Unit 32: Building Services Control Systems

Unit code: J/600/0384

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit will enable learners to develop a knowledge of the purpose and functions of building services control systems, an understanding of the operational characteristics of control components and devices, and the skills to develop control strategies, schemes and schematic drawings for building services systems.

Unit introduction

The need for, and complexity of, automatic control systems for use in building services installations has increased significantly in recent years. The ongoing need to reduce energy consumption, coupled with progress in technology, has resulted in the development of sophisticated systems which can monitor and optimise plant performance to meet building needs.

Although current legislation makes it impossible to avoid the use of control systems, generally these are not given sufficient consideration by designers, and are not understood by users.

A sound understanding of control systems, what they do and how they work, is fundamental to all those involved with building services engineering, whether as designers, installers, control engineers, commissioning engineers or owners and/or facilities managers.

The unit explores control systems in terms of fundamental control principles, the features of the equipment and components used, and the design and specification of control strategies for specific applications. It covers the standard forms of control application, but not the more specialised technology associated with building management systems or electronic control theory.

Learning outcomes

On completion of this unit a learner should:

1 Know the purpose of building services control systems and the functions they perform

2 Understand the principles associated with building services control systems

3 Know the operational characteristics of control components and devices

4 Be able to develop appropriate control strategies, schemes and schematic drawings for building services systems.

Unit content

1 Know the purpose of building services control systems and the functions they perform

Purpose of controls and control systems: what building services controls do; consequences of poor control for owner and environment; legislative requirements

Functions: generic functions eg temperature, humidity, air quality, level, flow, lighting level, time, contamination/pollution, pressure, fire and smoke; specific adaptations of the generic function eg weather compensation, night set-back, zone control, optimum start/stop, system frost protection, fabric protection, pump exercising, plant sequencing; safety controls (functions performed by safety controls and control systems eg flame failure, combustion, pressure relief, leak detection, high and low level warning)

2 Understand the principles associated with building services control systems

Principles: terminology; control loops; modes of control; operational features

Terminology: controlled condition; set point; controlled process; controlled variable; manipulated variable; deviation; disturbances; offset; controller; sensor; actuator; controlled device; lag; hunting; dead-band

Control loops: components eg open loop, closed loop, single loop, multi loop

Modes of control: eg two position, proportional, integral, derivative, proportional-integral (PI), proportional-integral-derivative (PID)

Operational features: lag; transport and transfer lag (causes, effects, methods of reduction); stability and accuracy; definition; causes and effects

3 Understand the operational characteristics of control components and devices

Control components: sensors; actuators; controlled devices; controllers: direct acting controls

Sensors: eg temperature, humidity, flow, velocity, pressure, level, air quality, rotational speed, gas detection, flame, smoke, light, presence, thermal radiation

Actuators: linear actuators; rotary actuators; types of power; drive and positional feedback

Controlled devices: control valves (types, operation, associated problems); control valve characteristics; valve authority; applications; control dampers (types, blade action, construction, operation); inherent and installed characteristics; applications; damper authority; mixing; other controlled devices (types, operating principles, features, characteristics); examples such as light dimmers, variable speed fans, pumps and compressors

Controllers: purpose; control signal media (mechanical; pneumatic; electrical; electronic); control data (examples of analogue and digital); conversion from analogue to digital; the role of microprocessors and software in control systems; types eg manual, simple automatic, direct digital control, building management system and integrated control systems

Direct acting controls: eg thermostatic radiator valves, float valves, thermostatic expansion valves, pressure relief valves, flame failure valves, thermostatic shower mixing valves, thermostatic hot water valves

4 Be able to develop appropriate control strategies, schemes and schematic drawings for building services systems

Control functions: desirable and essential; for installations, systems and items of plant

Functional design strategies: key features to be identified before control strategy; key factors to be considered when selecting appropriate control strategies

