Edexcel BTEC Levels 4 and 5 Higher Nationals specification in Aeronautical Engineering

Contents

Unit 82: Aircraft Systems Principles and Applications

Unit code: D/601/7188

QCF level: 5

Credit value: 15

Aim

This unit will develop learners' understanding of the principles and components of aircraft power and control systems.

Unit abstract

This unit will enable learners to apply the necessary mechanical, electrical and electronic principles to the examination of aircraft systems. Learners will investigate the principles and components used for the control and performance monitoring of aircraft systems, including transducers and signal conditioning and amplifiers. They will examine the construction and operation of aircraft power systems and the methods used to ensure the integrity and safety of aircraft power distribution. Finally, learners will analyse aircraft control systems and will apply aircraft system control methods to the response of typical aircraft systems.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the principles and components used for the control and performance monitoring of aircraft systems

2 Understand the operation and performance of aircraft power systems

3 Be able to apply control system fundamentals to the analysis of aircraft control systems.

Unit content

1 **Understand the principles and components used for the control and performance monitoring of aircraft systems**

Aircraft systems: system definition; system state and operating environment; basic electro-mechanical system components eg sensor/transducer, comparator (error detector), signal conditioner and actuation device; G notation; feedback signals; H notation; simple system transfer functions

Transducers: characteristics; operation and applications – optical eg photoconductive cell, photovoltic, photodiode, phototransistor; magnetic eg induction, reluctance, hall-effect; heat eg thermocouple, thermistor, radiation pyrometer; electro-mechanical (limit switches); other eg potentiometers, strain gauges, differential transformers, tacho-generators, pressure sensors, gauges (flow meters), incremental and absolute encoders

Signal conditioning and amplifiers: physical signals; digital and analogue signals; digital to analogue (DAC) and analogue to digital (ADC) converters; signal frequency and amplitude; error signal modification and amplification; open and closed loop control signal paths; introduction to feed-forward signals; mechanical amplifiers and signal conditioners; electrical amplifiers and comparators; active filters

2 **Understand the operation and performance of aircraft power systems**

Power generation: comparison of aircraft pneumatic, hydraulic and electrical power generation eg advantages and disadvantages, circuit operation, power distribution, alternative power supplies

Safety of aircraft power distribution: primary and secondary systems; standby and emergency provision; circuit and system components; duplication and failsafe philosophy

Power actuation systems: principles; constructional detail; control and protection methods; comparison of fluid and electrical power actuation methods and systems eg fluid motors and actuators (single, double acting, rotary, linear, reciprocating piston, spur gear), electric motors and actuators (alternating current (AC) and direct current (DC) motors, induction, synchronous, stepper motor, multi-phase cage motor), linear and rotary actuators

Performance parameters: aircraft applications; high and fractional horsepower; fluid and electrically driven motors and actuators; parameters for DC applications eg speed, torque, on and off load characteristics; parameters for AC applications eg speed of rotation related to applied voltage, power available on constant rated applications

3 **Be able to apply control system fundamentals to the analysis of aircraft control systems**

Remote position control systems: applications eg guide vane control of missile, radar aerial movement, positioning of aircraft control surfaces, autopilot platform displacement, gyro compass platform positioning, inertial navigator platform stabilisation, nose wheel steering system, engine speed control, engine pressure ratio signalling and control, engine speed and temperature control, generator frequency and voltage control, hydraulic servo rate and positioning control, electric motor positioning and control, cabin temperature control, engine fuel control

Response of control systems: step and ramp inputs; transient and steady state response; stability of response; overshoot and hunting

Damping methods: damping terms and definitions; Coulomb and viscous friction damping; electrical damping; velocity feedback damping; damping methods used in aircraft systems

System control methods: proportional and derivative control; proportional and integrative control; analogue/digital hybrid control; system response to control methods

Servomechanism control systems: control system definitions; open and closed loop control systems; servo-mechanism motion control; rate and position sensing and control synchros; remote positioning control (RPC) systems

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	**Assessment criteria for pass** **The learner can:**
LO1 Understand the principles and components used for the control and performance monitoring of aircraft systems	1.1 represent typical aircraft systems in block diagram form 1.2 explain the use of transducers in aircraft systems 1.3 carry out block-diagram reduction exercises and so determine open and closed loop transfer functions, using G and H notation 1.4 explain the operation of signal conditioning and amplifier circuits used in aircraft systems
LO2 Understand the operation and performance of aircraft power systems	2.1 differentiate between mechanical, fluid and electrical methods of power generation for given aircraft usage 2.2 explain the methods used to ensure the continuing integrity and safety of aircraft power distribution 2.3 explain the construction and control and protection methods for aircraft power actuation systems 2.4 evaluate the performance parameters of motors and actuators
LO3 Be able to apply control system fundamentals to the analysis of aircraft control systems	3.1 explain the operation of aircraft remote position control systems 3.2 determine the response of control systems to step, ramp and sinusoidal inputs 3.3 analyse the damping methods used to overcome control system overshoot and hunting 3.4 explain aircraft system control methods and apply them to the response of typical aircraft systems 3.5 select appropriate components and control methods for a given set of typical aircraft control system parameters 3.6 analyse selected aircraft servomechanism control systems.

Guidance

Links

This unit can be linked with *Unit 2: Engineering Science*, *Unit 85: Automatic Flight Control Systems* and *Unit 87: Construction and Operation of Aircraft Fluid Systems*.

Essential resources

Centres need to provide access to a range of electro-mechanical laboratory facilities including equipment needed to analyse servo-systems, transducers, electrical, fluid and mechanical machines/mechanisms and equipment.

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 aerospace companies.

Unit 83: Aerodynamic Principles and Aircraft Design

Unit code: H/601/7189

QCF level: 4

Credit value: 15

Aim

This unit will develop learners' understanding of how aerodynamic principles influence aircraft design.

Unit abstract

This unit will provide learners with an understanding of aircraft flight principles, including the means by which aircraft are controlled, manoeuvred and stabilised. The unit begins by looking at the properties of air and how these relate to the behaviour of aircraft. Learners will then investigate the forces that act on an aircraft in subsonic flight such as lift, drag and thrust. They will also examine the main design features of aircraft that are required to assist aircraft to fly safely. Finally, learners will analyse the factors that influence aircraft stability and control and the systems used to achieve this.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the properties and behaviour of air

2 Understand the forces acting on an aircraft in subsonic flight

3 Understand the design features of high-speed aircraft

4 Understand how stability and control are achieved in conventional aircraft.

Unit content

1 **Understand the properties and behaviour of air**

Properties: International Standard Atmosphere (ISA); properties of air as a static gas only (P, ρ and T variation in atmosphere); further properties eg laminar and turbulent flow, lapse rate, P, ρ and T calculations link to ISA chart

Equations: of state; speed of sound; continuity; Bernoulli for incompressible inviscid flow; shear forces and stresses; laminar flow; flow in boundary layer link to shear forces and viscosity, continuity equation

Applications: altitude and airspeed measurement; equivalent airspeed (EAS); Venturi; wind tunnels; flow in boundary layers; flow meters link to Bernoulli

2 **Understand the forces acting on an aircraft in subsonic flight**

Flight forces: weight; lift; drag; thrust; line of action of forces

Modes of flight: steady level flight; steady balanced turn including bank angle; load factor, flight envelope, structural limits and rate of turn; glide; climb; stall

