# Unit 80: Aircraft Hydraulic Systems

**Unit code:** J/600/7254

**QCF Level 3:** BTEC Nationals

**Credit value:** 10

**Guided learning hours:** 60

## Aim and purpose

This unit aims to provide learners with an understanding of hydraulic transmission principles, hydraulically powered aircraft landing gear and flight control systems.

## Unit introduction

Nearly all modern aircraft use some form of hydraulic actuation, for example to power the aircraft landing gear, retardation equipment and flying controls. Hydraulic actuation provides instant response, rigidity and the immense power needed to operate such systems.

This unit has been designed to provide a thorough introduction to the principles of hydraulic transmission and the associated aircraft systems and components. In particular the principles associated with hydraulic power actuation and their application in modern hydraulic power supply systems is covered. The purpose, construction and operation of aircraft landing gear and retardation systems is also covered, including the provision made in an emergency for loss of system power. To emphasise the benefits that may be gained from hydraulic actuation and the current designs of modern aircraft, both manual and hydraulically powered flight control systems and their associated components are covered.

This unit covers the knowledge for some of the units in the SEMTA Level 3 National Occupational Standards in Aeronautical Engineering as well as providing 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 hydraulic transmission principles and the aircraft applications for hydraulic power

2 Understand the purpose and operation of hydraulic power supply systems and their associated components

3 Understand the construction, purpose and operation of aircraft landing gear and retardation systems and their associated components

4 Understand the construction, purpose and operation of manual control systems and the purpose and operation of hydraulic flight control systems and their components.

# Unit content

## 1 Understand hydraulic transmission principles and the aircraft applications for hydraulic power

*Hydraulic transmission principles*: fluid transmission including direction and flow control eg pressure in a fluid, transmission of force by a hydraulic fluid, Pascal's law, hydraulic actuation, hydraulic press, system requirements (need for fluid storage); fluid types and properties eg vegetable, mineral, ester-based oils, hydraulic fluid identification, handling, conditioning and filtration; sources and consequences of fluid contamination

*Aircraft applications*: power system comparisons (electrical, hydraulic, pneumatic); hydraulic power applications eg landing gear, retardation systems (thrust reverser, arrestor hook, wheel brake, steering, auto-braking, antiskid), flying controls (ailerons, rudder, elevator, tail plane, lift augmentation, lift reduction, trim, artificial feel)

## 2 Understand the purpose and operation of hydraulic power supply systems and their associated components

*Hydraulic power supply systems*: purpose and operation of a power supply system eg power source (such as hand pump, fixed and variable displacement engine driven pumps (vane or piston), electric pumps, emergency provision (multiple system provision, ram air turbine, standby pumps)

*Hydraulic power supply system components*: purpose and operation of power source and fluid control components eg pipes (rigid, flexible), hoses, seals, fittings, reservoir, filter, actuator, fluid control (directional control valves, non-return valves, temperature and pressure control valves, cut-out valves, accumulators, heat exchanger), cabin and external warning indicators and gauges, hydraulic power circuit diagrams

## 3 Understand the construction, purpose and operation of aircraft landing gear and retardation systems and their associated components

*Landing gear*: construction eg single, double, multi bogies, doors and fairings, shock absorbers (oleo pneumatic, liquid spring); purpose and operation of extension/retraction systems eg hydraulic sequencing, relief valves, shuttle valves, emergency provision (blow-down, multiple hydraulic supplies, accumulators), weight switches, indication and warning devices

*Retardation systems*: associated hydraulic system eg arrestor hook, wheel brake, steering, anti-skid, auto-braking; purpose, construction and operation of major retardation components eg brake parachute attachment mechanism, arrestor hook, steering actuator, steering mechanism, wheel assembly (tyres, wheels, bearings), brake units (liners, adjusters, rotors, stators), anti-skid devices (conventional hydro-mechanical, modern hydro-electronic)

## 4 Understand the construction, purpose and operation of manual control systems and the purpose and operation of hydraulic flight control systems and their components

*Manually operated systems and components*: construction, purpose and operation of rod and cable operated systems eg primary control surface systems, trim and balance tab systems, cable/pulley and control rod systems, cables, cable tension regulators, turnbuckles, eye and fork ends, bell-cranks, pulleys, fairleads, control rigging

*Hydraulic powered systems and components*: purpose and operation eg primary and secondary control systems, lift augmentation systems (flaps, slats), lift reduction systems (lift dumper, spoilers, speed brakes), other systems (such as artificial feel, Mach corrected trim, stall control, protection and warning, rudder limiter and gust lock systems), systems interfacing

