

# **City & Guilds**

## **Level 4 Award in Diagnosis and Rectification of Faults in Electric and Hybrid Vehicles (7290-04)**

July 2022 Version 1.1

**Qualification Handbook**

## Qualification at a glance

<b>Subject area</b>	Automotive
<b>City &amp; Guilds number</b>	7290-04
<b>Age group approved</b>	18+
<b>Entry requirements</b>	None
<b>Assessment</b>	Online multiple-choice tests Practical assessments
<b>Approvals</b>	Full approval required
<b>Support materials</b>	Sample test materials SmartScreen
<b>Registration and certification</b>	Consult the Walled Garden/Online Catalogue for last dates

<b>Title and level</b>	<b>City &amp; Guilds number</b>	<b>Qualification number</b>
City & Guilds Level 4 Award in Diagnosis and Rectification of Faults in Electric and Hybrid Vehicles	7290-04	610/0082/1

<b>Version</b>	<b>Date</b>	<b>Change detail</b>	<b>Section</b>
V1.0	June 2022	Document created	All
V1.1	July 2022	Sources of general information – added information on Centre Assessment Standards Scrutiny strategy	Appendix 1

# Contents

<b>Qualification at a glance</b>	<b>2</b>	
<hr/>		
<b>Contents</b>		
<hr/>		
<b>1 Introduction</b>	<b>4</b>	
<hr/>		
<b>2 Centre requirements</b>	<b>6</b>	
Approval	6	
Resource requirements	6	
Quality assurance	6	
Learner entry requirements	7	
Access arrangements and special considerations	7	
<hr/>		
<b>3 Delivering the qualification</b>	<b>8</b>	
Initial assessment and induction	8	
Support materials	8	
Recording documents	8	
<hr/>		
<b>4 Assessment</b>	<b>9</b>	
Assessment of the qualification	9	
Summary of assessment methods	9	
Assessment strategy	9	
Time constraints	9	
Test specifications	10	
<hr/>		
<b>5 Grading</b>		
Grading of individual assessments	12	
Grading of qualification	12	
<hr/>		
<b>6 Units</b>		
<hr/>		
<b>Unit 604</b>	<b>Knowledge of Diagnosing and Rectifying Faults in an Electric Vehicle Powertrain and Ancillary systems</b>	<b>14</b>
<hr/>		
<b>Unit 605</b>	<b>Knowledge of Testing, Removing and Storing Electric Vehicle High Voltage Batteries</b>	<b>32</b>
<hr/>		
<b>Unit 614</b>	<b>Skills in Diagnosing and Rectifying Faults in an Electric Vehicle Powertrain and Ancillary Systems</b>	<b>42</b>
<hr/>		
<b>Unit 615</b>	<b>Skills in Testing, Removing and Storing Electric Vehicle High Voltage Batteries</b>	<b>50</b>
<hr/>		
<b>Appendix 1</b>	<b>Sources of general information</b>	<b>55</b>
<hr/>		

# 1 Introduction

This document tells you what you need to do to deliver the qualification:

Area	Description
Who is the qualification for?	This qualification is designed for people looking to develop their knowledge and skills to allow them to safely diagnose and rectify high voltage system faults, test, remove and replace high voltage battery packs and battery modules and to safely store high voltage battery packs.
What does the qualification cover?	<p>This qualification covers the competence and knowledge needed to safely diagnose and rectify high voltage system faults in an electric vehicle.</p> <p>The qualification also covers competence and knowledge on testing and storing high voltage batteries, as well as removing and replacing high voltage battery modules/packs and re-fitting high voltage battery packs in electric vehicles.</p>
What opportunities for progression are there?	This qualification allows learners to develop and practise the skills required for employment and/or career progression in the repair and diagnosis of high voltage system faults in electric vehicles.
Who did we develop the qualification with?	This qualification has been developed using the National Occupational Standards as set by automotive industry experts.

## Structure

### Level 4 Award in Diagnosis and Rectification of Faults in Electric and Hybrid Vehicles

City & Guilds unit number	Unit title	GLH
<b>Mandatory</b>		
604	Knowledge of Diagnosing and Rectifying Faults in an Electric Vehicle Powertrain and Ancillary Systems	28
605	Knowledge of Testing, Removing and Storing Electric Vehicle High Voltage Batteries	14
614	Skills in Diagnosing and Rectifying Faults in an Electric Vehicle Powertrain and Ancillary Systems	7
615	Skills in Testing, Removing and Storing Electric Vehicle High Voltage Batteries	6

### Total Qualification Time

Total Qualification Time (TQT) is the number of notional hours which represents an estimate of the total amount of time that could reasonably be expected for a learner to achieve and demonstrate the achievement of the level of attainment necessary for the award of a qualification.

TQT is comprised of the following two elements:

1. The number of hours which an awarding organisation has assigned to a qualification for Guided Learning.
2. An estimate of the number of hours a Learner will reasonably be likely to spend in preparation, study or any other form of participation in education or training, including assessment, which takes place as directed by - but, unlike Guided Learning, not under the Immediate Guidance or Supervision of - a lecturer, supervisor, tutor or other, appropriate provider of education or training.

Title and level	GLH	TQT
City & Guilds Level 4 Award in Diagnosis and Rectification of Faults in Electric and Hybrid Vehicles	55	64

## 2 Centre requirements

### Approval

To offer this qualification, centres will need to gain both centre and qualification approval. Please refer to **City & Guilds Centre Approval Process Quality Assurance Standards document** for further information, see **Centre Document Library**.

Centre staff should familiarise themselves with the structure, content and assessment requirements of the qualifications before designing a course programme.

### Resource requirements

#### Equipment

Centres must have access to sufficient equipment (including recommended Electric Vehicle safety tools and specialist equipment) in the college, training centre or workplace to ensure candidates have the opportunity to cover all of the practical activities. Further information on the equipment required can be found in the Assessment Pack.

#### Centre staffing

Staff delivering these qualifications must be able to demonstrate that they meet the following occupational expertise requirements. They should:

- be occupationally competent or technically knowledgeable in the area[s] for which they are delivering training and/or have experience of providing training. This knowledge must be to the same level as the training being delivered
- have recent relevant experience in the specific area they will be assessing
- have credible experience of providing training.

Centre staff may undertake more than one role, e.g., tutor and assessor or internal verifier, but cannot internally verify their own assessments.

### Quality assurance

Approved centres must have effective quality assurance systems to ensure optimum delivery and assessment of qualifications. Quality assurance includes initial centre approval, qualification approval and the centre's own internal procedures for monitoring quality.

Centres are responsible for internal quality assurance and City & Guilds is responsible for external quality assurance. For more detail on this visit the **Quality Assurance Standards** documents on the City & Guilds website.

Standards and rigorous quality assurance are maintained by the use of:

- Internal quality assurance

- City & Guilds external quality assurance.

In order to carry out the quality assurance role, Internal Quality Assurers must

- have appropriate teaching and vocational knowledge and expertise
- have experience in quality management/internal quality assurance
- hold or be working towards an appropriate teaching/training/assessing qualification
- be familiar with the occupation and technical content covered within the qualification.

External quality assurance for the qualification will be provided by City & Guilds EQA process. EQAs are appointed by City & Guilds to approve centres, and to monitor the assessment and internal quality assurance carried out by centres. External quality assurance is carried out to ensure that assessment is valid and reliable, and that there is good assessment practice in centres.

The role of the EQA is to:

- provide advice and support to centre staff
- ensure the quality and consistency of assessments within and between centres by the use of systematic sampling
- provide feedback to centres and to City & Guilds.

## **Learner entry requirements**

City & Guilds does not set entry requirements for these qualifications. However, centres must ensure that candidates have the potential and opportunity to gain the qualifications successfully.

We recommend that centres ensure that learners hold a Level 3 qualification in high voltage Electric Vehicles, or have relevant knowledge and experience on working on high voltage Electric Vehicles, prior to starting this qualification.

## **Age restrictions**

This qualification is approved for learners aged 18 or above.

City & Guilds cannot accept any registrations for candidates under 18 as this qualification is not approved for under 18s.