Lift and drag: aerofoil geometry; flow patterns; pressure distributions; air reaction; centre of pressure; coefficients of lift and drag; stall; pitching moments; aerodynamic centre; wing planform geometry; incidence; twist; stall; induced drag; lift augmentation; boundary layer control; drag of whole aeroplane; lift/drag ratio; adverse pressure gradients; vortex theory; ground effect; formation flying; downwash; camber chord; mean aerodynamic chord; angle of attack; wash in/out; fineness ratio; aspect ratio

3 **Understand the design features of high-speed aircraft**

Airflow: compressibility; velocity; density; temperature; Mach number; Mach angle; shockwave types and development

Effects of compressibility: critical Mach number; transonic, supersonic speeds and effects on flow, pressures, lift drag and pitching moments, coefficients and aerodynamic centre; shock stall

Design features: transonic and supersonic aerofoil sections; wing planforms; area ruling

4 **Understand how stability and control are achieved in conventional aircraft**

Motion: aircraft axes; degrees of freedom; yaw; pitch; roll

Stability: static/dynamic stability; longitudinal, directional and lateral stick fixed stability; weight/cg envelope; static margin; horizontal stabiliser; longitudinal dihedral; vertical stabiliser; fuselage; lateral dihedral; wing sweep; simple stability equations; anhedral; active stability

Control: reversible/irreversible controls; rudder elevator; low-speed and high-speed ailerons; spoilers; speed brakes; variable incidence tail-planes; engine out/system failure design requirements; artificial feel; yaw dampers; Mach trim; gust lock systems; stall protection

Types of aircraft: hi-wing; mid-wing; modern examples of aircraft

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	**Assessment criteria for pass** **The learner can:**
LO1 Understand the properties and behaviour of air	1.1 explain the properties and behaviour of air 1.2 apply equations to solve problems for specified aerodynamic applications
LO2 Understand the forces acting on an aircraft in subsonic flight	2.1 explain the origin of the four main flight forces 2.2 describe basic modes of flight 2.3 use experimental techniques to investigate lift and drag production 2.4 apply equations for lift, drag and pitching movements 2.5 explain the influence of aerofoil and wing geometry on force generation
LO3 Understand the design features of high-speed aircraft	3.1 explain, qualitatively and numerically, the effects of compressibility on airflow 3.2 relate the effects of compressibility to lift, drag and pitching movements 3.3 explain the purpose of the design features of high-speed aircraft
LO4 Understand how stability and control are achieved in conventional aircraft	4.1 analyse the motion of aircraft 4.2 distinguish between stability and control 4.3 describe the factors that influence the static stability of an aircraft and relate them to given types of aircraft 4.4 compare the control systems of given types of aircraft.

Guidance

Links

This unit supports *Unit 85: Automatic Flight Control Systems* and *Unit 89: Aircraft Structural Integrity*.

Essential requirements

Learners will need access to a subsonic wind tunnel with facilities for flow visualisation, lift, drag and pitching moment measurement and pressure distribution measurement.

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Aerospace companies may also be able to provide access to full-size aircraft where centres do not have the resources themselves.

Unit 84: Aerodynamic Principles and Aircraft Stability and Performance

Unit code: Y/601/7190

QCF level: 5

Credit value: 15

Aim

This unit will give learners an understanding of experimental aerodynamics, the analysis of aircraft manoeuvres and aircraft performance.

Unit abstract

This unit will enable learners to carry out practical wind tunnel investigations and will develop their understanding of the use and limitations of experimental aerodynamics. Learners will also examine aircraft instability and the methods used to control it. The forces acting on an aircraft during manoeuvres are explored along with the related potential hazards. Finally, learners will investigate the effects that aerodynamics can have on aircraft performance.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to carry out experimental wind tunnel investigations

2 Understand aircraft stability and control methods

3 Understand the forces acting on aircraft during manoeuvres

4 Understand how aerodynamics affects aircraft performance.

Unit content

1 **Be able to carry out experimental wind tunnel investigations**

Model and tunnel parameters: scale effect; dynamic similarity; Reynolds number; Mach number; wind tunnel types eg sizes, pressures, temperatures

Wind tunnel investigation: flow visualisation; lift, drag and pitching moment measurement

Contribution of wind tunnel tests: limitations eg size, inability to produce extremes of weather; aerodynamic development eg Concorde wing, variable geometry wings, large aircraft configurations; aircraft performance eg wing profiles, external equipment such as aerials and external loads

2 **Understand aircraft stability and control methods**

Instability modes: long- and short-period oscillations; spiral dive; Dutch roll

Common control systems: forces; hinge moments; stick forces; stick gearing; trim; trim curves; non-conventional controls; canard; elevons; tailerons; flaperons; active control; artificial stability; control response speed; control power; manoeuvrability; flight envelope protection; weight and drag savings

Less common control configurations: Vertical Take-Off and Landing (VTOL); Very Short Take-Off and Landing (VSTOL); helicopters; variable geometry winged aircraft

3 **Understand the forces acting on aircraft during manoeuvres**

Forces on aircraft: gravitational forces due to aircraft manoeuvres; weight, thrust, drag and atmospheric conditions

Manoeuvres: instantaneous level co-ordinated turn and symmetrical pull-up/push-over; load factors; power/thrust for sustained turn and pull-up; spin; incipient; developed; recovery

Manoeuvre envelope: buffet limits; lg-stall; cruise; manoeuvre speeds; limit load factors; gust load lines

Aeroelastic effects: aeroelasticity; wing torsional divergence; control reversal; flutter of fixed surfaces and control surfaces; methods of alleviation

4 **Understand how aerodynamics affects aircraft performance**

Aircraft performance: aircraft drag and power required versus airspeed curves; minimum drag and power speeds; unpowered flight; glide angle; rate of descent; speed; range; endurance; stalling speed; powered flight; piston propeller and jet power/thrust available versus airspeed; minimum and maximum level flight speeds; rate of climb; airspeed for maximum rate of climb; absolute and service ceilings; take-off; ground roll; air distance; climb-out; V_1; V_{TD}; factors affecting take-off and landing; temperature; pressure altitude; ground effect; wind; runway surface; brakes; airworthiness performance regulations

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	**Assessment criteria for pass** **The learner can:**
LO1 Be able to carry out experimental wind tunnel investigations	1.1 specify appropriate model and tunnel parameters for a proposed wind tunnel test 1.2 conduct an experimental investigation in a wind tunnel, record and comment on the validity of the results 1.3 give examples of the contribution of wind tunnel tests in the development of aerodynamics and in individual aircraft performance
LO2 Understand aircraft stability and control methods	2.1 describe common instability modes and explain their effects and means of avoidance or mitigation 2.2 analyse the size and balance of forces within a control system 2.3 assess the merits and disadvantages of less common control configurations 2.4 review current application of automatic/active control and discuss the implications of future developments
LO3 Understand the forces acting on aircraft during manoeuvres	3.1 calculate the forces acting on an aircraft during manoeuvres 3.2 identify and describe the potential hazards arising from manoeuvres 3.3 explain and interpret manoeuvre envelopes 3.4 analyse aeroelastic effects and explain methods of alleviation
LO4 Understand how aerodynamics affects aircraft performance	4.1 evaluate aircraft performance in relation to airworthiness regulations and operators' requirements 4.2 use and explain the terminology required to describe aircraft performance 4.3 draw conclusions from equations, graphs and tables of aircraft performance.

