City & Guilds
Level 3 Award in Knowledge of Hydrogen Fuel Cell Electric Vehicles and Components (7290-53)

Version 1.0 (December 2023)

Qualification Handbook

Qualification at a glance

Subject area	Automotive
City & Guilds number	7290-53
Age group approved	16+
Entry requirements	Yes
Assessment	Online multiple-choice test
Grading	Pass/Fail
Approvals	Full approval required
Support materials	Sample assessment SmartScreen
Registration and certification	Consult the Walled Garden/Online Catalogue for last dates

Title and level	City & Guilds qualification number	Regulatory reference number	GLH	TQT
City & Guilds Level 3 Award in Knowledge of Hydrogen Fuel Cell Electric Vehicles and Components	7290-53	610/2775/3	28	32

Version and date	Change detail	Section
December 2023	Document created	All

Contents

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 on how to safely work on and around Hydrogen Fuel Cell Electric Vehicle (FCEV) systems and components.
What does the qualification cover?	This qualification covers how to identify and understand the function and operation of different types of hydrogen systems and components and the knowledge to safely carry out the removal and replacement and testing of components in hydrogen FCEV systems. The qualification also ensures that learners are aware of the hazards posed by hydrogen FCEV systems and the safe working practices to follow when carrying out removal and replacement activities.
What opportunities for progression are there?	This qualification allows learners to learn and develop the knowledge required to safely work on and around Hydrogen Fuel Cell Electric Vehicles. This qualification allows learners to progress on to higher education and/or further employment in the advancement of Hydrogen Fuel Cell Electric Vehicle technology.
Who did we develop the qualification with?	This qualification has been developed using the National Occupational Standards as set by automotive industry experts.

Structure

To achieve the City & Guilds Level 3 Award in Knowledge of Hydrogen Fuel Cell Electric Vehicles and Components, learners must achieve:

City & Guilds unit number	Unit title	GLH
Mandatory units:		
Learners must achieve the below mandatory unit.		
630	Knowledge of Working on Hydrogen Fuel Cell Electric Vehicles	28

Total Qualification Time (TQT)

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 demonstrate the achievement of the level of attainment necessary for the award of a qualification.

TQT comprises of the following two elements:

1) the number of hours that 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
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2 Centre requirements

Approval

Full approval

To offer this qualification, new centres will need to gain both centre and qualification approval. Please refer to the document **Centre Approval process: Quality Standards** for further information.

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

Resource requirements

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.

Continuing professional development (CPD)

Centres are expected to support their staff in ensuring that their knowledge remains current of the occupational area and of best practice in delivery, mentoring, training, assessment and quality assurance, and that it takes account of any national or legislative developments.

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. All external quality assurance processes reflect the minimum requirements for verified and moderated assessments, as detailed in the Centre Assessment Standards Scrutiny (CASS), section H2 of Ofqual's General Conditions. For more information on both CASS and City & Guilds Quality Assurance processes visit: the What is CASS? and 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

As part of the assessment for this qualification, learners must 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 16 or above.

Access arrangements and reasonable adjustments

City & Guilds has considered the design of this qualification and its assessment in order to best support accessibility and inclusion for all learners. We understand however that individuals have diverse learning needs and may require reasonable adjustments to fully participate. Reasonable adjustments, such as additional time or alternative formats, may be provided to accommodate learners with disabilities and support fair access to assessment.

Access arrangements are adjustments that allow learners with disabilities, special educational needs, and temporary injuries to access the assessment and demonstrate their skills and knowledge without changing the demands of the assessment. These arrangements must be made before assessment takes place.

The Equality Act 2010 requires City & Guilds to make reasonable adjustments where a disabled person would be at a substantial disadvantage in undertaking an assessment.

It is the responsibility of the centre to ensure at the start of a programme of learning that learners will be able to access the requirements of the qualification.

Please refer to the JCQ access arrangements and reasonable adjustments and Access arrangements - when and how applications need to be made to City & Guilds for more information. Both are available on the City & Guilds website: http://www.cityandguilds.com/delivering-our-qualifications/centre-development/centre-document-library/policies-and-procedures/access-arrangements-reasonable-adjustments

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.

Inclusion and diversity

City & Guilds is committed to improving inclusion and diversity within the way we work and how we deliver our purpose which is to help people and organisations develop the skills they need for growth.

More information and guidance to support centres in supporting inclusion and diversity through the delivery of City & Guilds qualifications can be found here:

Inclusion and diversity | City & Guilds (cityandguilds.com)

Sustainability

City & Guilds are committed to net zero. Our ambition is to reduce our carbon emissions by at least 50% before 2030 and develop environmentally responsible operations to achieve net zero by 2040 or sooner if we can. City & Guilds is committed to supporting qualifications that support our customers to consider sustainability and their environmental footprint.