## **Access arrangements and special considerations**

For information on how to apply for access arrangements please refer to ***How and when to apply for access arrangements and special consideration (cityandguilds.com)***

### 3 Delivering the qualification

#### Initial assessment and induction

An initial assessment of each learner should be made before the start of their programme to identify:

- if the learner has any specific training needs,
- support and guidance they may need when working towards their qualification,
- any units they have already completed, or credit they have accumulated which is relevant to the qualification
- the appropriate type and level of qualification.

We recommend that centres provide an induction programme so the learner fully understands the requirements of the qualification, their responsibilities as a learner, and the responsibilities of the centre. This information can be recorded on a learning contract.

#### Support materials

The following resources are available for this qualification:

Description	How to access
MCQ sample assessments	<a href="http://www.cityandguilds.com">www.cityandguilds.com</a>
Learning Assistant	<a href="http://www.cityandguilds.com/eportfolios">www.cityandguilds.com/eportfolios</a>
SmartScreen	<a href="http://www.smartscreen.co.uk">www.smartscreen.co.uk</a>

#### Recording documents

Learners and centres may decide to use a paper-based or electronic method of recording evidence.

City & Guilds endorses several ePortfolio systems, including our own, **Learning Assistant**, an easy-to-use and secure online tool to support and evidence learners' progress towards achieving qualifications. Further details are available at: [www.cityandguilds.com/eportfolios](http://www.cityandguilds.com/eportfolios).

City & Guilds has developed a set of *Recording forms* including examples of completed forms, for new and existing centres to use as appropriate. *Recording forms* are available on the City & Guilds website.

Although new centres are expected to use these forms, centres may devise or customise alternative forms, which must be approved for use by the external verifier, before they are used by candidates and assessors at the centre. Amendable (MS Word) versions of the forms are available on the City & Guilds website.



## 4 Assessment

### Assessment of the qualification

Candidates must:

- successfully complete the following mandatory units: 604, 605, 614, 615.

### Summary of assessment methods

Assessment Types			
Unit	Title	Assessment method	Where to obtain assessment materials
604	Knowledge of Diagnosing and Rectifying Faults in an Electric Vehicle Powertrain and Ancillary Systems	Multiple-choice questions	Examinations provided on e-volve
605	Knowledge of Testing, Removing and Storing Electric Vehicle High Voltage Batteries	Multiple-choice questions (this assessment allows the use of a calculator)	Examinations provided on e-volve
614	Skills in Diagnosing and Rectifying Faults in an Electric Vehicle Powertrain and Ancillary Systems	Practical assessment	Assessment Pack found on City and Guilds website/ Walled Garden
615	Skills in Testing, Removing and Storing Electric Vehicle High Voltage Batteries	Practical assessment	Assessment Pack found on City and Guilds website/ Walled Garden

### Assessment strategy

The knowledge will be covered by multiple-choice questions for the essential knowledge criteria and observed practical assessments including oral questioning for the skills criteria.

### Time constraints

#### Multiple-choice online tests

The multiple-choice online tests should be scheduled for candidates only once the Knowledge unit delivery for the associated test is complete and candidates are ready to take the assessment. The test should be sat under invigilated examination conditions, as defined by the JCQ: <http://www.jcq.org.uk/exams-office/ice---instructions-for-conducting-examinations>.

## Practical assessments

Assessors should schedule the practical assessment for unit 614 once candidates have **passed** the Evolve on-line test for unit 604 and gained sufficient practice in order to fairly attempt the practical assessment to the best of their ability.

Assessors should schedule the practical assessment for unit 615 once candidates have **passed** the Evolve on-line test for unit 605 and gained sufficient practice in order to fairly attempt the practical assessment to the best of their ability.

Candidates must complete their assessments within their registration period.

## Recognition of prior learning (RPL)

Recognition of prior learning means using a person's previous experience or qualifications which have already been achieved to contribute to a new qualification. RPL is not allowed for this qualification.

## Test specifications

The way the knowledge is covered by each multiple-choice question test is laid out in the tables below:

### Unit 604: Knowledge of Diagnosing and Rectifying Faults in an Electric Vehicle Powertrain and Ancillary Systems

Duration: 1 hour

LO number	Learning Outcome	Number of questions
1	understand the structure, component layout and the electrical systems of electric vehicles, and the safe operation and charging of electric vehicles	3
2	understand electrical and electronic principles and their application to low and high voltage systems and components	4
3	understand the features, function and construction of high and low voltage system components and their faults and failures	3
4	understand how to diagnose and rectify faults within high and low voltage systems, components and units	10
5	understand the health and safety, legislative and workplace procedures required to be followed when carrying out repair activities of electric vehicles	5
6	understand the risks and hazards associated with working on electric vehicles and how to minimise risk to themselves and others when diagnosing and repairing electric vehicles	5
<b>Total</b>		<b>30</b>

### Unit 605: Knowledge of Testing, Removing and Storing Electric Vehicle High Voltage Batteries

**Duration: 45 minutes**

<b>LO number</b>	<b>Learning Outcome</b>	<b>Number of questions</b>
1	understand the differences between electric vehicle battery types and structures, the connections made from the battery to other components and parts within the vehicle, and how to calculate battery cell voltages	4
2	understand the legislative and workplace requirements that must be adhered to when working with high voltage batteries, the hazards associated with high voltage batteries and the procedure for the safe removal, storage and disposal of a high voltage battery pack	6
3	understand how to carry out tests and use the appropriate equipment to determine the condition of batteries and know how to correctly interpret test results	5
<b>Total</b>		<b>15</b>

**Grade boundaries:** The grade boundaries for both tests will be approximately:  
Pass: 60 % (18 marks for unit 604 and 9 marks for unit 605).

These boundaries may be subject to slight variation to ensure fairness should any variations in the difficulty of the test be identified.

## 5 Grading

### Grading of individual assessments

All the assessments within this qualification are graded at a Pass only.

### Grading of qualification

The overall grading of this qualification is Pass/Fail only.

Candidates must achieve a Pass in:

- Unit 604 Multiple-choice online test
- Unit 605 Multiple-choice online test
- Unit 614 Practical Assessment
- Unit 615 Practical Assessment

to achieve a Pass in the full qualification.

## 6 Units

### Availability of units

All of the units can be found in this document.

### Structure of the units

The units each have the following:

- City & Guilds reference number
- Title
- Level
- Guided learning hours (GLH)
- Unit aim
- Assessment type
- Learning outcomes, which are comprised of a number of assessment criteria

Centres must deliver the full breadth of the range within the units. For the practical assessments within this qualification, centres should ensure that there are sufficient resources to complete the task but are not required to use all the equipment or commodities in the range.

### Guidance for delivery of the units

This qualification is comprised of four **units**. A unit describes what is expected of a competent person in particular aspects of their job.

Each **unit** is divided into **learning outcomes** which describe in further detail the skills and knowledge that a candidate should possess.

Each **learning outcome** has a set of **assessment criteria** which specify the desired criteria that have to be satisfied before an individual can be said to have performed to the agreed standard.

**Range** statements define the breadth or scope of a learning outcome and its assessment criteria by setting out the various circumstances in which they are to be applied.