Guidance

Links

This unit links with *Unit 83: Aerodynamic Principles and Aircraft Design*, *Unit 85: Automatic Flight Control Systems* and *Unit 89: Aircraft Structural Integrity*.

Essential requirements

Learners will need access to a subsonic wind tunnel with facilities for flow visualisation, lift, drag and pitching moment measurement and pressure distribution measurement.

Employer engagement and vocational contexts

Centres should try to develop links with aerospace companies so that learners can gain access to full-size aircraft.

Unit 85: Automatic Flight Control Systems

Unit code: F/6017216

QCF level: 4

Credit value: 15

Aim

This unit will develop learners' understanding of the function, characteristics and operating parameters of aircraft automatic flight control systems.

Unit abstract

This unit will examine the automatic flight control systems that are key to the safe operation of aircraft. Learners will investigate and carry out a systems analysis on aircraft servo-mechanisms, such as control and indication systems and integrated flight control systems. They will then analyse the function and operation of yaw damper systems and will examine yaw channel instability. The behaviour and parameters of auto pilot and auto throttle systems are also investigated, before learners look at the characteristics of auto land systems.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to carry out systems analysis on aircraft servo-mechanisms

2 Understand the function and operation of yaw damper systems

3 Understand auto pilot and auto throttle systems

4 Understand auto land systems.

Unit content

1 **Be able to carry out systems analysis on aircraft servo-mechanisms**

Aircraft servo-mechanisms: control and indication systems; remote position control (RPC) servomechanisms; digital and analogue control systems; integrated flight control systems; autopilots and autostabilisers

Block diagram analysis: closed and open loop systems; input signals (transient and steady state); position and velocity feedback; integral control; transfer functions

Nyquist diagrams and Bode plots: use of data to determine accuracy, stability and gain in servo-systems

2 **Understand the function and operation of yaw damper systems**

Characteristics and operating parameters: use of system schematics to determine effect of aileron cross-feed, integration of yaw and aileron channels

System functions: band pass filters; rate gyro control

3 **Understand auto pilot and auto throttle systems**

Auto pilot inputs: radio including Instrument Landing System (ILS), Extended Twin-Engine Operations (ETOPS); collision avoidance such as Traffic alert and Collision Avoidance System (TCAS)

Auto pilot parameters: inner loop; series and parallel systems; synchronising; demand limiting evaluation; logic diagrams; detailed operation in various modes; fault diagnosis; built-in test equipment (BITE)

Auto throttle parameters: engine pressure ratio (EPR) control; Mach hold; airspeed control; flap rate; pitch rate; long-term errors; auto land

4 **Understand auto land systems**

Characteristics: categories of landing; reliability requirements; auto land profile

Parameters: terrain clearance; landing profile; captive and track; attitude hold; exponential flare; kick-off drift; instinctive cut-off

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	**Assessment criteria for pass** **The learner can:**
LO1 Be able to carry out systems analysis on aircraft servo-mechanisms	1.1 carry out a system analysis on an aircraft servo-mechanism 1.2 prepare a block diagram for a servo-mechanism and reduce to a transfer function 1.3 produce Nyquist diagrams and Bode plots from data obtained practically and theoretically
LO2 Understand the function and operation of yaw damper systems	2.1 determine the function, operation and characteristics of a yaw damper system 2.2 examine yaw channel instability
LO3 Understand auto pilot and auto throttle systems	3.1 describe the inputs to an auto pilot system 3.2 determine and explain the behaviour and parameters of an auto pilot system 3.3 determine and explain the behaviour and parameters of an auto throttle system 3.4 interpret typical auto pilot and auto throttle schematics
LO4 Understand auto land systems	4.1 explain the characteristics and operating parameters of an auto land system 4.2 evaluate safety margins in multiplex systems 4.3 interpret auto land system schematics.

Guidance

Links

This unit can be linked with *Unit 91: Integrated Flight Instrument Systems*.

Essential requirements

Learners will need access to basic avionic training rigs. Visits to modern aircraft operating facilities are considered to be an essential part of unit delivery.

Employer engagement and vocational contexts

Centres will need to create links with aircraft maintenance companies or airlines so that learners can view flight control systems on full-size aircraft.

Unit 86: Aircraft Communication and Navigation Systems

Unit code: J/601/7217

QCF level: 4

Credit value: 15

Aim

The aim of this unit is to develop learners' understanding of the principles of operating aircraft communication and navigation systems.

Unit abstract

In this unit learners will investigate the operation of radio transmitters, receivers and aircraft radio navigation systems. They will examine aircraft inertial navigation systems and their operation and will carry out calculations to solve navigation problems. The unit also provides an opportunity for learners to investigate the types, operation and operating parameters of continuous wave aircraft radar systems.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the operation of a radio transmitter and receiver

2 Understand the operation of aircraft radio navigation systems

3 Understand aircraft inertial navigation systems

4 Understand pulsed and continuous wave aircraft radar systems.

Unit content

1 **Understand the operation of a radio transmitter and receiver**

Legal requirements: licensing; regulatory authorities; frequency of operation; spurious emissions

Amplitude modulation (AM) transmitters: principles of transmission eg electromagnetic radiation, electromagnetic spectrum and propagation of radio waves; types and principles of modulation; use of block/flow diagrams to aid explanation of the operation and stages within a transmitter system

Receivers: principles of radio reception eg demodulation, Automatic Gain Control (AGC), Automatic Frequency Control (AFC); types of receivers; use of block/flow diagrams of radio receiver systems; operation of stages within receivers; effects of noise and interfering signals on radio reception; signal to noise

Receiver performance: use of measurement and test equipment eg signal generator, power meter, oscilloscope, noise test set, spectrum analyser; performance characteristic eg sensitivity, signal to noise, adjacent channel, image channel rejection ratios

2 **Understand the operation of aircraft radio navigation systems**

Type of radio navigation systems: instrument landing system (ILS); very high frequency (VHF) omni-directional radio range (VOR); automatic direction finding (ADF); distance measuring equipment (DME); logan and omegal; global positioning systems (GPS)

Principles of operation: frequency bands; aerial pattern; system block diagrams; hyperbolic patterns; signal formats; GPS position determination

Aircraft systems: use of block diagrams to identify and explain a typical integrated aircraft radio navigation system; operation of the complete system

3 **Understand aircraft inertial navigation systems**

Principle and operations: basic principles relating to inertial navigation; Schuler tuning; block diagram of Schuler tuned Inertial Navigation System (INS); accelerometers; gyros; alignment and gyro compassing; errors; choice of platform axes; strap-down INSs; aided INSs; Kalman filters

Aircraft INS: use of block diagram of complete INS; applications of a typical align sequence; IN augmentation eg using Doppler, GPS, Kalman filter; operating principles of analogue computing systems as used in navigation systems

IN problems: calculation on acceleration, velocity, distance; errors encountered in INSs and how corrections are applied

4 **Understand pulsed and continuous wave aircraft radar systems**

Radar systems: pulsed; carrier wave (CW); primary; secondary; Doppler; applications of each system; use of block diagrams of typical radar systems

Parameters measured: range/bearing/height; radar equation; solve problems related to range/bearing/height

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	**Assessment criteria for pass** **The learner can:**
LO1 Understand the operation of a radio transmitter and receiver	1.1 explain the legal requirements for transmitter operation 1.2 explain the principles of operation of an AM radio transmitter 1.3 explain the principles of operation of a radio receiver 1.4 evaluate the performance of a radio receiver
LO2 Understand the operation of aircraft radio navigation systems	2.1 compare the different types of radio navigation systems and justify the best fit for a particular aircraft 2.2 explain the principles of operation of a complete aircraft radio navigation system
LO3 Understand aircraft inertial navigation systems	3.1 explain the principles and operation of aircraft inertial navigation systems 3.2 analyse the effects on aircraft performance of inertial navigation problems 3.3 select and use equations of motion to solve inertial navigation problems
LO4 Understand pulsed and continuous wave aircraft radar systems	4.1 explain the principles of operation of aircraft radar systems 4.2 analyse the factors affecting aircraft radar performance 4.3 solve problems relating to range, bearing and height of aircraft radar returns.

