Unit 9: Diesel Fuel Injection Systems for Compression Ignition Engines

NQF Level 3: BTEC National

Guided learning hours: 60

Unit abstract

Advances in technology and a tightening of exhaust emissions requirements have led to a considerable improvement in the performance of diesel engines. Once exclusively used in large heavy vehicles, plant or marine applications, diesel engines are now an acceptable alternative to petrol engines in light vehicles. To compete effectively as an alternative, the light diesel engine must have similar attributes to the petrol. Modern fuel injection systems in diesel engines enable improved engine performance and economy and control of emissions, enabling parity with the petrol engine. This unit aims to give learners an understanding of the design and operation of different types of light and heavy vehicle diesel fuel injection systems.

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 diesel fuel injection systems.

Learning outcomes

On completion of this unit a learner should:

1 Understand the operational differences of diesel fuel injection systems

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

3 Understand the operation of diesel engine control systems and components

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

Unit content

1 **Understand the operational differences of diesel fuel injection systems**

Diesel injection system: principles of diesel fuel combustion, combustion phases, turbulence and the compression of induced air, composition of fuels used in diesel engines, abnormal combustion and its causes; conventional diesel fuel injection systems eg inline, rotary fuel injection pump, high pressure common rail injection system using electronic injector control, low pressure common rail injection system using combined pump and injector, electronic diesel control using conventional fuel injection pump; operational factors eg technical improvements relative to performance and emissions

Diesel fuel supply: fuel supply pumps eg types (diaphragm, gear vane and plunger), multi-stage pressure development, provision for hand priming, single and double pumping action; means of operation, eg fuel pump camshaft, engine camshaft auxiliary drives, electrical drives; fuel supply pressure regulating valves (control of fuel flow rates in high-pressure systems); fuel heaters and coolers eg waxing prevention methods, cooling of returned fuel before entering fuel tank; procedures for venting diesel fuel injection systems eg requirements to bleed air from the system, self venting systems, faults associated with entrapment of air in the fuel injection system; fuel injection system settings eg phasing and calibration of fuel injection pumps, requirements to seal maximum fuel and maximum speed stops, methods used to identify injection timing marks/position for refitting to engine, adjustment of plunger travel or torque methods on combined pump and injector types

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

Air supply system components: air cleaners; induction manifold design; use of resonance chambers to improve engine volumetric efficiency; variable geometry induction manifolds and variable geometry turbo chargers

Diesel fuel supply components: fuel tank eg construction, methods used to minimise aeration of the fuel; filtration of the fuel eg requirements to filter the fuel, effects of low temperature wax formation on fine filters, filter placement, effects of water ingress, methods used to trap and remove water, construction and position of primary and secondary filters, effect of blocked filtration system (loss of power, misfire, engine shut down); control valves eg delivery valves with anti-dribble control, manual shut down, solenoid shut down valves and reverse flow valves (used on electronically governed inline pumps to ensure engine shut down), application of electronic control; injector nozzles eg single hole, multi-hole, pintle, pintaux; fuel injection pump eg in-line fuel injection pumps, single and multi-cylinder, drive couplings, mechanical advance/retard system, electronic control of injection timing, firing order control, anti-reverse cams, methods used to meter quantity of fuel injected; high and low pressure pipes eg high pressure injection pipes, factors that govern internal and external diameter, length of high pressure pipes, factors that affect injection timing, size and affects on volume flow rates (low pressure pipes), need for adequate clamping of pipes

3 **Understand the operation of diesel engine control systems and components**

Sensors and actuators: sensors eg engine speed, air mass, coolant temperature, throttle position, fuel pressure intake manifold pressure, intake manifold temperature, governor control rod position, throttle position; actuators eg electrical/hydraulic servo units, glow plugs (methods to reduce diesel knock), injectors, fuel pressure regulating valve, rotary injection pumps (distributor type injection pumps, drive methods and engine timing), auto-advance system, method to ensure correct firing order

Control systems: common rail, electronically controlled, low pressure systems eg combined pump and injector, drive mechanism for injector, control strategies, operation of the injector on its cycle, fuel supply pump operation pump drive and timing arrangements; common rail electronically controlled high-pressure system eg fuel supply circuitry, operation of the supply pump, fuel rail pressure sensors, pressure limiting valve, construction and operation of the injector, pre-injection phase, main injection phase; diesel fuel injection cold start devices eg retardation of injection timing, excess fuel device (including the legal implications of its use), manifold combustion heaters, heater plugs, ether injection, decompression devices; single, two and variable speed governing eg governor cut in/cut out, maximum speed, over-run, hysteresis, over-shoot, speed droop; hydraulic and electrical governors eg components and operation under idling, maximum speed, over-run and variable speed

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 emissions under normal and abnormal running conditions eg methods employed to reduce emissions (exhaust gas recirculation (EGR), urea injection into exhaust using selective catalytic reduction); legal requirements for emissions (EURO 4/5); effect of diesel engine operating conditions eg cranking, cold/hot start, cold idle, hot idle, light load, full load, acceleration, deceleration, engine speed limitation

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

Diagnostic equipment, tests and adjustments: exhaust gas analysis eg use of smoke meters for exhaust gas opacity, idle speed adjustments and maximum speed settings; 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; checking common rail operational pressures, effects of low rail pressure on starting and performance; induction system leakage, affects of changes in boost pressure on turbocharged engines, affects of fuel injection quantities of changes in boost pressure; use of multimeter eg system voltage and circuit tests on injector control solenoids, circuit resistance, circuit integrity; pressure gauge eg fuel line pressure and regulator settings; oscilloscope eg engine/camshaft speed sensor patterns and injection duration

