop respect for electricity
  - a) be aware of dangers of shock
  - b) describe locations of potential shock hazards
  - c) demonstrate use of no contact voltage indicators and other devices to determine if the system is energized
  - d) demonstrate techniques for working on energized circuits
4. Hazards created by poor housekeeping on the job
5. Maintain safe work area and tools
6. Be aware of the dangers of falling object
7. Respect and obey job safety rules

### **B. Emergency procedures**

1. First aid training + CPR

### **C. Compliance with OSHA and EPA regulations**

1. Attend and/or conduct regular safety meeting
2. General OSHA requirements on the jobsite
3. The guidelines for OSHA Assured Equipment Grounding and GFCI usage
4. Use of material safety data sheets (MSDS) to identify and properly handle hazardous materials (e.g. cleaning fluids, transformer oils)

### **D. Substance abuse**

## II. TOOLS, MATERIALS AND HANDLING

### A. Proper tool management

1. Identify common hand and power tools
2. Proper selection and application of hand tools
3. Proper selection and application of power tools
4. Proper care for tools
5. Safe techniques for using ladders
6. Defects that make tools unsafe to use
7. Use of meters to take readings

### B. Proper rigging methods

1. Proper knots
2. Proper techniques for rigging and hoisting
3. Safe capacities for lifting arrangements

### C. Proper digging techniques

1. Depth and shape of holes for supporting poles
2. Proper techniques for digging, grading and leveling trenches for the installation of duct work

### D. Proper use of motorized tools (use of platform lifts, bucket trucks, and truck-mounted cranes)

### E. Proper material management

1. Identify commonly used materials by name
2. Proper selection and application of materials

## III. MATH

### A. Appropriate mathematical calculations to solve for unknowns

1. Arithmetic operators
2. Solving word problems
3. Problems involving fractions
4. Reducing fractions to lowest terms
5. Converting decimals to fractions and back
6. Angles and sides of triangles
7. Unknown angles and sides of triangle
8. Metric prefixes and converting different prefixes
9. Using powers of ten to perform math functions
10. Converting from English to metric measurement systems
11. Algebraic formulas
12. Square roots
13. Ratio, percentages, and proportion
14. Problems using direct and inverse relationships

## IV. ELECTRICAL THEORY

### A. Basic electrical theory

1. Define terms, units of measure
2. Electron flow
3. Producing electrical current
4. Products (effects) of electrical current

### B. Ohm's Law, Kirchoff's Laws, Lenz's Law, Thevenin's and Nortons Theorems

### C. Series circuits

1. Components
2. Resistance of circuits
3. Total resistance
4. Effects of changing voltage and resistance
5. Law of proportion for series voltage divider circuits
6. Power used in circuits
  - a. By components
  - b. Wasted power

### D. Parallel circuits

1. Components
2. Differences between series and parallel circuits
3. Ohm's Law
4. Circuits
5. Total resistance using product-sum and reciprocal methods
6. Alternate current paths
7. Currents
8. Law of proportion
9. Power requirements of components

### E. Combination circuits

1. Combination circuits
2. Components
3. Equivalent resistance
4. Alternate current paths
5. Ohm's Law
6. Power use and dissipation

- F. Characteristics of voltages in circuits
  - 1. Polarity and flow of electrons
  - 2. Distribution and voltage drops
  - 3. Proper wire size needed to lower losses
- G. Characteristics of magnetism/electromagnetism
- H. Theory of superposition and solving for multiple voltage sources circuits
- I. Operation and characteristics of three wire systems
- J. Operation and characteristics of three phase systems
  - 1. identify differences between 3 wire single phase and three phase circuits
  - 2. voltage drop and power loss
- K. AC Theory
  - 1. Terms associated with AC theory
  - 2. Currents and voltages for components and circuits
  - 3. Conductor size using NEC
  - 4. Current and voltage sine waves to demonstrate phase relationships
  - 5. Maximum, effective (rms), average, and peak-to-peak voltage and current
  - 6. Inductance
    - a. Factors that affect inductance
    - b. Behavior of current when inductance is present
    - c. Relationship between current, applied voltage, and counter-electromotive force
    - d. Inductive reactance when frequency and inductance are known
    - e. Inductance, inductive reactance, and unknowns in various circuits
  - 7. Capacitance
    - a. Effects on circuits of capacitance
    - b. Capacitance, capacitive reactance, and frequency
  - 8. Relationships and behaviors of series RL, parallel RL, series RC, parallel RC, series LC, Parallel LC, series LCR and parallel LCR circuits
  - 9. Function, operation and characteristics of rectifiers
    - a. Actions of full-wave and half-wave rectifiers
    - b. Schematics
  - 10. Series resonance, parallel resonance and circuits
  - 11. Filters
  - 12. Power Factor
    - a. Watts, vars and volt-amperes
    - b. Reactive power
    - c. Proper placement of power factor correction capacitors
    - d. Procedure to recognize and correct poor power factor arrangements