Guidance

Links

This unit can be linked with Unit 91: Integrated Flight Instrument Systems.

Essential requirements

There are no essential resources for this unit.

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 87: Construction and Operation of Aircraft Fluid Systems

Unit code: L/6017218

QCF level: 4

Credit value: 15

Aim

This unit will develop learners' understanding of the construction and operation of aircraft hydraulic and pneumatic systems. Learners will interpret fluid circuit diagrams and inspect and test aircraft fluid systems.

Unit abstract

This unit will invest igate the constructional detail, operating principles and system function of a variety of aircraft hydraulic and pneumatic system components. Learners will interpret and analyse hydraulic and pneumatic circuit drawings and use a variety of illustrative methods and conventions so that fluid system operational status may be determined. The unit will also enable learners to inspect a range of aircraft hydraulic and pneumatic systems.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the construction, operation and control of aircraft hydraulic systems and components

2 Understand the construction, operation and control of aircraft pneumatic systems and components

3 Be able to read and interpret fluid circuit diagrams to determine the operational status of fluid circuits

4 Be able to inspect and carry out functional tests on aircraft hydraulic and pneumatic systems.

Unit content

1 **Understand the construction, operation and control of aircraft hydraulic systems and components**

Hydraulic power: use; advantages/disadvantages of hydraulic actuation on aircraft; hydraulic system fluid principles

Aircraft hydraulic systems: power supplies; powered flying controls; landing gear; nose wheel steering; flaps; airbrakes; arrestor gear; braking and anti-skid; thrust reversers; emergency systems

Hydraulic system components: function and operation; oil types and properties; seals; pumps; linear actuators; rotary actuators (motors); pressure control valves; flow control valves; powered flying control units; accumulators; reservoirs; fluid conductors and plumbing; filters; pressure switches and gauges; fluid conditioning equipment; interface with other systems

2 **Understand the construction, operation and control of aircraft pneumatic systems and components**

Air as a fluid power medium: use; advantages/disadvantages of pneumatic power on aircraft; pneumatic fluid power principles; properties of air including the special characteristics needed by a fluid when subject to extremes of environmental change; related safety precautions for air and oxygen

Aircraft pneumatic systems: pneumatic sources eg engine bled, ram air, blowers, compressors, Auxiliary Power Unit (APU), bottles, oxygen generators, ground cart; air conditioning and pressurisation; wing and nacelle anti-icing; rain protection; reservoir/tank pressurisation; gyro instrument supply; engine starting; pneumatic landing gear/flaps/brakes; cabin/cargo heating and smoke detection; anti-g systems; oxygen systems; equipment cooling

Pneumatic system component: bottle; compressor; fan; turbine; blower; receiver; filter; dryer; humidifier; lubricator; pressure regulator; drainage points; oil separator; water separator; heat exchanger; cold air unit; cooling/refrigeration pack; duct; louvre; pipe; gauge; plenum chamber; check valve; mixing valve; sensor; switch, pressure controller; discharge valve; temperature controller; pneumatic actuator; air motor; relief valve; pressure control valve; directional control valve; non-return valve; flow control valve; solenoid valve; in/out flow valve; interface with other systems

3 **Be able to read and interpret fluid circuit diagrams to determine the operational status of fluid circuits**

Literature illustrating fluid power circuits: circuit diagrams and graphical representations eg pictorial, schematic, diagrammatic, block diagram; standard symbols; fluid system publications eg Air Transport Association (ATA) 100 system, air publications (APs), books, periodicals, manufacturers' literature, maintenance manuals, operational manuals, wall charts and diagrams

ISO and BS circuit system diagrams: ISO 1219/BS 2917 fluid power symbols; use of symbols for fluid storage; power sources and other components eg blowers, compressors, turbines, pumps and motors, drives, linear actuators, valve control mechanisms, directional control, servo and proportional control, pressure control, flow control, fluid plumbing and storage, fluid conditioning, fluid heating and cooling, refrigeration; associated electrical components

Interpret aircraft system diagrams: use of fluid power circuit diagrams eg ATA 100, ISO 1219, BS 2917; translation of ISO 1219/BS 2917 into other conventions and vice-versa; use of aircraft fluid power circuit diagrams eg determining system operation, identifying possible causes of system failure, suggestions for remedial action

4 **Be able to inspect and carry out functional tests on aircraft hydraulic and pneumatic systems**

Hydraulic systems: use of appropriate techniques to assemble, prime, bleed and analyse aircraft hydraulic systems

Pneumatic systems: use of appropriate techniques to dismantle, inspect and assemble aircraft pneumatic, pressurisation and conditioning systems

Fluid system functional tests: identification of required system functional tests and checks; proving integrity of fault diagnosis in practice and return system(s) to serviceable status

Learning outcomes and assessment criteria

Learning outcomes On successful completion of this unit a learner will:	Assessment criteria for pass The learner can:
LO1 Understand the construction, operation and control of aircraft hydraulic systems and components	1.1 explain the reasons for using hydraulic power as a major source of energy for aircraft systems operation 1.2 determine the properties of aircraft hydraulic fluids and their behaviour when subject to pressure and to extreme operating environments 1.3 explain the function, operation and control of aircraft hydraulic systems and their associated status indicators 1.4 explain the operation and constructional features of hydraulic system components
LO2 Understand the construction, operation and control of aircraft pneumatic systems and components	2.1 determine the properties of air as a fluid power medium for aircraft systems 2.2 explain the function and operation of aircraft pneumatic systems and their associated status indicators 2.3 investigate the function, nature and operation of selected aircraft pressurisation, air conditioning and refrigeration systems and their associated status indication systems 2.4 explain the operation and constructional features of pneumatic system components 2.5 explain the operation and constructional features of components used in aircraft pressurisation, cabin conditioning and refrigeration systems

Learning outcomes **On successful completion of this unit a learner will:**	**Assessment criteria for pass** **The learner can:**
LO3 Be able to read and interpret fluid circuit diagrams to determine the operational status of fluid circuits	3.1 identify and use appropriate sources of literature illustrating aircraft fluid power circuits 3.2 interpret ISO and BS circuit/system diagrams and translate these conventions into standard aircraft system schematic diagrams and vice-versa 3.3 produce circuit diagrams in standard and other conventions for given aircraft fluid system services 3.4 read and interpret aircraft system diagrams for selected hydraulic, pneumatic and environmental control systems 3.5 identify possible aircraft fluid system and component defects by interpreting circuit diagrams for given situations
LO4 Be able to inspect and carry out functional tests on aircraft hydraulic and pneumatic systems	4.1 assemble, prime and bleed hydraulic systems and analyse system performance, using appropriate training rigs or aircraft systems 4.2 dismantle, inspect and assemble selected aircraft pneumatic, pressurisation and conditioning systems/ components, using system mock-ups and/or aircraft 4.3 carry out aircraft fluid system functional tests, determine and prove defects and return system(s) to an airworthy condition.