Injection systems faults and symptoms: removal and refitting of main fuel injection system components eg removal and refitting of injectors including common rail, removal and refitting of a fuel injection pump; servicing of fuel system eg fuel filters, bleeding and rectification of leaks; checking the operation of the fuel injection system eg in situ adjustments of fuel quantities injected and speed, checking of injection timing, producing fault finding algorithms; testing of injectors eg safety factors associated with high pressure fluids and vapour, spray patterns, setting pressures, nozzle back leakage, nozzle tip leakage, specialised equipment to test combined pump and injector types; maintenance of fuel systems eg fuel filter condition, condition of pipes and securing clamps, leaks, checking the condition and security of fuel injection pumps and drive couplings, security of maximum fuel and speed seals, check indication of visible vapour from the exhaust; test rectification techniques eg location of misfire on conventional injection system and/or on common rail using dedicated software, poor performance through lack of power, excess exhaust gas opacity, fuel leaks, air ingress, probable causes of black, blue and white smoke; legal implications of defects on diesel fuel injection systems, eg excessive smoke, loss of power weight ratio and fuel leaks onto the road surface

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 diesel fuel injection systems used on modern diesel engines P2 describe two different types of diesel fuel supply methods P3 identify and explain the function and operation of the air and diesel fuel supply components of a given diesel fuel injection system P4 describe the function and operation of four major diesel injection system input sensors, the related actuators and their relationship with the engine electronic control unit P5 explain the emission control measures and associated components used for a given diesel fuel injected engine system	M1 compare the relative advantages and disadvantages of a conventional fuel injection system with a high pressure common rail system M2 compare two governor types used on modern automotive diesel engines in terms of their modes of operation and levels of sensitivity M3 evaluate and compare the diagnostic tests and repair strategies that can be performed on two different modern diesel injection systems, including the equipment that may be used.	D1 evaluate two typical modern diesel injection systems in terms of their legal, environmental and operational requirements 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 diesel injection systems.

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:**
P6 describe the diagnostic equipment required and the tests that need to be carried out to check the satisfactory operation of two different diesel fuel injection systems P7 describe the symptoms associated with three different diesel fuel injection system faults found in modern engines and the repair strategy for each.		

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 diesel injection and combustion principles 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 opportunities 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 conventional injection systems with the high pressure, electronically controlled, common rail system. 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 a practical investigative approach and this should be reflected in the assessment strategy wherever possible.

P1 and P2 are closely linked and could be assessed together. The same vehicles could then be used for both criteria. For P1, learners need to explain and compare the operation of two different diesel injection systems used on modern diesel 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 two different types of diesel fuel supply methods. Ideally, one will be a conventional fuel lift pump with hand priming and the other a two-stage high-pressure pump and flow control valve for a common rail system.

For P3, learners need to identify and explain the function and operation of the air and diesel fuel supply components of a given diesel fuel injection system. This should include an explanation of the principles of induction system design used to improve engine volumetric efficiency. Specifically this should be the use of acoustic design on normally aspirated engines to aid the induction ram effect and the use of geometrical variable manifolds and turbochargers to improve engine performance characteristics. Included within this criterion, the learner should consider the effects of turbo charger boost pressure on fuel quantities injected and emissions would enable the learner to appreciate the control strategies involved.

For P4, learners need to describe the function and operation of four major diesel injection system input sensors and related actuators used to monitor engine parameters and enable the fuel and timing of injection to be controlled with accuracy through the ECU. P5, for which learners need explain emission control measures and associated components can be linked with P3 and P4.

P6 and P7 can be linked through a practical assessment during a workshop session or at the learner's own place of work. If work-based evidence is used care must be taken to ensure may its validity and authenticity.

For M1, learners need to compare the relative advantages and disadvantages of a conventional fuel injection system and the high-pressure common rail system. This is closely linked to P1, P2, P4 and P5.

For M2, the learner is required to compare two different engine governing systems. It is important that the related operational characteristics of these governors are analysed and compared in relation to their operation and levels of sensitivity.

M3 requires learners to evaluate and compare the diagnostic tests and repair strategies performed on two different diesel injection systems. This builds on the knowledge gained through P6 and P7 and could be built in to the same practical assignment.

For D1, learners need to evaluate two modern diesel injection systems in terms of their legal, environmental and operational requirements.

D2 requires them to evaluate the use of diagnostic tests using standard workshop equipment in comparison to dedicated on board diagnostic facilities, equipment and software used with modern diesel injection systems. Emphasis should be placed on the comparisons with diagnostic algorithms using standard workshop test equipment and on-board diagnosis (OBD), which require dedicated test equipment. Learners will need to give 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 also 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.

Suggested reading

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

Nunney M J — *Light and Heavy Vehicle Technology* (Butterworth-Heinemann, 1998) ISBN 0750638273

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:**
• researching the various diesel injection systems • describing and comparing diesel injection systems, diagnostic equipment and fault finding/repair methods.	C3.2 Read and synthesise information from at least **two** documents about the same subject. Each document must be a minimum of 1000 words long. C3.3 Write **two** different types of documents each one giving different information about complex subjects. One document must be at least 1000 words long.
Information and communication technology Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• searching for information on the various diesel injection systems • preparing their descriptions, comparison and explanations of diesel injection systems, diagnostic equipment and fault finding/repair methods and presenting their results.	ICT3.1 Search for information, using different sources, and multiple search criteria in at least one case. ICT3.2 Enter and develop the information and derive new information. ICT3.3 Present combined information such as text with image, text with number, image with number.