

Scottish Health Technical Memorandum 03-01 (Interim Version – Additional guidance related to COVID 19 to be added in an update in 2022)

Specialised ventilation for healthcare premises
Part A: The concept, design, specification, installation
and acceptance testing of healthcare ventilation systems

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Executive Summary

Scottish Health Technical Memorandum 03-01 – ‘Specialised ventilation in healthcare premises’ is published in two parts:

Part A: The concept, design, specification, installation and acceptance testing of healthcare ventilation systems.

Part B: The management, operation, maintenance and routine testing of existing healthcare ventilation systems.

The documents give comprehensive advice and guidance on the legal requirements, design implications, maintenance and operation of specialised ventilation in healthcare premises providing acute care. The use of these premises is very intense, the occupancy level high and the patients may be particularly susceptible to airborne infection risks. Their condition may also require close control of the environment.

The ventilation of non-healthcare facilities within the hospital curtilage should be designed to suit the application and specific guidance relating to the activity should be followed, for example pharmacy, central decontamination unit, etc. However, as they are on the hospital site, the means of providing ventilation should not adversely impact upon the hospital (for example, evaporative cooling towers should not be installed, sound levels should be appropriate and if the facility is within or attached to an area accessed by patients, their needs and the risk of airborne contamination should be considered).

In other types of healthcare facility that are outside of the hospital curtilage, for example GP practices, health centres, minor injuries units, dental, ophthalmic and podiatry clinics, mental health facilities, respite and long stay care homes and hospices, a risk assessment of the nature of the treatment being delivered, condition of the patients and intensity of use needs to be undertaken by those responsible for the facility in order to determine the extent to which this guidance will be applicable.

The guidance contained in Part A of this Scottish Health Technical Memorandum applies to new installations and major refurbishments of existing installations and should be considered as the standard to be achieved.

The guidance contained in Part B of this Scottish Health Technical Memorandum applies to all ventilation systems installed in healthcare premises irrespective of the age of the installation and should be considered as the standard to be achieved.

Scottish Health Technical Memorandum 03-01 (2022) supersedes all previous versions of Scottish Health Technical Memorandum 03-01 – ‘Specialised ventilation in healthcare premises’ (2014). It also supersedes SHTM 2025 (1994) and DV4 (1983).

Who should use this guidance?

This document is aimed at specifiers, designers, suppliers, installers, estates and facilities managers and operations. Elements of the document will also be relevant to

managers concerned with the day-to-day management of healthcare facilities and senior healthcare management.

Main changes since the 2014 edition

- design information for specific healthcare applications has been revised and information on the reason for ventilation given. For example, endoscopy rooms may now be either negative (to contain and remove odours and manage airborne risks to staff) or positive pressure (to maintain a higher level of cleanliness where it is intended to puncture body membranes with the endoscope). These endoscopy-specific risks (i.e. waste anaesthetic gases and pathogenic material (for example, multi-drug-resistant tuberculosis) discharged by the patient during the procedure being undertaken) were identified prior to the SARS-CoV-2 pandemic. As with other elements in Part A, the application of this change is not retrospective but applies to new installations and major refurbishments (see Preamble above);
- the client's needs and legal requirements are more clearly explained;
- this edition of Scottish Health Technical Memorandum 03-01 introduces the concept of the Ventilation Safety Group in healthcare organisations (similar to the Water Safety Group in Scottish Health Technical Memorandum 04-01 and the Electrical Safety Group in Scottish Health Technical Memorandum 06-01). This is a multidisciplinary group whose remit will be to assess all aspects of ventilation safety and resilience required for the safe development and operation of healthcare premises;
- the SHTM introduces a standard method of identifying and labelling ventilation systems and the creation of an inventory of installed systems;
- the issues of resilience and diversity are addressed;
- guidance is provided on refurbishments or when changing the use of an existing installation;
- guidance is given on lifecycle and the updating of mid-life plant;
- design information for specific healthcare application has been extensively revised;
- issues around rooms where anaesthetic agents are used are addressed;
- airflow rates are more tailored to the applications to take advantage of new fan and control technology and so reduce energy consumption;
- revised air quality and filter standards are given;
- new and emerging technologies are catered for;
- advice is given on installation standards and the appointment of an independent validator;
- more detailed information is given on the commissioning process;
- validation acceptance standards and methodology has been completely revised;
- routine inspection and maintenance guidance has been revised and updated.

Net Zero Carbon

Scottish Health Technical Memorandum 03-01 supports UK legislation to bring all greenhouse gas emissions to net zero by 2045, and promotes sustainable methods of ventilation in healthcare facilities.

SHTM's core principle is that the default method of ventilation should as far as possible be natural ventilation followed by mixed mode (natural with mechanical ventilation), with mechanical ventilation being the last option.

The energy consumption of ventilation systems should be further minimised by specifying solutions with the lowest lifecycle environmental cost. The basic objective of energy-saving strategies in this SHTM is to provide the required ventilation service using the minimum energy. To this end, Scottish Health Technical Memorandum 03-01 recommends switching a system "off" when not required to be the most energy-efficient policy. If the system is needed to maintain a minimum background condition, reducing its output by "setting back" to the minimum necessary to achieve and maintain the desired condition is the next best option.

Fans represent an enormous potential for energy savings to reduce carbon emissions, as they are among the largest single users of energy (they use approximately 40% of all electricity in ventilation systems). The European Regulation 1253/2014, implementing the Energy-related Products (ErP) Directive, has significantly reduced the power to drive fans. Accordingly, Scottish Health Technical Memorandum 03-01 recommends using electronically commutated fans, as these have been proven to be the most energy-efficient, while also advising that belt-driven fans should no longer be installed.

There have been many legislative changes aimed at reducing energy consumption and technical advances that have increased operational efficiency. This revised SHTM incorporates those changes and has amended many of the design parameters for healthcare ventilation. Designs that are simply repeated from previous installations designed to superseded standards and guidance will not meet the revised energy or operational standards and will not produce a compliant result.

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1. Introduction

The needs of the building occupants

- 1.1 Ventilation is used extensively in all types of healthcare premises to provide a safe and comfortable environment for patients and staff and control odours. More specialised ventilation is provided to help reduce airborne infection risks in areas such as operating departments, critical care facilities, isolation rooms and primary patient treatment areas.
- 1.2 The Health and Social Care Act places a duty of care on healthcare providers. Increased health risks to patients will occur if ventilation systems do not achieve and maintain the required standards. The link between surgical site infection and theatre air quality has been well established. If the ventilation plant has been installed to dilute or contain harmful substances, its failure may expose people to unacceptable levels of risk. Proven breaches of the statutory requirements can result in prosecution and may also give rise to a civil suit against the operators.

The building environment

- 1.3 Healthcare buildings are visited and used by large numbers of people. Many will be unwell or anxious so a well-ventilated environment with a fresh feel and an absence of noxious odours is essential.
- 1.4 Ventilation may also be installed:
- to ensure compliance with highly regulated quality assurance requirements of items processed in pharmacies and central decontamination units;
 - to protect staff from airborne microorganisms and toxic substances (for example, in laboratories and anaesthetic rooms);
 - to contain the spread of smoke between fire compartments as part of the fire strategy.
- 1.5 Healthcare buildings are continuously occupied, intensively used and because of the specialised nature of the facilities it may be extremely difficult to provide the service elsewhere if the ventilation fails. In order to ensure continuity of service, ventilation systems should be designed and installed so that they can be quickly and easily maintained. The resilience of the proposed system in the event of service outage should also be considered.
- 1.6 The ventilation of healthcare facilities consumes a significant portion of their energy load, so wherever possible natural ventilation is the preferred option. Where mechanical ventilation is used, sustainable design concepts allied to good-quality installation and the provision of controls that maintain the desired environment when the facility is in use will result in the minimum energy input for the maximum benefit.

Airborne risks to staff

- 1.7 Most healthcare staff are no more at risk from airborne hazards when at their workplace than they are when not in a healthcare environment; however, certain groups as detailed below may be exposed to a variety of airborne contaminants.
- staff who administer anaesthetic agents or who work in areas where they are routinely used will be at risk of casual exposure to these agents;
 - staff who routinely work in areas where they may come into close contact with patients who have respiratory symptoms will be at risk of exposure to the microorganisms causing the symptoms;
 - staff who routinely work in areas where they may come into close contact with patients that have skin lesions, an infectious disease or a dermatological condition will be at risk of exposure to the microorganisms causing the condition;
 - staff who routinely process pathology specimens;
 - staff who decant, mix and/or process chemicals used as reagents for the setting or processing of pathology specimens;
 - staff who harvest organs, tissues and specimens at a post-mortem;
 - staff who handle drugs or the components of drugs;
 - staff who pre-clean used scopes, surgical instruments and equipment prior to decontamination;
 - staff who may be routinely exposed to airborne hazards listed in EH40 issued under the Control of Substances Hazardous to Health Regulations (COSHH) (for example, woodworking dust, welding fumes, chemical vapours).
- 1.8 A well-designed ventilation system can mitigate the airborne risks to staff. It should:
- supply sufficient unvitiated air to dilute the possible contaminants;
 - have air terminals located to efficiently scour the ventilated space;
 - move the air from the clean to the less clean space and/or out of the building;
 - supply the air at high level and remove it at low level so that the breathing zone of staff is in a clean airflow path.
- 1.9 Adoption of these principles will be sufficient to control the general risk to the staff identified above in their particular working environment. More specific airborne hazards should be captured at source and removed by local exhaust ventilation (LEV) systems provided under the COSHH Regulations (see paragraphs 3.3–3.5).

Airborne risks to patients

- 1.10 In general terms an environment that is satisfactory for staff will be satisfactory for patients. There are, however, exceptions as below:
- intensive treatment units of any type;
 - haematology/oncology units;

- transplant units and units treating patients that have had their immune system compromised;
- bone marrow transplant units (BMT);
- burns units;
- cystic fibrosis units;
- operating theatres.

Patients being treated in these areas will need an environment supplied with good-quality filtered air and that is maintained at a positive pressure with respect to surrounding areas

Note: Patients who are particularly at risk from airborne microorganisms will normally be placed in an isolation room or suite that is maintained at a positive pressure. Patients who have a condition that could be transmitted to others are normally placed in a negative pressure isolation suite. When the patient's exact condition is unknown they may be placed in a neutral pressure (PPVL) isolation suite (see Health Building Note 04-01 Supplement 1 – 'Isolation facilities for infectious patients in acute settings for detailed guidance).

- 1.11 A more general airborne risk will result from poorly designed and constructed air handling units (AHUs) that allow water to stagnate inside; they can then become a source of microorganisms such as Legionella. If their intake is badly sited or housekeeping in the area is poor, fungal spores such as aspergillus can be drawn in. The ventilation system will then become a means of spreading these microorganisms and fungal spores around the healthcare building.
- 1.12 All ventilation systems should conform to the principles set out in the Health and Safety Executive's (HSE) Approved Code of Practice and guidance document HSG274 'Legionnaires' disease: the control of Legionella bacteria in water systems' and Scottish Health Technical Memorandum 04-01 – 'Safe water in healthcare premises'.

Specialist equipment environment

- 1.13 Imaging and other non-invasive scanning equipment will require stable environmental conditions to stay within calibration and provide accurate repeatable results. Health Building Note 06-01 and Health Building Note 10 (2021) give detailed guidance and the equipment manufacturers should be consulted.

Note: Health Building Note 26 – 'Facilities for surgical procedures' (2004) and Health Building Note 10-02 – 'Facilities for day surgery units' (2007) are under revision at the time of writing and will become Health Building Note 10-01 once updated.

Health Building Note 06-01 (2001) on diagnostic imaging and interventional radiology is also under revision at the time of writing.

Medicinal products environment

- 1.14 Pharmacists are required to ensure that any manufacture or preparation activities involving medicinal products undertaken in their units conform with the requirements of the Medicine Act. Processes must be carried out in a suitable facility usually termed an aseptic preparation facility. The quality of air supply and design of the ventilation cascade are essential to ensure a suitable environment for the activities undertaken.

Fire and smoke control fundamentals

- 1.15 Scottish Health Technical Memorandums 81 to 87 (including sub-parts) are the base documents for fire aspects. When designing a ventilation system, a fire and smoke control strategy should be developed that is relevant to the site and its function. The fire and smoke strategy should take account of the planned activity within the area, the type of patient present, staff-to-patient ratio and treatment being delivered (see also Chapters 5 and 7).
- 1.16 When ventilation systems are originally designed, they will conform to an agreed fire strategy. This will determine the compartmentation, provision of fire-rated ductwork, fitting of sprinklers, the siting of fire and smoke dampers and an agreed control action for the ventilation in the event of a fire. The agreed fire and smoke control strategy must be clearly set out as part of the design specification.
- 1.17 The fire regulations require that, if ventilation ductwork penetrates the fabric of a building, it should be designed and installed to contain the spread of fire (see Health Technical Memorandum 05-02 – ‘Guidance in support of functional provisions for healthcare premises’ for further guidance).
- 1.18 If a ventilation system is upgraded or altered to suit a change of use, it will be necessary to reassess the fire strategy.
- 1.19 It is management’s responsibility to ensure that the fire strategy applied during the design and installation of a system is not reduced during the subsequent operation and maintenance of the equipment.
- 1.20 The number and location of fire and smoke dampers can be problematic. Fire-rated ductwork within fire zones will reduce the need for fire and smoke dampers. It will eliminate the need to provide access for routine damper testing and the infection control problems associate with reversed airflow paths resulting from damper failures and nuisance tripping (see also Chapter 7 for ventilation control in the event of fire).

Note: In developing a fire and smoke containment strategy the design of ventilation for infection control cannot be ignored. Over-compartmentation and poorly chosen fire lines can prevent air moving from clean to less clean areas and thus increase the infection risk. This can be a particular problem in operating departments where the desire to create a protected escape route can be at odds with the need to cascade air through a suite of rooms and out into a corridor in order to control the airborne infection risk.

2. The User Requirements

2.1 Patient treatment falls into four basic categories:

- surgical procedures – physical interventions to diagnose, repair, remove or rebuild damaged or infected tissue;
- medical care – the administering of drugs or various forms of practical, non-invasive treatment to diagnose, cure or reduce the severity of an infection or condition;
- mental health – the use of counselling, often in conjunction with drugs, to control or alleviate abnormal behavioural or false perception issues in patients;
- palliative care – treatment to temporarily or partially relieve or mitigate long-term conditions;

In all cases a patient may require treatment in one or more of the categories as either an in-patient or an out-patient.

Surgical procedures

2.2 It is thought that up to 25% of infections that occur as a result of a surgical intervention are caused by the airborne route. The source of these infections are predominantly as a result of airborne microorganisms, typically skin scales, liberated during the surgical procedure becoming airborne and landing in the wound or on surgical instruments. These then become a means of inoculating the patient with the contaminant. There are five possible routes that may result in airborne infections:

- skin scales liberated by the surgical team during the procedure;
- organic material liberated from the patient as a result of the procedure;
- microorganisms remaining from a previous use of the space becoming airborne;
- airborne microorganisms liberated outside of the space entering during the procedure;
- microorganisms in the supply air from a ventilation system that has been contaminated with biological material.

2.3 The level of airborne organic material present or biological burden (bioburden) is typically defined in terms of the number of colony forming units (cfus) present at the wound site during the procedure. It will be dependent on:

- the number of persons present;
- the completeness and effectiveness of their gowning;
- the duration of the procedure;
- the type of procedure;
- the use of air-driven power tools;
- the extent to which a patient contributes to the bioburden in the space;

- the general cleanliness of the space;
- the discipline of the surgical team;
- the measures that have been taken to prevent or control contaminants from outside sources entering the space;
- the quality and volume of the incoming supply air;
- the efficiency of the incoming air to “scour” the space;
- the means of removing contaminated air from the space.

2.4 Good surgical discipline, effective patient preparation, the cleanliness of the space and control of the entry and exit of personnel during the procedure will all contribute to reducing the bioburden present.

2.5 A well-designed ventilation scheme that provides a suitable quality of air and efficiently scours the space will further reduce the bioburden. If the ventilation maintains the space at a positive pressure to adjoining areas, the risk of contaminants originating outside of the space entering will be reduced.

2.6 In addition to controlling the bioburden, the ventilation should provide comfortable conditions for the staff and patient.

2.7 The ventilation system should also control the risks to staff from anaesthetic agents and other hazardous fumes and emissions typically found in surgical facilities (see paragraphs 1.10–1.12).

2.8 Minor procedures may be carried out in a treatment room or at the bedside so surgical procedures are not exclusive to the operating department. (See Humphreys et al (2012) for further guidance on facilities for minor surgical procedures and minimal access interventions).

Medical care

2.9 In general the main requirement will be to ensure that staff and patients are kept in comfortable conditions.

2.10 There are specific instances where staff can be at risk of contracting an illness by the airborne route from a patient. This is the case in infectious disease units where the ventilation will be designed to maintain the unit and individual patient rooms at negative pressure relative to adjacent areas. This will protect persons outside of the unit from infection by the airborne route but not staff entering and working in the unit, who may need to take additional precautions to protect themselves.

2.11 The opposite problem occurs when patients are neutropenic, that is, they have a reduced or extremely low resistance to infection. They are then at risk of infection by the airborne route from other persons such as staff and visitors. This will be the case in cancer/oncology units, critical care areas, and bone marrow and general transplant units. The ventilation in these areas will need a higher air quality and be set to maintain a positive pressure to adjacent areas.

Mental health

- 2.12 Any specific patient needs should be assessed and addressed. The main requirement will be to ensure that staff and patients are kept in comfortable conditions (see comments on other types of healthcare facility in the Executive Summary).
- 2.13 The fire risk may be considered more likely and additional steps may need to be taken to control it.

Palliative care

- 2.14 The main requirement is to ensure that staff and patients are kept in comfortable conditions. Temperature control may be more stringent for patients with long-term and/or end of life conditions (see the Executive Summary for further information).
- 2.15 Difficulties with evacuating patients in the event of fire may need to be considered.

Diagnostic and support services

Imaging and Interventional imaging

- 2.16 There are major advances in diagnosis and minimally invasive treatment involving imaging. It may be necessary during these invasive or non-invasive procedures to provide sedation or general anaesthesia to help with anxiety or pain. This may involve the use of inhaled anaesthetic agents and/or nitrous oxide (N₂O). Staff working in these areas may be exposed to these anaesthetic agents when they are administered or subsequently when they are exhaled as the patient is recovered.
- 2.17 A similar situation occurs in maternity units, where a mixture of nitrous oxide and oxygen (N₂O/O₂) (Entonox) is used as an inhaled analgesic.
- 2.18 In both of the above cases ventilation should be designed to provide a clean airflow path and dilute any casual spillages of the gas. This approach will help control the casual exposure of staff to the anaesthetic agent (see paragraphs 3.3–3.5).

Post-mortem and pathology

- 2.19 Staff who harvest organs and specimens at a post-mortem and place them into preservative solutions may be exposed to the microorganisms present and fumes from the preservative.
- 2.20 Staff who section organs and prepare specimens for analysis may be exposed to the microorganisms present and the chemicals used for staining and fixing the specimens.
- 2.21 In both of the above situations local exhaust ventilation (LEV) in the form of downflow benches, safety cabinets and fume cupboards need to be provided to control the risk.

Pharmacy

- 2.22 Exposure to the active ingredients of drugs represents a hazard to pharmacy staff who are involved in their production. These activities are carried out in an aseptic

preparation facility to ensure that the drugs themselves are not contaminated. The actual production typically takes place inside an isolator so that there is a physical barrier between the hazard and the operator.

- 2.23 Alcohol sprays are used and staff exposure may be controlled by the provision of downflow LEV systems to remove the hazard.
- 2.24 Comfortable conditions are essential for staff working in preparation facilities as they need to be fully gowned, and entry and exit is restrictive.

Decontamination facilities

- 2.25 Staff may be exposed to airborne biological material and chemicals when handling and processing used scopes, surgical instruments and equipment as part of the decontamination process. The ventilation should provide a clean airflow path to control staff exposure. The quality, quantity and flow pattern of the air are also critical to the protection of the decontaminated items.

Estates and facilities

- 2.26 Staff may be engaged in welding, soldering, machining wood or paint- spraying. They may also decant chemicals in quantity (for example, for boiler treatment or hydrotherapy-pool dosage). LEV systems are routinely used to control the hazards arising.

3. Legal Requirements – Applicable Legislation

Health and Safety at Work etc. Act

- 3.1 The Health and Safety at Work etc. Act 1974 is the core legislation that applies to ventilation installations. As these installations are intended to prevent contamination, closely control the environment, dilute contaminants or contain hazards, their very presence indicates that potential risks to health have been identified.
- 3.2 The Act places a duty of care on ALL to provide and maintain a safe workplace. This includes designers and suppliers of goods or services. Those trading as competent designers or suppliers are therefore liable to provide outcomes that meet the client's needs and are without hazard to staff, patients and others who may be affected by the work activity.

Control of Substances Hazardous to Health Regulations

- 3.3 The Control of Substances Hazardous to Health (COSHH) Regulations 2002 place upon management an obligation to ensure that control measures are in place to protect their staff and others affected by the work activity. These methods may include both safe systems of work and the provision of a specialised ventilation system. In laboratories the requirements are often met by the provision of fume cupboards and microbiological safety cabinets.
- 3.4 Where specialised ventilation plant is provided as part of the control measures, there is a statutory requirement that it be correctly designed, installed, commissioned, operated and maintained. The local exhaust ventilation (LEV) section of COSHH requires that the system be examined and tested at least every 14 months by a competent person (P601 certified) and that management maintain comprehensive records of its performance, repair and maintenance.
- 3.5 Certain substances have workplace exposure limits (WELs) as set out in the Health and Safety Executive's (2005) Guidance Note EH40 – 'Workplace exposure limits'. This contains the list of workplace exposure limits for use with the Control of Substances Hazardous to Health Regulations 2002 (as amended). If specialised ventilation systems are provided in order to achieve these standards, they will be subject to the COSHH Regulations.

Workplace (Health, Safety and Welfare) Regulations

- 3.6 These state that:
- all enclosed workplaces must be ventilated by natural or artificial means;
 - any plant provided under this legislation must include an effective device to give an audible or visual warning of plant failure where necessary for health and safety;
 - the Regulations require that ventilation systems are maintained in an efficient state, in efficient working order and in good repair.

The Building Regulations

3.7 Approved documents L and F:

- apply to domestic and non-domestic buildings;
- clarify satisfactory methods of providing ventilation and give ventilation rates;
- set minimum standards for:
 - the protection of the supply position;
 - precautions against *Legionella*;
 - the purity of recirculated air;
 - access for service and maintenance;
 - documentation and proof of performance;
 - energy performance.

Health and Social Care Act 2008 (Regulated Activities)

Regulations 2014

3.8 Regulation 12(2)(h) of the Act decrees that registered providers must assess the risk of, and prevent, detect and control the spread of, infections, including those that are healthcare associated.

3.9 Appropriate standards of cleanliness and hygiene should be maintained in premises used for the regulated activity. DH (2015) issued 'The Health and Social Care Act 2008 Code of Practice on the prevention and control of infections and related guidance' (the HCAI Code of Practice), which contains statutory guidance about compliance with regulation 12(2)(h).

3.10 Regulation 15 of the Act states that:

All premises and equipment used by the service provider must be:

- clean;
- secure;
- suitable for the purpose for which they are being used;
- properly used;
- properly maintained; and
- appropriately located for the purpose for which they are being used.

The registered person must, in relation to such premises and equipment, maintain standards of hygiene appropriate for the purposes for which they are being used.

Note: The “registered person” means, in respect of a regulated activity, the person who is the service provider or a registered manager in respect of that activity. A “service provider” means a person registered with the CQC under Chapter 2 of Part 1 of the Health and Social Care Act 2008 as a service provider in respect of that regulated activity.

The Medicines Act 1968 and Human Medicines Regulations 2012

- 3.11 Pharmacy aseptic preparation facilities should conform to the requirements of EudraLex – Volume 4 – Good Manufacturing Practice (GMP) guidelines or equivalent UK legislation, and the requirements of the UK Medicines Inspectorate (MHRA) if a licensed manufacturing unit.
- 3.12 There are specific requirements under the Medicines Act 1968 to maintain accurate records of plant performance, room conditions and maintenance events. Such records would need to be preserved for up to 25 years as part of a quality assurance audit trail.
- 3.13 Specialised ventilation plant installed in laboratories dealing with research, development or testing, whether involving drugs, animals or genetically modified microorganisms, may be subject to legislation regarding their operation in addition to that mentioned above.

Indoor air quality (IAQ)

- 3.14 There is increasing awareness that IAQ has an important impact on health and well-being. The World Health Organization and the Royal College of Paediatrics and Child Health (2020) have produced papers on the importance of IAQ, and the National Institute for Health and Care Excellence (NICE) (2020) has issued guidelines for domestic environments. Indoor and outdoor sources of contaminants are important contributors to IAQ, and designers of ventilation systems should consider both. The Department for Environment, Food and Rural Affairs (Defra) gives data for outdoor air quality by postcode for the UK. This enables designers to choose suitable filter grades by location and application (see the Specialised Ventilation for Healthcare Society’s (2018) SVHSoc.02 – ‘Change in air filter test and classification standards’ for further information).

Other relevant standards and sources of guidance

- 3.15 The Chartered Institution of Building Services Engineers (CIBSE) Guides and associated published documents (TMs) are the principal source of general ventilation specification and design guidance.
- 3.16 ISO 14644 and ISO 17141 provide basic information on cleanrooms used in pharmacy preparation facilities and inspection, assembly and packing (IAP) rooms for the processing of medical devices in central decontamination units.
- 3.17 BS EN 15780 applies to both new and existing ventilation and air-conditioning systems and specifies the assessment criteria of cleanliness and cleaning procedures of these systems.

- 3.18 HSG 258 issued by the Health & Safety Executive provides guidance on the design of local exhaust ventilation (LEV) systems.
- 3.19 Other relevant guidance is listed in the References.
- 3.20 The Board and their supply chain must ensure that the competence of all parties is considered at the point of their introduction and on an ongoing basis. The philosophies that are included in the HSE leaflet INDG368 (current revision), "Using Contractors" should be adopted. In addition, the outputs from the "Setting the Bar" report should be adopted as they are introduced through legislation. Evidence that the recommendations of "Setting the Bar" are being implemented in advance of the legislation would be considered to be good practice, particularly for high risk buildings. BSI Flex 8670 "Built environment. Core criteria for building safety in competence frameworks. Code of practice" should also form part of the project planning.

Note: In all cases the most recent version of any legislation, regulation, standard or guidance document should be consulted.

4. The Design and Specification Process

Project brief

- 4.1 The ventilation aspects of a contract will normally form part of a wider project to provide, upgrade or replace a healthcare facility. It is important that the ventilation designer closely liaises with the architect, as the layout of the facility and the adjacency of spaces within it will have a major impact on the ability of the ventilation system to achieve the client's requirements. All new major projects are required to use building information modelling (BIM) in order to ensure a coordinated design and provide information for the subsequent operation and possible future development of the facility.
- 4.2 The Building Services Research and Information Association (BSRIA) has produced an approach to project delivery known as "Soft landings" (BSRIA, 2018). It aims to ensure that the client's success criterion is kept in focus during the inception and briefing, design, construction, pre-handover, initial aftercare and extended aftercare phases of a project. It is strongly recommended that the client and project contractor adopt this approach.

Basis of design

- 4.3 This SHTM assumes that designers will be familiar with current CIBSE guidance and will use it as the basis for specifying and designing ventilation systems. However, the actual guidance contained in this SHTM may differ from the CIBSE guidance due to healthcare-specific issues and will take precedence over the CIBSE guidance where there are conflicts.

Note: Scottish Health Technical Memorandum 03- 01 Parts A and B need to be read and considered in their entirety when specifying and designing ventilation systems to ensure that the end result will comply with the client's needs.

Ventilation Safety Group (VSG)

- 4.4 The management of the ventilation systems of a healthcare provider should be overseen by a Ventilation Safety Group (VSG). The VSG should have clearly defined roles and responsibilities, be part of a healthcare organisation's governance structure and report to the "Designated Person" at Board level. It should be led and chaired by a person who has appropriate management responsibility, knowledge, competence and experience (for example, the Designated Person). (See Chapter 2 in Part B of Health Technical Memorandum 03-01 for further information.)
- 4.5 The VSG should be a multidisciplinary group and should typically comprise:
- an Authorising Engineer/independent adviser for ventilation (AE(V));
 - an Infection Prevention and Control person;
 - the Authorised Person(s) for ventilation services (AP(V));
 - estates (operations and projects) staff;

- clinicians and specialist departments (for example, theatres, critical care areas, pharmacy, medical microbiology, nursing, decontamination);
- personnel from the finance department with accountability for capital and revenue evaluation;
- other stakeholders as appropriate;
- coopted expertise (for example, ventilation designers, consultants and suppliers).

4.6 The VSG remit should be to assess all aspects of ventilation safety and resilience required for the safe development and operation of healthcare premises. It should inform the following areas:

- the design process for new healthcare premises;
- the design process for modifications to existing premises;
- the commissioning and validation process;
- operational management and maintenance;
- annual verification and performance testing;
- prioritising the plant replacement programme;
- decommissioning and removal of redundant equipment.

Note: Where estates and facilities provider services are part of a contract (including PFI), it is essential that these providers participate fully in all those aspects of estate and facilities management that can affect patients. This includes responding to specific requests from the VSG, which may be in addition to relevant guidance and documentation.

4.7 It is important that decisions affecting the resilience, safety and integrity of the ventilation systems and associated equipment are not taken without the agreement of the VSG. The VSG should ensure that appropriate expertise and competence is available when making such decisions.

4.8 Whenever significant building work is undertaken; the VSG should consider its effects on the existing ventilation system air intakes. These may need to be protected from airborne dust during construction by the fitting of temporary additional filtration. There will also be a need to identify any risks to construction personnel who may be working in the vicinity of extract air discharges.

4.9 When construction or alteration work is undertaken inside an occupied building, its effects on the occupiers should be considered. The VSG should be consulted, and they may require that the area be sealed off from the occupied parts of the building and that a temporary extract be provided to maintain the worksite at a negative pressure to prevent the spread of dust into the rest of the building.

Derogations and alternative design strategies

- 4.10 Any derogations or alternative design strategies from this guidance should be subject to the scrutiny and agreement in writing by the VSG. The reason for the derogation or alternative design strategy and limits to its application should be recorded.
- 4.11 Designers proposing a derogation or alternative design strategy should be able to supply a body of evidence that their proposal will provide a degree of safety no less than if the guidance in this document had been followed.

Definition of clinical areas and critical systems

- 4.12 Healthcare ventilation may serve clinical or non-clinical areas of the estate:
- clinical areas are defined as spaces within the building where surgical or medical treatment is administered to patients. This includes patient bedrooms;
 - non-clinical areas are defined as spaces where patients may be present but are not under direct treatment. It also includes staff and healthcare services areas.
- 4.13 Certain clinical and non-clinical areas within a healthcare establishment are considered critical to its ability to provide healthcare. Typically, ventilation systems serving the following are considered critical:
- operating suites of any type including rooms used for image-guided surgical procedures and their recovery areas;
 - airborne isolation facilities, both source and protective;
 - critical care areas and neonatal units;
 - invasive treatment, endoscopy and bronchoscopy rooms;
 - containment level 3 laboratory;
 - pharmacy aseptic preparation facility;
 - inspection, assembly and packing (IAP) room in a central decontamination unit;
 - MRI, CAT and other types of emerging imaging technologies that require particularly stable environmental conditions to remain within calibration;
 - any system classified as an LEV system under the COSHH Regulations;
 - any other system that clearly meets the definition that “a loss of service from such a system would seriously degrade the ability of the premises to deliver optimal healthcare”.

Note: If any doubt exists about whether a system falls within this definition, the VSG should be consulted regarding the risk to patient safety and business continuity.

Resilience and diversity

- 4.14 When planning the ventilation of healthcare facilities, it is important at the outset to consider how the service will be delivered if the installed ventilation system fails or the area served has to close due to the effects of fire, flood or an outbreak of

infection. The loss of power, primary heating or cooling medium, or an integrated control system can cause the loss of ventilation to an area, so subsystem resilience is an important consideration.

- 4.15 Resilience in critical healthcare areas can be provided by splitting the ventilation load between two or more AHUs and/or employing a design that allows two or more AHUs to feed a common plenum with isolation dampers on individual branches to each critical zone. (Note that it is not proposed that duplicate back-up units be provided.) As an example, a large critical care area (CCA) level 2 or 3 could be split into two sections with an AHU for each. A small CCA cannot easily be split, so a decant area with a suitable level of ventilation should be pre-designated.
- 4.16 Diversity can be achieved by having several facilities each served by its own AHU. As an example, in an operating department, if each theatre suite is fed from its own dedicated AHU, the loss of one suite, while inconvenient, will not shut the department. The same scenario applies to isolation rooms if several of them are each independently ventilated (see Health Building Note 04-01 for further information).

Note: Providing twin ventilation fans in an AHU delays the time at which the system needs to be completely shut down in the event of a fan failure. It does not in itself provide resilience in terms of delivering healthcare (see Chapter 9 for further guidance).

New build facilities

- 4.17 New build healthcare facilities must be fully compliant with the requirements of all legislation in force at a date agreed when signing the contract. They should comply with the guidance contained in the current SHTM unless a derogation has been agreed with the VSG (see paragraphs 4.10 and 4.11).

Assessment of service requirements: selection of design criteria

External design conditions

- 4.18 The most accurate data that is available for the summer and winter conditions at the site should be used. The Meteorological Office supplies data for the United Kingdom; data is also available from CIBSE and other sources. It is essential that the designer agrees with the client as to which source of data is used and the design risk associated with the chosen external design conditions.

Note: It is essential to design to future climate projection to ensure design temperatures are maintained even in the event of prolonged heatwave conditions. CIBSE (2014) publishes design summer year weather files morphed to reflect future climate change.

- 4.19 Local adjustments for height above sea level, exposure factor, or other local climate peculiarities should be made as appropriate.

Internal design conditions

- 4.20 The design conditions selected within patient areas should strike a balance between the comfort requirements of staff and patients, who often have very different levels of clothing and activity.

4.21 Recommendations for the operative temperature and humidity of individual spaces are given in Activity Data A-Sheets (see Chapter 8 for specific requirements). Particular departmental requirements are given in the respective SHPN/HBN and room data sheets. However, the determination of the room environment must be driven by the patient cohort plus the range of procedures envisaged for that room.

Minimum fresh air requirements

4.22 In general areas and wards within healthcare premises, odour control is the main reason for providing ventilation. In the absence of other guidance, 10 L/s/person should be taken as the minimum ventilation requirement. Healthcare ventilation systems will normally be “full fresh air” either by natural, mixed mode or mechanical means, with energy recovery from the extracted air.

4.23 In non-clinical areas recirculated air systems may be considered. At least 20% of the recirculated air should be fresh. Additional filtration will be required to remove airborne particulate contamination and, if necessary, odours. This will affect running and maintenance costs and, given the high ErP rating of heat recovery devices, it will be necessary to prove that recirculating the air will be more energy- efficient overall.

Note: Ultra clean ventilated (UCV) operating theatres use air recirculation. The fresh air requirements of this specific application are given in Chapters 8 and 9.

4.24 Smoking is generally not permitted in healthcare premises, so no allowance need be made. Reference should be made to local national policy guidance.

4.25 In treatment and support areas the overriding requirement may be due to airborne infection control, hazard containment, the stability of specialist equipment or relate to a specific department’s function. Each case should be considered independently in order to determine the overriding minimum requirement for ventilation (see Chapter 8 for specific guidance).

Limiting supply air conditions

4.26 For most applications in healthcare buildings, it is the temperature differential between the supply and room air, rather than the actual temperature of the supply air, which is the critical factor. The maximum recommended supply-to-room air temperature differential is:

- summer cooling: 7 K
- winter heating: 10 K

4.27 Room air humidity should be kept below 70% in order to minimise risks associated with condensation and mould growth. There is no lower limit in unoccupied spaces.

4.28 Some types of diagnostic imaging technologies require close control of both temperature and humidity as well as the rate of change of conditions to ensure clarity of the image and accuracy of the data generated. The manufacturer’s guidance should be followed.

Air purity

- 4.29 In healthcare premises, the standard of filtration will depend on the activities within the occupied spaces. Except for special areas (for example, manufacturing pharmacies), the requirement for aerobiological needs is not stringent and filtration is only required to:
- maintain hygienic conditions for the health and welfare of occupants, or for processes such as centralised food preparation facilities;
 - protect finishes, fabrics and furnishings – to reduce redecoration costs;
 - protect equipment either within the supply air system – to prevent blocking of coils – or in the space itself to prevent dust accumulation
- 4.30 Given that almost all viable particles will originate from the occupants of a space and not from the incoming air, dilution is the more important factor aerobiologically. Therefore, for general areas an ISO ePM 2.5 $\geq 55\%$ filter may be suitable. More critical areas would require an ISO ePM1 $\geq 50\%$ filter. Efficiency or high-efficiency (EPA or HEPA) filters will only normally be required in ultra-clean systems, designated “cleanrooms” (see Chapter 9 for specific information) or for some immune-suppressed patient areas
- 4.31 In some inner-city areas the local airborne particulate level may be particularly high. In those special cases filters to ISO ePM1 $\geq 50\%$ may be required to achieve the required indoor air quality. (See Defra’s website and the Specialised Ventilation for Healthcare Society’s (2018) SVHSoc.02 – ‘Change in air filter test and classification standards’.)

