Unit 35: Ventilation and Air Conditioning Design in Building Services Engineering

Unit code: H/600/0375

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit aims to give learners the opportunity to develop their knowledge and understanding of ventilation and air conditioning design and develop skills in designing and specifying effective and efficient installations for a variety of buildings.

Unit introduction

For many centuries, ventilation has been recognised as being essential to the promotion of healthy and comfortable buildings. Nowadays, ventilation is considered even more important because buildings are more airtight and legislation requires buildings to have a clean, wholesome, comfortable and fresh environment.

Many buildings have a tendency to overheat in summer and often require methods of cooling them down. Air conditioning, once seen as a benchmark for luxury, is a method of doing this but at a price that has to be justified and minimised in the modern energy-conscious world.

A sound understanding of the principles, procedures and technologies of modern ventilation and air conditioning is fundamental to the role of the building services engineer. This is particularly true for those involved in the heating ventilating and air conditioning (HVAC) sector, often referred to as the mechanical building engineering services.

The unit explores the development of ventilation, ducted warm air heating and air conditioning installations in a progressive manner. It begins with agreeing the client requirements for a system, proceeds through the design of layouts and the sizing, selection and specification of ductwork and equipment, and concludes with the commissioning of the system and its subsequent maintenance.

Refrigeration is an essential part of any air conditioning installation and although basic principles and fundamental components of refrigeration are included in the unit content it is not the main focus of this unit. There are other units at this level that deal with refrigeration technology in more depth. The unit does not consider in any depth installations that provide multi-zone air conditioning associated with large and complex buildings. These systems, and other more specialised ventilation installations, are dealt with in other qualifications.

Learning outcomes

On completion of this unit a learner should:

1 Be able to establish ventilation, warm air heating and air conditioning requirements for buildings

2 Understand the operational characteristics of ventilation and air conditioning equipment, plant and materials

3 Be able to design ventilation, warm air heating and simple single zone air conditioning installations

4 Be able to size, select and specify ventilation and air conditioning systems, ductwork, plant and equipment.

Unit content

1 Be able to establish ventilation, warm air heating and air conditioning requirements for buildings

Requirements: purpose of ventilation; reasons for providing comfort and process ventilation; client, user and environmental requirements and considerations; health and safety and other statutory requirements; identification of locations with specific ventilation requirements; types of contaminant; reasons for providing air conditioning in buildings; user and environmental requirements and considerations; sources of heat gain to buildings; identification of locations requiring air conditioning; advantages and disadvantages of warm air heating as an alternative to LTHW and other heating distribution media; identifying zones and locations suitable for warm air heating; establishing performance requirements for proposed installations

Design conditions: methods of specifying ventilation rates; selection of ventilation rates for specific locations; occupational exposure limits (OEL), workplace exposure limits (WEL), maximum exposure limits (MEL) for single specific contaminants; selection of internal and external design conditions for warm air heated and air conditioned rooms; impact of room air velocity and temperature on comfort

Cooling loads: estimation of heat gains and cooling loads using tabulated data and established 'rules-of-thumb'

Ventilation systems: operating principles; applications and key performance characteristics of natural ventilation; mechanical ventilation; comfort cooling/warm air heating/air conditioning and mixed mode ventilation systems; energy and environmental implications of ventilation and air conditioning installations; energy implications of alternative systems; selecting ventilation and air conditioning strategies; local exhaust ventilation (LEV)

2 Understand the operational characteristics of ventilation and air conditioning equipment, plant and materials

Air terminal devices: characteristics, terminology, operational features, materials, installation requirements and application of supply and extract air terminal devices; control of quantity and direction of air discharge in supply and extract devices; operational features, installation requirements, materials and suction dynamics of booths, canopies, hoods and other extract devices used in commercial kitchens and industrial applications; grease filters, grease removal and fire prevention in kitchen canopies

Ductwork and jointing systems: ductwork shapes and materials used for HVAC systems; characteristics and features of jointing, assembly and installation procedures; relationship between physical properties of ductwork materials and their application; flexible and fire-rated ductwork; criteria for selection of materials and shape; published standards and specification for ductwork

Ductwork ancillary components: requirement for, characteristics, operational features and selection criteria of various types of ductwork items eg volume control dampers, fire and smoke dampers, access doors, flexible connections, test points

Air handling plant – fans: types of fan; characteristics, operational features and application of fans; types of drive; installation requirements and ductwork connections

Heater/cooler batteries: types, materials, characteristics, operational features and application of heater batteries; chilled water and direct expansion cooling coils; installation requirements and ductwork connections

Heat recovery devices: types of heat recovery device; characteristics, operational features and application of heat recovery devices; installation requirements and ductwork connections

Air cleaning devices: terminology and definitions associated with filters and air cleaning devices; group and class of filter; filter testing methods; types, characteristics, operational features and application of filters and dust collection/removal devices for air handling systems; installation requirements and ductwork connections