More information and guidance to support centres in developing sustainable practices through the delivery of City & Guilds qualifications can be found here:

Our Pathway to Net Zero | City & Guilds (cityandguilds.com)

Centres should consider their own carbon footprint when delivering this qualification and consider reasonable and practical ways of delivering this qualification with sustainability in mind. This could include:

- reviewing purchasing and procurement processes (such as buying in bulk to reduce the amount of travel time and energy, considering and investing in the use of components that can be reused, instead of the use of disposable or single use consumables)
- reusing components wherever possible
- waste procedures (ensuring that waste is minimised, recycling of components is in place wherever possible)
- minimising water use and considering options for reuse/salvage as part of plumbing activities wherever possible.

Support materials

The following resources are available for this qualification:

Description	How to access
MCQ Sample assessment	www.cityandguilds.com
SmartScreen	www.smartscreen.co.uk

4 Assessment

Assessment of the qualification

Learners must:

- successfully complete the x1 assessment for the mandatory unit 630.

Assessment types			
Unit	**Title**	**Assessment method**	**Where to obtain assessment materials**
630	Knowledge of Working on Hydrogen Fuel Cell Electric Vehicles	Multiple-choice questions	Examinations provided on e-volve

Assessment strategy

City & Guilds has written the following assessment to use with this qualification:

- sample assessment that can be downloaded from the City & Guilds website.

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.

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 test is laid out in the table below:

Graded: Pass/Fail

Learners must achieve a Pass in:

- Unit 630 Multiple-choice online test

to achieve a Pass in the full qualification.

Pass mark: the pass mark for this examination is set at 19/30 marks.

Knowledge of Working on Hydrogen Fuel Cell Electric Vehicles			
Duration: 60 minutes			
Unit	**Outcome**	**Number of questions**	**Percentage %**
630	LO1: Understand how to identify and operate different types of hydrogen fuel cell electric vehicle systems	3	10
	LO2: Understand how to identify the components associated with hydrogen fuel cell electric vehicle systems and their features, function and construction	6	20
	LO3: Understand the types and sources of hydrogen production, the purpose and operation of the hydrogen polymer electrolyte/proton exchange membrane (PEM) fuel cell, and the differences between PEM and alternative fuel cell technologies	6	20
	LO4: Understand the importance of adhering to health and safety legislation, regulations, guidelines and workplace procedures and know how to work safely around hydrogen fuel cell electric vehicles	5	17
	LO5: Understand the hazards associated with removing and replacing components associated with hydrogen fuel cell electric vehicles	3	10
	LO6: Understand the process of testing, removing and replacing components in hydrogen fuel cell electric vehicles and evaluating vehicle system performance following component replacement activity	7	23
	Total	30	100%

5 Units

Structure of the unit

The unit in this qualification contains 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
- range statements

Centres must deliver the full breadth of the range within the unit. Specialist equipment or commodities may not be available to all centres, so centres should ensure that their delivery covers their use. This may be covered by a practical demonstration (eg video).

Guidance for delivery of the unit

This qualification comprises of one **unit**. A unit describes what is expected of a competent person in particular aspects of their job.

The **unit** is divided into **Learning outcomes** which describe in further detail the knowledge that a learner should possess.

Each **learning outcome** has a set of **assessment criteria** (performance and knowledge and understanding) which specify the desired criteria that must 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 630 Knowledge of Working on Hydrogen Fuel Cell Electric Vehicles

Level:	Level 3
GLH:	28
Assessment type:	Multiple-choice questions
Aim:	To know how to identify and understand the function and operation of different types of hydrogen systems and components. To understand the importance of adhering to legislation/workplace procedures and the hazards associated with working on hydrogen vehicles. To understand the knowledge required to safely remove, test and replace components using the correct tools and equipment, following the manufacture's procedures and how to evaluate vehicle performance following replacement activities.

Learning outcome

The learner will:

LO1 Understand how to identify and operate different types of hydrogen fuel cell electric vehicle systems

Assessment criteria

The learner must know:

AC1.1 The **operational** and **constructional differences** between a **hydrogen fuel cell electric vehicle** (FCEV) and a battery electric vehicle (BEV)

AC1.2 The different **types** of hydrogen fuel cell electric vehicle systems and their hydrogen **storage systems**

AC1.3 The **evacuation and re-fueling systems** associated with **hydrogen fuel cell electric vehicles**

AC1.4 How to **safely operate** a **hydrogen fuel cell electric vehicle**

AC1.5 How hydrogen fuel cell electric vehicle **system components interact** with **other vehicle systems**

Range

AC1.1

Operational

The method of generating and using electricity to supply energy to propel the vehicle

Constructional

The process of how electricity is stored, generated and supplied to the motor

Differences between BEV and FCEV

a) Shutting down (powering off)
b) Charging systems
c) Power sources
d) Distance range
e) Safety and control systems
f) Regenerative braking
g) Layouts
h) Badging
i) High voltage battery size capacity
j) Battery weight
k) Energy density
l) Emissions
m) Fueling
n) Charging time
o) Storage tanks (types/construction/hazards/risks)
p) Fuel cell / fuel cell stack

