Unit 79: Airframe Structural Concepts and Construction Methods

Unit code: M/600/7250

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Unit aim and purpose

This unit will give learners an understanding of the structural concepts, construction methods, general design features and protection methods needed for the successful manufacture, production and maintenance of aircraft airframe structures.

Unit introduction

An understanding of airframe structures, the loads imposed on these structures and the construction, design and prevention methods used to ensure their airworthiness are of prime importance to all those mechanical engineers involved with the manufacture, production, maintenance or overhaul of aircraft airframes and/or their associated structural components.

The unit has been designed to provide learners with a general understanding of airframe structural concepts, construction and protection methods. In particular, the loads imposed on airframe structures, the basic structural members used to take these loads and the structural design concepts used to ensure continued airworthiness are covered. The assembly, construction and protection methods for the aircraft fuselage, wings and ancillary structures, are covered in detail. A section has also been included on aircraft wooden and fabric structures.

This unit is closely associated with *Unit 70: Aircraft Materials and Hardware* as well as with *Unit 71: Inspection and Repair of Airframe Components and Structures*. This unit will not only be of benefit to those studying at the BTEC National level but also to those following an apprenticeship in aircraft manufacture, production or maintenance, as well as those mechanical technicians currently undergoing aircraft engineering training with the armed forces. It also covers part of the knowledge required for those taking the European Aviation Safety Agency (EASA) Part 66 examinations.

Learning outcomes

On completion of this unit a learner should:

1 Understand airframe loading, structural members and general structural concepts

2 Understand airframe general construction and protection methods

3 Understand construction and assembly of aircraft fuselage, wings and ancillary structures

4 Know about aircraft wood, wooden structures, fabrics and their repair.

Unit content

1 Understand airframe loading, structural members and general structural concepts

Airframe loading: static loads eg those due to weight of engines, wings, fuselage, fuel, external stores, passengers and cargo; dynamic loads eg thrust, lift, weight, drag, manoeuvre, turbulence, gust; fatigue loads eg those created by engine vibration, pressure cycles and undercarriage cycles

Structural members: basic types (struts, ties and beams), stresses taken by structural members (tension, compression, torsion, shear, bending, hoop), stresses taken by major structural members (such as fuselage, skin, empennage, wings, undercarriage, engine pylons)

Structural concepts: eg airworthiness requirements for structural strength, structural classification (primary, secondary, tertiary), zonal and station identification systems; design concepts (such as, failsafe, safe life and damage tolerant structures, drains and ventilation provision, lightning strike protection provision and aircraft bonding provision), airframe symmetry(such as methods of alignment, symmetry checks)

2 Understand airframe general construction and protection methods

Construction methods: for eg stressed skin fuselage, stringers and longerons, frames and formers, bulkheads, floor structures, beams, struts and ties, empennage, engine attachments; assembly techniques (riveting, bolting and bonding)

Protection methods: anti-corrosive protection eg materials selection, jointing compounds, drain holes, stringer design, chromating, anodising, painting and surface cleaning

3 Understand construction and assembly of aircraft fuselage, wings and ancillary structures

Fuselage: construction and assembly eg skin, frames, formers, longerons, pressure bulkheads, fuselage sections, wing, stabiliser, pylon, arrestor gear, and undercarriage/landing gear attachments; construction, installation and operation eg fuselage seats, cargo loading system, doors and emergency exits, door safety devices, windows and windscreens

Wings: construction eg stressed skin, stiffeners, spars, ribs, milled, etched, integral, wing boxes, torsion boxes, integral fuel tanks, composite bonding; assembly eg landing gear, pylon, control surface and high lift/drag devices

Ancillaries: construction and methods of attachment eg empennage, stabilisers, flight control surfaces, propellers, nacelles, pylons, engine mounts, firewalls; mass and aerodynamic balancing of flight controls

