ELECTRIC VEHICLE TECHNICIAN (EVT)

Competency requirements

The EVT basic competencies shown here were produced by the ETA EVT committee members and the staff of ETA in Greencastle, Indiana. They are shown first as CATEGORIES of knowledge, then the Individual ITEMS (pg.2) that are important under and related to each Category. Then the Items are verbalized as COMPETENCIES (pg.8). These describe for each item what a technician must know or have an ability to interact with in performing his/her job as an EV technician.

ELECTRIC VEHICLE TECHNICIAN CATEGORIES LIST:

1.0 Safety Requirements

2.0 Electric Vehicle Fundamentals

3.0 Electrical Theory

4.0 Electronic Systems Components

5.0 Motor Theory

6.0 EV Electronics and Testing Fundamentals

7.0 Batteries

8.0 Energy Delivery Systems

9.0 Charging

10.0 BEV Maintenance and Troubleshooting

ELECTRIC VEHICLE TECHNICIAN
ITEMS LIST:
(Topics of knowledge required by EV technicians)

1.0 SAFETY REQUIREMENTS

1.1. Personal Protection Equipment (PPE)
- 1.1.1. High Voltage Electrical Glove rating system
- 1.1.2. Dangers of working around high voltage
  - 1.1.2.1. Arc Flash, Arc Blast
- 1.1.3. Shop protection equipment requirements
- 1.1.4. Electrical Meter safety requirements and standards
- 1.1.5. PPE required practices

1.2. OSHA Requirements on High Voltage
- 1.2.1. Basic OSHA High Voltage electrical standards
- 1.2.2. Cable color-code system associated with levels of voltage
- 1.2.3. Vehicle work area set up

1.3. Electrical Shock Prevention
- 1.3.1. Personal safety precautions - accident mitigation
- 1.3.2. 'One Hand' rule for working on electrical equipment
- 1.3.3. 'Never Work Alone' concept

1.4. Electrical Shock Response
- 1.4.1. Human physiological reactions to electrical shock
- 1.4.2. Degrees of current the human body can tolerate
- 1.4.3. First Aid for electrical shock victims
- 1.4.4. Dangers involved with artificial respiration
- 1.4.5. Dangers involved in detaching a shock victim from the source of voltage

1.5. High Voltage Safety
- 1.5.1. High Voltage components and connections
  - 1.5.1.1. Safety Interlocks (including high voltage)
  - 1.5.1.2. Service plugs and receptacles
  - 1.5.1.3. High voltage service disconnect
  - 1.5.1.4. High voltage fuse
  - 1.5.1.5. Ignition key block
  - 1.5.1.6. Battery connections
  - 1.5.1.7. Charge port
  - 1.5.1.8. Charge controller
  - 1.5.1.9. DC/DC converter
  - 1.5.1.10. Inverter/motor controller
  - 1.5.1.11. Traction motor
  - 1.5.1.12. Air conditioner
  - 1.5.1.13. Power steering
- 1.5.2. DC current leakage in an EV

1.6. Fire Safety
- 1.6.1. Different classes (A, B, C, D, & K) of fires
- 1.6.2. National Fire Protection Association (NFPA®) extinguisher types and combinations
- 1.6.3. Fire safety regulations of the NFPA® 70, National Electrical Code (NEC®) pertinent to electric vehicles
- 1.6.4. Fire extinguishing procedures

1.7. Explain Emergency Response Guides (ERG), overview familiarization
- 1.7.1. Vehicle Emergency Response Guide Information
- 1.7.2. First Responder extraction process

1.8. Battery Safety
- 1.8.1. Flooded Lead Acid(FLA) gas hazards

1.8.2. Flooded Lead Acid(FLA) spill hazards
1.8.3. Absorbed Glass Mat(AGM) hazards
1.8.4. Battery Pack Isolation (Short Circuit or Grounding Hazard)
1.8.5. Nickel- Metal Hydride hazards
1.8.6. Lithium-Ion hazards
1.8.6.1. Thermal runaway prevention

