Unit 15: Electro, Pneumatic and Hydraulic Systems and Devices

Unit code: K/600/0264

QCF Level 3: BTEC National

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit will give learners the knowledge and skills needed to safely inspect, test and maintain pressurised fluid systems that use electrical control devices to make them work.

Unit introduction

An understanding of how fluid power systems are used to control the operation of machinery and equipment is important for anyone thinking of taking up a career in engineering.

Pneumatic (pressurised air or gas) systems are widely used in manufacturing engineering to operate equipment such as packaging machines, automated assembly machines, clamping and lifting devices. There are many other everyday applications where air operated equipment is found, for example for opening doors on buses. Hydraulic (pressurised liquid) systems are used where greater amounts of power are involved, a good example of this being the linear actuators that move the arms on excavators and other types of earth-moving equipment.

This unit will give learners a broad understanding of the design and safe operation of pressurised fluid systems that use electrical control devices to make them work. This will include being able to read and produce simple fluid power circuit diagrams, understanding the principles of maintenance, and the use of test routines to identify faults in these systems.

Learners will investigate the impact that current legislation has on the design and safe operation of fluid power circuits, so that when carrying out practical work they are able to work safely. High pressure systems and devices, particularly air-based ones, have hidden dangers. Because hydraulic oil is carcinogenic learners will be made aware of the regulations covering the handling and disposal/recycling of this substance.

This is then followed by a look at a selection of the components used in fluid power systems and how they can be represented using universally recognised circuit diagram symbols. The components studied will include those used to generate a supply of high pressure air or hydraulic fluid, prime movers such as linear actuators (cylinders) and control devices such as valves and sensors.

Learners will be introduced to some of the calculations that need to be carried out before designing and setting up a system. These include some basic pressure and volume calculations involving gases, determination of the correct size of cylinder to produce a specified extending force, and calculation of fluid flow rates needed to keep a system operating effectively. Learners will then investigate how components can be linked together to form systems for a specific purpose.

The final section of the unit looks at how fluid power systems are maintained in service and what happens if they develop faults. The emphasis here is on applying safe working practices, using predetermined systematic schedules and keeping accurate records for future reference.

Learning outcomes

On completion of this unit a learner should:

1 Know about the legislation, regulations and safety precautions that apply when working with fluid power systems

2 Know the construction and operation of fluid power devices and how they are represented as symbols in circuit diagrams

3 Be able to apply fluid power principles in the design of circuits

4 Be able to carry out maintenance, inspection, testing and fault-finding on fluid power systems.

Unit content

1 Know about the legislation, regulations and safety precautions that apply when working with fluid power systems

Legislation and regulations: legislation eg Health and Safety at Work Act 1974, Employment Act 2002, Factories Act 1961, Fire Precautions Act 1971, Deposit of Poisonous Waste Act 1972, European Conformity (CE marking); regulations eg Employment Equality (Age) Regulations 2006, Management of Health and Safety at Work Regulations 1999, Provision and Use of Work Equipment Regulations 1998, Control of Substances Hazardous to Health (COSHH) Regulations 2002, Lifting Operations and Lifting Equipment Regulations 1998, Manual Handling Operations Regulations 1992, Personal Protective Equipment at Work Regulations 1992, Confined Spaces Regulations 1997, Electricity at Work Regulations 1989, Control of Noise at Work Regulations 2005, Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995, Workplace (Health, Safety and Welfare) Regulations 1992, Health and Safety (First Aid) Regulations 1981, Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2004, Simple Pressure Vessels (Safety) Regulations 1991 (SI 1994/3098), Supply of Machinery (Safety) (Amendment) Regulations 2005 (SI 2005/831)

Safety precautions: risk assessment of fluid power systems; assembling and testing electro, pneumatic and hydraulic systems and devices eg isolation of services (such as electrical, air, oil), escape of fluids at high pressure which may cause contact injury, hydraulic oil contact with the skin, sudden movement of linear actuators causing entrapment injuries; personal protective equipment (PPE) eg safety glasses, gloves, overalls, footwear