## 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 principles involved with fluid power transmission and how fluid flow and direction is controlled | **M1** explain the differences in the associated hydraulic circuitry and components needed to operate a fixed displacement vane pump and a variable displacement piston pump | **D1** compare and contrast a conventional hydro-mechanical anti-skid unit with a modern hydro-electronic anti-skid unit and report on findings |
| **P2** describe the types and properties of three different aircraft hydraulic fluids, state the possible sources of hydraulic fluid system contamination and explain the consequences of such contamination | **M2** explain the relationship between landing gear weight switches and the nature of the landing gear indications and warnings during a ground-air-ground operation that requires cycling the landing gear | **D2** compare and contrast a fully electrically powered and operated aircraft primary flight control system, with its electro-hydraulic counterpart. |
| **P3** explain why hydraulics is preferred over pneumatics, as the power source for modern aircraft braking and aileron flight control systems | **M3** explain two methods of providing a hydraulic supply to an aircraft's flying control actuators in the event of an emergency | |
| **P4** explain the operation of a basic hydraulic power supply system, including the purpose and operation of the major power source and fluid control components within the system | **M4** explain the inter-relationship between airspeed signal input and trim actuator operation when considering the operation of a typical Mach corrected trim system. | |
| **P5** state the purpose and explain the need for a reservoir and accumulators in an aircraft hydraulic power supply system | | |
| **P6** sketch the constructional arrangement for an aircraft alighting gear assembly, identifying the major component parts and describe their function within the assembly | | |

| 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:** |
| **P7** | with the aid of a suitable hydraulic circuit diagram, explain the operation of a hydraulic alighting gear system, over one complete extension-retraction-extension cycle | | |
| **P8** | explain the operation of two retardation systems and for each system describe the function and explain the operation of each of their major system components [IE1] | | |
| **P9** | describe the construction and explain the operation of a rod and a cable operated manual flying control system and for each system, state the purpose of their major components | | |
| **P10** | explain the operation of a hydraulically powered aircraft rudder system and state the purpose of each of the major components within the system [IE1] | | |
| **P11** | explain the operation of a hydraulically powered aircraft trailing edge flap system and state the purpose of each of the components within the system. | | |

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

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

# Essential guidance for tutors

## Delivery

When delivering the principles element of learning outcome 1, emphasis should first be placed on fluid power transmission principles. Then comparisons between, electrical, pneumatic and hydraulic power sources, needs to be taught. Emphasising the power advantages of hydraulic actuation, together with the disadvantages and risks associated with hydraulic fluid leakage, contamination and the dangers associated with hydraulic fluids under pressure. The properties of different fluid types, their identification and the need for cleanliness and care when handling these fluids should be comprehensively covered.

Aircraft power supply systems and their associated components need to be covered in detail, so that learners understand how complex aircraft systems operate. It is suggested that the starting point for delivering this part of outcome 2, is the presentation of a basic system, consisting of a reservoir, a pump, a directional control valve and a linear actuator. The need, function, operation and system plumbing of these components can then be identified. The short falls of this basic system can then be identified and the need for additional components for fluid flow, emergency provision, filtration, cooling, temperature, direction, pressure and flow control can then be introduced.

Modern aircraft hydraulic power supply systems and associated components (taken from actual aircraft maintenance manuals) may then be used as examples, to further aid learning. If the cohort being taught is specifically concerned with aircraft maintenance, they will also need to understand the external and cabin indication and warning systems used with hydraulic power supply systems.

When delivering learning outcome 3 the depth of treatment given will be dependent on the needs of the cohort and the type and availability of the landing gear and retardation systems/equipment at the centre. As a minimum, the construction and operation of single, double and multi-bogie undercarriage struts and their associated system circuitry and components need to be taught. This should include the basic braking system used with these types of undercarriage.

Learners should also be familiar with the methods and additional components used to lower the undercarriage in emergency situations. They should also be able to describe the operation of at least one additional retardation device other than aircraft brakes. Learners following a purely maintenance pathway should also be fully conversant with modern aircraft cabin alighting gear indicators and warning devices.

Learning outcome 4 is concerned with modern flying control systems and components and includes manually-operated as well as power-operated controls. When delivering the content on fully powered hydraulic control systems, emphasis should be placed on the particular system function and operation and on the purpose of the components, within the system. The use of system diagrams taken from aircraft manuals and access to real aircraft systems and components, will add to the delivery of this content. To achieve the higher grades learners will also need to investigate a wider range of systems, such as Mach corrected trim and anti-skid, as well as gaining a more in-depth knowledge of the workings of their components.