## Unit 604

# Knowledge of Diagnosing and Rectifying Faults in an Electric Vehicle Powertrain and Ancillary systems

<b>Level:</b>	Level 4
<b>GLH:</b>	28
<b>Relationship to NOS:</b>	EV05: Diagnose and rectify faults in an electric vehicle powertrain and ancillary systems
<b>Aim:</b>	To understand how to safely diagnose and rectify high voltage system faults in an electric vehicle To understand the types and causes of faults and failures within high and low voltage systems To understand how to safely remove and replace components in isolated high voltage systems in an electric vehicle
<b>Assessment type</b>	Multiple-choice questions

---

### Essential Knowledge

### Learning outcomes

The learner will:

1. understand the structure, component layout and the electrical systems of electric vehicles, and the safe operation and charging of electric vehicles
2. understand electrical and electronic principles and their application to low and high voltage systems and components
3. understand the features, function and construction of high and low voltage system components and their faults and failures
4. understand how to diagnose and rectify faults within high and low voltage systems, components and units
5. understand the health and safety, legislative and workplace procedures required to be followed when carrying out repair activities of electric vehicles
6. understand the risks and hazards associated with working on electric vehicles and how to minimise risk to themselves and others when diagnosing and repairing electric vehicles

---

## Learning outcome:

The learner will:

1. understand the structure, component layout and electrical systems of electric vehicles, and the safe operation and charging of electric vehicles

## Assessment criteria

The learner must know:

- 1.1 the different types of **electric vehicles**, their electrical systems, structures and component/vehicle powertrain **layout**
- 1.2 the differences between the phases of operation between different types of **electric vehicles** and conventional non-electric vehicles
- 1.3 methods of **sourcing information** on high and low voltage electrical, electronic, mechanical and fluid system operating specifications
- 1.4 how to use and interpret **technical information** on operating specifications
- 1.5 charge cable **types** and **modes** of **electric vehicle** charging systems and how they function and operate
- 1.6 how to **safely operate** an **electric vehicle**
- 1.7 how to **safely charge** an **electric vehicle**

---

## Range

1.1-1.2,  
1.5-1.7

### Electric vehicle(s)

- a) Pure (PEV) / battery electric vehicle (BEV)
- b) Extended range (ER-EV)
- c) Range extended (RE-EV)
- d) Fuel cell (FCEV)
- e) Hybrid (HEV)
- f) Plug-in hybrid (PHEV)
- g) Mild hybrid
- h) Micro hybrid

1.1

### Layout

- a) Single
- b) Twin
- c) Tri-motor
- d) Quad motor
- e) Series hybrid
- f) Parallel hybrid
- g) Series/parallel hybrid (power split)
- h) Dual hybrid four

1.3

### Sourcing information

- a) Manufacturer's guidance

- b) Hard copy manuals
- c) Data stored electronically
- d) Data from on-board diagnostic displays

1.4 **Technical information** to include:

- a) High voltage systems
- b) Low voltage systems
- c) Operating voltage ranges
- d) Electronic systems
- e) Mechanical systems
- f) Fluid systems
- g) Electrical diagrams
- h) Manufacture repair procedures
- i) Manufacturer test plans
- j) Manufacturer wiring diagrams
- k) 3rd party information

1.5 Charge cable **types / modes**

- a) Plugs / sockets (AC/DC)
- b) Modes:
  - i. 1 – standard socket outlet - domestic installation
  - ii. 2 – standard socket outlet with AC EV supply equipment
  - iii. 3 – AC EV equipment permanently connected to an AC supply network
  - iv. 4 – DC EV supply equipment
- c) Combined charging systems (CCS)
- d) Hybrid self-charging systems

1.6 **Safely operate** procedures, to include:

- a) Ensure vehicle is in ready mode
- b) Check for warning symbols on dashboard
- c) Check for system displays and messages
- d) Check surroundings before moving off
- e) Awareness that an engine may start at any time on a hybrid vehicle

1.7 **Safe charging** procedures, to include:

- a) Precautions when charging in the presence of water – e.g., rain, valeting bay
- b) Correct use of extension leads when charging
- c) Suitability of power supply used when charging
- d) Signage
- e) Cabling and connections
- f) Risks to personal health and safety



---

### Learning outcome:

The learner will:

2. understand electrical and electronic principles and their application to low and high voltage systems and components

### Assessment criteria

The learner must know:

- 2.1 **electrical and electronic theories** including electrical terminology, symbols and units
- 2.2 the application of **electrical and electronic theories** in relation to high voltage **systems**, including types of **sensors** and **actuators** and their operation
- 2.3 electrical and electronic operation of high and low voltage **systems**, including:
  - a) electrical component function
  - b) electrical inputs and outputs
  - c) the behavior of voltage and current within a circuit
  - d) oscilloscope patterns
  - e) digital and fibre optics principles
- 2.4 how electrical and electronic systems interlink, including:
  - a) multiplexing (CAN, LIN, MOST)
  - b) the principles of chassis earth and insulated earth return systems and their relevance to low and high voltage **systems**
- 2.5 the operating principles of **electric vehicle components**
- 2.6 how **interaction** occurs between **components** within **electric vehicle systems**

---

### Range

#### 2.1-.2.2 **Electrical and electronic theories**

- a) Ohms law
- b) Watts law
- c) Voltage
- d) Power
- e) Current (ac/dc)
- f) Resistance
- g) Magnetism
- h) Electromagnetism
- i) Electromagnetic induction

#### 2.2 **Sensors**

- a) Voltage
- b) Current
- c) Temperature
- d) Position
- e) Pressure

2.2

**Actuators**

- a) Idle speed control
- b) Swirl flaps
- c) Exhaust Gas recirculation
- d) Purge Solenoid Valve Control
- e) Turbocharger
- f) Heating and air conditioning

2.2-2.4, 2.6

**Systems**

- a) Electrical
- b) Electronic
- c) Mechanical
- d) Fluid

2.5-2.6

**Electric vehicle**

- a) Pure (PEV) / battery electric vehicle (BEV)
- b) Extended range (ER-EV)
- c) Range extended (RE-EV)
- d) Fuel cell (FCEV)
- e) Hybrid (HEV)
- f) Plug-in hybrid (PHEV)
- g) Mild hybrid
- h) Micro hybrid

2.5-2.6

**Components**

- a) High voltage batteries
- b) Low voltage batteries
- c) AC three phase motor / generators
- d) Cabling and wiring (wiring colour, size and cross-sectional area)
- e) Relays and contactors
- f) Electronic control units
- g) On-board charger and charging port
- h) DC-to-DC convertor
- i) Isolators (high/low voltage)
- j) Inverters/rectifiers
- k) Battery management units
- l) Vehicle start/stop control
- m) Driver instrumentation
- n) Multi-battery systems
- o) Drive trains (layout)
- p) Power sources, (engine / motor)
- q) Sensors (voltage, current, temperature, position, resolver)
- r) Ancillary components
- s) Air conditioning compressor

t) Heating components

2.6

**Interaction** to include

- a) Between electric motor and engine
- b) Controller Area Network (CAN)
- c) Local Interconnected Network (LIN)
- d) Media Oriented Systems Transport (MOST)
- e) FlexRay
- f) SRS (Supplementary restraint systems)
- g) Braking systems including (ABS)
- h) Steering-By-Wire (SBW)

---

### Learning outcome:

The learner will:

3. understand the features, function and construction of high and low voltage system components and their faults and failures

### Assessment criteria

The learner must know:

- 3.1 the features and purpose of **components** associated with **alternative fuel** sources and systems on **electric vehicles**
  - 3.2 how high and low voltage **systems** and system **components** are constructed
  - 3.3 how high and low voltage **systems** and system **components** operate
  - 3.4 the types of **faults** and failures that can occur within high and low voltage **systems**, components and units
  - 3.5 the causes of **faults** and failures in high and low voltage **systems**, components and units
- 

### Range

- 3.1 **Alternative fuel components**
  - a) Alternative fuels including hydrogen and liquefied petroleum gas
  - b) Re-fueling components
  - c) Supply pipes / fuel lines
  - d) Safety venting systems / pressure release, excess flow and in tank solenoid valves
  - e) Sensors (impact / hydrogen)
  - f) Fuel tanks
  - g) Fuel cell stack / proton-exchange membrane
  - h) Pressure reduction devices
  - i) Service items
  - j) Cooling components
  
- 3.1 **Electric vehicles**
  - a) Pure (PEV) / battery electric vehicle (BEV)
  - b) Extended range (ER-EV)
  - c) Range extended (RE-EV)
  - d) Fuel cell (FCEV)
  - e) Hybrid (HEV)
  - f) Plug-in hybrid (PHEV)
  - g) Mild hybrid
  - h) Micro hybrid

### 3.2-3.3

#### **Components**

- a) High voltage batteries
- b) Low voltage batteries
- c) AC three phase motor / generators
- d) Cabling and wiring (wiring colour, size and cross-sectional area)
- e) Relays and contactors
- f) Electronic control units
- g) On-board charger and charging port
- h) DC-to-DC convertor
- i) Isolators (high/low voltage)
- j) Inverters/rectifiers
- k) Battery management units
- l) Vehicle start/stop control
- m) Driver instrumentation
- n) Multi-battery systems
- o) Drive trains (layout)
- p) Power sources, (engine / motor)
- q) Sensors (voltage, current, temperature, position, resolver)
- r) Ancillary components
- s) Air conditioning compressor
- t) Heating components