### 13. Power quality issues

- a. Causes of poor power quality
- b. The effects of harmonics
- c. Locating harmonics through observation and test equipment
- d. Techniques to reduce or eliminate effects of harmonics

### L. Use of electronics

1. Electron flow through solid state components
2. Precautions against electrostatic discharges around semiconductor devices
3. Functions, operation and characteristics of diodes and zener diodes
  - a. Characteristic curves
  - b. Testing procedures
  - c. Schematics including diodes
4. Functions, operation and characteristics of transducers
  - a. Operation of transducers
  - b. Schematics including transducers
5. Functions, operation and characteristics of various types of transistors (diacs, triacs, SCRs, etc.)
  - a. Operation of transistors
  - b. Current and voltage values
  - c. Testing procedures
  - d. Schematics including transistors
6. Functions, operations, characteristics and circuit configurations of amplifiers
  - a. Basic circuit configurations for various types of amplifiers
7. Functions, operations and characteristics of integrated circuits (ICs)
  - a. Schematics of and including ICs
  - b. Information on data sheets for integrated circuits
8. Functions, operations and characteristics of three main categories of photo-operated
  - a. devices
9. Digital and logic circuits
  - a. Terms associated with digital and logic circuits
  - b. Types of circuits
  - c. The operative symbols for AND, OR, NOT operations
  - d. The use of Boolean Algebra equations, laws, operations and theorems
  - e. Truth tables from Boolean equations and digital switching circuits
  - f. Gate functions and gate circuits
  - g. BUFFER and INVERTER amplifiers and accompanying truth tables
  - h. Operation and characteristics of NAND and NOR logic and accompanying truth tables
  - i. Operation and characteristics of XOR and X NOR logic and accompanying truth tables
  - j. Positive and negative logic and its effect on gate operation
  - k. Digital logic equivalent circuits
  - l. Various optoelectronic devices

## V. CODE REQUIREMENTS

### National Electrical Code and local codes

1. Purpose and intent of electrical codes
2. Scope of NEC and local codes
3. How local codes may differ from NEC
4. Utilizing code book
  - a. Mandatory rules
  - b. Fine Print Rules
  - c. "Neat and workmanlike"
  - d. Locate definitions
  - e. Interpretations
  - f. Recognize and use exceptions
  - g. Materials recognized by the NEC
  - h. Identify code markings
  - i. Distinguish wet, damp and dry locations
  - j. Determine if specific installations are acceptable to the Code
  - k. Requirements for special occupancies and special equipment
  - l. Answer specific questions
5. Use NEC to calculate various general job requirements
  - a. Service conductors, feeders, branch circuits
  - b. Permissible loads on various circuits
  - c. Allowable cable tray fills
  - d. Imparity of various conductors and fill situations
  - e. Imparity of various circuits and load types
  - f. Overload protection for motors, equipment and phase converters
  - g. Minimum ampacity for motor disconnecting means
  - h. Horsepower ratings for motors and disconnecting means
  - i. Grounding requirements
6. Use NEC for hazardous locations
  - a. Hazardous locations by Class
  - b. Equipment and wiring methods necessary for particular hazardous locations

## VI. CONDUCTORS

### A. Various types of conductors

1. Types of conductors and insulators
2. Why some materials are better conductor or insulators than other
3. Effect of heat on insulators
4. Sizing and typing of conductors
  - a. Use letter symbols to identify insulator types
  - b. Use American Wire Gauge chart
  - c. And convert inches, mils, square mils, and circular mils from one to the other
5. Differences between aluminum and copper conductors
6. Properties of high voltage cable
7. Effects of soil conditions on underground cable

### B. Conductor installation techniques

1. Different wiring methods for particular conductors and situations
  - a. Wire connectors
  - b. Types, installation, limitations
2. Different methods of installing conductors in conduits, raceways and cable trays
  - a. Problems which may be encountered
  - b. Maximum tension allowed
  - c. Use of pulling machines to assist in installation of wire
3. Proper splicing methods and techniques for various conductors and locations