Guidance

Links

This unit may be linked with *Unit 82: Aircraft Systems Principles and Applications*.

Essential requirements

The unit requires access to aircraft hydraulic, pneumatic and environmental control systems and components (these may be in the form of system mock-ups). Appropriate sources of literature in the form of aircraft manuals, diagrams and charts will also be required.

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 88: Principles and Applications of Aircraft Fluid Systems

Unit code: D/601/7241

QCF level: 5

Credit value: 15

Aim

This unit will develop learners' understanding of the application of fluid mechanics, thermodynamics and heat transfer to the analysis of aircraft fluid systems and system components.

Unit abstract

In this unit learners will build on their understanding of aircraft fluid systems to analyse the performance of pneumatic and hydraulic system components. Learners will use mathematical, graphical and analytical methods to determine the parameters of fluid systems. They will apply the principles of fluid mechanics, thermodynamics and heat transfer to analyse the performance of hydraulic and pneumatic system components. Learners will then select components for a required system based on component performance characteristics.

Learning outcomes

On successful completion of this unit a learner will:

1 Be able to determine aircraft fluid system performance characteristics

2 Be able to apply the principles of fluid mechanics to analyse the performance of aircraft hydraulic system components

3 Be able to apply the principles of fluid mechanics, thermodynamics and heat transfer to analyse the performance of aircraft pneumatic system components.

Unit content

1 **Be able to determine aircraft fluid system performance characteristics**

Fluid power systems: fluid properties; fluid work and power; continuity and energy equations; viscous force and flow; system loads and service requirements

Linear actuator circuits: sizing; Euler's equation and piston buckling; flow control; velocity control; pressure control; dynamic braking; effects of load change; cavitation avoidance during overrun; emergency provision and accumulator sizing

Pump circuits and power packs: pump capacities; volumetric and mechanical efficiency; flow control; pressure control; flow; pressure and power matching

Fluid motor circuits: motor design; power requirements; motor system performance; pumps as motors; reversal control; speed control; torque control; motor sizing

Fluid conductors and fittings: laminar and turbulent flow; Reynolds number; pressure losses in straight pipes; estimate of losses in fittings; Darcy formula; friction factor; Moody diagram

2 **Be able to apply the principles of fluid mechanics to analyse the performance of aircraft hydraulic system components**

Pressure control components: general theory and the orifice equation; flow and force considerations for pressure control; relief valve orifice characteristics; restrictor valve equation

Flow and velocity control: components; pressure compensated flow control; modulating and electro-hydraulic flow control valves; directional control valves; speed control for fixed displacement pumps using metering systems

Aircraft system servo-valves: modulating and electro-hydraulic flow control; servo-valve characteristics; land/port overlap characteristics; servo-flying control units (valve pressure drop and displacement characteristics); general servo valve equation

Component selection: aircraft hydraulic system service requirements; aircraft hydraulic component characteristics; selection of linear actuators; pressure; flow and directional control valves; pumps and motors

3 **Be able to apply the principles of fluid mechanics, thermodynamics and heat transfer to analyse the performance of aircraft pneumatic system components**

Fans, blowers, compressors and turbines: classification and types (propeller fans, duct fans, centrifugal fan and compressors, axial compressors, screw compressors, fluid flow through pneumatic components, compressed air flow and specific weight)

Nozzles and flow measurement: nozzle (shape, critical pressure ratio, maximum mass flow, sonic velocity and adiabatic flow); variable head meters, turbine flow meter; mass flow measurement; pitot static head

Reciprocating machines: isothermal efficiency; volumetric efficiency; multi-stage compression

Air-conditioning heat exchangers: types of heat exchanger; constructional details; general equation for heat transfer across a surface; overall heat transfer coefficient; fouling factors; mean temperature difference; fluid properties through heat exchanger; boot strap systems

Refrigeration cycles: the reverse heat engine; properties of refrigerants; vapour-compression cycles; coefficient of performance; refrigerating load; pressure-enthalpy diagram; compressor displacement

Component selection: aircraft pneumatic system service requirements; aircraft pneumatic component characteristics; selection of nozzle valves, blowers, compressors, turbines, heat exchangers, evaporators and condensers

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	**Assessment criteria for pass** **The learner can:**
LO1 Be able to determine aircraft fluid system performance characteristics	1.1 mathematically determine work and power parameters, flow rates and velocities for system linear actuators and their associated circuits 1.2 determine fluid system accumulator size/capacity parameters, using graphical and analytical methods
LO2 Be able to apply the principles of fluid mechanics to analyse the performance of aircraft hydraulic system components	2.1 explain the effects on valve performance when different valve elements are used 2.2 determine flow and pressure values through the orifice of relief valves and restrictor valves, using the orifice equation and its variants 2.3 calculate flow and force parameters, through typical single stage valves 2.4 mathematically model mechanical lever and electro-mechanical servo-flying control units 2.5 investigate the service parameters needed for a variety of aircraft hydraulic system tasks, and use these parameters to select system components with appropriate performance characteristics
LO3 Be able to apply the principles of fluid mechanics, thermodynamics and heat transfer to analyse the performance of aircraft pneumatic system components	3.1 calculate pneumatic system nozzle discharge rates for sub-sonic and sonic flow through a nozzle discharging to atmosphere 3.2 determine the volumetric, compressor and overall efficiencies for an aircraft pneumatic system reciprocating compressor functioning under known conditions 3.3 estimate the shell and tube dimensions for a heat exchanger required for a typical aircraft cabin-conditioning pack, given the heat exchanger operating parameters 3.4 calculate the power output from a typical aircraft turbo-compressor cold air unit, for assumed system conditions 3.5 investigate vapour-compression refrigeration cycles and determine the operating parameters of the refrigeration system components to meet a given refrigerating load 3.6 determine the service parameters needed for a variety of aircraft pneumatic system tasks, and use these parameters to select components which meet these system requirements.

Guidance

Links

This unit may be linked with *Unit 92: Aircraft Gas Turbine Science*, since both units apply similar scientific principles.

Essential requirements

Learner access to aircraft hydraulic, pneumatic and environmental control components is essential, as is access to laboratory equipment for the study of thermofluids mechanics and heat transfer.

Employer engagement and vocational contexts

Centres should liaise with local employers in order to gain access to full-size aircraft enabling learners to view relevant modern aircraft systems.

Unit 89: Aircraft Structural Integrity

Unit code: J/6017248

QCF level: 5

Credit value: 15

Aim

This unit aims to develop the understanding and techniques necessary to ensure that aircraft are manufactured and maintained in such a manner that the integrity of their structure is assured.

