# Unit 83: Aircraft Gas Turbine Engines

**Unit code:** J/600/7271

**QCF Level 3:** BTEC Nationals

**Credit value:** 10

**Guided learning hours:** 60

## Aim and purpose

This unit will give learners a knowledge of the scientific principles that dictate aircraft gas turbine engine performance. Learners will gain a knowledge of gas turbine engine components, including intakes, compressors, combustion chambers, turbines and exhaust units.

## Unit introduction

This unit will give learners an understanding of the construction and operating principles of aircraft gas turbine engines. Learners will gain an understanding of the different types of aircraft turbine engine, their function, construction and installation arrangements. They will also look at factors that can affect engine performance, such as combustion processes and emissions. The unit will also cover the function of gearboxes and the different methods of coupling.

The unit has been designed to take into account the differences between military and civil applications of gas turbine engines and can be delivered to focus on the engine type most appropriate to centres and learner needs.

The unit also covers some of the underpinning knowledge required for those taking Module 15 of the European Aviation Safety Agency (EASA) Part 66 examinations for certifying staff.

## Learning outcomes

**On completion of this unit a learner should:**

1 Know the basic principles of gas turbine propulsion

2 Know the function and operation of gas turbine engines

3 Know the factors affecting engine operation and performance

4 Know about the basic function and operation of gearboxes and engine driven ancillary equipment.

# Unit content

## 1 Know the basic principles of gas turbine propulsion

*Propulsion engine principles*: fundamentals of turbine engine theory eg Newton's laws, Boyle's law, Charles' law and the ideal gas law, simple mass flow and thrust equations, gross thrust, net thrust, choked nozzle thrust, resultant thrust, thrust horse power, equivalent shaft horsepower, airflow through convergent and divergent ducts, ram effect, principles of energy transformation, work, power and efficiency; performance eg thrust distribution, specific fuel consumption, engine efficiencies, pressure, temperature and velocity of gas flow, engine ratings, static thrust, influence of speed, altitude and hot climate on efficiency, flat rating, limitation; working cycle (Brayton cycle); purpose of gas turbine engine sections eg intake, compressor, combustion chamber, turbine, exhaust

## 2 Know the function and operation of gas turbine engines

*General construction and principles of operation*: advantages and disadvantages of each type of engine; operation; construction and installation arrangements; engine noise reduction; types of gas turbine engine eg turbojet, turbofan, turbo-shaft, turboprop; auxiliary power units (APUs); ancillaries eg turbo-prop (reduction gears, integrated engine and propeller controls, over speed safety devices), turbo-shaft (arrangement, drive systems, reduction gearing, couplings and control systems)

*Intakes*: airflow; main types of intakes eg Pitot, divided, external/internal, variable throat

*Compressors*: function and operation eg airflow control, fixed and variable inlet guide vanes, bleed valves, variable stator vanes, rotating stator blades, compression ratio, by-pass ratios; centrifugal compressor eg single entry, double entry; axial flow compressor eg single spool and multi-spool

*Combustion chambers and components*: use of components eg burner, swirl vanes; chamber types eg annular, multiple can, tubo annular, single chamber; advantages

*Turbines*: types (impulse, reaction, impulse/reaction); fan balancing; modes of failure associated with common blade to disc attachment methods eg creep, stress; methods of cooling turbine blades eg film, convection, transpiration

*Exhausts*: components eg jet pipe, exhaust cone, fixed and variable propelling nozzles, thrust reversers

## 3 Know the factors affecting engine operation and performance

*Principle of operation*: starting systems for engine and ground run eg electric, hydraulic, direct air impingement, turbo starter, airstart, ignition systems with an emphasis on safety; factors affecting performance eg basic combustion processes and emissions, compression ratio, compressor surge and stall, noise, intake and exhaust danger zones, foreign object damage (FOD), thrust augmentation (such as water, water/methanol, after burners, mixing units, convergent, divergent and variable nozzles); operation of engine air distribution eg cooling, sealing and external air and anti-ice control, engine pressure ratio, turbine discharge and exhaust pressure systems, hot and cold stream thrust reversers

## 4 Know about the basic function and operation of gearboxes and engine driven ancillary equipment

*Functions and operation*: gearbox types eg radial, internal, external, intermediate, auxiliary drive systems and reduction gearing; coupling methods eg gas, free, gear coupled turbines