2.0 ELECTRIC VEHICLE FUNDAMENTALS

2.1 History
2.1.1 Battery development
2.1.2 EV economics, environmental factors and range anxiety
2.1.3 Internal combustion engine (ICE) vehicles vs. electric vehicles

2.2 EV Operations
2.2.1 Power regeneration basics
2.2.2 EV components

2.3 Basic wiring systems
2.3.1 EV/ICE block diagram comparison
2.3.2 Schematic wiring, schematic component/connection identification

2.4 EV Conversions/hybrids
2.4.1 EV conversion history
2.4.2 EV conversion basics
2.4.3 Hybrid vehicle history
2.4.4 Hybrid basics
2.4.5 Factory/aftermarket conversion factors

3.0 ELECTRICAL THEORY

3.1. Mathematics for Electronics
3.1.1. Math for electronics
3.1.2. Basic algebraic math for electronics
3.1.3. DC electronics' scientific symbols
3.1.4. Scientific notation
3.1.5. Metric prefixes:
Peta, Tera, Giga, Mega, Kilo, mili, micro, nano, pico
3.1.6. Standard metric conversions

3.2. Ohm's Law
3.2.1. Ohms law
3.2.1.1. Resistance
3.2.2. Watts Law
3.2.2.1. Voltage
3.2.2.2. Power
3.2.2.3. Current
3.2.3. Kirchhoff's Law
3.2.3.1. Current Divider Calculations
3.2.4. Energy Units
3.2.4.1. Kilowatt/hrs
3.2.4.2. Joules

3.3. Voltage drop meter measurements
3.3.1. Electronic measurements using meters:
3.3.1.1. Current
3.3.1.2. Voltage
3.3.1.3. Resistance
3.3.1.4. Power

3.4. Series circuits
3.4.1. Series circuit schematic in DC electronic equipment
3.4.2. Resistance in a series circuit
3.4.3. Current, voltage or resistance in a series circuit calculation

3.5. Parallel circuits
- 3.5.1. Parallel circuit as used in DC electronic equipment
- 3.5.2. Total resistance of a parallel circuit calculation
- 3.5.3. Current calculation in a parallel circuit using the current-divider rule

3.6. Principles of Alternating Current (AC)
- 3.6.1. AC wave form characteristics:
  - 3.6.1.1. Effective voltage (RMS)
  - 3.6.1.2. Average voltage
  - 3.6.1.3. Negative Alternation
  - 3.6.1.4. Positive Alternation
  - 3.6.1.5. Wavelength
  - 3.6.1.6. Amplitude
  - 3.6.1.7. Period
- 3.6.2. Peak, RMS, and average voltage values for an AC waveform
- 3.6.3. Frequency terms:
  - 3.6.3.1. Duty Cycle
  - 3.6.3.2. Hertz
  - 3.6.3.3. Phase

4.0 ELECTRONIC SYSTEM COMPONENTS

4.1 DC and AC isolation detection circuits
- 4.1.1 DC leakage from high voltage
- 4.1.2 Resistance and Capacitance testing for leaks

4.2 Isolation fault circuit
- 4.2.1 Resistors or Op-amps

4.3 Voltage sensing stages
- 4.3.1 Voltage comparators, voltage regulators

4.4 Logic / Digital output stages
- 4.4.1 Binary and Analog serial data

4.5 Voltage regulator circuits
- 4.5.1 Zener diode

4.6 Motor Power Control strategies IM /PM power inverter
- 4.6.1 Software algorithms

4.7 Instrumentation
- 4.7.1 Controlled Area Network (CAN)

5.0 MOTOR THEORY

5.1 Basic DC Motor theory
- 5.1.1 DC motor types
- 5.1.2 Back electromotive force (CEMF)
- 5.1.3 Brushless motors (PM/BLDC) (permanent magnet/brushless DC motor)