AC1.1
1.3-1.4

Hydrogen fuel cell electric vehicle(s)

a) Light vehicle
b) Heavy vehicle
c) Bus / coach
d) Motorcycle
e) Plant machinery

AC1.2

Types of FCEV systems / storage systems

a) Fuel cell / fuel cell stack
b) Hydrogen storage tanks
    i. Cryogenics
    ii. Pressure systems
c) States of hydrogen (liquid vs gas)
d) On-board fueling systems
e) Safety and control systems
f) High voltage batteries

AC1.3

Evacuation and refueling systems

a) Gas
b) Storage

c) Pressure systems
    i. Relief
    ii. Management
    iii. De-pressurisation
    iv. Re-pressurisation (including re-fill specifications in Bar)
    v. Purging

AC1.4 **Safely operate**

Powering up and shutting down in line with vehicle manufacturer's instructions

AC1.5 **Components**

a) Re-fuelling components
b) Supply pipes
c) Safety venting systems / pressure release, excess flow and in tank solenoid valves
d) Sensors (impact / hydrogen)
e) Storage tanks (including type approvals)
f) Insulation and protection methods and components
g) Fuel cell stack
h) Electronic control units
    i. Power
    ii. Pedal
    iii. Air flow
    iv. Fuel
i) Actuators
j) Driver inputs and instrumentation
k) Pressure reduction devices / regulator
l) Low voltage battery
m) Air conditioning compressor
n) Traction motor
o) High voltage battery
p) Inverter
q) DC-to-DC convertor
r) Auxiliary battery

AC1.5 **Interact**

The sending and receiving of information to communicate between systems

AC1.5 **Other vehicle systems**

a) High voltage system
b) Low voltage system

Learning outcome

The learner will:

LO2 Understand how to identify the components associated with hydrogen fuel cell electric vehicle systems and their features, function and construction

Assessment criteria

The learner must know:

AC2.1 How to **identify** hydrogen supply system **components** that make up **hydrogen fuel cell electric vehicles**

AC2.2 How to **locate** high-pressure hydrogen pipes in a **hydrogen fuel cell electric vehicle**

AC2.3 The **function** of on-board hydrogen fuel storage and supply system **components**

AC2.4 The **construction** of hydrogen supply system **components**

AC2.5 The operating **pressures** of **components** in **hydrogen fuel cell electric vehicles**

AC2.6 The **voltages** associated with **hydrogen fuel cell electric vehicles** and their **components**

AC2.7 Methods of **sourcing information** applicable to **component**:

a. Construction
b. Removal
c. Replacement

within a hydrogen fuel cell electric vehicle system

AC2.8 How to **interpret technical information** applicable to component:

a. Construction
b. Removal
c. Replacement

within a hydrogen fuel cell electric vehicle system

AC2.9 The **purpose** of **ancillary components** of the hydrogen fuel cell stack

AC2.10 The **benefits** of different types of **energy storage systems** in **hydrogen fuel cell electric vehicles**

Range

AC2.1-2.2 **Identify / locate**

a) Manufacturer specifications / operating manual / technical information
b) Marking and labelling
c) Colour
d) Materials
e) Insulation
f) Construction / design
g) System component location
h) Function
i) Component layout

AC2.1, 2.3-2.4 **Components**

a) Re-fuelling components
b) Supply pipes

c) Safety venting systems / pressure release, excess flow and in tank solenoid valves
d) Sensors (impact / hydrogen)
e) Storage tanks (including type approvals)
f) Insulation and protection methods and components
g) Fuel cell stack
h) Fuel cell components
i) Electronic control units
j) Actuators
k) Driver inputs and instrumentation
l) Pressure reduction devices / regulator
m) Low voltage battery

AC2.1-2.2, 2.5-2.6, 2.10 **Hydrogen fuel cell electric vehicles**

a) Light vehicle
b) Heavy vehicle
c) Bus / coach
d) Motorcycle
e) Plant machinery

AC2.4 **Construction**

How components are assembled / what materials are used to construct the component

AC2.5 **Pressures**

a) Atmospheric
    i. Low
    ii. High
b) Measurements
    i. Metric
    ii. Imperial

AC2.5 **Components**

a) Re-fuelling components
b) Supply pipes
c) Safety venting systems / pressure release, excess flow and in tank solenoid valves
d) Sensors (impact / hydrogen)
e) Storage tanks
f) Fuel cell / fuel cell stack
g) Actuators
h) Pressure reduction devices / regulator

AC2.6 **Voltages**

a) High voltage
b) Low voltage
c) Alternating current (AC) voltage
d) Direct current (DC) voltage

e) Voltage ranges of components (Volts (V) or millivolts (mV))