Control strategies: automatic or direct digital control strategies for various specific building services installations and plant eg low pressure hot water heating systems and boiler plant, central ventilation/ warm air heating/air conditioning systems and air handling units, domestic hot water installations, calorifiers and hot water generators, chilled water installations and refrigeration plant, packaged air conditioning systems, refrigeration plant for commercial applications; location of sensors to achieve required control functions; sequence of events and scenarios; functions of various sensors; selection of appropriate sensor set points, dead bands (differential)

Drawings: production of appropriate schematic control drawings and sketches; requirement to communicate control system detailed designs; use of drawing symbols and annotation

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 identify the purpose of controls and control systems for building services [CT1, CT2, RL2, RL3, RL6, SM2, SM3]	**M1** compare different types of building services controls	**D1** evaluate the energy, environmental, financial and operational benefits of specific control systems
P2 describe the functions control systems perform [CT1, CT2, RL2, RL3, RL6, SM2, SM3]		
P3 explain the fundamental principles of control loops [CT1, CT2, RL2, RL3, RL6, SM2, SM3]	**M2** produce control schemes for specific installations	
P4 explain the operational features, properties and characteristics of control loops [CT1, CT2, RL2, RL3, RL6, SM2, SM3]		
P5 describe how the features, characteristics and operating principles of control components and devices affect their specification [CT1, CT2, RL2, RL3, RL6, SM2, SM3]	**M3** interpret given drawings, schedules and specifications.	**D2** justify the rationale used in the production of control strategies.
P6 outline the operating characteristics of direct acting controls [CT1, CT2, RL2, RL3, RL6, SM2, SM3]		

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	identify control functions for specific applications [CT1, CT2, RL2, RL3, RL6, SM2, SM3]		
P8	produce functional design and control strategies for given building services installations [CT1, CT2, RL2, RL3, RL6, SM2, SM3]		
P9	produce detailed drawings to support control strategies. [CT1, CT2, RL2, RL3, RL6, SM2, SM3]		

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

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

Essential guidance for tutors

Delivery

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 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 linked and form a logical and progressive structure. Teaching and learning strategies should reinforce this integrated learner-centred approach. Learning outcomes 1, 2 and 3 provide the underpinning knowledge of what building services control systems do and how they work. This should prepare learners for learning outcome 4 where they are required to apply this knowledge by specifying control systems for real applications.

The method of delivery should be, as far as possible, activity based. Learning activities could include the use of case studies, product investigations, laboratory work and design exercises. The unit should not be perceived as an academic exercise and should at all times be based on real-life applications reflecting industry best practice.

Learners do not need to cover every possible control hardware or schemes for every mechanical and electrical building services installations. The unit content should be interpreted so that it meets the vocational needs of learners. It is recommended that as far as possible the unit is integrated with other specialist vocational technology units in the programme rather than delivered in isolation.

Given that this unit is inherently about a form of technology that is specifically applied to various mechanical and electrical building engineering services, there is an assumption that learners have a basic understanding or are studying one or more of these other building services units concurrently.

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

Health, safety and welfare issues are paramount and should be reinforced through close supervision of all workshops and activity areas, and risk assessments must be undertaken before practical activities are taken. Centres are advised to read the *Delivery approach* section in the specification.

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
Introduction to unit
Tutor input on purpose and function of building service control systems
Individual learner research for manufacturer information about control systems
Tutor input on fundamental principles Tutor demonstration and learner-centred practical activities on inspecting control systems Small group work on individual principles, followed by short presentations to class
Assignment 1: The Purpose, Function and Fundamental Principles of Building Services Control Systems
Tutor input on sensors and control components Learner practical activity on features/characteristics Visits to sites to see applications and uses Individual learner activity on features and characteristics Tutor demonstration of inspecting various features and characteristics, supported by individual learner practical activities
Tutor input on control strategies Individual practical activities and/or case studies on control strategies Visits to manufacturers/building services designers Individual learner activity – looking at design schedules – graphical detailing
Learner research for information on benefits of control systems Whole-class, tutor-led tutorial/discussion on benefits of control systems
Assignment 2: Control Systems: Components, Sensors, Strategies and Operational Benefits
Review of unit and assignment feedback

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 used and tutors are encouraged to consider and adopt these where appropriate. Some example 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.