5.2 DC motor types and usages
- 5.2.1 Segmented laminated core
- 5.2.2 Rotor magnetic design (V vs. rectangular shape)

5.3 DC Motor Math
- 5.3.1 DC motor math formulas
- 5.3.2 Input current/voltage

5.4 Output torque/speed-motor basics
- 5.4.1 Right-hand rule for motors

5.5 No load rule
- 5.5.1 No load rule: w =V/k

5.6 Controls
- 5.6.1 Permanent magnet electric controls
- 5.6.2 Synchronous field control

5.7 P/M machine stator design
- 5.7.1 Stator switching point

5.7.2 Air gap magnetic fields
5.7.3 Stator field generation
5.7.4 Flux vector control

5.8 Windings
5.8.1 Distributed windings
5.8.2 Concentrated windings
5.8.3 Frogleg windings

5.9 Motor phase
5.9.1 Phase change as it applies to EV motors

6.0 EV ELECTRONICS AND TESTING FUNDAMENTALS

6.1 Test Equipment
6.1.1 How to use the following High Voltage Analysis Tools:
6.1.1.1 Digital Volt Ohm Meter, (DVOM)
6.1.1.2 Oscilloscope
6.1.1.3 Differential Scope Probe
6.1.1.4 Digital Scope
6.1.1.5 Insulation Meter
6.1.2 Differences between multimeter test leads: ordinary vs. high voltage
6.1.3 Test equipment detecting resistance and capacitance leaks

6.2 CAT I electronics
6.2.1 Categories of voltages found in EVs

6.3 Transformer high voltage winding-resistance
6.3.1 Purpose and method of measuring transformer windings in EVs

6.4 CAT II electronics
6.4.1 CAT II electronics as used in EVs

6.5 Receptacle-connected loads
6.5.1 Receptacle-connected loads used with EVs

6.6 CAT III electronics
6.6.1 CAT III electronics as used in EVs

6.7 Equipment in fixed installations
6.7.1 Fixed installations applying to EV systems
6.7.2 Rules and precautions related to EMI in fixed installations

6.8 CAT IV electronics
6.8.1 Differences between the levels of CAT electronics and how CAT IV is related to CAT 1, 2, and 3 in EVs

6.9 Utility connection between pole and meter
6.9.1 Connection between pole and meter required for charging stations intended for EVs

6.10 Ground paths through meters
6.10.1 EV ground paths and why minimization is required

7.0 BATTERIES

7.1 Battery Ratings:
7.1.1 State of Charge (SOC)
7.1.2 Equations used in Ohms Power Law: P = E x I
7.1.3 Depth of discharge (DOD)
7.1.3.1 Bricking

7.2 Service Disconnects
7.2.1 Manual disconnect (MSD)
7.2.2 Power disconnect (PSD)
7.2.3 Service disconnect, (SDC)

7.3 Voltage Isolation Faults
7.3.1 Low power monitoring devices and their usage
7.3.2 Voltage sensing stage (resistor dividers)

7.4 Battery construction
- 7.4.1 Flooded lead acid, absorbed glass mat and gel cell batteries
  - 7.4.1.1 Gas recombination as used in EV batteries
- 7.4.2 Lithium-Iron Phosphate ($LiFePO_4$) Batteries
- 7.4.3 Nickel-Metal Hydride (Ni-MH) Batteries

7.5 Capacity rate and amp-hour rate of batteries
- 7.5.1 Energy and power density in EV batteries
- 7.5.2 Specific energy and power
- 7.5.3 Effects of temperature on the state and depth of charge

7.6 Charge and discharge characteristics
- 7.6.1 Charge and discharge characteristics of EV batteries
- 7.6.2 Discharging Station/Charger

7.7 Battery Management Systems
- 7.7.1 Battery coolant systems used in EVs
- 7.7.2 Forced air coolant systems used in EVs

8.0 ENERGY DELIVERY SYSTEMS

8.1. AC and DC Motor controls
- 8.1.1 Four functions of EV motor controllers
- 8.1.2 Current limit technology on inrush during start
- 8.1.3 Jogging and inching functions in EVs
- 8.1.4 Reversing controls

8.2 Inverter Controls
- 8.2.1 Transistor types utilized in EV inverters
- 8.2.2 Different waveforms used in EV control circuitry
- 8.2.3 Sine and six-step waveform creation
- 8.2.4 Calculating rotor frequency and motor speeds