### C. Methods for selecting conductors

1. Using Code to determine type of conductor to use in particular situation
2. Using mathematical calculations to determine current carrying capacity of conductors
3. Calculating or selecting cable ampacity from **NEC** tables
4. Loads for sizing conductors
5. Code requirements depending on types of circuits and loads (lighting, appliance, heating, service entrance)

### D. Cable fault situations

1. The types and causes of cable faults
2. Methods and equipment for locating cable faults including terminal, tracing and magnetic detection

## **VII. CONDUIT, RACEWAYS, PANELBOARDS AND SWITCHBOARDS**

- A. Terms associated with conduits and raceways
- B. Conduit and wiring support systems recognized by Code
  - 1. Select appropriate conduit type
  - 2. Select and utilize appropriate connectors
  - 3. Select and utilize appropriate fastening devices and reinforcements
  - 4. Special considerations
- C. Procedures for laying out various types of bends
  - 1. Take-up and gain
  - 2. Kicks and offsets
  - 3. Calculate degrees
  - 4. Back-to-back bends
  - 5. Determine overall Length of conduit for specific situations
  - 6. Locating bending points
  - 7. Four techniques for segment bending
  - 8. Techniques and operations for making concentric bends
  - 9. Radius of circle
- D. Procedures for making bends when fabricating conduits
  - 1. Hand benders to make bends on small diameter conduit
  - 2. Power benders to make bends on larger diameter pipe
    - a. Make offsets using "constants" or "shrink" methods
    - b. Make bends in proper sequence, direction and with necessary accuracy
- E. Fabricating raceways and wiring support systems
- F. Cable assembly wiring methods recognized by the Code
- G. Function, operation and requirements for various panel boards and switch gear
  - 1. Installation of panels
  - 2. Installation of components
  - 3. Wiring and connections
  - 4. Special considerations and occupancies

## **VIII. LIGHTING SYSTEMS**

### A. Function, operation and characteristics of various lighting systems

1. Incandescent
2. Florescent
3. HID
4. Low voltage

### B. Lighting distribution and layout

### C. Installation and connection of fixtures

## **IX. OVERCURRENT DEVICES**

### A. Function, operation and characteristics of overcurrent protection devices

1. Purpose and location of devices
2. Three consideration necessary for electrical component protection
3. Interrupting ratings
4. Short circuit currents
5. Overload and overcurrent situations
6. 10 and 25 foot tap rules
7. Operation and application of fuses
  - b Single element and time delay
  - b The effects of heat
8. Operation and application of various types of circuit breakers (e.g. molded case, air break)
9. Utilize Peak-Let-Thru charts and table
10. Function, operation and characteristic ground fault circuit interrupters
11. Function, operation and characteristics surge protectors
12. Appropriate devices for situation and according to Code

## **X. GROUNDING SYSTEMS**

### A. Functions, operation and characteristics of grounding systems

1. Reasons for grounding systems
2. General types of faults
3. Grounding electrode systems

### B. Sizing, layout and installation of grounding systems

1. NEC requirements and interpretations
2. Size of conductors and electrodes
3. Installation of electrodes
4. Installation of conductors and connections to electrodes

5. The impact of soil conditions on earth grounding systems and equipment
6. Principles and procedures of earth resistance testing
7. Determine when ground fault protection is required

C. Difference between insulation, isolation and elevation

D. Difference between grounding, grounded, and bonding

E. Special circumstances

1. Systems over 1,000 volts
2. Separately derived systems
3. Buildings sharing service

## **XI. PRINTS AND SPECIFICATIONS**

A. Creation of blueprints, plans, and specifications

1. Utilize symbols used in electrical and related trades
2. Recognize functions of basic line types
3. Identify drawing tools and techniques
  - a. Orthographic views
  - b. Types of projections
  - c. Drafting scales
4. Recognize and apply dimensions
5. Prepare "as-built" drawings
6. Differences between wiring diagrams, line drawings, schematics and ladder diagrams
  - a. Given schematics complete wiring diagrams
  - b. Given panels and equipment layouts create drawings showing conduits and conductors using appropriate scale

B. Use of blueprints, plans, and specifications

1. Recognize function of various types of plots, sections, details, schedules, specification sheets, addendums and revisions
2. Determine devices, locations, quantities, feeds, conduit types and sizes and conductor sizes
  - a. Parts of the electrical service
  - b. Identifying special purpose outlets and the loads they serve
  - c. Completing take-off sheets for ordering material
  - d. Determine costs for jobs
  - e. How costs affect job
3. Interpret non-electrical dimensions and considerations
4. Relationships between architectural considerations and electrical installations
5. Correlate information from other trades plans with electrical plans to determine potential conflicts