Humidity control requirements

- 4.32 Close control of humidification was originally required for some healthcare applications (for example, operating theatres) in order to control the risk associated with the use of flammable anaesthetic gases. The use of such gases has now ceased.
- 4.33 Providing humidification is expensive in terms of plant, running costs and maintenance, and therefore its use should be restricted to where it is necessary for physiological or operational reasons (see Chapter 8 and associated SHPNs/HBNs).
- 4.34 In general terms the humidity within an occupied building or space will naturally float between 30% and 70% RH (relative humidity). Humidity should not be allowed to rise above 70% at any time but there is no need to maintain a background minimum level when the building or space is unoccupied.

Maximum noise levels

- 4.35 Noise will be generated in an air distribution system by the fan, ductwork fittings, dampers and grilles. The specified maximum noise level will depend on the activities within the occupied spaces.
- 4.36 Attenuation should be incorporated into the ductwork system or plant arrangement as necessary to reduce noise from fans and plant items in order to achieve the acceptable limits within the rooms at the design airflows.

- 4.37 Plant room noise level from fans when starting up or running should not be greater than 80 dB(A), and should be reduced where the plant is near to departments sensitive to noise.
- 4.38 Attention should be given to the reduction of tonal components. High tonal components from air diffusers etc. can seriously disturb concentration over longer periods even when the overall noise level is low. Broadband noise causes less annoyance.
- 4.39 The values recommended in Table 1 are for the total noise environment of space. In general, there will be noise transmitted into the space and noise generated within the space. The designer requires knowledge of the total hospital layout and operational policies, to assign acceptance magnitudes to all the possible noise sources, in order to arrive at the correct rating.
- 4.40 In Table 1 the overall noise level takes account of all internal and external noise sources. The noise level is the level measured with a sound-level meter in the unoccupied room, taking account of the external noise together with the noise generated by the ventilation system. The ventilation plant design noise level is that generated by the plant alone with no other noise source being considered. The levels suggested make recognised allowance for the ingress of environmental noise which will have to be considered in the overall design, that is, in specifying the attenuation of walls, partitions, ceilings, etc.

Table 1: Interior Noise Level

Area	Room: overall noise level – dB(A)	Ventilation design value – dB(A)
Operating department all rooms including preparation, anaesthetic, scrub and utility, interventional and diagnostic imaging departments – all rooms	48	Operating department all rooms including preparation, anaesthetic, scrub and utility, interventional and diagnostic imaging departments – all rooms
UCV operating theatre and adjacent open- plan scrub only	53	–
Treatment rooms Consulting rooms Sleeping areas/rooms Recovery rooms	35	Treatment rooms Consulting rooms Sleeping areas/rooms Recovery rooms
Sanitary facilities	45	40
Aseptic preparation facility	45	40
Industrial areas	50	45
Circulation waiting areas	50	45
Plantrooms	85	80

- 4.41 The recommended criterion is measured as the “A” weighted sound pressure level expressed in decibels, which should not be exceeded for more than 10% of the time. See Scottish Health Technical Memorandum 08-01 – ‘Acoustics’ for further information.
- 4.42 The designer should also consider noise escaping to the external environment and this should not be unacceptable to occupants of adjacent buildings.

Calculation of building loads

Air infiltration

- 4.43 Air infiltration occurs due to a complex combination of wind pressure, thermal effects, location relative to other features and the construction standard of the building. The infiltration rate is governed by the size and number of doors and other openings in the building envelope and the complexity of internal air paths.
- 4.44 CIBSE guide TM52 provides information and formulae for the calculation of air infiltration in buildings. In all cases the requirements of the appropriate section of the current Building Regulations Part L (airtightness minimum requirements) must be met.

Summertime temperatures

- 4.45 To prevent overheating and avoid the future need for portable room air- conditioners, thermal modelling should be undertaken to ensure that internal temperatures in all areas do not exceed CIBSE Guide A guidance. Thermal modelling should be carried out whether the space is ventilated by natural, mixed mode or mechanical means. The modelling should be undertaken by a competent software user and take into account not only absolute values but also the time component.
- 4.46 Where thermal modelling indicates internal temperatures will exceed the recommended levels defined in CIBSE Guide A, additional measures should be explored to achieve compliance such as reducing solar and casual gains, improving building fabric performance, etc.

Peak heating load

- 4.47 Peak heating local calculations are necessary on all mechanical supply systems to establish the size of heater-batteries and subsequently the central plant. Note that with the introduction of the requirement to fit energy recovery set out in EU 1253, the heater-battery size will be reduced. If the energy-recovery value is ignored, the heater-battery and its control valve will be oversized and the system when put to use will be unstable and liable to hunt.
- 4.48 Where ventilation systems provide tempered air to spaces which have supplementary low pressure hot water (LPHW) to offset the building fabric losses, the AHU heating load should be calculated based on the external winter design temperature, the design internal air temperature, and the calculated total air volume (including a suitable allowance for leakage).
- 4.49 Where the ventilation system is the only means of heating a space, an increase in load equivalent to the calculated fabric heat losses from the space should be added to the ventilation load. A check of supply temperature difference should be made. If it exceeds that recommended in paragraph 4.26 the ventilation supply volume should be increased to suit.

Peak cooling load

- 4.50 In addition to the base data of airflow rates and temperatures, when calculating cooling loads, the designer should take into account:

- solar cooling loads;

- surface conduction cooling loads;
- internal gain cooling loads;
- air infiltration cooling loads;
- cooling loads due to high limit humidity control;
- method of control of internal conditions;
- fluctuations in internal temperatures.

Allowances must be made for all medical equipment in every space. Where the final item has not yet been selected, a unit that is reflective of the needs must be agreed with the stakeholders. A record must be included in the design documentation as to the unit which has been included in the design and the impact on all MEP systems of this unit. The stakeholders must have access to this data to ensure the compatibility of equipment and MEP systems can be checked against final medical equipment selections.

- 4.51 When the peak internal loads have been assessed and a suitable allowance made for non-coincidence, the supply temperature can be calculated.
- 4.52 Once the lowest required supply temperature of the air handling unit has been established, and an allowance made for temperature rise through the fan and ductwork (usually 1 K for low pressure systems), the off-plant enthalpy can be established from a psychrometric chart or table.
- 4.53 The cooling loads for all plant on the chilled water system should be calculated at each of the individual peak times in order to accurately establish the required (diversified) capacity of the chiller.

Note: Note that as with heating, the introduction of the requirement to fit energy recovery set out in EU 1253 means that the cooling-coil size will be reduced. If the energy-recovery value is ignored, the cooling coil and its control valve will be oversized and the system when put to use will be unstable and liable to hunt.

Annual energy consumption

- 4.54 The annual energy consumption of simple heating-only ventilation systems is simple to calculate, based on supply to external air temperature rise, and frequency of occurrence of external temperature data (see CIBSE Guide A).
- 4.55 Minimum air volumes are usually fixed by the room loads or fresh air requirements; however, the designer may increase airflow to some rooms or zones in order to balance loads, as detailed in paragraphs 4.63–4.68
- 4.56 The method of zoning and control can significantly influence energy consumption.
- 4.57 The nature of air-conditioning operation, that is, cooling and reheating for humidity or zonal temperature control, makes prediction of energy consumption very complex. It is imperative that these calculations are performed to ensure optimum energy efficiency.
- 4.58 The concept of load and plant operation charts is outlined in the CIBSE Guide TM52. The method requires the designer to establish the minimum and maximum loads on

all zones across the range of external temperatures between winter and summer design conditions. The total coil loads can be calculated taking account of the external air temperature and humidity plus the supply air conditions.

- 4.59 When all temperatures/enthalpies for all zones are plotted on the plant operation chart, set points and resetting schedules can be established. From this information, the outputs of individual heaters, coolers and humidifiers can be established at any given external condition. When those loads are computed against annual frequency of occurrence of external conditions as given in CIBSE Guide TM52, the annual energy consumption of individual elements, and thus the air-conditioning system, can be established.
- 4.60 In order to prevent surface condensation occurring, it is necessary to provide enough ventilation to maintain the maximum and ambient dew-point temperature below the lowest surface temperature, the coldest usually being the glazing.
- 4.61 Where this would require excessive ventilation levels, the designer should consider removal of the moisture at the source of the evaporation via an exhaust hood or similar device.
- 4.62 In intermittently heated buildings, it is necessary to consider the condensation risk at night set-back conditions as well as during normal operation. Calculation methods for this assessment are given in CIBSE Guide A.

Calculation of plant requirements

Air supply volumes

- 4.63 The minimum air supply volume for a room is determined by the greatest of:
- the minimum fresh air requirement;
 - the air required to achieve the room differential pressure and provide open door protection at the key door;
 - the minimum supply volume for the room load as determined by the maximum heating or cooling supply temperature differential;
 - the desired air-change rate;
 - the make-up air for a local extract (for example, cooker hood or LEV system).

Plant sizing

- 4.64 Once the design airflow has been established, the cross-sectional area of the air-handling unit can be calculated based on values given in Commission Regulation EU 1253/2014.
- 4.65 The fan duty should be calculated by adding the resistances of all elements that contribute to the pressure drop of the index circuit.
- 4.66 In order to establish the length of the AHU, it will be necessary to refer to manufacturers' literature, ensuring all necessary access panels and components are included as detailed in Chapter 9.

- 4.67 The designer should ensure that an allowance has been made for “dirty filter” conditions and confirm whether the fan pressure quoted is the total or static pressure.
- 4.68 Upon completion of the resistance calculation exercise, the designer should make allowances for calculation and construction tolerances as indicated below:

Total pressure loss margin:

- for leakage and balancing requirement =+5%
- for uncertainties in calculation = +5%

Combined total pressure loss margin =+10%.

Note: All installed ductwork whether new or reused should be subject to a leakage test on site prior to the application of any insulation. The leakage test should be to BESA DW144 but with a permissible leakage rate of not greater than 3%.

Refurbishment of existing facilities and fitting out shell schemes

- 4.69 When refurbishing existing facilities or fitting out “shell” schemes, every effort should be made to achieve full compliance with this SHTM and current Scottish Health Planning Notes (SHPNs). It is important that use of the space is revisited at this stage. Patient cohort, forms of treatment and all other stakeholder requirements must be compared to the capabilities of any existing system/plant and adjustments made to suit.
- 4.70 The physical constraints of the building may mean that some derogation in terms of layout and room dimensions are unavoidable, but it is vital that the infection control aspects, clean airflow paths, cascade of air from clean to less clean areas and fire and smoke requirements are not compromised and that the complete facility will be fit for purpose. The VSG should be consulted and agree in writing to any derogations.
- 4.71 A new AHU fully compliant with current standards will normally be required. The existing AHU should only be retained if it is not more than 10 years old and is (or can be made) fully compliant with current standards.

Note: The application of the ErP regulations may mean that new plant could be physically larger than that previously installed. If the replacement plant cannot be accommodated in the existing plant space, the plantroom may need to be expanded or a new plant space created. It may be that reconsidering how the ventilation load is determined, whether it can be shared, which type of AHU configuration will fulfill the design need, etc., will provide a satisfactory solution rather than just specifying like-for-like replacement plant.

- 4.72 The most commonly used original standard operating theatre design solutions from previous versions of this HTM have been revised and updated (see Appendix 7). They have been retained in this guidance as they will remain applicable to older theatre suites that are being refurbished within their original footprint. They may also be applicable where a pre-built “shell” is being fitted out.

Change of use of existing facilities

- 4.73 When a change of use of existing facilities is contemplated, the ventilation requirement should be completely revised to suit the new use (see paragraphs 4.63 and 4.69). All requirements must be agreed with the Ventilation Safety Group.
- 4.74 A new AHU fully compliant with current standards will normally be required. The existing AHU should only be retained if it is not more than 10 years old and is (or can be made) fully compliant with current standards.
- 4.75 If the ventilation load is to be increased or reduced and the existing system is retained, its output should be adjusted to suit. This will necessitate a recalculation of the heater and cooler loads and resizing of the control valves to match the new loads. It may also necessitate a change in fan size. Failure to carry out this exercise will carry an energy penalty and loss of control function.
- 4.76 The area/zone fire strategy should be reassessed to suit the new layout and purpose.

Computer-aided design (CAD) and building information modelling (BIM)

- 4.77 The design of new ventilation systems should be created using a CAD package, and the information generated should be incorporated into the BIM for the project. The client should have access to the BIM model as the project progresses; it will be transferred over to the client on completion (see paragraph 13.28 onwards)

5. Ventilation Strategies

5.1 In order to reduce energy costs and provide a more sustainable healthcare estate and support the declared zero- carbon target, ventilation selection should be as follows:

- first choice – natural ventilation;
- second choice – mixed mode ventilation;
- final option – mechanical ventilation.

Natural ventilation

5.2 Natural ventilation is usually created by the effects of wind pressure. It will also occur if there is a temperature difference between the inside and the outside of a building. The “thermo-convective” effect frequently predominates when the wind speed is low, and will be enhanced if there is a difference in height between inlet and outlet openings.

5.3 Ventilation induced by wind pressures can induce high air-change rates through a building, provided air is allowed to move freely within the space from the windward to the leeward side. However, in most healthcare applications, internal subdivisions will restrict or prevent this effect.

5.4 Current guidance restricts the opening of windows for safety reasons; also, as many designs are top-hung, their ability to permit natural ventilation is limited. Some types of window (for example, vertical sliding) can enhance single-sided air change by temperature difference, and these will improve the overall rate of natural ventilation in protected or sheltered areas where the effect of wind pressure is likely to be minimal.

5.5 Current healthcare building design philosophy suggests that windows are provided to allow light into and a view out of a healthcare building. Ventilation should be provided by purpose-made openings with appropriate consideration for thermal comfort and air quality. The airflow may need to be controlled by motorised dampers linked to temperature and/or occupancy sensors in the ventilated space.

Note: Natural cross-flow ventilation can provide reasonable air distribution for a distance of up to 6 m inwards from the external facade, provided that reasonably clear air paths are maintained. Beyond this distance – in areas where clear air paths cannot be maintained and in areas where high minimum air-change rates are specified – mechanical ventilation should be provided.

If natural ventilation is single-sided, it will usually only be effective for a 3 m depth within the space. Beyond that it should be supplemented by mixed- mode or mechanical ventilation.

5.6 With natural ventilation, it is almost impossible to maintain consistent flow rates and ensure that minimum ventilation rates will be achieved at all times. However, this variability is normally acceptable in non-clinical spaces such as office accommodation, staff areas, library/seminar rooms and dining rooms, and some

clinical areas such as level 0 and 1 care spaces and waiting and consulting rooms where risk of airborne infections is likely to be low. The design must still aim to achieve agreed limits for room temperatures and, for clinical areas, achieve the desired room air change rate with “thermo-convective” effect (at peak room temperature coincident with summer external design temperature). Where it is essential to achieve a minimum ventilation rate at all times, mixed mode or mechanical methods will be needed.

- 5.7 Constraints caused by a building’s shape and/or the functional relationships of specific areas will inevitably result in some measure of deep planning, thus reducing the opportunity for natural ventilation.
- 5.8 In all cases, for natural ventilation to be effective it will be necessary to take steps to reduce any solar gain to a minimum. Outdoor air-quality, excessive heat gain, indoor air-quality requirements or external noise are all factors that may limit or preclude the use of natural ventilation.
- 5.9 Further information can be found in Health Building Note 00-10 Part D – ‘Windows’, BS 5925 and CIBSE’s Applications Manual AM10 – ‘Natural ventilation in non-domestic buildings’.

Mixed mode ventilation

- 5.10 Mixed mode ventilation is an assisted form of natural ventilation. Fans are fitted in purpose-made damper-controlled ventilation openings. Alternatively, a separate draw- or blow-through ventilation unit may be installed. In both cases the dampers and fans are controlled by temperature and occupancy sensors to ensure a minimum airflow rate while taking advantage of natural ventilation effects when present.
- 5.11 Where natural or mixed mode ventilation is adopted with complex air paths, the designer should produce an airflow diagram in order to ensure correct provision of air-transfer devices. CIBSE’s Applications Manual AM13 – ‘Mixed mode ventilation’ gives guidance. Modelling of the airflows under a range of conditions should be undertaken to establish the airflow paths.

Mechanical ventilation

Central versus local plant

- 5.12 Mechanical ventilation is expensive so it should only be provided when the space being served requires close control of its environmental conditions.
- 5.13 If the ventilation loads throughout a department or building are in phase, or are not significant, a central plant with single zone control may be adopted. However, this is rarely the case, so the condition or quantity of supply air to different areas or zones of the building will be varied accordingly. This may be achieved by either providing individual plant to each zone or providing separate controls for each zone such as provided by a variable air volume (VAV) system. Where there is a high density of rooms with similar ventilation requirements in an area of a building or department, it is usually economical to combine them into a central system; however, the operational resilience should be considered.

- 5.14 In large buildings, a choice between a small number of large ventilation systems located in centralised plant areas, or a larger number of smaller locally distributed systems, may arise
- 5.15 Large distribution systems and their plant can have the advantage of lower capital costs, but because they operate to a fixed supply condition, reheating or cooling may be locally required which will reduce energy efficiency. The distribution system will require more space for vertical shafts. In general, very long runs of ducting should be avoided to prevent undue heat losses or gains, excessive leakage and difficulties in balancing during commissioning. As the pressure losses in the long runs will be greater and a higher initial static pressure will be required, this may lead to a more expensive class of ductwork.
- 5.16 Decentralised AHUs feeding multiple smaller distribution systems may be more expensive in capital costs but as they avoid long runs, large ducts and vertical shafts, this may reduce overall costs. They can provide a more robust service, as the failure of an individual system does not prevent the use of the rest of the building. Future refurbishment or replacement of AHUs is also simpler. See also Chapters 4 and 9.

Horizontal and vertical AHUs

- 5.17 AHUs may be configured as horizontal or linear units that are single or double-stacked in the case of combined supply and extract units. They may also be configured more compactly as vertical or cabinet-style units. Selection will be dependent on the plant space available and where the unit is to be located. Whichever style is selected, good access for service and maintenance is essential. See legal requirements in paragraphs 3.6 and 3.10.

Chilled beams

- 5.18 Active chilled beams can provide an energy-efficient means of controlling environmental conditions. They are, however, subject to increased maintenance requirements due to the need for regular cleaning if they are to remain working efficiently. Access for this will not pose problems in non-clinical and office areas, but in clinical areas and patient bedrooms, routine access will be a major problem in an operational hospital.
- 5.19 Chilled beams should not be installed in clinical areas without the agreement in writing of the VSG.

Note: Patient bedrooms are classed as clinical areas as treatment is often delivered at the bedside rather than in a designated treatment room.

- 5.20 Where chilled beams are installed in non-clinical areas, they should be positioned to ensure that cold draughts are avoided.
- 5.21 In order to avoid condensation on the beam coils and the potential for mould growth, the temperature of the secondary chilled water circuit needs to be kept above dew-point (usually 15°C). With active beams the supply air may, under some outside air conditions, need to be dehumidified. Manufacturers of these devices can provide specific advice on the design limits and siting of their equipment.

- 5.22 Where chilled beams are installed in rooms with opening windows, the window should be fitted with a switch to automatically turn off the beam when the window is open. To avoid condensation, chilled beams should not be installed in entry lobbies that directly connect to the outdoors.
- 5.23 Active and passive chilled beams require regular cleaning if they are to remain efficient. They should be of a design that allows full access to the beam coils for cleaning and be positioned where they will be accessible for maintenance and not installed above fixed items of equipment.
- 5.24 There is no benefit in installing chilled beams if the resources to keep them in efficient working order over their entire life cycle will not be available. The maintenance aspects of using chilled beams should be discussed and the decision to use them agreed in writing with the client.

Note: Maintenance access to chilled beams will require the use of pulpit steps or wheel-around access equipment. The use of such equipment in a working hospital is very restricted.

Stand-alone air-conditioners

- 5.25 Stand-alone air conditioners include fan coil units, split-comfort air-conditioners, room conditioners and cassette units. All of these devices recirculate air which affects indoor air quality and may increase the risk of healthcare-associated infections (HAIs). Therefore, they should not be installed in clinical areas.

Note: Patient bedrooms are classed as clinical areas as treatment is often delivered at the bedside rather than in a designated treatment room.

- 5.26 Stand-alone air conditioners may be installed in suitable non-clinical areas, but they should be positioned to ensure that cold draughts are avoided. The control settings should ensure that the external elements of the units are always above dew-point. Manufacturers of these devices can provide specific advice on the siting and design limits of their equipment.
- 5.27 Stand-alone air-conditioners recirculate air, therefore, a primary fresh air supply of at least 20% of the room air-change rate, or that required by the Building Regulations, or 10 L/s/person – whichever is the greatest – should be provided.
- 5.28 Whether single or multiple systems are used, it is essential that the designer give due consideration to the source of electrical supply, location of the heat rejection unit, environmental effects and flammability of the refrigerant used, and drainage provision for the cooling-coil condensate.
- 5.29 Stand-alone air conditioners require regular cleaning if they are to remain efficient and not become a source of airborne bio-hazards. If they incorporate an open water drainage system, they must be risk assessed under L8/HSG274 as part of the Legionella assessment (see the Health & Safety Executive's (HSE) Approved Code of Practice and guidance document HSG274 'Legionnaires' disease: the control of Legionella bacteria in water systems'). They should be easily accessible for maintenance and should not be installed above fixed items of equipment which would make access difficult.

Notes: Maintenance access to stand-alone air-conditioners will require the use of pulpit steps or wheel-around access equipment. The use of such equipment in a working hospital is very restricted.

Traditional refrigerants are being phased down because of their effects on the environment and are becoming ever more expensive. Their replacements at the time of writing have a degree of flammability. Both these factors pose serious consideration as to whether stand-alone air-conditioners are suitable devices to choose. In scanning and control equipment rooms, the use of chilled racks, shelves and embedded panels supplied with water above dew-point would be a more suitable option.

Where the refrigerant pipework is located must be checked against the need to restrict risk. This may necessitate the need for refrigerant gas monitoring. The requirement must be checked during the design (refer to BS EN 378, using the relevant current edition for the application).

System selection

5.30 Natural ventilation is always the preferred solution for a space, provided that the quantity and quality of air required, and consistency of control to suit the requirements of the space, are achievable. This should also take account of the guidance from the WHO (Natural Ventilation for Infection Control in Health-Care Settings). If this is not the case, mixed mode or a mechanical ventilation system will be required.

5.31 Ventilation costs can be minimised by ensuring that, where practicable, core areas are reserved for those rooms that need to have mechanical ventilation. Examples are:

- sanitary facilities, dirty utilities and those rooms where clinical or
- functional requirements have specific environmental needs; and
- those rooms where – for reasons of privacy, absence of solar gain, etc. – windowless accommodation is acceptable.
- Other spaces appropriate to core areas are those which have only transient occupation and therefore require little or no mechanical ventilation (for example, circulation and storage areas).

Zoning of the building

5.32 The efficiency and effectiveness of any ventilation or air-conditioning installation depends largely on the zoning and control of the installation. The factors to consider when determining the zoning of a ventilation system for a building or department are:

- periods of occupancy;
- the service delivery resilience;
- fresh-air/ventilation requirements;
- the fire and smoke control strategy for the area.

- 5.33 Where the ventilation system is not merely tempering the air, but also providing the heating and/or cooling requirements (air-conditioning) the following additional factors should be considered:
- internal or peripheral location;
 - orientation of windows;
 - variation of internal loads;
 - level of control required.
- 5.34 For single-zone plant in staff areas, local control (with a run-on-timer if required) is recommended, as the system can be turned off when the space is not in use, thus saving both thermal and electrical energy. Most clinical-zone supply and extract systems, conversely, are required to operate continuously while the department is occupied; thus some form of time or use control is necessary.
- 5.35 The control of individual plant items is covered in Chapter 9, with examples of typical control strategies in Chapters 6 and 7. For control parameters of particular critical ventilation and air-conditioning systems, see Chapter 8.
- 5.36 On rare occasions a duplicate standby air-handling plant may be justified. If installed, it should be provided with a gas-tight damper (see BS EN 1751) at its junction with the supply distribution duct so that no back-flow can occur. Standby plant can become sources of contamination if warm, moist air is allowed to dwell within them. Their design and control system should ensure that this cannot happen.

Note: The presence of duplicate plant should be reflected in the fire strategy.

Fire and smoke control

- 5.37 Within a designated departmental fire zone, the total mechanical supply and extract ventilation volumes should be approximately equal so that in the event of a fire, smoke is neither drawn into nor blown out of the zone. Note that individual sub-zones within the departmental zone may be positively or negatively pressured to suit the clinical need (for example, isolation rooms, operating theatres).

Note: In atria, stairwells and designated escape routes, dedicated smoke clearance fans may be installed to keep evacuation routes clear in the event of a fire. These together with their associated smoke dampers do not form part of the building's general ventilation system and their operation will be automatically initiated by the building's fire detection system and/or manually controlled by fire service personnel (see Health Technical Memorandum 05 Firecode).

Air-conditioning

- 5.38 Air-conditioning is the facility to filter, heat, cool, dehumidify and if required humidify the supply air to maintain an internal condition regardless of changes in the external conditions or internal load. It is expensive in plant and energy.
- 5.39 Due to capital and running costs, air-conditioning should only be used in essential areas. These include operating departments, critical care areas, manufacturing pharmacies and areas with particularly sensitive equipment. Information on system performance requirements for individual departments is given in Chapter 8.

Local exhaust ventilation

- 5.40 There is a statutory requirement under the COSHH regulations to prevent or control the escape of chemicals, toxic fumes, biological materials or quantities of dust into the general environment. For airborne hazards to people, control may be by the provision of an LEV system designed to the standard set out in HSG 258.

Ventilation for general areas

- 5.41 Chapter 8 and Appendix 2 provide recommended air-change rates, temperatures and pressures for general areas requiring mechanical ventilation in healthcare buildings.

Mechanical extract ventilation

- 5.42 General extract systems can vary in complexity from a single wall-mounted fan to a central ducted air system with dual extract fans.
- 5.43 Replacement air is provided by either a central supply system or enters the building through gaps in the structure or purpose-made openings. The design should ensure that the latter does not result in an unacceptable level of draughts occurring in winter.
- 5.44 If individual systems are used, the ventilation can be operated intermittently, provided it continues to run for at least 15 minutes after the room is vacated (as with light-switch-operated fans in individual toilets).
- 5.45 If general exhaust systems are used, filtered and tempered replacement air should be provided to adjoining lobbies or corridors, to prevent the risk of discomfort caused by the ingress of cold air. Fire compartmentation requirements should be maintained.
- 5.46 Information on specialised extract systems is given in Chapters 8 and 9.

Mechanical tempered-air-supply systems

- 5.47 Where mechanical supply systems are required, the fresh air should be tempered and filtered before being delivered to the space in order to avoid discomfort.
- 5.48 The majority of space air temperature heating load will be provided by the energy-recovery device with the balance from a constant or variable temperature battery. In most instances, the low pressure hot water (LPHW) heating system should offset any fabric loss so that set-back room temperatures can be maintained during unoccupied periods without the need for the ventilation system to operate.

Balanced ventilation

- 5.49 A balanced ventilation system is a combination of both a supply and an extract system of equal volume; either a single space or a whole building may be considered to be balanced.
- 5.50 A balanced system is necessary in instances where it is essential to maintain consistent air movement within an area (for example, recovery rooms).

Cascade ventilation

- 5.51 In operating departments, it is normal practice to supply air to the operating theatre and allow it to flow through less clean areas – corridors, utility rooms, etc (from where

it is eventually extracted). Pharmacy aseptic preparation facilities, maternity delivery rooms and treatment rooms are similar.

- 5.52 In negative pressure facilities it will be necessary to provide make-up air in order to promote the correct pressure cascade from the clean to the less clean (for example, supply in an outer area – to lobby to patient’s room – to toilet extract). Infectious diseases units and bronchoscopy rooms are similar.

Recirculation systems

- 5.53 Air recirculation systems are normally used in HEPA-filtered cleanrooms where the return air is significantly cleaner than the outside supply and where odour levels are not significant.
- 5.54 Recirculation is also routinely used in the canopy section of ultra-clean operating theatre ventilation systems (UCV). The recirculated air is EPA filtered to ensure that biological contaminants released by the surgical team are not discharged back into the clean zone.
- 5.55 Recirculation may also be used for swimming and hydrotherapy pool ventilation.
- 5.56 Where the designer is considering the installation of an air recirculation system, due account should be taken of:
- a 20% minimum fresh air supply volume or that required by the Building Regulations or 10 L/s/person, whichever is the greatest;
 - prevention of supply air contamination from vitiated return air;
 - prevention of stratification occurring within plenum chambers and mixing boxes, which may result in freezing of downstream coils;
 - ensuring sufficient velocities through automatic control dampers (ideally 5–6 m/s) where fitted, to provide suitable authority and good shut-off;
 - modulating control of mixing to provide optimum on-plant conditions;
 - the use of “free cooling” by cycling the dampers to minimum fresh air when the enthalpy of the outside air is greater than that of the extract air under conditions when cooling is required.

Note: Recirculating air can create particular problems when its ductwork breaches fire compartmentation. Designers should ensure that the system complies with the fire strategy in all modes of operation.

Dilution ventilation and clean airflow paths

- 5.57 In the past dilution ventilation has been used as the sole means of controlling levels of airborne hazardous substances in a space. This approach in itself is no longer considered acceptable. COSHH requires that airborne hazardous substances should be controlled at source by using a closed system (such as an anaesthetic gas scavenging unit) or a protective enclosure (such as a fume cupboard). A good level of background ventilation will assist in diluting any casual release of the substance.
- 5.58 In anaesthetic rooms, the casual exposure of staff to leakage or spillage when administering anaesthetic agents should be dealt with by establishing a clean airflow

path. Air should be supplied at high level above or behind the area where the staff will typically stand and extracted at low level directly behind the anaesthetic equipment position (see Figure A25 and photographs in Appendix 9).

- 5.59 The philosophy of establishing a clean airflow path – from the air-supply point, past the breathing zone of the staff, on to the patient or other source of airborne hazard, and out via a low-level extract – would also apply in recovery rooms, birthing rooms, bronchoscopy rooms, laboratories and post-mortem rooms. A suitable air-change rate (see Chapter 8) will provide background dilution ventilation as an additional safeguard. This approach ensures that regarding the ventilation aspects, “all reasonable steps are taken to prevent or control exposure (of staff) to the hazardous substance” as required by COSHH.

Note: In these areas the supply air should be 100% fresh and not recirculated.

- 5.60 In operating theatres, patients will be on a closed breathing circuit in a room with a high air-change rate. Under these circumstances, the dilution effect would be considered sufficient to control any casual exposure of staff to anaesthetic gases.

Displacement ventilation

- 5.61 Displacement ventilation introduces air at low level and removes it at high level. It uses the natural thermal buoyancy resulting from heat gain to achieve air movement throughout a space with minimal or no energy input. Displacement ventilation can be natural, mixed mode or mechanical with the supply untreated, tempered or fully conditioned depending on the application.
- 5.62 Displacement ventilation can be very energy-efficient and works well in applications that have significant casual heat gains from solar effects, people or equipment. Typical applications in a healthcare setting would be the ventilation of atria, central dining rooms, main kitchens, hydrotherapy pools, computer server rooms, lecture theatres and open-plan waiting or office areas. It is also applicable to non-interventional imaging and scanning suites where there are significant equipment-generated casual gains but no aerobiological infection risks.
- 5.63 Supply terminals will be located at low level, usually in the form of large perforated plate style diffusers mounted vertically. The supply air terminal face velocity is low so that it does not create draughts. It is essential that they are located in several positions so that they can ventilate the entire space. Care should be taken to ensure that fixed or movable equipment and devices cannot obstruct them. Extract will be at high level through vents or by a ducted extract system. The ventilation rate may be controlled by temperature or CO₂ sensor-initiated motorised dampers with or without fan assistance at the extract points. The supply air volume is then slaved to match.

6. Energy Control Strategies

- 6.1 The operation of ventilation systems should be monitored through a building management system (BMS). The basic objective should be to provide the necessary service utilising the minimum energy. To this end, switching a system “Off” when not required is the most energy-efficient policy.
- 6.2 If the system is needed to maintain a minimum background condition, reducing its output by “Setting back”, to the minimum necessary to achieve and maintain the desired condition, is the next best option.

Note on “Set back”:

In previous times when fan motors only had two speeds, turning the system to “Set back” meant switching to the lower fan speed. With modern fans the speed is widely variable so “Set back” is not a fixed fan speed but rather a control strategy that reduces the system output in order to maintain a desired minimum condition. This may be related to the air velocity at a fixed point, air-change rate, pressure differential, temperature, humidity or a combination of these parameters. Providing a dew- point sensor in an internal space that brings the system on to “Set back” is a simple way of maintaining a minimum condition.

- 6.3 The system should only run at full output when needed to achieve and maintain the defined “in-use” operating condition
- 6.4 Care should be taken when specifying plant to discover the true “in-use operating condition”. Overstating the condition will lead to oversized plant, unstable control and excessive energy consumption.
- 6.5 The design and selection of set points for an AHU and associated extract system will have a significant impact on the overall energy consumption and efficiency of the system as a whole (see Chapter 9 for detailed information).

Timed control

- 6.6 Switch the AHU “On” and “Off” at fixed times using a time clock or BMS programme. The AHU needs to come on early enough in the morning to bring the space up to temperature by the normal start time.
- 6.7 As above but with an “Optimum start” control that uses the outside temperature to determine the start time. In the winter, the lower the outside temperature, the earlier the AHU starts. In summer, the higher the outside temperature above that desired, the earlier the AHU starts.
- 6.8 As above but link the AHU to a temperature sensor in the space. If out of hours the temperature inside drops to the dew-point, typically 16°C in winter, or rises above 25°C in summer, the AHU will start and run at “Set back” (see definition in the Note after paragraph 6.2).

- 6.9 Any combination of the above or any other appropriate and applicable method that uses the least energy to maintain the specified condition is valid. Various options for the control of single- and multi-zone air-conditioning systems are given in CIBSE Guides F and H.

Occupancy control – user triggered

- 6.10 The ventilation system output should be linked to occupancy detectors. These may take the form of movement, CO₂, passive infrared (PIR) or other sensing technologies that can detect that the area served is in use and switch the system “On” or “Off” and/or adjust the ventilation output to suit the actual load.
- 6.11 In intermittently used spaces such as operating suites, movement sensors (for example, PIR or similar) should be installed in the space with a “double knock” program so that if movement is detected twice within 10 minutes the AHU will switch “On” to full speed. If no movement is detected for 30 minutes, the AHU switches “Off”. Double-knock detection prevents the system from switching on in situations where a person has briefly entered a space when it is not in use.
- 6.12 The above may be combined so that if there is no movement for 15 minutes, the AHU switches to “Set back” (see definition in the Note after paragraph 6.2) during the working day and “Off” outside of normal hours.

Note: In Ultra Clean Ventilated (UCV) operating theatres the UCV terminal should be linked to the AHU control so that when the AHU goes to “Set back” the UCV also goes to “Set back”, and if the AHU goes “Off”, the UCV terminal fans also switch “Off”. There is no aerobiological benefit in keeping the UCV terminal fans running when the theatre is not in use, it results in wasted energy.

- 6.13 An alternative strategy in operating suites is to link the AHU control to the lighting. If the theatre general lights are switched “On” the AHU switches “On” in “Set back” mode. If the main operating lamp is then switched “On” the AHU goes to “Full speed”. If all the lights are out the AHU goes “Off”.

Note: There are occasions when this approach may need to be used with caution; for example, if a type of surgical procedure requires the operating or general lights to be “Off” during a part of the operation, an override timer or plant extension switch will be needed. The operating department manager and VSG should be consulted for approval before adopting this strategy.

User control

- 6.14 Some applications require intermittent mechanical ventilation, frequently at a high air-change rate (for example, in certain types of treatment room for odour control). Local controls to facilitate this mode of operation if required should be placed in a prominent position to encourage economical use. Specifying timers that shut the system down after a suitable operating period and need to be reset manually will reduce energy waste.
- 6.15 Local controls that enable the user to select more than one mode of operation should be clearly labelled to identify the particular mode selected.

- 6.16 Where the system allows different room pressures to be selected, a direct-reading pressure gauge should be fitted within the eye line of the users, 1.5 m above floor level, adjacent to the selector control unit to provide an independent confirmation of the resultant mode of operation. A permanent notice giving a clear description of the selectable modes of operation should be mounted adjacent to the control unit.

Interim

7. Environmental Control

- 7.1 The primary objective of a ventilation control system is to keep the space served within the required environmental control limits, at the appropriate times – regardless of external conditions or internal loads – and with the minimum energy consumption.
- 7.2 The building heating load will normally be met by a wet heating system with ventilation provided to suit the activities within it. The control of the heating system will normally be compensated to the outside air temperature. Control of the ventilation will usually be via a building management system (BMS) with “outstations” in individual plantrooms and/ or for individual AHUs.
- 7.3 A BMS incorporating self-adaptive control algorithms that automatically adjust the set-point to suit the usage and load is preferred. This will enable the operating conditions and control tolerances to be set and monitored. It is often not possible to accurately predict building load variation at the design stage. Information provided by monitoring the operation of the plant via a BMS will enable optimum set-points to be established and energy consumption reduced.
- 7.4 The BMS may also be set to log the actual energy consumed by the system together with that recovered by the energy- recovery device. This will provide a useful check on overall operating efficiency and provide evidence that energy targets are being achieved. The provision of movement sensors within the controlled space in order to determine the actual occupancy will facilitate this process.
- 7.5 The failure of ventilation systems serving critical areas can have grave consequences for the delivery of healthcare. Control systems should therefore be simple, robust and reliable.
- 7.6 Computer-software-driven control systems are now the norm in building services. However, healthcare ventilation systems need to be available for operation outside of normal working periods when software support is not available. Should the software fail, it will be left to site staff, who may have little knowledge of the control algorithms, to restart the ventilation system. It is therefore essential to ensure that a simple means of restarting critical systems in the event of a software failure is provided (see also Chapter 9).
- 7.7 Where BMS use “outstations” to control plant, the “outstation” should be independently able to control the plant if the BMS link is lost.