8.3 DC/DC converters
- 8.3.1 Pulse width modulation (PWM) used in DC/DC converters
- 8.3.2 Functions of DC/DC converters in EVs
- 8.3.3 Step down (buck) and step up (boost) functions of converters

8.4 Transaxle design, (gears, torque)
- 8.4.1 Gear ratios as used in EV transaxles
  - 8.4.1.1 Torque multiplication
- 8.4.2 Continuously variable transmissions in EVs
- 8.4.3 Differentials as used in EVs

9.0 CHARGING

9.1 DC/DC Converters
- 9.1.1 Basic operating cycles of a DC/DC converter during charging

9.2 Charging Levels
- 9.2.1 Voltage and ampere/hour limits of level I EV charging
- 9.2.2 Voltage and Ah of level II charging systems
- 9.2.3 Voltage and Ah of level III charging systems
- 9.2.4 Purposes and requirements of fast charge systems
  - 9.2.4.1 CHAdeMO usage, level and advantages
- 9.2.5 Power input requirements for Level 1, 2 and 3 charging systems

9.3 On-board chargers
- 9.3.1 Parallel and Series paring in BEV (battery electric vehicles)
- 9.3.2 Voltage sensing as utilized in EVs

9.4 Off vehicle chargers
- 9.4.1 Charger Connectors
  - 9.4.1.1 SAE J1772 Standards for charger connectors
  - 9.4.1.2 Other contact connectors for EVs
  - 9.4.1.3 Inductive charging systems for EVs
- 9.4.2 Electric Vehicle Supply Equipment, (EVSE)

- 9.4.3 No-start features for EVs
- 9.4.4 Micro switch connections used in EV charger systems

9.5 Off Grid chargers (zero carbon footprint)

- 9.5.1 Photovoltaic power generation as used in EVs
- 9.5.2 Wind power generation use in EVs

9.6 Vehicle to Grid

9.7 Mini-EV Charging controls

- 9.7.1 Charge levels offered by different charge systems

9.8 Regeneration

- 9.8.1 EVs utilization of regeneration to reduce power consumption

10.0 BEV MAINTENANCE AND TROUBLESHOOTING

10.1 CAN bus

- 10.1.1 CAN - controller area networking system
- 10.1.2 OBDII error codes

10.2 Generic system controls

- 10.2.1 High voltage shut down system
- 10.2.2 (Interlock systems) operation in EVs

10.3 Cooling system

- 10.3.1 Service procedures unique to EVs
  - 10.3.1.1 Active and passive HVAC systems
- 10.3.2 Proper PH levels in EV coolants

10.4 Thermal Battery Controls and Monitoring

- 10.4.1 EV safety monitoring systems
- 10.4.2 Ventilation systems used in EVs
- 10.4.3 Temperature controls used in EVs

ELECTRIC VEHICLE TECHNICIAN COMPETENCY REQUIREMENTS:

1.0 SAFETY REQUIREMENTS

- 1.1. Personal Protection Equipment (PPE)
  - 1.1.1. Explain the High Voltage Electrical Glove rating system
  - 1.1.2. Describe the dangers of working around high voltage
    - 1.1.2.1. Explain Arc Flash, Arc Blast
  - 1.1.3. Explain shop protection equipment requirements
  - 1.1.4. Describe Electrical Meter safety requirements and standards
  - 1.1.5. Describe PPE required practices
- 1.2. OSHA Requirements on High Voltage
  - 1.2.1. Explain basic OSHA High Voltage electrical standards
  - 1.2.2. Describe the cable color-code system associated with levels of voltage
  - 1.2.3. Explain vehicle work area set up
- 1.3. Electrical Shock Prevention
  - 1.3.1. Describe personal safety precautions – accident mitigation
  - 1.3.2. Describe the 'one hand' rule for working on electrical equipment
  - 1.3.3. Explain the 'never work alone' concept
- 1.4. Electrical Shock Response
  - 1.4.1. Describe the human physiological reactions to electrical shock
  - 1.4.2. List the degrees of current the human body can tolerate
  - 1.4.3. Explain First Aid for electrical shock victims
  - 1.4.4. Describe the dangers involved with artificial respiration
  - 1.4.5. Describe the dangers involved in detaching a shock victim from high voltage sources
- 1.5. High Voltage Safety
  - 1.5.1. Identify the following high voltage components and connections
    - 1.5.1.1. Safety Interlocks (including high voltage)
    - 1.5.1.2. Service plugs and receptacles
    - 1.5.1.3. High voltage service disconnect
    - 1.5.1.4. High voltage fuse
    - 1.5.1.5. Ignition key block
    - 1.5.1.6. Battery connections
    - 1.5.1.7. Charge port
    - 1.5.1.8. Charge controller
    - 1.5.1.9. DC/DC converter
    - 1.5.1.10. Inverter/motor controller
    - 1.5.1.11. Traction motor
    - 1.5.1.12. Air conditioner
    - 1.5.1.13. Power steering
  - 1.5.2. Describe the potential danger posed by any level of DC current leakage in an EV
- 1.6. Fire Safety
  - 1.6.1. Describe the different classes (A, B, C, D, & K) of fires
  - 1.6.2. List NFPA® (National Fire Protection Association) extinguisher types and combinations of types
  - 1.6.3. List fire safety regulations of the NFPA® 70, National Electrical Code (NEC®) pertinent to electric vehicles
  - 1.6.4. Explain proper shop and EV firefighting / extinguishing procedures