AC2.6 **Components**

a) Excess flow and in tank solenoid valves
b) Sensors (impact / hydrogen)
c) Fuel cell stack components
d) Electronic control units
e) Actuators
f) Driver inputs and instrumentation
g) High voltage battery
h) Low voltage battery
i) AC three phase motor / generators
j) Cabling and wiring (wiring colour, size and cross-sectional area)
k) Relays and Contactors
l) On-board charger and charging port
m) Inverters/rectifiers
n) DC-to-DC convertor
o) Battery management systems
p) Heating / ventilation / air conditioning components

AC2.7 **Sourcing information**

a) Manufacturer's guidance / specification
b) Hard copy manuals
c) Data stored electronically
d) Data from on-board diagnostic displays

AC2.7 **Components**

a) Re-fuelling components
b) Supply pipes
c) Safety venting systems / pressure release, excess flow and in tank solenoid valves
d) Sensors (impact / hydrogen)
e) Storage tanks
f) Insulation and protection methods and components
g) Fuel cell stack
h) Fuel cell components
i) Electronic control units
j) Actuators
k) Driver inputs and instrumentation
l) Pressure reduction devices / regulator
m) Service items

AC2.8 **Interpret**

To understand the meaning of technical information

AC2.8 **Technical information to include data from:**

a) High voltage systems
b) Low voltage systems
c) Hydrogen fuel cell systems

d) Operating voltage ranges
e) Electronic systems
f) Mechanical systems
g) Fluid systems
h) Electrical diagrams
i) Testing equipment
j) Measurements
    i. Ampere Hour (Ah)
    ii. Resistance (Ohms)
    iii. Voltage (Volts, V)
    iv. Power (Watts)
    v. Time (seconds – s, milliseconds - m/s)
k) Manufacture repair procedures
l) Manufacturer test plans
m) Manufacturer wiring diagrams
n) 3rd party information

AC2.9 **Purpose**

To provide support to the primary operation of the vehicle

AC2.9 **Ancillary components**

a) Re-fuelling components
b) Supply pipes
c) Safety venting systems / pressure release, excess flow and in tank solenoid valves
d) Sensors (impact / hydrogen)
e) Storage tanks
f) Actuators
g) Pressure reduction devices / regulator
h) Hydrogen pump
i) Purge pump
j) Boost convertor
k) Air compressor
l) Cooling systems
    i. Pipes
    ii. Pumps
    iii. Filter
    iv. Connections
    v. Deionized water

AC2.10 **Benefits**

a) High voltage battery
    i. Increased range
    ii. Quick recharge
    iii. Variety of chemical makeup
    iv. Battery efficiency

b) Low voltage battery
    i. Compact in size

ii. Light in weight
iii. Variety of chemical makeup

c) Hydrogen fuel tanks
   i. Good structural integrity to withstand high pressures
   ii. Light in weight
   iii. Increased range

d) Boost convertor
   i. Compact in size
   ii. Light in weight
   iii. Ability to store electrical energy quickly
   iv. Ability to discharge electrical energy quickly

AC2.10 **Energy storage systems**

a) High voltage battery
   i. Nickel-metal hydride
   ii. Lithium-ion

b) Low voltage battery

c) Hydrogen fuel tanks

d) Boost convertor

Learning outcome

The learner will:

LO3 Understand the types and sources of hydrogen production, the purpose and operation of the hydrogen polymer electrolyte/proton exchange membrane (PEM) fuel cell, and the differences between PEM and alternative fuel cell technologies

Assessment criteria

The learner must know:

AC3.1 The purpose of the membrane in a PEM fuel cell
AC3.2 **How** a PEM fuel cell **operates**
AC3.3 The **electrochemical process** of a PEM fuel cell
AC3.4 The **by-products** of a PEM fuel cell chemical reaction including it's element symbol
AC3.5 The **differences** between PEM fuel cell and other **alternative fuel cell** technologies
AC3.6 The **reasons** for connecting PEM fuel cells into a stack
AC3.7 The **methods** of **hydrogen production**
AC3.8 **Define** the **categories** within the hydrogen **colour code system**

Range

AC3.2 **How a PEM fuel cell operates**

a) Conversion of chemical elements and physical energy into electricity
   Elements:
   i. Hydrogen
   ii. Oxygen
   iii. Platinum

AC3.3 **Electrochemical process**

a) Electrolysis
b) The role of:
   i. Anode
   ii. Cathode
   iii. Catalyst
   iv. Electrons (bound and free)
   v. Protons

AC3.4 **By-products**

a) Water
b) Heat

AC3.4 **Elements**

a) Water (H2O)
b) Hydrogen (H)
c) Oxygen (O2)

AC3.5 **Differences**

a) Size
b) Weight

c) Materials used in construction:
    i. Alloys
    ii. Precious metals
d) Operating temperature
e) Start-up time