Location of controls

- 7.8 Whether within the plant, duct or room, sensors should be located to provide accurate measurement of the condition of the air being monitored.
- 7.9 Sensors and control items such as control valves should be located close to the element being sensed or plant item being controlled in order to minimise time lags within the system. These may create over- shoot of conditions beyond the design envelope and result in additional energy consumption.
- 7.10 Where there is a requirement for close control of air-conditioning parameters in a number of zones (for example, an operating department), separate plant should be

provided for each zone in order to avoid the need for expensive over-cooling and reheating of individual zones. The control of most multi-zone systems within healthcare premises is based on off-coil control within the central plant, with trimmer heater-batteries on individual zones.

Note: In modern buildings the cooling load is often significantly greater than the heating load and may exist all year round. Whenever possible, the design should take advantage of free cooling when available.

- 7.11 Facilities to start, set back and stop the plant should be provided in the plantroom. Remote start and set-back control and indication, if required, should be provided at a manned staff location (for example at the reception or staff base).
- 7.12 Many ventilation systems may be completely shut down when the area served is not in active use (for example, operating suites). Alternatively, where there is a need to maintain a background condition, the ventilation output may be reduced by “setting back” the system (see paragraph 6.2 and associated Note). This will significantly reduce energy consumption and extend the life of filters and other system components

Multi-zone control methods and application

- 7.13 Close control of all air-conditioning parameters may be difficult to achieve with multi-zone systems, since each zone will in theory require a reheater and humidifier to give total control of humidity, if that is what is required. In reality, such close control is rarely required. It is therefore usual with multi-zone systems to provide control of zonal temperature only, with humidity control, where fitted, being based on average conditions within all zones, or a minimum condition within one zone.
- 7.14 Designers should consider whether it is necessary for the supply and extract fans to be interlocked – either so that the supply fan will not operate unless airflow is established within the extract system, or vice-versa depending on the required pressures within the rooms being served (see also Chapter 8).
- 7.15 The sequence switching of units in order to prevent transient reverse airflows will be particularly important in laboratories and pharmacies that contain fume cupboards, safety cabinets and other LEV systems.

Fire aspects

- 7.16 The control strategy for ventilation systems in the event of a fire should be set out in an agreed fire and smoke control strategy for the site (see Chapter 1).
- 7.17 All supply AHUs should have a smoke sensor linked to the fire control panel and mounted in the main supply duct immediately downstream of the AHU. In the event of a fire in the AHU or smoke being drawn into the system from an outside source, it should cause the AHU to shut down and the main supply-air damper and system fire damper(s) to close.
- 7.18 In critical areas a ventilation control panel should be mounted at the main entrance of the area that the ventilation serves (see Health Technical Memorandum 05-02 for more detailed guidance). Access to the panel should be restricted to the fire officer and appointed site AP(V). It should include independent on/off controls and an

indication of the status of the supply and extract systems. A notice should be affixed to the control panel stressing the need to liaise with departmental staff before switching off fan units

Note: In certain critical care areas, it is preferable to maintain the supply ventilation in case of a fire within the area. For example, in an operating department, while undergoing surgery, the patient cannot always be easily moved without significant risk. In the event of a fire in a staff or support area of the department, or adjoining zone, the continued supply of air to a theatre will maintain it at a positive pressure and protect the patient and staff from the effects of smoke. This will allow time for the patient to be stabilised so that they can be safely evacuated if necessary.

User requirements

Room temperature control

- 7.19 The limits for room temperature set- point are generally between 18°C and 22°C depending on the particular application. In some specialised applications (for example, operating departments), the user may require a wider range of adjustment (see Chapter 8).
- 7.20 The selection of temperature set-point for each room or zone may be by a control facility in the room/zone or be carried out remotely at the control panel or BMS. Where the control device is mounted within the room/zone and is adjustable by the user, it should be marked either “raise” and “lower” or “+” and “-”. It should control within a specified temperature range to suit the user requirement with a control tolerance of ± 1 K. All other control set- points should be selectable either on the control panel or at the BMS interface.
- 7.21 Where local control is provided, an indication of temperature will be required locally or at a staff base (if appropriate) using an analogue or digital indicator. The indicator should be large enough to be read from the normal working position (for example at the operating table in a theatre). This may be mounted in a supervisory control panel, with the signal repeated on the main system control panel or BMS. It is important that this indicator displays the actual measured temperature and not the selected temperature.

Alarms and indication

- 7.22 Supply and extract systems should include indicator lamps on the control panels to confirm the operational status of each system. Where the usage is on a regular daily pattern, time control with a user-operated, timed manual override should be provided.
- 7.23 Where a system is provided for a particular space, the indicator should be in, or immediately adjacent to, that space, and local controls should be provided with permanent labels clearly defining their function (for example isolation suites).
- 7.24 If room differential pressure gauges are required, they should be mounted directly adjacent to the entry door of the room to which they apply at a height of 1.5 m above floor level so that they are in the eye line of staff entering the room. If a mechanical gauge is fitted, it should have a green sector to indicate the acceptable normal

pressure range. If electronic, it should have a permanent label affixed underneath it giving the normal acceptable pressure range.

Note: For specific departmental control parameters, see Chapter 8. For plant controls see Chapter 9.

Maintaining balanced air flow rates

Consideration must be given to the method of maintaining the correct proportional balance throughout a system when in use. This becomes particularly important where duct or terminal mounted filters are to be used. As the filters soil, the pressure and flow balance of the system would change unless control measures are included to enable automatic compensation/adjustment (e.g. constant volume boxes, variable speed drives).

8. Specific Healthcare Department Requirements

General considerations

8.1 The foregoing chapters of this document contain general information on healthcare aspects of ventilation system design and specification. This chapter gives information relating to the specific design requirements for a range of healthcare applications.

8.2 The following departments will require a degree of ventilation appropriate to their function.

- the operating department;
- treatment rooms, endoscopy and minimally invasive suites;
- critical care area – levels 2 and 3;
- diagnostic and interventional imaging and cardiology suites;
- obstetrics/maternity;
- infectious diseases unit and isolation facilities;
- bone marrow and other transplant units;
- chemotherapy and oncology units;
- the pharmacy department;
- the pathology department, mortuary and post-mortem suite;
- central decontamination units;
- burns unit;
- cystic fibrosis unit;
- tissue bank, gene therapy and emerging treatment specialties;
- physiotherapy and hydrotherapy;
- estates infrastructure.

Design information for many of these applications is given below, in Appendix 2 or the relevant SHPN/HBN.

8.3 It is not possible to give definitive guidance for every healthcare ventilation application; however, the section on operating theatres contains much information that is common to other applications. Where no specific guidance is given, the principles set out below should be followed:

- the CIBSE guides and technical manuals contain basic information on ventilation design that can be applied to most applications;
- where a British or European standard exists that is specific to the application (for example, a cleanroom), it should be used as the basis of the design requirement;

- air should always move from clean to less clean areas. A hierarchy of room cleanliness is given in Appendix 3;
- differential pressure will prevent contamination between areas when doors are closed. Information on air leakage through gaps around closed doors and hatches for a range of differential pressures is given in Appendix 4;
- the flow of air will prevent contamination between areas of different cleanliness when doors are open. Information on airflow through open doors and hatches is given in Appendix 5;
- a methodology for calculating a design solution for a non-standard operating suite in terms of its room sizes, layout or number of people present is given in Appendix 8. This may be adapted as necessary to suit other less complex applications where air is required to cascade through rooms from clean to less clean areas.

Note: In all cases it is essential that the design solution adopted will ensure adequate scouring of the space being ventilated. The selected airflow rates, relative position of supply terminals, extract terminals, air transfer devices and pressure stabilisers will all have a bearing on the effectiveness of the room ventilation.

8.4 There are four routes by which airborne contaminants may appear in a room:

- shed directly by the room occupants;
- arising as a result of the work activities;
- transferred from adjacent spaces;
- through the supply air.

Particles shed directly by the room occupants can be controlled by:

- restricting access to essential persons only;
- the choice of the occupants' clothing;
- the room air-change rate.

Particles arising as a result of the work activity can be controlled by:

- enclosing, semi-enclosing or otherwise controlling the work-based source;
- the room air-change rate.

The transfer of particles from adjacent spaces can be controlled by:

- a differential pressure between spaces when doors are shut;
- airflow paths flowing from clean to less clean spaces when doors are open.

Particles entering with the supply air can be controlled by the selection of a suitable filter.

When designing ventilation for a healthcare application, the sources of airborne contamination, their degree of hazard to patients and/or staff and the ability of ventilation to control them should be taken into account. For any particular healthcare

application, the ventilation safety group (VSG) should be able to give advice on any specific risks to patients and staff.

8.5 The supply of air to a room has the following main functions:

- to dilute airborne contamination;
- to control air movement within such that the ingress or discharge of airborne contaminants from or to adjacent areas is minimised;
- to control the temperature and, if necessary, the humidity of the space;
- to aid the removal of and dilute fumes, odours and waste gases.

8.6 The supply air volume flow rate for any particular application will be that required to:

- achieve the application's recommended air-change rate;
- provide closed and/or open-door protection;
- achieve comfort or application-specific room conditions;
- replace (make up) that removed by an installed extract system;
- meet the fresh air requirement relating to the number of people anticipated to be present;
- achieve the minimum fresh air requirement if air is recirculated.

Whichever is the greatest amount.

Note: Air-change rates are given in Appendix 2. These figures have been found to give enough dilution of airborne contaminants, provided the mixing of room air is reasonably uniform. Closed and open door protection volumes are given in Appendices 4 and 5. Fresh air requirement is at least 10 L/s/person. Minimum fresh air volume if recirculated is 20%, whichever is the greater.

8.7 Natural and/or mixed mode ventilation should be used wherever possible. Where mechanical ventilation is chosen, a downward displacement turbulent air distribution is generally preferred, though displacement ventilation may be used if appropriate.

8.8 The supply and extract terminals should be positioned to ensure that all parts of the room are actively ventilated and that where necessary the staff will be in a clean airflow path. Extract and air-out paths via door gaps, transfer grilles, pressure stabilisers and low-level active extract should be evenly distributed to encourage efficient scouring of the room. (See paragraphs 8.37–8.40 and 9.161–9.172 for additional guidance on location and types of terminal.)

8.9 Horizontal flow room air distribution with or without a coanda effect (see paragraph 9.162) can be a source of draughts and difficult to set up correctly. Its use should be confined to non-critical areas or situations where ceiling-mounted diffusers could be obstructed by movable equipment support tracks (for example, in imaging rooms). Alternatively, a displacement ventilation scheme may be considered.

Temperature and humidity control

- 8.10 Supply flow rates to achieve the required room conditions are calculated conventionally, taking account of all heat and moisture gains and losses, and of maximum permissible temperature differences between the room and supply air. In most applications the base heating load will be provided by a heating system. In critical systems the room or suite being considered will be within the heated building envelope so the ventilation will be sized to suit the casual gains or losses.
- 8.11 Temperature differences between supply and room air of up to 10 K for winter heating and 7 K for summer cooling should not be exceeded.
- 8.12 Room air humidity should be kept below 70% in order to minimise risks associated with condensation and mould growth. There is generally no lower limit in unoccupied spaces; however, see application-specific guidance.

Ventilation where anaesthetic agents are present

- 8.13 During treatment, anaesthetic gas or anaesthetic agents may be delivered to the respiratory tract of a patient either directly or using a carrier gas. Anaesthetic gases and agents are subject to workplace exposure limits and while beneficial to the patient are harmful to staff. Waste anaesthetic gas should be contained and removed by a suitable anaesthetic gas scavenging system (AGSS). Some leakage from the anaesthetic equipment and the patient's breathing circuit will occur with all systems, particularly during connection and disconnection and from the interface with the patient. In recovery areas the patient will exhale the anaesthetic agent directly into the room air. The room ventilation scheme should ensure that any leakage or exhaled anaesthetic agents are diluted and removed.

Note: Staff tend to be standing and patients lying down when anaesthetic agents are delivered; also anaesthetic agents are slightly heavier than air, so locating the supply terminal at high level behind where staff normally stand, with an extract at low level adjacent to the source (for example, the anaesthetic gas terminal units), will ensure that staff are in a clean airflow path.

- 8.14 The design primary air supply to an operating suite anaesthetic room that is equipped with a N₂O terminal or in which an anaesthetic agent is delivered to the respiratory tract of a patient using a carrier gas, or an operating department recovery room, should be 15 ac/h.
- 8.15 In delivery rooms the intake of anaesthetic gas is controlled on demand by the patient, who will then exhale directly into the room air. Locating the supply air at high level at the foot end of the bed with extract at low level at the head end will establish a clean airflow path and reduce the casual exposure of staff to the waste gas.
- 8.16 The primary air supply to any other room that is equipped with a N₂O or N₂O/O₂ (Entonox) terminal or in which an anaesthetic agent is delivered to the respiratory tract of a patient using a carrier gas or in which the patient is subsequently recovered, where the anaesthetic is employed for the purpose of pain relief or sedation but not full anaesthesia, should be 15 ac/h. However, subject to risk assessment, consideration may be given to reducing this to no less than 10 ac/h, only where use of the anaesthetic gas release into the space will be both very infrequent and in very small quantities.

Note: Staff employed in operating suite anaesthetic rooms and an operating department recovery room will potentially be exposed to anaesthetic agents for the duration of their working day. In other areas (for example, maternity, imaging, treatment rooms), anaesthetic agents are only used for pain control and/or sedation. The strength, quantity and frequency of use may be significantly less, hence the the option to carry out a risk assessment.

Door protection

- 8.17 Air should flow from the cleaner to the less clean areas as shown in Appendix 3 and Figure A23 in Appendix 8. There are several factors that affect the likelihood of a reverse airflow through doorways:
- when a person passes through a doorway, both the passage of the person and the movement of the door flap cause a transfer of air between the areas separated by the door;
 - when a door is left open, there is a transfer of air between the two areas separated by the doorway. This is caused by air turbulence, but is greatly increased by any temperature differential between the areas (a 1.4 m wide doorway may allow the transfer of 0.19 m³/s of air in each direction when there is no temperature difference, but when the temperature differential increases to say 2 K, the volume transferred may increase to 0.24 m³/s). This may be a problem if for example the heat gain from a fluid warming cabinet is not allowed for.
- 8.18 In order to reduce the likelihood of contamination of a clean area by a reverse airflow from a less clean area two methods of door protection are used:
- closed door protection – a pressure differential is created across a closed door so that any air leakage is from the clean to the less clean area. Appendix 4 gives details of closed door leakage rates for a range of differential pressures;
 - open door protection – the pressure differential drops when a door is opened (see Appendix 6) and is effectively replaced by a flow of air through the doorway from the clean to the less clean area. The flow of air needs to be sufficiently large to ensure that significant reverse airflow cannot occur and will be related to the relative cleanliness of the areas being considered. Appendix 5 gives airflow rates for open-door protection related to door/opening size and the classification of the adjoining area.
- 8.19 Pressure stabilisers enable the room differential pressure to be set when the doors are shut, thus providing closed-door protection. When a door is opened, the stabilisers will close, forcing air to be directed through the doorway, thus providing open-door protection. Provided that the dilution criteria in Appendix 3 are met, the occasional small back-flows created (when two doors are opened simultaneously; or when there is a high temperature difference across an open door) will have little effect on the overall air cleanliness of the affected room.
- 8.20 In applications where it is critical to maintain a specific airflow and/or pressure regime, for example isolation rooms, all windows in the zone should be locked shut or sealed. Trickle vents, if fitted, should also be sealed.
- 8.21 The design of the ventilation system for an area depends on the overall configuration of the department. Where the department is served by more than one AHU the

control of the units may need to be interlocked so that reverse airflow patterns do not occur.

- 8.22 Extract grilles should be sited and balanced to promote air movement in the desired direction.
- 8.23 Transfer grilles enable air to pass in either direction between rooms of equal class and pressure. Pressure stabilisers operate in one direction only; they allow excess air to be directed to the area desired and assist in maintaining room pressure differentials.
- 8.24 The relative locations of supply and extract terminals and their design air volume rates will determine the basic airflow between adjacent spaces. Transfer grilles and pressure stabilisers will permit and control the flow of air between spaces, ensuring a flow from the clean to less clean areas of the suite. Failure to provide such devices will lead to uncontrolled airflows when personnel move between rooms and doors being held partially open by air pressure.

Air handling unit

- 8.25 AHUs should be to the standard set out in Chapter 9. The extent of the system served by an individual AHU should reflect the operational need and required resilience of the application.

Fire aspects

- 8.26 When considering the overall airflow movement, careful thought needs to be given to the operation of the ventilation system to limit smoke spread in the event of a fire.

Operating department

General

- 8.27 An operating department will consist of one or more operating suites, a recovery area, sterile pack and equipment stores, entry/exit/service corridors, office, staff changing and support facilities. Each operating suite will typically comprise a preparation room, operating theatre, anaesthetic room, scrub area and a utility room. In order to ensure satisfactory conditions and the correct movement of air, the entire department will usually be mechanically ventilated.
- 8.28 The information given in this section relates to conventional operating suites used for general surgery. It will be applicable to other types of operating suite such as maternity whose layout and dimensions conform to the principles of Health Building Note 26 (see Note below). Additional information for UCV theatres is given in paragraphs 8.75 onwards.

Note: Health Building Note 26 – ‘Facilities for surgical procedures’ (2004) and Health Building Note 10-02 – ‘Facilities for day surgery units’ (2007) are under revision and will be replaced by a single document: Health Building Note 10-01. It will provide guidance on the planning and design of infrastructure for in-patient and day-patient surgical services in the UK.

- 8.29 For other types of operating suite, the standard values may need to be adjusted to reflect non-standard room sizes, pressure regimes and air-change rates. A method of obtaining a design solution for non-standard theatres from first principles is given in Appendix 8 (see also paragraph 8.3 and accompanying Note).

Standard air movement control schemes

- 8.30 In all previous versions of this guidance, standard air-movement control schemes were given that provided a range of design solutions for typical operating-suite layouts. Improvements in the technology of ventilation control systems coupled with the ability to accurately sense and control real-time fan output has enabled operating-suite ventilation parameters to be tightened. These now more accurately meet the airborne-infection-control requirement (see the Lidwell Report). The previous standard design solutions have therefore been fully revised to take advantage of the technological advances and benefit from the reduced energy consumption and plant size they allow.
- 8.31 A new set of standard operating suite design solutions extensively amended to conform to the guidance contained in this edition of Scottish Health Technical Memorandum 03-01 are given in Appendix 7. They contain diagrams that show the relationship of rooms and the various doors and transfer devices between them but should not be regarded as architectural layouts. The schemes have been developed using the methodology described in Appendix 8.

These design solutions should be used for new projects and when refurbishing or upgrading existing operating suites.

- 8.32 Any other scheme may be used, and the standard solutions applied, if the following conditions are met:
- room relationships in air network terms are as shown in the plans;
 - room sizes and shapes approximate to those given in Health Building Note 26 (under revision at the time of writing and to become Health Building Note 10-01);
 - door gaps approximate to those given in the designer's notes in Appendix 4;
 - casual heat gains are accounted for;
 - a trimmer battery is installed in the air supply to the anaesthetic room and lay-up prep room;
 - leakage through the structure is kept to a minimum. Note that theatre suites will be subject to an air permeability test at first-fix and final validation (see Chapters 10 and 12).

It is recommended that every effort should be made to adopt one of the schemes described above.

Ventilation design requirement

- 8.33 The need for ventilation of the individual rooms and areas within the operating department will be as follows:
- Preparation room – to protect sterile packs and instruments from pre-contamination;

- operating theatre – to control the airborne infection risk, remove airborne contaminants and prevent the ingress of airborne contaminants from adjacent areas;
- anaesthetic room – to protect staff from casual exposure to anaesthetic agents and maintain a suitable environment for patients;
- scrub – to remove aerosolised microbiological contamination and moisture released when staff scrub- up;
- utility (also known as sluice or disposal) – to contain any airborne hazards arising from the initial processing of biological material, contaminated instruments and general waste and prevent it entering the operating theatre or adjacent spaces;
- entry/exit/service corridors – to remove vitiated air cascading from the operating suite(s);
- sterile pack/ Layup Prep and equipment stores – to prevent airborne contamination of the packs and equipment;
- staff changing, shower and toilet facilities – odour control and moisture removal;
- staff rest room – moisture and odour control;
- office and general areas – comfort conditions;
- recovery – to protect staff from casual exposure to exhaled anaesthetic agents and maintain a suitable environment for patients.

The ventilation requirement for each space will be met by the desired air-change rate, room pressure differential, relative position of the room supply and extract, comfort requirement or a combination of all elements.

8.34 **Preparation room – sterile pack store (SPS)** - The preparation room is used simply as a store; sterile packs are set out on trolleys but not opened. They are then transferred to the operating theatre and opened as required. The nominal room pressure can therefore be the same as that of the operating theatre and the air allowed flow between the rooms in either direction. Air supplied to the preparation room should be directed into the operating theatre either through a door-mounted transfer grille or if no door is fitted, through the opening. It should not flow via a pressure stabiliser or transfer grille into the corridor.

8.35 **Preparation room “lay up”** – When the preparation room is used as an instrument “lay up” room (that is, sterile packs are opened and their contents exposed ready for transfer to the operating theatre), it should be regarded as being of greater cleanliness than the operating theatre. The preparation room should be at 10 Pa above the operating theatre to minimise the transfer of air and prevent pre-contamination of the instruments. The design air supply volume should relate to the door protection factors (for example, open door to theatre and closed door or hatch to corridor, where provided) and result in not less than 22 ac/h. Air should discharge into the operating theatre through a pressure stabiliser fitted with a stand-off baffle plate on the theatre side (see photograph). It should not flow via a pressure stabiliser or transfer grille into the corridor. The volume of supply air being discharged through the pressure stabiliser may be used to offset the volume of supply air to the operating theatre.

Where the unpacking of the instruments involves not only the removal of the protective packing but also the opening of the sterile barrier, the supply air to the room must be delivered via a terminal HEPA filter (H12 grade). The system must include constant volume and variable speed controls to ensure that the air flow rates remain constant as the HEPA filter soils. In this case it is also necessary to design a specific air flow regime to enhance the cleanliness of the environment. The supply air must be delivered from the ceiling in a manner which directs that air down into the zone where the sterile barriers are to be removed. Air will then be relieved from the room at low level with an air pressure stabiliser into the theatre.

8.36 **Operating theatre** – The supply of air to an operating theatre has four main functions:

- to dilute airborne microbial contamination – this will arise from the surgical activity and microbiological material shed by staff;
- to aid the removal of and dilute fumes, odours and waste anaesthetic agents;
- to control air movement so that the airborne contaminants from other less clean areas do not enter;
- to control the temperature and if necessary, the humidity of the room.

Design notes

- an air-change rate of 22 ac/h will control (a) and (b) above. When calculating the air volume required to achieve the air-change rate, the physical volume of the operating theatre will be based on whether the scrub does or does not form part of it. See Note to paragraph 8.46 for further information;
- the room to corridor differential pressure and amount of air required to give door protection will control (c). Door protection is calculated on the basis that during use, only one door or a single leaf of a double door will be open transiently, and all the rest will be closed. The designated “open” door will be the worst case (for example, typically that between the operating theatre and utility). The volume of supply air can be calculated from the flow rates for open and closed door protection given in Appendices 4 and 5. The smaller the number of rooms (and therefore doorways) leading from the operating theatre the better, as traffic is reduced, and a less complicated air movement control scheme is required;
- the supply air volume to control (d) temperature and humidity conditions can be calculated conventionally, taking account of all heat and moisture gains and losses resulting from equipment, lighting and number of occupants. Supply to room air temperature differences of up to 10 K for winter heating and 7 K for summer cooling should not be exceeded. Room humidity should not exceed 70% saturation.

The design supply air volume for an operating theatre will be whichever of the above calculations yields the greater figure.

In the case of an operating suite with a “lay up” preparation room, the actual air volume supplied by the operating theatre terminals will be the design air volume determined above minus that entering via the preparation room pressure stabiliser.

Note: In the majority of operating theatres the air-change rate will be the dominant factor; however, for small operating theatres the door protection factor may dominate.

- 8.37 The supply and extract terminals should be positioned to ensure that all parts of the operating theatre are actively ventilated. The ceiling should be divided into four quadrants and a supply terminal positioned at the centre of each quadrant and along the lines that join them as necessary to ensure that all parts of the room are equally supplied. In a large theatre, additional terminals around the centre point may be necessary to promote efficient scouring and achieve satisfactory air movement at the operating table level. This will help create in ventilation terms a well-mixed space and ensure good dilution of any airborne contaminants. Extract and air-out paths via door gaps, transfer grilles, pressure stabilisers and low-level active extract should be evenly distributed to encourage efficient scouring of the room. A minimum of three and preferably four air-out paths, approximately equally spaced, should be provided.

Note: In order to ensure correct air distribution, it is essential that the supply terminal locations are not displaced by light fittings or ceiling-mounted pendants and articulated booms. Ideally the supply terminals should alternate with light fittings along the quadrant lines described above.

- 8.38 Supply terminals should be ceiling-mounted circular “air master” style, square “four-way blow” or perforated plate style that produce a downward displacement, turbulent airflow (see paragraph 9.170 onwards). Multi-section plenum-style perforated-flow diffusers with a footprint that encompasses the operating site are acceptable but may be prone to buoyancy effects as a result of temperature difference. Manufacturers’ type test data should be consulted to ensure that the terminal will achieve the required performance envelope. Note that these are not true laminar flow systems in the strict sense of the word but produce a downward displacement parallel flow style of air distribution.

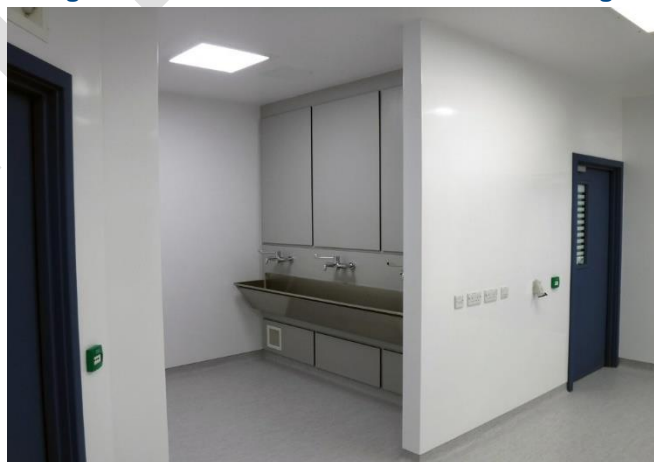
Note: Where an operating theatre requires a higher than normal air-change rate (for example, cranial surgery, which may specify 35 ac/h), the volume of supply air means that four-way blow diffusers would be noisy and probably cause unacceptable draughts. A UCV terminal would deliver too much air, which could result in exposed tissue drying out during the procedure. A multi-section, plenum-style perforated flow diffuser with a footprint that encompasses the operating site would be the most suitable option.

- 8.39 The diffuser equipment chosen should not cause “dumping” and provide an air velocity 1 m above floor level at the operating position of between 0.2 m/s and 0.3 m/s.
- 8.40 Horizontal flow distribution should not be used in new installations; however, space constraints may force its retention when refurbishing existing installations. Where fitted, the supply grilles will require a means of directional adjustment that is lockable in position to prevent casual alteration in future when being cleaned.
- 8.41 Anaesthetic room – Anaesthetic gas or anaesthetic agents will be delivered to the respiratory tract of a patient either directly or using a carrier gas. Anaesthetic gases and agents are subject to workplace exposure limits and while beneficial to the patient are harmful to staff. Some leakage from the anaesthetic equipment and the

patient's breathing circuit will occur with all systems, particularly during connection and disconnection, and from the interface with the patient. The room ventilation scheme should ensure that any leakage is diluted and removed, and that staff are in a clean airflow path. Locating the supply terminal on the ceiling in a position behind where the anaesthetist will normally stand, and the extract terminal at low level adjacent to the medical gas pipeline terminals, will encourage a clean airflow path past the breathing zone of the anaesthetist, thus reducing their casual exposure to airborne anaesthetic agents (see information in Appendix 9).

- 8.42 An operating theatre suite anaesthetic room that is equipped with a N2O terminal or in which an anaesthetic agent is delivered to the respiratory tract of a patient using a carrier gas should have a design primary supply and extract flow rate to achieve 15 ac/h.
- 8.43 In order to maintain the core temperature of patients being anaesthetised, a trimmer heater-battery should be provided in the anaesthetic room supply. It is also important that the location of pressure stabilisers and transfer grilles does not cause draughts across the patient.
- 8.44 The anaesthetic room will be at an intermediate pressure between the operating theatre and corridor.
- 8.45 **Scrub** – This may be a separate room or a bay within the operating theatre. If the scrub is a separate room, a door between the scrub and operating theatre is an inconvenience to scrubbed staff and may be replaced by an opening that is larger than a normal single doorway. If a door is fitted between the scrub and operating theatre it should have a transfer grille in its lower half. In either case there should be an active extract at low level under the end of the scrub trough most remote from the operating theatre, or a low-level pressure stabiliser that discharges onto a corridor at the end of the scrub room most remote from the operating theatre (see figure 1). If the scrub has an outside wall and/or is particularly large, additional extract terminals may be required to ensure air movement throughout the entire space and prevent surface condensation and mould growth.

Figure 1 Scrub room with extract under trough



- 8.46 Where the scrub is a trough on the wall or in an open bay within the operating theatre, it should have low-level extract under it.

Note: If the Scrub is in effect a separate room that is open (no door) to the operating theatre and it has a low-level pressure stabiliser discharging onto a corridor or an active low-level extract at its far end, so that air has to travel through the scrub to leave the operating theatre, the volume of the scrub will not be counted as being a part of the operating theatre room volume.

If the scrub is a trough on the wall or in an open bay within the operating theatre, the volume of space it occupies will be considered part of the operating theatre room volume for the purpose of calculating the operating theatre air supply.

- 8.47 **Utility (sluice or disposal)** – The room is kept at negative pressure with respect to the operating theatre so that contaminants contained in the surgical waste do not re-enter the operating theatre. A utility opening onto a clean corridor is considered to pose a greater risk than one opening onto a service corridor and so has a greater differential pressure. A utility may be shared between two operating theatres or be centralised to serve a group of operating suites.
- 8.48 **Entry/exit corridor** – Air cascading from the operating suite should be removed in the adjacent corridors. Note that though design flows may be calculated, the actual extract airflows may need to be adjusted at commissioning in order to achieve the design room differential pressures.
- 8.49 **Service corridor** – If materials to be disposed of are placed in impervious material for transportation, it is not necessary to have a separate corridor for this purpose. However, a service corridor has many operational advantages in terms of the flow of materials through the operating suite. It provides a heated envelope around the operating suite, thus obviating the need to run the theatre ventilation out of hours to maintain its temperature above dew-point, so significantly reducing energy consumption. Lastly it permits access for routine service and maintenance, and the eventual refurbishment of an operating suite without compromising the use of adjacent suites.
- 8.50 **Sterile pack store** – The central operating department sterile pack and prosthesis store should be supplied with 6 ac/h and be at a positive pressure to their corridor. It is important to coordinate the position of the supply air terminals with any racking so that the terminals are accessible for annual airflow measurement with a balometer.
- 8.51 **Equipment store(s)** – Supply air ventilation only to keep them at positive pressure to the corridor.
- 8.52 **Staff changing, shower and toilet facilities** – ventilation as per building regulations and for moisture control.
- 8.53 **Staff rest room** – Ventilation for kitchen area and general comfort.
- 8.54 **Office and general areas** – Ventilation as per building regulations and comfort.
- 8.55 **Recovery room** – Anaesthetic agents will be exhaled by patients while recovering; they are subject to workplace exposure limits and are harmful to staff. Anaesthetic gas scavenging systems (AGSS) will be provided but the room ventilation scheme should ensure that any leakage is diluted and removed.

- 8.56 The supply air terminals should be ceiling-mounted above the foot end of the recovery bed positions. Extract should be at low (bed height or below) level behind the bedhead positions or in the corners of the bed bay. This will establish a clean airflow path so that staff do not inhale anaesthetic agents exhaled by recovering patients (see the COSHH Regulations).
- 8.57 In an operating department recovery room, the design primary air supply will be 15 ac/h with a balanced airflow.

General notes

- 8.58 Supply flow rates for the main rooms of the operating suite are given in Appendix 7. For the other areas where room sizes and activities vary from site to site, air-change rates are given in Appendix 2 and Tables 2–7 in this chapter. These figures have been found to give enough dilution of airborne microbial contaminants, provided the mixing of room air is reasonably uniform.
- 8.59 For conventionally ventilated operating theatres, the primary air supply would be filtered in the AHU. Terminal filters, EPA or HEPA, are not required.
- 8.60 Air extracted from operating suites should not be recirculated as it may contain malodorous contaminants.

Note: Where thermal wheels are used for energy recovery, the small leakage across them from extract to supply should not cause odour problems and is not considered aerobiologically significant. In any event, all the air supplied will pass through the final filter.

Operating suite pressure regime

- 8.61 When designing the ventilation scheme the room pressure differentials given in Appendix 7 should be used. However, when the suite is balanced and commissioned these values are not to be taken as immutable but rather as desired orders of magnitude. What is important is the direction of airflow between rooms when doors are closed. Specifying doors of a laboratory standard that close and sit against a seal or have drop seals on their bottom edge is not necessary and will be counterproductive of the aim to allow air to flow from clean to less clean areas.

Note: Fire officers often require that doors are fitted with cold smoke seals as standard. These will significantly reduce the door-leakage rate and increase the differential pressure when new and undamaged. It is therefore recommended that provision for the design door leakage be factored into the sizing of the appropriate transfer grille or pressure stabiliser.

Temperature and humidity control and indication

- 8.62 In an operating theatre the temperature should be adjustable within the range 18°C to 25°C by the staff at the theatre control panel. The ventilation system should be capable of maintaining an internal temperature of 20°C at summer outside design and 22°C at winter outside design in all but the most extreme outside conditions. There may be instances where these temperatures may not be appropriate (for example, children and patients with a low body mass). The internal design temperatures should then be discussed with the VSG and agreed in writing.

- 8.63 Theatre temperature and humidity control sensors should be actively ventilated. They would typically be located in a sampling extract duct mounted in or adjacent to the theatre control panel, positioned at normal working height (1.5 m above finished floor level). Alternatively, they may be mounted in one of the operating theatre's low-level extract ducts. Whichever location is chosen they should be accessible for cleaning, and removable for periodic calibration and replacement.
- 8.64 Passive wall-mounted temperature and humidity sensors are not recommended.
- 8.65 Controls should be provided to enable operating department ventilation plant to be closed down when the operating suites are unoccupied (see also Chapter 9).
- 8.66 When in the "off" mode, to provide dewpoint protection the control system should switch the ventilation "on" to "Set back" if the space temperature falls below 16°C.
- 8.67 All operating theatres and rooms where surgical interventions are carried out should have a control panel mounted on a wall with its screen centre at 1.5 m high and in the direct line of sight of staff standing at the normal operating position. The theatre control panel should include plant status indication, clearly readable temperature and humidity indicating gauges, and a means of adjusting the set point for temperature. Theatre ventilation plant status indication should also be located at the operating department staff control base (see the Specialised Ventilation for Healthcare Society's (2017) SVHSoc.01 – 'Operating theatres: energy control strategies and the surgeon's panel' for further details).
- 8.68 The following indicators should be incorporated in the theatre control panel and their functions clearly labelled.
- a readout sufficiently large (25 mm) to be clearly visible from the operating table that shows the temperature of the air in the theatre;
 - a readout sufficiently large (25 mm) to be clearly visible from the operating table that shows the relative humidity of the air in the theatre;
 - a red indicator light that will illuminate when either the supply AHU fails or is switched off or is in "Set back" (legend: "Theatre not to be used in this condition");
 - a green indicator light that will illuminate when the supply AHU is operating at full speed (legend: "Conventional theatre mode").

Note: In touch-screen panels, the red indicator should be a band across the screen with the statement "Theatre ventilation not operational. Do not use". The green indicator may be moving arrows representing airflow with the legend "Ventilation operational".

- 8.69 The humidity within the operating department when in use should fall within the range 35% to 60%. Where it is considered necessary to fit a humidifier, it should be selected to humidify to 40% saturation at 22°C during the design winter outside conditions. The cooling coil should be able to remove sufficient moisture so that 60% saturation at 20°C is not exceeded during the design summer outside conditions.

Note: When not in use the humidity may be allowed to fall below 35% but should not be allowed to rise above 70%.

- 8.70 The automatic control of ventilation in operating suites needs to be simple and robust. Over-reliance on complex room pressure and flow relationships linked to automatic fan speed control are unnecessary and in the long term have been shown to be unreliable. Complex software algorithms that can only be accessed and interpreted by off-site specialists should not be used. Whichever control strategy is chosen, it is important that on-site staff have the facility to override the control system and keep the ventilation operating at least until the surgical procedure is complete (see also Chapter 9).