1.7. Emergency Response Guides (ERG) overview familiarization
  1.7.1. Identify Vehicle Emergency Response Guide Information from EV manufacturers
  1.7.2. Describe First Responder extraction process
1.8. Battery Safety
  1.8.1. List the Flooded Lead Acid (FLA) gas hazards
  1.8.2. List the FLA spill hazards and acid mitigation
  1.8.3. List the Absorbed Glass Mat (AGM) hazards
  1.8.4. Describe Battery Pack Isolation (Short Circuit or Grounding Hazard)
  1.8.5. List the Nickel Metal Hydride hazards
  1.8.6. List the various Lithium-Ion battery hazards (Li-Co, LiFePO4, etc.)
    1.8.6.1. Explain Thermal Runaway in EV batteries including prevention measures or practices

2.0 ELECTRIC VEHICLE FUNDAMENTALS

2.1 History
  2.1.1 Chronicle battery development for electric vehicles
  2.1.2 Explain EV economics, environment factors and range anxiety
  2.1.3 Compare Internal Combustion Engine (ICE) vehicles vs. Electric Vehicles
2.2 EV Operations
  2.2.1 Describe regeneration basics
  2.2.2 Identify basic EV components
2.3 Basic wiring systems
  2.3.1 Compare EV wiring block-diagrams with ICE vehicle diagrams
  2.3.2 Identify EV wiring, schematic components and connections
2.4 EV Conversions/hybrids
  2.4.1 Chronicle EV conversion history
  2.4.2 Explain conversion basics
  2.4.3 Chronicle hybrid vehicle history
  2.4.4 Explain hybrid basics
  2.4.5 Compare factory vs. aftermarket conversions factors

3.0 ELECTRICAL THEORY

3.1 Mathematics for EV electronics
  3.1.1 Describe mathematics for electronics
  3.1.2 Explain basic algebraic math for electronics
  3.1.3 Identify DC electronics' scientific symbols
  3.1.4 Identify scientific notation
  3.1.5 Explain and compare the metric prefixes below:
    3.1.5.1 Peta
    3.1.5.2 Tera
    3.1.5.3 Giga
    3.1.5.4 Mega
    3.1.5.5 Kilo
    3.1.5.6 Milli
    3.1.5.7 Micro
    3.1.5.8 Nano
    3.1.5.9 Pico
  3.1.6 Explain standard metric conversions
3.2 Ohms Law
  3.2.1 Summarize Ohms law
  3.2.2 Explain resistance
  3.2.3 Measure or calculate voltage
  3.2.4 Measure or calculate current
  3.2.5 Measure or calculate power
  3.2.6 Summarize Watts Law