## 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** describe the basic principles of jet propulsion using simple equations | **M1** explain the working cycle of a gas turbine engine and the relationship between pressure, velocity, volume and temperature | **D1** analyse and evaluate one type of gas turbine in terms of performance under varying conditions |
| **P2** sketch the working cycle of a gas turbine engine | **M2** explain the function and operation of two methods of thrust augmentation and their effects on performance | **D2** compare and contrast two main types of gas turbine including their ancillaries when installed on a different aircraft type. |
| **P3** describe the purpose of three sections of a gas turbine engine | **M3** compare the function and operation of free, gas coupled and gear coupled turbines, giving examples for the use of each. | |
| **P4** state the advantages and disadvantages of two main types of engine including the use of APUs, in relation to operation, construction and installation arrangements [IE4] | | |
| **P5** describe the flow of air through one of the main types of intake | | |
| **P6** describe the function and operation of centrifugal and axial flow compressors | | |
| **P7** describe the use of components and the differences between multiple can, tubo-annular and annular combustion chambers, giving the advantages of each type | | |

| 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** describe the function of impulse, reaction and impulse/reaction turbines, one form of failure and one method of cooling turbine blades | | |
| **P9** describe the use of exhaust components for two of the main types of engine | | |
| **P10** describe one type of starting system | | |
| **P11** describe the basic factors affecting engine performance and air distribution | | |
| **P12** describe the basic function of one type of ancillary gearbox and one method of coupling. | | |

**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 variety of methods including lectures, tutor-led demonstrations, case studies, mini-projects and visits to aircraft workshops. An initial, broad introduction could make comparisons between the different types of gas turbine engine including turbojet, turbofan, turbo-shaft and turbo-prop. It would then be advantageous for learners to focus on one particular type as it is likely they will only encounter one type of gas turbine engine in the learning environment.

There are differences between military and civil applications of gas turbine engines, and while the fundamentals remain the same the unit has been designed so that learners can study the engine most relevant to their vocational area.

Delivery of learning outcome 1 should focus on the science behind the gas turbine and learners will need to relate these principles to a working engine. Simple thrust and mass flow equations should be practised and learners given an understanding of the gas laws and the Brayton cycle.

Because of the importance of learning outcome 2 to the rest of the unit, more time should be devoted to its teaching than the other learning outcomes. Delivery should focus on the components of a gas turbine and their function. Although it is not necessary to have more than one type of engine for identification purposes, learners must be familiar with the four main types, including APUs, and the differences between them.

Learning outcome 3 looks at the operational use of engines and the factors affecting performance. The highly topical area of gas turbine emissions should only be taught in basic form – learners should know what the products of combustion are, such as CO, $CO_2$, unburnt hydrocarbons and oxides of nitrogen.

Learners will also need to understand anti-ice systems, thrust augmentation and thrust reversal together with the reasons why they are used. Learning outcome 4 looks at the function and operation of gearboxes and the arrangement on the engine, engine driven ancillaries, drive systems and coupling methods.

A practical delivery approach should be used for this unit where possible. Visits to manufacturers, airlines and/or aircraft maintenance facilities where installation, commissioning or maintenance of gas turbine engines takes place would be of immense value to support learning.

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.

## 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:*<br>• introduction to unit content, scheme of work and methods of assessment<br>• explain the fundamental principles of turbine engine operation and performance<br>• describe the purpose of the sections of a gas turbine engine.<br>*Individual learner and practical laboratory activities:*<br>• carry out tasks relating to thrust and mass flow equations and practical laboratory equipment to experimentally determine gas laws. |
| Prepare for and carry out **Assignment 1: Principles of Gas Turbine Propulsion** (P1, P2, P3, M1). |
| *Whole-class teaching:*<br>• describe the four main types of engine, their operation, construction and installation arrangements<br>• describe the purpose and function of APUs.<br>*Small-group activity:*<br>• comparison of the different types of engine to identify main advantages and disadvantages of each.<br>*Whole-class teaching:*<br>• describe the main types of engine intake and explain the behaviour of airflow through the intake towards the combustion chamber<br>• explain the function and operation of compressors<br>• explain the different types of combustion chamber, the advantages of each type and the use of combustion chamber components<br>• explain the different types of turbine, the methods used to cool turbine blades and the common modes of failure<br>• describe function of the main exhaust components.<br>*Practical workshop activities:*<br>• investigation of a gas turbine engine and engine components, its construction, function and operation.<br>*Industrial visit:*<br>• visit to an airline or aircraft maintenance centre to view a variety of gas turbine engines, engine sections and components. |
| • Prepare for and carry out **Assignment 2: Function and Operation of Gas Turbine Engines** (P4, P5, P6, P7, P8, P9, D2). |
| *Whole-class teaching:*<br>• describe the starting systems for engine and ground run and outline the related safety factors<br>• describe gas turbine engine emissions and the products of combustion<br>• describe the factors that can affect engine performance<br>• describe the operation of engine air distribution systems.<br>*Individual learner activities:*<br>• investigation of the factors affecting engine performance. |

| Topic and suggested assignments/activities and/assessment |
| --- |
| Prepare for and carry out **Assignment 3: Gas Turbine Engine Performance and Operation** (P10, P11, M2, D1) |
| *Whole-class teaching:*<br>• describe the function and operation of different types of gearboxes and auxiliary drive systems<br>• describe coupling methods. |
| Prepare for and carry out **Assignment 4: Function and Operation of Gearboxes and Ancillary Equipment** (P12, M3). |
| Feedback on assessment and unit evaluation. |

## Assessment

Assessment evidence for this unit can be collected from a mixture of written assignments and practical activities.