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

The structure of the unit suggests that the grading criteria could be addressed fully by using two integrative assignments.

Although this unit can be stand alone, it is strongly recommended that, where learners are studying other units concurrently, centres consider integrative assignments. For example, the assessment evidence for the learning outcomes of this unit could be integrated with assessments associated with heating, ventilation and air conditioning, refrigeration, lighting and hot water.

This approach provides added realism and avoids unnecessary duplication. As a general principle, assessments should be contextualised to reflect learners' vocational background or aspirations.

Assessment should include the control requirements associated with two or more types of building services installations within the specialist group. For example, heating, ventilation and air conditioning, or refrigeration, ventilation and air-conditioning, or heating and hot water, or lighting. As services control installations often fall within the remit of electrical installation engineers, learners with an electrical installations bias are expected to also include controls associated with mechanical building services.

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

For P1, learners must identify the purpose of controls and control systems for building services systems. There is no requirement for a deeper treatment at this level.

For P2, learners must describe the functions controls and control systems commonly perform. They could contextualise the functions to include the generic, specific and safety functions expected for a variety of vocationally-relevant applications. Evidence could take the form of a presentation or a report, supported by appropriate diagrams and other images.

For P3, learners must explain, using correct terminology, the fundamental principles of control loops and, for P4, the operational features, properties and characteristics of the modes of control performed by these loops. It is important that control terminology is used correctly and appropriately throughout the explanation and that all features and characteristics are explained and illustrated with vocationally-relevant applications. Examples of suitable evidence approaches are as for P1.

For P5, learners must describe how the features, characteristics and operating principles of control components and devices affect their specification. This should include reference to the features and characteristics of the various types of sensors, actuators, controlled devices and controllers that most accurately reflect their vocational background or aspirations. This must include the range of control components for two or more different types of vocationally-relevant building services installations. Evidence could take the form of a presentation or a report, supported by appropriate diagrams and other images. Manufacturers' brochures and specifications are not sufficient on their own but could be used to support the required evidence.

For P6, learners must outline the operating characteristics of direct acting components. Having identified the locations where such controls might be used, learners are expected to describe the construction, operating principles, functions and limitations of those controls within the context of that installation. The installations used should be those that most accurately reflect learners' vocational backgrounds or aspirations but must contain a range of different buildings services installations and their associated plant. The tutor could identify the installations in the form of a services installation layout and/or schematic drawings or they could be learners' own designs if used as part of an integrated assignment.

For P7, learners must identify control functions required for specific applications in order to satisfy the requirements of legislation, good practice and client needs. The installations used should be those that most accurately reflect learners' vocational backgrounds or aspirations but must contain a range of different buildings services installations and their associated plant.

The tutor could identify the installations in the form of a services installation layout and/or schematic drawings or they could be learners' own designs if used as part of an integrated assignment. Learners must refer to why a particular function is required, and whether it satisfies legislative requirements, good practice recommendations or a particular client need.

For P8, learners must produce functional and workable automatic or direct digital control scheme designs and control strategies appropriate to specific building services installations.

For P9, learners must produce detailed schematic drawing(s) indicating the locations of all necessary sensors and control components, together with the controller requirements. These should relate to the design and control strategies evidenced in P8.

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

For M1, learners are expected to compare alternative types of sensors, actuators, controlled devices and controllers for given, specific building services installations and recommend the most suitable. They must make informed and appropriate recommendations as to the most appropriate for specific vocationally-relevant installations. Learners should relate their decisions to the needs and characteristics of the particular installation and comment on the compatibility of the various components with each other, including details of the type of control signal. In making the recommendations, learners could make use of manufacturers' literature and data. This must be to support their recommendations and must not be a mechanistic use with little demonstration of understanding. This could be a natural extension of the work carried out for P1 and P2.