Operating suite air handling unit

- 8.71 Each conventional operating theatre suite should have its own dedicated AHU to the standard set out in Chapter 9. To ensure operational flexibility and permit routine maintenance, an air handling unit should not be shared between suites.
- 8.72 In retrofit installations, site conditions may preclude individual AHUs for each suite. In these circumstances, subject to VSG approval, an AHU may be shared between not more than two operating suites providing each suite has its own control of temperature. An accessible airflow measurement test point should be provided in the supply branch duct to each theatre suite so that the primary air volume to each can be determined. In addition, the branch supply and extract should be capable of being physically isolated and the main airflow rate reduced so that either suite can be taken out of use without detriment to operating conditions in the other.

Note: An AHU provided under paragraph 8.72 may be shared between two conventional operating suites, but not between a conventional and a UCV suite

- 8.73 The AHU supply and extract fans should be interlocked so that the supply starts up first and shuts down last, thus preventing reverse airflows. If the extract plant fails when the theatre is in use, it may continue to be used but a warning should show on the BMS and theatre control panel. If the supply fails when the theatre is in use the extract should shut down to prevent reverse airflows and an alarm should sound and show on the theatre control panel.

Fire aspects

- 8.74 When considering the overall airflow movement, careful thought needs to be given to the operation of the ventilation system to limit smoke spread in the event of a fire. However, this is a highly staffed department with a low fire risk/load status and these factors need to be recognised when developing the fire strategy. Operating departments typically comprise a series of linked rooms with multiple exits. Over-compartmentation can lead to difficulties in establishing clean airflow paths and room air dilution rates. This will lead to an increased risk of healthcare-acquired infections. Staff areas within the department should be treated as a subcompartment.

Ultra-clean ventilation system

General requirements

- 8.75 The design philosophy of a conventionally ventilated operating suite is based on the need to dilute contaminants and control both the condition and movement of air in an operating suite. Ultra-clean ventilation (UCV) is a means of significantly increasing

the dilution effect by providing a large volume of clean filtered air to the zone in which an operation is performed, and sterile items are exposed. Air is discharged above the operating zone and while not truly laminar, its downward displacement purges the clean zone of contaminants and particles generated by the activities within it. The airflow in and around the clean zone also serves to prevent particles originating outside the zone from entering it. The resulting reduction in contaminants has been shown to significantly reduce post-operative sepsis following certain orthopaedic procedures.

Note: The number of microorganisms that are present in the air at the wound site and exposed surgical items is dependent on the operating team, their procedural discipline, choice of clothing and the type of UCV system. Ultra-clean air is defined as that containing not more than 10 colony forming units per cubic metre of air (10 cfu/m³) present at the wound site during a surgical procedure. In practice levels of only 1 cfu/m³ are often attained.

- 8.76 UCV systems are very successful in reducing contaminants at the wound site so it is often considered that there is no need for complex air movement control schemes in the rest of the suite. However, when designing the ventilation scheme, it should be noted that the users may switch the UCV terminal to “low speed” when non-orthopaedic surgery is taking place. This is because the high airflow rates can cause increased moisture evaporation of exposed tissue which may be detrimental to the surgical outcome. In recognition of this, the ventilation scheme should be capable of providing operating conditions to at least a “conventional” theatre standard throughout the suite with the UCV in “low speed” mode. It should also be remembered that suitable levels of ventilation will always be required in the peripheral rooms.
- 8.77 UCV systems can be designed and built from first principles or a range of bespoke modular units of varying shapes and sizes are available, with each manufacturer having a slightly different approach to UCV design. Notwithstanding any variation in their design philosophy, all UCV systems will be required to completely achieve the performance standard set out in Chapter 12.
- 8.78 As with conventional theatres, each UCV operating suite should have its own dedicated AHU to the standard set out in Chapter 9. To ensure operational flexibility and permit routine maintenance, an AHU should not be shared between suites.
- 8.79 In retrofit installations, site conditions may preclude individual AHUs for each suite. In these circumstances, subject to VSG approval, an AHU may be shared between not more than two UCV operating suites providing each suite has its own control of temperature. An accessible airflow measurement test point should be provided in the supply branch duct to each theatre so that the primary air volume to each UCV canopy can be determined. In addition, the branch supply and extract should be capable of being physically isolated and the main airflow rate reduced so that either suite can be taken out of use without detriment to operating conditions in the other.

Note: An AHU provided under paragraph 8.79 may be shared between two UCV operating suites, but not between a conventional and a UCV suite.

- 8.80 An inherent feature of a UCV system is its large airflow so it is essential to recirculate the air supplied to the operating theatre and/or to recover its energy in order to optimise operating costs.
- 8.81 The primary fresh air volume supplied to a UCV operating suite will be the same as for a conventional suite and it should be dispersed to the rooms in the suite in the same manner. The UCV canopy will typically incorporate recirculation fans. In order to prevent these fans “robbing” the air supply to the rooms, the primary air supply to the UCV theatre suite should be split into two ducts each with a volume control damper, one duct to feed the UCV canopy and the other for the anaesthetic and preparation rooms (which will be subdivided to accommodate heater batteries before they serve their respective room).
- 8.82 “Laying up” instruments in the clean zone is preferable microbiologically and considered best practice by the Royal College of Orthopaedic Surgeons, so an SPS preparation room should be provided. A transfer grille will be needed in the door between the theatre and preparation room.
- 8.83 If the client requires a “lay up” preparation room, a pressure stabiliser will be required between the preparation room and theatre. It should be fitted with a baffle on the theatre side to prevent air transfer interfering with the airflow distribution under the UCV canopy (see figure 2). Where space planning permits, consideration may be given to a location of the lay up preparation room in which the air pressure stabiliser discharges from it into the theatre at a point beyond the end of the canopy.

Figure 2 Pressure stabiliser fitted in preparation “lay up” room with stand-off baffle in theatre



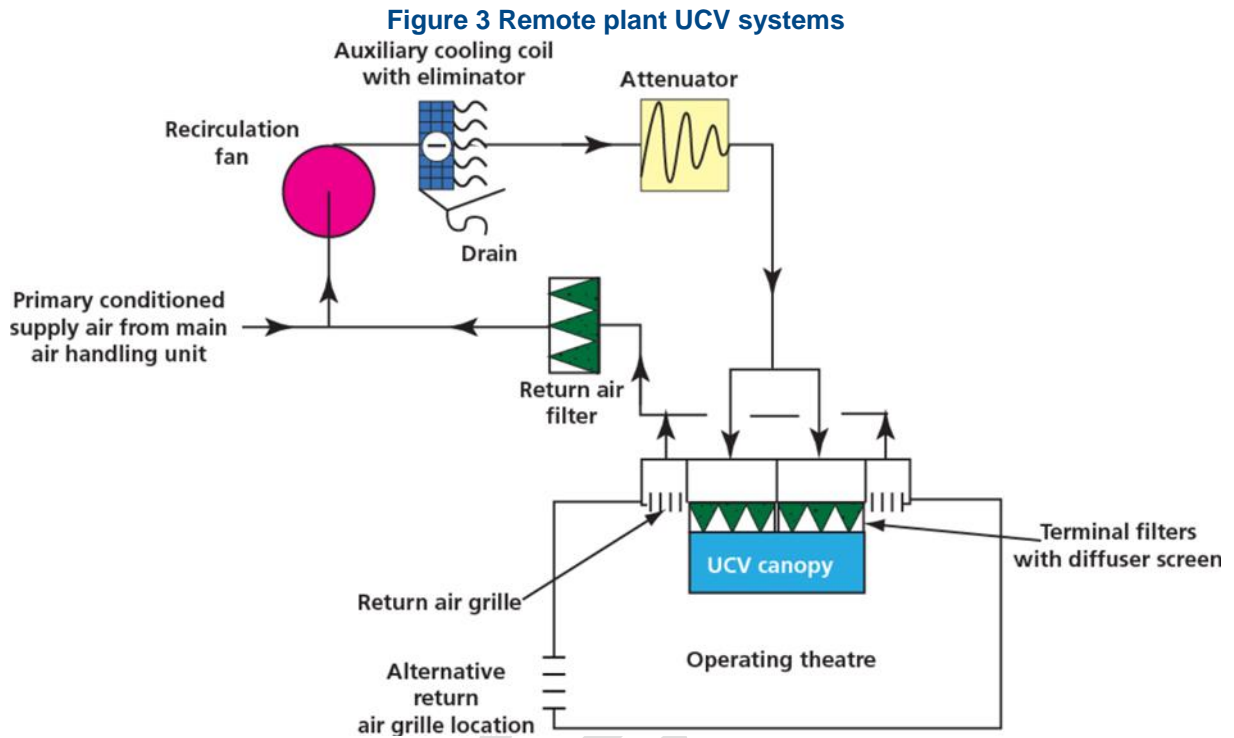
- 8.84 Separate scrub-up or disposal facilities are not necessary for air cleanliness, although operational policy may prefer such a provision. A separate anaesthetic room should however be provided.

Types of UCV system

Remote plant systems

- 8.85 In a remote plant system, all the air- conditioning equipment is located outside of the operating theatre, except for the unidirectional airflow terminal, terminal filter, air diffuser and the return air grilles (see Figure 3).
- 8.86 This arrangement has the following advantages:
- the recirculation fans are out of the theatre, thus reducing noise. Multiple recirculation fans may be replaced by a single fan unit.
 - casual heat gains from recirculation fan(s), canopy lights, equipment and people within the theatre can be removed by a cooling coil in the return air stream. This will prevent heat build-up in the theatre.

- the return air filters can be changed without needing access to the theatre, making routine maintenance more feasible.
- the opportunity exists to locate the EPA filter in the primary supply duct rather than the theatre terminal. This will reduce the number of filters required and allow them to be changed without entering the theatre.



Modular systems

8.87 Vertical-flow modular units comprise a ceiling-mounted canopy containing return air filters, final filter and air diffuser. Primary air is supplied by a remote air-conditioning unit at the volume and to the standard required for a conventional operating suite. The UCV-canopy return-air fans may be within the unit or mounted independently of it in the ceiling void or wall space (see Figure 4).

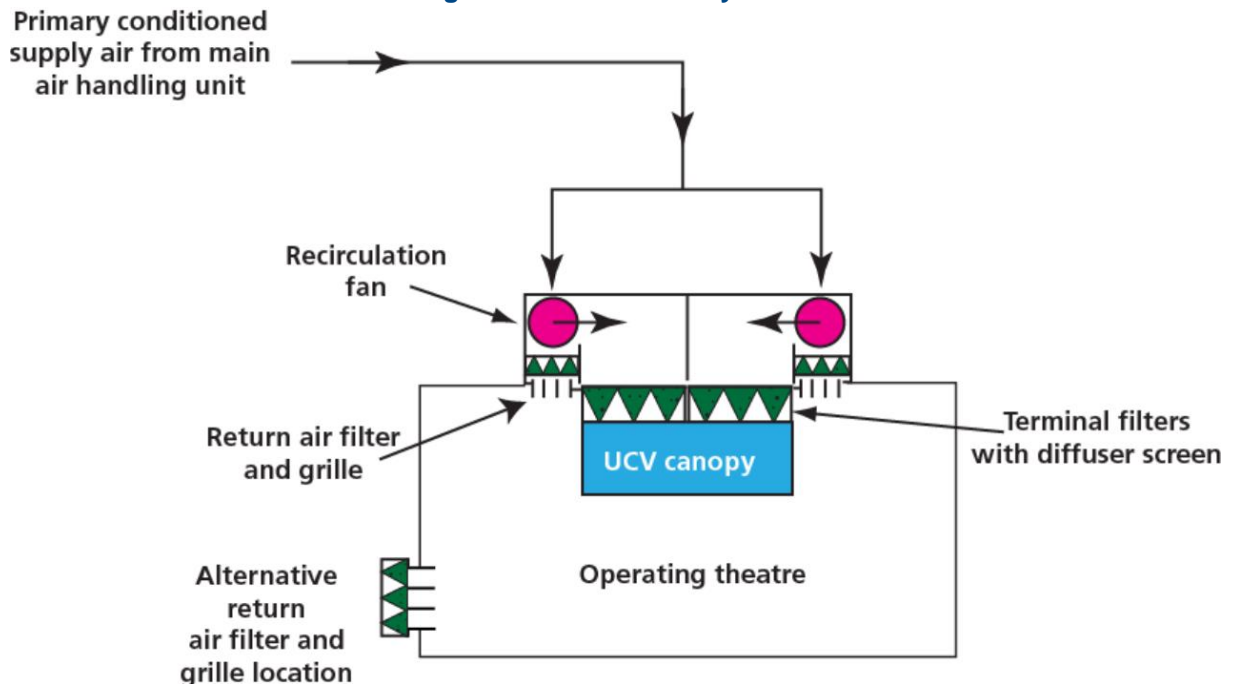
8.88 Modular units have the following advantages:

- as they are produced in a modular form, installation is generally more straightforward;
- they can be used to upgrade an existing conventional operating suite to a UCV suite without the need to change the AHU;
- all the UCV elements are in one place, making maintenance simpler.

8.89 UCV systems can be designed and built from first principles, or a range of bespoke modular units of varying shapes and sizes are available, with each manufacturer having a slightly different approach to UCV design. Whichever system is used, in order for the UCV terminal to produce the desired airflow within its footprint without entraining non-filtered air, the physical outside edge of the UCV canopy unit should not be less than 1 m from the operating theatre wall.

Notwithstanding any variation in their design philosophy, all UCV systems will be required to completely achieve the performance standard set out in Chapter 12.

Figure 4 Modular UCV systems



Vertical flow UCV systems

- 8.90 Vertical flow systems are effective at reducing infection risks (Lidwell et al., 1982). Some systems have no walls and use auxiliary fans to create an air curtain around the clean zone. Partial wall systems have side screens that terminate 2 m above floor level and full wall UCV have side screens that terminate 1 m above floor level.
- 8.91 Full wall systems provide a physical barrier between the operating team and other theatre occupants and guide the air down to the operating table level. They can therefore work at a lower air velocity.
- 8.92 Siting the return air grilles around the periphery of the theatre at low level will help control short-circuiting and give an improved airflow path. In any event there should be an “air out” path on each face or in each corner of the theatre. These may be provided by combination of pressure stabilisers and passive or active low-level extract grilles. Failure to provide “air out” paths on all faces of the theatre may result in the surplus air causing entrainment into the clean zone.
- 8.93 Vertical systems should have a clean zone large enough to encompass the operating site and all instrument trays likely to be needed for the procedures to be undertaken. Where the surgical site is small, a 1.4 m circular or rectangular terminal may be provided. For major orthopaedic procedures, a minimum size of 2.8 m × 2.8 m will be required. This is the area projected on the floor under the supply air terminal within the full walls, partial walls or air curtain. Any air outside this zone cannot be guaranteed to be ultra-clean although given the dilution factor, the level of microbiological contamination will be much lower than the general level in a conventional operating theatre. Having a contrasting coloured area on the floor delineating the extent of the “clean zone” will assist staff and is therefore essential.

Note: The entire “clean zone” footprint of the UCV canopy will be designated by a contrasting coloured inlay in the floor covering. A line marked on, or cut into, the floor covering is not sufficient and will not be accepted at validation.

- 8.94 When upgrading an existing conventional theatre to an ultra-clean standard the only solution may be the installation of a modular system. In these units, the heat gains from the return air fans may warrant the inclusion of supplementary cooling within the module. However, issues of cooling-coil drainage, condensate removal and maintenance access within the space constraints of the module may make this option impracticable. The additional cooling load should then be catered for by conditioning the primary air to compensate.
- 8.95 If an existing AHU is to be retained, it may require modification to ensure that it achieves the standards set out in Chapter 9 of this document (see also paragraph 4.73). The fan may need re-rating to accommodate the change in system resistance. The cooling coil may also need to be upgraded to cater for the increased load resulting from the return air fans and terminal lights. Failure to make adequate provision for this may make the theatre unusable during prolonged warm spells.
- 8.96 A factor affecting the airflow pattern is the supply/room air temperature difference. When the supply air temperature is significantly above room temperature, buoyancy effects will reduce the volume of air reaching the operating zone. This can occur at start-up in a large theatre where the temperature when not in use has dropped below 18°C. If it is anticipated at design stage that this will be a regular occurrence, a system incorporating full walls should be used. Demountable extensions that convert a partial wall to a full wall unit are available.
- 8.97 Convection up-currents from the surgical team and operating lamp tend to counter the movement of clean air towards the operating site, hence the air velocity reaching the operating level is critical. The minimum velocity given below has been selected to take account of these factors and is greater than the theoretical minimum value. For all vertical UCV systems the design discharge velocities will be as follows:
- air velocity 2 m above floor level:
 - no side wall system = 0.38 m/s average;
 - partial wall system = 0.38 m/s average;
 - full wall system = 0.30 m/s average.
 - air velocity 1 m above floor level:
 - all systems = 0.2 m/s minimum within the inner operating zone.

Chapter 12 gives details of the method of measurement.

- 8.98 Variable speed recirculation fans with differential pressure control may be the most suitable solution for maintaining consistent performance and energy saving. The recirculation fans should be accessible for replacement without the need to disturb the fabric of the operating suite.

UCV filters

- 8.99 The AHU primary and secondary filters should be to the standards and in the location set out in Chapter 9.
- 8.100 Terminal filters should be provided within the UCV canopy or in the air supply to it. Efficiency particulate air (EPA) filters grade E10 as specified in BS EN 1822 will be required as a minimum. There is no aerobiological benefit in fitting filters of a higher grade than this.
- 8.101 In some modular UCV units their manufacturers state that the terminal filter is used as a pressure equaliser to balance airflow so a grade higher than E10 is fitted. The increased resistance may affect the velocity of air reaching the operating level and there will be penalties in terms of installed fan power, energy consumption and higher noise levels.
- 8.102 The final filters should be installed in a leak-proof housing in a manner which allows the terminal unit, filters and their seals to be validated. The UCV canopy and its terminal filters will be scanned with a light scattering airborne particle counter (LSAPC) during validation to prove the effectiveness of the complete installation.
- 8.103 Where UCV units are constructed in sections, a means of measuring the pressure drop across the terminal filters in each section should be provided. The pressure test points should be located outside of the partial wall, capped to prevent air leakage and accessible within the theatre without the need to open the unit inspection panels. Alternatively, direct-reading non- electronic pressure gauges (of the minihelic type) may be fitted.
- 8.104 The UCV system will require a return air filter to capture the relatively coarse particles which would otherwise significantly reduce the life of the final filter. This should be at least an ISO 16890 Coarse 60%. In remote recirculation systems there may be advantages in fitting a higher- grade return air filter as it will reduce the load on the terminal EPA filters and extend their life.

Noise level

- 8.105 If sound-attenuating material is used to line any portion of the inside of the UCV unit it should be non-particle shedding and non-combustible.
- 8.106 The maximum noise level in an operating theatre fitted with a UCV terminal of any type should not exceed 53 dB(A). Chapter 12 gives details of the method of measurement.

Lighting and operating lights

- 8.107 The position of the UCV light fittings and style of partial walls, where fitted, should neither adversely disturb the airflow nor result in significant spatial variations in illuminance levels.
- 8.108 In vertical units, specialised task lighting should be provided by toroidal, cruciform or small multiple dome-shaped luminaires as they have good aerodynamic properties. The ideal luminaire will have a minimal effect on the airflow regardless of where it is positioned. Large diameter saucer-shaped luminaires should not be used in vertical

flow systems as they will occlude the airflow in the critical central zone. It is important to consider the suitability of existing luminaires when retrofitting UCV systems.

- 8.109 In vertical UCV installations the distance between the UCV canopy diffuser screen and the floor should be between 2.75 m and 3 m. This will allow space for the operating lamps and their articulation arms, and ensure that air at the correct velocity arrives at the operating level. When parked the lowest point of the central light stem, luminaire, monitor, camera, their associated articulation arms and any other ceiling-hung equipment should never be less than 2 m above floor level.

Note: The traditional means of light support is a central column that passes through the UCV canopy and is rigidly fixed to the building structure. The position of the support therefore prevents air being supplied at the centre of the canopy. Separate supports displaced from the centre of the clean zone would lead to improved airflow. This approach was advocated in the 1994 version of this guidance but at the time of writing no UK manufacturer has chosen to adopt this solution. Alternatively, equipping the operating team with battery-powered headset lamps may remove the need for traditional operating lamps and their supports.

Controls and instrumentation

- 8.110 The functions of the supply AHU and extract ventilation should be continuously monitored by a BMS control unit and interlocked with the UCV terminal control and monitoring functions. The room temperature sensor should be located in the re-circulated air return path. The controls and instrumentation for the main plant are set out in Chapter 9.
- 8.111 UCV systems will additionally require a low speed facility that can reduce the air supplied through the UCV canopy to a volume that equates to not less than 22 ac/h of the operating theatre gross volume or that required for door protection, whichever is greater, whilst still leaving the supply AHU operating at full speed. In this operational mode the theatre may be used as a conventional operating suite. A means of switching between conventional and UCV mode will be provided on the theatre control panel and its function clearly labelled (see the Specialised Ventilation for Healthcare Society's (2017) SVHSoc.01 – 'Operating theatres: energy control strategies and the surgeon's panel' for further details).

Note: UCV theatre ventilation may be completely switched off when the theatre is not in use, but the room temperature should not be allowed to drop below 18°C (see paragraph 8.96). The AHU and UCV control should be interlocked so that when the AHU goes to "Set back" the UCV also goes to "Set back", and if the AHU goes "Off", the UCV terminal fans also switch "Off".

There is no aerobiological benefit in keeping the UCV terminal fans running when the theatre is not in use, it results in wasted energy.

- 8.112 The following indicators should be incorporated in the theatre control panel and their functions clearly labelled. In retrofit installations, an auxiliary panel for the UCV may be the most practical option. If fitted it should be mounted adjacent to the theatre panel and their control functions interlocked.

- A readout sufficiently large (25 mm) to be clearly visible from the operating table that shows the temperature of the air at the UCV canopy.
- A readout sufficiently large (25 mm) to be clearly visible from the operating table that shows the relative humidity of the air at the UCV canopy.
- A red indicator light that will illuminate when either the supply AHU or the UCV canopy fails, or either or both are switched off or the AHU is in “Set back” (legend: “Theatre not to be used in this condition”).
- An amber indicator light that will illuminate when the UCV canopy is at low speed and the supply AHU is running at full speed (legend: “Conventional theatre mode”).
- A green indicator light that will illuminate when both the supply AHU and UCV canopy are operating at full speed (legend: “UCV theatre mode”).
- A blue indicator light that will illuminate when the UCV canopy airflow, as detected by a differential pressure sensor, falls below 80% of the design flow rate (legend: “UCV requires service”).

Note: In touch screen panels the red indicator should be a band across the screen with the statement “Theatre ventilation not operational. Do not use” The amber indicator may be moving arrows representing airflow with the legend “Conventional Theatre mode”. The green indicator may be moving arrows representing airflow with the legend “UCV Theatre mode”. The blue indicator may be a band across the UCV terminal mimic stating “UCV requires servicing”.

- 8.113 When a system is designed to have partial walls with full wall extensions, a volume control facility may be incorporated to allow the system to be run with reduced velocity when the demountable full walls are in place. It would be the responsibility of the user to ensure correct operation of the system. To assist the user, an explanatory notice should be included on the theatre control panel.
- 8.114 The UCV unit manufacturer’s control box should be located in an accessible position preferably in the operating department adjacent to the operating theatre that it serves. A service corridor, if provided, is an ideal location. The control box should be clearly labelled with the identity of the operating theatre that it serves.

Barn and semi-barn theatres

- 8.115 There is no aerobiological reason why two or more UCV systems should not be installed in a common area if adequate spacing is provided. These are known as barn theatres and require special design considerations and operational discipline. The relative positions of the UCV units, temperature control range and location of doors and openings to other areas will all significantly affect the airflow at the operating positions.
- 8.116 A barn theatre has two or more operating positions each ventilated by a UCV canopy all in one open operating theatre. There may be a common scrub trough, SPS preparation room and shared utility, all of which reduce the facility’s footprint. For reasons of privacy and dignity, there is usually a separate anaesthetic room for each operating position. The operating positions may be separated by glass screens to

prevent bone fragments being propelled from one position to another when high-pressure air-driven surgical tools are being used.

8.117 A semi-barn theatre is very similar but would have a full-height dividing wall between the operating positions. The wall will not extend across the full width of the room, only its middle section. This creates a degree of physical separation between the operating positions but allows staff to walk from one to another around the ends of the dividing wall.

8.118 It is important that the physical layout and ventilation strategy of the barn or semi-barn are in harmony if the installation is to work successfully. The following points should be resolved with the architect and VSG when considering the design:

- in order to reduce the risk of pre- contamination, surgical instruments should not have to pass one operating position in order to get to the one that they are destined for;
- staff having scrubbed should not have to pass one operating position in order to get to the one that they are destined for;
- waste material being cleared from an operating position should not pass another when being removed from the operating theatre;
- the operating positions and their UCV canopies should be placed in line and not staggered or offset, otherwise their airflow patterns will interfere with each other;
- while barns and semi-barns have, from the staffing and space utilisation point of view, many advantages, they can create problems with temperature control and energy efficiency. It is not advisable to shut their ventilation off at night or weekends as if the operating theatre temperature drops it can take a considerable time for the ventilation to achieve the required air velocity at the operating position (paragraph 8.96). Because the barn is a large open space, when it becomes cold the warm air supplied by the UCV canopies tends to rise and stratification occurs. As a result, although from the user's point of view the ventilation appears to be running, the air being delivered does not actually have enough velocity to reach the operating table;
- access for service, maintenance and future upgrades or refurbishment will be restricted as this can only be carried out when none of the operating positions is in use.

8.119 Ventilation of each UCV canopy and associated anaesthetic room will be by a dedicated AHU; ventilation of the shared spaces and perhaps recovery area would either be shared between the operating position AHUs or provided by a separate AHU.

Hybrid theatres

8.120 A designation given to operating theatres that contain scanning equipment on a robotic arm. Major surgical procedures are carried out and the patient is scanned as necessary during the procedure. The scanning equipment may be floor-mounted or ceiling-hung and there will be one or more large monitors, a variety of screens and the medical gas terminal units all ceiling-hung on articulated pendants. The number of pendants and their supporting steelwork can reduce the space available to install

ventilation ductwork and compromise the location of the supply air terminals. Liaison with the architects at an early stage in the project design is essential to ensure a satisfactory ventilation solution.

- 8.121 Hybrid theatres tend to be significantly larger than conventional theatres and may have a radiation protected control room and an equipment room to house the servers for the scanning equipment and its robotic arm in addition to the standard operating suite of rooms. The ventilation load will therefore be larger and standard solutions should be adapted to suit or the designer will need to return to first principles (see Appendix 8).
- 8.122 Because of the increased airflow requirement, the AHU will be larger than for a standard conventional operating suite.
- 8.123 In all other respects the ventilation design and theatre control panel will be as for a conventional operating suite as above.

Neutral pressure theatres for infectious patients

- 8.124 The client may have a requirement for an operating suite for surgery on infectious patients. This may be a dedicated neutral-pressure operating suite or a standard operating suite that is designed to be easily convertible to a neutral-pressure suite. If airborne microorganisms liberated from a patient during a surgical procedure are allowed to cascade out into the adjacent corridors, they could infect other patients or the staff in the operating department.
- 8.125 The room provision and layout will be as for a conventional operating suite with the following variation to the ventilation scheme:
- the operating theatre will have a balanced supply and extract so that it is at the same pressure as the corridor;
 - air should not cascade from the theatre to the surrounding rooms, so pressure stabilisers and/or transfer grilles should not be fitted. In the case of a convertible operating suite, permanently fitted hinge-down blanking plates with clamps should;
 - be provided to close the pressure stabiliser/transfer grille openings when required;
 - the preparation room may be dispensed with to avoid having stock that could become pre-contaminated. Sterile packs, instruments and consumables would be delivered to the theatre on a case by case basis. If a preparation room is required, it should be maintained at 10 Pa to both the theatre and corridor;
 - the anaesthetic room should have a supply in excess of extract so that is maintained at 10 Pa above both the corridor and the theatre. There should be a pressure stabiliser between the anaesthetic room and the corridor but no transfer device between the anaesthetic room and the theatre;
 - the scrub should have an active extract as for a conventional operating suite but no pressure stabiliser between it and the corridor;
 - the utility should be at negative pressure of not less than -5 Pa to the theatre and its corridor;

- the corridor extract will be sized to cater for the air leakage from the preparation and anaesthetic rooms.

Overall, the ventilation scheme should ensure that all air supplied to the operating theatre is removed in the theatre. The theatre should be neutral (at the same pressure) to the corridor so that when the theatre exit door is open there is effectively no interchange of air between them. When the preparation or anaesthetic doors are opened, air flows from them into the theatre and not the other way.

- 8.126 The theatre control panel, automatic control strategy and air handling unit will be as for a conventional operating suite.

Interventional imaging suites

- 8.127 Interventional imaging refers to rooms in which surgical interventions are carried out guided by imaging equipment. The risk of infection by the airborne route is low as the surgical site is small, and sterile instruments tend to be unwrapped immediately before use. Anaesthetic gas or agents are used for pain relief or sedation. Patients requiring full anaesthesia will normally be treated in a hybrid or conventional operating suite. The VSG should advise on the likely scope of use.
- 8.128 An interventional image suite may simply be a room containing the imaging equipment, an adjoining radiation protected control room or bay for staff and an equipment room for the imaging server. Support rooms for patient changing, sit recovery, toilets and a utility may also be needed.
- 8.129 Ventilation of the imaging room would be 10 ac/h with the room at a positive pressure to the corridor. Ceiling-mounted steelwork to support the imaging equipment may reduce the space available to install ventilation ductwork and compromise the supply terminal locations. This may mean that sidewall linear terminals are the only viable option. If fitted, their discharge velocity should not cause draughts and the direction vanes should be fixed or capable of being locked to prevent alteration during routine cleaning. Alternatively, a displacement ventilation scheme may be considered.
- 8.130 A full “theatre style” control panel is not required, but a green light to show the ventilation is operational and a red one to show it is not should be provided.
- 8.131 Radiation shielding and warning notices may be required to ductwork where it penetrates ceilings, walls or floors to plantrooms or adjacent spaces to which staff may need access.

Other application-specific design guidance

Application: Bronchoscopy, Endoscopy, Dental and General treatment facilities

Table 2: Treatment and procedure facilities

Area/zone	Reason for ventilation	Typical design factors
Bronchoscopy procedure room	Control of exposure of staff to airborne pathogenic material discharged by the patient e.g. multi-drug-resistant tuberculosis (MDR-TB) during the procedure being undertaken. (COSHH Regs) Control of exposure of staff to waste anaesthetic agents when used. (COSHH Regs)	Establish a clean airflow path – Supply terminal at high level at foot end of patient's chair/couch and extract terminal at patient's head level behind the chair/couch. Design parameters Air change: 15 per hour Pressure regime: Where patient membranes are breached and the procedure would present an infection risk to the patient, the pressure should be +10 Pa to the corridor. In Bronchoscopy and all other Endoscopy procedure rooms –5 Pa to corridor shall be established. (NOTE The decision as to the preferred pressure regime for each room must be made at design stage. They must not be designed and set up as switchable pressure rooms) Noise level: 40 d(B)A Temp range: 20 to 25°C must maintain any selected set point in the range via BMS Humidity: Floating; max 70%RH Air quality: BS EN 16798 - SUP2 Extract discharge – Discharge in safe position away from people or open windows. If no suitable position available treat the discharge in the same way as a LEV with a discharge stack at a minimum of 3 m above the roof line.
Endoscopic procedure room	As above and odour control	
Dental treatment room	Control of exposure of staff to airborne pathogenic material discharged by the patient during the procedure being undertaken. (COSHH Regs) Control of exposure of staff to waste anaesthetic agents when used. (COSHH Regs)	Establish a clean airflow path – Supply terminal at high level and extract terminal at low level near patient's chair/couch. Design parameters Air change: 10 per hour Pressure regime: Neutral to corridor Noise level: 40 d(B)A Temp range: 20 to 25°C must maintain any selected set point in the range via BMS
Emergency department resuscitation room	As above	Humidity: Floating; max 70%RH Air quality: BS EN 16798 - SUP2
General treatment room	Comfort conditions only	

All of the above rooms are suitable for aerosol-generating procedures (AGPs)

Applications: Level 2 and 3 critical care areas, bone marrow transplant (BMT), oncology, organ and tissue transplant units

Table 3: Airborne protective facilities

Area/zone	Reason for ventilation	Typical design factors
Note: Level 2 & 3 Critical care areas should be treated identically in terms of service provision as their only difference is the staff- to-patient ratio.		
Level 2 or 3 critical care individual room	Protection of patients from airborne organisms and fungal spores	Supply only in patient's room and cascade air out via door undercut, transfer grille or pressure stabiliser through rooms of a lower classification. Design parameters Air change: ≥ 10 per hour Pressure regime: +10 Pa to general area Noise level: 35 d(B)A Temp range: 20 to 25°C must maintain any selected set point in the range via BMS Humidity; Floating; max 60%RH Final filter; BS EN 1822 – EPA10
Level 2 or 3 critical care open bays	As above	
Bone Marrow Transplant (BMT) unit	Protection of patients from airborne organisms and fungal spores Note: Patient(s) will have a very poor immune system (neutropenia) so will be particularly vulnerable to infection by the airborne route.	Supply only in room and cascade air out via door undercut, transfer grilles or pressure stabilisers through rooms of a lower classification. Design parameters Air change: ≥ 10 per hour Pressure regime: +15 Pa to corridor Noise level: 35 d(B)A Temp range: 20 to 25°C must maintain any selected set point in the range via BMS Humidity: Floating; max 60%RH Final filter: BS EN 1822 – EPA12
Haematology/Oncology ward	As for BMT	
Organ and Tissue Transplant unit	As for BMT	

Applications: Isolation rooms category 2 & 3, Infectious disease units, Containment level 3 rooms

Table 4: Airborne isolation facilities

Area/zone	Reason for ventilation	Typical design factors
Category 2 isolation room Category 3 isolation room	Protection of staff and all other building occupants from airborne organisms dispersed by a patient with an infectious disease. See Scottish Health Planning Note 4 Supplement 1	Extract only in patient's room and ensuite. Supply air from corridor passing into room via door undercut, transfer grille or pressure stabiliser. Alternatively the patient's room may have a supply and extract provided they are interlocked to ensure that the room is always at -ve pressure with regard to the corridor. Design parameters: Air change: ≥ 10 per hour Pressure regime: -5 Pa to general area Noise level: 35 d(B)A Temp range: 20 to 25°C must maintain any selected set point in the range via BMS Humidity: Floating; max 60%RH Air quality: BS EN 16798 – SUP2

Area/zone	Reason for ventilation	Typical design factors
Positive pressure ventilated lobby (PPVL) isolation room Universal isolation facility	Protection of building occupants from patients who may be infected and protection of patients who may be immunocompromised and protection for patients with both conditions. See Scottish Health Planning Note 4 Supplement 1	Supply in lobby flowing through a pressure stabiliser to patient's room and on via a door undercut or transfer grille to an extract in the en-suite. Design parameters: Bedroom air change: ≥ 10 per hour Lobby pressure: +10 Pa to corridor Bedroom pressure: Neutral En-suite pressure: -ve Comfort parameters as above Air quality: BS EN 16798 – SUP2 With facility to fit BS EN 1822 – EPA12
Containment level 3 laboratory	Protection of occupants in adjoining spaces from airborne bio-hazards	For design details see the Medical Research Council's "Standards for containment level 3 facilities"
Category 4 facility	Design advice will be provided by the client	

Application: Obstetrics theatre, delivery rooms, nursery, neonatal intensive care and special care baby units

Table 5: Maternity facilities

Area/zone	Reason for ventilation	Typical design factors
Obstetrics theatre	Protection of patients from airborne organisms and fungal spores. Control of exposure of staff to waste anaesthetic agents (COSHH Regs)	Ventilation design parameters as for a conventional operating suite. System should normally be at "set back" with a minimum temperature of 18°C and be able to attain full operating conditions within 5 minutes of triggering the system
Delivery room	Control of exposure of staff to waste anaesthetic agents. (COSHH Regs)	Establish a clean airflow path – Supply terminal at high level at foot end of bed and extract terminal at low level at head end of bed.
Delivery room with birthing pool	As for standard delivery room above	Design parameters:
Specials delivery room	As for standard delivery room above	Air change: 15 per hour Pressure regime: Neutral to corridor Noise level: 35 d(B)A Temp range: 20 to 25°C must maintain any selected set point in the range via local control Humidity: Floating – max 70%RH Air quality: BS EN 16798 – SUP2
Nursery	Comfort conditions only	
Neonatal intensive care unit or special baby care unit (SCBU)	Protection of neonates from airborne organisms and fungal spores. Neonates are kept in incubators but may be removed for feeding, changing etc. so local temperature control and ensuring a draught-free environment is essential.	Standard supply and extract Design parameters: Air change: 10 per hour Pressure regime: +5 Pa to corridor Noise level: 45 d(B)A Temp range: 20 to 28°C must maintain any selected set point in the range via local control Humidity: Floating – max 70%RH Air quality: BS EN 16798 – SUP1 (Filter grade depends on ODA category – see the Specialised Ventilation for Healthcare Society's (2018) SVHSoc.02)
N.B. This is a critical healthcare facility and consideration should be given to system resilience and/or how suitable alternative accommodation may be provided in the event of a ventilation system failure.		