AC3.5 **Alternative fuel cell**

a) Alkaline electrolyte fuel cell
b) High temperature fuel cells
c) Natural gas fuel cell
d) Liquefied petroleum gas (LPG)
e) Direct methanol fuel cell
f) Diesel fuel cell
g) Solid oxide fuel cell

AC3.6 **Reasons**

a) Size
b) Weight
c) Energy generation
d) Power output

AC3.7-3.8 **Methods of hydrogen production / categories**

a) Steam methane reform
b) Electrolysis
c) Carbon capture systems
d) Renewable energy sources (wind / solar / wave technology)

AC3.8 **Define**

The method of production used to create hydrogen and be able to recognise the associated colour code

AC3.8 **Colour code system**

a) Brown
b) Grey
c) Blue
d) Green

Learning outcome

The learner will:

LO4 Understand the importance of adhering to health and safety legislation, regulations, guidelines and workplace procedures and know how to work safely around hydrogen fuel cell electric vehicles

Assessment criteria

The learner must know:

AC4.1 Current **health and safety legislation**, **industry codes of practice** or **guidelines** relevant to working with **hydrogen fuel cell electric vehicles**

AC4.2 The **importance** of manufacturer's guidance and the **precautions** necessary to take when:

a. Connecting an auxiliary power source to a **hydrogen fuel cell electric vehicle**
b. Towing and/or lifting a **hydrogen fuel cell electric vehicle**

AC4.3 How to **check** appropriate **personal protective equipment** and **vehicle protective equipment** when working on **hydrogen fuel cell electric vehicles**

AC4.4 **How** to ensure a **safe working environment**

AC4.5 **Workplace requirements and procedures** for:

a. Reporting/referring **problems**
b. Making **others** aware that work is being carried out on a **hydrogen fuel cell electric vehicle**
c. Working to agreed **timescales** and keeping **others** informed of progress

AC4.6 How to confirm a **hydrogen fuel cell electric vehicle** is **safe**, before carrying out any maintenance or repair activities

AC4.7 How to remove and store hydrogen fuel cell electric vehicle **components** in line with **legislative, environmental and organisational requirements**

AC4.8 How to return, dispose or recycle hydrogen fuel cell electric vehicle **components** in line with **legislative, environmental and organisational requirements**

AC4.9 The **precautions** to take when using **hydrogen refueling equipment**

AC4.10 How to **safely immobilise, store and mobilise** a **hydrogen fuel cell electric vehicle** and its components in line with manufacturer's recommendations and workshop risk assessment procedures

AC4.11 How to work safely avoiding:

a. Damage to **other vehicle systems**
b. Damage to **components**
c. **Injuries** and personal contact with leakage and **hazardous substances**

Range

AC4.1, 4.7-4.8 **Health and safety legislation, industry codes of practice, guidelines legislative, environmental and organisational requirements**

a) Health and Safety at Work, etc. Act
b) Control of Substances Hazardous to Health (COSHH)
c) Dangerous Substances and Explosives Atmospheres Regulations (DSEAR)
d) Equipment for Potentially Explosive Atmospheres (ATEX)
e) Electrical Equipment (Safety) Regulations

f) 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
g) Electricity at Work Regulations
h) Health and Safety Executive (HSE) guidelines
i) Manufacturer technical repair information
j) Environmental Agency guidance
k) EC No. 79/2009 Type Approval of Hydrogen Powered Motor Vehicles Regulation – annex VI 'Requirements for the installation of hydrogen components and systems' and annex I 'List of hydrogen components to be type approved'
l) The pressure systems safety regulations, PSSR
m) Pressure equipment directive

AC 4.1-4.3, 4.5-4.6**,** 4.10 **Hydrogen fuel cell electric vehicle(s)**

a) Light vehicle
b) Heavy vehicle
c) Bus / coach
d) Motorcycle
e) Plant machinery

AC4.2 **Importance**

a) To minimise risk of damage to vehicle electrical systems
b) To minimise risk of harm to self and others
c) To minimise risk to environmental property

AC4.2 **Towing/lifting precautions** to include

a) Speed limitations
b) Distance limitations
c) Potential energising of components / systems

AC4.3 **Check** for

a) Damage
b) Expiry date
c) Serviceability
    i. Wear and tear
    ii. Deterioration
    iii. Pinholes

AC4.3 How to **check**

a) Visual
b) Physical
c) Functional check in line with manufacturer's specification

AC4.3 **Personal protective equipment** to include

a) Overalls

b) Foot protection
c) Gloves (correctly rated)
d) Eye/ face protection

AC4.3 **Vehicle protective equipment** to include
a) Seat covers
b) Floor mats
c) Steering wheel covers
d) Wing protectors
e) Insulated cable connection covers

