Unit 81: Aircraft Propulsion Systems

Unit code: H/600/7259

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit will develop learners' knowledge of the construction and operating principles of aircraft propulsion systems.

Unit introduction

This unit will give learners an understanding of the major systems associated with aircraft gas turbine engines including fuel and lubrication systems, engine control and fire/ice detection and protection systems. The unit will emphasise the underlying reasons for these systems and their layout.

The unit covers some of the underpinning knowledge required for those taking module 15: Gas Turbines of the European Aviation Safety Agency (EASA) Part-66 examinations for certifying staff. The unit also supplies a limited amount of underpinning knowledge across other modules.

Learning outcomes

On completion of this unit a learner should:

1 Know the function and operation of typical gas turbine fuel systems

2 Know the function, construction and operation of gas turbine lubrication systems

3 Know about engine control systems

4 Know about the operation and components of engine fire detection and protection systems and the operation of ice detection and protection systems.

Unit content

1 Know the function and operation of gas turbine fuel systems

Function and operation: layout of fuel systems (methods of operation, system equipment and components); fuel systems eg fuel pumps and pressurisation, atomising and vaporising fuel nozzles, pressure control, flow control, bypass valves, fuel filters, fuel heaters, dump valves, cross feed system, hydro-pneumatic fuel controls, electronic (EEC) and manual engine control

Fuel: types and grades used in aviation eg Jet-A, Jet A-1 and Jet-B or their military equivalents (Avtur and Avtag); additives eg anti-icing and microbial agents; identification codes eg equipment controls colour, pipe markings and refueler decals; health and safety precautions when working with pressurised fuel systems

2 Know the function, construction and operation of gas turbine lubrication systems

Function, construction and operation: operation of gas turbine engine lubrication system types and layout (wet and dry-sump) eg recirculatory pressure relief system, full flow and total loss systems; characteristics and functions of engine lubricants eg types of lubricants, viscosity, flash point, anti-foaming additives, adhesion and cohesion; oil identity codes (type 1 and type 2) and grading system eg Commercial Aviation Number, AN specification (Military), SAE system; requirements for gas turbine engine oil systems; lubrication system components eg oil reservoirs, deaerators, constant displacement oil pumps (gear, vane and gerotor), oil filters, filter ratings, chip detectors (indicating and pulsed), contaminants, relief valve systems, oil jets, vents, check valves, pressure and temperature gauges, oil coolers (hot and cold tank) and scavenge systems

3 Know about engine control systems

Basic engine control systems: layout of engine control cables eg Teleflex, cable and rod controls, forward and reverse thrust levers, fuel control switches/levers, friction brake, tension regulation, auto-throttle regulation; engine control cable rigging eg control pulley box, directional control valves, feedback cables, cable grommets, pressure seals, cable turnbuckles, locking, control cable quick stops, start/thrust cable control drum; fuel shut-off valves; electrical fuel cock actuator; miscellaneous switches eg go-around switch, auto-throttle disengage switch, mode control panel; electronic engine control; flight/ground idle control; basic operation of full authority digital engine control (FADEC)

4 Know about the operation and components of engine fire detection and protection systems and the operation of ice detection and protection systems

Fire detection and protection systems: fire protection systems eg classes of fire, requirements for overheat and fire protection systems; main components eg gas turbine engine fire zones, types of fire or overheat detectors, flame resistant materials and fire walls; ground fire protection; extinguishing agents (carbon dioxide, halogenated hydrocarbons); fire extinguishing systems (conventional, high rate discharge); smoke and toxic gas detection systems (carbon monoxide, smoke detectors, light refraction, ionisation and solid state); multi-engine fire protection systems (operation and components); fire extinguishing system inspection and trouble shooting (container pressure check, discharge cartridges and agent containers)

Ice detection and protection systems: de-icing and anti-icing systems eg bleed air, electrical, pressure control (constant, manual and cyclic); ice detection and indication systems; intake/inlet ice protection; air systems (operation of air distribution and anti-ice control systems including internal engine cooling/sealing and external air services)