Humidifiers: types of humidifier; characteristics, operational features and application of humidifiers; installation requirements and ductwork connections; water supply; maintenance and health and safety implications of humidifiers

Refrigeration plant: principles, components and application of vapour compression refrigeration systems; application of refrigeration in air conditioning systems; operation, features and application of heat pumps

Air handling units: configurations and features of simple, composite air handling units (AHUs), local exhaust ventilation systems, dust collection and packaged air conditioning systems; control requirements and arrangements for ventilation and warm air heating installations

3 Be able to design ventilation, warm air heating and simple single zone air conditioning installations

Design of HVAC installations: layout of supply air devices to achieve good room air distribution; location of extract devices for effective operation; relationship between supply and extract devices in balanced supply and extract systems; design of simple local exhaust ventilation and other industrial/commercial process ventilation; ductwork systems and arrangements for comfort/process ventilation; warm air heating and air conditioning installations; features of good ductwork design; prevention of noise problems; accommodation of ductwork within buildings; use of ductwork design and installation standards and codes; criteria and methods for zoning installations; designing for energy efficiency; prevention of spread of smoke and fire via ductwork installations; provision for maintenance and testing ductwork

Design of air handling plant: space requirements; types of accommodation for air handling units; refrigeration/chiller plant and fans; location of air intake and discharge points; structural and builder work requirements to accommodate air handling plant and ductwork

Provision for maintenance and commissioning: reasons for commissioning duct networks; location of flow regulation devices

Design drawings: communication of detailed designs; use of drawing symbols and annotation; production of appropriate drawings and sketches

4 Be able to size, select and specify ventilation and air conditioning systems, ductwork, plant and equipment

Air flow rates and supply conditions: calculation of air flow rates for mechanical supply and extract ventilation systems; supply air conditions, mass and volumetric flow rates to maintain design room conditions for warm air heating and single zone air conditioning applications; plotting summer and winter psychrometric cycles for simple air conditioning applications; balance between fresh air and thermal requirements in warm air heating and air conditioning installations; determining re-circulation rates

Air terminal devices: selection of supply air terminal devices and booths, canopies, hoods and other extract devices using manufacturer information; throw, resistance and noise characteristics; production of air terminal device specifications and schedules

Ductwork: selection of ductwork design parameters; use of manual calculations and computer software to determine duct sizes by use of constant pressure drop and/or constant velocity methods, total, static and velocity pressure in ductwork; total resistance of index circuits; methods of producing balanced systems and absorbing excess pressure at branches; establishing commissioning data for ductwork distribution networks

Fans: application of margins; determining fan duty; selection of fans from manufacturer data; efficiency and operational features; production of fan schedules; establishing commissioning data

Air conditioning plant: use of psychrometric cycles to determine cooler coil, heater battery, frost coil and humidifier duties; selection of plant and components from manufacturer data; production of plant specifications and schedules

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 produce pre-design appraisals of the ventilation, warm air heating and air conditioning requirements of a building [IE1, IE2, IE3, IE4, IE6, CT1, CT2, CT3]	**M1** evaluate the purpose and use of exposure limits for air contaminants	**D1** justify the different purposes of occupational, workplace and maximum exposure limits
P2 establish ventilation, warm air heating and air conditioning design data and parameters for buildings [IE1, IE2, IE3, IE4, IE6, CT1, CT2, CT3]		
P3 estimate cooling loads using tabulated data and rules of thumb [IE1, IE2, IE3, IE4, IE6, CT1, CT2, CT3]		
P4 describe the operational characteristics of commonly used plant and equipment associated with ventilation, warm air heating and air conditioning installations [IE1, IE2, IE3, IE4, IE6, CT1, CT2, CT3]	**M2** specify components of ventilation, warm air heating and air conditioning installations for specific purposes and situations	
P5 explain how the operational features of ventilation and air conditioning plant and equipment influence their application [IE1, IE2, IE3, IE4, IE6, CT1, CT2, CT3]		
P6 select appropriate plant, materials and equipment to meet the needs of the air systems in buildings [IE1, IE2, IE3, IE4, IE6, CT1, CT2, CT3]	**M3** produce comprehensive and detailed designs for air-based heating, ventilation and air conditioning installations	

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 plan ductwork installation configurations and design air-based system layouts [IE1, IE2, IE3, IE4, IE6, CT1, CT2, CT3]		
P8 plan a simple air handling unit plant room and central plant arrangements and configurations [IE1, IE2, IE3, IE4, IE6, CT1, CT2, CT3]		
P9 produce appropriate design drawings of proposed air-based installations [IE1, IE2, IE3, IE4, IE6, CT1, CT2, CT3]		
P10 calculate mass/volumetric flow rates, duct sizes and resistances for air supply and extract ductwork [IE1, IE2, IE3, IE4, IE6, CT1, CT2, CT3]	**M4** analyse installation drawings, calculations and manufacturers' data to produce detailed schedules and commissioning data.	**D2** justify the rationale and data used in the sizing and specification of the various components of ventilation, warm air heating and air conditioning installations.
P11 perform the calculations required to select fans for ductwork installations [IE1, IE2, IE3, IE4, IE6, CT1, CT2, CT3]		
P12 select heater/cooler batteries, humidifiers, air terminal devices and other plant to meet the needs of ventilation, warm air heating and air conditioning installations. [IE1, IE2, IE3, IE4, IE6, CT1, CT2, CT3]		

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 other online resources and use of personal and/or industrial experience are all suitable. Delivery should stimulate, motivate, educate and enthuse learners. Visiting expert speakers and manufacturers could add to the relevance of the subject.