## **XII. MOTORS, MOTOR CONTROLLERS AND PROCESS CONTROLLERS**

A. Function, operation and characteristics of various types of motors (AC, DC, dual voltage, repulsion, universal, 3 phase, squirrel cage, synchronous)

1. Physical parts of various motors
2. Utilize information sheets, plans, schematics, and motor nameplates to gain information
3. Motor losses
4. Starting and operating characteristics
5. Methods to identify windings in DC motors
6. Means for providing for field failure, current limit, voltage and speed control
7. Block diagrams to demonstrate power supplies, armature, field and control features
8. Torque, locked rotor current, no-load speed, and slip
9. Reasons for low-voltage starting
10. Function, operation and characteristics of stepping motors

B. Proper techniques for motor installations

1. Necessary calculations for electrical requirements per Code
2. Correct power factor
3. Proper wire type and size
4. Appropriate connections
5. How various motors can be made to run at different speed or in reverse direction
  - a. Schematics
  - b. Connections to reverse or change speeds
6. Identify unmarked motor leads
7. Steps for proper handling of motors
  - a. Checks for mechanical defects
  - b. Factors to be checked when a motor arrives at jobsite
  - c. Methods for putting motor into storage

C. Function, operation and characteristics of motor controllers, circuits and devices

1. Ways and means of starting and stopping motors
2. Operation of magnetic coil
3. Use of magnetic starters and controllers
4. Correct sizing of magnetic starters and controllers
5. Difference between starters and contactors
6. Function, operation and characteristics of overload protective devices
  - a. Thermal overload
  - b. Magnetic overload
7. Schematics for various control circuits
8. Two-wire control circuits
9. Three-wire control circuits
10. Interlocking methods
11. Reversing and sequential controllers

12. Jogging, inching, plugging
13. Multiple start-stop controls and selector switches
14. Phase failure relays
15. Various manual and automatic speed control techniques
16. Function, operation and characteristics of variable frequency drives
17. Function, operation, characteristics and installation procedures for programmable logic controls
  - a. Function of central processing unit
  - b. Memory types and sizes
  - c. User and storage memory
  - d. Back-up batteries
  - e. Peripheral devices
18. Ladder diagrams
19. Function, operation and characteristics of timers, counters, sequencers
20. Utilize appropriate manuals and information for start-up, maintenance and testing
21. Utilize schematics for manual starters, automatic starters, speed regulators and controllers

#### D. Function, operation and characteristics of switches and relays

1. Schematics including switches and relays
2. Installation and connection methods for various switch types
3. Installation and connection methods for various relays
4. Function, operation and characteristics of electronic sensor and pilot devices
5. Function, operation and characteristics of control transformers
  - a. Leads of control transformers
  - b. Proper sizing of control transformers

#### E. Mechanical connections to utilize motors

1. Operation of mechanical clutches and magnetic drives
2. Direct and offset drives
3. Proper pulley sizes required

#### F. Process control systems and devices

1. Operating requirements followed by manual and automatic controllers
2. Function, operation, characteristics and installation of:
  - a. Closed loop and open loop systems
  - b. Feedback control
  - c. Proportional control
  - d. Integral control
  - e. Derivative control
3. Block diagrams including control systems and devices
4. The function, operation, and characteristics of sensors and transmitters

### **XIII. GENERATORS AND POWER SUPPLIES**

A. Principles of electromotive force

B. Principles of generating electricity

1. the parts, functions, operation and characteristics of the AC generator
2. the parts, functions, operation and characteristics of the DC generator
3. the "left hand rule" for generators
4. RPM, frequency and number of poles in a given generator
5. 3 phase generation
6. Wye and delta windings
7. 3 phase sine wave

C. Types and configurations of uninterruptible power supplies (UPS)

D. Types and configurations of battery systems used for UPS systems

### **XIV. TRANSFORMERS**

A. Function, operation, and characteristics of transformers

1. electrical principles involved in transformer operation
2. transformer classifications and applications
3. transformer losses
4. ratios for voltage and amperage with respect to turns

