Unit 36: Fluids Static and Dynamic in Building Services Engineering

NQF Level 3: **BTEC National**

Guided learning hours: 60

Unit abstract

Although much of modern society relies on the transport and use of fluids, putting fluids to use is not a modern phenomenon. In 300 BC the Chinese were using waterwheels to operate smelting bellows, and by the 9th century air was being used in windmills in Persia to grind corn.

To make appropriate and efficient use of fluids it is crucial that we understand their properties and can describe, at least approximately, their behaviour under varying conditions. It is also necessary to control the flow of fluids under these varying conditions and so be able to specify equipment capable of that control.

Learners will understand that fluids can be usefully characterised by their state of motion, their state of compression and by their internal temperature. To understand how a static or moving fluid interacts with its immediate surroundings, such as in a pipe, a duct, or a vessel therefore requires an understanding of the changes in energy, velocity, pressure, mass, volume, and temperature within the fluid.

Two of the fluids still most commonly transported and used today are water and air, and this unit is predominantly concerned with the characteristics and behaviour of these, when static and in motion.

Learning outcomes

On completion of this unit a learner should:

1 Understand the properties and behaviour of compressible and incompressible fluids

2 Be able to examine and analyse static fluid systems

3 Be able to define a ‘real’ dynamic fluid and analyse the flow of real fluids

4 Understand the design practices of typical fluid systems and the equipment commonly used in such systems.

Unit content

1 **Understand the properties and behaviour of compressible and incompressible fluids**

General definitions: general definitions and associated units for, eg ideal fluids, real fluids, viscosity, steady flow, unsteady flow, laminar flow, turbulent flow and boundary layer, density and its variation with temperature; pressure units (multiples and submultiples); measurement of pressure (absolute, atmospheric and gauge pressure)

Definition of fluids as: either compressible or incompressible

Principles: macroscopic approach to determining fluid behaviour; physical properties of a fluid; use of correct symbols and units

2 **Be able to examine and analyse static fluid systems**

Theory: Pascal’s principle

Pressure recording devices: construction, operating principle and application of, eg compound pressure gauges, barometers, ‘U’ tubes, differential pressure and inclined limb manometers

Definitions: pressure expressed as ‘metres head’

Calculations: simple problems using P = hdg

3 **Be able to define a ‘real’ dynamic fluid and analyse the flow of real fluids**

Principles and practices: continuity of flow equation (conservation of mass) and its use to solve duct and pipe flow problems; conservation of energy theory; steady flow energy equation; energy forms for PE, KE, U, Pv, Q and W; use of steady flow equation to solve simple problems

Application: Bernoulli’s equation and its applications; solution of problems using Bernoulli’s formula for pipe and ducted systems; viscosity and its effects; flow arrangements through orifice and pipe contractions; types and arrangements; fluid flow through orifices and venturi as an application of Bernoulli’s equation and continuity of flow

4 **Understand the design practices of typical fluid systems and the equipment commonly used in such systems**

Principles: hydraulic gradients; factors contributing to energy losses in pipe and duct systems; good design practice for piped and ducted systems minimising energy losses; causes of energy losses due to friction within pipe and ducted systems; principles of energy loss within straight pipe and duct; principles of energy losses due to turbulence caused by fittings and changes

Energy losses in pipe and duct systems: energy loss in systems with laminar flow; solution of problems involving Poiseuille's Equation; energy loss in systems with turbulent flow; solution of problems involving D'Arcy's and Chezy's formula; coefficient of friction; energy losses due to fittings; velocity pressure factors for pipe and ductwork fittings; expressing fittings as equivalent lengths of pipe; solution of problems involving pressure loss due to fittings and changes

Operation of: propeller, centrifugal and axial fans; liquid pumping devices, reciprocating compression devices and rotary compression devices; simple fan and pump laws; ways of changing the performance; matching pumps and fans to pipe and ductwork systems; connecting in series and parallel

Compressible fluids: application of gas laws and general gas equation; universal gas equation to problems involving compressible fluids

Grading grid

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all of the learning outcomes for the unit. The criteria for a pass grade describes the level of achievement required to pass this unit.

