Unit 73: Aircraft Electrical Machines

Unit code: L/600/7210

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit will provide learners with an understanding of the construction, operation and control of aircraft electrical machines and power distribution systems.

Unit introduction

For any avionic/electrical technician involved in the maintenance or manufacture of aircraft it is important that they have an understanding of how aircraft electrical power is generated and distributed. It is also important that they have an understanding of motors and other electrical machines that are used to power and control various systems fitted to the aircraft.

This unit will provide learners with a practical introduction to aircraft electrical machines and power distribution. It encourages learners to investigate the range of electrical machines available for use in aviation and to understand the reasons for selecting a particular machine for specific tasks.

The unit will also look at how an aircraft's power supply system operates. In order to develop their practical competence and awareness of safety precautions, learners will study the operation of machines. On completion of the unit, learners should be able to describe how machines are constructed and operate, say which machines are most suitable for various tasks and describe the power distribution and protection system of a typical aircraft.

The unit is designed to provide underpinning knowledge for learners working towards EASA Part 66 licensing requirements, employment with the armed forces or in the aircraft manufacturing industry.

Learning outcomes

On completion of this unit a learner should:

1 Understand the construction, operation and control of aircraft electrical generators and transformers

2 Understand the construction, operation and control of aircraft electrical motors

3 Be able to interpret test results from representative electrical machines and confirm fitness for purpose

4 Know how aircraft electrical power is generated, distributed, monitored and controlled.

Unit content

1 Understand the construction, operation and control of aircraft electrical generators and transformers

AC and modern (brushless) DC generators: underpinning principles; single-phase and polyphase; construction detail; machine characteristics; operation of single-phase generators/three-phase generators/ brushless DC generators, starter generator; generator control parameters (frequency, voltage, phase, methods of achieving these parameters); three-phase star/delta connections; generator internal and control circuitry; principles of operating AC generators in parallel

Specialist transformers: current transformers, purpose and principles of operation; transformer rectifier units (TRUs), purpose and principles of operation

2 Understand the construction, operation and control of aircraft electrical motors

DC motors: motor principles, including the limiting effect of back EMF; construction detail of simple DC motors; methods of automatic control; performance characteristics (starting, torque, speed, reversing); typical uses eg starter motors, windscreen wiper motors, fuel pumps, servo motors

AC single phase, three-phase synchronous and induction motors: motor principles; construction details; characteristics (starting, torque, speed, reversing); typical uses eg starter motors, windscreen wiper motors, fuel pumps, servo motors; methods of control

3 Be able to interpret test results from representative electrical machines and confirm fitness for purpose

Generators: characteristic/performance tests on representative generators eg brushless DC, single-phase, three-phase

Motors: characteristic/performance tests on DC and AC representative motors eg synchronous, three-phase induction, single-phase induction, capacitor start, shaded pole, series DC, shunt DC, compound DC, stepper motors

Electrical safety: safe set up of machines for testing; mechanical and electrical safety precautions eg guards for moving parts, avoidance of exposed live connections, correct earthing and bonding, personal protection (correct clothing, no loose clothing), actions to be taken in cases of electric shock, safe working practices on aircraft power supply systems

4 Know how aircraft electrical power is generated, distributed, monitored and controlled

Aircraft power generation and distribution: primary and secondary power; single and multiple generators systems; bus bars; auxiliary airborne power units; inverters; external/ground power; emergency power provision eg main batteries, emergency batteries, battery installation and operation, standby generators, ram air turbines (RATs)

Aircraft power monitoring and control: DC generators voltage control; paralleling AC generator control systems; voltage control; frequency control eg fixed frequency, frequency wild; constant speed drive units; integrated drive generators

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 explain the construction, principle of operation and output characteristics of a DC generator	**M1** compare series and shunt motors in terms of their speed/torque characteristics and give typical uses for each	**D1** evaluate the suitability of a given motor for a specified task, referring to the motor's characteristics, size, cost and performance characteristics
P2 explain the construction, principle of operation and output characteristics of an AC generator	**M2** compare different types of single-phase motors in terms of their speed/torque characteristics and give typical uses for each	**D2** with the aid of given documentation, explain how a modern AC brushless generator is controlled and protected when supplying power to an aircraft system.
P3 describe the purpose and explain the principle of operation of a current transformer	**M3** compare different types of three-phase motors in terms of their speed/torque characteristics and give typical uses for each.	
P4 describe the purpose and explain the principle of operation of a TRU, when fitted into an aircraft power supply		
P5 explain the construction, operation, use and performance characteristics of a DC motor		
P6 explain the construction, operation, use and performance characteristics of an AC motor		
P7 carry out, in a safe manner, a functional test on a DC or an AC generator and use the results to explain the characteristics of the resulting outputs [SM3, SM4]		