For M2, learners must produce comprehensive control schemes for specific building services installations. The control schemes should include the more complex installations including control of multiple plant and multi-circuit distribution networks etc. The designs should include details of all control components and their locations. There should be clear evidence that learners have considered the proposed design carefully including features of the installations, legislative constraints and the client's requirements. Controls, schematic drawings and reports should be well produced, detailed and unambiguous. This could be a natural qualitative extension of the work carried out for P3 and P4.

For M3, learners must interpret given drawings, schedules and specifications for specific installations. They should use these to produce detailed and comprehensive explanations of the control system operational sequence and settings. They are expected to use this information to write a comprehensive explanation of the sequence of events as an installations control system goes through its sequence from initial start, through the operational phase, to eventual shut down. This should include the roles of each control component, together with typical set points and dead bands, sensed and controlled condition values. This could be a natural extension of the work carried out for P5, P6, P7, P8 and P9.

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

For D1, learners must evaluate the energy, environmental, financial and operational benefits of a variety of specific control systems within building services installations. The evaluation must include factual evidence as well as engineering opinion. This could be a natural extension of the work carried out for P1, P2, P3, P4, M1 and M2.

For D2, learners must justify the rationale used in the production of control strategies and demonstrate how proposed control systems satisfy operational needs. In justifying the rationale learners must demonstrate clearly how a proposed strategy meets the needs of the building, client and end users. As part of the justification learners are expected to link the features of the strategy with appropriate, underpinning fundamental principles. This could be a natural extension of the work carried out for P5, P6, P7, P8, P9 and M3.

Programme of suggested assignments

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

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, P4, M1, M2, D1	The Purpose, Function and Fundamental Principles of Building Services Control Systems	A building service company is producing materials to market itself to hotel and holiday chains. As a building services engineer, you have been asked to contribute to this and to an up-to-date manual of fundamental principles for new trainees.	Leaflet, booklet and manual.
P5, P6, P7, P8, P9, M3, D2	Control Systems: Components, Sensors, Strategies and Operational Benefits	As a quality control building services engineer, you have been contracted to research into a range of sensors, control components, control strategies and the benefits of control systems, and to produce a report for a facilities manager.	Report with text, drawings, images, photographs, graphs, charts and calculations as appropriate, and a presentation to support the report.

Links to other BTEC units

This unit forms part of the BTEC Construction and the Built Environment sector suite. This unit has particular links with the following unit titles in the Construction and the Built Environment suite:

Level 1	Level 2	Level 3
		Unit 1: Health, Safety and Welfare in Construction and the Built Environment
		Unit 5: Construction Technology and Design in Construction and Civil Engineering
		Unit 6: Building Technology in Construction

Essential resources

There are no specific resources necessary other than access to a wide range of technical and manufacturers' literature, some of which are listed below.

The availability of visual aids, such as the range of components indicated in learning outcome 3, is considered to be highly advantageous. These can be either in the form of individual items or preferably as part of live installations.

Employer engagement and vocational contexts

Support to enable centres to initiate and establish links to industry, and to networks arranging visits to industry and from property practitioners is given below:

- Learning and Skills Network
- National Education and Business Partnership Network
- The Royal Institution of Chartered Surveyors

Delivery of personal, learning and thinking skills (PLTS)

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 ...
Creative thinkers	producing scheme designs for given building services installations
Reflective learners	producing scheme designs for given building services installations
Self-managers	producing scheme designs for given building services installations.

Functional Skills – Level 2

Skill	When learners are ...
ICT – Develop, present and communicate information	
Enter, develop and format information independently to suit its meaning and purpose including: • text and tables • images • numbers • records	describing features and characteristics of sensors, actuators, etc
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	identifying the purpose of controls and control systems
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	describing features and characteristics of eg sensors.