The learning outcomes are closely linked and form a logical and progressive structure. Teaching and learning strategies should reinforce this integrated learner-centred approach. Learners should appreciate that each aspect and topic form a stage in the overall process of designing and specifying air-based HVAC installations.

The method of delivery should, as far as possible, be activity based where learning activities could include case studies, site visits, product investigations and design exercises. The unit should not be seen as an academic exercise and should at all times be based on real-life applications and reflect industry best practice.

The teaching process should balance the calculations implicit within learning outcome 4, the knowledge and understanding required in learning outcomes 1 and 2, and the creativity and application required in learning outcome 3.

Reference should be made to appropriate regulations, building services design guides and sources of reference wherever necessary. Learners should be encouraged to use these documents to make informed decisions concerning the design of HVAC installations, and to understand the consequences of those decisions. Energy efficiency, sustainable construction and the environmental implications of HVAC system design and specification are not identified as separate topics but they must form an inclusive theme in the delivery of all parts of this unit.

The use of current manufacturers' product information is also encouraged to help learners apply the principles and procedures they learn to real-life situations. This does not mean that mechanistic use of manufacturers' data, with little understanding, is acceptable. The same logic applies to the use of specialist building services engineering design software and spreadsheets. Their use is encouraged, but only after an understanding of the underlying principles required for manual calculations has been established.

The focus of this unit is on the application of principles and procedures to make decisions and produce solutions to realistic scenarios. This implies that before starting this unit learners will have an understanding of the science of thermal comfort, heat transfer, the psychrometric properties of air, the gas laws, the concepts of latent heat and sensible heat and their relationship to pressure, fluid flow, the operating characteristics of fans, control strategies for building engineering services, and the mathematics associated with the manipulation of these properties. Even if learners do not have this knowledge and understanding on entry, there will be no delivery and/or assessment issues if these relevant core principles are delivered early in the programme or concurrently with this unit.

The delivery of the various scientific topics needs to be coordinated with those in this unit. There is considerable scope however for the integration of the teaching and assessment of scientific principles with the application of those principles via this unit.

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, and *Annexe H: Provision and Use of Work Equipment Regulations 1998 (PUWER).*

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 content and grading criteria, importance of good design in ventilation and air conditioning systems and the consequence of poor design, fundamental definitions, features and essential components of ventilation, warm air heating and air conditioning systems
Whole-class teaching: understanding and interpreting buildings and their functioning, client briefs and end users needs, reasons for providing ventilation to buildings, legislative and statutory requirements for ventilation, recognising locations with potential requirements for air conditioning and warm air heating, sources of heat gain, effect of overheated buildings
Learner exercises to study and assimilate architectural drawings, gather site and design information and identify client's ventilation, air conditioning warm air heating needs
Whole-class teaching: methods of specifying ventilation rates, use of sources of reference, legislation associated with ventilation provision, identifying ventilation rates for various locations requiring ventilation for different purposes, selection of internal summer and winter design conditions for air conditioned spaces, relationship between thermal comfort factors and temperatures selected for locations, methods and techniques for estimating cooling loads for locations
Learner exercises to select ventilation rates for locations requiring a fresh air provision and selecting internal design conditions for locations requiring air conditioning
Whole-class teaching: features, principles and characteristics of various types of natural, mechanical and mixed mode ventilation for comfort and process ventilation, warm air and air conditioning systems commonly used
Assignment 1: Client Needs, Cooling Loads, Ventilation and Air Conditioning Systems and Strategies
Whole-class teaching: terminology, features, operational characteristics, location, materials and installation standards for supply air terminal devices, extract terminal devices, booths, hoods, canopies and local exhaust ventilation devices, positioning and layout of different types of supply air and extract devices to achieve effective room air distribution. Use of transfer grilles, positioning local exhaust ventilation (LEV) devices, hoods and canopies for local exhaust and catering applications. Provision of make-up air for exhaust ventilation applications
Learner-guided research activities: ductwork and jointing systems; shapes, materials, sizes, standard fittings and jointing methods, standards and specifications for various types of ductwork and ductwork fittings, uses and limitations of flexible ductwork
Whole-class teaching: minimising fire and smoke hazards within ductwork, fire-rated ductwork, preventing spread of fire, fire stopping, use of fire and smoke dampers
Assignment 2: Operational Characteristics of Ventilation and Air Conditioning Equipment, Plant and Materials
Whole-class teaching: design of ductwork layouts for comfort, process ventilation and LEV applications, accommodating ductwork in buildings, spatial requirements for ductwork, factors affecting shape of ductwork and the materials used, good ductwork design to produce efficient, inherently balanced installations which minimise noise generation, criteria for selection of bend types and radius, branch types and other ductwork fittings for ductwork installation, location of access doors, test points and other ancillary equipment, standards and conventions for installation drawings
Learner exercises on positioning air supply and extract devices and designing ductwork layouts for various applications