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 describe compressible and incompressible fluids in terms of their physical properties and the factors that affect them	M1 produce clear and accurate answers to a range of problems associated with the physical properties of fluids	
P2 describe static fluid systems in terms of the laws that govern their behaviour and determine pressure due to static fluids		
P3 describe the flow of real fluids in terms of general principles and practices	M2 produce clear and accurate answers to a range of problems associated with fluid flow using the continuity of flow and Bernoulli's equations	
P4 describe fluid system design practices as they apply to energy losses within piped and ducted systems P5 examine the functions and operating principles of compression devices, fans, and liquid pumping devices.	M3 produce clear and accurate answers to a range of problems associated with energy losses in piped and ducted systems M4 produce clear and accurate answers to a range of problems associated with the gas laws and compressible fluids.	D1 evaluate how the combined factors that affect fluid flow influence the design of building services installations D2 justify the selection and specification of a range of fans, pumps and/or compressors in terms of design data and operating principles.

Essential guidance for tutors

Delivery

Tutors delivering this unit have opportunities to use a wide range of techniques. Lectures, discussions, seminar presentations, site visits, supervised practicals, research using the internet and/or library resources and the use of personal and/or industrial experience are all suitable. Delivery should stimulate, motivate, educate and enthuse learners. Visiting expert speakers could add to the relevance of the subject.

The learning outcomes are related to the behaviour of fluids in systems. Although the main theme is fluid mechanics, learning outcome 1 provides an initial overview and general definitions and learning outcomes 2, 3 and 4 deal with different aspects which build and develop in a logical sequence.

The focus of this unit is on linking scientific principles with practical applications detailed in a variety of other units. The delivery of this unit and its assessment should be either integrated or co-ordinated with the delivery of the appropriate sections of the practical units. The sequence of delivery of this unit and the design of the assessment instruments, are likely to be influenced by the delivery and assessment of these related units.

Teaching and learning strategies designed to support delivery of the learning outcomes should take an integrated learner-centred, investigative and supervised, hands-on experiential learning approach. Practical activities should be used whenever possible. This would involve learners taking measurements, making observations, consulting standards, making decisions and suggesting alternatives.

Calculations are part of all learning outcomes but the unit should not be seen as a mathematical exercise. Delivery should provide a balance between calculations, knowledge and understandings. Calculations used to support the delivery process should always reflect real-life and standard practice.

Group activities are permissible, but tutors will need to ensure that individual learners are provided with equal experiential and assessment opportunities.

Health, safety and welfare issues are paramount and should be strictly reinforced through close supervision of all workshops and activity areas, and risk assessments must be undertaken prior to practical activities. Centres are advised to read the *Delivery approach* section on page 24, and *Annexe G: Provision and Use of Work Equipment Regulations 1998 (PUWER)*.

Assessment

Evidence for this unit may be gathered from a variety of sources, including well-planned investigative assignments, case studies or reports of practical assignments.

There are many suitable forms of assessment that could be employed, and tutors are encouraged to consider and adopt these where appropriate. Some examples of possible assessment approaches are suggested below. However, these are not intended to be prescriptive or restrictive, and are provided as an illustration of the alternative forms of assessment evidence that would be acceptable. General guidance on the design of suitable assignments is available on page 19 of this specification.

Some criteria can be assessed directly by the tutor during practical activities. If this approach is used then suitable evidence would be observation records or witness statements. Guidance on their use is provided on the Edexcel website.

The structure of the unit suggests that the grading criteria may be fully addressed by using four assignments. The first of these would cover P1 and M1, the second would cover P2, the third would cover P3 and M2 and the fourth would cover P4, P5, M3, M4, D1 and D2.

To achieve a pass grade learners must meet the five pass criteria listed in the grading grid.

For P1, learners must describe compressible and incompressible fluids in terms of their physical properties and the factors that affect them. The description should include the distinction between ideal and real fluids; viscosity and its meaning, effects and units; the distinction between steady, unsteady, laminar and turbulent flow; the implications of these types of flow; formation of boundary layers; pressure in fluids, its units and how it is measured. Evidence could be in the form of a presentation or a report.

For P2, learners must describe static fluid systems in terms of the laws that govern their behaviour and determine pressure due to static fluids. They must explain Pascal's principle and illustrate the principle via building services related applications. Learners are required to calculate the pressure at given points in a static fluid system and calculate pressures indicated on various types of manometers using various manometer liquids. The answers to the calculations should be substantially correct, but small errors in calculation are acceptable, if they are corrected after feedback from the tutor. Evidence for P2 could be provided in the form of a presentation or a report supported by appropriate calculations and practical notes.