4 Know about aircraft wood, wooden structures, fabrics and their repair

Wood and wooden structures: types eg Sitka Spruce, Balsa, Douglas Fir, Western Hemlock, Birch plywood; characteristics eg inconsistent grain structure, types of cut, moisture content, variation in hardness, strength and toughness; inspection for defects eg dote disease, decay, rot, heart-shake, knots, gum pockets, glue line faults, joint failure, water penetration, shrinkage; structures eg plywood fabricated 'I' section spars, box spars, laminated spars, frames, ribs, propellers, assemblies

Wood repairs: eg glued joints (such as plastic resin, resorcinol, epoxy resin), butt plates, bolted joints, screws, replacement parts

Fabrics: characteristics, properties and types eg tapes, thread, cord, filaments, weaved clothes, cotton, linen, glass fibre, polyester (Dacron, poly-fibre), fabric dopes (such as cellulose, vinyl, polyurethane); doping and fabric covering defects eg doping (such as adhesion, blisters, poor finish, blushing) fabric covering (such as excessive tension, coating cracks, loose fabric, torn and cut fabric)

Fabric repairs: techniques and procedures for eg cuts and tears, stitching, darning, inserts, wooden frame patch repair, re-doping, replacement

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 nature, causes and effect of two types of static load, dynamic load and cyclic fatigue load	**M1** explain the airworthiness requirements for structural strength and their relationship to the structural loading and structural classification	**D1** compare fail-safe, safe-life and damage tolerant designs, both from a structural airworthiness and maintenance perspective
P2 detail the loads taken by struts, ties and beams and explain the differences in the loads taken by the fuselage skin, the wings and the aircraft undercarriage	**M2** explain the circumstances under which aircraft airframe symmetry checks are required and explain the effect on aircraft performance when the aircraft wings and empennage are out of symmetry	**D2** investigate the manufacturing techniques used for the production of carbon fibre reinforced plastic flying control and empennage components and compare them with their conventional metallic counterparts.
P3 define, primary, secondary and tertiary aircraft structure	**M3** explain how the provision of drains, materials selection, jointing compounds, surface protection and stringer design help reduce the risk of corrosion damage to the base of an aircraft fuselage	
P4 explain the provision for protecting the aircraft airframe and its systems in the event of a lighting strike	**M4** investigate the nature and production of aircraft composite propellers and rotor blades and compare and contrast them with their conventional metallic counterparts.	
P5 describe how composite floor panels and bulkheads are constructed and give the relative advantages and disadvantages for using riveting and bonding to assemble aircraft airframe structure [IE3]		

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:**
P6 explain the need for and describe a typical procedure for both the chromating and anodising surface corrosion protection method		
P7 sketch and label a metallic stressed skin fuselage, constructed using frames, longerons, stringers, bulkheads and skin, and state the function of each of these fuselage components		
P8 describe the construction and explain the operation of fuselage doors, emergency exits and door safety devices		
P9 describe one construction method for an aircraft metallic wing integral fuel tank and the construction and assembly to wing of a metallic flying control surface		
P10 explain the need for and nature of mass and aerodynamic balancing of flight controls		
P11 describe the properties and characteristics of Sitka Spruce, Birch Plywood and Dracon fibre and give one aircraft structural application for each material that utilise these qualities		
P12 describe the procedure and safety precautions required to carryout a glued joint wood repair and a fabric repair that involves re-doping.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills which are embedded in the assessment of this unit. By achieving the criteria, learners will have demonstrated 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

For the reasons given above this unit is best delivered in the second year of the programme after learners have acquired an understanding of aircraft materials. The learning outcomes have been written so that they may be delivered in the order presented. When delivering the learning outcomes the amount of tuition time and the bias given to each, will depend on the needs of the industrial stakeholders, as well as the needs of the individual learner and the whole cohort. For instance, the outcome on wooden and fabric structures is likely to be given a cursory treatment for most learners, except perhaps those with a direct involvement in the manufacture, repair or maintenance of older light aircraft, micro-lights or similar.