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	carry out, in a safe manner, tests on a DC and an AC motor when subject to varying load, and record and use the results to explain the output characteristics [SM3, SM4]		
P9	describe the power generation and distribution system of a specified aircraft		
P10	describe the power monitoring and control system of a specified aircraft.		

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

The first three learning outcomes of this unit are strongly linked and provide the underpinning knowledge required for learning outcome 4. Knowledge of electrical machines should be built from general principles to specific applications so that learners appreciate why different machines are required for different purposes. This includes why different types of motors are required for different applications and what makes specific motors suitable for some applications and not others. A similar approach should be used for different types of generators. Learning outcome 4 then moves on to power generation and distribution in typical aircraft.

The unit has been written so that it can be studied by learners in full-time education with limited access to aircraft and aircraft equipment. However, at the very least, they should be able to observe the testing of real industrial machines and the related safety precautions. It would not be sufficient for practical activities to rely on miniature machines. Whilst it may not be practicable for each learner to carry out tests individually, centres should aim for learners to be working in small groups. If the testing has to be carried out by demonstration, and/or if there are only a limited number of different machines available for testing, then a portfolio of results for the range of machines specified in the unit content should be provided for learners to study.

Learning outcomes 1, 2 and 3 should be studied concurrently, ie moving from the principles of generators to the testing of generators, and then on to DC motors and then AC motors. The principles of current transformers and TRUs could be left until just before starting learning outcome 4.

Learning outcome 4 would benefit from being taught with reference to representative aircraft systems that learners are likely to encounter. The relevance of this unit relies on centres keeping up to date with current and medium-term future systems and equipment. For instance, reference could be made to modern magnetic materials which are allowing the development of electrical motors capable of replacing hydraulic actuators.

The ultimate purpose of delivery must be to prepare learners to work in the aircraft maintenance or manufacturing industries and as such a practical approach would ideally be used.

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: • introduction to unit content, scheme of work and methods of assessment • explain the underpinning principles of single-phase and polyphase generators • describe the constructional detail and machine characteristics for a range of generators • explain the operation of single-phase, three-phase, brushless DC and starter generators • explain generator control parameters and the use of control circuitry.

Topic and suggested assignments/activities and/assessment
Individual learner activities: • individual research into the construction and operation of aircraft electrical generators • short quiz or multiple choice test on the operation of single-phase, three-phase, brushless DC and starter generators.
Whole-class teaching: • explain the underpinning principles of motors and effect of back EMF • explain the constructional detail of DC motors, the methods of automatic control and typical performance characteristic • describe typical uses of DC motors. *Practical workshop activities:* • practical investigation of simple DC motors, their construction and operation.
Prepare for and carry out **Assignment 1: Aircraft Electrical Generators, Transformers and Motors** (P1, P2, P3, P4, P5, P6).
Whole-class teaching and demonstration: • explain and demonstrate the safety precautions that need to be followed when carrying out tests on electrical machines • describe and demonstrate the purpose and use of characteristic and performance tests on generators and DC and AC motors. *Small-group practical activities:* • working in small groups to carry out testing on electrical machines, observing relevant safety precautions. *Individual learner activities:* • interpret and explain test results • quiz/multiple choice test on electrical safety.
Prepare for and carry out **Assignment 2: Testing of Aircraft Generators and Motors** (P7, P8)
Whole-class teaching: • describe the function and operation of aircraft electrical power generation and distribution systems • describe aircraft power monitoring and control systems. *Industrial visit and/or practical workshop activities:* • view/investigate aircraft electrical power systems.
Prepare for and carry out **Assignment 3: Aircraft Electrical Power** (P9, P10, D2)
Prepare for and carry out **Assignment 4: Comparing and Evaluating Aircraft Electrical Machines** (M1, M2, M3, D1).
Provide feedback on assessment and evaluation of unit.