Topic and suggested assignments/activities and/assessment
Learner research activities on types of fan, characteristics, types of drive, installation and duct connections, heater/cooler batteries, heat recovery devices, types, materials, operational features and characteristics of heater/cooler batteries and heat recovery devices; humidifiers: types, operational features and application of humidifiers, health and safety risks associated with humidifiers, maintenance requirements, types and classification of filters and air cleaning devices, operating methods by which filters and air cleaning devices remove airborne contaminants, application for different filter classes, grease filters and grease removal devices, terminology and definitions for filter and air cleaning device properties, installation and maintenance requirements, construction and configuration of air handling units
Whole-class teaching: reasons for refrigeration in buildings and a/c applications, global warming and climate change associated with the use of refrigeration and refrigerants, operating principles and features of the main components of the vapour compression cycle, application of refrigeration via direct expansion (DX) and chilled water, design of air handling plant rooms, planning space requirements, space allowance, provision for maintenance and cleaning, air intake to AHU builders' work requirement
Learner exercises in producing annotated layout and schematic drawings
Whole-class teaching: calculation of air flow rates for supply and extract ventilation installations to provide required ventilation rate, selection of supply air temperatures, calculation of flow rates for winter warm air heating to maintain design temperatures
Whole-class teaching: use of psychrometric charts and formulae to determine summer and winter supply temperatures and moisture content, calculation of mass and volumetric supply rates, plotting psychrometric cycles for summer and winter air conditioning applications, maintaining fresh air requirements in thermal comfort applications, re-circulated air, re-circulation rates, plotting mixed air conditions
Learner exercise to find flow rates, supply conditions and plot psychrometric cycles
Assignment 3: HVAC Equipment, Feasible Options and Layout Designs
Whole-class teaching: determining required throw for supply air devices, interpreting manufacturer data for supply and extract air devices to select appropriate sizes identifying throw, noise criteria rating, resistance face/throat velocity etc from manufacturer data, production of supply and extract air devices schedules
Learner exercise to select air terminal devices for applications using appropriate data
Whole-class teaching: selection of ductwork design parameters for low pressure (low velocity) ductwork circuits, selection of preliminary duct sizes for calculated flow rates using constant pressure drop and constant velocity methods, ductwork resistance; identification of index runs, determining pressure loss due to straight duct, pressure loss caused by fittings and plant, calculating total pressure loss of index circuits, methods used for producing balanced circuits and absorbing excess pressure at branches, production of commissioning data for ductwork circuits, use of manual duct sizing calculation sheets, computer spreadsheets/commercial software
Individual exercise on duct network resistance calculations, for both supply and extract
Whole-class teaching: fan duties, application of margins, criteria for selecting fans for efficiency and performance, interpreting manufacturer data for a variety of fan types, production of fan schedules and commissioning data for selected fans, determining heater/cooler battery duties from psychrometric charts, selecting individual items of plant and composite air handling units using psychrometric and manufacturer data
Assignment 4: Sizing and Selection of Ductwork, Plotting of Air Conditioning Psychrometric Cycles, Sizing and Selection of HVAC Plant
Review of unit and assignment feedback

Assessment

Evidence for this unit may be gathered from a variety of sources but the unit has been written to allow all the assessment evidence to be produced from well-designed project-based assignments on the detailed design of ventilation, warm air heating and air conditioning installations for a real building.

The building(s) selected for the purpose of assessment should have a wide variety of uses, functions, activities and features. This will give learners the opportunity to consider options and make decisions. For example, office buildings with large numbers of similar rooms would not be appropriate as they provide insufficient opportunity for variety or decision making. It is equally important that any selected buildings are not too complex and are capable of realistically incorporating standard comfort and process ventilation, warm air heating and single zone air conditioning installations. In order to maintain the freshness and rigor of the assessment process centres should avoid using the same buildings year-on-year.

Learners should be given a range of architectural drawings for them to extract the required information. These could be some or all of plans, elevations, sections and/or details. Drawings should be supported by a simple client brief to provide background information on both the client and their aspirations and the functional requirements for the building.

Where centres intend to use buildings of their own design, the buildings must meet current building design standards and should contain the same information as would be present in professionally produced architectural drawings. Although this unit can stand alone it is strongly recommended that, where learners are studying other units concurrently, the assessment evidence is coordinated to avoid duplication.