## Outline learning plan

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

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

| Topic and suggested assignments/activities and/assessment |
|---|
| *Whole-class teaching:*<br>• introduction to unit content, scheme of work and assessment strategy<br>• explain hydraulic fluid transmission principles, (including Pascals law, fluid pressure, fluid flow, force transmitted by a liquid, the hydraulic press, fluid actuation, fluid system requirements)<br>• discuss fluid types and their properties, fluid identification methods, fluid handling and storage, fluid conditioning and filtration, sources and consequences of fluid contamination<br>• demonstrate hydraulic actuation on appropriate hydraulic equipment<br>• discuss the relative merits and uses for electrical, pneumatic and hydraulic power systems and to discuss the aircraft applications to which, hydraulic power is applied<br>• multiple-choice quiz on hydraulic transmission principles, alternative sources of power and aircraft application for hydraulic power. |
| Prepare for and carry out **Assignment 1: Hydraulic Transmission Principles and Aircraft Applications** (P1, P2, P3). |
| *Whole-class teaching:*<br>• explain (and demonstrate where possible) a power supply system or power pack and system components, including power source (hand-pump, fixed and variable displacement engine driven pumps, electrically driven pumps), other components including, fluid plumbing, reservoir, linear actuators, control valves (pressure, direction, temperature) filters, accumulators, heat exchangers, gauges and indicators<br>• explain (as necessary), review and reinforce learners' ability to read aircraft hydraulic circuit diagrams, taken from appropriate aircraft publications.<br>*Individual learner activity:*<br>• investigative and report on the function and operation of a wide selection of hydraulic power system components. |
| Prepare for and carry out **Assignment 2: Hydraulic Power Supplies and Their Components** (P4, P5, M1). |
| *Whole-class teaching sessions:*<br>• discuss/explain the construction, design and operation of aircraft landing gear assemblies, (including oleos, bogies, multiple bogies, wheel and brake unit assemblies), retardation systems (such as steering, anti-skid) and retardation components (such as arrestor hook, steering actuator, anti-skid devices).<br>*Individual learner activity:*<br>• investigate the construction, function and operation of a range of landing gear and retardation systems and equipment, other than those being assessed. |
| Prepare for and carry out **Assignment 3: Aircraft Landing Gear, Retardation Systems and Components** (P6, P7, P8, M2, D1). |

| Topic and suggested assignments/activities and/assessment |
| --- |
| *Whole-class teaching:*<br><br>explain and where possible demonstrate the construction, function and system operation of manual control system and equipment (such as cable and rod primary control systems, cables, cable tension regulators, turnbuckles, forked eye ends, bell-cranks, pulleys, fairleads, controls rigging) and hydraulically powered flying control systems and equipment (such as aileron, tail plane, rudder, flaps, lift dumper, spoilers, trim, feel and stall warning and control)<br><br>*Individual learner activity:*<br><br>investigate and determine the construction, function and operation of a range of manual and hydraulically powered flight control systems and equipment, other than those being assessed. |
| Prepare for and carry out **Assignment 4: Manual and Hydraulic Flight Control Systems and Components** (P9, P10, P11, M3, M4, D2). |
| Assessment review and feedback. |

## Assessment

This unit could be assessed through the use of four assignments.

P1, P2 and P3 cover learning outcome 1 and might best be assessed using a formal written assignment, with assessment evidence being obtained from the answers to set tasks. Learners must explain the principles involved with fluid power transmission (including the hydraulic press) as well as explain how fluid flow and direction is controlled (using control valves) (P1). In order to meet P2 they must describe the properties of vegetable, mineral and ester-based hydraulic fluids (and the seals used with these fluids) and state the sources and consequences of replenishing hydraulic systems with a contaminated or incorrect fluid. To meet (P3) learners must explain why hydraulics is preferred over pneumatics, as the power source for modern braking and aileron flight control systems. This will essentially be an argument based on the increased power requirements needed by both of these systems.

P4 and P5 and M1 could be assessed through a second formal written assessment. For P4 learners must explain the function and operation of the hydraulic power supply system and describe the function and operation of components used to control the flow, pressure, direction, temperature and condition of the hydraulic fluid within the system. They must also state the purpose and explain the need for the addition of the reservoir and accumulators into the system (P5). In order to provide sufficient evidence for M1 learners will need to understand in detail the operation of variable and constant displacement pumps and be able to draw-up diagrams that clearly show the associated circuitry.

A third assignment could cover P6, P7, P8, M2 and D1 and require learners to produce a sketch of an alighting gear assembly, identify the major component parts and describe their function within the assembly (P6). The sketch should be labelled showing all major components within the assembly (such as the oleo strut, doors, retraction actuator/s, casing, attachments, torque links, bogie, wheel brake and wheel sub-assemblies). For P7, learners must, with the aid of a suitable circuit diagram, explain the operation of an alighting gear assembly, through one complete cycle of its operation. They must be able to explain (using circuit diagrams) the operation of two retardation systems and also be able to describe the function and explain the operation of each of the major components in each system (P8). In order to be able to successfully achieve M2, learners must explain the signal interfacing between the undercarriage pressure switches and the cockpit/cabin indicators and warning devices. Evidence of achievement of D1, will need to contain a detailed exposition on the constructional feature of each anti-skid unit as well as providing a well researched argument, as to their relative merits and drawbacks.

