

Unit 8: Petrol Injection Systems for Spark Ignition Engines

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

Most modern vehicles are fitted with fuel injection systems that allow the engine to work more efficiently and usually result in greater power and cleaner exhaust emissions. These systems work by forcing pressurised fuel through a tiny nozzle that atomises the fuel, allowing it to burn more quickly when mixed with air. This unit will introduce learners to petrol injection systems and give them an appreciation of how these systems operate.

Learners will study a variety of fuel injection systems in order to appreciate their function, their operation and the differences between systems. The unit will enable learners to understand the air and fuel supply systems and the operation of the engine control systems and components. Learners will also gain an understanding of the equipment and methods used to test, maintain and repair petrol fuel injection systems.

Learning outcomes

On completion of this unit a learner should:

- 1 Understand the operational differences of petrol injection systems
- 2 Understand the function and operation of air and fuel supply components and systems
- 3 Understand the operation of electronic control systems and components
- 4 Understand the methods used to test, maintain and repair petrol fuel injection systems.

Unit content

1 Understand the operational differences of petrol injection systems

Petrol injection system: principles of fuel combustion eg composition of atmospheric air, calorific value of fuel, mixture strength and the range of combustibility, influence of air/fuel ratio on engine power output; vaporization of fuel and cooling effects on charge density; injector layout (single point, multi-point, phased and continuous injection); mechanical and electronic control (open and closed loop systems); specification eg technical improvements relative to performance, emissions and costs

Fuel Injector positioning: single/multi-point injectors; positioning of injector within the induction manifold eg up-stream, down-stream or direct into the cylinder; quality of the homogeneity of the charge and volumetric efficiency eg requirements for compensatory enrichment, effects of fuel condensation on manifolds walls

Stoichiometric and lean burn technology: phasing of injection eg induction cycle injection (stoichiometric cycle), compression stroke injection (direct injection, stratified engine operation); fuel injection strategies eg continuous injection, intermittent injection, semi sequential and sequential injection, asynchronous and grouped injection; operational conditions eg cold starting, idling, maximum power; thermal efficiency and the formation of pollutants; exhaust gas composition eg composition of the exhaust gases under rich, lean and stoichiometric conditions, legal requirements

2 Understand the function and operation of air and fuel supply components and systems

Air supply system components: air intake tract; air cleaner; air throttle valve (butterfly valve); throttle body; use of an electric throttle; induction manifold and plenum chamber; variable geometry induction manifolds

Fuel supply components: fuel tank construction eg steel with soldered joints, welded joints, moulded plastic, use of internal baffles and swirl pots; electric fuel pump eg vane, roller gear, plunger; valves eg pressure relief, non return; fuel lines eg accumulator, pipelines, fuel pipe connections, fuel filter; continuous injection mechanical systems; pressure regulator with induction manifold pressure correction; common fuel rail injection (direct injection) eg low pressure supply pump, low pressure sensor, high pressure pump, high pressure injectors, high pressure sensor; methods employed to reduce fuel vapour escape eg charcoal canister, purge control valve

3 Understand the operation of electronic control systems and components

Sensors, switches and actuators: sensors eg crankshaft position, camshaft position, coolant temperature, ambient air temperature, fuel temperature, mass air flow (vane type, thermal type (hot wire and hot chip), manifold pressure sensors (manifold absolute pressure (MAP) sensor, exhaust gas oxygen sensor (step response lambda, broad band lambda), engine speed and throttle position sensor; switches eg thermo-time switch, idle speed switch, inertia switch; actuators eg solenoid injectors, variable manifold butterfly actuators, electrical throttle valve actuator

Electronic control unit (ECU): input and output processes; injector driver circuits; fuel mapping; basic programming theory eg use of input parameters to enable the software to calculate correct fuel quantity for injection; software updating eg use of specialised software to change fuel map setting at varying engine/operational conditions; software self diagnostics; controller area network (CAN) data bus eg single wire, twin wire, fibre optic

Emission control principles and components: exhaust gas oxygen sensing; catalytic converter eg reduction, oxidising, nitrogen oxide (NOx); exhaust gas recirculation (EGR) and components eg outline of the process to reduce NOx formation, operation strategies, EGR valve, vacuum modulator, vacuum sensing valve; air injection and components eg air pump, air injector, pulse air injection, electronic control of EGR and air injection systems; effect of engine operating conditions eg cranking, cold start enrichment, hot start enrichment, cold idle, hot idle, light load, full load, acceleration, deceleration, engine speed limitation

4 Understand the methods used to test, maintain and repair petrol fuel injection systems

Diagnostic equipment, tests and adjustments: exhaust gas analysis eg use of exhaust gas analysers, lambda values, air/fuel ratio, idle speed adjustments; on-board diagnostics (OBD) eg fault code reading, data logging, use of break out box to locate faults, data link connection to dedicated code readers; vacuum pump eg induction system leakage, simulation of manifold depression to check fuel pressure regulator; multimeter eg system voltage and circuit tests, circuit resistance, circuit integrity; pressure gauge eg fuel line pressure and regulator settings; injector delivery and spray pattern eg injection quantity, spray pattern and leakage; oscilloscope eg engine/camshaft speed sensor patterns, injection duration, lambda sensor output

Injection systems faults and symptoms: eg throttle position sensor, mass air flow sensor, coolant sensor, crankshaft/camshaft speed/position sensor, exhaust oxygen sensor, idle speed control valve

Grading grid

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all of the learning outcomes for the unit. The criteria for a pass grade describes the level of achievement required to pass this unit.

Grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:	To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:
P1 explain and compare the operation of two different petrol injection systems used on modern fuel injected engines	M1 compare the relative advantages and disadvantages of port injection and direct injection with reference to timing of the injection process	D1 evaluate two typical modern petrol injection systems in terms of their legal, environmental and operational requirements
P2 describe the methods used to position the fuel injector for an induction port injection and a direct injection into the cylinder	M2 compare the injection, combustion cycle and exhaust emissions within a stoichiometric air fuel ratio engine and a lean burn stratified charge engine	D2 evaluate the use of diagnostic tests using standard workshop equipment in comparison to dedicated on board diagnostic facilities, equipment and software used with modern petrol injection systems.
P3 describe the principles of stoichiometric and lean burn technology with reference to petrol injection engines	M3 evaluate and compare the diagnostic tests and repair strategies that can be performed on two different modern petrol injection systems, including the equipment that may be used.	
P4 identify and explain the function and operation of the air and fuel supply components of a given fuel injection system		

Grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:	To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:
<p>P5 describe the function and operation of four major input sensors, their related switches and actuators and how the electronic control unit uses feedback from these devices to calculate quantity of fuel injected</p> <p>P6 explain the emission control measures and associated components used for a given fuel injected engine system</p> <p>P7 describe the diagnostic equipment required and the tests that need to be carried out to check the satisfactory operation of two different fuel injection systems</p> <p>P8 describe the symptoms associated with three different injection system faults found in modern engines and the repair strategy for each.</p>		

Essential guidance for tutors

Delivery

This unit should be delivered using a balance of theoretical and practical study. Where possible the function, operation and principles of injection systems should be demonstrated through investigation using rigs, units, vehicles, components and equipment.

The learning outcomes could be delivered in order. This will allow learners to develop an overall understanding of the operational differences of a range of systems before going into too much detail. Learners would then understand the design principles and requirements of petrol injection prior to targeting the complexities of specific components, testing, maintenance and repair.

Although the unit does not require the use of diagnostic equipment to carry out tests and fault diagnosis, it would be good practice to provide learners with an opportunity to do so where such equipment is available.

Formative assessment, with effective feedback and support, will play an important part in the development of learners throughout this unit, particularly for their achievement of the merit and distinction grades. Learners should be encouraged to compare and consider relative advantages and disadvantages of stoichiometric and lean burn technology. In particular, they should consider how current and proposed changes in emission requirements will impact upon fuel injection technology. Learners should also consider the interrelationship of all components that contribute to mixture correction and hence the emission control process.

Note that the use of 'eg' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'eg' needs to be taught or assessed.

Assessment

A variety of evidence could be used to support assessment. For example, a mixture of written tests and practical investigative assignments could be used requiring learners to explain, describe, identify, compare and evaluate as required by the criteria. Although all of the pass criteria require descriptive evidence, it is not expected that centres will only use written tests to achieve this. The unit lends itself to an investigative approach and this should be reflected in the assessment strategy wherever possible.

For P1, learners need to explain and compare the operation of two different petrol injection systems used on modern fuel injected engines. A task could be developed requiring learners to inspect two different types of systems (selected from those outlined in the unit content) in a practical environment. P2 requires learners to describe the methods used to position the fuel injector for an induction port injection and a direct injection into the cylinder. P1 and P2 are closely linked and could be assessed together. The same vehicles could then be used for both criteria.

There are similar close links between P3 and P4. For P3 learners need to describe the principles of stoichiometric and lean burn technology with reference to petrol injection engines. This should include phasing of injection, fuel injection strategies, operational conditions, thermal efficiency and the formation of pollutants including exhaust gas composition. It is expected that learners will make reference to more than one type of petrol injected engine in order to cover the requirements of the unit content. They will need to demonstrate an understanding of the combustion of fuel within an engine and the differences between the homogenous/stoichiometric charge and the stratified, overall lean mixtures associated with modern direct injected engines. To achieve P4, learners need to identify and explain the function and operation of the air and fuel supply components of a given fuel injection system. This relates with P3 and both should be covered within a single activity. Learners will, by necessity, need to make reference to open and closed loop control methods and their relevance to the function, operation and fundamental principles affecting fuel delivery.