Centres may want to consider integrative assignments. For example, assessments associated with thermal comfort, properties of materials, sustainable development, environmental impact, psychrometric properties of air, flow of fluids, performance of fans and/or control applications, can be integrated within a single assessment instrument.

To achieve a pass grade learners must meet the 12 pass criteria listed in the grading grid.

For P1, learners must produce pre-design appraisals of the ventilation, warm air heating and air conditioning requirements of a building. They must assimilate information provided via drawings and a client's brief to complete an appraisal of the building, the client and the end user. They will use this information to establish the ventilation, warm air heating and air conditioning needs of the building. The appraisal should consider the form, fabric and function of the building itself and the characteristics and requirements of the client and their end users.

For P2, learners must establish ventilation, warm air heating and air conditioning design data and parameters for buildings. Learners must demonstrate that they are able to recognise the operational activities, features and usage of both the building in general and individual locations in particular. For those areas requiring ventilation (comfort or process) learners are expected to select ventilation rates expressed in appropriate terms such as air changes or volumetric flow rates. Learners are also expected to identify parts of a building which may need warm air heating or air conditioning and establish design data and parameters for these systems.

For P3, learners must estimate cooling loads using tabulated data and established estimating methods or 'rules of thumb' such as the *BSRIA Rules of Thumb*. In all cases it is important that learners support their selections by indicating the sources of reference and the factors in their selection. To avoid the mechanistic use of tables, locations requiring a degree of judgement should be included. Evidence could be in the form of a presentation or a report supported by appropriate data and tables.

For P4, learners must describe the operational characteristics of commonly used plant and equipment. They should refer to the operating principles, features, characteristics, advantages and disadvantages of the different plant and equipment commonly used to provide ventilation and maintain thermal comfort in buildings via air-based systems.

For P5, learners must explain how the operational characteristics described in P4 influence the applications to which the plant and equipment is put. This should include reference to natural and mechanical ventilation, warm air heating, comfort cooling, single zone air conditioning and mixed mode systems, including the various sub-divisions within these. The evidence should build on that produced for P4.

For P6, learners must select appropriate plant, materials and equipment for various locations within a building, but they do not need to justify or explain the selection. The selections must however be fit for purpose.

For P7, learners must plan ductwork installation configurations and design air-based system layouts. There is no need for selection, specification or sizing at this point as this is dealt with later.

For P8, learners must plan a simple air handling unit plant room and central plant arrangements and configurations. The broad principles applied in for P7 apply again here.

For P9, learners must produce simple design drawings for air-based heating, ventilation and air conditioning for a variety of installations. This should include ventilation (including simple process ventilation) warm air heating and air conditioning/comfort cooling installations. In order to complete the designs, learners must clearly select appropriate types (but not at this stage the particular size or model) of air terminal devices, fans, heater/cooler batteries, heat recovery devices, humidifiers, air cleaning devices, ductwork and ancillary equipment. Designs should indicate that the type of system, ductwork routing, air terminal placement, plant accommodation and appearance have been considered appropriately for the particular building. Learners must include appropriate layout and basic ductwork schematic drawings. The designs produced must be workable and appropriate.

For P10, learners must calculate consequent mass/volumetric flow rates, duct sizes and resistances for air supply and extract ductwork. Evidence should include the calculations necessary to determine ductwork sizes, flow rates and resistances using recognised procedures. The size of the circuits within the network should be representative of those selected in P6 and planned for in P7. Industry-standard software may be used for these procedures but this should be used to support and check manual calculations, not to replace them. Learners may wish to use spreadsheets or proforma calculation sheets. This is to be encouraged, but learners must demonstrate that they understand the procedures involved. Learners are not required to demonstrate their understanding of the underpinning principles of fluid flow in ducts, as these are assessed elsewhere. They are however required to demonstrate the ability to apply the recognised standard procedures derived from these principles. Evidence could be in the form of a report supported by calculations and diagrams as appropriate.

For P11, learners must size and select appropriate makes and models of fans for ductwork in HVAC installations. Calculations appropriate to the selection must be completed where necessary. For air conditioning and warm air heating installations, learners must plot summer and winter psychrometric cycles to establish the heater/cooler battery duties, refrigeration loads and humidifier duties as appropriate. It is implicit that learners will use manufacturer information and data to support their selection but there should be evidence that learners understand the procedures used.

For P12, learners must select appropriate plant and describe the features and characteristics of air terminal devices, heater/cooler batteries, humidifiers and other plant. Learners must relate how the features and characteristics of these items influence and contribute to their typical application. To achieve P12, learners are not required to exercise judgement in relating the features and characteristics to a particular application or to make comparisons between different types of plant.

It is recognised that many applications will tend to favour the use of air handling units and other 'packaged' plant arrangements rather than individual items. This is acceptable providing the required duties are established and the selected solutions are appropriate and fit for purpose. Evidence could be in the form of a report or presentation supported by calculations, diagrams and manufacturer data as appropriate.