- 3.3 Kirchhoff's Law
  - 3.3.1 Summarize Kirchhoff's Law
  - 3.3.2 Interpret Current Divider Calculations
- 3.4 Energy Units
  - 3.4.1 Explain kilowatt/hrs
  - 3.4.2 Define Joules
- 3.5 Electronic Measurements
  - 3.5.1 Describe appropriate procedures to measure the following quantities:
    - 3.5.1.1 Current
    - 3.5.1.2 Voltage
    - 3.5.1.3 Resistance
    - 3.5.1.4 Power
  - 3.5.2 Explain how voltage-drop measurements are interpreted
- 3.6 Series Circuits
  - 3.6.1 Interpret a series circuit schematic in DC electronic equipment
  - 3.6.2 Define resistance in a series circuit
  - 3.6.3 Calculate current, voltage and resistance in series circuits
- 3.7 Parallel Circuits
  - 3.7.1 Explain how a parallel circuit is used in DC automotive systems
  - 3.7.2 Solve for total resistance in a parallel circuit
  - 3.7.3 Calculate current in a parallel circuit using the current-divider rule
- 3.8 Alternating Current
  - 3.8.1 Describe and identify the following AC waveform characteristics:
    - 3.8.1.1 Effective voltage (RMS)
    - 3.8.1.2 Average voltage
    - 3.8.1.3 Peak voltage
    - 3.8.1.4 Positive Alternation
    - 3.8.1.5 Wavelength
    - 3.8.1.6 Amplitude
    - 3.8.1.7 Period
- 3.9 Frequency
  - 3.9.1 Explain the following frequency terms:
    - 3.9.1.1 Duty Cycle
    - 3.9.1.2 Hertz
    - 3.9.1.3 Phase

4.0 ELECTRONIC SYSTEMS COMPONENTS

- 4.1 DC and AC isolation detection circuits
  - 4.1.1 Describe the potential danger posed by any level of DC leakage current in an EV
    - 4.1.1.1 Describe the causes of DC leakage from high voltage components in EVs
    - 4.1.1.2 Describe the effects of DC leakage in an EV
  - 4.1.2 Describe how to test for resistance and capacitance leaks
- 4.2 Isolation Fault Circuit (IFC)
  - 4.2.1 Explain the use of resistors in IFCs
  - 4.2.2 Explain how op-amps are used in IFCs to detect malfunctions
- 4.3 Voltage sensing stages
  - 4.3.1 Explain how voltage comparators and voltage regulators differ and the purposes of each
- 4.4 Logic / Digital output stages
  - 4.4.1 Describe the differences between binary and analog serial data
- 4.5 Voltage regulator circuits
  - 4.5.1 Describe how zener diodes operate and explain their usage in voltage regulator circuits

- 4.6 Motor Power Control strategies IM/PM power inverter
  - 4.6.1 Define software algorithm
  - 4.6.2 Explain how algorithms are used in computerized motor control circuits
- 4.7 Instrumentation
  - 4.7.1 Describe how a controlled area network (CAN) is used in EVs

5.0 MOTOR THEORY

- 5.1 Basic DC Motor theory
  - 5.1.1 Identify DC motor types
  - 5.1.2 Explain counter (or back) electromotive force (CEMF)
  - 5.1.3 Identify brushless motors (PM/BLDC = permanent magnet/brushless DC motor)
- 5.2 DC motor types and usages
  - 5.2.1 Explain segmented laminated core
  - 5.2.2 Identify rotor magnetic design (V vs. rectangular shape)
- 5.3 DC Motor Math
  - 5.3.1 Express DC motor math formulas
  - 5.3.2 Describe Input current/voltage
- 5.4 Output torque/speed-motor basics
  - 5.4.1 Explain the Right-hand rule for motors
- 5.5 No load rule
  - 5.5.1 Explain the no load rule: $\omega = V \div k$
- 5.6 Controls
  - 5.6.1 Describe permanent magnet electric controls
  - 5.6.2 Describe synchronous field control
- 5.7 P/M machine stator design
  - 5.7.1 Identify the stator switching point
  - 5.7.2 Identify air gap magnetic fields
  - 5.7.3 Explain stator field generation
  - 5.7.4 Explain flux vector control
- 5.8 Windings
  - 5.8.1 Identify distributed windings
  - 5.8.2 Identify concentrated windings
  - 5.8.3 Describe frogleg windings
- 5.9 Motor phase
  - 5.9.1 Explain phase change as it applies to EV motors