### 3.2-3.5

#### **Systems**

- a) Electrical
- b) Electronic
- c) Mechanical
- d) Fluid

### 3.4-3.5

#### **Faults** that occur within:

- a) High voltage system:
  - i. high voltage electrical components
  - ii. high voltage mechanical components
  - iii. high voltage batteries
- b) Low voltage systems:
  - i. charging systems
  - ii. low voltage electrical components
  - iii. low voltage mechanical components
  - iv. batteries
  - v. network systems
- c) Onboard plug-in charging systems
- d) Fluid systems

---

### Learning outcome:

The learner will:

4. understand how to diagnose and rectify faults within high and low voltage systems, components and units

### Assessment criteria

The learner must know:

- 4.1 the relationship between test methodology and the **faults** repaired
- 4.2 how to identify the most appropriate **diagnostic testing method** for the **fault** symptoms presented on high and low voltage:
  - a) electrical and electronic components
  - b) mechanical system operating specifications
  - c) fluid system operating specifications
- 4.3 how to carry out systematic **diagnostic testing** of high and low voltage **systems** to make an accurate diagnosis of **faults**
- 4.4 how to prepare and check the accuracy of **diagnostic testing equipment**
- 4.5 how to use diagnostic and rectification **equipment** to correctly and safely diagnose faults
- 4.6 the importance of working to recognised **diagnostic** and rectification **procedures**
- 4.7 methods of sourcing correct information for diagnostic and rectification activities to proceed
- 4.8 how to interpret vehicle **data** and tests results in order to identify the location and cause of high and low voltage **system faults**
- 4.9 how to assess the condition of high and low voltage electrical, electronic, mechanical and fluid components and units
- 4.10 the circumstances which will necessitate unit or component replacement
- 4.11 how to carry out the **rectification activities** required to correct **faults** in the high and low voltage **systems**
- 4.12 how high and low voltage **systems** are:
  - a) dismantled
  - b) re-assembled
  - c) adjustedto manufacturer's specifications, to include coding and calibration of electronic parts
- 4.13 the importance of documenting the diagnosis and **rectification activities** of **systems** and **components**
- 4.14 how to make cost effective recommendations for rectification

---

## Range

- 4.1-4.3,  
4.8, 4.11
- Faults** that occur within:
- a) High voltage system:
    - i. high voltage electrical components
    - ii. high voltage mechanical components
    - iii. high voltage batteries
  - b) Low voltage systems:
    - i. charging systems
    - ii. low voltage electrical components
    - iii. low voltage mechanical components
    - iv. batteries
    - v. network systems
  - c) Onboard plug-in charging systems
  - d) Fluid systems
- 4.2-4.4, 4.6
- Diagnostic testing method / procedures**
- a) Identify the fault
  - b) Verify the fault
  - c) Collect further information
  - d) Develop a test plan
  - e) Carry out further tests in a logical sequence
  - f) Evaluate the evidence
  - g) Rectify the problem
  - h) Check all systems
- 4.2
- Test methodology / testing methods** to include
- a) Visual inspection
  - b) Voltage, resistance, current, frequency measuring
  - c) Fault codes / live data
  - d) Dedicated and computer-based testing
  - e) Oscilloscope waveforms / checking for noise
- 4.3, 4.8  
4.11-4.12
- Systems**
- a) Electrical
  - b) Electronic
  - c) Mechanical
  - d) Fluid
- 4.13
- Components**
- a) High voltage batteries
  - b) Low voltage batteries

- c) AC three phase motor / generators
- d) Cabling and wiring (wiring colour, size and cross-sectional area)
- e) Relays and contactors
- f) Electronic control units
- g) On-board charger and charging port
- h) DC-to-DC convertor
- i) Isolators (high/low voltage)
- j) Inverters/rectifiers
- k) Battery management units
- l) Vehicle start/stop control
- m) Driver instrumentation
- n) Multi-battery systems
- o) Drive trains (layout)
- p) Power sources, (engine / motor)
- q) Sensors (voltage, current, temperature, position, resolver)
- r) Ancillary components
- s) Air conditioning compressor
- t) Heating components

#### 4.4-4.5

#### **Equipment**

- a) Electrical multimeters / voltmeter rated to a minimum 1000V (CAT. III) or 600V (CAT.IV) including leads and probes
- b) Hand tools
- c) Insulation tester
- d) Code readers / scan tool
- e) Oscilloscope
- f) Specialist tools (manufacturer specific testing/diagnostic equipment and software)
- g) Relevant safety equipment

#### 4.8

#### **Data**

- a) Fault codes
- b) Electrical test equipment
  - i. multimeter
  - ii. oscilloscope
- c) Live data
- d) Data from other suitable testing methods

#### 4.11, 4.13

#### **Rectification activities** to include

- a) Component removal / replacing / fitting procedures



---

## Learning outcome:

The learner will:

5. understand the health and safety, legislative and workplace procedures required to be followed when carrying out repair activities of electric vehicles

## Assessment criteria

The learner must know:

- 5.1 current **health and safety legislation, industry codes of practice** and **guidelines** relevant to working on **electric vehicles**
- 5.2 the how to select, check and use the appropriate **high voltage tooling, personal protective equipment (PPE)** and **vehicle protective equipment (VPE)** including:
  - a) associated international European standards
  - b) double insulation
  - c) double triangle (live electrical)
- 5.3 the health and safety related precautions and actions associated with the removal and replacement of high voltage components
- 5.4 the importance of manufacturers guidance and the **precautions** necessary to take when:
  - a) charging an **electric vehicle**
  - b) connecting an auxillary power source to an **electric vehicle**
  - c) **towing** or lifting **an electric vehicle**
- 5.5 workplace procedures for:
  - a) **recording** fault location and correction activities
  - b) **reporting** the results of tests carried out
  - c) completing and **storing** documentation relating to diagnosis and repair work
  - d) **reporting/referring** problems
  - e) **reporting** delays to the completion of work to managers and customers
  - f) use of **risk assessments**
  - g) **safe working environment**
- 5.6 workplace procedures that must be followed in the event of **emergencies**
- 5.7 the legislative and organisational requirements for
  - a) storage
  - b) disposal
  - c) recycling
  - d) returnof any removed high voltage components
- 5.8 how to safely mobilise an **electric vehicle** in line with manufacturer's recommendations
- 5.9 the **importance** of working to **agreed timescales** and keeping others informed of progress
- 5.10 the **relationship** between time, costs and productivity

5.11 the **importance** of reporting anticipated delays to the relevant person(s) promptly

---

## Range

- 5.1 **Health and safety legislation, industry codes of practice, guidelines**
- a) Health and Safety at Work act
  - b) Electrical equipment regulations
  - c) Regulation No 100 of the Economic Commission for Europe of the United Nations (UNECE) – ‘High Voltage means the classification of an electric component or circuit, if it’s working voltage is > 60 V and ≤ 1500 V DC or > 30 V and ≤ 1000 V AC root mean square (ms)
  - d) Electricity at Work Regulations
  - e) HSE guidelines
  - f) Manufacturer technical repair information
  - g) End of Life Vehicle regulations
  - h) COSHH
- 5.1, 5.4, 5.8 **Electric vehicle**
- a) Pure (PEV) / battery electric vehicle (BEV)
  - b) Extended range (ER-EV)
  - c) Range extended (RE-EV)
  - d) Fuel cell (FCEV)
  - e) Hybrid (HEV)
  - f) Plug-in hybrid (PHEV)
  - g) Mild hybrid
  - h) Micro hybrid
- 5.2 **High voltage tooling** (including European and International standards)
- a) Insulated tools
  - b) CAT 3 multimeter
- 5.2 **Personal protective equipment** to include
- a) Overalls (with non-conductive fastenings)
  - b) Feet protection
  - c) Gloves (including class and IEC/EN numbers)
  - d) Eye / face protection
  - e) Rubber/insulated mats (including class and IEC/EN numbers)
  - f) Insulated tools (including class and IEC/EN numbers)
- 5.2 **Vehicle protective equipment** to include
- a) Seat covers