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

For M1, learners must evaluate the purpose and use of exposure limits for air contaminants. Reference should be made to indoor air quality, reduction of air leakage from buildings and the possible presence of carbon dioxide (CO_2) and volatile organic compounds (VOCs), amongst other contaminants.

For M2, learners must specify components of ventilation, warm air heating and air conditioning installations for specific purposes and situations. Learners must demonstrate that they have exercised judgement in making their selections and should relate their decisions to the identified needs of particular clients and particular buildings. They must also explain any constraints and environmental considerations that may have influenced their recommendations. This could be a natural extension of the work carried out for P4 and P5.

For M3, learners must produce comprehensive and detailed designs for air-based heating, ventilation and air conditioning installations. The designs should include details of all items of plant and equipment (including controls) and their locations. There should be clear evidence that learners have carefully considered all aspects of the proposed design. This includes features and constraints of the building, the space requirements for the accommodation of ductwork and air handling plant, the client's requirements and the need for maintenance and commissioning. Detailed layout and schematic drawings should be produced. All drawings and reports must be well produced, detailed, annotated and unambiguous. This is an extension of the work carried out for P6, P7, P8 and P9.

For M4, learners must analyse installation drawings, calculations and manufacturers' data to produce detailed schedules and commissioning data. The drawings and data used should be provided by the tutor but the evidence should build on the knowledge and understanding gained in producing evidence for P10, P11 and P12.

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 justify the different purposes of occupational, workplace and maximum exposure limits. There is no requirement for an in-depth scientific treatment but it must be clear what the differences between the three are and how the exposure limits relate to each other for common contaminants. The evidence should build on that provided for M1.

For D2, learners must justify the rationale and data used in the sizing and specification of the various components of ventilation, warm air heating and air conditioning installations. This implies a review of the plant and equipment selections recommended in M4 and an explanation of how the proposed selections satisfy the appropriate performance requirements. In justifying the design parameters learners must explain clearly why they used particular parameters, what alternative parameters could have been used and the effect of using other parameters. For plant and components, learner justification should establish appropriate performance standards.

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 Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, M1, D1	Client Needs, Cooling Loads, Ventilation and Air Conditioning Systems and Strategies	As an air conditioning and ventilation engineer, you have been asked to complete the initial stages of the design process for the ventilation, warm air heating and air conditioning of a building. You have been provided with a detailed brief that contains all the information you need for the pre-design appraisal. You will need to gather design data and select the appropriate design process.	A report supported by drawings, images, graphs, tables, charts and calculations as appropriate.
P4, P5, M2	Operational Characteristics of Ventilation and Air Conditioning Equipment, Plant and Materials	The client is keen to know what plant and equipment is being considered for the HVAC design. You have been asked to complete a manual of the options available, the advantages and disadvantages of each and the reasons why specific items are preferable for the project in question.	A manual or catalogue of the items of plant and equipment from which the final selection will be made, together with recommendations.
P6, P7, P8, P9, M3	HVAC Equipment, Feasible Options and Layout Designs	You have been asked to explain to the client the features of the various options available for the items of plant and equipment to be used for the HVAC system for a building. You must also recommend what you believe to be the most appropriate HVAC designs for the building.	Appropriate and detailed HVAC systems designs.
P10, P11, P12, M4, D2	Sizing and Selection of Ductwork, Plotting of Air Conditioning Psychrometric Cycles, Sizing and Selection of HVAC Plant	You have been asked to perform the calculations necessary to complete the ductwork, equipment and plant sizing and selection stages of the HVAC design process.	A report supported by drawings, images, graphs, tables, completed psychrometric charts and calculations as appropriate.

Links to other BTEC units, other BTEC qualifications and other relevant units and qualifications

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
		Mathematics in Construction and the Built Environment
		Science and Materials in Construction and the Built Environment
		Building Services Control Systems
		Building Services Science
		Fluids – Static and Dynamic in Building Services Engineering

This unit links to the Level 3 NOS in BE Design.

Essential resources

Centres should have access to a wide range of hard copy or online technical publications, textbooks and manufacturers' literature. The use of readily available visual aids (such as the range of HVAC plant and components indicated in learning outcome 2) would be advantageous. These can be in the form of individual items, laboratory models or as part of live installations. Where live installations are used the requisite risk assessments should be completed. Centres should have access to sets of architectural drawings, ventilation and air conditioning system installations and schematic drawings to support the learning process and facilitate assessment. These could be in hard copy or electronic format. Where these drawings are used as part of the assessment process, it is recommended that repeated use of the same building is avoided in order to maintain the freshness of the assessment process. Learners may begin to use the industry-recognised software capable of sizing, selecting and specifying ductwork, plant and equipment. It is however vital that, if such software is used, learners can complete the calculations required in learning outcomes 1 and 4 using recognised manual procedures. The same principle applies to the graphical detailing required for learning outcome 3.