Assessment and grading criteria

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

Assessment and 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 sketch the layout and describe the basic function and operation of typical components used in a given gas turbine fuel system [IE1]	**M1** explain the operation of a typical gas turbine engine fuel control system	**D1** compare and evaluate the fuel and lubrication systems for two main types of gas turbine engine
P2 describe the different types of fuel used in gas turbines (military or civil) and identify their colour codes and identification markings	**M2** explain the differences between a wet and dry sump lubrication system	**D2** analyse the causes and effects of engine fires and how they are detected and contained.
P3 describe the safety precautions that need to be followed when working with aviation fuels and pressurised fuel systems	**M3** compare the operational requirements for two given gas turbine fire detection and protection systems.	
P4 describe the operation of a lubrication system for a typical gas turbine engine		
P5 describe the characteristics of lubricants used in gas turbines and state why they are suitable for the requirements of gas turbine engines		
P6 sketch the layout and describe the basic functions of the main components found in a given gas turbine lubrication system [IE1]		
P7 identify and describe the basic engine controls of a gas turbine engine		

Assessment and 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:**
P8	identify and describe the main components of a given type of gas turbine engine fire detection and protection system and describe the principles of operation		
P9	describe the principles of operation of an engine ice detection and protection system.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

This unit should be delivered using a mixture of lectures, tutor-led demonstrations, case studies, visits to aircraft factories and practical collection of data from a chosen type of gas turbine engine. Delivery should, where possible, include a comparison of different types of gas turbine engines including turbojet, turbofan, turboshaft and turboprop. It would be advantageous to then focus on a particular type of gas turbine and relate the fuel and lubrication systems to the chosen engine. This allows delivery to be tailored to learners' requirements and the most appropriate form of gas turbine application.

Learners will need access to a gas turbine engine together with the fuel components, lubrication, fire and ice protection and controls systems. However where learners are employed they should be encouraged to use the resources available at their workplace. A practical approach could be used for parts of the unit, particularly where centres have access to small gas turbine engine test rigs, for example to monitor oil temperature and pressure, or the use of engine controls and servicing, although this is not essential.

If possible visits should be made to an engine manufacturer, airline and/or aircraft maintenance facility where installation, commissioning or maintenance of gas turbine engines takes place. Learners should be encouraged to take an investigative approach throughout and to use an appropriate engine to identify the main components.

For learning outcome 1, learners will need to know about the layout of the main components of a gas turbine fuel system and understand the function, operation and contribution of each main component to the fuel system as a whole. They should learn about the types of fuel used, including the main additives and the reasons for those additives, their identification codes and the equipment colour markings used for gas turbine engines. These markings can then be compared to those used for reciprocating engine fuels used in aviation such as Avgas 80/100/100LL or the military equivalents to ensure that learners are aware of the differences of each type of fuel system. Learners must also be made aware of the health and safety implications of high pressure fuel systems.

In learning outcome 2 learners must understand the layout, function and operation of the main components which make up a typical gas turbine lubrication system and which can be related to any of the four main types of engine application whether civil or military.

Learners should understand the types and characteristics of lubricants used in gas turbines and why synthetic oils are used almost exclusively in preference to mineral oils and also have a basic understanding of why they should not be mixed. They should be aware of the different types of synthetic oils used, such as type 1 and type 2, and the basic differences between them. They will have a knowledge of the grading system and be able to recognise either the commercial aviation number or the AN specification (military) and relate these to the SAE system, as appropriate to the learner.

Learning outcome 3 is concerned with engine controls, their layout, function and operation. Learners should understand how the basic controls are built up from their components parts to control a relevant and typical gas turbine engine. Full Authority Digital Engine Control (FADEC) should be introduced, but only in very basic terms so that learners are aware of its existence.