When delivering learning outcome 1, not only should the different types of load and the way they are set-up be mentioned but also the effect they have on the major structural members and the related dangers of the induced stresses should be emphasised. This is particularly important with the cyclic nature of fatigue loading and the damage that may occur as a result of the fluctuating stresses that are induced in the major structural components. The causes and effects of tensile, shear, bending and hoop stresses also need to be covered in detail, in a qualitative rather than quantitative manner. The airworthiness requirements for structural strength should be taught using the structural repair manual, operations manual or similar documentation, as appropriate. The strength requirements and other requirements for primary, secondary and tertiary structures should also be covered. When delivering the material concerned with structural design concepts, the function and nature of safe life, failsafe and damage tolerant structure should be emphasised, particularly with respect to airframe fatigue damage limitation.

When delivering the material concerned with construction methods in learning outcome 2, tutors should emphasise the modular nature of the construction of the whole airframe and how the major airframe components are assembled. Examples should also be given of the various assembly techniques (riveting, bolting, bonding) used for the manufacture and attachment of, for example, main spars, bulkheads, engine attachment, tail planes and fins. Corrosion protection by materials selection, design, jointing compounds and surface treatments should be covered in detail.

Learning outcome 3 is concerned with the detailed construction, fabrication, assembly and attachment of fuselage, wings and ancillary airframe structures and their associated attachments and should therefore, be covered comprehensively, emphasising both metallic and composite manufacture, construction and fabrication techniques. The emphasis placed on the delivery of the learning material associated with, the installation and operation of fuselage equipment, access doors, transparencies and emergency exits, will vary according to the needs of the cohort, being of particular importance to all those learners following an aircraft maintenance pathway and to a lesser degree to those engaged with the manufacture/construction of aircraft airframe structures.

Learning outcome 4 is included primarily for those involved with the construction, repair and overhaul of light aircraft constructed mainly from wood and fabric materials and also to meet the requirements for the small amount of content found in the EASA Part-66 syllabus concerned with those engaged in the maintenance and repair of light general aviation aircraft. When delivering the content of this outcome, the onus placed on it will thus be determined by the needs of the cohort, being taught. However, the common types of wood, their characteristics, defects and fabrication properties should be covered and related to the aircraft structural use of these materials, as should, the characteristics, types and defects associated with airframe fabrics. Mention should also be made of the techniques and procedures for the more common repairs such as, stitching, patch repairs, re-doping and replacement.

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 assessment strategy • explain static, dynamic and cyclic fatigue loads, basic structural members and major structural components, that take the loads. *Individual learner activity*: • short formative assignment consisting tasks covering all important aspects of airframe loading and structural members. *Whole-class teaching:* • with the aid of specialist manuals and structural hardware explain airworthiness requirements for structural strength and stiffness, structural classification and its relationship to loads imposed on structure • explain structural identification methods (using specialist manuals/documentation) and structural design concepts. *Individual learner activity*: • questionnaire or multiple-choice quiz on structural concepts.
Prepare for and complete **Assignment 1: Airframe Loading, Structural Members and General Structural Concepts** (P1, P2, P3, P4, M1, M2, D1).
Whole-class teaching: • using appropriate airframe structures explain general airframe construction methods for both metallic and composite structure • explain metallic structure anti-corrosive measures, including design, materials selection and surface corrosion treatments. *Individual learner activity:* • questionnaire or multiple-choice quiz on general construction methods and protection methods.
Prepare for and complete **Assignment 2: Airframe General Construction and Protection Methods** (P5, P6, M3).