2 Know the construction and operation of fluid power devices and how they are represented as symbols in circuit diagrams

Fluid power devices: fluid conditioning eg supply tank, filter, pump, cooler, compressor, dryer, receiver, accumulator; fluid supply eg pipework, fittings, seals, drainage points; electrical supply systems eg mains, low voltage regulated power supply units, AC, DC; fluid control valves eg directional (manual and solenoid), pilot, 4 port, 5 port, pressure reducing, non-return, flow rate; actuators eg linear, rotary; motors eg electric, air, hydraulic; position sensors eg reed switch, pressure switch, inductive, micro-switch; system control eg programmable logic controller (PLC), electro mechanical

Symbols: relevant and current standards eg BS3939, BS2917, ISO 1219, European Fluid Power Committee (CETOP); symbols for common components eg fluid conditioning, fluid supply, electrical supply, control valves, actuators, motors, sensors, control

Circuit diagrams: diagrams eg pneumatic, hydraulic, block diagrams, system layout, displacement step diagrams; reference material eg component and equipment data sheets, ISO 1219-2, software (such as FluidSIM or Automation Studio)

3 Be able to apply fluid power principles in the design of circuits

Fluid power principles: properties and behaviour of air and hydraulic fluids; gas laws eg Boyle's, Charles', Gay-Lussac's, general gas, dew point; fluid flow eg Bernoulli's principle, volumetric rate, receiver volume, actuator flow requirements; fluid pressure eg units of measurement, Pascal's law, inlet and outlet pressure, pressure drop, actuator efficiency, clamping force; formulae ($P_1V_1T_2 = P_2V_2T_1$, displaced volume = piston area x stroke, volumetric flow rate = displaced volume/time, absolute pressure = gauge + atmospheric pressure, force = pressure x area, actuator force = pressure x area x efficiency)

Circuits: pneumatic eg multi-cylinder sequential operation, single-cylinder reciprocation with dwell, position and clamp an object using a two-cylinder arrangement, rotary actuator with reversing action; hydraulic eg multi-cylinder sequential operation, single-cylinder reciprocation with dwell and regeneration, hydraulic motor with reversing action

4 Be able to carry out maintenance, inspection, testing and fault-finding on fluid power systems

Maintenance: routines eg frequency of maintenance, manuals and reference documentation, keeping of accurate records using paper- or software-based systems; components (electro, pneumatic, hydraulic); systems eg electro-pneumatic, electro-hydraulic

Inspection: functional eg at component level, as a system, performance against specification; keeping of accurate records; report eg component drawing, system circuit diagram, digital images, inspection checklist, record of visual observations made against checklist, conclusions, recommendations

Testing: performance eg against specification, reliability; keeping of accurate records; report eg system circuit diagram, system specification, test schedule, list of test equipment, record test results, record visual observations, compare test results with system specification, recommendations for future actions

Fault finding: identify faults in fluid power systems eg manual diagnosis, visual examination, unit substitution, input to output, injection and sampling, half-split technique, six-point technique, self-diagnostic techniques using programmable electronic equipment, effect of malfunctions; fault-finding aids eg functional charts, diagrams, flow charts, troubleshooting charts, component data sheets, operation and maintenance manuals, specialised equipment; record faults eg paper based, software based, analyse data; report eg system circuit diagram, record test results, record visual observations, compare test results with system specification, record faults and cross reference to circuit diagram, identify type of fault, strategy for rectification of fault

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 list the aspects of health and safety legislation and regulations that apply when working with fluid power equipment and systems	**M1** explain and compare the construction and operation, including legislation and safety precautions, of a pneumatic system with that of a hydraulic system	**D1** evaluate the use of self-diagnostic techniques to monitor the performance of fluid power systems used in industry
P2 describe the safety precautions that apply when working with fluid power equipment and systems	**M2** explain the procedures used when fault finding in electro-pneumatic and electro-hydraulic systems.	**D2** explain the importance of carrying out maintenance, inspection, testing and fault-finding on fluid power systems.
P3 describe, with the aid of suitable diagrams, the construction and operation of a given electro-pneumatic device and a given electro-hydraulic device		
P4 use standards to identify electro, pneumatic and hydraulic components shown as symbols in given circuit diagrams and reference materials [IE4]		
P5 carry out calculations that relate to the fluid power principles used in the design of circuits [IE1]		
P6 produce a circuit diagram to meet a given pneumatic system specification		
P7 produce a circuit diagram to meet a given hydraulic system specification		

Assessment and grading criteria			
To achieve a pass grade the evidence must show that the learner is able to:		**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P8	use routines and carry out maintenance on given electro, pneumatic and hydraulic components and a given electro-pneumatic or electro-hydraulic system		
P9	carry out inspection, testing and fault-finding on a given electro-pneumatic or electro-hydraulic system and produce a report of their findings.		