Learning outcome 4 looks at fire and ice protection systems, and learners will need to understand how these systems work. Learners should know the main fire zones, how fires can start and how they are detected and dealt with to stop them from spreading. Ice detection and protection requires an understanding of the differences between de-icing and anti-icing and the main areas that need particular protection.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • introduction to unit content, scheme of work and methods of assessment • explain the safety precaution that need to be followed when working with aviation fuel and pressurised fuel systems • describe aircraft fuel systems and fuel system components • explain fuel system layout, function and operation • explain the main types and grades of aviation fuel, the use and purpose of additives and the identification codes used. *Practical workshop activity:* • view different types of gas turbine engine and investigate and compare the function and operation of fuel systems and system components. *Individual learner activities:* • research and investigative project on gas turbine fuel systems • multiple choice questions/quiz on health and safety relevant to working with fuel and fuel systems.
Prepare for and carry out **Assignment 1: Gas Turbine Engine Fuel Systems** (P1, P2, P3, M1, D1 (part)).
Whole-class teaching: • describe the main types of gas turbine lubrication system and explain the function and layout of lubrication systems and system components • identify and describe the different types of engine lubricants, oil identity codes and grading systems. *Practical workshop activities:* • investigate the function and operation of lubrication systems and components in different types of gas turbine engine • use of gas turbine engine/test rig to monitor oil temperature and pressure. *Individual learner activities:* • investigate types and characteristics of lubricants and the use and applications of synthetic and mineral oils.
Prepare for and carry out **Assignment 2: Gas Turbine Engine Lubrication Systems** (P4, P5, P6, M2, D1 (part)).
Whole-class teaching: • describe the layout of engine control cables and the function and operation of cable rigging • describe the function and operation of fuel shut-off valves, electrical fuel cock actuators, and other miscellaneous switches • describe the function and operation of electronic engine control system and flight/ground idle control. *Individual learner activities:* • investigate basic engine control systems • multiple choice questions/quiz on main control cables and systems.
Prepare for and carry out **Assignment 3: Engine Control Systems** (P7).

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • explain the function and operation of engine fire protection systems and system components • explain the main fire zones and how fires can start • describe the use of extinguishing agents and extinguishing systems • describe the use of smoke and gas detection systems • explain the function and operation of ice detection and protection systems. *Individual learners activities:* • investigation of how fires can start and how they are detected and dealt with • investigation of differences between de-icing and anti-icing.
Industrial visit: • visit to aircraft engine manufacturer or maintenance facility to view gas turbine fuel, lubrication and control systems.
Prepare for and carry out **Assignment 4: Aircraft Engine Fire and Ice Detection and Protection Systems** (P8, P9, M3, D2).
Feedback on assessment and unit evaluation.

Assessment

Assessment evidence can be collected from assignments and practical activities undertaken either in the laboratory or in the workplace.

To achieve a pass, learners must have a basic knowledge and understanding of the principles of aircraft propulsion systems. Learners must be able to sketch and describe the basic layout of a fuel system and the components that are used to make up that system (P1). They should also be able to describe the types and grade of fuel used and should also be able to recognise the colour codes used to identify the markings for these fuels either Military or Civil (P2). Learners must also demonstrate a clear understanding of the dangers of dealing with pressurised fuel systems (P3).

Learners should be able to sketch and describe a typical lubrication system both wet and dry (P4, P5, P6) and understand the difference between the two (M2). Learners will need to describe a basic system that includes, for example, pumps, filters, deaerators, oil reservoirs and other components within the system. They will need to understand the types and characteristics of lubricants used in gas turbines, the reasons why synthetic oils are used almost exclusively in preference to mineral oils and why they should not be mixed. They should also be aware of the different types of synthetic oils used, such as Type 1 and Type 2, and the basic differences between each type.

Learners must demonstrate a basic understanding of engine controls by identifying and describing their basic function (P7).

Ice and fire detection and protection systems should be identified and described at component level to show that learners understand how they form a system (P8, P9).