Applications: pharmacy aseptic suite, gene therapy, radiopharmacy, support rooms

Table 6: Pharmacy facilities

Area/zone	Reason for ventilation	Typical design factors
Aseptic suite Cleanroom	<p>Protection of product during and after processing.</p> <p>Protection of the wider environment from cytotoxic agents and antibiotics.</p> <p>EUGGMP standards (European Commission, 2011) apply and the Medicine Act if the facility is licensed.</p> <p>Control of exposure by the airborne route to staff of substances during and after processing products. (COSHH Regs).</p> <p>Note: While this application is a critical facility, it is usual to have a plan in place to decant to another site in the event of a ventilation system failure</p>	<p>Supply only in cleanroom and cascade air out via pressure stabilisers through rooms of a lower classification or where there are multiple cleanrooms, a balanced supply and stable cascade out. Thimble extract may be provided for class 3 safety cabinets depending on the location of room within the building.</p> <p>Note: Advice from the client's lead pharmacist should be sought prior to engaging in detailed design.</p> <p>Design parameters:</p> <p>Air change: ≥ 20 per hour Pressure regime: +15 Pa between unclassified rooms and +10 Pa between classified rooms</p> <p>Noise level: 45 d(B)A</p> <p>Temp range: 20–24°C must maintain any selected set point in the range via BMS</p> <p>Humidity: Floating – max 60%RH Final filter: BS EN 1822 – HEPA14</p>
Gene therapy cleanroom	As above, plus protection of the wider environment from product	As per cleanroom above plus negative-pressure access lobby and controlled exhaust
Radiopharmacy cleanroom	As for standard cleanroom with additional requirements of the Ionising Radiation (Medical Exposure) Regulations	As per cleanroom above
Non-sterile stores and support rooms	Comfort conditions only	

Application: decontamination facilities

Table 7: Decontamination unit

Facility	Applicable Standards
Central Decontamination Unit	<p>These are highly regulated production facilities dictated by:-</p> <p>Planning note - Scottish Health Planning Note 13 Part 1: 2010 Decontamination Facilities: Central Decontamination Unit. HFS, 2011</p> <p>Mandated by compliance document - Requirements for Compliant Central Decontamination Units Version 2 – GUID 5014, HFS 2019</p> <p>Equipment manufacturer's design and installation instructions</p>
Local Decontamination Unit	<p>These are highly regulated production facilities dictated by:-</p> <p>Planning note - Scottish Health Planning Note 13 Part 2 Decontamination Facilities: Local Decontamination Units, HFS 2008</p> <p>Mandated by two compliance documents - Compliant Dental Local Decontamination Units in Scotland Version 2 – GUID 5005, HFS 2019</p> <p>and Provision of Compliant Podiatry Instruments – GUID 5007 Version 3.0, HFS 2020.</p> <p>Equipment manufacturer's design and installation instructions</p>

Facility	Applicable Standards
Endoscope Decontamination Unit	<p>These are highly regulated production facilities dictated by:-</p> <p>Planning note - Scottish Health Planning Note 13. Part 3 – Decontamination Facilities: Endoscope Decontamination Units, HFS 2010</p> <p>Mandated by compliance document - Requirements for Compliant Endoscope Decontamination Units, v2 – GUID 5013 HFS 2014</p> <p>Equipment manufacturer's design and installation instructions</p>

Hydrotherapy: general requirements

- 8.132 In a hydrotherapy suite, heat recovery should be via a heat pump.
- 8.133 In general, the quantity of supply air should be calculated as 25 L/s/m² wetted surface, with the wetted surface taken as 110% of the pool water surface area. (See the Swimming Pool and Allied Trades Association (SPATA) for detailed guidance.)
- 8.134 A recirculation plant is recommended, with fresh air make-up to the standard required by the Building Regulations Part F – Non-domestic Buildings. In practice this may need to be increased to control condensation.
- 8.135 As far as practicable, recirculated pool air should be provided to the ancillary changing and recovery accommodation, with the only extract from the toilets, laundry/utility room and pool hall.
- 8.136 Supply air to the pool hall should be introduced at high level and directed towards the perimeter to mitigate condensation, with extract air taken from directly over the pool.
- 8.137 The ceiling void above the pool may need to be ventilated to prevent condensation.

Control of hydrotherapy pool installations

- 8.138 The supply and extract fans should be interlocked so that the supply fan does not operate until flow is established within the extract system.
- 8.139 Time-clock control should be provided, with a local override switch to extend the normal operating period as required.
- 8.140 Night set-back temperature (in the range of 21–25°C) and high humidity control (in the range of 60–75% sat) should be provided to override the time clock in order to prevent condensation. The exact set points should be ascertained post- installation.
- 8.141 A remote indication panel should be provided in the pool hall, giving a visual display of the pool water and pool air temperature.

Extract systems

LEV systems

- 8.142 Devices that use an inflow of air to control exposure of staff to hazardous substances are classified as local exhaust ventilation (LEV) systems under the COSHH

Regulations. Note that the supply or make-up air to a room containing an LEV system may itself be considered to be a part of the LEV system.

- 8.143 An LEV system may comprise a self-contained unit incorporating its own carbon filter such as a simple bench-top fume cupboard. Alternatively, it may be a complete “ventilation system” comprising a make-up air supply, multiple exhaust protected workstations, branch and central extract ductwork, duplex extract fans and a high-level discharge terminal. It may also incorporate a special filtration system appropriate to the hazardous substance being controlled. Such systems could be required for workshops containing woodworking machinery or large centralised pathology laboratories housing multiple safety cabinets, cut-up benches, fume cupboards and specimen stores.
- 8.144 It is important to recognise at the design stage whether an extract is being provided for comfort, to remove odours or as an LEV system. Typical LEV systems in healthcare include:
- microbiological safety cabinets and containment level 3 rooms;
 - fume cupboards;
 - welding fume extracts;
 - woodworking-machinery duct collectors;
 - lead-acid battery charging-bay extracts;
 - powered plaster and bone saws;
 - pharmaceutical preparation cabinets and tablet machines;
 - dissection benches, cut-up tables and some specimen stores;
 - medium- and high-risk infectious diseases isolation facilities;
 - dental furnaces, grinders and polishers.

Note: Post-mortem tables may incorporate downflow peripheral ventilation but unless otherwise specified by the equipment supplier, their ventilation is only provided to control odours.

- 8.145 Information on the design of ductwork, fan and discharge stack arrangements will be applicable to all types of LEV system and is given in Chapter 9.
- 8.146 LEV systems are statutory items that will be subject to an independent examination and test at least every 14 months by a competent person holding an in-date P601 certificate.

Note: For AGSS, see Scottish Health Technical Memorandum 02-01.

Bench extract systems

- 8.147 Bench extract ventilation is required in departments such as pathology and mortuary, where activities involve the release of malodorous or toxic fumes which should not be inhaled. They may also be required in central decontamination units and wash-rooms within endoscope reprocessing units to remove airborne biological material liberated when the used items are given a preliminary clean.

- 8.148 In all cases bench extract systems that create an airflow from the front to the rear are preferred over those that rely on a downflow of air through a perforated surface, as the airflow is easily obstructed when in use.

Typical arrangements

- 8.149 Each ventilated position will usually be accommodated in a continuous run of benching, which should not be more than 650 mm from front to rear and which should be provided with a continuous upstand at the rear. Each position should have a 1200 mm × 150 mm linear extract grille mounted on a purpose-designed plenum box (incorporating guide vanes as necessary), with its face flush with the upstand. The bottom of the grille should be as close as practicable to the level of the working surface (usually 75 mm above, to allow for cleaning). The minimum velocity across any part of the grille should be 1 m/s. The grille should be readily demountable to allow for cleaning.

Control of bench extract systems

- 8.150 Provided that it does not interfere with the operation of the department when not in use, the ventilation system for the bench extract and any associated supply may be shut down. However, a run-on timer with a minimum setting of 30 minutes should be provided. To this end, local control should be provided.
- 8.151 Processes that produce hazardous vapours, fumes, dusts or noxious vapours should be enclosed or semi-enclosed in a suitable cabinet or exhaust-protected workstation (LEV).

Microbiological safety cabinets and fume cupboards

- 8.152 Safety cabinets and fume cupboards are devices that have an inflow of air to control exposure of staff to hazardous substances. The units and their exhaust systems, filters, fans and discharge terminals are all classified as LEV systems under the COSHH Regulations. The make-up air system to a room that contains an LEV system may also be considered as an essential part of the system and be included in the LEV classification.

Special requirements

- 8.153 The supply air system should not distort the unidirectional and stable air pattern required for fume cupboards and microbiological safety cabinets. In general, supply air ceiling diffusers should not discharge directly towards fume cupboards or safety cabinets, unless the terminal velocity is such that the airflow pattern at the front of the cabinet is unaffected. The design should ensure that high air-change rates, and/or the opening and closing of doors, do not have any adverse effect on the performance of safety cabinets or fume cupboards. A damped door closure mechanism may help.

Arrangements for safety cabinet installations

- 8.154 The manufacture and installation of microbiological safety cabinets will be in accordance with the relevant national standards and guidance issued by the Advisory Committee on Dangerous Pathogens (ACDP).
- 8.155 A Class 1 microbiological safety cabinet will be specified for routine work involving Group 3 pathogens. It should be housed in a containment level 3 room. Specific

design information on containment rooms is issued by ACDP in conjunction with the Health and Safety Commission.

- 8.156 Siting and installation of microbiological safety cabinets are of particular importance because:
- the protection afforded to the operator by the cabinet depends on a specific and stable unidirectional airflow through the open front;
 - the protection to the environment by the cabinet depends on the high-efficiency particulate air (HEPA) filters. The exhaust air should never be considered as totally free from microbiological hazard.
- 8.157 Microbiological safety cabinet extract is HEPA filtered prior to being discharged to outside. Current standards permit the installation of microbiological safety cabinets with integral fans, provided that the extract ductwork can be kept short (that is, less than 2 m); such an installation, however, is likely to be noisy and is not recommended for use in new buildings.
- 8.158 Ductwork and discharge arrangements should be as set out in Chapter 9.
- 8.159 Discharge should be to outside but where this is impracticable, discharge into the room via a double HEPA filter will be accepted if approved in writing by the VSG.

Arrangements for fume cupboard installations

- 8.160 The manufacture and installation of fume cupboards will be in accordance with the relevant national standards and associated guidance.
- 8.161 The primary factors which contribute to the effective performance of fume cupboards include:
- an adequate volume of supply air and its means of introduction;
 - an effective exhaust system to promote the safe dispersal of waste products to atmosphere.
- 8.162 The air velocities through sash openings should be enough to prevent hazardous materials from entering the laboratory while avoiding excess flow rates that interfere with the investigation process. Average face velocities should be between 0.5 and 1 m/s, with a minimum at any point within 20% of the average, the upper end of the range being applicable to the containment of materials of high toxicity. The design velocity should be maintained irrespective of whether the sash opening is varied, or whether doors or windows are open or closed (see BS EN 14175).
- 8.163 The possibility of a fire or explosion which may not be contained by a fume cupboard should always be considered. A fume cupboard should not, therefore, be sited in a position where exit to an escape route will necessitate passing directly in front of it.

Control of extract systems

- 8.164 It is desirable to provide local control of safety cabinets in order to maximise the life of the HEPA filter, and to permit the sealing of the cabinet and room for fumigation if spillage occurs.

- 8.165 To cope with the risk of an accident or spillage outside safety cabinets, a panic button should be provided to switch off the supply to that area and to discharge all extracted air to atmosphere.
- 8.166 In pathology departments, it will always be necessary to have one or more microbiological safety cabinets and one or more fume cupboards available for use, including weekends; therefore, local overriding controls for all these items and any associated ventilation plant will be necessary.

Hood extract systems

Special requirements

- 8.167 Extract canopies will be required over steam-and-heat-emitting appliances, for example sterilisers, catering and washing equipment and for the extraction and removal of unpleasant odours. These installations are for the control of non-hazardous airborne contaminants, they are not LEV systems.
- 8.168 Perimeter drain gulleys and corrosion-proof grease eliminators should be provided on kitchen hoods (see BESA DW 172 – ‘Specification for kitchen ventilation’).

Typical arrangements

- 8.169 The airflow rate should be enough to ensure an adequate capture velocity in the vicinity of the process. Advice from equipment suppliers should be sought, as excessive velocities will be wasteful of power and generate noise.
- 8.170 The lowest edge of the canopy should be 2 m above finished floor level, with a minimum of 300 mm overhang beyond the edge of the equipment on all sides.
- 8.171 A compact arrangement of equipment (but with access for maintenance) will minimise the canopy area, and hence reduce the air volume necessary to achieve the optimum capture velocity.
- 8.172 Hoods required for the control of heat gain and vapours may be connected to the general extract system when it is convenient to do so, but where non-corrosive ductwork materials are necessary, a separate extract system is preferred.
- 8.173 Lighting and internal divider plates are often required to be built into the perimeter of large canopies; however, built-in shelving systems are not recommended, as they interfere with the airflow, and constitute a maintenance problem.

Control of hood extracts

- 8.174 Provided that it does not interfere with the operation of the department when not in use, the ventilation system for the hood extract and any associated supply may be shut down. To this end, local control should be provided.

Plantroom ventilation

General requirements

- 8.175 Plantrooms are required to be ventilated in order to maintain acceptable temperatures for satisfactory operation of the plant and controls, and for maintenance activities. Natural ventilation through louvred openings protected from infestation by a

mesh with openings of no less than 6 mm and no more than 12 mm are required. Powered plantroom ventilation should only be needed if natural ventilation is not adequate.

- 8.176 Ventilation requirements should consider all heat sources within a plantroom, and where there are large glazing areas, solar gains. The ventilation rate should limit the maximum temperature within the plantroom to 32°C.
- 8.177 Air handling equipment cannot be located in a fire compartment that houses combustion equipment.
- 8.178 AHUs and other ventilation equipment that serve occupied areas cannot draw their intake air from a plantroom. Neither should extract ventilation plant or medical vacuum pumps discharge air into a plantroom.
- 8.179 Statutory regulations for plantroom ventilation are contained in the Building Regulations, and further guidance in the CIBSE Guide B2. Note the need to assess the risk of services to AHUs freezing in unheated plantrooms.

9. Equipment Selection Factors

General requirements

- 9.1 The following gives detailed guidance on the design and selection of ventilation equipment, the distribution system, terminals and control aspects. Designers should take note of the supporting information given in Chapters 10 and 12. Failure at the design stage to make due allowance for the standards to be achieved may mean that the installed ventilation system will not be acceptable to the client's validator at handover.

Location and access

- 9.2 The plant should be located so that it is remote from possible sources of contamination, heat gains and adverse weather conditions. The design should ensure that wind speed and direction have a minimal effect on plant throughput.
- 9.3 Safe access to and around plant is essential to facilitate inspection, routine maintenance, repair and plant replacement.
- 9.4 Air-handling units (AHUs) should be located in an accessible area secured from unauthorised entry. They may be grouped together in dedicated plantrooms or distributed around the building with AHUs located adjacent to or within the area that they serve. In the healthcare setting, because of the difficulty in gaining access for routine service and maintenance, mounting ventilation units of any type in ceiling voids above clinical spaces is not permitted.

Note: If it is proposed to install ventilation units of any type in a ceiling void above a non-clinical area, it should be subject to a formal risk assessment and its use being agreed by the ventilation safety group (VSG) prior to design approval. Their assessment will consider how the unit may be safely accessed and maintained.

- 9.5 AHUs should be located in purpose-built plantrooms or designated service spaces within a building. This will allow for routine service and maintenance (which is a statutory requirement) to be carried out at any time of day and regardless of weather conditions. It will also protect the plant from contamination by bird droppings, so reducing the risk of fungal spore contamination of the air supplied by the AHU. Control of pests and vermin will be simpler and while not in themselves a source of airborne contamination, their corpses can become a reservoir of biological material that may lead to insect infestations within the AHU.

Note: In a new building it is not envisaged that there will be any need to locate AHUs outside. The design of the building should incorporate central or distributed plant spaces of sufficient size to accommodate the plant required to service the building.

- 9.6 When refurbishing or changing the use of an existing building, plant space should be created to house the ventilation plant and other services. If located on a roof they should be enclosed in a plantroom with a safe means of access. If located at ground level they should be secured within a plantroom to prevent unauthorised access. Measures should be taken to exclude vehicles from the vicinity to ensure that exhaust fumes will not be drawn into intakes. Intakes for ground level AHUs should

be extended to a height and distance from contamination sources that allows them to draw in unvitiated air.

- 9.7 In the unlikely event that an internal or external plant room cannot be provided, and ventilation units have to be located outside, they should be fully weatherproof to IP65 and secured from unauthorised access. Protection against the elements should also be provided for personnel carrying out routine inspection and maintenance activities. As an example, when two units are outside, and they are installed with their access doors facing each other, if the gap between them is roofed over and the open ends capped, the AHUs themselves create what is in effect a plant room (see photographs).
- 9.8 Water will be used during routine cleaning or spilt when maintenance is being undertaken. The area around plant should be tanked to prevent water penetration to adjacent areas and adequately drained

Figure 5 AHU formed plant room (external)



Figure 6 AHU plant room (internal)



Note: Plant rooms should be provided with a sink so that glass drainage traps may be cleaned out and staff can wash their hands after handling contaminated/dirty filters. A source of domestic hot water (DHW) with a valved hose connection point will also be required so that AHUs can be washed out internally as part of their routine maintenance. Plant rooms at roof level should be served by a lift.

- 9.9 Fire precautions should be incorporated in accordance with the Health Technical Memorandum 05 Firecode series. Guidance is available in Chapter 1 of this document.

- 9.10 Combustion equipment cannot be located in a fire compartment that houses air handling equipment

Standard requirements

Identification and labelling

- 9.11 All ventilation systems should be clearly identified with a permanent (traffolyte type preferred) label in accordance with the requirements of Chapter 13. The label should identify both the AHU and the area that it serves. The lettering should be at least 100 mm high and be screwed or riveted onto the AHU in an easily visible place near the fan of the unit, adjacent to the local electrical isolator. Any subsystems and the principal branch ducts should be similarly labelled.

Note: The AHU identification code should conform to the plant identification system in use at the premises (see Chapter 13).

- 9.12 The nature of air and direction of flow should be clearly marked on all ducts using the symbols given in BS 1710.
- 9.13 All airflow test-points should be clearly identified with a permanent label and the design information given (for example, TPS 1 – Anaesthetic supply; 400 × 300; Design 185 L/s).

Plant minimum standards

- 9.14 Plant should comply with the minimum standards set out in Table 8.
- 9.15 External finish to be corrosion resistant and may be available in a variety of colours at no additional cost. This can aid identification by colour-coding of units in a plantroom (for example, green for general ventilation; blue for theatres; red for laboratories and isolation facilities; grey for extract).
- 9.16 Organic materials or substances that can support the growth of microorganisms cannot be used in the construction of the plant or its distribution system. The water fittings and materials directory list suitable materials for sealants and gaskets (see also BS 6920).
- 9.17 AHU internal wiring should comply with BS 7671 and be installed in a cable containment system providing suitable mechanical protection. The wiring and its containment system should not allow air bypass at the filters. The wiring, its containment system, connection boxes and fixings should permit the effective internal cleaning and inspection of the AHU.
- 9.18 Plastic-bladed dampers and plastic plate heat exchangers should not be fitted. This accords with the national policy to reduce the use of plastics.
- 9.19 Motorised spring-return low-leakage (BS EN 1751 class 3) isolation dampers should be located at the intake, supply, return air and discharge duct connections of an AHU and associated extract unit. They should be of the opposed-blade type and be fitted with end switches. They should close automatically in the event of power failure or plant shutdown to prevent any reversal of the system airflow. They will also function to isolate the plant from the distribution system when undertaking cleaning or maintenance.

Note: Internal plant dampers or provision for the fitting of shut-off plates, also known as dagger plates, between elements within an AHU are not required.

9.20 Access to elements that require routine service such as filters, fans and all types of heat-transfer device should be via hinged doors. In horizontal units the doors should be wide enough: 500 mm minimum at a unit height >1 m. For smaller units the doors need to be at least 600 mm wide, to allow easy access. Items requiring infrequent access such as attenuators may be via removable panels fitted with lifting handles, or access hatches. All doors and panels should be secured from casual access, close-fitting and without leaks.

Table 8: Plant minimum standards

AHU Element	Minimum Standard	Notes
Construction	Double metal or composite skin with sandwiched insulation to "Euroclass A" fire rating Smooth internal surface without channels or ridges No projecting spire or tech screws inside the unit.	Note: Capping projecting spire screws is not acceptable.
Internal surface finish	Non-corrodible, washable and smooth and of a colour that allows accumulations of dirt to be easily seen	Stainless steel or white powder coated mild steel or with an equivalent protective treatment; but NOT surface galvanised
Thermal transmittance	BS EN 1886 Class T2	Manufacturer's declaration
Thermal bridge	BS EN 1886 Class TB2	Manufacturer's declaration
Deflection	BS EN 1886 Class D2	Manufacturer's factory test
Factory airtightness test – pre-delivery	BS EN 1886 Class L2	Test at +700 Pa and –400 Pa
Site airtightness test	BS EN 1886 Class L2	+700/–400 Pa
Filter frame bypass leakage	BS EN 1886 Section 7	
Supply and extract intake and discharge isolation dampers	BS EN 1751 C3 (low loss)	Motorised opening and fitted with an end switch and spring return
Access doors	Secured from casual access. Fan chamber doors to be fitted with a two-stage latch	Key or similar device required to open access doors Door hinges should be adjustable to so that leakage can be eliminated on site
Specific fan power -Internal (SFPint)	Current Eco design requirement for energy-related products (ErP)	EU 1253 – 2014
Specific fan power - System (SFPsyst)	UK Building Regs	Part L2
Energy recovery	Current ErP EU 1253	Run-around coil – 68% Heat pipes – 73% Plate heat exchanger – 73% Thermal wheel – 73% Heat pump – EU 2281/201 Any other device – see standard

9.21 All access doors should be fitted with seals and have adjustable hinges so that leakage can be eliminated once the unit is installed on site. Access doors to fan chambers should have a two-stage opening sequence to prevent the door blowing violently open if it is unlatched while there is still residual pressure in the unit.

Note: Providing the AHU is located in a plantroom or area secured from unauthorised entry, its access doors can only be opened with a key or similar device, the fan door is fitted with a viewing port and a two-stage opening latch and there is a fan electrical isolation switch adjacent to the fan-chamber access door, there is no requirement to fit an internal fan chamber mesh guard.

- 9.22 In the healthcare setting it can be difficult to turn off AHUs in order to inspect filters and drainage trays. Viewing ports and internal illumination will therefore facilitate routine inspection of such items. Viewing ports should be at a convenient height so that temporary ladders are not required. In double-stacked units the viewing ports in the upper section will be located in the lower portion of their access doors. Internal illumination should be provided by fittings to at least IP55 rating. Light fittings should be positioned inside the unit (not on the access doors) so that they provide illumination for both inspection and task lighting. All lights in a unit should be operated by a single switch and be powered independently of the AHU main switch. LED lights are preferred.
- 9.23 Access to air intakes and discharges, AHUs and items in the distribution system such as filters or auxiliary trimmer batteries located in a plantroom or plant area above 1.5m should be via platforms, fixed ladders, hook ladders, pulpit style movable steps or access platforms. The method of access chosen should reflect the frequency and nature of the maintenance requirement. The installation of distribution ductwork and other electrical or mechanical services should provide sufficient clearance to allow access equipment to be moved into position.

Chiller units: heat rejection devices

- 9.24 The design conditions given in Chapter 8 make no allowance for the elevated temperatures that can occur on the roof of buildings. Refrigeration condensers and chiller units should, if practicable, be shaded from direct solar radiation, or the design adjusted to take account of the gain. Care should be taken to ensure that there is sufficient clearance around the plant to allow effective air movement. Allowance may also be needed for the effect of walls, obstruction or other equipment in the area and for the prevailing wind direction.
- 9.25 Air-cooled condensers and/or dry coolers will always be the first choice for heat rejection from any refrigeration plant. The use of heat pump systems is also an option. Wet evaporative cooling systems cannot be used in healthcare premises unless limitations of space mean that they are the only way that the cooling load can be met. If they are used, national guidance on preventing and controlling Legionella should be closely followed (see the Health and Safety Executive's (HSE) Approved Code of Practice and guidance document HSG274 'Legionnaires' disease: the control of Legionella bacteria in water systems').
- 9.26 Traditional refrigerants are being phased down and some of their replacements at the time of writing have a degree of flammability. The level of risk this poses should be formally addressed at the design stage and agreed with the client or their fire safety representative. The selection of a refrigerant should be made with reference to the F-Gas Regulations and should take account of the life expectancy of the plant versus the future availability and increasing cost of the refrigerant. Ultimately, choosing refrigerants with the lowest global warming potential is the ideal and will ensure that

greenhouse gas emissions are minimised. Refrigerant gas monitoring must be included where required under BS EN 378.

Chiller selection: size and resilience

- 9.27 There is a tendency to meet the calculated maximum chiller load by specifying multiples of a standard size of chiller (for example, the calculated load to be met by three chillers each capable of 33% and an extra chiller of the same size to achieve the N+1 resilience requirement). This approach does not lend itself to efficient operation. It is preferable to split the load with, for example, two chillers capable of 40% each and two capable of 25% each. This will give an overall minimum capacity of 90% resilience at maximum summer design conditions and allow for the actual part load demand to be met in the most energy-efficient way.

Supply AHUs and associated extract units

Typical sequence of components

- 9.28 The AHU should be arranged so that most of the items are under positive pressure. Cooling coils and humidifiers will require a drain and should be on the positive pressure side of the fan. The following arrangement of components is typical, although in many instances not all elements will be required:

- fresh air intake;
- motorised isolation damper;
- fog coil if energy recovery fitted or frost coil if no energy recovery fitted;
- pre-filter;
- energy-recovery device (possible location);
- attenuator1;
- supply fan;
- attenuator1;
- energy-recovery device (possible location);
- cooling coil;
- eliminator (for face velocities above 2 m/s);
- heater-battery;
- humidifier (if required);
- final filter;
- motorised isolation damper.

- 9.29 AHUs may be configured as horizontal, linear single or double-stacked; or as cabinet type units. For double-stacked supply/extract units, the fans should be located on the bottom deck where possible as it will make them simpler and safer to change (see Figures A1–A3 in Appendix 1 for possible arrangement.).

Intakes and discharges

- 9.30 Air intakes and discharge points should preferably be located at high level, to minimise the risks of noise nuisance to surrounding buildings, contamination and vandalism.
- 9.31 Intakes and discharges should be designed and located so that wind speed and direction have a minimal effect on the plant throughput.
- 9.32 Helicopter landing pads in the vicinity of ventilation intakes and discharges can result in large short-term pressure changes. This can cause pressure surges in supply systems and reverse airflows in extracts. Exhaust fumes from the helicopter may also be drawn into intakes.

Note: It is not appropriate to “plan to turn the ventilation off when a helicopter lands” as a means of permitting the location of a helipad adjacent to ventilation intakes and discharges.

- 9.33 Intake points should be situated away from cooling towers, heat sources, boiler flues, vents from oil storage tanks, fume cupboards and other sources of contaminated air, vapours and gases and places where vehicle exhaust gases may be drawn in.

Note: Attenuators may be located in the intake and discharge duct if they are of a suitable type and provided with cleaning access both sides (see paragraph 9.116).

Note: Steps should be taken to prevent birds landing or roosting in the vicinity by removing ledges or fitting anti-pigeon spikes.

- 9.34 On the rare occasions where intakes have necessarily to be sited at or near ground level, the surrounding area should be paved or concreted to prevent soil or vegetation being drawn in. In addition, intakes should not be situated near established gardens/trees so as to avoid intake of environmental microorganisms. They should be caged or located within a compound to restrict unauthorised access and prevent rubbish being left in the vicinity. The likely proximity of vehicle exhausts should also be taken into account when determining the protected area around the intake and additional filtration may be required. The VSG should be consulted about the standard of air quality required. There should be a minimum 4 m clear zone around the intake (see paragraph 9.50 and paragraphs 9.63–9.64).
- 9.35 The discharge from an extract system will be located so that vitiated air cannot be drawn back into the supply air intake or any other fresh air inlet. Ideally, the extract discharge will be located on a different face of the building from the supply intake(s). At all times, there has to be a minimum separation of 4 m between them, with the discharge mounted at a higher level than the intake.

Note: Ventilation intakes and discharges cannot face each other across a passageway or courtyard even if they are 4 m or more apart.

- 9.36 Each intake and discharge point should be fitted with a corrosion-resistant weatherproof (BS EN 13030 class B) louvre or cowl to protect the system from

driving rain. Louvres should be sized based on a maximum face velocity of 1.5 m/s in order to prevent excessive noise generation and pressure loss.

Note: If there is a bend in the ductwork directly behind a louvre, it will affect the air velocity through the louvre. This may result in moisture carry-over or increased noise.

- 9.37 The inside of the louvres should be fitted with a mesh of not less than 6 mm and not more than 12 mm to prevent infestation by vermin.
- 9.38 The duct behind a louvre should be self-draining. If this is not practicable, it should be tanked and provided with a drainage system.
- 9.39 Cleaning access should be provided either from the outside via hinged louvres or by access doors in the plenum behind the louvre. Where a floor-level common plenum is provided, cleaning access should be via a walk-in door. High-level plenums should be able to be safely accessed by temporary or permanent means

Note: Builders' work plenums or intake ducts will need to have a smooth finish and be surface-sealed to prevent dust shedding (see paragraph 10.5).

Fans

- 9.40 Direct-drive electronically commutated (EC) fans are the preferred choice for ventilation systems. If necessary, resilience and an increased capacity can be achieved by installing two or more EC fans with gravity or motorised dampers to prevent backflow.

Note: At the time of writing the concept of a "fan wall" made up of multiple small variable speed fans all controlled as a single unit was under development. This concept has several advantages as the failure of one fan can be accommodated by speeding up the rest. Because the fans cover the full area of the duct, it will result in a more uniform air velocity downstream at the battery face. This will increase the heat transfer efficiency and may allow a reduction in battery size. Nothing in this document will preclude the use of such innovation that improves resilience and reduces energy usage.

- 9.41 For an application outside of the capacity range of EC fans, direct-drive plug fans controlled by an inverter mounted externally to the air stream may be selected.
- 9.42 In either case, the fan motor will be protected with a high-temperature safety cut-out.
- 9.43 Whichever type of fan is selected, if it serves a critical area it will be fitted in a way that allows it to be changed within 20 minutes. Mounting the fan unit on slide rails with plug and socket connections for power and control cables will facilitate this. Whenever possible, both supply and extract fans should be located on the bottom deck of a double-stacked AHU.
- 9.44 Selecting fans from a preferred size range will reduce the number of spares held.
- 9.45 Belt- and pulley-driven fans should not be installed in healthcare ventilation systems.
- 9.46 Supply fans should be positioned to blow through the central plant so that the cooling coil and humidifier drains (when fitted) will be under positive pressure. The energy-

recovery device may be either side of the fan and should have a drainage system on the extracted air discharge side.

- 9.47 In extract systems where the air is potentially contaminated, explosive, aggressive or has a high moisture content, the extract fan motor will be located outside the air stream and be capable of being changed without the need to access or change the fan impeller.

Control

- 9.48 Where two or more fans are fitted in a fan wall, the preferred normal operation is all fans running in parallel. In case of a single fan failure the remaining fan(s) should provide at least 80% of the design output.
- 9.49 For most healthcare applications, the fan output should be set to give a constant volume of air. This should be controlled by measuring the pressure drop across the fan suction nozzle using a sensing ring and associated volume controller that will automatically integrate the fan K factor to determine and control the preset output air volume. The fan output will then in air volume terms remain constant regardless of changes of system resistance. The actual volume delivered will be related to the air-change rate for the application.

Note: Measuring the air pressure in the main supply duct and using that to set the supply fan speed as a percentage of its rated output and using that to set the extract fan speed as a percentage of the supply fan speed is not a satisfactory, accurate or an acceptable way of controlling the desired supply and extract air volumes.

Filters

- 9.50 The purpose of filtration is to reduce the level of airborne contamination in an air stream. It is generally carried out in stages
- 9.51 Filters should be securely mounted in well-fitting frames designed so that the airflow pushes the filter into its housing to minimise air bypass. Vertical supports with seals should be provided to master the joints between filters and eliminate bypass. Mounting frames that withdraw so that the filter can be changed without having to reach into the unit are preferred.
- 9.52 Filters need to be readily accessible, so a hinged access door should be provided. The upstream side of the filter should be visible for inspection through a viewing port with internal illumination.
- 9.53 For AHUs, provided that each filter's pressure drop is monitored by a sensor linked to the BMS, direct reading gauges or manometers will not be required. Capped pressure tappings should be provided so that a portable manometer can be connected for diagnostic purposes when necessary.
- 9.54 General air filters (see Table 9) are divided into four categories, related to the size of particle (in microns (μm)) that they can remove as a percentage of the load.
- coarse filters – remove less than 50% of 10 μm particles;
 - PM10 medium filters – remove 50 to 95% of 10 μm particles;

Table 9: General filters: typical healthcare selections

ISO 16890 Class	Notes and typical healthcare
ISO Coarse 60%	May be used as temporary addition filtration at an air intake when building or demolition works are being undertaken in the vicinity
ISO ePM10 ≥50%	Panel pre-filter or return air filter to protect the energy-recovery device
ISO ePM2.5 ≥50%	Supply air filter for areas with temporary occupancy
ISO ePM1 ≥50%	Supply air filter for areas with permanent occupancy

- PM2.5 medium filters – remove 50 to 95% of 2.5 µm particles;
- PM1 fine filters – remove 50 to 95% of 1 µm particles.

Note: Ventilation filters can only remove particles from the incoming air. Most particles that could cause an infection originate from the occupants and activities within the building. In AHUs the pre-filter and return air filter will keep the energy-recovery device, cooling coil and heater-batteries clean and working efficiently. The secondary filter will keep the distribution ductwork and supply air terminals clean.

Note: For additional information on filter selection and indoor air quality, see the Specialised Ventilation for Healthcare Society's (2018) SVHSoc.02 – 'Change in air filter test and classification standards'.

9.55 In areas of high atmospheric pollution, a higher standard of filtration may be required in order to meet the indoor air quality standard (IAQ).

9.56 Compact filters are preferred, because bag filters are often incorrectly oriented and prone to damage when changed.

Efficiency and high efficiency particulate air (EPA and HEPA) filters

9.57 These filters are designed to provide filtration of particles in the sub-micron size range. EPA and HEPA filters self-select the particle that they are least able to trap and are graded against that "most penetrating particle size" (MPPS) (see Table 10):

- efficiency particulate filters (EPA): three grades E10 to E12;
- high efficiency particulate filters (HEPA): two grades H13 to H14;
- ultra-low particulate air filters (ULPA): three grades U15 to U17.

Table 10: EPA and HEPA filters: typical healthcare selections

Typical healthcare application	Minimum filter grade to BS EN 1822 - 2019	% Efficiency @ MPPS
UCV theatre terminal	EPA – E10 – (EU10)	85
No standard healthcare application	EPA – E11 – (EU11)	95
Immunosuppressed and neutropenic patient rooms or wards	EPA – E12 – (EU12)	99.5

Typical healthcare application	Minimum filter grade to BS EN 1822 - 2019	% Efficiency @ MPPS
No standard healthcare application	HEPA – H13 – (EU13)	99.95
Pharmacy aseptic preparation facility supply Containment level 3 room extract	HEPA – H14 – (EU14)	99.995
*Incorporates ISO 29463 tests methods.		

Note: ULPA filters are designed to remove particles below a size that is either surgically or aerobiologically significant. There would have to be exceptional circumstances in order to justify their use in a healthcare ventilation system.

9.58 EPA and HEPA filters are expensive, so their use should be kept to a minimum. When used they should be of the replaceable panel type with leakproof seals and installed in a manner that permits the validation of the filter and its housing (see Chapter 12).

9.59 In supply systems an EPA or HEPA filter will have a non-shedding metal case.

Return air and extract air filters

9.60 Return air filtration will always be required where heat recovery devices are installed. Return air filters are also used to reduce the load on EPA filters in recirculating applications such as ultra clean operating suite ventilation canopies and pharmacy aseptic preparation facilities. They should be the same grade as their AHU pre-filter.

9.61 EPA or HEPA filters are sometimes fitted in extract systems to capture hazardous substances or organisms. Design provision should be made for the subsequent safe handling of contaminated filters by maintenance staff. This may be achieved by:

- sealing the hazardous substance into the filter before it is removed;
- providing a system to fumigate the filter to kill any organisms;
- housing it in a “safe change” unit that permits the filter to be ejected into a bag and sealed without personnel having to come into direct contact with it.

Notes:

1 In view of the costs and problems associated with placing EPA or HEPA filters in extracts, it is essential that a full risk assessment be carried out at the design stage. This should include defining the true need for a filtered extract, the validation of its performance at installation, the method of safely changing a contaminated filter, and its subsequent disposal.

2 General extracts from mortuaries and post-mortem rooms may contain odours, but these are not in themselves hazardous to health and do not require filtration prior to discharge. In high-risk post-mortems (for example, known or suspected tuberculosis cases), the infected organs will be removed and then dissected in a class 1 microbiological safety cabinet provided under the COSHH Regulations.

Extracts from infectious disease Isolation rooms or wards do not normally require filtration prior to discharge. However, if the discharge cannot be made in a safe location and it is likely that the vitiated air could be drawn back into the building or there are people in its vicinity (for example, a discharge into a courtyard), filtration would be required

- 9.62 Extract EPA or HEPA filters should have a particleboard or plywood case so that they can be incinerated.

Activated carbon filters

- 9.63 Activated carbon filters can remove gases and vapours from an air stream and are graded according to the range of substances they can remove. They are not normally fitted in air-conditioning supply systems. They are occasionally fitted retrospectively because an air intake has been poorly sited and is drawing in noxious fumes or the outdoor air quality is exceeding WHO levels for NOX/O3 or SOX. Where used they should be protected by or incorporated into a particulate air filter.