6.0 EV ELECTRONICS AND TESTING FUNDAMENTALS

- 6.1 Test Equipment
  - 6.1.1 Describe how to use the following High Voltage Analysis Tools:
    - 6.1.1.1 Digital Volt Ohm Meter, (DVOM)
    - 6.1.1.2 Oscilloscope
    - 6.1.1.3 Differential Scope Probe
      - 6.1.1.3.1 Hall Effect Current Sensor Probe
    - 6.1.1.4 Digital Scope
    - 6.1.1.5 Insulation Meter
  - 6.1.2. Describe the differences between ordinary multimeter test leads and high voltage test leads
  - 6.1.3. Describe the procedures and test equipment used to test for resistance and capacitance leaks
- 6.2 CAT I electronics

6.2.1 Explain and name the categories of voltages found in EVs
6.3 Transformer High-voltage winding-resistance
6.3.1 Explain the purpose and method of measuring transformer windings in EVs
6.4 CAT II electronics
6.4.1 Define CAT II electronics as used in EVs
6.5 Receptacle-connected loads
6.5.1 Name the types of receptacle-connected loads used with EVs
6.6 CAT III electronics
6.6.1 Define CAT III electronics as used in EVs
6.7 Equipment in fixed installations
6.7.1 Define Fixed installations applying to EV systems
6.7.2 Explain the rules and precautions regarding EMI, related to fixed installations
6.8 CAT IV electronics
6.8.1 Explain the differences between the levels of CAT electronics and how CAT IV is related to CAT 1, 2, 3 and 4 in EVs
6.9 Utility connection between pole and meter
6.9.1 Describe the connection between pole and meter required for charging stations intended for EVs
6.10 Ground paths through meters
6.10.1 Explain the problems associated with EV ground paths and why minimization is required

7.0 BATTERIES

7.1 Battery Ratings:
7.1.1 Define State of Charge (SOC)
7.1.2 Calculate equations used in Ohms Power Law: $P = E \; x \; I$
7.1.3 Explain depth of discharge (DOD)
7.1.3.1 Explain Bricking
7.2 Service Disconnects in EVs
7.2.1 Identify or locate the manual disconnect (MSD)
7.2.2 Identify or locate the power disconnect (PSD)
7.2.3 Identify or locate the service disconnect, (SDC)
7.3 Voltage Isolation Faults
7.3.1 Explain how low power monitoring devices work and their usage
7.3.2 Describe voltage sensing stage (resistor dividers)
7.4 Battery construction
7.4.1 Contrast flooded lead acid, absorbed glass mat and gel cell batteries
7.4.1.1 Explain gas recombination as used in EV batteries
7.4.2 Describe Lithium-Iron Phosphate ($LiFePO_4$) and other Lithium-Ion batteries
7.4.3 Describe Nickel-Metal Hydride (Ni-MH) batteries
7.5 Capacity rate and amp-hour rate of batteries
7.5.1 Explain energy and power density in EV batteries
7.5.2 Define specific energy and power
7.5.3 Explain the effects of temperature on the state and depth of charge
7.6 Charge and discharge characteristics
7.6.1 Explain charge and discharge characteristics of EV batteries
7.6.2 Describe the function of a Discharging Station/Charger
7.7 Battery Management Systems
7.7.1 Describe battery coolant systems used in EVs
7.7.2 Describe forced air coolant systems used in EVs