To achieve a merit, learners must be able to explain how the fuel is controlled in a typical gas turbine engine. M1 is developed from P1, P2, P3 and P7. For the lubrication system and its components, M2 requires an understanding of the system's operation and should focus on an engine and system relevant to the learner, while demonstrating an understanding of the other systems available. This should be shown in the differences between wet and dry sump systems. Learners should also be able to compare the operational requirements for both fire detection and protection (M3).

To achieve a distinction learners must demonstrate an understanding of both fuel and lubrication systems and compare and evaluate two main types of gas turbine engines for these systems (D1). They must also analyse the causes and effects of fires, how they are detected and contained (D2). They must also understand how fires are dealt with using a variety of different methods.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, M1, D1 (part)	Gas Turbine Engine Fuel Systems	Learners investigate the lubrication systems used in different types of gas turbine engine.	A written report, based on practical investigations.
P4, P5, P6, M2, D1 (part)	Gas Turbine Engine Lubrication Systems	Learners investigate the fuel systems used in different types of gas turbine engine.	A written report, based on practical investigations.
P7	Engine Control Systems	Learners show and describe the engine controls of a gas turbine engine to a new apprentice.	A short written report, information leaflet or oral presentation supported by observation records.
P8, P9, M3, D2	Aircraft Engine Fire and Ice Detection and Protection Systems	Learners show and describe the fire and ice detection and protection systems of a gas turbine engine to a new apprentice.	A short written report, information leaflet or oral presentation supported by observation records.

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

This unit forms part of the BTEC Engineering sector suite. This unit has particular links with:

Level 1	Level 2	Level 3
		Principles and Applications of Aircraft Mechanical Science
		Aircraft Maintenance Practices

This unit also has a strong link to Module 15: Gas Turbines for EASA Part 66 and the license examinations and to a lesser extent some of the science for Module 2:Physics.

The unit supports the Level 3 National Occupational Standards in Aeronautical Engineering, particularly:

- Unit 153: Carrying Out Tests on Aircraft Engines and Systems
- Unit 154: Carrying Out Tests on Aircraft Control Systems
- Unit 155: Carrying Out Tests on Aircraft Fuel and Storage Systems
- Unit 310: Maintaining Fire Protection Systems on Aircraft
- Unit 314: Maintaining Ice and Rain Protection Systems on Aircraft.

Essential resources

This unit is intended to provide learners with a practical introduction to gas turbine engines. Centres should ensure that learners have access to:

- an aircraft gas turbine engine
- data books and manufacturers' specifications
- AP manuals
- the internet
- appropriate textbooks.

Employer engagement and vocational contexts

Much of the work for this unit can be set in the context of learners' work placements or be based on case studies of local employers. Further information on employer engagement is available from the organisations listed below:

- Work Experience/Workplace learning frameworks – Centre for Education and Industry (CEI – University of Warwick) – www.warwick.ac.uk/wie/cei/
- Learning and Skills Network – www.vocationallearning.org.uk
- Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme – www.stemnet.org.uk
- National Education and Business Partnership Network – www.nebpn.org
- Local, regional Business links – www.businesslink.gov.uk
- Work-based learning guidance – www.aimhighersw.ac.uk/wbl.htm

Indicative reading for learners

Textbooks

Eastop, M – *Applied Thermodynamics for Engineering Technologists* (Longman, 1996) ISBN 0582091934

Rogers, M – *Engineering Thermodynamics – Work and Heat Transfer* (Longman, 1992) ISBN 0582045665

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	planning and carrying out research into the function and operation of gas turbine engine systems, appreciating the consequences of decisions.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Reflective learners	setting goals with success criteria for their development and work.

Functional Skills – Level 2

Skill	When learners are ...
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	sketching the layout and describing the basic functions of the main components found in gas turbine fuel and lubrication systems
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating a range of gas turbine engine fuel, lubrication and control systems
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	sketching the layout and describing the basic functions of the main components found in gas turbine fuel and lubrication systems.