- 9.64 Activated carbon filters are more commonly used in specialised fume extraction systems when the location of the discharge means that dilution cannot be relied upon to disperse noxious fumes.

Energy-recovery devices

General requirements

- 9.65 Energy recovery will be fitted to all supply and extract healthcare ventilation systems. It may be omitted only where permitted by the current ErP Directive EU 1253/2014.
- 9.66 For most systems in healthcare premises, a plate heat exchanger, “run- around coil” system or thermal wheel would be appropriate. Selection should be based on the relative locations of the supply and extract units, ease of maintenance and practicality. Cleaning access will be required to both sides of any energy-recovery device.

Note: Plate heat exchangers are the preferred option as they require the least maintenance to retain their energy transfer efficiency. Thermal wheels may be used, as the degree of air transfer from extract to supply is not sufficient to cause aerobiological problems and in any event the air will be filtered before being supplied to the user. Run-around coils are used when the supply and extract units are separate or in case of space problems.

- 9.67 At the time of writing, the following are the minimum energy transfer efficiencies required under EU 1253 for devices handling equal air volumes:

- run-around coil – 68%;
- plate heat exchanger – 73%;
- thermal wheel – 73%;
- heat pipe – 73%;
- heat pump or any other device – see specific regulations.

Note: These efficiencies are regularly reviewed and are likely to be increased periodically.

- 9.68 If a plate heat exchanger is chosen, the plates should be constructed of metal; in coastal areas stainless steel is preferred. Plastic should not be used for the plates, internal bypass dampers or gears. (This is in keeping with the reduction in the use of single use plastics.)
- 9.69 If a thermal wheel is selected, only a sensible heat wheel should be used that incorporates a purge sector. In order to reduce bypass leakage, brush seals should not be used; enhanced airtightness seals should be fitted.
- 9.70 Whichever energy-recovery device is chosen, the extract side should be protected by at least an ISO ePM10 $\geq 50\%$ filter and provided with a drainage system as described in paragraphs 9.105–9.112, to remove condensate. Note that most condensate will occur at intermediate rather than at extreme outside air conditions.
- 9.71 The energy-recovery device should be located downstream of the fog coil and pre-filter, before the cooling coil and main heater-battery. It may be on either side of the supply fan.
- 9.72 It is essential to consider the set points and control of the fog coil, energy-recovery device, cooling coil and heater-battery in order to achieve the most efficient operation for the maximum time. The primary energy provided by the fog coil will directly reduce the heat exchange of the energy-recovery device. To this end, the off-coil setting of the fog coil should be the minimum possible to keep the pre-filter dry (2 to 3 K above intake air temperature) (see paragraph 9.75 onwards for further guidance).
- 9.73 The energy-recovery device should be controlled in sequence with the main heater-battery and should incorporate a control to prevent the transfer of unwanted heat when the air-on condition rises above the required plant set-point.
- 9.74 In instances where the plant is cooling the air, it may be possible to remove heat from the supply air at high ambient conditions, under the dictates of enthalpy sensors in the intake and extract ducts.

Heater-batteries

General requirements

- 9.75 Fog coils are installed to protect the downstream filters from low temperature, high humidity intake air conditions. They should raise the incoming air temperature by 2 K so that it is above its dew-point when it arrives at the filter. As they handle unfiltered air they should be constructed of plain tubing without fins and be as near to the outside as possible to minimise condensation during cold weather. Access for cleaning should be provided to both sides of the coil. In order to prevent them freezing they should be controlled as constant flow variable temperature devices.
- 9.76 Traditionally frost coils were set to raise the incoming air temperature to between +2°C and +5°C to protect the batteries downstream. All new AHUs should be equipped with an energy-recovery device (see paragraph 9.65); the greater the temperature difference across this device, the more heat will be recovered. Also, the

device will now provide the frost protection. Where an energy-recovery device is fitted, the frost coil will be replaced by a fog coil.

- 9.77 Where steam coils are used for a fog or frost coil, they may be constructed using spiral finned copper tube. As they will be prone to fouling, the tube layout and spacing should permit easy access for regular cleaning.
- 9.78 Main and branch heater-batteries should be constructed of solid drawn copper tube coils with copper fins, generally connected in parallel. In coastal and particularly exposed areas the client may require an anti-corrosion treatment.
- 9.79 Where there is a wet heating system in the areas served, the main heater-battery should be sized, in conjunction with the energy-recovery device, for the ventilation requirements only and not for the building fabric loss. Ventilation should only be used for heating the building fabric if the room specification precludes the use of heat emitters and it is not within the heated volume of the building (for example, a cleanroom or operating theatre with external walls).
- 9.80 Access for cleaning will be provided to both sides of all fog coils and heater-batteries.
- 9.81 Main heater-batteries may be water or steam. Electric heaters are expensive to operate, and their efficiency is particularly dependent on the air velocity through them. Their use should be restricted to branch trimming control.
- 9.82 Where steam supplied heater- batteries are used, their control, venting and trapping systems should be designed so that a vacuum cannot occur within the coil. The condensate drainage arrangements should not allow pressure to build in the condensate main as this will result in a back-up of condensate in the battery.
- 9.83 Where possible, wet trimmer heater- batteries should be located in plant areas.
- 9.84 Where it is necessary to locate heater- batteries in false ceilings etc, consideration should be given to the use of electric heaters (note that additional fire detection may be required). If this is not practicable and a LPHW system is used, a drip-tray should be installed under the control valve assembly to protect the ceiling. A moisture sensor and alarm should be fitted in the tray. In any event, to facilitate maintenance access, they should be located above corridors or other non-clinical areas and never above patient-occupied spaces
- 9.85 Auxiliary fan coil units are not to be installed in the ceiling above a patient- occupied space. They should be accessible for routine maintenance and cleaning without the need to cause significant disruption to the operation of the area that they serve.

Cooling coils and drift eliminators

- 9.86 Cooling coils supplied with chilled water are the preferred option. For small loads, or where chilled water cannot be made available, direct expansion (DX) coils may be used.

Note: For DX coils, it may be necessary to divide the chiller circuits unevenly in order to achieve efficient operation under part-load conditions. The turn- down ratio should allow stable control down to 10% of the peak load.

- 9.87 Cooling coils should be periodically decontaminated so the fin spacing needs to be ≥ 2.5 mm and the fins rigid enough to withstand cleaning (for example, ≥ 0.25 mm thick). Hinged access doors with viewing ports and illumination inside the AHU or duct should be provided both sides of the coil.
- 9.88 In an AHU when the cooling-coil face velocity is greater than 2 m/s a drift eliminator will be required downstream of the coil. The eliminator will be an entirely separate device mounted on slide rails so that it can be easily removed without the need for tools. If the size of the AHUs precludes the use of slide rails, and the eliminator is constructed in sections which maintenance personnel will have to enter the unit to remove, each section should have lifting handles. In order to reduce the use of plastics, alternative materials should be considered for the eliminator elements.
- Note:** For small DX coils and in fan coil units, the eliminator may take the form of a joggled extension of the fins.
- 9.89 All cooling coils are to be fitted with their own independent drainage system as specified in paragraph 9.105 onwards. A baffle or similar device should be provided in the drip-tray to prevent air bypassing the coil. The tray should be large enough to capture the moisture from the coil headers and drift eliminator.
- 9.90 Where coils are greater than 1.8 m high and the air velocity is >2 m/s, either intermediate drip-trays will be required or the fin spacing should be increased to ≥ 3 mm.
- 9.91 In order to minimise electrolytic action resulting from condensation on the air side, cooling coils constructed from copper tubes with copper fins and electro- tinned after manufacture are preferred. Aluminium fins should only be used if vinyl- coated.
- 9.92 All parts of the coil and its associated ductwork in contact with moisture will be manufactured from corrosion-resistant materials. Pressed steel coil headers, even if treated, have been shown to be prone to corrosion over time and should not be used. Steel mounting frames and casings present similar problems so stainless steel is preferred.
- 9.93 Where a cooling coil has to be located above a ceiling, a drip-tray should be installed under the battery and control valve assembly to protect the ceiling from leaks and condensation drips. A moisture sensor and alarm should be fitted in the tray. To facilitate maintenance access, they should be located above corridors or other non-clinical areas and never above patient- occupied spaces. The air velocity should be below 2 m/s to avoid the need for a drift eliminator. All drainage piping should be rigid type not flexible hose.
- 9.94 Auxiliary fan coil units should not be installed in the ceiling above an occupied space. They should be accessible for routine maintenance and cleaning without the need to cause significant disruption to the operation of the department that they serve. The drainage of such items is often problematic. If a suitable fall in the drain line cannot be achieved, a pump out system should be provided. Drainage piping should be rigid type (not flexible hose).

Humidifiers

- 9.95 Humidification was originally required for some healthcare applications in order to control the risk associated with the use of flammable anaesthetic gases. The use of such gases has now ceased. Humidification is therefore no longer required unless there is a very specific application requirement (see Chapter 8 and associated SHPNs/HBNs).

Note: In an operating theatre, if high humidity is required to help prevent tissue drying during surgery, it should be provided when required using sterile water in a disposable nebuliser driven by medical air, and not from a humidifier installed in the ventilation system. In that way the quality of the moisture delivered will be assured.

- 9.96 If it is unclear at design stage whether humidification is required, provision for retrofitting in terms of space provision and a capped drainage system may be provided either in the AHU or in a zone branch duct. The need for such provision and the amount of space allowed for it should be agreed in writing with the client.
- 9.97 If a humidifier is required, the manufacturer's instructions regarding selection, capacity, installation and control need to be followed. Incorrectly sized, installed or operated humidifiers can become a source of fungal and microbiological contamination within a ventilation system. This may result in a significant airborne infection risk to patients and staff.
- 9.98 Only steam injection manifold-type humidifiers are considered suitable for use in health building air-conditioning systems. The injected steam will be generated locally either by mains steam or electricity, within or adjacent to the humidifier. Water-curtain, water mist or spray humidifiers of any type cannot be used.

Note: Jacketed lance mains steam humidifiers will always be a source of heat within the system during the cooling season unless completely isolated when not required.

- 9.99 All parts of the humidifier and its associated ductwork in contact with moisture should be manufactured from corrosion-resistant materials. Stainless steel is preferred.
- 9.100 For self- and locally-generated steam humidifiers, the cleanliness of the water supply is essential for their safe operation. The water supply should be derived from a wholesome source or demineralised supply. Chemical treatments cannot be added to the water supply to humidifier units. The electrodes of self-generating electrode boiler-type humidifiers should be stainless steel.
- 9.101 If the quality of the water supply to a self-generating humidifier unit cannot be assured, an ultraviolet (UV) system to control microbiological growth may be installed. However, given the limitations of UV systems, this will require high-quality water filtration to ensure the effectiveness of exposure of organisms to the UV irradiation. As with all water treatment systems the unit should be of proven efficacy and incorporate UV monitors so that any loss of transmission can be detected.
- 9.102 Provision should be made for draining down supply pipework and break tanks for periodic disinfection and cleaning during the seasons when they are not required in service. The humidifier branch water supply isolation valve will be located at the junction with the "running" main to prevent the creation of a dead leg. All parts of the system should be capable of being cleaned or disinfected as necessary. Hinged

access doors with viewing ports and internal illumination should be provided. A label warning that the device emits live steam and should be isolated prior to opening should be affixed to the access door.

- 9.103 A zone humidifier, if required, may be installed in a supply branch. The ductwork in which the humidifier is mounted and for at least 1 m downstream should be stainless steel.
- 9.104 All humidifiers wherever installed will be fitted with their own independent drainage systems as detailed in paragraph 9.105 onwards and be completely accessible for cleaning.

Drainage

- 9.105 All items of plant wherever located that could produce moisture should be provided with a drainage system. The system will comprise a drip-tray, glass trap, air break and associated drainage pipework.
- 9.106 The drip-tray should be constructed of a corrosion-resistant material (stainless steel is preferred) and be so arranged that it will completely drain. To prevent “pooling”, it is essential that the drain connection should not have an up-stand; and that a slope of approximately 1 in 20 in all directions should be incorporated into the drain outlet position.
- 9.107 In AHUs that have access doors large enough for a person to enter, the drip-tray should be easily accessible for inspection and cleaning.
- 9.108 In AHUs with access doors too small for a person to enter, the complete drip- tray should be capable of being withdrawn. It should be clamped into the AHU with thumb screws so that it can be removed without the need for tools (see photograph).

Figure 7 Removable AHU drainage tray



- 9.109 Each drip-tray should be provided with its own drain trap. The drain trap should be of the clear (borosilicate) glass type. This permits the colour of the water seal to be observed, thus giving an early indication of corrosion, biological activity or contamination within the duct. The trap should have a means for filling and incorporate couplings to facilitate removal for cleaning. It should be located in an easily visible position where it will not be subject to casual knocks. The pipework connecting the drainage tray to the trap should have a continuous fall of not less than 1 in 20.

- 9.110 Traps fitted to plant located outside or in unheated plant rooms need to be trace heated in winter. The trace heating should not raise the temperature of water in the trap above 5°C.
- 9.111 Water from each trap will discharge directly via a clear air gap of at least 15 mm above the unrestricted spill-over level of either an open tundish connected to a foul drainage stack via a second trap, or a floor gully (or channel). A support should be provided to ensure that the air gap cannot be reduced. More than one drain trap may discharge into the tundish providing each has its own air-break.
- 9.112 Drainage pipework from the tundish may be thermoplastic, copper or stainless steel. Glass should not be used. The pipework should be a minimum diameter of 22 mm and have a fall of at least 1 in 60 in the direction of flow. It should be well-supported and located so as not to inhibit access to the AHU.

Note: In the case of fan coil units, the glass trap and air-break may be omitted and a pump out system fitted. The unit drainage should connect to the main drainage system via a waterless trap that does not allow discharged water to return. The drainage tray itself will be easily removable for routine inspection and cleaning.

Attenuators

- 9.113 Provided care is taken in the design and construction of low pressure systems to avoid significant noise generation in the ductwork, attenuation should only be needed to absorb fan noise
- 9.114 Fans radiate noise through both the inlet and outlet connections, and it may be necessary to provide attenuation to limit the noise from both of these connections. It is always preferable and more economic to control noise and vibration at source, or as close to source as possible. It should be noted that attenuators offer a resistance to airflow and by causing turbulence can be the cause of regenerated noise in a system.
- 9.115 A thorough assessment of the design should be made to assess the potential noise problems. It should consider the following factors:
- fan and plant noise generation;
 - airflow-generated noise in ductwork fittings and dampers;
 - noise generated at grilles, diffusers and other terminals;
 - noise break-in and break-out of ductwork;
 - cross-talk and similar interference;
 - the noise limitations for the building and surrounding areas;
 - external noise generation.

A method of assessment of these factors and the sound attenuation requirements of ductwork systems is given in CIBSE Guide B

Note: Attenuators fitted in distribution ducts can themselves become a source of regenerative noise if the air velocity through them exceeds their tested performance value.

- 9.116 Attenuator units with a sound- absorbing in-fill suitable for the quality of air being handled and protected by a perforated sheet metal casing are the preferred option. Absorption of moisture, dirt and corrosive substances into the “in- fill” and the release of fibrous particles into the airstream should be prevented using a membrane with a declared service life of at least 25 years. If these conditions can be met, the attenuator may be located in the supply ductwork downstream of the final filter. Cleaning access should be provided at both ends of the unit.
- 9.117 Sound-absorbing material should not be applied to the inside surface of a duct.
- 9.118 End of line mixing and VAV boxes may be supplied lined internally with sound-absorbing material. The material will be non-particle-shedding, protected from casual damage during maintenance and be fire-resistant.
- 9.119 See paragraph 9.149 onwards for guidance on distribution and point of use noise control.

Note: Developments in “dynamic attenuation” may replace the more traditional physical attenuators and overcome noise “break in” and point of use noise regeneration issues.

Recirculation – minimum fresh air requirement

- 9.120 Where return air is recirculated, fresh air should be introduced equivalent to at least 20% of the supply air volume, or that required by the Building Regulations, or at least 10L/s/person, whichever is greater.

Distribution system

- 9.121 The CIBSE guide B2 provides the standard design Information for ventilation systems, their ductwork and terminal devices. The guidance in this SHTM highlights the specific factors that are required for or excluded from healthcare ventilation installations.
- 9.122 For normal applications in healthcare buildings, low velocity systems are recommended; velocities below 2 m/s are unlikely to be justified.
- 9.123 The site will often dictate the main routing of ductwork systems, as will the location of the AHU relative to the load. Grouping AHUs in centralised plantrooms results in large vertical service shafts and long main duct runs. Decentralising AHUs into service spaces adjacent to the load results in a more compact duct layout.
- 9.124 Whichever option is chosen, the design should seek to make the layout as symmetrical as possible; that is, the pressure loss in each branch should be as nearly equal as possible. This will aid balancing and may reduce the number and variety of duct fittings that are needed.
- 9.125 Main distribution ductwork should not be routed above sleeping areas. Where there is no alternative route, additional external acoustic insulation may be required.
- 9.126 Where auxiliary air-conditioning units, fans, filters or trimming devices are installed in the distribution system, they will be independently supported and fitted with a suitable drainage system where appropriate. If they are a source of vibration, they should be linked to the distribution ductwork via flexible connections.

Ductwork materials and construction

- 9.127 The choice of duct material should take account of the nature of the air or gas being conveyed and the environment in which the duct will be placed.
- 9.128 Galvanised sheet steel is suitable for normal ventilating and air-conditioning applications. Its inherent mechanical strength renders it resistant to casual damage both during the construction phase and throughout its service life when mechanical and electrical services around it are accessed. It may also readily withstand the impacts sustained when rotary equipment is used to clean it internally.
- 9.129 In instances where moisture levels and/or corrosive elements in the air being conveyed are very high, aluminium, stainless steel, PVC or GRP ducts should be used. Stainless or black steel are the only suitable materials for high temperature ductwork.
- 9.130 Where other ductwork materials are considered, care should be taken to ensure that the material is satisfactory for the application having regard to the likely service life, possibility of mechanical damage and performance in the event of a fire. Where used it will be installed strictly in accordance with its manufacturer's instructions.
- 9.131 Rectangular ducting with an aspect ratio of 1:1 is preferred but ratios of up to 3:1 are acceptable where there are space constraints. Circular spiral-wound or flat-oval are also acceptable providing they meet the leakage standard when tested (see Note after paragraph 9.136). Flexible ductwork is not suitable for air distribution in healthcare applications. In situations where solid ductwork cannot be used, flexible ductwork may be used to make the final connection to a terminal providing it does not exceed 0.5 m in length, is extended as far as possible and is never used in lieu of a bend (see paragraph 9.160).
- 9.132 The inside of the ductwork should be free from structural projections and as smooth as possible. Flanged gasketed joints between sections are preferred for rectangular ductwork, blind-riveted mastic-sealed slip-joints for circular and flat-oval.
- 9.133 In inherently wet areas, such as the base of fresh air inlet ducts and some extract systems, the ductwork may require draining to prevent a build-up of standing water. The layout of the drains should be as specified in paragraph 9.105 onwards.
- 9.134 Where builders' work plenum chambers or ducts are employed, all internal surfaces should have a smooth finish and be sealed to prevent dust shedding.
- 9.135 All types of ductwork should be manufactured and installed to the appropriate current BESA specification.
- 9.136 Ductwork should be supported with threaded rod and channel. Note that sheet metal ductwork cannot use bolt-through supports. Gripple wire may only be used for circular galvanised spiral-wound or flat-oval ductwork.

Note: All installed ductwork whether new or reused should be subject to a leakage test on site prior to the application of any insulation. The leakage test will be to BESA DW144 but with a permissible leakage rate of not greater than 3%.

Fire aspects: damper types and locations

- 9.137 It is essential that all relevant fire aspects of ducting systems are agreed with the fire officer before the design is finalised (see paragraph 1.15 onwards).
- 9.138 Ductwork will be fire-stopped where it penetrates fire compartment walls, floors and enclosures, cavity barriers and subcompartment walls or enclosures, and provided with weatherproof collars where roofs or external walls are penetrated.
- 9.139 Fire and smoke dampers should be provided at the locations required by the Health Technical Memorandum 05 series of documents. The damper mounting frame should be securely attached to the building fabric strictly in accordance with the manufacturer's tested details. Where a fire and smoke damper is not mounted directly in a fire compartment wall, it must be correctly supported and the ductwork between it and the fire wall must possess the same fire rating as the fire wall that it penetrates. The fire-rated portion of ductwork must not be penetrated by test holes or inspection hatches (see also BESA DW145).
- 9.140 Any non-standard fire duct or damper arrangement should be agreed in writing by the client's fire advisor and subsequently tested and signed off by the installer.
- 9.141 An access hatch should be provided adjacent to each fire and smoke damper so that its correct operation can be directly observed. The hatch will be as large as necessary to permit inspection, testing and maintenance. The damper test switch should be mounted adjacent to the inspection hatch so that the routine test and visual confirmation of the damper operation can be carried out by a single person. For circular ductwork, rectangular saddle mounted hatches should be fitted (see BESA DW144).
- 9.142 Smoke-diverting dampers will be provided on recirculation air systems to automatically divert any smoke-contaminated return air to the outside of the building in the event of a fire. It should be arranged so that the normally open diverting damper in the return air branch to the input unit closes and all the return air is exhausted to outside (see paragraph 5.53 onwards).

Duct sections

- 9.143 When sizing ductwork, the designer should consult the CIBSE B2 guide.
- 9.144 All fittings should conform to the current BESA specification. Wherever possible, long radius bends, large radius main branches, not more than 45° angle sub-branches and long taper transformations should be used.
- 9.145 Bad design in relation to airflow can lead to vibration of flat duct surfaces, an increase in duct-generated noise, pressure loss in ductwork, unpredictable behaviour in branch fittings and terminals, and adverse effects on the performance of installed plant items, such as trimmer batteries.

Thermal insulation

- 9.146 In order to reduce energy consumption, achieve efficient energy recovery and prevent condensation in service voids, all supply and return air ductwork should be thermally insulated. Insulated ductwork runs outdoors should be weatherproofed.

- 9.147 The thermal insulation of intake and discharge ductwork will be dependent on its location in heated or unheated plant spaces and risk of surface condensation.
- 9.148 In normal circumstances, the insulation thickness for heat resistance is sufficient to prevent surface condensation, but in extreme conditions the insulation thickness for vapour resistance may be greater than that for heat resistance. When cold ducts pass through areas of high dew-point, carefully selected vapour barriers should be applied externally to the insulation.

Noise generation within the ductwork

- 9.149 Noise is generated in ductwork at sharp edges, by tie rods, damper blades, duct obstructions, sharp bends, etc. This airflow-generated noise becomes an important factor if it is about the same or greater level than the upstream noise level. Airflow-generated noise is often referred to as regenerated noise.
- 9.150 The noise level generated by airflow in ductwork is very sensitive to the velocity. The sound power of this noise is approximately proportional to the sixth power of the velocity; that is, a doubling of the duct velocity will increase the sound power by a factor of 64 (or about 18 dB). The duct velocities should therefore be kept as low as possible. In general, duct fittings which have lower pressure loss factors in similar flow conditions will generate less noise.
- 9.151 Ductwork serving quiet areas should not be routed through noisy areas, where noise break-in can occur and increase the noise level in the ductwork.
- 9.152 Grille register and louvre noise should be kept to the minimum by selecting types having low noise-producing characteristics, without high tonal noise; and should be fitted with acoustically treated external inlet and outlet louvres.
- 9.153 Cross-talk attenuators may be necessary where noise intrusion between adjacent spaces can arise and where individual room confidentiality is required. They will normally be of the “through-the- ceiling, up-and-over” type and may include a fire and smoke damper.

Volume control damper locations

- 9.154 In order to be able to carry out a full proportional balance, manually operated dampers are typically needed:
- in branches of zone ducts;
 - in sub-branch ducts serving four or more terminals;
 - in dedicated sub-branch ducts serving a room;
 - at terminals not covered by any of the above.
- 9.155 Dampers integral with terminals are to be avoided for final trimming of air volumes, as they often create noise and air distribution problems.
- 9.156 Dampers in rectangular ducts should be opposed-blade multi-leaf type. In circular ducts, iris-type dampers are recommended. Dampers should be accessible, incorporate a position indicator and means of locking in the commissioned position. They should be installed with the adjusting handle or knob at the lower vertical edge

so that they are accessible for the commissioning team once the ceilings are in place. Dampers should be located as far away as possible from adjacent branches or plant items.

Duct cleaning and access door locations

- 9.157 Cleaning and access doors are required to facilitate access to plant items and ductwork components for inspection, maintenance, cleaning and replacement, and should be of sufficient size to permit safe access for the required functions.
- 9.158 Recommended locations for access doors are given in the current BESA TR/19 specification and are generally provided to give access to:
- every regulating damper;
 - every fire-and-smoke, and motorised damper;
 - filters (to facilitate filter withdrawal);
 - both sides of trimmer cooling/heating coils;
 - zone humidifiers;
 - auxiliary fans;
 - ducts, where required for cleaning.
- 9.159 Care should be taken when siting access doors to ensure that no other services to be installed will prevent reasonable access.

Flexible ducting

- 9.160 Flexible ductwork can only be used to make the final connection between rigid ductwork and a terminal in exceptional circumstances where a solid connection is not possible. Where used it will cause a significant frictional loss and may be difficult to clean, so it should take the most direct route and be as short as possible, never exceeding 0.5 m in length. It can never be used in lieu of a bend and will possess the same fire rating as the ductwork it is connected to.

Terminal fittings selection and sizing

- 9.161 The effectiveness of all ventilation and air-conditioning systems depends on the methods by which air is introduced to, and vitiated air is removed from, the space. The usual results of poor air-terminal selection and/or positioning are:
- draughts;
 - stagnation;
 - poor air quality;
 - large temperature gradients;
 - excessive noise.
- 9.162 Air can be supplied to a space in a number of ways, although any device can be broadly placed into one of two categories:
- that producing a diffused supply;

- that producing a perpendicular jet.

Diffusers may be radial or linear, and normally utilise the coanda effect (that is, adhesion of the air stream to an adjacent surface) to reduce the risk of excessive room air movement. A perpendicular jet is formed by discharging air through grilles, louvres or nozzles, which are generally adjustable.

9.163 Supply air terminals can be incorporated into any room surface, for example, floors, walls (high or low level), desktop.

9.164 As they operate on the jet principle, the use of sidewall and linear grilles is restricted to areas where air-change rates are low, that is, less than 10 per hour.

Perforated rectangular diffusers can provide acceptable conditions within the occupied zone at up to 15 ac/h. In areas where a higher air-change rate is required, square or circular ceiling-mounted diffusers should be used.

9.165 The performance of supply air terminal devices is based on three criteria – throw, spread and drop:

- throw is defined as perpendicular or parallel distance from the terminal to the point at which the air velocity is;
- 0.5 m/s isovel;
- Spread is defined as the width of the;
- 0.5 m/s isovel;
- Drop is defined as the vertical distance from the centre line of the terminal to the bottom edge of the 0.25 m/s isovel.

9.166 It is necessary to consider each of these parameters in both summer and winter conditions to ensure satisfactory operation of the air terminal device, as warm jets behave very differently from cold jets.

9.167 A warm jet tends to rise until it attaches itself to a horizontal surface, while a cold jet falls. Care should be taken to ensure that this does not lead to unacceptable temperature gradients in winter, or excessive air velocities in the occupied zone in summer.

9.168 In order to ensure satisfactory air movement within a space, it is necessary to consider interaction between air movement from adjacent terminals, and ceiling-mounted fixtures (light fittings, etc), as well as interaction between air movement and room surfaces.

9.169 If the supply and extract terminals are too close, short-circuiting may occur, while if they are too far apart, stagnant zones may be formed. Where two opposing air streams meet, the individual velocities should not be greater than 0.25 m/s. Further guidance on the selection of grilles and diffusers is given in the CIBSE Guide B

9.170 In operating theatres, the supply terminals should be able to produce a movement of air in the operating zone 1 m above floor level of between 0.2 and 0.3m/s:

- ceiling-mounted diffusers with fixed directional vanes that provide a downward turbulent airflow are the preferred option: 600 × 600 four-way blow or circular “air-master” style;
- plenum boxes fitted with perforated screens to produce a laminar downflow are also acceptable;
- linear ceiling-mounted diffusers that provide a downward-flowing air curtain around the operating theatre may also be used (additional supply terminals may be located within the area bounded by the linear diffusers to provide ventilation within the;
- air-curtained zone).

9.171 The following terminal types are not suitable for use in operating theatres because they do not produce an appropriate pattern of air distribution:

- swirl diffusers;
- single- or multi-outlet adjustable directional nozzles or jets of any type;
- sidewall-mounted linear diffusers that utilise the coanda effect to send air across the ceiling and “droop” it into the operating zone.

9.172 Extract terminals should be of an easy-to-clean design and, in order to assist identification when commissioning and subsequently measuring, be of a different design style to the supply terminals. Extract terminals mounted at low level should be of the spring clip retained, pull off face type to enable ease of cleaning. The terminal should be mounted on an angled face to prevent it becoming occluded by movable equipment or stores (see Appendix 9 for examples). Perforated plates are not to be fitted in extract terminals or extract plenums as they quickly become blocked with lint. Extract terminals do not need any directional adjustment so fixed-vane or “egg-crate” styles are preferred.

UCV terminal canopy

9.173 UCV canopies should be fitted with one or more non-electronic, mechanical, direct reading pressure gauge(s) to indicate the pressure drop across either a representative terminal EPA filter or the pressure in each zone of the canopy.

9.174 If a UCV canopy incorporates a method of adjusting the air discharge direction so that the canopy can be “tuned” to the room in which it is installed, the directional adjustment device(s) are to be capable of being locked in position once commissioning is complete to prevent future casual alteration.

9.175 Ceiling-mounted canopy diffusion screen(s) can become contaminated with blood spatter when in use. If the UCV canopy is fitted with perforated diffusion screens the blood spatter can penetrate, so the screens should be capable of being hinged down for cleaning between theatre cases. The screen retaining mechanism will have a double action to release the screen. Mono-filament diffusion screens should be retained by clip-in profiles or an alternative system that allows them to be easily removed when necessary.

9.176 For the validation of UCV terminal canopies, see Chapter 12.

Transfer grille: size and location

- 9.177 Air transfer grilles in walls, partitions or doors form an integral part of the building's air distribution system. Modern door sets have very low leakage rates so cannot be relied upon to permit even quite small airflows. Failure to make adequate provision for air to move from room to room will result in excessive pressure differentials and "door whistle".
- 9.178 Transfer grilles are required in locations where there is a significant imbalance between the supply and extract rates in a room. They will relieve any pressure differentials which may affect the operation of the spaces and/or the ventilation system and permit airflow in a known direction.
- 9.179 Care needs to be taken to ensure that the positioning of transfer grilles does not interfere with the fire or smoke integrity of the building. In general, the air transfer grilles should not be installed within fire- resisting boundaries, although if this is unavoidable, they should be fitted with fire or smoke dampers.
- 9.180 Where installed, transfer grilles should be of the non-vision type, sized for a maximum face velocity of 1.5 m/s.

Note: Cross-talk attenuators may be necessary where noise intrusion between adjacent spaces can arise and where individual room confidentiality is required.

Pressure stabilisers: size and location

- 9.181 Pressure stabilisers are required in areas where it is necessary to maintain a pressure differential between adjacent rooms and to prevent reversal of airflows for example, in operating suites, isolation facilities and cleanrooms (see paragraph 8.24).
- 9.182 Fire precautions for pressure stabilisers are the same as for transfer grilles. If the pressure stabiliser is fitted with a fire and smoke damper, the damper test switch should be easily accessible from, in airflow terms, the least clean side of the damper.
- 9.183 Pressure stabilisers should be of the balanced blade type, with the facility to make fine adjustment of the pressure setting. They should be silent in operation and give a seal as tight as practicable when closed. The materials of construction and method of assembly should allow for cleaning and disinfection.
- 9.184 Pressure stabilisers should be wall- mounted in a visible location so that their operation can be readily observed. For sizing criteria, refer to the manufacturer's information. When fitted at low level, they may require a stand-off cage to prevent occlusion (see photograph).

Figure 8 Pressure stabiliser with stand-off cage



- 9.185 Pressure stabilisers may need to be fitted with a stand-off baffle on their discharge side to prevent a sight line in situations where a laser will be used, and may be lead-lined for radiological protection if required (see photograph after paragraph 9.184). Baffles may also be needed to preserve privacy or prevent discharge air causing draughts within an anaesthetic room or bedroom. A stand-off baffle will always be needed on the theatre side of the pressure stabiliser between a “Lay-up” preparation room and a UCV theatre to prevent perturbation of the UCV canopy air pattern

Note: Baffles should be easy to clean and where radiological or laser protection is not required can be made of a rigid transparent material so that the action of the pressure stabiliser can be easily observed.

Distributed air-conditioning elements

Active and passive chilled beams

- 9.186 See paragraph 5.18 onwards for information on the use of these devices in healthcare premises and CIBSE Guide B for technical guidance.

Constant volume boxes

- 9.187 These are units fitted in or at the termination of ductwork that contain a mechanism to maintain a constant output air volume regardless of variation in the air pressure to the supply side of the unit. Where fitted they should be accessible for maintenance as the internal mechanism that controls the constant output will need periodic cleaning.

Variable Air Volume (VAV) boxes

- 9.188 Variable air volume systems are all-air systems which achieve local control by varying (throttling) the amount of air being supplied to each space, room or zone.

Standard type VAV systems deliver air that has been cooled to a set temperature (usually 13°C) and then control the temperature in a space by varying the quantity of air supplied rather than the supply air temperature – which is kept constant.

VAV boxes are used as terminal devices at the supply end of ductwork to modulate the quantity of supply air to the space.

There are variations to standard VAV systems which allow air supply temperatures to modulate upwards with the aim of:

- reducing energy usage by allowing higher air supply temperatures at part-load conditions;
- improving ventilation effectiveness at part-load by having higher airflows
- – VAV can be as low as 10% of peak at low-load conditions depending on the equipment used;
- allowing the system to operate using warm air in winter for pre-heating warm-up in well-insulated buildings where heating is only used in very cold weather and for building pre-heat.

9.189 In most critical areas of a hospital a fixed air-change rate is required when they are in use. VAV is therefore generally limited to non-clinical applications.

Stand-alone air-conditioners

9.190 See paragraph 5.25 onwards for information on these units. The ceiling void should never be used as a plenum either for the primary air supply or fan coil supply or return air paths. (See CIBSE Guide B for installation notes.)

Powered air terminal filter units

9.191 This is an air-distribution-supply terminal box fitted with a fan and EPA or HEPA filter. Their use in the healthcare setting would be confined to spaces where a high air quality is required for a single room in an area supplied by a general AHU (for example, a local cleanroom).

9.192 They are not suitable for use in patient bedrooms due to the fan noise and maintenance access issues.

AHUs: automatic control

9.193 Chapter 6 of this document gives guidance on energy control strategies and Chapter 7 gives guidance on the point of use factors. Chapter 8 contains guidance to specific healthcare departments and their environmental and functional requirements. This section gives guidance on the control of the AHU and its subsystems. When developing a “controls specification”, the designer should consider the guidance given in all of these chapters.

9.194 Various options for control of single- and multi-zone air-conditioning systems are given in CIBSE Guide B.

General requirements

9.195 The basic requirements for an automatic control system are as follows:

- plant start, run, set-back and stop sequence;
- control of the volumetric airflow;

- control of the system or room pressure;
- temperature control and indication;
- humidity control and indication;
- devices to monitor and indicate the plant's operating state;
- alarms to indicate plant failure, low airflow, and filter state;
- the facility to collect data of actual usage and energy consumption.

The control functions actually provided will depend on the purpose of the ventilation system.

- 9.196 The designer should consider whether it is necessary for the supply and extract fans to be interlocked, either so that the supply fan will not operate unless airflow is established within the extract system, or vice-versa depending on the required pressures within the rooms being served.
- 9.197 The sequence switching of units in order to prevent transient reverse airflows will be particularly important in laboratory and pharmacy areas that also contain fume cupboards, safety cabinets and other LEV systems.
- 9.198 There will also be a need to determine the control strategy in the event of a fire either within the zone being served or within an adjoining zone and as detailed in the fire alarm cause and effect statement (see paragraph 7.16 onwards).
- 9.199 All supply AHUs should have a smoke sensor linked to the fire control panel and mounted in the main supply duct immediately downstream of the AHU. In the event of a fire in the AHU or smoke being drawn into the system from an outside source, it should cause the supply air fire damper to close and shut down the AHU.

Note: In certain critical departments, it is preferable to maintain the ventilation in the case of a fire within the area. For example, in an operating department while undergoing surgery the patient cannot always be easily moved without significant risk. In the event of a fire in a staff or support area of the department or adjoining zone, the continued supply of air to a theatre will maintain it at a positive pressure and protect the patient and staff from the effects of smoke.

This will allow time for the patient to be stabilised so that they can be safely.

Location of controls

- 9.200 Facilities to start, set-back and stop the plant should be provided in the plantroom. Remote start and set-back control and indication, if required, should be provided at a manned staff location, for example, at the reception or staff base.
- 9.201 Many ventilation systems may be completely shut down when the area served is not in active use. Alternatively, where there is a need to maintain a background condition, the ventilation output may be reduced by "setting back" the system. This will significantly reduce energy consumption and extend the life of filters and other system components. Controls to facilitate this should be triggered by the actual occupancy of the area rather than by a fixed time program (see paragraph 6.2 and associated Note).

Start up and shut down control sequence

- 9.202 The AHU should start and shut down in a pre-determined sequence. It should ensure that the fan does not start until the main dampers are open and the energy-recovery device is operational. On shut down there may be a need for a “run on” time to purge the area served before stopping the fan and closing the main dampers. Whether the supply or extract fan should start first and stop last will be determined by the pressure regime for the area served.