For P3, learners must describe the flow of real fluids in terms of general principles and practices. This should include an explanation of the continuity of flow principle as it applies to both compressible and incompressible fluids. It should also include an explanation of the different forms of energy in a flowing fluid and the continuity of energy principle as provided in Bernoulli's equation. Although at this stage learners are not required to use the continuity of flow or Bernoulli's equations to solve problems they are expected to provide more than mechanistic definitions or reproduce equations. Learners should show that they understand the concepts that are contained within these equations and principles, and how and where they can be applied to provide solutions in various flowing fluid systems. Suitable evidence could be as for P2.

For P4, learners must describe fluid system design practices as they apply to energy losses within piped and ducted systems. This should include a recognition of why losses in pipes and ducts are different to fittings, changes of direction and components. Learners should also explain the effect that the type of flow has on energy losses and why laminar flow has different energy losses than turbulent flow in the same pipe or duct. An explanation of the different factors, constants and variable, that contribute to the energy losses in a pipe or ductwork system is also required. Although at this stage learners are not required to use the energy loss equations to solve problems they are expected to provide more than mechanistic definitions or reproduce equations. Learners should show that they understand the concepts contained within these equations and principles and how and where they can be applied to provide solutions in various flowing fluid systems. Suitable evidence could be as for P2.

For P5, learners must examine the functions and operating principles of compression devices, fans, and liquid pumping devices. This should include the construction, physical features and operating characteristics of the various devices. Learners should explain the performance characteristics appropriate to the various devices, such as flow/pressure (head) relationship, efficiency, power, npsh. Learners may make use of manufacturers' performance curves and data but they must show that they understand the concepts that are contained within this information and how this data can be applied to match the device to the requirements of the system in which it is installed. Suitable evidence could be as for P2, supported by appropriate drawings.

To achieve a merit grade learners must meet all of the pass grade criteria **and** the four merit grade criteria.

For M1, learners must produce clear and accurate answers to a range of problems associated with the physical properties of fluids. This should include calculation of pressure, density of fluids and Reynolds number. The answers to the calculations should be substantially correct, but small errors in calculation are acceptable, if they are corrected after feedback from the tutor. This could be a natural extension of the work completed in P1.

For M2, learners must produce clear and accurate answers to a range of problems associated with fluid flow using the continuity of flow and Bernoulli's equations. The problems provided should be related to practical realistic building services applications preferably which reflect learners' own field of building services. The answers to the calculations should be substantially correct, but small errors in calculation are acceptable, if they are corrected after feedback from the tutor. This could be a natural extension of the work completed in P3.

For M3, learners must produce clear and accurate answers to a range of problems associated with energy losses in piped and ducted systems. The problems should reflect real life and the standard practices associated with realistic pipe and ductwork installations as encountered in everyday building services installations. This could include determining the resistances of index circuits so as to specify fan and pump duties, additional resistances to balance branches and sub-circuits (including energy loss due to fittings and changes in direction etc). This should not be a mechanistic application of rules and procedures, in producing these solutions learners should show their understanding of the principles of energy loss in pipe and duct systems.

For M4, learners must produce clear and accurate answers to a range of problems associated with the gas laws and compressible fluids. This could include applications related to heater batteries, refrigeration or air compressors, cylinder gases, pressurisation units, steam boilers/mains. Where these problems are associated with items of plant or systems that are outside the scope of this programme, at this level, the problems should be presented in such a way that detailed knowledge of the technology of these systems is not required. The emphasis should be on the application of the various gas laws in scenarios that are related to building services applications.

To achieve a distinction grade learners must meet all of the pass and merit grade criteria **and** the two distinction grade criteria.

For D1, learners must evaluate how the combined factors that affect fluid flow influence the design of building services installations. This evaluation should not only illustrations where different fluid flow situations occur, it must also evaluate how fluid flow principles influence design and performance of installations and equipment. Learners might evaluate why specific design criteria are used for a particular pipe or ductwork installation, how design data which would otherwise have to be calculated is made readily available to designers, how knowledge and applications of the principles of fluid flow can minimise pump and fan duties, how commissioning equipment and instruments have evolved to be more effective or might be improved etc. It is strongly recommended that these should be contextualised by use of realistic practical applications taken from learner's own field of building services engineering.