Unit abstract

In this unit learners will analyse possible causes of aircraft structural failure, including fracture, fatigue and creep. The unit will develop learners' understanding of bonded repair concepts, enabling them to design and analyse bonded repairs for metal and composite aircraft structures. Finally learners will gain the skills needed to assess damage to structural components and produce procedures for the inspection of aircraft structures. This will enable them to devise and produce manufacturing schedules and manage preventative maintenance programmes.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand failure mechanisms in aircraft structures

2 Be able to design and analyse bonded repairs for both metal and composite structures

3 Be able to devise and manage production schedules or preventative maintenance programmes.

Unit content

1 **Understand failure mechanisms in aircraft structures**

Fracture strength: significance of fracture mechanics; strength; toughness; critical crack length; Griffith energy balance approach; Irwin's theory; stress intensity approach; crack tip plasticity; fracture toughness; critical crack growth

Fatigue and creep: the nature of fatigue; fatigue effects; sources of fatigue eg cyclic, thermal, acoustic, sonic, fretting and corrosion fatigue; fatigue strength; S-N curves; endurance limit; determination of fatigue life; fatigue testing; creep eg characteristics, stages, creep rate and rupture times, kinetic heating and creep

Design methods: design philosophy; safe-life and fail-safe structures

Crack growth: nature of fatigue crack growth and stress intensity factors; prediction of fatigue crack growth under constant amplitude loading; environmental effects

Fracture mechanisms: study of fracture surfaces; slip; plastic deformation and dislocations; ductile transgranular fracture by microvoid coalescence; brittle transgranular fracture (cleavage); transgranular and intergranular fracture by fatigue; the effects of fracture path and microstructure; material behaviour and mechanisms of fracture

2 **Be able to design and analyse bonded repairs for both metal and composite structures**

Micromechanics and properties: mechanical properties of unidirectional composites eg longitudinal stiffness and tensile strength, transverse stiffness and strength; fibre volume fraction and the equation of mixtures; off-axis stiffness and strength; properties of cross-ply and angle-ply laminates; discontinuous fibre laminates; the use of fibre composite materials in aircraft structures

Adhesion and surface treatments: analysis of bonded v rivet repairs; adhesives; adhesion and adhesive testing; surface preparation; surface treatments eg structural aluminium alloys, titanium alloys, phosphoric acid anodising, chromic acid anodising

Metal bonded repairs: thin sheet metal construction eg sheet thickness criteria, overlap lengths, material specification, strength considerations; residual strength of flawed or damaged adhesive bonded joints; acceptable criteria for bond flaws and damage; life prediction for adhesively bonded joints

Composite bonded repairs: repair materials; composite repair concepts and methods eg bolted repairs, bonded repair categorisation (non-structural, secondary structural and primary structural), non-patch repairs, bonded external patch, scarft and flush repairs; effects of moisture on bonded repair of composites; design of bonded repairs eg general considerations, external patch design, laminate design

3 **Be able to devise and manage production schedules or preventative maintenance programmes**

Damage assessment: structures and structural components eg use of equipment to assess general damage, nature and identification of types of corrosion; non-destructive evaluation (NDE) of structures eg using optical, penetrate dye, ultrasonic, radiographic, eddy current, acoustic emission and thermography techniques

Policy and procedures: corrosion damage prevention methods eg detail design, protective coatings, inhibitors, anodic protection, materials selection and treatment; repair policy eg downtime considerations, costs, repair by replacement, repair and rectification organisation; quality assurance procedures; out sourcing; repair procedures for metal and polymer matrix composites (PMC) structures and components; repair materials handling, storage and procurement; field repair considerations eg simple techniques, limited use of repair equipment, first-aid repair techniques, availability of cure facilities

Integrity of aircraft structures: inspection procedures eg nature and frequency of inspection, structural component access and component life considerations; condition monitored maintenance eg hard-time, on-condition and condition monitoring and their relationship to aircraft structure; statistical information sources and corresponding reliability techniques; data collection and structural component history; maintenance reporting procedures; corrective action methodology and quality assurance procedures; Civil Aviation Authority (CAA) and Military regulations for the manufacture and maintenance of aircraft structures and structural components; temporary repairs

Learning outcomes and assessment criteria

Learning outcomes On successful completion of this unit a learner will:	Assessment criteria for pass The learner can:
LO1 Understand failure mechanisms in aircraft structures	1.1 explain the significance and determine mathematically the fracture strength of aircraft structural materials 1.2 determine the nature and likely sources of fatigue and creep on aircraft 1.3 explain the significance of the operating environment on aircraft fatigue and the nature of the design methods used to minimise fatigue effects 1.4 determine the (CAA, FAA) structural damage tolerance requirements for aircraft 1.5 analyse the methods used to estimate fatigue crack growth and aircraft fatigue life 1.6 investigate the nature of fracture mechanisms for aircraft light alloys, subject to static and fatigue loading
LO2 Be able to design and analyse bonded repairs for both metal and composite structures	2.1 analyse the nature and mathematically determine the micromechanical properties of aircraft carbon matrix composite (CMC) materials 2.2 describe the adhesion and surface treatments used for bonded metal structure repairs 2.3 mathematically determine the strength limits, dimensional requirements and curing times for metal and composite bonded repairs 2.4 design and prepare an adhesive joint using composite or light alloy adherends and analyse the results when the joint is subject to a non-destructive or destructive test

Learning outcomes **On successful completion of this unit a learner will:**	**Assessment criteria for pass** **The learner can:**
LO3 Be able to devise and manage production schedules or preventative maintenance programmes	3.1 carry out damage assessment and devise procedures to repair damage on aircraft structure or structural components 3.2 evaluate the integrity of aircraft structures and/or structural components, subject to manufacture or repair using appropriate NDE techniques 3.3 formulate organisational policy for base maintenance structural repairs or field repairs 3.4 devise and produce simple manufacturing or maintenance inspection procedures for aircraft structures or structural components that comply with regulatory body legislation 3.5 produce policy documents and associated procedural networks, for a quality system that ensures the integrity and safety of an aircraft structural component during manufacture or during its operational life.

Guidance

Links

This unit can be linked with *Unit 4: Mechanical Principles* and *Unit 21: Materials Engineering*.

Essential requirements

Aircraft-related structures/structural components and tools suitable for aircraft structural repairs need to be available for the delivery of this unit. Materials testing (eg destructive/non-destructive) facilities for metals and/or polymer matrix composites are also required.

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

Unit 90: Aircraft Propulsion Technology

Unit code: L/601/7249

QCF level: 4

Credit value: 15

Aim

This unit aims to develop learners' understanding of the principles and laws of aircraft propulsion and their application to gas turbine systems and design.