AC4.4 **How to ensure a safe working environment**
a) Leak detection (building, personal and location)
b) Fire detection
c) Ventilation
d) Hydrogen alarms (for leaks and fire)
e) Emergency procedures

AC4.5 **Workplace requirements and procedures**
a) Accident book
b) Reporting of injuries, diseases, and dangerous occurrences (RIDDOR)
c) Emergency action plan

AC4.5a **Problems**
a) Personal injury
b) Incidences and occurrences
c) Near misses
d) Environmental damage
e) Damage to property

AC4.5b **Others**
a) Work colleagues
b) Customers
c) Workplace visitors
d) Members of the public
e) Emergency services

AC4.5c **Others**
a) Line manager
b) Customers
c) Service reception

AC4.5c **Timescales**
a) Internal timescales
    i. Repair times (from manufacturers)
    ii. Workshop loading
b) External timescales

i. Customers
ii. Part suppliers

AC4.6 **Safe**

a) Carry out relevant checks, tests and measures to ensure:
   i. no leaks present
   ii. isolation of stored energy systems
      Stored energy:
      - Electrical energy
      - High voltage system
      - Hydrogen storage systems
   iii. safety systems in place to reduce risk of unintended energy release

AC4.7 **Components** to remove and store

a) Re-fuelling components
b) Supply pipes
c) Safety venting systems / pressure release, excess flow and in tank solenoid valves
d) Sensors (impact / hydrogen)
e) Storage tanks
f) Insulation and protection methods and components
g) Fuel cell stack
h) Fuel cell components
i) Electronic control units
j) Actuators
k) Driver inputs and instrumentation
l) Pressure reduction devices / regulator

AC4.8 **Components:**

Returned

a) Re-fuelling components
b) Safety venting systems / pressure release, excess flow and in tank solenoid valves
c) Sensors (impact / hydrogen)
d) Storage tanks
e) Fuel cell stack
f) Fuel cell components
g) Electronic control units
h) Pressure reduction devices / regulator

Recycled

a) Re-fuelling components
b) Supply pipes
c) Insulation and protection methods and components
d) Actuators
e) Driver inputs and instrumentation

Disposed

a) Safety venting systems / pressure release, excess flow and in tank solenoid valves
b) Sensors (impact / hydrogen)

AC4.9 **Precautions**

a) Grounding
b) Secure connections
c) Sufficient ventilation
d) Leak detection

AC4.9 **Hydrogen refueling equipment**

a) Controller
b) Compressor
c) Cooler
d) Dispenser (charging part)

AC4.10 **Safely immobilise** adhering to manufacturer's instructions

a) Isolate electric system
b) Isolate the hydrogen storage system
c) Depressurise the hydrogen supply system
d) Purge the hydrogen supply system

Safely store adhering to manufacture's instructions

a) Sufficient ventilation
b) Leak monitoring
c) Hydrogen alarms (for leaks and fire)

Safely mobilise adhering to manufacturer's instructions

a) Pressurise system with inert tracer gas
b) Check for leaks at specified range of pressures
c) Re-instate the hydrogen supply
d) Carry out leak test
e) Re-instate the electrical system
f) Check for correct vehicle operation

AC4.11a **Other vehicle systems**

a) Comfort and convenience
b) Heating, ventilation and air conditioning
c) Driver vehicle safety
d) Immobiliser and security
e) Chassis systems

AC4.11b **Components**

a) Excess flow and in tank solenoid valves
b) Electronic control units
c) Actuators
d) High voltage battery

e) Low voltage battery
f) AC three phase motor / generators
g) Cabling and wiring (wiring colour, size and cross-sectional area)
h) Relays and Contactors
i) On-board charger and charging port
j) Inverters/rectifiers
k) DC-to-DC convertor
l) Battery management systems
m) Heating / ventilation / air conditioning components
n) Re-fuelling components
o) Supply pipes
p) Safety venting systems
q) Pressure release valve
r) Sensors (impact / hydrogen)
s) Storage tanks
t) Fuel cell stack
u) Fuel cell components
v) Pressure reduction devices / regulator

AC4.11c **Injuries**

a) Frost bite
b) Skin damage / abrasions
c) Respiratory ailments
d) Asphyxiation
e) Burns
f) Impairment to sight
g) Impairment to hearing

AC4.11c **Hazardous substances**

a) Gasses
    i. Hydrogen
    ii. Inert tracer gasses (to include nitrogen and helium)
    iii. Oxides
b) Liquids
    i. Coolant
    ii. Contaminated water
    iii. Lubricants
c) Solids
    i. Lubricants
    ii. Alloys, metals and ores

Learning outcome

The learner will:

LO5 Understand the hazards associated with removing and replacing components associated with hydrogen fuel cell electric vehicles

Assessment criteria

The learner must know:

AC5.1 The **hazards** associated with hydrogen and hydrogen under high-pressure, including the **physiological**, **mechanical** and **chemical effects** of hydrogen