To achieve a pass grade, learners must have an understanding of the principles of aircraft propulsion and be able to make simple thrust calculations. They will need to be familiar with the configuration of the major types of gas turbine engine and understand the functions of their main components. This will include an understanding of the factors affecting engine performance.

Learners should also be able to explain how thrust augmentation is obtained and how thrust reversal is achieved together with the reasons why they are required. Learners must be able to describe the purpose and function of engine driven ancillaries, starting systems and engine air distribution systems.

To achieve a merit grade, learners must build on their understanding of the working cycle of a gas turbine engine in terms of pressure, volume and temperature (Brayton cycle). Learners will also need to demonstrate an understanding of thrust augmentation and the function and operation of different turbines.

To achieve a distinction grade, learners will need a thorough understanding of the factors that affect the design and development of different types of gas turbine. They will need to compare and contrast different types, such as those in the commercial or military sectors utilising either turbojet, turbofan, turbo-shaft or turboprop. This includes being able to give an informed opinion for selecting a particular engine for a given role.

Four assignments could be used to assess this unit. The first of these could cover criteria P1, P2, P3 and M1. Written tasks could be set requiring learners to describe the principles of jet propulsion and the purpose of three sections of a gas turbine engine. A sketch would also be required to show the working cycle of a gas turbine engine and this task could be extended to meet M1.

The second assignment would need to be given once learners have fully covered and are familiar with the function and operation of gas turbine engines as in learning outcome 2. The assignment could again involve a range of written tasks to enable learners to develop evidence to meet the requirements of P4, P5, P6, P7, P8 and P9.

Assignment 3 may well be a smaller written assignment covering P10 and P11 along with M2.

The fourth and final assignment could cover P12 and M3. Further written tasks could then be given to allow opportunities to develop evidence against the requirements of D1 and D2. These should be the last tasks set for the learner as they will need to have an understanding of most aspects of the unit to produce suitable evidence in written form.

### 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 | Principles of Gas Turbine Propulsion | Produce an information leaflet detailing the underpinning principles of engine operation. | An assignment consisting of written tasks and sketches. |
| P4, P5, P6, P7, P8, P9, D2 | Function and Operation of Gas Turbine Engines | A technician needs to give a new apprentice an introduction to the function and operation of a gas turbine engine. | An assignment consisting of a series of written tasks and/or a presentation supported by tutor observation and relevant handouts. |
| P10, P11, M2, D1 | Gas Turbine Engine Performance and Operation | A technician needs to give a new apprentice an outline of the factors affecting engine performance. | An assignment consisting of written tasks. |
| P12, M3 | Function and Operation of Gearboxes and Ancillary Equipment | A technician needs to give a new apprentice an outline of the function and operation of gearboxes. | An assignment consisting of written tasks. |

## 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 strong links to Module 15: Gas Turbines, and, to a lesser extent, some of Module 2: Physics, for EASA Part 66 and the license examinations.

## Essential resources

Learners will need access to suitable aircraft gas turbine engines, data books, manufacturers' specifications and AP manuals.

## 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, 1993) ISBN 0582215714

Moran M – *Fundamentals of Engineering Thermodynamics* (John Wiley and Sons, 2006) ISBN 0470030372

Sonntag R and Bourgnakke C – *Introduction to Engineering Thermodynamics* (John Wiley and Sons, 2006) ISBN 0471737593

## 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** | analysing and evaluating information when determining the advantages and disadvantages of different types of engine. |

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 | describing principles of propulsion and the purpose of sections of the gas turbine engine<br>describing the function and operation of centrifugal and axial flow compressors<br>describing the use of components and the differences between multiple can, tubo-annular and annular combustion chambers<br>describing the function of impulse, reaction and impulse/reaction turbines, one form of failure and one method of cooling turbine blades |
| Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions | researching and investigating the function and operation of gas turbine engines |
| Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively | describing principles of propulsion and the purpose of sections of the gas turbine engine<br>describing the function and operation of centrifugal and axial flow compressors<br>describing the use of components and the differences between multiple can, tubo-annular and annular combustion chambers<br>describing the function of impulse, reaction and impulse/reaction turbines, one form of failure and one method of cooling turbine blades. |