Set-back control

- 9.203 In previous times when fan motors only had two speeds, turning the system to “Set back” meant switching to the lower fan speed. With modern fans the speed is widely variable so “Set back” is not a fixed fan speed but rather a control strategy that reduces the system output in order to maintain a desired minimum condition. This may be related to the air velocity at a fixed point, air-change rate, pressure differential, temperature, humidity or a combination of these parameters. Providing a dew-point sensor in an internal space that brings the system onto “Set back” is a simple way of maintaining a minimum condition.

AHU running controls

Fog/frost coil control

- 9.204 Fog coils supplied by low pressure hot water (LPHW) should be controlled using the Proportional mode. Their sensor should be located downstream of the coil to give “closed loop” control. The coil should raise the incoming air temperature by 2 K in order to ensure that air entering the pre-filter is above its dew-point, thus keeping it dry. The greater the energy put into the incoming air by the fog coil, the lower will be the efficiency of the energy-recovery device.
- 9.205 If the temperature downstream of the fog coil, as sensed by a serpentine thermostat, falls below the required set point over any part of the coil, the plant should automatically shut down in order to prevent damage to the other batteries. The serpentine thermostat cannot be in direct contact with the coil and should cover the entire coil face.
- 9.206 Steam-supplied fog or frost coils should be operated as an on/off device to ensure that there is no standing condensate at the base of the coil. They should be fitted with a serpentine sensor mounted upstream of the coil but not in contact with it. This will give “open loop” control; a set point of +1°C is recommended.

Energy-recovery device

- 9.207 The energy-recovery device is normally controlled by sensors in the air intake downstream of the supply fan, before the cooling coil and the extract duct from the ventilated space.

Supply & extract fans

- 9.208 The ErP Directive 1253/2014 requires a means of adjusting the fan speed. For plug fans this is provided by a separate inverter unit; for EC fans the control is integral to the fan motor. It should be remembered that most healthcare applications require known amounts of air to be delivered while the system is in use. Constant volume systems that deliver specified air-change rates are therefore the norm. Duct- or room-

pressure-controlled variable-volume systems have a limited application in healthcare. However, fan-speed control is beneficial when “setting back” the system.

- 9.209 Inverters should not be mounted inside the air stream within the AHU. Ideally, they will be mounted on a frame with the control valves. Where inverters are mounted inside a control box with a safety master switch to cut the power supply when the box is opened, the inverter control and indicator pad will be located on the outside of the box. This will allow on-site staff to view the operating parameters and switch the system to manual control if a fault occurs with the automatic control system.
- 9.210 It is necessary to ensure that should the computer control system or its software develop a fault, the fan can be switched to manual operation. This is particularly important for critical systems serving operating suites, high dependency care units of any type, patient isolation facilities, laboratories and pharmaceutical production suites.

Note: In the healthcare setting it is important to recognise that “off-site” software support is no substitute for the ability of “on-site” staff to override the automatic control and keep the system operating in an emergency. Under these circumstances actions that may shorten the life of the plant are considered of secondary importance to that of preserving the health and safety of patients and staff.

Heater-batteries

- 9.211 The main heater-battery should be controlled in the same manner under the dictates of an off-coil temperature sensor, or a room temperature sensor, or the return air temperature depending on the plant configuration and method of control. Trimmer heater-batteries are generally controlled by a temperature sensor within the room, or by averaging temperature sensors within a zone.
- 9.212 Heater-battery control valves should drive closed on system shutdown or fan failure. The control system should then automatically set to provide frost protection.

Cooling coils

- 9.213 There are two basic methods of control for cooling coils:
- off-coil control – used in multi-zone systems or single-zone systems where close humidity control is required, to provide a constant maximum off-plant condition which satisfies the temperature and humidity requirements of the zone with the highest load;
 - sequential control – used in single-zone systems, or multi-zone systems with averaging sensors where close control is not required. A room or duct temperature sensor controls the cooling coil and heater-battery in sequence to maintain constant room conditions.
- 9.214 The advantage of off-coil control is that accurate humidity control can be provided without relying on humidity sensors, which are prone to inaccuracy and drift. Off-coil control is expensive to operate in terms of energy consumption because of the lack of feedback of room loads. As a result, at low loads and in systems where there are large zonal variations, significant over-cooling and reheating will occur.

- 9.215 The control logic should prevent the cooling coil and heat recovery and/or heater-battery being on at the same time.

Humidifier control

- 9.216 Accurate humidity control can only be provided on single-zone systems, or multi-zone systems with zonal humidifiers. In the above systems, humidity sensors control the humidifier for low-level humidity control, and override the temperature controls to open the cooling-coil valve for high-level humidity control.
- 9.217 Multi-zone systems are more usually controlled by a minimum humidity sensor located in the supply duct(s) following the last heater-battery.
- 9.218 Overriding controls separate from the normal plant humidistat should be installed. Their purpose is to prevent excessive condensation in the conditioned space when starting up. A time delay should be incorporated into the humidifier control system such that the humidifier does not start until 30 minutes after the ventilation/ plant start-up. In addition, a high limit humidistat should be installed to limit the output of the humidifier so that the saturation in the duct does not exceed 70%. This humidistat is to control the added moisture; it is not necessary to install a dehumidifier to reduce the humidity of the incoming air if it already exceeds 70% (part load control).
- 9.219 The humidifier control valve should close when the ventilation system is in “set back”. In addition, on system shutdown, low airflow or fan failure, the humidifier should be isolated.
- 9.220 In a self-generating humidifier, if the humidifier is unused for a period exceeding 48 hours, it should automatically drain its water content, including that contained in the supply pipework, right back to the running main and leave itself empty.
- 9.221 With certain types of steam humidifier, it may be necessary to install a thermostat in the condensate line from the humidifier’s steam supply, to ensure that the steam at the control valve is as dry as possible before it is injected into the air supply.
- 9.222 The humidifier control system should ensure that it is switched off with the fan. It is preferable to design the control system so that the humidifier is isolated for an adequate time before the fan is turned off to purge humid air from the system.

Control valves: general

- 9.223 The fog/frost battery control valve should fail-safe, that is open in the event of power or airflow failure. All other valves will stop in their current position in the event of power failure and should drive closed in the event of airflow failure.
- 9.224 Control valves should be located in an accessible position. Isolation valves should be provided to enable the control valve to be removed for service or replacement without the need to drain down the system
- 9.225 Care should be taken to ensure that the installation of control valves and their associated pipework do not obstruct access to the AHU inspection doors, removable drainage trays, eliminator units and access hatches.

Note: There are practical advantages in locating all control valves for an AHU in a bank (at a convenient height) at one end of the unit. (This should not result in an

additional control lag.) The bank will hold the control valves and actuators, and fan inverters/controllers as necessary, and can be constructed “off site” (see also paragraph 9.209).

Monitoring and alarms

- 9.226 Monitoring of the plant performance should be via a BMS to the estates and maintenance department.
- 9.227 The “plant failure” and “low airflow” alarm should be initiated by a sensor located in the main air supply duct. This should operate when the air quantity fails to reach or falls to around 80% of the design value and will give indication of fan failure, damper closed, access door left open, or any other eventuality that could cause a reduction of air quantity. Monitoring the current drawn by the fan motor is not a substitute for a sensing device that is directly affected by the airflow. The sensing ring fitted to plug and EC fans will fulfil this function.
- 9.228 The “filter fault alarm” should be initiated by a predetermined increase of pressure differential across the filters, thereby indicating a dirty filter. The filter fault indication and alarm is information for the maintenance department; it should not appear on any point of use indicator or control panel.
- 9.229 Visual indication that the AHU is operating within its prescribed parameters should be provided in critical areas at a manned staff location, for example, the reception or staff base. These need only take the form of a green light to show the system is operational and a red light to show that it is not.

Room temperature control

- 9.230 The limits for room temperature set point are generally between 18°C and 25°C depending on the particular application, and in some specialised instances (for example, operating departments) are adjustable within a predetermined range by the user.
- 9.231 The selection of temperature set point for each room or zone may be by a control facility in the room/zone, or remotely at the control panel or BMS. Where the control device is mounted within the room/zone and adjustable by the user, it should be marked either “raise” and “lower” or “+” and “-“. It should control within a specified temperature range to suit the user requirement with a control tolerance of +1 K. All other control set points should be selectable either on the control panel or at the BMS interface.
- 9.232 Where local control is provided, an indication of temperature will be required locally, or at a staff base (if appropriate), using an analogue or digital indicator. The indicator should be large enough to be read from the normal working position (for example, at the operating table in a theatre). This may be mounted in a supervisory control panel, with the signal repeated on the main system control panel or BMS. It is important that this indicator displays the actual measured temperature and not the selected temperature.

Local exhaust ventilation (LEV)

- 9.233 Devices that use an inflow of air to control exposure of staff to hazardous substances are classified as LEV systems under the COSHH Regulations.
- 9.234 An LEV system will typically comprise a unit where the airborne hazard is captured, ductwork to convey the extract air to the fan and a discharge stack. The extract air may be filtered or centrifugally separated to remove any particulate material prior to discharge. HSG 258 produced by the Health & Safety Executive gives detailed guidance.
- 9.235 It is important to recognise at the design stage whether an extract is being provided for comfort, to remove odours or to remove hazards, in which case it will be an LEV system. Chapter 8 lists typical devices used in healthcare applications.
- 9.236 The quantity and location of the terminals supplying the make-up air is an important factor in the design of LEV systems.
- 9.237 LEV systems are statutory items that will be subject to an independent examination and test at least every 14 months by a competent person.

Extract ductwork and fan

- 9.238 Extract ductwork for an LEV system should, where possible, be installed outside of a building. Where it has to be inside, it should take the most direct route through, with as few bends or changes of direction as possible.
- 9.239 All ductwork joints should be sealed and ideally there should be no access hatches. Where access hatches have to be provided, they should be of a type that has a hermetic seal.
- 9.240 Some substances are particularly corrosive, so the choice of material for the ductwork, and type of extract fan fitted, should reflect the nature of the substance being conveyed.
- 9.241 The ductwork should either be fire rated or fitted with intumescent collars where it passes through fire compartments within the building. This will ensure that the extract system is unobstructed and always open to atmosphere up to the discharge point.
- 9.242 Some LEV systems (for example, microbiological safety cabinets) HEPA-filter the extract air within the cabinet unit, but it should not be assumed that the exhaust air will be totally free from microbiological or other hazardous material.
- 9.243 The extract ductwork should as far as practicable be kept under negative pressure while inside the building. The extract fan should be located outside of the building or if this is not practicable, as close as possible to the outside so that any ductwork on the discharge side inside the building is kept to an absolute minimum.
- 9.244 The extract fan drive motor should be out of the airstream and it should be possible to change the motor without disturbing the fan or its casing.
- 9.245 Duplex fans are only required when several LEV systems share a common extract system (for example, multiple fume cupboards in a large pathology department where it can be anticipated that at least one cupboard will always be in use or need to be

available for use). In such a situation each cupboard should be fitted with a non-return damper at the point that it joins the common system and be capable of being isolated from the common extract system. The common extract duct should be large enough to handle the combined extract volume from all the systems that feed into it.

- 9.246 If extract filters are fitted in the ductwork the system design should allow them to be changed safely.
- 9.247 Current standards permit the installation of microbiological safety cabinets with integral fans, provided that the extract ductwork can be kept short (that is, less than 2 m); such an installation, however, is likely to be noisy and is not recommended for use in new buildings.

LEV discharge stack arrangements

- 9.248 Roof-level discharge, wherever practicable, is preferred since it removes much of the uncertainty over air re- entering the building through ventilation inlets or windows. In such an installation, the extract fan should be situated separate from the LEV captor unit and close to the discharge stack to maintain the duct within the building under negative pressure.
- 9.249 The discharge point on a flat roof should be through a terminal at least 3 m above roof level but as high as necessary to limit re-entry into supply air inlets or other plant openings. This will protect those who may need to access the roof. Terminals at other roof types need to be high enough to prevent the wind blowing across the roof from causing downdrafts.
- 9.250 Where there are adjacent buildings with opening windows, or where downdrafts are likely to occur, it may be necessary to increase the height of the discharge stack in order to achieve adequate dispersal. In complex locations, airflow modelling or wind tunnel tests may be required to determine the optimum height.
- 9.251 The discharge stack should have an open end. It may be fitted with a collar to reduce its area and so increase the air efflux velocity at the point of discharge (known as the venturi effect). To ensure that air leaving the terminal is not deflected down but allowed to disperse freely, the terminal cannot be fitted with any sort of cover or hat. A drain may be required at the base of the discharge stack to remove any rain that enters (see photograph).

Figure 9 Typical LEV discharge stacks



LEV system information and identification

- 9.252 Once installed, all elements of each LEV system should be uniquely identified with a permanent label as described in Chapter 13. There is a statutory requirement to have information on the design and required operational performance of an LEV system available to those who are responsible for its operation and
- 9.256 maintenance. The designer should ensure that this information is available at handover.

Interim

10. Installation Standards

General

- 10.1 AHUs, ductwork sections and associated elements of the ventilation system will be delivered to site suitably packaged to protect them from damage and casual contamination. They should remain protected when stored on site awaiting installation.
- 10.2 Ductwork should be installed to the “Advanced Level” as defined in BESA’s (2019) ‘TR/19: Guide to good practice – internal cleanliness of ventilation systems’. Should any doubt exist as to whether the guidance has been observed, the ducts should be cleaned internally to restore them to this standard and be visibly clean before being taken into use.
- 10.3 When the ventilation elements are installed, all open ends have to be sealed to prevent the ingress of construction dust as installation progresses. The access doors and panels of AHUs should be kept closed. All AHU dampers and fire dampers should be covered to prevent casual contamination during the construction phase. This is particularly important for fire dampers mounted in the plantroom floor. The damper blades should be wiped clean before final connection to the distribution ductwork.
- 10.4 The area around the supply air intake should be kept free of vegetation, waste, rubbish, builders’ debris or any other possible source of contamination.
- 10.5 “Builders’ work” ducts of brick or concrete should have a smooth internal finish and be surface sealed to prevent the release of dust before being taken into use. They should be fitted with a drainage system if not self-draining.
- 10.6 Every effort should be made to prevent the internal contamination of the ventilation system during the construction phase as once contaminated, it is extremely difficult to completely remove dust and debris. In particular, extract and recirculation fans should not be run up until the area is at least “builders clean” – that is, the floors swept and wet-mopped – otherwise the energy-recovery device in the AHU could become contaminated and its efficiency significantly reduced.

AHUs

- 10.7 Units should have a working life of up to 20 years; it can be anticipated that over this period there will be a need to access every element within the unit for deep cleaning. It is also quite possible that during the life of the unit, the main fan and all control valves will need replacement. Heater and cooling coils may also need to be repaired or replaced. Suitably positioned service connection joints and adequate spacing should permit these items to be isolated and withdrawn without the need to drain down entire systems or dismantle other installed plant.
- 10.8 Care should be taken during installation to ensure that electrical and mechanical services are not installed in positions that will reduce or impede access. Mounting all control valves and fan controllers on a frame positioned adjacent to the unit is the

preferred option. This approach has the advantage that the frame and its components can be built and tested “off-site”.

- 10.9 In order to reduce the effects of galvanic corrosion, black iron fittings should not be used in the pipework installation. Rolled jointed stainless-steel pipework is preferred.
- 10.10 Vibration from a remote plantroom can be transmitted by the structure of the building, and may be regenerated and sometimes magnified many times. Pipe and ductwork should incorporate anti-vibration couplings, pipe hangers and supports, preferably in two planes at right angles, as close to the vibration source as possible.
- 10.11 The service connection points for pipework and electrical conduits will have been made during construction of the unit. The unit will then have been leak-tested in the factory prior to delivery to site. If there is a need to drill through the AHU casing or panels (for example, to mount a sensor), the hole should be as small as practicable and sealed to prevent air leakage.
- 10.12 It is essential that the AHU/ductwork is mounted far enough from the floor to permit the correct installation of drainage systems for cooling coils, humidifiers and heat recovery systems. If the AHU is located on a roof, it will require a clearance of 600 mm to provide access to maintain the building structure below. Sufficient height for the installation of drainage pipework and traps should always be allowed. Easy access for maintenance of drainage systems and their associated pipework should be provided. It should be possible to fully withdraw the drainage tray if it is of the removable type.
- 10.13 AHUs should be positioned so that all parts are easily and safely accessible for routine inspection and service. If a unit is located against a wall or backs onto another unit, access to all parts should be available from the front. Units greater than 1 m wide should preferably have access from both sides or access doors large enough to permit the full and safe entry of maintenance personnel.
- 10.14 Air filters, cooling-coil drainage trays and drift eliminators are all items that should be changed, inspected or withdrawn on a regular basis. The installation of the AHU should permit this without the need for tools or to dismantle other plant or systems.
- 10.15 Access to air intakes and discharges, AHUs and items in the distribution system such as filters or auxiliary trimmer batteries located in a plantroom or plant area should be via fixed ladders, hook ladders, pulpit style steps or other moveable access platforms. The installation of distribution ductwork and other electrical or mechanical services should provide sufficient clearance to allow access equipment to be moved into position.

Distribution systems

- 10.16 Where ductwork penetrates a roof, it should be protected by an upstand to prevent water penetration. Where it penetrates an outside wall, the method of installation should prevent water tracking along the ductwork into the building or its wall cavity.
- 10.17 The installation of all services in service ducts and above ceilings should be coordinated so that cable trays, medical gas and other pipework do not obstruct or

prevent access to the ductwork cleaning doors, dampers and any auxiliary plant elements. The use of BIM should highlight clashes at the design stage.

- 10.18 Plant elements such as VAV boxes, trimmer heaters or cooling coils, humidifier lances or branch filters that are located outside of plant spaces should be accessible for routine inspection and have a cleaning access door on both sides. They cannot be installed above any of the following areas:
- operating theatres;
 - preparation rooms or sterile pack stores;
 - anaesthetic rooms or recovery areas;
 - rooms containing imaging equipment;
 - pharmacy cleanrooms;
 - containment laboratories;
 - patient bedrooms and isolation rooms.
- 10.19 Rectangular ductwork sections should be joined by bolted or clipped gasketed flanges. Circular and flat-oval slip-joints should be mastic-sealed and held with blind rivets, not screws. The mastic used should not support biological growth. The ductwork installation will be leak-tested prior to acceptance.
- 10.20 Volume control dampers (VCD) should be oriented so that their adjusting handles or knobs are located at the lower vertical edge or bottom of the damper when mounted above ceilings. The means of adjusting the damper will be within sight and reach from a designated ceiling void access hatch once the ceiling is complete. Volume control dampers mounted in any location should have the control adjuster mounted to allow easy access for the commissioning team and for future access when a post-cleaning rebalance is undertaken.
- 10.21 Access to VCDs or local auxiliary fans mounted above ceilings should be via low-leakage access hatches mounted in the ceiling or hatches integral to a light fitting.
- Note:** Obtaining access by removing a light fitting is not acceptable.
- 10.22 Where ducts are drilled to provide test holes or to mount sensors, the swarf should be removed, and the hole deburred before the fan is started.
- Note:** Care should be taken to prevent the inadvertent drilling of attenuators.
- 10.23 Flexible ductwork may only be used if there is no other way of connecting an air terminal to a duct. The flexible duct should be not more than 0.5 m in length, be as fully extended as possible and never used in lieu of a bend. The fire rating of the flexible duct should be no less than that of the fixed duct that it is connected to (see also paragraphs 9.131 and 9.160).
- 10.24 Fire and smoke dampers must be installed strictly in accordance with their manufacturer's instructions. There will be a rectangular access hatch (saddle mounted for circular ducts) and test switch adjacent to the damper so that a single person can trigger the damper and directly observe its operation during the annual

test (see photograph). When pressure stabilisers incorporate a fire damper, the test switch is to be located in an easily accessible position on the less clean side of the pressure stabiliser.

Figure 10 Fire damper with test switch and inspection hatch



Point of use

- 10.25 Items of equipment that require access for inspection and cleaning should not be accepted if they are installed in locations that prevent easy access.
- 10.26 Items of equipment that require access for inspection and cleaning such as fan coil units will not be accepted if they are installed directly above medical or diagnostic equipment.

Note: A common problem occurs because installation layout drawings show fan coil or similar units on the room plan. These are often only “indicative” of the fact that there will be a unit in the room but are taken as the desired position by those carrying out the installation. As an example, the installation drawing for an interventional imaging room shows a fan coil unit in the centre of the ceiling. If it is installed in this position it will be directly above the scanner once that is installed. The fan coil unit will then not be accessible for routine inspection and maintenance, and should it leak water, it will put the scanner out of action.

- 10.27 The installed position of ceiling terminals in storerooms (for example, a theatre's bulk sterile pack store) should coordinate with the siting of the storage racking. The airflow at the terminals should be routinely measured, so the racking and its contents should not obstruct access to the terminal when using a calibrated hood. The same problem can occur in recovery rooms and ward areas where bed curtain rails and bed hoist tracks can prevent the measurement of airflow from ceiling terminals.
- 10.28 Low-level extract grilles should be of the pull off face type for ease of cleaning.
- 10.29 See pictures of low level extract installations in Appendix 9.

Service penetrations

- 10.30 Where services penetrate the fabric of the building, they should be sealed to prevent any uncontrolled air leakage between rooms and service spaces or voids. Situations where this occurs will be:
- service spaces behind IPS panels at wash basins and scrub troughs;
 - cased in wall-mounted medical gas pipeline units and ceiling-mounted pendants;
 - electrical trunking and bedhead rail systems;
 - boxed-in main and local drainage pipework;
 - ceiling-mounted operating lights, examination lights and other pendant-supported items.
- 10.31 The sealing should be at the point that the service penetrates the wall, ceiling or floor and not at the access panels or covering shrouds as these will need to be removed from time to time. Sealing of the penetrations should be done at first-fix stage as access will become progressively more difficult once final covers and finishes are applied. In certain applications, permeability testing will be carried out at first-fix stage to ensure that this has been done.

Note: The “clean zone” is not the same as the overall size of the canopy, and it is vital to consult the UCV canopy supplier in order to get the position and size of the zone correct, as mistakes are expensive to rectify.

11. Commissioning Systems

General

- 11.1 Commissioning is the process of advancing a system from physical completion to an operating condition. It will normally be carried out by specialist commissioning contractors working in conjunction with equipment installers. Commissioning of the ventilation system will normally be the responsibility of the main or mechanical contractor who should coordinate the process.
- 11.2 Commissioning is often subdivided into sections (for example, air handling unit, automatic controls, air side balance, building fabric and fittings). Each section may be commissioned by its specialist installer, and they are often accepted in isolation.
- 11.3 Commissioning is an essential process for ventilation systems. It is therefore important that adequate provision for the process be made at the design stage of the project. Procedures for commissioning air-handling systems are given in CIBSE Commissioning Codes and BSRIA BG 49 – Commissioning Air Systems.
- 11.4 The duct design process should take into account the requirements of system balancing. The position and number of regulating dampers included in the design should be sufficient for this purpose.

Location of dampers and test holes

- 11.5 Balancing/commissioning dampers will be required in each branch of the distribution ductwork. In a critical system such as an operating suite, the branch to each room and each location where it is required to carry out a proportional balance should have a balancing damper.
- 11.6 Test holes for the measurement of airflow will be required at carefully selected points in main and all branch ducts. The number and spacing of holes are given in the BSRIA BG 49/2015 Commissioning Air Systems. Their positions should be identified at the design stage.
- 11.7 The test positions need to be accessible for commissioning to take place. They may also be required for subsequent annual verification of the system performance, so they should not be covered by permanent lagging.
- 11.8 The measurement point should be in a straight length of duct as far away as possible from any upstream bends, dampers or other elements that could cause disturbance to the airflow. The actual location should be:
- at least 1.5 duct diameters upstream of sources of turbulence such as dampers and bends;
 - if this is not possible, ten diameters downstream of dampers, bends or tees, and five diameters downstream of eccentric reducers;
 - where there is enough space round the duct to insert the pitot tube and take readings;
 - where the duct has a constant cross-sectional area.

Test holes for measuring total airflow from a fan should be located either four diameters upstream or ten diameters downstream of the fan. Provision should also be made for measuring the fan's speed of rotation.

Note: Plug and EC fans are supplied with a measuring ring so their output can be read directly. This needs to be connected to an external pressure tapping or electronic fan control unit.

Information to be provided

11.9 It is essential that the designer should pass on the system-design intent fully to the commissioning engineer by providing:

- relevant parts of the specification;
- schematic drawings indicating data listed in Table 11;
- equipment schedules;
- controller and regulator schedule;
- fan performance curves;
- wiring diagrams for electrical equipment, including interlock details

Table 11: Information to be provided on schematic drawings

Items in system	Information to be provided
Fans	Fan total pressure Volume flow rate at normal and set back speed Maximum motor current
Plant items	Type and identification numbers from equipment schedules Fluid and air volume flow rates Fluid and air side pressure losses Dry bulb temperatures Wet bulb temperatures Humidity
Dampers, including motorised and fire dampers	Identification numbers from equipment schedules Location Identification number Volume flow rate
Main and branch ducts	Dimensions Volume flow rates and velocities Identification numbers from equipment schedules
Test holes and access panels	Location and size of duct Identification number Design airflow rate
Room supply and extract terminals	Location Identification number Grille or diffuser factor Volume flow rate and neck velocity Operating static pressure
Pressure cascade	Room differential pressures Airflow direction between rooms Pressure stabiliser and transfer grille locations
Internal environment conditions	Design room conditions and adjustable range Specific room air velocity if specified Noise level
Controllers	Set points

Notes: Fan total pressure is the difference between the total pressure (static pressure + velocity pressure) at the fan outlet and the total pressure at the fan inlet. Where volume flow rates are variable, maximum and minimum values should be provided.

Commissioning personnel

- 11.10 It is unlikely that all the required commissioning skills will be possessed by one individual; a commissioning team is therefore usually needed. The objective of commissioning is to ensure that the necessary performance and safety requirements are met.
- 11.11 During the commissioning process a great deal of information will be generated which will form an invaluable future source of reference about the plant. It is essential to ensure that it is collected together in the form of a commissioning manual and handed over to the client on completion of the contract together with the “as fitted” drawings.
- 11.12 In order to be successful the commissioning process will need to start before practical completion, as many parts of the system will become progressively less accessible. The correct installation of those parts should be witnessed and leak rate tests carried out as construction proceeds. Failure to establish responsibility for commissioning early enough will delay the completion of the project or lead to unsatisfactory plant performance (see CIBSE Commissioning Code M).

Commissioning brief

- 11.13 The commissioning team will require a detailed brief from the system designer. This should include:
- a “user” brief comprising a description of the installation and its intended mode of operation;
 - the precise design requirements with regard to the scheme of air movement, room static pressures, supply and extract airflow rates and acceptable tolerances;
 - full details of the design conditions both inside and out, for winter and summer, together with the control strategy;
 - equipment manufacturers’ type test data, commissioning, operation and maintenance recommendations;
 - drawings showing the layout of the system, positions of airflow measurement test points, dampers, regulating devices and filters within the duct runs, together with sizes of ducts and terminal fittings. It will save time if these drawings are annotated with the design volumes and static pressures required at each branch and outlet point;
 - wiring diagrams for all electrical equipment associated with the air-handling systems, including motor control circuit details and any interlocking and safety devices.
- 11.14 CIBSE Commissioning Code A – ‘Air distribution’ or BSRIA BG 49 – ‘Commissioning air systems’ provide full guidance on the information that will be required by the commissioning team.

- 11.15 Designers should specify the type of measuring instruments and test procedures. They should include in the contract documents instructions on verifying the accuracy of test instruments, which should be supported by reference to relevant calibration certificates.
- 11.16 The system, on completion, should be operated by the contractor as a whole and subject to performance tests in accordance with the contract requirements. These will include independent validation of the system performance on behalf of the client.
- 11.17 The commissioning process should be carried out in the order in which it appears in this guidance document. That is to say, the static checks and visual inspections itemised in paragraphs 11.20–11.26 should be followed by the dynamic tests described in paragraphs 11.27–11.46, the performance tests listed in paragraphs 11.47–11.64 and finally the handover procedures set out in paragraphs 11.63–11.65.
- 11.18 Once the system is shown to meet the design intent, the handover documentation should be completed. In the event of performance not being acceptable, the matter should be dealt with in accordance with the contract arrangements.

Pre-commissioning checks

- 11.19 The pre-commissioning checks consist of visual inspection, manual operation of equipment, static measurements and functional tests of individual components. They should be carried out prior to setting the system to work and undertaking the dynamic commissioning process set out in paragraph 11.27 onwards.

Note: Before commencing commissioning, it is essential that builders' work in the area served by the system is complete. The doors and windows should be fitted, floor finishes applied, walls and ceilings completed and their final finish applied. Fans should not be run until the area is clean (see paragraph 10.6).

Standard of installation

- 11.20 During the installation of the system the following will be witnessed:
- that the plant and installations have been provided and installed in accordance with the design specification and drawings;
 - that only approved sealants have been used in the installation;
 - that all components function correctly;
 - that the satisfactory sealing of access doors and viewing ports has been carried out;
 - that the AHU airtightness test as per BS EN 1886 has been carried out;
 - that air-pressure tests and air-leakage tests on ventilation ducting have been carried out in accordance with the methods set out in the BESA DW143 – 'Ductwork leakage testing' but the leakage rate to be not greater than 3% (it is usual to carry out these tests a section at a time as the ductwork is installed and before its insulation is applied. The results will be recorded in the commissioning manual);
 - that gaps around doors and hatches are as specified in the design;

- that the permeability tests are carried out as per paragraph 12.17;
- that the correct operation of pressure stabilisers, control dampers, isolating and non-return dampers have been checked;
- that test holes have been provided in their specified locations and are sealed with suitable grommets;
- that control dampers are secured and their quadrants fitted correctly;
- that any interlocks are operative and in accordance with specification;
- that the electric circuits are completed, tested and energised;
- that electric motors have been checked for correct direction of rotation both at full speed and set back;
- that cooling and heating media are available at correct temperatures and pressures and in specified quantities
- that the air-conditioning plant components and controls function correctly;
- that the air-conditioning plant interlocks and safety controls function correctly;
- that the plant is physically complete, insulation is applied and all ducts and pipework are identified as specified;
- that all service penetrations of the fabric of the area are sealed at the point of penetration (see also paragraph 10.30);
- that the building housing the ventilation plant is generally in a fit condition for commissioning and performance tests to commence, that is, windows, doors, partitions, ceilings, etc. are completed, surfaces sealed and their final finish applied;
- that the areas containing the ventilation plant and those being served by it are clean;
- that access to all parts of the system is safe and satisfactory.

Certification of equipment

11.21 The following test certificates should be assembled by the commissioning team and be available for inspection at any time during the contract period. They will form part of the handover information and should be placed in the commissioning manual:

- type test performance certificates for fans;
- pressure test certificates for:
 - heater-batteries;
 - cooling coils;
 - humidifier (if appropriate);
- type-test certificates for attenuators;
- type-test certificates for primary and secondary filters;
- individual test certificates for EPA or HEPA air filters.

Equipment tests

11.22 Prior to setting the system to work the following will be witnessed and proving tests should be carried out as detailed:

Filters

11.23 The quality of filter housing and in particular, the seals, is a critical factor in maintaining the efficacy of the filtration system by ensuring that air does not bypass the filter elements. Therefore, the following checks should be made:

- filter seals should be fitted and in good condition;
- filters should be installed correctly with respect to airflow;
- bag filters should be installed so that the bags are vertical and their pockets free;
- all filters should be checked to ensure they are free of visible damage;
- EPA or HEPA filters should be scanned with an LSAPC to prove that they and their housings achieve the specified filter efficiency;
- the differential pressure indicators should be checked for accuracy and that they are marked with the initial and final filter resistance.

Drainage arrangements

11.24 The drain should conform in all respects to the standard set out in paragraph 9.105 onwards. In addition, the following should be proved:

- that the drain tray is easily removable or completely accessible;
- that the drift eliminator (if fitted) is removable without the use of tools;
- that a borosilicate glass trap is fitted and is easily removable;
- that the trap discharge point to drain has a clear air-gap of at least 15 mm;
- that the pipework is supported so that the air-break cannot be reduced;
- that the drain system from each drain tray is independent up to the air- break.

11.25 The operation of the drainage system is then proved by introducing water into the duct at the drain tray and observing that it completely drains out. This check is to be repeated both at normal speed and set back once the fans have been commissioned. At this time the clear trap can be marked to indicate the normal water level with the fan running.

Fire dampers

11.26 The following will be witnessed and proving tests should be carried out as detailed:

- the operation of all fire and smoke dampers (fire dampers fitted with a thermally actuated “memory metal” mechanism should be proved using a hot air heat source);
- the access provided to enable the dampers to be visually inspected and/ or reset should be sufficient for the purpose;
- indication should be provided of the dampers’ position (open/tripped);

- indication of the fire dampers' location should be provided both on the ductwork and at a visible point on the building fabric if the ductwork is concealed.

Dynamic commissioning

Air-handling and distribution system

- 11.27 Before commencing the dynamic commissioning all rubbish should have been removed and the floors swept and wet- mopped (see paragraph 10.6). Any IPS panels should be in position, access hatches closed, light fittings in place and ceiling tiles clipped down as necessary.
- 11.28 The fan drive, direction of rotation, speed and current drawn should be set in accordance with their manufacturer's instructions. In the vast majority of healthcare applications, the fan output should be set to give a constant volume of air. This to be controlled by measuring the pressure drop across the fan using a sensing ring and associated volume controller that will automatically integrate the fan 'K' factor to determine and control the pre-set output air volume. The fan output will then in air volume terms remain constant regardless of changes of system resistance. The actual volume delivered will be related to the air-change rate for the application.
- 11.29 After the installation has been checked to ensure that it is in a satisfactory and safe condition for start-up, it should be set to work and regulated to enable the plant to meet its design specification. The proportional balancing method described in the CIBSE Commissioning Code A should be followed. The airflow rates will be set within the tolerances laid down in the design brief. This will normally be the design airflow rate +10%; -0%.

Note: Plug fans are fitted with a measuring ring so that the design volume flow can be set when first started. It can then be reset as the airflow balance progresses. This method will result in the correct airflow with the least total system resistance once balancing is completed.

Air commissioning measuring equipment standards

- 11.30 All test and measuring equipment used will have a certificate to prove that its calibration has been checked within the previous 12 months at a facility using traceable national standards.
- 11.31 System performance should be measured at the main and branch duct supply and extract test points using a pitot and manometer or a thermal anemometer.
- 11.32 Supply and extract air volumes at the room terminals should be measured using a calibrated hood with back pressure compensation. If a hood correction factor is applied, it should be determined by a direct comparison with a duct measurement immediately adjacent to a terminal and not a general comparison between air at the main supply duct and the total as measured at the terminals. For multi-directional terminals a correction cross will be fitted in the measuring hood.

Note: Measurements taken with a "home- made" hood or cone will not be accepted.

- 11.33 Measurements at extract grille faces should, where possible, be taken using a calibrated hood. Alternatively, they may be measured with a rotating vane anemometer fitted with a hood, or as a last resort, scanned using a rotating vane anemometer and a free area factor applied. The grille face free area and factor used should be stated in the commissioning report.

Order of commissioning

- 11.34 When combined supply and extract systems are to be balanced and the area that they serve is to be at or above atmospheric pressure, the supply should be balanced first with the extract fan switched off, and then the extract balanced with the supply fan(s) on. The supply balance should then be rechecked.
- 11.35 For combined systems where the area that they serve is to be below atmospheric pressure, the extract should be balanced first with the supply fan switched off and then the supply balanced with the extract fan on. The extract should then be rechecked.
- 11.36 On completion of the balance, all volume airflows in supply and extract ducts and from grilles and diffusers will be measured and recorded. The true air- change rate can then be calculated from the data obtained.

Note: For accuracy the room dimensions should be actually measured on site rather than deriving them from design drawings.

- 11.37 All supply and extract duct volume control dampers should be locked and their position marked and the fan motor settings noted and recorded.
- 11.38 All grille and diffuser volume control registers should be locked to prevent alteration and their final position marked.

Room air distribution

- 11.39 The pressure relief dampers and pressure stabilisers will be set to achieve the specified room differential pressures and locked. The grille direction control vanes and diffuser cones will be set to give the specified air movement pattern. Visualisation techniques may need to be employed to prove the required airflow pattern is being achieved and detect any adverse coanda effects (see paragraph 9.162).

Note: When balancing combined supply/ extract cascade ventilation systems (for example, operating suites, cleanroom suites), the airflow through the extract terminals in the adjacent corridors may need to be adjusted outside of their original design values in order to achieve the desired room pressure differentials.

Air-conditioning plant

- 11.40 The specified flow rate and/or pressure drops will be set for all heater- batteries, cooling coils and humidifiers. The methods described in the CIBSE Commissioning Codes W and R should be followed. On completion their regulating devices will be locked to prevent alteration.

Control system

- 11.41 The control system should not be commissioned until both the air distribution system and air-conditioning equipment have been commissioned.
- 11.42 Because of the specialised nature of control systems and the fact that each manufacturer's system will contain its own algorithms and settings, commissioning should be completed by the supplier, and witnessed and documented by a representative of the client (for example, the healthcare organisation's appointed validator).
- 11.43 In the vast majority of healthcare applications, the fan output should be set to give a constant volume of air. This to be controlled by measuring the pressure drop across the fan using a sensing ring and associated volume controller that will automatically integrate the fan factor to determine and control the pre-set output air volume. The fan output will then in air volume terms remain constant regardless of changes of system resistance. The actual volume delivered will be related to the air-change rate for the application.