AC5.2 The **impact** of **hazards** associated with **hydrogen fuel cell electric vehicles** when exposed to extreme temperatures, vehicle impact and **other adverse conditions**

AC5.3 The **implications** of electrical conductivity through the human body regardless of voltage or current type present in a hydrogen fuel cell electric vehicle

AC5.4 How to carry out a **dynamic risk assessment** on **damaged hydrogen fuel cell electric vehicles**

Range

AC5.1, 5.2 **Hazards** from electric system

a) Fire / thermal runaway
    i. Exothermic reaction
    ii. Endothermic reaction
b) Explosion
c) Arc flash
d) Pressures
e) Gases / fumes (and their properties)
f) Chemicals
g) Electric shock
h) Damage to cables
i) Dangerous voltage retention in components even when vehicle is switched off
j) Electromagnetic fields (EMF) – which may affect pacemakers and other medical devices

AC5.1 **Physiological**

a) Frost bite
b) Respiratory ailments
c) Asphyxiation
d) Burns
e) Overpressure

AC5.1 **Mechanical**

a) Embrittlement
b) Overpressure

AC5.1 **Chemical**

a) Flammable
b) Colourless or pale blue (burns without visible flame / difficult to detect)
c) Odourless
d) Tasteless
e) Hydrogen lighter than air

AC5.1, 5.2 **Hazards** from hydrogen system

a) Physiological
b) Injury from unexpected release of pressure
c) Asphyxiation
d) Mechanical
e) Chemical
f) Flammable
g) Colourless (burns without visible flame)
h) Causes explosive atmospheres, lighter than air, including explosive limits of hydrogen
i) Odourless

AC5.2 **Impact**

a) Personal injury
b) Environmental damage
c) Damage to property / vehicle
d) Ability to operate vehicle
e) Emergency response resources
f) Explosion (excessive heat or light)
g) Arc flash
h) Arc blast

AC5.2 **Other adverse conditions**

a) Floods
b) High winds
c) Direct sunlight
d) Snow
e) Ice

AC5.2, 5.4 **Hydrogen fuel cell electric vehicle(s)**

a) Light vehicle
b) Heavy vehicle
c) Bus / coach
d) Motorcycle
e) Plant machinery

AC5.3 **Implications**

a) Cardiac arrest (if voltage above 10 amps)
b) Muscle, nerve and tissue damage
c) Thermal burns

d) Medical equipment damage eg, pacemakers
e) Tingling sensations (if voltage between 1-4 milliamps, mA)

AC5.4 **Dynamic risk assessment**

a) Evaluate the environment
b) Identify the hazard / risk
c) Select a safe system of work
d) Assess the system of work
e) Implement controls
f) Proceed with the task

AC5.4 **Damaged**

a) Fire
b) Water
c) Electrical
d) Mechanical failure
e) Collision impact
f) Modification
g) Leakage (gas, fluid, chemical)

Learning outcome

The learner will:

LO6 Understand the process of testing, removing and replacing components in hydrogen fuel cell electric vehicles and evaluating vehicle system performance following component replacement activity

Assessment criteria

The learner must know:

AC6.1 How to **identify faults** and **damage** in hydrogen fuel cell electric vehicle systems and **components**

AC6.2 How to **identify** and **check** the correct testing **equipment** for carrying out isolation

AC6.3 How to **identify** and **check** suitable **equipment** for the removal and replacement of **components**

AC6.4 How to conduct **tests** on **energy sources** and **systems** to confirm isolation and re-instatement of hydrogen fuel cell electric vehicle systems

AC6.5 How to **determine** the **serviceability** of a **component** in a hydrogen fuel cell electric vehicle system

AC6.6 The **importance** of the manufacturer's specification on the type and quality of **components** to be used for replacement

AC6.7 How to remove and replace a **component** in a **hydrogen fuel cell electric vehicle** following manufacturer's instructions

AC6.8 How to conduct **tests** on hydrogen fuel cell electric vehicle systems and **components** following removal and replacement activities

AC6.9 The **importance** of **testing** and **evaluating** the performance of **components** and the reassembled system against manufacturer's operating specifications and legal requirements

AC6.10 **How to interpret** the **results** of your **tests** to make **recommendations**

AC6.11 The **importance** of ensuring all vehicle **systems** and **components** are functioning correctly and safely before the vehicle is released to the customer

Range

AC6.1 **Identify** by

a) Sensory methods (visual, sound, smell, touch for temperature or vibration)
b) Functionality
c) Measurement methods
d) Tests (insulation, current flow, voltage, resistance)

AC6.1 Electric **faults**

a) Open circuit
b) Short circuit
c) High resistance circuit
d) Loose wires
e) Overheating / cooling

f) Poor connections

AC6.1 Fuel system **faults**

a) Loss of pressure
b) Excessive pressure
c) Gas leaks
d) Overheating / cooling
e) Fuel system valve failures
f) Poor connections