For D2, learners must justify the selection and specification of a range of fans, pumps and/or compressors in terms of design data and operating principles. As part of the justification learners are expected to make the link with appropriate underpinning principles. The selections must be supported by appropriate calculations, such as to plot system curves, apply fan and pump laws to determine operating performance requirements. Learners must also make appropriate use of manufacturers data and select a range of plant commensurate to their field of vocational speciality within building services. Learners should cover at least two of the three devices, ie fans, pumps and compressors.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

The learning outcomes in this unit are closely linked with, for example, *Unit 34: Heating in Building Services Engineering*, *Unit 35: Ventilation and Air Conditioning in Building Services Engineering*, *Unit 37: Refrigeration Technology in Building Services Engineering* and *Unit 38: Plumbing Technology in Building Services Engineering,* together with similar units at Higher Nationals and degree level.

This unit may have links to the Edexcel Level 3 Technical and Professional NVQs for Construction and the Built Environment. Updated information on this, and a summary mapping of the unit to the CIC Occupational Standards, is available from Edexcel. See *Annexe D: National Occupational Standards/mapping with NVQs*.

This unit presents opportunities to demonstrate key skills in application in number, communication and problem solving. Opportunities for satisfying requirements for Wider Curriculum Mapping are summarised in *Annexe F: Wider curriculum mapping*.

Essential resources

Equipment which provides learners with 'hands-on' experience of observing and measuring processes such as venturi meters, pressure loss in pipe/duct, laminar and turbulent flow, pressure measuring equipment, pump performance, while not essential would be highly advantageous. Centres are encouraged to use as much practical science as possible. While specialist laboratory hydraulic test benches are very useful, some of these specialist units can be expensive but many items can be improvised at lower costs.

Health, safety and welfare issues must be considered at all times and risk assessments should be undertaken for all demonstrations and experiments used in the delivery or assessment of the unit.

Indicative reading for learners

Textbooks

Eastop T and McConkey A — *Applied Thermodynamics for Engineering Technologists, 5th Edition* (Longman, 1993) ISBN 0582091934

Moss K — *Heat and Mass Transfer in Building Services Design* (Spon Press, 1998) ISBN 0419226508

Rogers G and Mayhew Y— *Thermodynamics and Transport Properties of Fluids, 5th Edition* (Basil Blackwell, 1994) ISBN 0631197036

Sherwin K and Horsley M — *Thermofluids* (Spon Press, 1995) ISBN 0412598000

Key skills

Achievement of key skills is not a requirement of this qualification but it is encouraged. Suggestions of opportunities for the generation of Level 3 key skill evidence are given here. Tutors should check that learners have produced all the evidence required by part B of the key skills specifications when assessing this evidence. Learners may need to develop additional evidence elsewhere to fully meet the requirements of the key skills specifications.

Application of number Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• examining static fluid systems in terms of the laws that govern their behaviour and determining pressure due to static fluids • producing clear and accurate answers to a range of problems associated with the physical properties of fluids • producing clear and accurate answers to a range of problems associated with fluid flow using the continuity of flow and Bernoulli's equations • producing clear and accurate answers to a range of problems associated with energy losses in piped and ducted systems • producing clear and accurate answers to a range of problems associated with the gas laws and compressible fluids.	N3.1 Plan an activity and get relevant information from relevant sources. N3.2 Use your information to carry out multi-stage calculations to do with: a amounts or sizes b scales or proportion c handling statistics d using formulae. N3.3 Interpret the results of your calculations, present your findings and justify your methods.

Communication Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• evaluating how the combined factors that affect fluid flow influence the design of building services installations • justifying the selection and specification of a range of fans, pumps and/or compressors in terms of design data and operating principles.	C3.1a Take part in a group discussion. C3.1b Give a talk of at least eight minutes using an image or other support material. C3.2 Read and synthesise information from at least **two** documents about the same subject. Each document must be a minimum of 1000 words long. C3.3 Write **two** different types of documents each one giving different information about complex subjects. One document must be at least 1000 words long.

Problem solving Level 3	
When learners are:	**They should be able to develop the following key skills evidence:**
• producing clear and accurate answers to a range of problems associated with the physical properties of fluids • producing clear and accurate answers to a range of problems associated with fluid flow using the continuity of flow and Bernoulli's equations • producing clear and accurate answers to a range of problems associated with energy losses in piped and ducted systems • producing clear and accurate answers to a range of problems associated with the gas laws and compressible fluids • justifying the selection and specification of a range of fans, pumps and/or compressors in terms of design data and operating principles.	PS3.1 Explore a problem and identify different ways of tackling it. PS3.2 Plan and implement at least one way of solving the problem. PS3.3 Check if the problem has been solved and review your approach to problem solving.