For P5, learners need to describe the function and operation of four major input sensors, their related switches and actuators and how the electronic control unit uses feedback from these devices to calculate quantity of fuel injected. This criterion should not be fragmented into sensors, switches, actuators and ECU. One activity should be designed to enable the whole criterion to be covered at the same time. Learners should include, for each major input sensor considered, suitable references to the interrelationships between each of the components within the systems.

P6 requires learners to examine and explain the emission control measures and associated components used for a given fuel injected engine system. Learners should consider exhaust gas sensing, catalytic converter, EGR and associated components and the effect of engine operating conditions on emissions.

P7 and P8 focus on system defects, symptoms and the testing procedures necessary used for maintenance and repair processes. It is likely, although not essential, that the three faults in P8 will be associated with the two systems considered for P7. It is expected that faults associated with more than one system will be considered. Wherever possible the descriptions associated with P7 and P8 should be the product of a practical investigation undertaken by the learner. Where centres do not have the equipment to do this they may wish to consider work-based evidence if practicable.

For M1, learners will need to compare the relative attributes of port injection and direct cylinder injection. They should also clearly define the point at which injection commences relative to the engine cycle.

M2 is linked to P3, P4, P5 and P6 in as much as learners need to explore in more detail the differences in combustion strategy to meet the close limits set by environmental legislation. It is expected that learners will refer to the use of closed loop control and the use of step response and/or broadband (or both) oxygen sensors to enable accurate reduction and oxidation to occur within the catalytic converter.

M3 is linked to P7 and P8. Learners need to evaluate and compare the effectiveness of the tests that can be used to locate faults and the appropriate repair strategies. This should draw on and bring together the understanding gained at pass level enabling them to demonstrate a coherent understanding of testing and fault finding methods.

For D1 learners need to evaluate two typical modern petrol injection systems in terms of their legal, environmental and operational requirements. For D2, they will need to evaluate the use of diagnostic tests. Emphasis should be placed on the comparison with diagnostic algorithms using standard workshop test equipment and on-board diagnosis (OBD) which require dedicated test equipment. Learners should cite examples of actual testing.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit covers some of the knowledge and understanding associated with the Automotive Skills Level 3 National Occupational Standards in Maintenance and Repair, particularly:

- Unit MR06: Inspect Vehicles
- Unit MR07: Diagnose Rectify Vehicle Engine and Component Faults
- Unit MR10: Identify and Agree Customer Vehicle Needs
- Unit AE04: Diagnose and Rectify Engine Electrical Faults.

The unit can be linked to *Unit 2: Vehicle Engine Principles, Operation, Service and Repair*, *Unit 3: Vehicle Fault Diagnosis and Rectification* and *Unit 6: Vehicle Electrical and Electronic Principles*.

Essential resources

Learners will need access to a range of components, assemblies and rigs and, wherever possible, access to the diagnostic equipment identified in the unit content. Access to suitable vehicles and tools will need to be provided along with a range of relevant information sources and operational manuals.

Indicative reading for learners

Bonnick A – *Vehicle Electronic Systems and Fault Diagnosis* (Butterworth-Heinemann, 1998) ISBN 0340706309

Hillier V and Coombes P – *Hillier's Fundamentals of Motor Vehicle Technology* (Nelson Thornes, 2006) ISBN 0748780998

Hillier V – *Fundamentals of Automotive Electronics* (Nelson Thornes, 1996) ISBN 0748726950

Stan C – *Direct Injection Systems: The Next Decade in Engine Technology* (SAE International, 2002) ISBN 0768010705

White C – *Automotive Engine Management and Fuel Injection Systems Manual* (Haynes, 1997) ISBN 1859603440

Key skills

Achievement of key skills is not a requirement of this qualification but it is encouraged. Suggestions of opportunities for the generation of Level 3 key skill evidence are given here. Tutors should check that learners have produced all the evidence required by part B of the key skills specifications when assessing this evidence. Learners may need to develop additional evidence elsewhere to fully meet the requirements of the key skills specifications.

Communication Level 3	
When learners are:	They should be able to develop the following key skills evidence:
<ul style="list-style-type: none"> researching the various petrol injection systems describing and comparing petrol injection systems, diagnostic equipment and fault finding/repair methods. 	<p>C3.2 Read and synthesise information from at least two documents about the same subject.</p> <p>Each document must be a minimum of 1000 words long.</p> <p>C3.3 Write two different types of documents each one giving different information about complex subjects.</p> <p>One document must be at least 1000 words long.</p>
Information and communication technology Level 3	
When learners are:	They should be able to develop the following key skills evidence:
<ul style="list-style-type: none"> searching for information on the various petrol injection systems preparing their descriptions, comparison and explanations of petrol injection systems, diagnostic equipment and fault finding/repair methods and presenting their results. 	<p>ICT3.1 Search for information, using different sources, and multiple search criteria in at least one case.</p> <p>ICT3.2 Enter and develop the information and derive new information.</p> <p>ICT3.3 Present combined information such as text with image, text with number, image with number.</p>