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • explain the construction and assembly methods used for the fuselage and attachment of structural components. To include modern methods of producing fuselage skin, fuselage sectioning and assembly methods, fuselage components, their manufacture method and purpose, together with the installation procedures and operation of seats, cargo-loading systems, doors, emergency exits, canopies and other transparencies (emphasis, as appropriate to the needs of the learner) • explain the modern construction and assembly methods for aircraft metallic and composite wings, including milling, chemical etching, bonded, co-bonded and riveted construction methods • explain the methods for assembling components such as flying controls, undercarriage and pylons to the wing • with the aid of equipment explain the modern construction and methods of attachment for metallic and composite structural components (emphasis, as appropriate for the needs of the learner). *Individual learner activity*: • investigation of the construction, assembly and methods of attachment for the fuselage, wings and ancillary structures.
Prepare for and carry out **Assignment 3: Construction and Assembly of Fuselage, Wings and Ancillary Structures** (P7, P8, P9, P10, M4, D2).
Whole-class teaching: • using physical examples and photographs explain the types of wood and their characteristics, qualities and possible defects and the types of structure and airframe components that may be fabricated from wood for aircraft use. Also provide an explanation of wooden repair methods and their limitations (as appropriate to the needs of the learner) • explain the characteristics, properties types and use of fabrics, the defects associated with doping and fabric covering and the techniques and procedures used for repairs to airframe fabric structures. *Individual activity*: • multiple-choice quiz on wood, fabrics, their structures and repair.
Prepare for and carry out **Assignment 4: Wood and Fabric Structures and Repair** (P11, P12).
Feedback on assessment and unit evaluation.

Assessment

It is expected that a range of assessment methods will be used for this unit. Evidence may be gathered from written responses to investigative assignments and formal timed assessment. There may also be some opportunities to gather evidence from tutor observation records or witness testimony, depending on whether learners carry out practical assignments.

Four assignments could be set for the assessment of this unit. The first assignment, covering learning outcome 1 could consist of a series of formal written tasks or be an investigative assignment, carried out during a planned visit to an appropriate manufacturing, overhaul or maintenance company. The assignment would require learners to explain static, dynamic and cyclic fatigues loads (P1) and the loads taken by basic structural members and by major airframe components such as the fuselage skin, the wings and the aircraft undercarriage (P2). The assignment would also require learners to define primary, secondary and tertiary structure (P3) and explain the provision for protecting the airframe and its systems in the event of a lightning strike (P4).

Further tasks could be set for which learners must explain the airworthiness requirements for structural strength and the relationship of these requirements to the structural loading and classification of aircraft airframe structures (M1). They will need to explain the circumstances under which there would be a

requirement to carryout aircraft symmetry checks and explain the effect on aircraft performance when the aircraft wings and the empennage (tail plane/fin assemblies etc) are out of symmetry (M2). Learners should also compare a, fail-safe, safe-life and damage tolerant structural designs, from both the structural airworthiness perspective (taking into account the imposed loads and stress paths etc) and from a maintenance perspective (explaining the implications for maintenance and the design of maintenance schedules) (D1).

The second assignment could consist of written tasks or a report, based on a theoretical investigation. The assignment would require learners to describe the construction of composite sandwich floor panels and bulkheads and give the benefits and problems associated with both riveting and bonding assembly methods (P5). They must also explain the need for and describe typical chromating and anodising surface corrosion protection methods (P6). A further task would give learners an opportunity to investigate how the provision of drains, materials selection, jointing compounds, surface protection and stringer design helps reduce the risk of corrosion damage to corrosion prone areas, such as the base of an aircraft fuselage (M3).

A third assignment could cover learning outcome 3 and consist of a mixture of written tasks and an investigative report. Learners will need to sketch and label a complete stressed skin fuselage structure complete with bulkheads and be able to state the function of all structural components used in the construction of the fuselage (P7). They must describe the construction and explain the operation of fuselage doors, emergency exits and door safety devices (applicable to either civil or military aircraft, according to learner needs) (P8). They will also need to describe the construction of a wing integral fuel tank and the construction, assembly and means of attachment of a metallic flying control surface (P9). This should include all component parts that go to make-up the control surface. A further written task would require learners to explain the need for and nature of the methods used for the mass and aerodynamic balancing of flight control surfaces (P10).

The investigative report could cover the related merit and distinction criteria and require learners to investigate the nature/construction of aircraft composite propellers and rotor blades and the production techniques used to produce these components and then compare and contrast them with their more conventional metallic counterparts (M4). Learners could also investigate and analyse the manufacturing techniques used to produce CFRP flying control surfaces and empennage components and compare and contrast them with their conventional metallic counterparts (D2).