AC6.1 Mechanical **faults**

a) Bearing failure
b) Transmission
c) Motor
d) Oil / coolant leaks

AC6.1 **Damage**

a) Fire
b) Water
c) Electrical
d) Mechanical failure
e) Collision impact
f) Modification

AC6.1 **Components**

6.5, 6.9, 6.11

a) Re-fuelling components
b) Supply pipes
c) Safety venting systems / pressure release, excess flow and in tank solenoid valves / quick release couplings
d) Sensors (impact / hydrogen)
e) Storage tanks
f) Insulation and protection methods and components
g) Fuel cell stack
h) Fuel cell components
i) Electronic control units
j) Actuators
k) Pressure reduction devices / regulator
l) Ancillary components
m) Low voltage battery
n) Air conditioning compressor
o) Heating components

AC6.2, 6.3 **Identify** by

a) Visual methods
b) Manufacturer's specification
c) Technical information
d) Compliance and regulation

AC6.2, 6.3 **Check** for

a) Damage
b) Calibration
c) Operational
d) Specification
e) Compliance and regulation

AC6.2 **Equipment** for isolation

a) Electrical multimeters / voltmeter rated to a minimum 1000V (CAT. III) or 600V (CAT.IV) including leads and probes
b) Hand tools (insulated)
c) Code readers
d) Special tools (manufacturer specific equipment and software)
e) Hydrogen leak detector
f) Hydrogen evacuation equipment
g) Relevant safety equipment
h) Ventilation equipment
i) Hydrogen alarms (leak and fire)

AC6.3 **Equipment** for removal and replacing

a) Electrical multimeters / voltmeter rated to a minimum 1000V (CAT. III) or 600V (CAT.IV) including leads and probes
b) Hand tools (insulated)
c) Code readers
d) Special tools (manufacturer specific equipment and software)
e) Hydrogen leak detector
f) Hydrogen evacuation equipment
g) Hydrogen purge
h) Hydrogen recharge
i) Relevant safety equipment
j) Ventilation equipment
k) Hydrogen alarms (leak and fire)

AC6.3, 6.6-6.8 **Components**

a) Re-fuelling components
b) Supply pipes / fuel line
c) Safety venting systems / pressure release, excess flow and in tank solenoid valves / quick release couplings
d) Sensors (impact / hydrogen)
e) Storage tanks
f) Insulation and protection methods and components
g) Fuel cell stack
h) Fuel cell components
i) Actuators
j) Pressure reduction devices / regulator
k) Air conditioning compressor
l) High voltage battery
m) Low voltage battery

n) DC-to-DC convertor
o) Inverter

AC6.4 **Tests**

a) Electrical testing
    i. Insulation
    ii. High voltage
    iii. Low voltage
b) Hydrogen fuel pressure
c) Hydrogen leak detection

AC6.4 **Energy sources and systems**

a) Charging systems
b) Regenerative systems
c) High voltage battery
d) Low voltage battery
e) Hydrogen fuel tanks
f) Hydrogen fuel cell
g) DC-AC inverter
h) DC-DC convertor

AC6.5 **Serviceability**

The component conforms to and operates within the manufacture's specification

AC6.5 **Determine**

a) Timeframe
b) Distance travelled
c) Operational requirements (number of fills)
d) Wear and tear

AC6.8-6.10 **Tests, testing and evaluating**

a) Fault codes information
b) Voltage/current
c) Wiring and cable routing integrity
d) Hydrogen pressure systems integrity / leak detection
e) On-board displays / driver information
f) Road tests
g) Using diagnostic equipment

AC6.5, 6.9-6.11 **Importance**

Minimise the risk of liability due to premature component failure to prevent personal injury, environmental damage, vehicle damage and damage to property

AC6.7 **Hydrogen fuel cell electric vehicle(s)**

a) Light vehicle
b) Heavy vehicle

c) Bus / coach
d) Motorcycle
e) Plant machinery

AC6.10 **Interpret**

Comparing test results / understanding live data in table or graphical format

AC6.10 **Results**

a) Live data (time, resistance, voltage, current)
b) Measurements (seconds, m/s, ohms, volts, amphour)
c) Calculations
d) Fault codes

AC6.10 **Recommendations**

Suggestion or proposal for the best course of action

AC6.11 **Systems**

a) Electrical
    i. High voltage
    ii. Low voltage
b) Hydrogen supply
c) Fuel cell
d) Mechanical
    i. Chassis
    ii. Transmission

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:

Centre Handbook: Quality Assurance Standards

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.

Centre Handbook: Quality Assurance Standards

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.

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.

Useful contacts

Please visit the **Contact us** section of the City & Guilds website.

City & Guilds

For almost 150 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.

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Published by City & Guilds Limited, a company registered in England and Wales (company number 16513878).

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