- b) Floor mats
  - c) Steering wheel covers
  - d) Wing protectors
  - e) Insulated cable connection covers
- 5.4        **Towing precautions** to include
- a) Speed limitations
  - b) Distance limitations
  - c) Potential energising of components / systems
- 5.5a-e     **Recording/reporting/storing** ensuring
- a) Accurate records
  - b) Auditable records
  - c) Compliance with data protection
- 5.5        **Risk assessment** types
- a) Static
  - b) Dynamic
- 5.5        **Risk assessment** procedures include
- a) Risk assessment documentation and responsible persons
  - b) Taking action to eliminate or reduce risk
  - c) Observing, assessing, analysing an environment while working, to identify and remove risk
  - d) Monitoring situation
  - e) Reviewing situation
- 5.5g       **Safe working environment** to include
- a) Signage
  - b) Barriers
  - c) Cordoning
  - d) Secure key box
  - e) Spill kit
  - f) Warning labels
- 5.6        **Emergencies** to include
- a) Electric shock
  - b) Burns
  - c) High voltage vehicle fires
  - d) Chemical leakage
  - e) Other emergencies

5.9

**Agreed timescales**

- a) Manufacturers' recommended work times
- b) Job times set by the company
- c) Job time agreed with the customer

5.10

**Relationship**

- a) How extended labour times can affect costs and productivity
- b) The consequences of mistakes and rework and its effect on time, cost and productivity
- c) The effects of uneconomical use of resources, materials / consumables
- d) Methods of increasing efficiency through planning, organisation of the workspace and maintaining tools and equipment
- e) How training and personal development can be advantageous to saving time, costs and being more productive

5.9, 5.11

**Importance**

- a) Customer satisfaction
- b) Business productivity
- c) Business reputation
- d) Repeat business
- e) Reduces risk of liability accusations

---

### Learning outcome:

The learner will:

6. understand the risks and hazards associated with working on electric vehicles and how to minimise risk to themselves and others when diagnosing and repairing electric vehicles

### Assessment criteria

The learner must know:

- 6.1 how to safely power down and isolate a high voltage system and confirm an **electric vehicle** is safe to work on
- 6.2 the precautions to take to ensure the high voltage system cannot be re-energised without knowledge and agreement
- 6.3 the **hazards** associated with **high voltage components** and systems
- 6.4 the **hazards** associated with alternative fuel systems and how to check for leaks
- 6.5 the **hazards** associated with interrupting a circuit with high current flow and the need for high voltage circuit protection
- 6.6 how to identify and reduce the risk of high voltage **hazards** when working on and around **electric vehicles**
- 6.7 the **implications** of **electrical conductivity** through the human body
- 6.8 the **implications** of working around strong magnetic fields
- 6.9 the impact of **hazards** associated with **electric vehicles** when exposed to extreme temperatures, vehicle impact and other adverse conditions
- 6.10 how to work safely avoiding **damage** to high voltage and other vehicle systems, components and units and contact with leakage and hazardous substances

---

### Range

- 6.1, 6.6      **Electric vehicle(s)**  
6.9
- a) Pure (PEV) / battery electric vehicle (BEV)
  - b) Extended range (ER-EV)
  - c) Range extended (RE-EV)
  - d) Fuel cell (FCEV)
  - e) Hybrid (HEV)
  - f) Plug-in hybrid (PHEV)
  - g) Mild hybrid

- 6.3, 6.5,  
6.6, 6.9      **Hazards** to include
- a) Fire / thermal runaway
    - i. Exothermic reaction
    - ii. Endothermic reaction
  - b) Explosion

- c) Pressures
- d) Arc flash
- e) Gases/fumes
- f) Chemicals
- g) Electric shock
- h) Damage to cables
- i) Dangerous voltage retention in components even when vehicle is switched off

**6.3 High voltage components**

- a) High voltage batteries (to include Nickel Metal Hydride (Ni-Mh), Lithium (Li-ion))
- b) Inverter
- c) High voltage cables
- d) DC-to-DC convertor
- e) Fuel cell
- f) Cooling components
- g) PTC heaters
- h) Heat pumps
- i) High voltage air conditioning compressors
- j) Charging equipment and cables
- k) AC three phase motor/generators
- l) Power/battery management system
- m) Auxiliary systems

**6.4 Hazards to include**

- a) Fire
- b) Explosion
- c) High/low pressures
- d) Gases/fumes
- e) Chemicals
- f) Electric shock
- g) Damage to high pressure fuel lines/pipes

**6.7-6.8 Implications**

- a) Cardiac arrest
- b) Muscle, nerve and tissue damage
- c) Thermal burns
- d) Medical equipment damage e.g., pacemakers

6.7

**Electrical conductivity**

- a) Specific values (voltage, current) that can cause harm

6.10

**Damage** to high voltage components includes:

- a) Overheating
- b) Physical impact damage
- c) Chemical leakage
- d) Smoke
- e) Water damage
- f) Different battery chemistries
- g) Reduction in energy holding capacity
- h) Overcharging due to internal electrical damage
- i) Reduction in wiring insulative properties

## Unit 605

# Knowledge of Testing, Removing and Storing Electric Vehicle High Voltage Batteries

<b>Level:</b>	Level 4
<b>GLH:</b>	14
<b>Relationship to NOS:</b>	EV06: Test, remove and store electric vehicle high voltage batteries
<b>Aim:</b>	To understand how to test and store high voltage battery packs, remove and replace high voltage battery modules and re-fit high voltage battery packs in electric vehicles.

**Assessment type** Multiple-choice questions

---

### Essential Knowledge

### Learning outcomes

The learner will:

1. understand the differences between electric vehicle battery types and structures, the connections made from the battery to other components and parts within the vehicle, and how to calculate battery cell voltages
2. understand the legislative and workplace requirements that must be adhered to when working with high voltage batteries, the hazards associated with high voltage batteries and the procedure for the safe removal, storage and disposal of a high voltage battery pack
3. understand how to carry out tests and use the appropriate equipment to determine the condition of batteries and know how to correctly interpret test results



---

## Learning outcome:

The learner will:

1. understand the differences between electric vehicle battery types and structures, the connections made from the battery to other components and parts within the vehicle, and how to calculate battery cell voltages

## Assessment criteria

The learner must know:

- 1.1 the different **battery types** and the vehicles they are fitted to, including:
  - a. battery structure
  - b. voltage (potential difference)
  - c. chemical makeup
- 1.2 how to calculate **battery** cell voltages in series and parallel
- 1.3 the terminology used in relation to **electric vehicle** systems, system **component** parts, structures, and sub-structures
- 1.4 where to access appropriate **technical information** to aid the diagnostic and removal process
- 1.5 how to **identify** high voltage **components** and parts that are connected to the high voltage system throughout the vehicle and within the battery
- 1.6 the purpose of high voltage connections and how they function

---

## Range

- |         |   |
|---------|---|
| 1.1-1.2 | <b>Battery types / battery</b> <ol style="list-style-type: none"><li>a) Nickel metal hydride</li><li>b) Lithium-ion</li><li>c) Flooded (including enhanced)</li><li>d) Absorbed glass mat (AGM)</li><li>e) Lead acid</li></ol>  |
| 1.3     | <b>Electric vehicle(s)</b> <ol style="list-style-type: none"><li>a) Pure (PEV) / battery electric vehicle (BEV)</li><li>b) Extended range (ER-EV)</li><li>c) Range extended (RE-EV)</li><li>d) Fuel cell (FCEV)</li><li>e) Hybrid (HEV)</li><li>f) Plug-in hybrid (PHEV)</li><li>g) Mild hybrid</li><li>h) Micro hybrid</li></ol> |

1.3

**Component**

- a) Transistors
  - i. Insulated-gate bipolar transistor
- b) Diodes
- c) Capacitors
- d) Fuses
- e) Relays
- f) Contactors
- g) Sensors
- h) Circuit board

1.4

**Technical information** to include

- a) Manufacture repair procedures
- b) Manufacturer test plans
- c) Manufacturer wiring diagrams
- d) 3rd party information

1.5

**Identify** from:

- a) Labelling
- b) Colour
- c) Materials
- d) Insulation
- e) Cross-sectional area
- f) Function