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:

- Chartered Institution of Building Services Engineering – www.cibse.org
- Heating and Ventilation Contractors Association – www.hvca.org.uk
- Learning and Skills Network – www.vocationallearning.org.uk
- National Education and Business Partnership Network – www.nebpn.org
- Summit Skills – www.summitskills.org.uk
- Work Experience/Workplace learning frameworks – Centre for Education and Industry (CEI University of Warwick) – www.warwick.ac.uk/wie/cei/

Indicative reading for learners

Textbooks

BSRIA – *A Guide to HVAC Building Services Engineering Calculations* (BSRIA, 2007) ISBN 9781903287910

BSRIA – *AG15 2002 The illustrated Guide to Mechanical Building Services* (BSRIA, 2002) ISBN 0860226069

Chadderton D – *Air Conditioning: A Practical Introduction, 2nd Edition* (Spon Press, 1999) ISBN 0419226109

Chartered Institution of Building Services Engineers – *B2 Ventilation & Air Conditioning* (CIBSE, 2001) ISBN 1903287162.

Chartered Institution of Building Services Engineers – *AM10 Natural Ventilation in Non Domestic Buildings* (CIBSE, 2005) ISBN 1903287561.

Chartered Institution of Building Services Engineers – *TM42 Fan Application Guide* (CIBSE, 2006) ISBN 1903287685

Chartered Institution of Building Services Engineers – *Guide A: Environmental Design, 7th Edition* (CIBSE, 2006) ISBN 1903287669

Chartered Institution of Building Services Engineers – *Guide F: Energy Efficiency in Buildings* (CIBSE, 2004) ISBN 1903287340

Chartered Institution of Building Services Engineers – *Guide B3: Ductwork* (CIBSE, 2002) ISBN 1 903287200

Chartered Institution of Building Services Engineers – *KS13: Refrigeration* (CIBSE, 2008) ISBN 9781903287910

Heating Ventilation & Air Conditioning Manufacturers Association – *Guide to Air Distribution Technology for The Internal Environment* (HEVAC, 2000)

Heating and Ventilating Contractors Association – *DW171; Specification for Kitchen Ventilation Systems* (HVCA, 2005) ISBN 0903783290

Martin P, Oughton D and Hodkinson S – *Faber and Kell's Heating and Air-conditioning of Buildings, 10th Edition* (Butterworth-Heinemann, 2008) ISBN 9780750683654

Journals

Building Services and Environmental Engineering – Datateam Publishing Ltd

Building Services Journal – CMP Information

Modern Building Services – Portico Publishing Ltd

Websites

www.bsria.co.uk	The Built Environment Experts
www.cibse.org	Chartered Institution of Building Services Engineers
www.modbs.co.uk	Modern Building Services

Delivery of personal, learning and thinking skills (PLTS)

The following table identifies opportunities for delivering PLTS within the assessment criteria of this unit:

Skill	When learners are ...
Independent enquirers	assimilating and analysing information provided by drawings and client briefs to identify the ventilation and air conditioning needs making decisions and exercising judgement on ventilation rates appraising the ventilation and air conditioning needs of a building from the perspective of the client, end user and legislation resolving problems relating to cooling loads and ventilation rates for buildings exercising judgement when extracting information from drawings and design guides to select appropriate ventilation rates researching the operational features and characteristics of HVAC systems exercising judgement when selecting appropriate HVAC strategies analysing and concluding how the features and characteristics of HVAC plant and equipment affect their application using judgement to select the most appropriate forms of HVAC plant solving problems associated with designing workable heating ventilating and air conditioning layouts exploring appropriate ductwork configurations for different HVAC systems using information to select HVAC plant and design functional layouts resolving problems associated with ductwork flow rates, sizes and consequent resistances selecting the ductwork design parameters and judging the consequences of their decisions analysing ductwork circuits and selecting appropriate data required for the network analysis solving problems in relation to sizing plant appropriate to specified installations researching heating equipment manufacturer performance data to identify appropriate items analysing manufacturer data and exercising judgement to select plant to match calculated requirements considering how the environmental implications of the plant and equipment influenced their selection providing evidence for the conclusions reached for the plant selected
Creative thinkers	generating designs for warm air heating and air conditioning proposals for buildings and considering alternative strategies and approaches researching HVAC plant and equipment to establish potential applications producing innovative designs based on research and case studies challenging pre-conceived or standard solutions for HVAC installation designs when considering feasible options refining designs to try out alternative strategies.