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

To establish the context of fluid power systems, this unit should begin with a general overview of their use in industry and the contribution they make to the effective operation of a business. It might be useful to pick up on the complexity of producing linear movement using a conventional electric motor and the reasons why a pneumatic or hydraulic actuator do the job much more effectively. A video presentation showing applications of fluid power systems would be a good way of introducing learners to the unit.

Examples of where fluid power systems are used should focus on their use in manufacturing industry, for example packaging machines, handling devices and clamping equipment. However, breadth can be added if the discussion about applications is widened to include situations which are of common knowledge to learners, such as earth-moving equipment and power-operated doors on public transport.

Learning outcome 1 covers legislation, regulations and safe working and links to *Unit 1: Health and Safety in the Engineering Workplace*. Care should be taken to ensure that delivery concentrates only on the specific legislation relating to fluid power systems. There is a huge amount of data available and when learners carry out research they should be given structured tasks which lead them to the relevant information. It is important that they are fully aware of the safety issues relating to working with electrical control equipment, hydraulic oil and compressed air before carrying out practical work later in the unit.

Before starting work on learning outcome 2 it would be beneficial if learners are able to see fluid power systems in operation, preferably by visiting local industry. Because of the health and safety issues this links with learning outcome 1. It could be that some of the understanding and knowledge required to generate the evidence for criterion P1 is gathered at this time.

Learning outcome 2 should involve some practical work so that learners can get their hands on devices and take them apart to see how they are constructed. Learners are not expected to produce detailed sectioned assembly drawings of the given devices. To achieve P2 they are only required to produce evidence that relates to one electro-pneumatic device and one electro-hydraulic device. Examples of suitable devices might be a solenoid-operated pilot valve, a linear actuator with micro-switch position sensors, an air compressor or a hydraulic pump.

Learning outcome 3 combines fluid power system calculations with the opportunity to carry out some design work. The formulae used for calculations should be given and it would add interest if one of the tasks for achieving P4 is contextualised and based on the design specifications for simple circuits. An example might be the calculation of pressure and flow rate requirements when a twin-cylinder clamping unit is required to work at a given stroke rate and produce a specified rod force. This could then lead on to the selection of a suitable power supply, control device and actuators from equipment suppliers' data sheets.

The second part of learning outcome 3 may be best delivered using a learner centred activity that requires the use of a software package such as Automation Studio. Learners will need to be given a basic list of component symbols to work with and the aim would be to produce circuit diagrams which are operationally correct but not necessarily to industry standard in terms of presentation. This aspect is better covered in *Unit 16: Engineering Drawing for Technicians* and *Unit 17: Computer Aided Drafting in Engineering*. To check for correct operation, learners should be given the opportunity to build up their circuits using hardware or, where this is not practical, to carry out simulation using software. Sequential circuits can be limited to just two actuators, each with a pair of limit switches.

When designing the delivery and assessment of learning outcome 4, it is important to ensure that learners are only required to carry out simple procedures relating to the maintenance, inspection, testing and fault finding of fluid power systems. Complex arrangements should not be considered and any reference documentation given to the learner should be tailored to the specific systems being looked at.

Note that the use of 'eg' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'eg' needs to be taught or assessed.