The fourth assignment could cover P9, P10, P11, M3, M4 and D2. Learners must describe the construction and explain the operation of both a cable and a rod manual flying control system and for each system state the purpose of their major components (P9). They must explain the operation of an aircraft hydraulically powered rudder system and state the purpose of each of the major components within the system (P10). Finally, learners must explain the operation of a hydraulically powered trailing edge flap system and state the purpose of each of the components within the system (P11).

To achieve (M3) learners need to explain two separate methods of providing a hydraulic supply to an aircraft's flying control actuators in the event of an emergency situation. Learners should also explain the inter-relationship between airspeed signal input and trim actuator operation when considering the operation of a typical Mach corrected trim system (M4).

Learners must be able to produce a well-researched argument after comparing and contrasting fully electrical powered flying controls with their electro-hydraulic counterparts (D2).

### Programme of suggested assignments

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

| Criteria covered | Assignment title | Scenario | Assessment method |
|---|---|---|---|
| P1, P2, P3 | Hydraulic Transmission Principles and Aircraft Applications | A formal assignment requiring learners to respond to written tasks. | Written responses to set tasks, carried out under controlled conditions. |
| P4, P5, M1 | Hydraulic Power Supplies and Their Components | A formal assignment requiring learners to respond to written tasks. | Written responses to set tasks, carried out under controlled conditions. |
| P6, P7, P8, M2, D1 | Aircraft Landing Gear, Retardation Systems and Components | A two part investigative assignment, set in an aircraft workshop environment, to first cover the pass criteria (P6, P7, P8) and then cover (M2, D1), as appropriate for the learner. | A two part written report, resulting from the investigations. |
| P9, P10, P11, M3, M4, D2 | Manual and Hydraulic Flight Control Systems and Components | A two part investigative assignment, set in an aircraft workshop environment, to first cover the pass criteria (P9, P10, P11) and then cover (M3, M4, D1), as appropriate for the learner. | A two part written report, resulting from the investigations. |

## 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 Workshop Principles and Practice |

This unit has been mapped against the EASA Part-66 examinations and, together with the *Unit 70 Aircraft Workshop Principles and Practice*, covers the knowledge requirements for 11.9, 11.11 and 11.13 of Module 11 Aeroplane Aerodynamics, Structures and Systems. This unit also contributes knowledge towards SEMTA Level 3 National Occupational Standards in Aeronautical Engineering, particularly:

- Unit 41: Installing Aircraft Hydraulic Systems
- Unit 146: Removing and Replacing Components of Aircraft Hydraulic Systems
- Unit 169: Overhauling Components of Aircraft Hydraulic Systems
- Unit 313: Maintaining Hydraulic Power Systems on Aircraft
- Unit 316: Maintaining Landing Gear on Aircraft
- Unit 331: Maintaining Flight Control Systems on Aircraft

## Essential resources

Learners will require access (on or off-site) to:

- a range of hydraulic power system components (including engine driven pumps, reservoirs, actuators, accumulators, filters, plus an assorted range of directional, pressure, relief and non-return valves)
- a manual control system training rig or similar
- a hydraulically powered aircraft undercarriage system rig, complete with wheel, brake and anti-skid assemblies
- a powered flying control system rig and associated miscellaneous hydraulic flying control components or preferably access to a modern training aircraft equipped with a hydraulically powered flying control system
- ATA – 100 Series, specialist textbooks and publications from the Joint Aviation Authority and sanctioned by the European Aviation Safety Agency (Civil)
- Air Publications – 101 Series of manuals and Air Publications (Military).

## Employer engagement and vocational contexts

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

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

## Indicative reading for learners

### Textbooks

Jeppersen, S – *A&P Technician Airframe, Textbook* (Jeppersen Sanderson Training Products, III Edition 2003) ISBN 978-0884873310

Moir, I and Seabridge, A – *Aircraft Systems Mechanical, Electrical and Avionic Sub-systems Integration* (Longman, 2004) ISBN 1860582893

Neese, W A – *Aircraft Hydraulic Systems* (Krieger Publishing Company, 1991) ISBN 0894645625

## 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** | investigating the operation of aircraft hydraulic retardation systems, explaining their operation and defining the function of the components within each system<br><br>investigating the operation of a hydraulically powered rudder flying control system and defining the function of the components within the system. |

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 ... |
|---|---|
| **Creative thinkers** | investigating, comparing and contrasting a fully electrically powered and operated primary flying control system, with its electro-hydraulic counterpart |
| **Self-managers** | organising time and resources and prioritising actions, to satisfy the assessment criteria for the unit. |

## 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 | explaining and describing aircraft hydraulic systems and components |
| Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively | explaining and describing aircraft hydraulic systems and components. |