8.0 ENERGY DELIVERY SYSTEMS

- 8.1. AC and DC Motor controls
  - 8.1.1 List the four functions of EV motor controllers
  - 8.1.2 Explain current limit technology on inrush during start
  - 8.1.3 Describe jogging and inching functions in EVs
  - 8.1.4 Describe reversing controls
- 8.2 Inverter Controls
  - 8.2.1 Describe the transistor types utilized in EV inverters
  - 8.2.2 Explain the different waveforms used in EV control circuitry
  - 8.2.3 Describe sine and six-step waveform creation
  - 8.2.4 Explain how to calculate rotor frequency and motor speeds
- 8.3 DC/DC converters
  - 8.3.1 Explain how pulse width modulation (PWM) is used in DC/DC converters
  - 8.3.2 Describe the functions of DC/DC converters in EVs
  - 8.3.3 Explain step down (buck) and step up (boost) transformers
- 8.4 Transaxle design, (gears, torque**)**
  - 8.4.1 Describe how gear ratios are used in EV transaxles
    - 8.4.1.2 Define torque multiplication
  - 8.4.2 Explain how continuously variable transmissions operate in EVs
  - 8.4.3 Explain how differentials are used in EVs

9.0 CHARGING

- 9.1 DC/DC Converters
  - 9.1.1 Describe the basic operating cycles of a DC/DC converter during charging
- 9.2 Charging Levels
  - 9.2.1 List the voltage and ampere/hour limits of level I EV charging
  - 9.2.2 List the voltage and Ah of level II charging systems
  - 9.2.3 List the voltage and Ah of level III charging systems
  - 9.2.4 Explain the purposes and requirements of fast charge systems
    - 9.2.4.1 Define CHAdeMO and list its usage, level and advantages
  - 9.2.5 Describe the power input requirements for Level 1, 2 and 3 charging systems
- 9.3 On-board chargers
  - 9.3.1 Describe parallel and series paring in BEV (battery electric vehicles)
  - 9.3.2 Explain voltage sensing as utilized in EVs
- 9.4 Off vehicle chargers
  - 9.4.1 Charger Connectors
    - 9.4.1.1 Describe the SAE J1772 Standards for charger connectors
    - 9.4.1.2 Describe other contact connectors for EVs
    - 9.4.1.3 Explain inductive charging systems for EVs
  - 9.4.2 List Electric Vehicle Supply Equipment, (EVSE)
  - 9.4.3 List no-start features for EVs
  - 9.4.4 Describe micro switch connections used in EV charger systems
- 9.5 Off Grid chargers (Zero Carbon Footprint)
  - 9.5.1 Explain how photovoltaic power generation is used in EVs
  - 9.5.2 Explain how wind power generation can be used in EVs
- 9.6 Describe the principles of Vehicle to Grid technology for EVs
- 9.7 Mini-EV Charging controls
  - 9.7.1 Compare the charge levels offered by different charge systems

9.8 Regeneration
9.8.1 Explain how EVs utilize regeneration to reduce power consumption.

10.0 BEV MAINTENANCE AND TROUBLESHOOTING

10.1 CAN bus
10.1.1 Describe the controller area networking (CAN) system
10.1.2 Interpret the OBDII error codes (On Board Diagnostic II)
10.2 Generic system controls
10.2.1 Describe how the high voltage shut down system
10.2.2 Describe how an interlock system(s) operate(s) in EVs
10.3 Cooling system
10.3.1 Explain service procedures unique to EVs
10.3.1.1 Explain active and passive HVAC systems
10.3.2 Explain the need for proper PH levels in EV coolants
10.4 Thermal Battery Controls and Monitoring
10.4.1 Describe EV safety monitoring systems
10.4.2 Describe ventilation systems used in EVs
10.4.3 Describe the temperature controls used in EVs

End of Electric Vehicle Technician Competency Listing

Find An ETA Approved School Site http://www.eta-i.org/eta_schools.html

Find An ETA Test Site http://www.eta-i.org/testing.html

Suggested Reviewable Text Materials:

NFPA 70E®: Standard for Electrical Safety in the Workplace® 2012 Ed; National Fire Protection Association; ASIN# B005MEQW8I; paperback, 103pp.
NFPA 10®: Standard for Portable Fire Extinguishers®, 2010 Ed; National Fire Protection Association; ASIN# B003UY1TV2; paperback, 65pp.
NEC 2011®: National Electrical Code; National Fire Protection Association; ISBN# 978-0877659143; paperback, 875pp
Electric Vehicle Emergency Field Guide, 2012 Ed.; National Fire Protection Association; ISBN# 978-1455905041; paperback, 145pp, www.evsafetytraining.org

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