Assessment

Criteria P1 to P6 cover the underpinning knowledge upon which the rest of the unit builds and could be evidenced via short-answer questioning (either verbal or written), or via a vocationally contextualised assignment based on familiar equipment. While P1 to P4 require descriptions of four different machines, it would not be sufficient to limit teaching to just these as this would not provide sufficient breadth for the merit criteria.

P7 and P8 could be assessed through practical exercises. Evidence could be recorded in a workbook, with space for learners to record results of the tests, draw the resulting graphs and provide an explanation of the results in their own words. The range of tests required will be governed by the type of motors used. However, as motors operate in starting, torque, speed and reversing modes, three of these four would be appropriate. The various loads will come from the different mode of operation. Additional guidance, such as outline calculations, could be provided, into which learners can enter their own results, together with questions about what the results mean and how they compare to ideal results.

P9 and P10 could be tackled in different ways depending on the mode of delivery in use at the centre. Part-time learners with employment in the aircraft industry could be asked to prepare a brief about an aircraft their company operates (or manufactures) for a qualified aircraft technician who is new to the aircraft. For full-time learners, it might be necessary to provide the aircraft manual/publication for the specified aircraft and to ask them to write a summary of how the systems operate.

To achieve the three merit criteria, learners should compare enough different machines to cover the range of typical uses given in the unit content. These criteria could be met by a series of tables listing different machines, providing a sketch graph of their characteristics and saying what each machine is used for and why the characteristics make the machine suitable for the stated application.

D1 evidence is likely to build on that provided for the merit criteria. The task and the motor to be evaluated should be given to the learner. To ensure fairness of assessment, a variety of motors should be available so that each learner works with a different combination of task and motor. It is not necessary that the motors provided be suitable for the task stated; an explanation of why the motor is unsuitable is valid evidence of the learners' understanding of the machine.

D2 can either be assessed individually or could be part of the assignment covering P9 and P10. The task used should relate either to a familiar aircraft to which learners have access or an aircraft from the sector they are most likely to go on to work in. The explanation should be in sufficient depth to allow a qualified technician, who is unfamiliar with the aircraft being described, to work on the system.

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, P4, P5, P6	Aircraft Electrical Generators, Transformers and Motors	A technician needs to provide an explanation of the operation of a range of aircraft electrical machines.	An assignment consisting of a series of written tasks or verbal questioning.
P7, P8	Testing of Aircraft Generators and Motors	A technician has to carry out tests on generators and motors and record the results.	A practical assignment supported by tutor observation, written records and test results.

Criteria covered	Assignment title	Scenario	Assessment method
P9, P10, D2	Aircraft Electrical Power	A technician has been asked to brief a new colleague on an aircraft's power generation, distribution and monitoring systems.	A written report or presentation supported by tutor observation records and relevant handouts.
M1, M2, M3, D1	Comparing and Evaluating Aircraft Electrical Machines	A technician has been asked to determine the best machines to use for applications in their workplace.	A written report.

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
		Electrical and Electronic Principles
		Aircraft Electrical Systems

The unit also provides some of the knowledge and understanding associated with SEMTA Level 3 National Occupational Standards in Aeronautical Engineering, particularly:

- Unit 134: Carrying Out Tests on Aircraft Electrical Power Control, Distribution and Protection Systems.

Essential resources

To meet the needs of this unit it is essential that the centre has, or has access to facilities for carrying out characteristic/performance tests on electrical machines. This should include sufficient electrical machines to cover the range specified in the unit content. Centres should also have texts showing ideal characteristics for the machines tested to enable learners to compare these with observed results.

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

Hiley J, Brown K, Hughes E and Smith I – *Electrical and Electronic Technology* (Prentice Hall, 2004) ISBN 0131143972

Pallett E – *Aircraft Electrical Systems* (Longman, 1988) ISBN 0582988195

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 interpreting test results
Self-managers	organising time and resources, prioritising actions and anticipating and managing risks when carrying out functional tests on electrical machines.

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
Team workers	collaborating with others when working in small groups to carry out testing on electrical machines.

Functional Skills – Level 2

Skill	When learners are ...
Mathematics	
Interpret and communicate solutions to practical problems in familiar and unfamiliar routine contexts and situations	planning and carrying out tests on AC and DC generators and motors, using the results to explain the characteristics of the resulting outputs
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	describing the construction, operation and output characteristics of a range of aircraft electrical machines
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating the construction and operation of a range of aircraft electrical machines
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	describing the construction, operation and output characteristics of a range of aircraft electrical machines.