Outline learning plan

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

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

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • introduction to unit, scheme of work and assessment method • identify and describe the legislation and regulations that apply when working with fluid power systems • identify and describe the safe working practices that apply when working with fluid power systems. *Practical group activities*: • carry out a risk assessment for a fluid power system.
Preparation for and carry out **Assignment 1: Legislation and Safety Precautions** (P1 and P2).
Industry visit: • view the operation of a variety of fluid power system components in an industrial setting. *Whole-class teaching*: • explain the construction and operation of fluid conditioning and supply components • explain the construction and operation of electrical supply systems and fluid control valves • explain the construction and operation of actuators, motors, sensors and systems control methods. *Practical activity*: • examining a range of different fluid power devices. *Whole-class teaching*: • identify and describe the use of symbols in circuit diagrams and other reference material.
Preparation for and carry out **Assignment 2: Construction and Operation of Fluid Power Devices** (P3, P4 and M1).
Whole-class teaching: • explain the properties and behaviour of air and hydraulic fluids. Explain the gas laws and principles of fluid flow and fluid pressure • explain and demonstrate the use of formulae in relation to fluid circuits • explain and demonstrate the production of circuit diagrams for pneumatic and hydraulic circuits. *Practical activities*: • produce circuit diagrams for a range of given circuits.
Preparation for and carry out **Assignment 3: Fluid Power Principles and Circuits** (P5, P6, P7).

Topic and suggested assignments/activities and/assessment
Whole-class teaching: • explain and demonstrate the use of maintenance routines • demonstrate maintenance of system components and systems • demonstrate inspection and reporting techniques for fluid power systems • demonstrate testing and reporting for fluid power systems • demonstrate fault-finding techniques, use of fault-finding aids and methods of reporting and recording faults. *Group practical activities*: • learners practise maintenance, inspection, testing and fault-finding techniques.
Preparation for and carry out **Assignment 4: Carrying out Fluid Power Maintenance** (P8, P9 and M2).
Preparation for and carry out **Assignment 5: Evaluating Monitoring and Maintenance Techniques** (D1 and D2).
Feedback on assessment, unit evaluation and close.

Assessment

It may be appropriate to structure the assessment of this unit as five assignments, using four to cover the pass and merit criteria and the fifth one the two distinction criteria.

The first assignment could cover P1 and P2 and should be structured so that learners remain focused on the content of learning outcome 1. Learners are expected to use their own words when referring to legislation and, whilst much of their research will be done using the internet, it is important that what they present is not just a simple cut and paste exercise. Evidence to support knowledge of safety precautions could be generated by giving learners a list of situations/scenarios and then asking them to detail what needs to be done to work safely. This leads into risk assessment and learners could be asked to carry out an assessment for equipment which they will be using later in the unit.

Grading criteria P3, P4 and M1 complement each other and could be assessed through a second assignment which covers the whole of the content for learning outcome 2. P3 asks for information about the construction and operation of equipment and, provided that any written explanation is supported by diagrams there is no requirement for learners to present fully detailed drawings of the devices considered.

To meet the requirements of P4 learners could be given a suitable set of circuit diagrams and manufacturers' reference material for the equipment described for P3. This would determine the amount of components and symbols needed to meet the requirement of P4. Examples of such devices are found in the unit content and delivery guidance.

P5, P6 and P7 are linked and could be assessed using a third assignment which will involve calculation and the production of circuit diagrams which meet given design specifications. These can be hand drawn but it is better if learners use a software package, so that simulation can be carried out to ensure correct operation of the circuits. This could be evidenced in the form of screen prints consolidated by a witness statement or observation record.

Grading criteria P8, P9 and M2 could be assessed using a fourth assignment. Evidence of learner competence when carrying out practical tasks will need to be recorded using witness statements, observation records and digital images.

The tasks set to generate evidence for P8 should involve the use of a small range of components and just one fluid power system (ie pneumatic or hydraulic). Similarly, when producing evidence for P9 it is only necessary to work with one type of system. Both criteria require learners to keep accurate records and use relevant documentation in addition to carrying out the practical tasks. Learners who built the circuits that they designed to achieve P6 and P7 could work on these when gathering evidence for P8 and P9.

D1 and D2 build on the content from learning outcome 4 but, to effectively explain and evaluate, learners should make reference to the legislative and safety issues covered in learning outcome 1. In particular, to achieve D2 learners will need to present a very detailed piece of writing which considers not just the mechanical problems associated with equipment failure but also the legislative and economic implications.