Unit abstract

In this unit learners will examine the scientific principles that relate to aircraft gas turbines and how they affect the performance of aircraft propulsion engines. Learners will also consider the aerodynamic and mechanical design of gas turbine engine modules and propellers. The unit will develop learners' understanding of the performance parameters of gas turbine engines, the material limitations of engine modules and the information used to monitor engine performance. Finally learners will investigate the construction, operation and layout of aircraft engines and engine components.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand propulsion engine performance

2 Understand the design of gas turbine engine modules and propellers

3 Understand engine performance characteristics

4 Understand the construction and operation of aircraft piston engines.

Unit content

1 **Understand propulsion engine performance**

Gas turbine science: Newton's laws; momentum; inertia; thrust; mechanics of reaction propulsion; nozzles and ducts; gas laws eg Boyle's Law

Working cycles of gas turbine and piston engines: Brayton cycle; velocity; temperature; pressure; propulsive efficiency; piston engine fundamentals and indication systems

Gas turbine and piston engine systems: turbo-prop; turbo-jet; high and low by-pass; 2- and 4-stroke engines

Performance data: power and thrust to weight ratio; engine dimensions; specific fuel consumption; engine rpm; effects of compressor bleed; nozzle areas; inlet temperatures; drag and ram pressure rise

Graphical methods: performance graphs and charts

2 **Understand the design of gas turbine engine modules and propellers**

Modules of a gas turbine engine: intakes eg requirements for subsonic and supersonic intakes and intake design, effect of internal and external geometry on boundary layer and ram recovery, variable flight conditions, engine failure protection, high bypass engines, ice protection; compressors eg centrifugal, axial, multi-spool, transonic, performance, stalling, surging, interaction between mechanical and aerodynamic design, in-service problems; combustion chambers eg design criteria, typical combustion and ignition systems, types of burners; turbines eg turbine geometry, blade cooling, design and aerodynamic performance of blades, nozzle guide vanes, related calculations, mechanical design of discs, blade attachment in relation to aerodynamic requirements, blade materials, vibration, root stresses, fatigue, creep; exhaust eg function and design of jet pipe nozzle, control and direction, gas flow velocity, construction and operation of reverse thrust, after burners, noise reduction

Maintenance activities: engine condition inspections; blade clearance checks; assessment of internal damage; fuel, lubricant and fluid system checks; pre-flight checks; controls inspections; ground running

Propeller aerodynamics: thrust; torque; lift and drag; blade angle; angle of attack; blade twisting; forces along blade; propeller efficiency; type eg fixed, two pitch, constant speed and variable pitch propellers; windmilling; reverse pitch; aerodynamic and centrifugal turning moments

Propeller control: pitch change mechanism; control units eg propeller governor, unfeathering accumulators, pitch control mechanism; operation; feathering system; pitch locks and beta control; synchronising

3 Understand engine performance characteristics

Performance parameters: design applications and performance parameters for turbo-prop, turbo-jet and turbo-fan; engine airflow graphs; choked nozzles; mechanical forces; thrust calculations and thrust load paths; dependent and independent accessories (gross, net, choked nozzle, thrust); thrust HP, ESHP

Material limitations: power rating; centripetal forces; temperatures

Engine performance monitoring: instrumentation eg temperature and power output; thermocouple position; exhaust gas temperature (EGT) and jet pipe temperatures (JPT); thrust and rotational speed; engine pressure ratio and integrated engine pressure ratio; data analysis and performance trend monitoring

Engine condition monitoring: vibration; lubrication systems; FADEC systems

4 Understand the construction and operation of aircraft piston engines

Engine construction: crankcase; crankshaft; sumps; accessory gearbox; cylinder and piston assemblies; valve mechanism and timing; propeller reduction gearboxes

Fuel, lubrication and ignition systems: carburettors; fuel injection; starting and ignition; exhaust and cooling; supercharging/turbo-charging; lubrication; operation; layout and components; FADEC

Power plant installation: configuration of firewalls; cowlings; acoustic panels; engine mounts; anti-vibration mounts; control systems

Engine monitoring and ground operation: starting and ground run-up; engine power output and parameters; engine inspection and maintenance

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	**Assessment criteria for pass** **The learner can:**
LO1 Understand propulsion engine performance	1.1 apply Newton's law and gas laws to gas turbine and piston engine cycles 1.2 explain the working cycles of gas turbine and piston engine systems 1.3 calculate performance data for gas turbine and piston engines 1.4 use graphical methods to present and evaluate engine performance data
LO2 Understand the design of gas turbine engine modules and propellers	2.1 explain the maintenance activities associated with each of the modules of a gas turbine engine 2.2 explain the aerodynamic and mechanical requirements of each module 2.3 analyse propeller aerodynamics and control
LO3 Understand engine performance characteristics	3.1 determine performance parameters of gas turbine engines 3.2 explain the material limitations for each of the modules of a gas turbine engine 3.3 investigate the information used to monitor engine performance and engine condition
LO4 Understand the construction and operation of aircraft piston engines	4.1 explain engine construction 4.2 explain the operation, layout and components of fuel, lubrication and ignition systems 4.3 evaluate a power plant installation 4.4 describe engine monitoring and ground operation procedures.

Guidance

Links

This unit may be linked with *Unit 1: Analytical Methods for Engineers* and *Unit 2: Engineering Science*.

Essential requirements

Centres will need to provide access to appropriate laboratory equipment for the demonstration and determination of Boyle's Law, Charles' Law and Adiabatic index. Simple gas turbine tests will also need to be available.

Employer engagement and vocational contexts

Liaison with employers would prove of benefit to centres, especially if they are able to offer help with the provision of suitable laboratory equipment or access to engine modules and propellers.

Unit 91: Integrated Flight Instrument Systems

Unit code: F/601/7250

QCF level: 5

Credit value: 15

Aim

This unit aims to develop learners' understanding of the principles and applications of aircraft flight instrument systems such as aircraft attitude indicators, air data systems and flight deck instruments.

Unit abstract

This unit is concerned with aircraft flight instruments and their integration into aircraft flight deck systems. It aims to develop learners' understanding of the scientific principles that underpin the design and construction of aircraft flight instruments. It also considers the purpose and application of the main traditional groupings of flight data instruments and the ways in which traditional and newer forms of flight information are being integrated into current flight deck systems.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the properties and applications of gyroscopes in aircraft attitude indicators

2 Understand the application of directional references to aircraft systems

3 Understand the principles of operation and applications of air data systems

4 Understand the construction and operation of integrated flight deck instrument systems.

Unit content

1 **Understand the properties and applications of gyroscopes in aircraft attitude indicators**

Gyroscopes: development of the gyroscope and its properties; drift and transport wander; practical gyroscopes; pneumatic, vacuum and electrically driven gyros; errors and limitations

Flight instrument applications: direction indication eg the horizontal axis gyroscope; artificial horizons eg principle of the gyro horizon, use as standby attitude indicators; turn and bank indication eg for turn rate detection and bank and slip indication; erection and levelling methods; error sources and control

2 **Understand the application of directional references to aircraft systems**

Terrestrial magnetism: nature of magnetism; variation; dip; direct reading compasses; compass construction; location considerations; errors and dynamic behaviour; analysis of deviation and compensation

Remote indicating compass/magnetic heading reference system (MHRS): principles of synchronous data transmission and synchro types; flux valves; the directional gyro unit and its application as a directional reference; system operating modes; deviation compensation; integration with radio and inertial systems

3 **Understand the principles of operation and applications of air data systems**

Features of the atmosphere: layers of the atmosphere eg ionosphere, troposphere; effects on pressure and temperature

Air data measurement: horizontal speed measurement eg pitot systems and engineering considerations, direct and indirect systems, airspeed indication and terms, mach meters; altitude measurement eg principle of the barometric altimeter, pressure settings; vertical speed measurement eg principle of differential pressure measurement; air temperature measurement eg total air temperature, static air temperature; construction; types of sensor; indicators; integration into other systems; error sources

Air data computers: advantages of integrating air data; analogue and digital methods of air data computation; utilisation of computed data; alerting and warning requirements; applications

4 **Understand the construction and operation of integrated flight deck instrument systems**

Flight director systems: use of the vertical gyro; systems inputs; computation; Attitude Director Indicators (ADI); Horizontal Situation Indicator (HSI); interface to other aircraft systems; typical aircraft control panels and mode selectors