1.5

**Components**

- a) High voltage batteries
- b) AC three phase motor / generators
- c) Cabling and wiring (wiring colour, size and cross-sectional area)
- d) Relays and contactors
- e) Electronic control units
- f) On-board charger and charging port
  - i. Type 2
  - ii. Combined charging system
  - iii. Chademo
- g) DC-to-DC convertor
- h) Isolators (high/low voltage)

- i) Inverters/rectifiers
- j) Battery management units
- k) Vehicle start/stop control
- l) Driver instrumentation
- m) Multi-battery systems
- n) Drive trains (layout)
- o) Power sources, (engine / motor)
- p) Sensors (voltage, current, temperature, position, resolver)
- q) Ancillary components
- r) Air conditioning compressor
- s) Heating components

---

## Learning outcome:

The learner will:

2. understand the legislative and workplace requirements that must be adhered to when working with high voltage batteries, the hazards associated with high voltage batteries and the procedure for the safe removal, storage and disposal of a high voltage battery pack

## Assessment criteria

The learner must know:

- 2.1 the current **health and safety legislation, industry codes of practice** or **guidelines** and specific vehicle manufacturer's safety procedures relevant to working with **electric vehicle high voltage** and auxiliary **batteries**
- 2.2 how to check and use the appropriate **personal protective equipment (PPE)** and **vehicle protective equipment (VPE)** including:
  - a) class rating
  - b) international standards / international electrotechnical commission (IEC) references
- 2.3 how and when to carry out the different types of **risk assessment**
- 2.4 manufacturers' and workplace requirements and procedures for:
  - a) authorisation to allow an individual to work on high voltage systems
  - b) making others aware of potential hazards prior to carrying out repair work
  - c) making others aware that work is being carried out on high voltage systems
  - d) accurately reporting to relevant persons and documenting that work has been carried out on a vehicle, including vehicle damage
- 2.5 the **factors** to consider when moving and storing **high voltage batteries**
- 2.6 the procedures for the safe removal and storage of **electric vehicle high voltage battery** modules and packs, following manufacturer and legislative guidelines
- 2.7 how to safely dispose or recycle **high voltage batteries** or its components in line with **legislation** and organisational procedures
- 2.8 the impact of **hazards** associated with electric high voltage vehicles and their **batteries** when exposed to extreme temperatures, vehicle impact and other adverse conditions

---

## Range

- 2.1 **Health and safety legislation, industry codes of practice, guidelines**
  - a) Health and Safety at Work act
  - b) Electrical equipment regulations
  - c) Regulation No 100 of the Economic Commission for Europe of the United Nations (UNECE) – 'High Voltage means the classification of an electric component or circuit, if it's working voltage is > 60 V and ≤ 1500 V DC or > 30 V and ≤ 1000 V AC root mean square (ms)
  - d) Electricity at Work Regulations including 'Written procedures'

- e) Permit to work
- f) HSE guidelines
- g) Manufacturer technical repair information
- h) End of Life Vehicle regulations
- i) COSHH

2.1, 2.6      **Electric vehicle(s)**

- a) Pure (PEV) / battery electric vehicle (BEV)
- b) Extended range (ER-EV)
- c) Range extended (RE-EV)
- d) Fuel cell (FCEV)
- e) Hybrid (HEV)
- f) Plug-in hybrid (PHEV)
- g) Mild hybrid
- h) Micro hybrid

2.1, 2.8      **Battery types / batteries**

- a) Nickel metal hydride
- b) Lithium-ion
- c) Flooded (including enhanced)
- d) Absorbed glass mat (AGM)
- e) Lead acid

2.2      **Personal protective equipment** to include

- a) Overalls (with non-conductive fastenings)
- b) Feet protection
- c) Gloves (including class and IEC/EN numbers)
- d) Eye / face protection
- e) Rubber/insulated mats (including class and IEC/EN numbers)
- f) Insulated tools (including class and IEC/EN numbers)

2.2      **Vehicle protective equipment** to include

- a) Seat covers
- b) Floor mats
- c) Steering wheel covers
- d) Wing protectors
- e) Insulated cable connection covers

2.3 **Risk assessment**

- a) Static
- b) Dynamic

2.5 **Factors** to consider

- a) Legislative governance
- b) Health and Safety
- c) Manual Handling
- d) Appropriate lockable storage of high voltage unit
- e) Restricted area
- f) Insulation requirements (IP68)
- g) Appropriate signage
- h) Environment (including temperature)
- i) Weight

2.5-2.7 **High voltage batteries**

- a) Nickel metal hydride
- b) Lithium-ion

2.7 **Legislation**

- a) Regulations: Waste Batteries

2.8 **Hazards** to include

- a) Fire / thermal runaway
  - i. Exothermic reaction
  - ii. Endothermic reaction
- b) Explosion
- c) Pressures
- d) Arc flash
- e) Gases/fumes
- f) Chemicals
- g) Electric shock
- h) Damage to components/cables
- i) Dangerous voltage retention in components even when vehicle is switched off

---

### Learning outcome:

The learner will:

3. understand how to carry out tests and use the appropriate equipment to determine the condition of batteries and know how to correctly interpret test results

### Assessment criteria

The learner must know:

- 3.1 the impact of **damage** to the **battery** and the high voltage connections and cables
- 3.2 how to carry out appropriate **tests** and procedures to determine the **condition** of the **battery** cells or modules
- 3.3 how to select, check and calibrate the **equipment** required to test, remove and move **electric vehicle high voltage batteries**
- 3.4 how to use diagnostic and test **equipment** safely
- 3.5 how to analyse and interpret test results to ensure:
  - a) the state of charge (SOC) of **batteries** and modules
  - b) the state of health (SOH) of **batteries** and modules
  - c) the integrity and safety of the high voltage system
- 3.6 known manufacturer's **values** of **high voltage batteries**

---

### Range

- 3.1 **Damage** includes:
  - a) Overheating
  - b) Physical impact damage
  - c) Chemical leakage
  - d) Smoke
  - e) Corrosion
  - f) Water damage
  - g) Different battery chemistries
  - h) Reduction in energy holding capacity
  - i) Overcharging due to internal electrical damage
  - j) Reduction in wiring insulative properties
  
- 3.1-3.2, 3.5 **Battery** types / **batteries**
  - a) Nickel metal hydride
  - b) Lithium-ion
  - c) Flooded (including enhanced)
  - d) Absorbed glass mat (AGM)

e) Led acid

3.2 **Condition**

a) State of health (SOH)

3.2 **Tests** to include

a) Static voltage test

b) Load test

c) Insulation test

3.3-3.4 **Equipment**

a) Electrical multimeters / voltmeter rated to a minimum 1000V (CAT. III) or 600V (CAT.IV) including leads and probes

b) Other safe and appropriate electrical testing

c) Hand tools

d) Code readers / scan tools

e) Oscilloscopes

f) Special tools (manufacturer specific testing/diagnostic/calibrating equipment and software)

g) Lifting/moving equipment

h) Spill kit

i) Relevant safety equipment

3.3 **Electric vehicle(s)**

a) Pure (PEV) / battery electric vehicle (BEV)

b) Extended range (ER-EV)

c) Range extended (RE-EV)

d) Fuel cell (FCEV)

e) Hybrid (HEV)

f) Plug-in hybrid (PHEV)

g) Mild hybrid

h) Micro hybrid

3.3, 3.6 **High voltage batteries**

a) Nickel metal hydride

b) Lithium-ion



3.6

**Values**

- a) Resistance
- b) Voltages
- c) Amperage / current
- d) Wattage

## Unit 614

# Skills in Diagnosing and Rectifying Faults in an Electric Vehicle Powertrain and Ancillary Systems

<b>Level:</b>	Level 4
<b>GLH:</b>	7
<b>Relationship to NOS:</b>	EV05: Diagnose and rectify faults in an electric vehicle powertrain and ancillary systems
<b>Aim:</b>	To be able to demonstrate how to safely diagnose and rectify high voltage system faults in an electric vehicle following manufacture's procedures.