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	assessing their own progress and performance against the grading criteria within assignments programming and scheduling the work required for the successful completion of assignments against targets deadlines reviewing their own progress against programmes and work schedules and adjusting the programme accordingly dealing with feedback and criticism as a result of submitted work and formative exercises reflecting on feedback from assignments and using the information to improve their performance making verbal, graphical and written presentations to both formal and informal audiences, from the formative and summative assessments and exercises within the unit
Team workers	Where a teamwork approach is used for assessments or where learners work with others on formative exercises, opportunities exist for the following: • collaborating with others in establishing standards, design data and approaches which are common to all members of the team or to the building being considered • meeting and working effectively together as a member of a team to reach agreements and resolve issues • identifying and participating in the various roles and responsibilities that exist within the teamwork situation • working considerately, responsibly and effectively with other members of the team • reviewing and appraising the team's performance
Self-managers	working towards and completing assignments against deadlines and using initiative to resolve problems and issues producing and following a programme and work schedule for the completion of assignments against set deadlines balancing the competing pressures of their responsibilities at work and at home
Effective participators	Where a teamwork approach is used for assessments or where learners work with others on formative exercises, opportunities exist for the following; • resolving issues and concerns that arise within the team in a way that is acceptable to all members • discussing, agreeing and planning progression in a manageable way • establishing working practices and improvements within the team.

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	selecting and using appropriate software and ICT applications for the reports, research, data management, designs, graphical detailing, calculations, presentations implicit within assignments
Use ICT to effectively plan work and evaluate the effectiveness of the ICT system they have used	using ICT applications for planning assignments and reviewing the ICT applications used within the assignments
Manage information storage to enable efficient retrieval	maintaining the files and data produced when completing assignments in an efficient and effective way
Follow and understand the need for safety and security practices	using ICT for assignments
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	selecting and using information and data from web-based reference sites, e-publications, manufacturers' technical data, standards and graphical images for use within assignments
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	effectively accessing, selecting, evaluating fitness for purpose and using data, standards, legislation manufacturers' information, images and reference material via search engines, online reference sites and browsers when completing assignments
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	completing assignments including the appropriate use of correctly formatted, structured, justified and presented: • text for descriptions and explanations etc • tables for recording results, data and schedules • images from manufacturer information and CAD drawings etc • numerical information presented as formulae (with solutions) and spreadsheet(s) for the calculation of ventilation rates, heat gains, areas and volumes, duct sizing, network resistances • records presented as graphs, schedules, or spreadsheets for the calculated results required for plant selection and commissioning data
Bring together information to suit content and purpose	assembling the various components (text, images, tables, drawings, spreadsheets, records, charts, and calculations etc) implicit for assignments in a format appropriate for the mode of assessment ie report, portfolio and/or presentation

Skill	When learners are ...
Present information in ways that are fit for purpose and audience	reviewing and editing the various components (text, images, tables, drawings, spreadsheets, records, charts, and calculations etc) implicit for assignments so that it is fit for purpose for the audience and mode of assessment ie report, portfolio and/or presentation
Evaluate the selection and use of ICT tools and facilities used to present information	reviewing the suitability and performance of the ICT tools used during the completion of assignments, taking action as appropriate
Select and use ICT to communicate and exchange information safely, responsibly and effectively including storage of messages and contact lists	communicating and exchanging information via email or e-learning platforms with staff, colleagues, other team members or manufacturers
Mathematics	
Understand routine and non-routine problems in a wide range of familiar and unfamiliar contexts and situations	using scales to determine dimensions from drawings calculating room and building areas and volumes calculating ventilation and air flow rates calculating flow rates in duct distribution networks to meet heat output requirements estimating heat gains and cooling loads interpolating within graphs and tables to obtain data calculating frictional resistances for index circuits and additional resistance required to balance branch circuits using area and velocity ratios to determine pressure loss factors for ductwork fittings calculating supply conditions to satisfy sensible and latent heat loads in rooms performing calculations relating to the psychrometric properties of air applying percentage margins for plant selection applying correction factors to plant performance data to allow for varying operating conditions calculating performance requirements for HVAC plant using formulae in all of the above
Identify the situation or problem and the mathematical methods needed to tackle it	
Select and apply a range of skills to find solutions	
Use appropriate checking procedures and evaluate their effectiveness at each stage	using estimating and analytical techniques to check the reliability and appropriateness of mathematical results ie comparisons with 'rules of thumb', average results such as W/m^2 or W/m^3 for average heat gains, Pa/m for fan duties etc recognising sensible answers
Interpret and communicate solutions to practical problems in familiar and unfamiliar routine contexts and situations	using solutions obtained from calculations to select and specify plant and equipment and checking compliance with standards
Draw conclusions and provide mathematical justifications	analysing calculations to establish performance data for plant and equipment using mathematical techniques to justify design data and rationale

Skill	When learners are ...
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	contributing to formal and informal presentations and discussions on operating characteristics of plant and equipment etc as part of formative exercises and as part of formal presentations for assignments
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	reading design guides, standards, legislation, approved documents, textbooks, course notes, manufacturers information, websites, technical standards, design briefs, application manuals, technical memorandum etc in order to gather information for assignments
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	producing portfolio(s), reports and presentations implicit in assignments.