Electronic displays: cathode ray tube displays; alphanumeric displays; Liquid Crystal Displays (LCDs); symbol generation; ambient light sensors

Electronic flight instrument systems: Electronic Attitude Director Indicator (EADI); Electronic Horizontal Situational Indicator (EHSI); system inputs; typical displays; failure and reliability considerations; aircraft case study

Learning outcomes and assessment criteria

Learning outcomes **On successful completion of this unit a learner will:**	**Assessment criteria for pass** **The learner can:**
LO1 Understand the properties and applications of gyroscopes in aircraft attitude indicators	1.1 explain the properties and limitations of a gyroscope 1.2 explain how gyroscopes are adapted for use in various flight instrument applications
LO2 Understand the application of directional references to aircraft systems	2.1 explain terrestrial magnetism and the dependant effects 2.2 explain the principles and applications of the remote indicating compass/MHRS 2.3 explain how MHRS are integrated into modern aircraft types
LO3 Understand the principles of operation and applications of air data systems	3.1 explain the principal features of the atmosphere that are relevant to air data systems 3.2 explain the construction and applications of air data measurement devices 3.3 explain the applications of analogue and digital air data computers
LO4 Understand the construction and operation of integrated flight deck instrument systems	4.1 explain the construction and operation of flight director systems 4.3 explain the construction and operation of electronic displays 4.4 explain the construction and operation of typical electronic flight instrument systems.

Guidance

Links

This unit can be linked with *Unit 85: Automatic Flight Control Systems* and *Unit 86: Aircraft Communication and Navigation Systems*.

Essential requirements

Learners will need access to an aircraft flight instrument panel, preferably on the flight deck of a contemporary aircraft, although the use of a detached unit would be acceptable.

Employer engagement and vocational contexts

Centres are encouraged to create links with aircraft maintenance companies and airlines so that learners can view integrated flight systems on full-size aircraft.

Unit 92: Aircraft Gas Turbine Science

Unit code: J/601/7251

QCF level: 5

Credit value: 15

Aim

This unit will develop learners' understanding of the principles of aircraft gas turbine technology and their application in gas turbine engine modules and systems.

Unit abstract

In this unit learners will investigate aircraft gas turbine fluids, including the measurement of fluid flow and aerodynamic losses in gas turbine modules. Learners will apply the thermodynamic principles that relate to aircraft gas turbine engines and investigate the importance of thermodynamics in the design of aircraft engines and control systems. The unit will also provide a basis for further study in aircraft thermofluids.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the properties of aircraft gas turbine fluids and energy losses

2 Be able to apply thermodynamic laws and principles

3 Understand the application of thermodynamic principles in the design of gas turbine modules and control systems.

Unit content

1 **Understand the properties of aircraft gas turbine fluids and energy losses**

Measurement of fluid flow: instrumentation eg manometers, bourdon gauge, pressure transducers, micro-manometers; forces on curved surfaces; continuity equation; energy of a moving fluid; venturi meter; pitot tube

Velocity diagrams and power: velocity and pressure distribution in nozzles; air velocity change through blade rows; forces acting on blades; power requirements for compressor and turbine stages

Aerodynamic losses: losses in axial compressors and turbines; jet and propeller propulsion; flow-through turbines; fans; compressors; primary and secondary losses; operating characteristics and surge; losses due to sudden enlargement and contraction in turbulent flow

2 **Be able to apply thermodynamic laws and principles**

First law of thermodynamics: non-flow energy equation; reversibility; displacement work transfer; reversible non-flow processes; relationship of perfect gases; application of non-flow energy equation; steady-flow energy equation; continuity equation; application of steady-flow energy equation

Second law of thermodynamics: ideal heat engine and reversed heat engine; ideal heat engine cycle; entropy changes in adiabatic processes; isentropic efficiency; processes on T-S diagram; entropy changes for perfect gases

Gas turbine cycle: gas turbine cycle with isentropic efficiency; velocity diagrams and power calculations

3 **Understand the application of thermodynamic principles in the design of gas turbine modules and control systems**

Air intakes: design considerations of duct rating; types of intake; ideal airflow behaviour; shock waves; variable geometry intakes; supersonic intakes; flow through intake under static; climbing and high-speed conditions; asymmetrical intakes; area ratio; flow matching; loss characteristics; performance parameters; methods of diffusion; aerodynamic considerations for design of subsonic high-bypass fan; throat sizing; lip sizing; diffuser design; external cowl design

Compressors: degree of reaction and effects; blade design; compressor stage power requirements; work done factor; flow coefficient; stage temperature rise coefficient; surge at various operating conditions (mapping) and surge control; blade flutter; calculations for a stage

Combustion chambers: design features of combustion chambers; gas turbine combustion eg diffusion, combustion, fuel injection, dilution; diffuser performance and stability loop; dilution zone performance; dilution zone mixing performance; losses due to dissociation; combustion system pressure losses; temperature distribution; combustion efficiency; derivation of pressure loss equation

Flame stabilisation: definition of stability performance; measurement of stability performance; experimental data on stability; factors controlling stability; fuel type; fuel-air-ratio; velocity; temperature; pressure; flame holder size and shape

Turbines: performance characteristics for a single stage; type of turbine stage; blade design; stage loading coefficient eg flow coefficient characteristics; non-dimensional blade speed; non-dimensional temperature drop eg flow velocity characteristics, reaction

Pressure ratio: non-dimensional mass flow characteristics; pressure ratio; non-dimensional mass flow; reaction; design charts; metallurgical requirements; problems associated with turbines; forms and types of cooling; effects of reaction; blade loading; flow coefficient; stage loading coefficient; efficiency contours for single stage turbines; data for axial-flow gas turbine calculation

Learning outcomes and assessment criteria

Learning outcomes On successful completion of this unit a learner will:	Assessment criteria for pass The learner can:
LO1 Understand the properties of aircraft gas turbine fluids and energy losses	1.1 explain the measurement of fluid flow 1.2 determine velocity change, forces and power for a single stage 1.3 explain aerodynamic losses in gas turbine modules
LO2 Be able to apply thermodynamic laws and principles	2.1 analyse concepts of phase change in energy conversion 2.2 determine and apply non-flow and steady-flow energy equations 2.3 analyse the relationship between entropy and cycle efficiency and apply these concepts to thermodynamic processes 2.4 determine relationship between theoretical and real power plan cycles 2.5 determine module characteristics for a given thrust rating
LO3 Understand the application of thermodynamic principles in the design of gas turbine modules and control systems	3.1 explain the design criteria for a gas turbine intake 3.2 explain the design criteria for a gas turbine compressor 3.3 explain the design criteria for a gas turbine combustion chamber 3.4 explain the design criteria for a turbine and analyse efficiency contours 3.5 analyse design charts, metallurgical and cooling requirements.

Guidance

Links

This unit can be linked with *Unit 1: Analytical Methods for Engineers* and *Unit 2: Engineering Science*.

Essential requirements

Learners will require access to laboratory equipment for gas turbine testing or PC-based simulations of gas turbine tests. Where such equipment is not available this testing could be carried out at an industrial gas turbine test house or through a local university, etc. Adequate gas turbine modules and associated control systems should be available for demonstration of design criteria.

Employer engagement and vocational contexts

The delivery of this unit will benefit from centres establishing strong links with employers willing to contribute to the delivery of teaching, work-based placements and/or detailed case study materials.

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