**Assessment type** Practical assessment

---

### Essential Skills

Learning outcome:

The learner will:

1. be able to demonstrate safe and appropriate working methods when carrying out diagnostic and rectification activities of high voltage electric vehicle systems and components
2. be able to diagnose high voltage vehicle system and component faults in a safe, methodical and efficient manner
3. be able to carry out the repair of the high voltage vehicle following the diagnosis of a high voltage system component fault
4. be able to accurately record work activities and effectively communicate throughout the repair process with colleagues, supervisors, and customers

---

## Essential Skills

### Learning outcome:

The learner will:

1. be able to demonstrate safe and appropriate working methods when carrying out diagnostic and rectification activities of high voltage electric vehicle systems and components

### Assessment criteria

The learner must:

- 1.1 identify the type of electric vehicle being worked on
- 1.2 locate and record relevant information about the vehicle
- 1.3 ensure the work area is clearly identified using signs and barriers as appropriate
- 1.4 perform the correct procedures to make the vehicle safe prior to starting any work activities
- 1.5 ensure work cannot be started without relevant individuals' knowledge and agreement
- 1.6 follow current regulatory requirements and legislation relevant to working on electric vehicles
- 1.7 prepare the work area and vehicle systems, following safe working procedures as appropriate to the vehicle and the nature of the fault
- 1.8 support work activities by using vehicle system manufacturer's technical data
- 1.9 select, check and use the appropriate **personal protective equipment (PPE)** and **vehicle protective equipment (VPE)**
- 1.10 work in a way which minimises risk of:
  - a) injury
  - b) damage to the working environment
  - c) **damage** to other vehicle systems, components and units
- 1.11 conduct a **dynamic risk assessment** on the vehicle and work area to determine potential hazards

---

## Range

- 1.9        **Personal protective equipment** to include
- a) Overalls (with non-conductive fastenings)
  - b) Feet protection
  - c) Gloves (including class and IEC/EN numbers)
  - d) Eye / face protection
  - e) Rubber/insulated mats (including class and IEC/EN numbers)
  - f) Insulated tools (including class and IEC/EN numbers)
- 1.9        **Vehicle protective equipment** to include
- a) Seat covers
  - b) Floor mats
  - c) Steering wheel covers
  - d) Wing protectors
  - e) Insulated cable connection covers
- 1.10       **Damage** includes:
- a) Overheating
  - b) Physical impact damage
  - c) Chemical leakage
  - d) Smoke
  - e) Water damage
  - f) Different battery chemistries
  - g) Reduction in energy holding capacity
  - h) Overcharging due to internal electrical damage
  - i) Reduction in wiring insulative properties
- 1.11       **Dynamic risk assessment** procedures include
- a) Risk assessment documentation and responsible persons
  - b) Taking action to eliminate or reduce risk
  - c) Observing, assessing, analysing an environment while working, to identify and remove risk
  - d) Monitoring situation
  - e) Reviewing situation

---

### Learning outcome:

The learner will:

2. be able to diagnose high voltage vehicle system and component faults in a safe, methodical and efficient manner

### Assessment criteria

The learner must:

- 2.1 support the identification of faults by using vehicle technical data
- 2.2 collect and record sufficient diagnostic information in a logical and systematic way to enable an accurate diagnosis of the high voltage system faults
- 2.3 use **diagnostic testing methods** which are relevant to the symptoms presented appropriately and methodically
- 2.4 prepare, check and use appropriate test **equipment** following manufacturer's instructions
- 2.5 identify and record any system deviation from manufacturer's specifications accurately
- 2.6 assess components and units to establish their condition and suitability for repair or replacement
- 2.7 carry out diagnostic activities following:
  - a) manufacturers' instructions
  - b) health, safety and environmental requirements
  - d) workplace procedures
- 2.8 collate and analyse test results accurately
- 2.9 complete diagnostic activities within the agreed timescales

---

### Range

- 2.3 **Diagnostic testing method**
  - a) Identify the fault
  - b) Verify the fault
  - c) Collect further information
  - d) Evaluate the evidence
  - e) Carry out further tests in a logical sequence
  - f) Rectify the problem
  - g) Check all systems
- 2.3 **Testing methods** (or test methodology) to include
  - a) Visual inspection
  - b) Voltage, resistance, current, frequency measuring
  - c) Fault codes / live data
  - d) Dedicated and computer-based testing
  - e) Oscilloscope waveforms / checking for noise

2.4

**Equipment**

- a) Electrical multimeters / voltmeter rated to a minimum 1000V (CAT. III) or 600V (CAT.IV) including leads and probes
- b) Other safe and appropriate electrical testing / repair and replacement equipment
- c) Hand tools
- d) Code readers
- e) Oscilloscope
- f) Lifting/moving equipment
- g) Specialist tools (manufacturer specific testing/diagnostic equipment and software)
- h) Relevant safety equipment

---

### Learning outcome:

The learner will:

3. be able to carry out the repair of the high voltage vehicle following the diagnosis of a high voltage system component fault

### Assessment criteria

The learner must:

- 3.1 evaluate repair options considering time, cost and safety
- 3.2 carry out rectification activities following:
  - a) manufacturer's instructions
  - b) industry recognised repair methods
  - c) health, safety and environmental requirements
  - d) workplace procedures
- 3.3 select replacement **components** which meet the manufacturer's recommendations and conform to operating specification
- 3.4 adjust components correctly to ensure that they operate to system requirements
- 3.5 evaluate the performance of the rectified high voltage system accurately using suitable testing methods
- 3.6 monitor and analyse the rectified system to ensure it performs to the manufacturer's operating specifications and legal requirements prior to returning to customer
- 3.7 complete diagnostic and repair activities within the agreed industry relevant timescales / manufacturers specific

---

### Range

- 3.3 **Components** to include
  - a) High voltage batteries
  - b) AC three phase motor / generators
  - c) Cabling and wiring (wiring colour, size and cross-sectional area)
  - d) Relays and contactors
  - e) Electronic control units
  - f) On-board charger and charging port
    - i. Type 2
    - ii. Combined charging system
    - iii. Chademo
  - g) DC-to-DC convertor
  - h) Isolators (high/low voltage)
  - i) Inverters/rectifiers
  - j) Battery management units
  - k) Vehicle start/stop control

- l) Driver instrumentation
- m) Multi-battery systems
- n) Drive trains (layout)
- o) Power sources, (engine / motor)
- p) Sensors (voltage, current, temperature, position, resolver)
- q) Ancillary components
- r) Air conditioning compressor
- s) Heating components



---

### Learning outcome:

The learner will:

4. be able to accurately record work activities and effectively communicate throughout the repair process with colleagues, supervisors, and customers

### Assessment criteria

The learner must:

- 4.1 record and report accurately any faults or issues noticed during inspection or repair work
- 4.2 record and report accurately to the **relevant person(s)** the work activities that have carried out on or near the vehicle
- 4.3 ensure records are complete and passed to the **relevant person(s)** within the agreed timescale and in the format required
- 4.4 report any anticipated delays in completion of diagnosis and rectification work to the **relevant person(s)** promptly and effectively
- 4.5 communicate appropriately to inform the **relevant person(s)** where repairs are uneconomic or unsatisfactory to the customer

---

### Range

- 4.2-4.5      **Relevant person(s)** to include
- a) Customer
  - b) Supervisor
  - c) Colleagues

## Unit 615

# Skills in Testing, Removing and Storing Electric Vehicle High Voltage Batteries

---

<b>Level:</b>	Level 4
<b>GLH:</b>	6
<b>Relationship to NOS:</b>	EV06: Test, remove and store electric vehicle high voltage batteries
<b>Aim:</b>	To demonstrate how to test, remove and replace high voltage battery modules and battery packs, and how to safely store battery packs.