The fourth assignment is also likely to be a written assignment, requiring learners to describe the properties and characteristics of wood and fibres and give relevant aircraft applications for them (P11). They will also need to describe the safety precautions required to carryout a glued joint wood repair and a fabric repair that involves re-doping (P12).

Assignments

The following table shows how the suggested assignments match and cover the assessment grading criteria.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, P4, M1, M2, D1	Airframe loading, structural members and general structural concepts	A formal assignment requiring learners to respond to written tasks. Note: This assignment could be set in two parts – the first to cover the pass criteria and the second at a different time to cover the merit and distinction criteria.	Written responses to set tasks, carried out under controlled conditions.

Criteria covered	Assignment title	Scenario	Assessment method
P5, P6, M3	Airframe general construction and protection methods	A formal assignment requiring learners to respond to written tasks.	Written responses to set tasks, carried out under controlled conditions.
P7, P8, P9, P10, M4, D2	Construction and Assembly of Fuselage, Wings and Ancillary Structures	A two part assignment, part 1 consisting of a set of formal written tasks (P7, P8, P9, P10) and part two being a theoretical investigative assignment to cover (M4, D2).	Written responses to set tasks, carried out under controlled conditions (P7, P8, P9, P10) and a written report resulting from an investigation.
P11, P12	Wood and Fabric Structures and Repair	A formal assignment requiring learners to respond to written tasks.	Written responses to set tasks, carried out under controlled conditions.

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
		Aircraft Materials and Hardware
		Aircraft Workshop Principles and Practice
		Inspection and Repair of Airframe Components and Structures
		Aircraft Maintenance Practices

This unit has been mapped against the EASA Part-66 examinations and when taken with *Unit 70: Aircraft Materials and Hardware*, covers the knowledge requirements for the Airframe Structures section of Modules 11 and 13 Aeroplane Aerodynamics, Structures and Systems.

The unit also contributes knowledge towards SEMTA Level 3 National Occupational Standards in Aeronautical Engineering, particularly:

- Unit 10: Producing Composite and/or Metallic Aircraft Sub-assemblies
- Unit 11: Producing Composite and/or Aircraft Major Assemblies
- Unit 13: Repairing Airframes and Structures
- Unit 14: Modifying Airframes
- Unit 151: Removing and Replacing Major Assemblies of Aircraft Airframes
- Unit 173: Overhauling Major Components of Aircraft Airframes
- Unit 202: Producing Aircraft Composite Mouldings using Pre-Preg Laminating Techniques
- Unit 326: Maintaining Doors on Aircraft
- Unit 327: Maintaining Fuselage, Nacelles/Pylons on Aircraft

Essential resources

Learners will require access to an aircraft engineering workshop environment suitably equipped with:

- major airframe assemblies
- a range of airframe structural components
- access to specialist manuals, manufacturers data, maintenance and other related documentation and information.

Employer Engagement and Vocational Contexts

Liaison with employers can help centres arrange on-site visits so that learners can observe first hand a range of construction and production techniques and view airframe component production, overhaul or repair.

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

Baker A, Dutton S and Kelly D – *Composite Materials for Aircraft Structures* (American Institute of Aeronautics and Astronautics, 2004) ISBN 9781563475405

Crane D – *Airframe Volume 1: Structures* (Aviation Supplies and Academics, 2007) ISBN 9781560275480

Other

Air Publications – 101 series of manuals and aircraft engineering publications (Military)

ATA – 100 Series, specialist manuals and publications from the Joint Aviation Authority sanctioned by the European Aviation Safety Agency (Civil)

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	exploring issues from different perspectives when analysing the advantages and disadvantages of using riveting and bonding to assemble airframe structures analysing information on the properties of different woods and fabrics and judging its relevance and value.

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 ...
Independent enquirers	identifying questions to answer and problems to resolve when researching airframe loading, structural members and general structural concepts.

Functional Skills – Level 2

Skill	When learners are ...
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating airframe structures
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	explaining **t**he nature, causes and effect of two types of static load, dynamic load and cyclic fatigue load explaining the differences in the loads taken by the fuselage skin, the wings and the aircraft undercarriage.