B. Selection and installation of transformers

1. nameplate information
2. techniques for sizing transformers (one and three phase)
3. determining if given transformer meets voltage, current, and impedance requirements
4. calculating voltages and currents for load and windings
5. determining whether to use wye or delta wiring schemes
6. steps for receiving and preparing transformer for installation
7. necessary tests to assure proper operation
8. proper techniques for connecting power and load conductors
9. methods for determining proper types and values of electrical protective devices
10. proper grounding procedures

C. Distribution systems

1. functions, operation and characteristics of various types of distribution systems
2. criteria for selecting particular type of distribution system

## **XV. PERSONAL DEVELOPMENT**

### **A Orientation**

1. Make up and organization of the industry
  - a. Jobsite chain of command
    - (1) owner/customer
    - (2) architects/engineers
    - (3) inspection authorities
    - (4) construction managers
    - (5) general contractors
    - (6) other contractors and trades
2. Organizations within industry
  - a. manufacturers
  - b. distributors

### **B. Methods of working with others**

1. the three basic theories of motivation
2. need levels of humans
3. the role of supervisors
  - a. leadership styles appropriate to certain situations
  - b. need for competent supervisors
4. effective communications
  - a. importance of communications in the industry and on the job
  - b. barriers to communications
  - c. keys to effective communications

### **C. Economic considerations**

1. why worker future is tied to employer's
2. responsibilities to employer
  - a. keeping skills current
  - b. managing your future
3. costs of doing business
4. importance of satisfying customers
5. impact of job performance, behavior and appearance on prospects for future work
6. functions of marketing

## **XVI. JOBSITE MANAGEMENT**

- A. Coordinating tool needs with office of other jobs
- B. Coordinating schedule with other crafts
- C. Developing timetables and progress charts
- D. Completing time sheets, logs and other necessary documentation
- E. Clearances or permits if necessary
- F. Inventory and order necessary equipment according to job needs
- G. Developing alternative solutions and choose the best alternative
- H. Planning and organizing tasks to meet deadlines
- I. Supervising and monitoring others
- J. Picturing the way the project will appear when completed

## **XVII. TESTING**

- A. Steps used for various testing processes
  - 1. acceptance testing of cables
  - 2. maintenance testing of generators
  - 3. insulation tests using megohmmeter
- B. Utilizing the results of testing procedures
  - 1. Special requirements for high voltage testing
  - 2. describe potential safety hazards
  - 3. characteristics and properties of high voltage cable and insulators
  - 4. appropriate tests methods, voltages and equipment

## **XVIII. SPECIALTY SYSTEMS**

### **A. Fire Alarms**

- 1. functions, operations and characteristics of various types of fire alarm systems and components
- 2. Code requirements and use Code to answer specific questions
- 3. the functions, operation and characteristics of alarm initiating and indicating devices
- 4. multiplexing of system components
- 5. various types of areas and methods to protect them
- 6. appropriate wiring methods and devices
- 7. utilize manuals to start-up and check out system
- 8. utilize proper manuals and techniques for system maintenance and troubleshooting

### **B. Security Alarms**

- 1. functions, operations and characteristics of various types of security systems and components
- 2. Code requirements and use Code to answer specific questions

3. the functions, operation and characteristics of alarm initiating and indicating devices
4. multiplexing of system components
5. various types of areas and methods to protect them
6. appropriate wiring methods and devices
7. utilize manuals to start-up and check out system
8. utilize proper manuals and techniques for system maintenance and troubleshooting

#### C. Voice, Data, TV, Signaling Systems

1. functions, operation and characteristics of various types of voice, data, TV and signaling systems
2. the proper cabling systems required for various systems (telephone, data, Local Area Networks, etc.)
3. installation and connection techniques for cables and devices
4. how cable defects and installation errors can degrade data transfer
5. utilize manuals to install, test and start-up and check out systems
6. utilize proper manuals and techniques for system maintenance and troubleshooting

#### D. Lightning Protection Systems

1. functions, operation and characteristics of lightning protection systems
2. the sizing, layout and installation of lightning protection systems
3. NEC requirements and interpretations
4. size of conductors and electrodes
5. installation of electrodes
6. installation of conductors and connections to electrodes

#### E. Fiber Optic Systems

1. functions, operation and characteristics of fiber optic cable
2. proper installation techniques
  - a. minimum bend radius
  - b. pulling techniques
  - c. installation hardware
  - d. splicing and termination
3. utilize appropriate manuals and equipment to perform system tests and troubleshooting

#### F. Heating, Air Conditioning and Refrigeration

1. the function, operation and characteristics of heating, air conditioning and refrigeration systems and components
2. utilize appropriate manuals and equipment to perform system tests and troubleshooting