---

### Essential Skills

Learning outcome:

The learner will:

1. be able to work safely when working with high voltage batteries, adhering to legislation and workplace and manufacturer requirements
2. be able to carry out diagnostic testing activities on an electric vehicle high voltage battery and accurately analyse and interpret technical information and test results
3. be able to correctly and safely disconnect and remove a high voltage system battery pack/module, replace and balance battery modules and safely store and re-fit a high voltage battery pack back to an electric vehicle

---

## Learning outcome:

The learner will:

1. be able to work safely when working with high voltage batteries, adhering to legislation and workplace and manufacturer requirements

## Assessment criteria

The learner must:

- 1.1 identify the type of electric vehicle and **high voltage battery** being worked on
- 1.2 collect and record relevant **technical information** about the vehicle
- 1.3 select, check and use appropriate signs and barriers to ensure the work area is clearly identified
- 1.4 perform the correct procedures to make the vehicle safe prior to starting any work activities
- 1.5 ensure work cannot be started without relevant individuals' knowledge and agreement
- 1.6 follow current regulatory requirements and legislation relevant to working on electric vehicles and high voltage batteries
- 1.7 prepare the work area and vehicle systems, following safe working procedures as appropriate to the vehicle and the nature of the fault
- 1.8 support work activities by using vehicle system manufacturer's technical data and manufacturer's instructions
- 1.9 select, check and use the appropriate **personal protective equipment (PPE)** and **vehicle protective equipment (VPE)**
- 1.10 work in a way which minimises risk of:
  - a) injury
  - b) damage to the working environment
  - c) damage to other vehicle systems, components and units
- 1.11 conduct a **dynamic risk assessment** on the vehicle and work area prior to commencement of any repair work, to determine potential hazards

---

## Range

- 1.1 **High voltage battery**
  - a) Nickel metal hydride
  - b) Lithium-ion
- 1.2 **Technical information** to include
  - a) Manufacture repair procedures
  - b) Manufacturer test plans
  - c) Manufacturer wiring diagrams

d) 3rd party information

1.9

**Personal protective equipment** to include

- a) Overalls (with non-conductive fastenings)
- b) Feet protection
- c) Gloves (including class and IEC/EN numbers)
- d) Eye / face protection
- e) Rubber/insulated mats (including class and IEC/EN numbers)
- f) Insulated tools (including class and IEC/EN numbers)

1.9

**Vehicle protective equipment** to include

- a) Seat covers
- b) Floor mats
- c) Steering wheel covers
- d) Wing protectors
- e) Insulated cable connection covers

1.11

**Dynamic risk assessment** procedures include

- a) Risk assessment documentation and responsible persons
- b) Taking action to eliminate or reduce risk
- c) Observing, assessing, analysing an environment while working, to identify and remove risk
- d) Monitoring situation
- e) Reviewing situation

---

## Learning outcome:

The learner will:

2. be able to carry out diagnostic testing activities on an electric vehicle high voltage battery and accurately analyse and interpret technical information and test results

## Assessment criteria

- 2.1 inspect the external and visible parts of the high voltage battery pack, including connections and cables for **damage**
  - 2.2 test the battery modules using diagnostic and test **equipment** to assess the integrity of the high voltage battery and the high voltage system prior to commencing removal
  - 2.3 interpret test results obtained from the diagnostic test **equipment**
- 

## Range

- 2.1 **Damage** includes:
  - a) Overheating
  - b) Physical impact damage
  - c) Chemical leakage
  - d) Smoke
  - e) Water damage
  - f) Different battery chemistries
  - g) Reduction in energy holding capacity
  - h) Overcharging due to internal electrical damage
  - i) Reduction in wiring insulative properties
  
- 2.2-2.3 **Equipment**
  - a) Electrical multimeters / voltmeter rated to a minimum 1000V (CAT. III) or 600V (CAT.IV) including leads and probes
  - b) Hand tools
  - c) Insulation tester
  - d) Code readers / scan tool
  - e) Oscilloscope
  - f) Lifting/moving equipment
  - g) Special tools (manufacturer specific testing/diagnostic equipment and software)
  - h) Relevant safety equipment

---

### Learning outcome:

The learner will:

3. be able to correctly and safely disconnect and remove a high voltage system battery pack/module, replace and balance battery modules and safely store and re-fit a high voltage battery pack back to an electric vehicle

### Assessment criteria

The learner must:

- 3.1 demonstrate the correct electric vehicle power down and safe isolation procedure of the high voltage system in line with manufacturer's guidance
- 3.2 select, check, and use appropriate **equipment** in line with manufacturer's guidelines and specification
- 3.3 disconnect and remove the high voltage battery pack / battery module following manufacturer's guidance
- 3.4 replace battery modules from the battery pack
- 3.5 balance battery modules
- 3.6 store the high voltage battery pack in a suitable, isolated area with restricted access and appropriate signage
- 3.7 re-fit the battery pack to the vehicle
- 3.8 carry out all battery testing and removal activities within the agreed industry relevant / manufacturers recommended timescales
- 3.9 carry out checks to ensure vehicle is functioning safely and is fully operational

---

### Range

- 3.2 **Equipment**
  - a) Electrical multimeters / voltmeter rated to a minimum 1000V (CAT. III) or 600V (CAT.IV) including leads and probes
  - b) Other safe and appropriate electrical testing
  - c) Hand tools
  - d) Code readers / scan tools
  - e) Oscilloscopes
  - f) Specialist tools (manufacturer specific testing/diagnostic/calibrating equipment and software)
  - g) Lifting/moving equipment
  - h) Spill kit
  - i) Relevant safety equipment

## Appendix 1 Sources of general information

The following documents contain essential information for centres delivering City & Guilds qualifications. They should be referred to in conjunction with this handbook. To download the documents and to find other useful documents, go to the **Centre Document Library** on **www.cityandguilds.com** or click on the links below:

### **Quality Assurance Standards: Centre Handbook**

This document is for all approved centres and provides guidance to support their delivery of our qualifications. It includes information on

- Centre quality assurance criteria and monitoring activities
- Administration and assessment systems
- Centre-facing support teams at City & Guilds / ILM
- Centre quality assurance roles and responsibilities.

The Centre Handbook should be used to ensure compliance with the terms and conditions of the Centre Contract.

### **Quality Assurance Standards: Centre Assessment**

This document sets out the minimum common quality assurance requirements for our regulated and non-regulated qualifications that feature centre assessed components. Specific guidance will also be included in relevant qualification handbooks and/or assessment documentation.

It incorporates our expectations for centre internal quality assurance and the external quality assurance methods we use to ensure that assessment standards are met and upheld. It also details the range of sanctions that may be put in place when centres do not comply with our requirements, or actions that will be taken to align centre marking/assessment to required standards. Additionally, it provides detailed guidance on the secure and valid administration of centre-assessments.

Any centre-based assessments must be carried out in line with our Centre Assessment Standards Scrutiny (CASS) Strategy which can be found on **www.cityandguilds.com**.

### **Access arrangements - When and how applications need to be made to City & Guilds**

provides full details of the arrangements that may be made to facilitate access to assessments and qualifications for candidates who are eligible for adjustments in assessment.

The **Centre Document Library** also contains useful information on such things as:

- Conducting examinations
- Registering learners
- Appeals and malpractice
- Reasonable adjustments

## Useful contacts

Please visit the Contact Us section of the City & Guilds website, [Contact us](#)

## City & Guilds

For over 140 years we have worked with people, organisations and economies to help them identify and develop the skills they need to thrive. We understand the life changing link between skills development, social mobility, prosperity and success. Everything we do is focused on developing and delivering high-quality training, qualifications, assessments and credentials that lead to jobs and meet the changing needs of industry.

We partner with our customers to deliver work-based learning programmes that build competency to support better prospects for people, organisations and wider society. We create flexible learning pathways that support lifelong employability, because we believe that people deserve the opportunity to (re)train and (re)learn again and again – gaining new skills at every stage of life, regardless of where they start.

The City & Guilds community of brands includes Gen2, ILM, Intertrain, Kineo and The Oxford Group.

## Copyright

The content of this document is, unless otherwise indicated, © The City and Guilds of London Institute and may not be copied, reproduced or distributed without prior written consent. However, approved City & Guilds centres and candidates studying for City & Guilds qualifications may photocopy this document free of charge and/or include a PDF version of it on centre intranets on the following conditions:

- centre staff may copy the material only for the purpose of teaching learners working towards a City & Guilds qualification, or for internal administration purposes
- learners may copy the material only for their own use when working towards a City & Guilds qualification

The Standard Copying Conditions (see the City & Guilds website) also apply.

Please note: National Occupational Standards are not © The City and Guilds of London Institute. Please check the conditions upon which they may be copied with the relevant Sector Skills Council.

Published by City & Guilds, a registered charity established to promote education and training

City & Guilds of London Institute  
Giltspur House  
5-6 Giltspur Street  
London  
EC1A 9DE

[cityandguildsgroup.com](http://cityandguildsgroup.com)