A single assignment could be used to assess the distinction criteria with one of the tasks set for achieving D2 being based on a scenario. For example, learners could assume the role of a maintenance technician who has been tasked with investigating the malfunction of a fluid power system. The malfunction has caused damage to equipment, resulted in injury to an employee and is under review by the Health and Safety Executive (HSE).

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 and P2	Legislation and Safety Precautions	Carry out a risk assessment for a piece of fluid power equipment.	A written assignment in which learners detail the legislation and safety precautions that apply to a piece of fluid power equipment that they are going to use.
P3, P4 and M1	Construction and Operation of Fluid Power Devices	Use and interpret circuit diagrams to identify and describe the operation of fluid power devices and components.	A written assignment with tasks requiring learners use diagrams to describe fluid power devices and identify components.
P5, P6, P7	Fluid Power Principles and Circuits	Learners have been asked to produce circuit diagrams to meet the requirements of a customer specification.	A practical assignment requiring learners to produce two circuit diagrams and carry out calculations.
P8, P9 and M2	Carrying out Fluid Power Maintenance	Learners have been asked by their supervisor to carry out maintenance on fluid power systems.	A practical assignment supported by a logbook/report of activities carried out plus observation records.
D1 and D2	Evaluating Monitoring and Maintenance Techniques	Learners have been asked to investigate a faulty fluid power system.	A written report evaluating the use of self-diagnostic techniques and the importance of maintenance.

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 the following units in the Engineering suite:

Level 1	Level 2	Level 3
	Operation and Maintenance of Fluid Power Systems and Components	Health and Safety in the Engineering Workplace
		Engineering Drawing for Technicians
		Computer Aided Drafting in Engineering
		Principles and Applications of Fluid Mechanics

The unit covers some of the knowledge and understanding associated with the SEMTA Level 3 NVQ in Installation and Commissioning, particularly:

- Unit 6: Installing Electrical/Electronic Equipment
- Unit 9: Installing Fluid Power Equipment.

Essential resources

To meet the needs of this unit it is essential that centres have access to the following:

- industrial-standard electro, pneumatic and hydraulic equipment and systems
- fluid power circuit design software eg FluidSIM or Automation Studio
- test equipment and measuring instruments
- relevant British and international standards
- health and safety publications.

Employer engagement and vocational contexts

Centres should try to encourage companies involved with hydraulics, pneumatics, transport and civil engineering aspects of fluid power, to join the centre's unit and programme industrial focus committees. Having close contact with such companies opens up opportunities for learners to visit them, view or use equipment and arrange possible work placements.

There are a range of organisations that may be able help centres engage and involve local employers in the delivery of this unit, for example:

- 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

Darbyshire A – *Mechanical Engineering BTEC National Option Units* (Elsevier, 2008) ISBN 075068657X

Kay M – *Practical Hydraulics* (Taylor and Francis, 2008) ISBN 0415351146

Parr A – *Hydraulics and Pneumatics* (Jaico Publishing, 2005) ISBN 9788172241896

Turner I – *Engineering Applications of Pneumatics and Hydraulics* (Butterworth-Heinemann, 1996) ISBN 0340625260

Zhang Q – *Basics of Hydraulic Systems* (Taylor & Francis, 2008) ISBN 9781420070989

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	identifying questions to answer and problems to resolve relating to fluid power principles analysing and evaluating information when using standards to identify components shown as symbols.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Reflective learners	asking questions to extend their learning
Team workers	collaborating with others when working in groups on practical activities
Self-managers	organising time and resources and prioritising actions

Functional Skills – Level 2

Skill	When learners are ...
ICT – Use ICT systems	
Select, interact with and use ICT systems independently for a complex task to meet a variety of needs	using a software package to produce fluid power circuit diagrams
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	researching and accessing information relating to fluid power systems and components
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	researching and accessing information relating to fluid power systems and components
Mathematics	
Select and apply a range of skills to find solutions	carry out calculations that relate to fluid power principles
Draw conclusions and provide mathematical justifications	carry out calculations that relate to fluid power principles
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and accessing information relating to fluid power systems and components.