Note: Measuring the air pressure in the main supply duct and using that to set the supply fan speed as a percentage of its rated output and using that to set the extract fan speed as a percentage of the supply fan speed is not a satisfactory, accurate or acceptable way of controlling the desired supply and extract air volumes.

- 11.44 The location of all control and monitoring sensors should be checked and their accuracy proved.
- 11.45 The control system's ability to carry out its specified functions will need to be proved. The correct operation of any alarm systems should also be proved.
- 11.46 If the plant is provided with a "users" control panel in addition to the one located in the plantroom, the operation of both should be proved. This will typically apply to operating departments and laboratory systems.

Specific performance standards

- 11.47 The performance of the system should be measured and compared with information provided by the designer.

Plant capacity and control

- 11.48 When setting to work and proving the design, both the manufacturer of the air handling plant and the control specialist should attend site together and jointly commission the system.
- 11.49 If any doubt exists as to the capacity of the installed system, its ability to achieve the specified inside design conditions with the plant operating at winter and summer outside design conditions should be proved. Artificial loads will be required in order to simulate the internal gains/losses and the outside design conditions.
- 11.50 On completion of the plant performance test, recording thermo- hygrographs should be placed in each room/ area served by the plant and also the supply air duct upstream of the fog coil. The plant should be run for 24 hours with all doors closed.

During this period the inside conditions should stay within the tolerances specified. Alternatively, the BMS may be used to obtain the information required.

Noise levels (general)

- 11.51 The commissioning noise level is that measured with a sound level meter in the unoccupied room, taking account of the external noise together with the noise generated by the ventilation system. Chapter 8 and Table 1 in Chapter 4 give information for many applications.
- 11.52 The noise levels apply at the maximum velocity for which the system is designed to operate. Acoustic commissioning tests should be carried out with all plant and machinery running normally and achieving the design conditions of airflow, temperature and humidity.
- 11.53 An industrial-grade Type 2 sound level meter will normally be sufficient to check the noise level. Its accuracy should be checked using a calibrated sound source before use.
- 11.54 The noise level readings are to be taken at typical normal listening position 1.5 m above floor level and at least 1 m from any surface and not on any line of symmetry. In critical rooms the noise should be measured at the centre of the room and at the centre of each quarter. The mean of the five readings should then be calculated
- 11.55 In the event of a contractual deficiency a Type 1 precision-grade sound level meter should be used and the noise level determined by the procedure given in Scottish Health Technical Memorandum 08-01.

Filter challenge

General ventilation filters

- 11.56 In-situ performance tests will not normally be required for primary and secondary filters and their housings. However, the filters should be visually inspected for grade, tears, orientation and fit within their housing. Filters should be clean and a replacement set available. Bag filters should be installed so that their bags are vertical and spaced so that air can move through them freely.
- 11.57 Air leakage around a filter housing significantly reduces the filter efficiency. The as-fitted filter housing and access door arrangement should not permit air to bypass.
- EPA or HEPA filters (for exhaust protective enclosures and laboratories)
- 11.58 Pathogenic material may be discharged through damaged or badly installed EPA or HEPA terminal filters. The complete installation should be tested using the method set out in BS EN ISO 14644 and ISO 17141.

The challenge tests may be carried out using either of the following techniques:

- a light scanning airborne particle counter (LSAPC) and a natural challenge to detect leaks;
- dispersed oil particle (DOP) to provide the challenge and a photometer to detect leaks.

- 11.59 In both cases the upstream challenge should be measured. A measurement of particle penetration through a representative section of the EPA filter media is then taken and used as the reference background level. These two readings enable the range of the detecting instrument to be set.
- 11.60 With an LSAPC the filter face is sampled at several points to establish the smallest non-penetrating particle size. This will directly relate to the grade of filter under test. The filter face, its seal and housing are then scanned, and if a significant number of particles at or above this size are detected, there is deemed to be a leak at or near the test position.
- 11.61 With DOP a challenge aerosol of inert particles of the type produced by a dispersed oil particle generator is introduced into the air, upstream of the EPA or HEPA filter. The downstream face of the filter, its mounting seal and housing are then scanned for leakage using a photometer. A leak should be deemed to have occurred if a steady and repeatable reading on the photometer at any point exceeds 0.01% of the upstream reading.
- 11.62 Should the EPA or HEPA filter fail this test, it will be replaced. Should the filter mounting seal or housing fail this test, it may be repaired and the test repeated.

Ventilation system commissioning records

- 11.63 Following commissioning, the main contractor will collate the individual commissioning reports together with the plant user manuals ready for handover.
- 11.64 The fire dampers will have been tested by a specialist, and a written statement detailing which fire dampers were tested, when and by whom should be provided. If any fire dampers in the system were not tested, they should be listed and appended to the statement.
- 11.65 The airflow balancing report compiled by the commissioning engineers should be available to the validator. The report should include copies of the equipment calibration certificates.

12. Acceptance Testing: Validation

- 12.1 All new and refurbished ventilation systems should be independently validated prior to acceptance by the client.
- 12.2 Validation differs from commissioning in that its purpose is to look at the complete installation from air intake to extract discharge and assess its “fitness for purpose as a whole”. This involves examining the fabric of the building being served by the system and inspecting the ventilation equipment fitted as well as measuring the actual ventilation performance. Validation is not a snagging exercise; see the Note after paragraph 12.30.
- 12.3 Validation is a process of proving that the system in its entirety is fit for purpose and achieves the operating performance originally specified. It will normally be a condition of contract that *“The system will be acceptable to the client if at the time of validation, it is considered fit for purpose and will only require routine maintenance in order to remain so for its projected life.”*

Appointment of validator

- 12.4 In order to ensure that the complete system operates correctly it will be necessary to validate it as a whole from the air intake through to the extract discharge. It is unlikely that the client’s in-house staff will possess the knowledge or equipment necessary to undertake this process. Validation should therefore be carried out by a suitably qualified competent engineer appointed by the client. The validator would be the client’s AE(V) (see Chapter 2 in Part B of Scottish Health Technical Memorandum 03-01) or someone of similar standing who is familiar with the ventilation requirements for healthcare facilities. They will be completely independent of the system designers, contractors, suppliers, installers, commissioners and those who will subsequently operate and maintain the system.
- 12.5 To retain independence, the validator should be appointed and paid directly by the client. The validator will act as the client’s representative to inspect the system, check its performance and recommend acceptance, or not, to the client.

Note: “Client” means the healthcare provider, not a contractor or service provider.

Design proposal review

- 12.6 It is essential that whoever has been appointed to carry out the final validation acceptance of the system should be involved in the initial client’s brief and design specification, preferably prior to the project being put out to tender. They will then be fully aware of the client’s requirements and any limiting factors.

Note: While it is beneficial to involve the client’s validator in the design process, it should be remembered that the appointed designer carries the “design risk” and advice from the validator will not obviate this.

- 12.7 It is important that the validator understands the complete project and not just the obvious ventilation aspects. Decisions about the type of ceilings, doors, access

hatches, fire compartmentation, floor markings, room functions, their adjacency and the proposed workflow patterns all have a direct effect on the likelihood of being able to achieve the desired ventilation performance. It is not sufficient to consider the ventilation in isolation.

- 12.8 During this process any derogations proposed by the contractor/supplier should be clearly defined, agreed and documented with the client (for example, through the VSG). All parties will then be clear as to what will be the acceptable standard of installation and performance when finally validated.
- 12.9 The ventilation designer(s) should provide the validator with system information listed in Table 11. The information should be in the form of an annotated drawing for each ventilation system to be validated. They should also provide any other design or specification information that will assist the validation process.
- 12.10 The contract arrangement should give the validator the right to visit the site as often as they deem necessary during the contract period.

First fix inspection

- 12.11 The validator should carry out a physical walk-around inspection of the installation at a point in the project when the AHU is “on site” and the main and branch ductwork is for the main part installed, but prior to the ductwork being concealed behind wall panelling or ceilings.
- 12.12 If possible, the following airtightness tests should be witnessed during the inspection:
- AHU installation leakage (BS EN 1886);
 - supply and extract duct leakage (BESA DW/143);
 - initial permeability test (see paragraph 12.17).
- 12.13 The quality of the installation, compliance of the AHU, suitability of the basic installation, location and future accessibility of commissioning dampers, location and compliance for testing of fire dampers, etc., can all be assessed during the visit.
- 12.14 When validating large projects that have many AHUs, it is worthwhile to visit the AHU manufacturer to inspect a specimen unit and agree its compliance before all remaining units are built and transported to site. At that time the leakage and deflection tests can be demonstrated by the AHU supplier in their factory.
- 12.15 Once units are delivered to site, it is useful to get all mechanical and electrical services connected to a specimen AHU. The location of pipework joints, drain points, anti-vibration couplings, isolating and control valves can all be agreed, as can the route of cable ways and control wiring. The object will be to create an agreed “exemplar unit”. If all other AHUs are installed in an identical fashion, they will normally be considered compliant at the time of final validation.
- 12.16 On completion of the first fix visit the validator should provide the client with a short report identifying items that are not compliant with the specification.

Permeability testing

12.17 The following areas will require permeability testing:

- isolation suites of any type;
- operating suites of any type;
- pharmacy aseptic preparation facilities;
- IAP cleanrooms in central decontamination units (containment leak test in accordance with BS EN ISO 14644-3:2019);
- category 3 and 4 containment facilities;
- any other area specified within the contract.

The methodology for permeability testing is set out in BSRIA document BTS 3 – ‘Air permeability testing of isolation facilities’.

12.18 An initial permeability test should be witnessed at first-fix stage when the envelope of the suite is physically complete but before wall, ceiling and floor finishes are applied. The objective will be to find and eliminate any construction leaks (for example, between a floor slab and curtain wall) before they become covered up during the fit-out stage (see paragraph 10.30).

12.19 A full permeability test in accordance with the methodology given in BSRIA BTS 3 will be carried out at practical completion to ensure that all service penetrations have been adequately sealed.

Note: Any leaks discovered during the test are to be sealed at the point of penetration of the building fabric envelope and NOT at the gaps around IPS panels, ceiling hatches or bedhead trunking covers, etc. (see also paragraph 10.30).

Follow-on inspections

12.20 Dependent on the size and complexity of the installation, a second and further inspection visits may be required. The validator should attend site as frequently as necessary in order to try to eliminate any installation issues as the project develops and while trades are still in attendance, rather than having to resolve them at the time of final acceptance.

Final acceptance inspection: validation

12.21 The commissioning of a ventilation system will normally be carried out by the suppliers of the various elements. The final acceptance validation will check that all of the elements work as a whole to achieve the project aim.

12.22 The following regime of inspection and testing should be applied to the validation of all new and refurbished ventilation systems. It may also be applied to systems that have undergone significant changes such as the replacement of a fan or other major component.

Basic requirements

- 12.23 The area served by the ventilation system to be validated should be physically complete with final finishes applied. The doors should fully close against the design pressure differential with IPS panels fitted and any access hatches closed. All ventilation plant serving it should be operating correctly and have been commissioned in accordance with the project contract.

Note: In projects on existing sites, the area of the building being built/refurbished is often sealed off from the “in use” part to prevent dust penetration. At final validation the seals need to be at least temporarily breached in order to be able to determine the ventilation performance in “normal” conditions.

If this is not possible, validation will be conditional on a final “actual” performance check when the seal is removed at the time of handover.

- 12.24 The area served should be free of any rubbish, debris, obvious dust and have been wet-mopped before the validation is undertaken.

Note: There is no need to clean the area to the point that the validator needs to gown up in order to enter it. A certain amount of disturbance to hatch seals, ceilings, panels, etc. will be inevitable during

the validation process, so the area will require a final “clinical” clean prior to being taken into use.

- 12.25 The validation process should be a continuation of the earlier site inspections and will in many cases be carried out in parallel with the commissioning process.

- 12.26 Unless stated elsewhere in the design specification, the conditions in the principal space served by the ventilation system being validated should be stable and within the given ranges.

Temperature: 18–22°C dry bulb.

Humidity: 30–70% Relative humidity.

- 12.27 Any test or measuring equipment used should have a certificate to prove that it has been calibrated within the previous 12 months at a facility using traceable national standards.

- 12.28 In the case of a noise meter, its “matched sound source” should have a certificate to prove that it has been calibrated within the previous 12 months at a facility using traceable national standards. The noise meter should be calibrated to the sound source on each occasion that it is used.

- 12.29 The validator has the right to either witness readings taken by the commissioning team or to independently take such readings and measurements as they deem fit in order to satisfy themselves as to the actual performance of the system.

Validation process

12.30 The validation process should follow the sequence given below. Any failures discovered during the process should be rectified before continuing. The validator should check the following:

- the location of the air intake and discharge and their position relative to each other and other intakes and discharges;
- inspection and cleaning access to the vermin mesh and as necessary throughout the installation;
- the security, suitability of and access to the AHU location;
- sufficient space and access arrangements for service and maintenance;
- that the AHU is uniquely identified (see paragraph 13.17) and complies with the minimum standards set out in Chapter 9;
- that the AHU and distribution system have been leak-tested and comply with the design;
- that the AHU and supply ductwork system are clean and free of visible dust;
- that all fire and smoke dampers have been inspected and tested for correct installation and operation. A certificate to that effect, signed and dated by the inspector and tester, will be available for inspection;
- that the area served by the ventilation system is complete and free from significant defects that could invalidate the validation process;
- that the supply and extract airflow rates are in accordance with the design +10%; –0% and the system terminals are in balance. Note that the total supply and extract air volumes measured at the AHU should equate to those measured at the terminals. A discrepancy in the totals would indicate a leak in the system which should be resolved before proceeding further;
- that the air-change rate calculated from the measured airflow and room dimensions accords with the design specification;
- that the room differential pressure regime is in accordance with the design and that if pressure stabilisers are fitted, they operate correctly and silently;
- the air velocity at a specific location(s) if required in the application specification;
- that the noise level does not exceed the design value;
- that the system indicators correctly and clearly show whether or not the ventilation system is in an operational state;
- that any user controls fitted operate correctly (for examples of “cause and effect testing”, see Appendix 10);
- that the temperature and humidity in the space being ventilated are accurately indicated on the user panel and that they can be adjusted within the specified limits, if applicable;
- that the estates control functions operate correctly and the plant condition is clearly shown both on the plant control panel and at the BMS/ BEMS interface;
- that the fire cause and effect strategy has been demonstrated and operates correctly. This may be carried out by others, in which case a statement signed

and dated by the person carrying out the test will form part of the handover information;

- that any additional tests called for in the project specification have been carried out and witnessed by the validator or the client's appointed expert.

Note: Validation is not a “snagging” inspection. The main contractor has presented the installation as being complete, fully commissioned, achieving the specified level of performance and ready for handover. The validator's role is to check on behalf of the client that the contractor is correct in that assertion.

If the validator discovers that there are a significant number of snags and non-compliances, the validation should be terminated. It is the contractor's responsibility to snag the project, carry out remedial works and re-present the installation for acceptance. The validator will then need to repeat the validation process. The client is entitled to deduct any resulting additional validation fees incurred from the contractor.

- 12.31 It is vitally important to complete the validation process before the system is accepted by the client. Due to the nature of the ventilation installation and the intensity of use in the healthcare setting, it will not be possible to correct any faults or non-compliances once the system has been accepted and taken into use. There are also medico-legal aspects around taking a non-compliant system into use. Pre-announced handover or occupancy dates are not a reason for the validator or client to accept a non-compliant installation.

Validation report

- 12.32 Following validation, a full report detailing the findings will be produced and sent to the client's lead project manager. The report should conclude with a clear statement on whether the system achieved or did not achieve the standard set out in the agreed design specification.

- 12.33 The client's lead project manager should lodge a copy of the validation report with:

- head of the user department;
- infection prevention and control;
- estates and facilities.

Additional specialist tests

- 12.34 Certain critical areas will require additional testing and validation in addition to the process given above.

UCV theatres

- 12.35 The following regime of inspection and testing should be applied to the validation of new installations designed to provide ultra-clean conditions in an operating suite. The test regime has been devised to ensure that the system as installed fully achieves the operational requirement for these systems as set out in Chapter 8.

UCV canopy validation procedure

- 12.36 The validation procedure set out in paragraph 12.30 onwards should have been satisfactorily completed prior to attempting to validate the UCV canopy. The

operating suite to be validated should be physically complete with final finishes applied. All ventilation systems serving it should be operating correctly and delivering their design airflow rates.

- 12.37 Tests to validate the suitability and performance of a UCV canopy should be undertaken in the order that they appear below. If an item fails to meet the required standard it should be rectified and successfully retested before passing on to the next test.

Summary of test regime

- 12.38 Leakage tests should ensure that:

- the UCV canopy is correctly assembled and sealed so that no air will bypass the filters;
- the canopy terminal filters are correctly sealed in their housings;
- the canopy terminal filters are of a uniform quality and undamaged.

- 12.39 Air velocity measurements should ensure that:

- a sufficient quantity of air is being delivered by the canopy;
- the airflow has sufficient velocity to reach the operating site plane.

- 12.40 An entrainment test should ensure that contaminants arising outside of the UCV canopy footprint are not drawn into it.

- 12.41 Visualisation techniques should gain an understanding of the overall system performance.

- 12.42 Noise measurement should ensure that working conditions are satisfactory.

- 12.43 Control system “cause and effect” checks should ensure that the system operates and indicates as specified (for example, see Appendix 10).

- 12.44 The successful completion of the test regime will ensure that the system will be effective if used correctly.

Test and measuring background conditions

- 12.45 The entire theatre suite should be clean and free from debris and visible dust. It should be in a condition that if the validation is successful the suite will only require a final clinical clean before being taken into use (see paragraph 12.24).

- 12.46 All doors should remain closed when readings and scans are being taken.

- 12.47 The conditions in the operating theatre should be stable and within the given ranges.

Temperature: 18–22°C dry bulb.

Humidity: 30–70% Relative humidity.

Test and measuring equipment

- 12.48 Any test or measuring equipment used should have a certificate to prove that it has been calibrated within the previous 12 months at a facility using traceable national standards.
- 12.49 In the case of a noise meter, its “matched sound source” should have a certificate to prove that it has been calibrated within the previous 12 months at a facility using traceable national standards. The noise meter should be calibrated to the sound source on each occasion that it is used.

Test grid – vertical flow canopies

- 12.50 A test grid should be constructed on the floor within the UCV canopy footprint as projected by the inside dimensions of the side walls or boundary air curtain. A suitably marked test sheet will provide a consistent standard of test grid.

Note: The entire clean zone footprint of the UCV canopy will be designated by a contrasting coloured inlay in the floor covering. A line marked on or cut into the floor covering is not sufficient and will not be accepted.

- 12.51 The test grid should comprise test squares of 280 mm × 280 mm dimension.
- 12.52 The test grid should be aligned along the centre lines of the canopy footprint with its centre under the centre point of the canopy.
- 12.53 Any test square with 80% of its area within the UCV footprint should be used as a test position.
- 12.54 An inner zone will be designated that is not less than 36% of the total footprint. It will be made up of a number of test squares distributed symmetrically about the canopy footprint centre line. Regardless of the size or shape of the canopy footprint, the inner zone will comprise a minimum grid of 6 × 6 test squares.
- 12.55 Unless specified otherwise, a test position should be in the geometric centre of a test square.
- 12.56 Test position 1 will be the left-most test square in the row nearest to the operating theatre wall that houses the theatre control panel. (For an example of a grid for a 2.8 m × 2.8 m canopy, see Figure 11.)

UCV canopy leakage tests

- 12.57 The diffuser screen fitted below the face of the canopy terminal filters should be lowered or removed while the leakage tests are being carried out.
- 12.58 The installed terminal EPA filters are to be checked to ensure that their grade accords with the design specification and that their performance has been certified by their manufacturer.

Test equipment

- 12.59 An LSAPC connected to an isokinetic fishtail scanning probe will be used to detect the size and number of particles present.

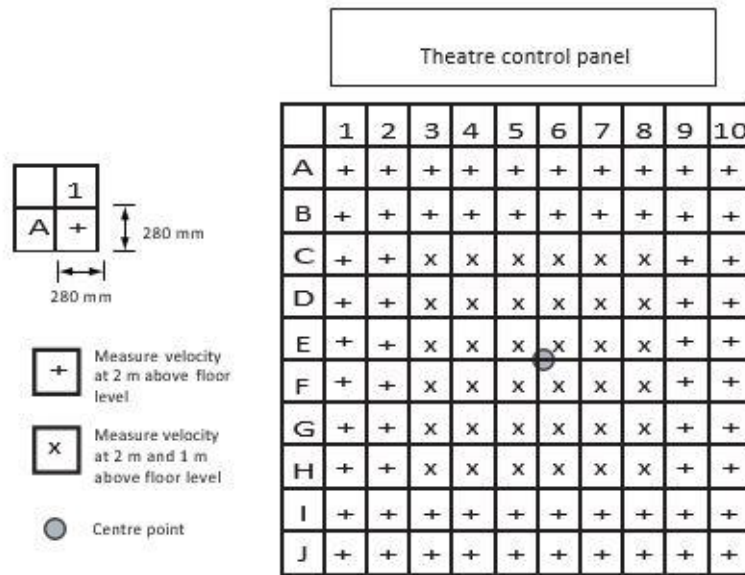
12.60 Spot readings are taken at several filter faces to establish the smallest non-penetrating particle size. If particles at or above this size are detected when subsequent scans are made, there is deemed to be a significant leak at, or near, the test position.

UCV canopy clean zone leak test

12.61 The test will confirm that there is no unfiltered air leakage in the canopy.

12.62 The construction joints and service penetration points under the UCV canopy within its side walls or boundary air curtain should be scanned to prove that there are no leaks.

Figure 11: Example of a test grid for a 2.8 m x 2.8 m UCV terminal



Note: For larger UCV terminals, add extra (280 mm x 280 mm) test squares symmetrically around the periphery of the grid and increase the inner zone in accordance with the guidance in paragraphs 12.50–12.56 of Scottish Health Technical Memorandum 03-01 Part A.

12.63 A leak is defined as a significant and repeatable rise above the background level.

Terminal EPA filter seal leak test

12.64 The test will confirm that there is no unfiltered air bypassing the EPA filter seal.

12.65 Each EPA filter seal should be scanned to prove that there are no leaks.

12.66 A leak is defined as a significant and repeatable rise above the background level.

EPA filter media leak test

12.67 The test will confirm that the EPA filters have not sustained damage while being installed.

12.68 The face of each EPA filter should be scanned to prove that there are no leaks.

12.69 A leak is defined as a significant and repeatable rise above the background level.

Vertical flow UCV canopy air velocity tests

Test setup

- 12.70 The canopy face diffuser screen should be in place for these tests.
- 12.71 Take spot readings to establish that the room is within the specified temperature and humidity test conditions.
- 12.72 Set out the test grid as described previously.
- 12.73 Swing the operating lamp arms and any other stem arms so that they align to present the least resistance to airflow, are perpendicular to the front edge of the test sheet and face the back edge. Any lamp and equipment heads should as far as practicable be outside of the UCV canopy footprint (see photographs).

Test instrument

- 12.74 The measuring instrument should be a thermal anemometer with a digital readout. The instrument resolution should be at least 0.01 m/s, have a tolerance of ± 0.015 m/s or 3% and be calibrated down to 0.15 m/s or lower. An alternative instrument may be used providing it is of no lesser specification.

Test method

- 12.75 The instrument should be mounted on a test stand and set to take a mean reading over a 10-second sample interval.
- 12.76 The test instrument should record readings automatically for later download or be connected to a printer.
- 12.77 The test stand should be positioned on each test point in turn and the reading taken when the instrument has stabilised.
- 12.78 When taking a reading, the test person should not stand within the same quadrant as the test instrument.
- 12.79 Readings are to be taken at the test positions with the instrument probe facing the wall housing the theatre control panel commencing at the first test position. Readings are taken either working along the rows from left to right or for all test positions in one quadrant at a time.
- 12.80 When all test positions under one half of the canopy have been covered, readings of temperature and humidity are taken at the specified height in the centre of the canopy. The readouts from the theatre control panel should be recorded at this time.
- 12.81 Having completed one half of the test grid, the operating lamp arms and any other stem arms should be swung round through 180° and the test stand reversed so that the wall housing the theatre control panel is behind the test person. Readings are recommenced starting at the right of the test row and working from right to left or a quadrant at a time, as above.

UCV canopy high level discharge velocity test

- 12.82 Measurements of air velocity are to be taken at every test position 2 m above floor level and the results averaged. The average of the total readings taken is to be not less than:
- 0.38 m/s for a canopy with no side walls or side walls that terminate at 2 m above floor level.
 - 0.30 m/s for a canopy with side walls that terminate 1 m above floor level.
- 12.83 For UCV canopies that are an assembly of two or four units, each fed by a recirculation fan, the average air velocity for each unit should not exceed $\pm 6\%$ of the measured average velocity for the canopy.

Figure 12: UCV 2m air velocity test set-up



UCV canopy low level air velocity test

- 12.84 Measurements of air velocity are to be taken at each of the inner zone test positions 1 m above floor level.
- 12.85 The measured velocity at every test position in the inner clean zone should be not less than 0.20 m/s.

Figure 13: UCV 1m air velocity test set-up



UCV canopy entrainment test

Rationale for the entrainment test

- 12.86 The performance of a UCV canopy may be compromised by room air being drawn into the ultra clean airflow, a phenomenon known as entrainment. Significant levels of entrainment could lead to microbial contamination of items left exposed on instrument trolleys laid out beneath the canopy.

- 12.87 UCV canopies having permanently fitted side walls that terminate 1 m above floor level do not need to be tested, as the walls physically prevent entrainment.

Principle of the test

- 12.88 A source of particles is produced outside of the UCV canopy footprint and is used to challenge the system. A sample probe and detector are placed within the ultra clean airflow and used to determine the percentage penetration of the test particles at predefined locations under the UCV canopy footprint. The source and sample probe are moved in tandem around the UCV canopy and pairs of readings taken at the detector, from which the percentage penetration at specified locations is calculated. The degree of penetration should be below specified maximum limits if entrainment is to be declared not significant.

Test setup

- 12.89 The challenge will be provided by using non-EPA-filtered air emerging from the preparation room via the pressure stabiliser or transfer grille and ducted to the specified release position.
- 12.90 The canopy face diffuser screen should be in place for these tests.
- 12.91 The test is performed without any theatre equipment in place beneath or closely adjacent to the UCV canopy. All doors in the theatre suite should be closed and remain so for the duration of the test.
- 12.92 The operating lights and support booms should be moved to a central position beneath the canopy and raised to 2 m above floor level, so as not to interfere with the peripheral airflows (see photograph).
- 12.93 Spot readings are taken at the centre of the canopy, 1 m from floor level, to establish that the room is within the specified temperature and humidity limits (see paragraph 12.47).
- 12.94 The test grid is set out as described previously (see paragraph 12.50).

Test equipment

- 12.95 The source unit will be a fan/blower or other method that ducts non-EPA- filtered air (see paragraph 12.89) and expels it via a delivery head mounted on a test stand or clamped to the UCV canopy sidewall at the specified release position to provide the particle challenge. The challenge air will be delivered vertically downwards from a position 2 m above floor level alongside the outside edge of the side wall or in line with the downward air curtain if the canopy does not have side walls. The challenge airflow velocity should be the same as the measured average velocity at the 2 m level for the canopy under test.

Figure 14 UCV entrainment test setup



- 12.96 The detector will be an LSAPC capable of sampling a minimum of 28.3 L of air (1 ft³) per minute and providing readings for particle sizes from 5 μm to 0.3 μm . Measuring instruments should be compliant with the requirements of BS EN ISO 14644 or ISO 17141 to reflect the type of test. An alternative instrument may be used providing it is of no lesser specification
- 12.97 The sampling head will be an isokinetic fishtail scanning probe mounted horizontally on a test stand 1 m above floor level and connected to the LSAPC by a hose no longer than 2 m

Test positions and orientation of source and detector sampling probe

- 12.98 The test positions will be at the centre of each test square, as defined for the velocity test (see paragraph 12.50).
- 12.99 For rectangular UCV canopies, measurements of penetration are to be taken at the four corner test squares of the test grid and at intermediate positions along the line of test squares between the corners. The number of intermediate test positions will be

as equally spaced as possible around the periphery, with not fewer than three and not more than five complete test squares between test positions.

- 12.100 A further series of measurements are to be obtained around the periphery of the inner zone (defined in paragraph 12.54). Measurements of penetration are to be taken at the four corner test squares of the inner zone of the test grid and if necessary at intermediate positions along the line of test squares between the corners as equally spaced as possible, with not fewer than three and not more than five complete test squares between test positions.
- 12.101 The centre of the challenge particle source delivery head is aligned with the centre of the designated test square, with its longer edge against the outer edge of the side wall or air curtain and delivering the challenge 2 m above floor level. The air containing challenge particles is directed vertically downward. Where there is physical interference due to obstructions such as gas pendants, the source will be moved to the next available non-obstructed test square location nearest to the stipulated test position. The sampling probe will then also be moved to remain opposite the source.
- 12.102 In the case of non-rectangular canopies, an interpretation of the above strategy should be adopted that will yield a no less searching examination of the unit's ability to control entrainment.

Test method

- 12.103 A measurement of particle penetration through a representative section of the EPA filter media is to be taken. The smallest non-penetrating particle size will be used as the reference background level and set in the detector instrument. The detector instrument should be set to take a reading over a 15-second sample interval and record the number of particles at the non-penetrating particle size determined above.
- 12.104 An initial sample of air at the source delivery head should be taken to check that there are sufficient particles of the considered size present. The challenge will be considered suitable if:
- the particles are within the size range 5 to 0.3 μm and thus capable of remaining airborne for a substantial time;
 - the particles should not be able to penetrate the canopy EPA filters in sufficient numbers to cause a background count that is more than 0.1% of the challenge count;
 - the number of particles present will enable a minimum of three logarithm (1000-fold) range of counts to be recorded between the source and background readings. A concentration of approximately 105 particles per cubic metre of source air has been shown to be adequate.

Note: The same equipment should be used to measure both the challenge source and penetration so as not to bias results through particle losses within the test equipment.

- 12.105 The sampling probe of the detector instrument is mounted on a test stand with its orifice facing outwards horizontally from the centre of the UCV canopy, 1 m above floor level. The sampling probe will be orientated at right angles to the partial wall

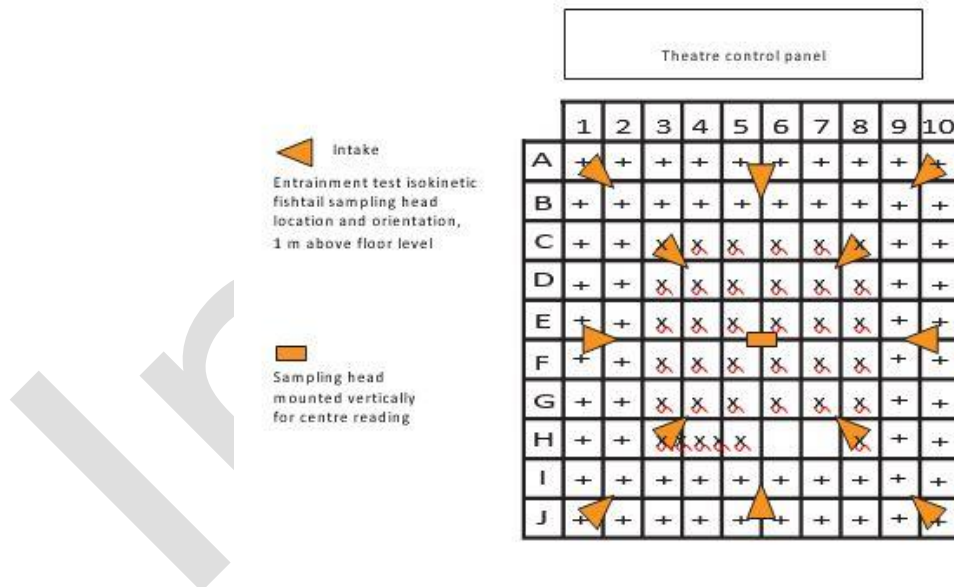
when sampling along the sides of the test grid but will be set to bisect the angle when measuring at the corner test positions. (See Figure 15 for test locations and see photograph of entrainment test equipment in Figure 13.)

- 12.106 The test will commence at the first test position; this being designated the left-most corner of the test grid when facing the wall housing the theatre control panel. The penetration will also be measured at the corresponding test point on the inner zone commencing at the corner nearest to the first test position.

When these tests have been completed, the source distribution head and sampling probe will be moved to the next test positions, working around the test grid in a clockwise direction.

- 12.107 The test stands will be positioned on each test point in turn and a pair of readings (challenge, then penetration) taken when the instrument has stabilised.
- 12.108 When taking a reading, the test person should stay within the UCV canopy footprint but on the side opposite the sampling probe.
- 12.109 A single measurement will be taken at the geometrical centre of the UCV canopy footprint. The centre measurement will be taken with the sampling probe mounted vertically 1 m above floor level

Figure 15: Entrainment test locations for a 2.8 m x2.8 m UCV terminal



Note: Test grid layout is as for Figure 11. Entrainment test set-up and guidance is given in paragraphs 12.86 onwards.

For this test the challenge source distribution head will be placed at the test position that yielded the greatest penetration at the periphery of the canopy footprint.

Analysis and interpretation

- 12.110 The following standard is to be achieved:

- penetration to be no greater than 10% of the challenge at each test position in the outer zone;

- penetration to be no greater than 1% of the challenge at each test position in the inner zone;
- penetration to be no greater than 0.1% of the challenge at the centre of the test grid.

12.111 If a result is close to or above the given limits, a further reading should be obtained using a longer time base (1 minute) and the penetration should not exceed the given limit.

UCV canopy flow visualisation

12.112 The use of smoke to gain an understanding of the overall performance of the canopy may prove useful at this stage in the validation process but cannot be relied on to produce a contractually definitive measure of performance.

UCV canopy noise level

12.113 An industrial-grade sound level meter to BS EN 61672 Type 2 fitted with a muff will be used to check the noise level. The instrument should be calibrated using a matched sound source prior to each set of readings.

12.114 The noise level readings are to be taken at a typical normal listening position 1.5 m above floor level and at least 1 m from any surface and not on any line of symmetry. Measurements should be taken under the centre of each quadrant and in the centre of the canopy, and the five readings averaged.

12.115 The readings should be taken with the UCV canopy at operational speed and repeated with it at set back.

12.116 For UCV operating suites, the noise level should not exceed:

- operating theatre and spaces without doors that are open to it (for example, the scrub): 53 dB(A);
- all other peripheral rooms of the suite: 48 dB(A).

UCV terminal control system checks

Temperature

12.117 The readings of temperature taken under the UCV canopy should be within $\pm 1^{\circ}\text{C}$ of the readout on the theatre control panel.

Humidity

12.118 The readings of humidity taken under the UCV canopy should be within $\pm 5\%$ RH of the readout on the theatre control panel.

Direct reading differential pressure gauges

12.119 The differential pressure across the terminal filter should be measured to confirm the accuracy of the indicated reading of any gauge.

Control functions

- 12.120 The operation of all control functions provided on the theatre control panel should be checked for conformity with the design specification (see Appendix 10).
- 12.121 If an auxiliary panel has been fitted, its interlocking with the main theatre control panel control functions will be checked for conformity with the design specification.

Panel indicator lights

- 12.122 The panel indicators should illuminate as appropriate when the control functions are selected, or warning levels are reached (see Appendix 10 for an example “cause and effect” test regime).

BMS interface

- 12.123 The operation, monitoring and alarm functions should be checked for conformity with those set out in the design specification.

UCV theatre microbiological tests

- 12.124 There is little value in performing microbiological sampling in an empty operating theatre supplied with ultra clean ventilation. The foregoing filter challenge tests, air velocity measurements and entrainment test will have proved that the system operates satisfactorily and achieves the contracted level of performance. The EPA filters will remove bacteria-sized particles from the air supplied through the UCV canopy. Therefore, there will be an insignificant number of bacterial and/or fungal cfus present until the theatre is actually used.
- 12.125 Following full validation, in-use microbiological sampling during a surgical procedure will not be required unless specified by the client's VSG.

UCV operating suite validation report

- 12.126 Following validation, a full report detailing the findings will be produced and sent to the client's lead project manager. The report should conclude with a clear statement on whether the UCV operating suite as a whole achieved or did not achieve the standard set out in the agreed design specification.
- 12.127 The client's lead project manager should lodge a copy of the report with:
- theatre manager;
 - infection prevention and control;
 - estates and facilities.

Pharmacy aseptic preparation facilities

- 12.128 The following regime of inspection and testing should be applied to the validation of new installations. The test regime has been devised to ensure that the system as installed fully achieves the operational requirement for these systems as set out in EUGGMP and the design specification.

Basic requirement

- 12.129 The validation procedure set out in paragraphs 12.1–12.33 should have been satisfactorily completed prior to attempting to validate the aseptic preparation facility. The suite to be validated should be physically complete with final finishes applied and have been completely cleaned. All ventilation systems serving it should be operating correctly and delivering their design airflow rates.

Aseptic preparation facility validation procedure

- 12.130 Tests to validate the suitability and performance of the aseptic preparation facility should be undertaken in the order that they appear below. Should an item fail to meet the required standard it should be rectified and successfully retested before passing on to the next test.

Summary of test regime

- 12.131 Challenge tests should ensure that:

- the supply terminal HEPA filters are sealed in their housings so that no air will bypass them;
- the terminal filters are of a uniform quality and undamaged.

- 12.132 Differential pressure measurements should ensure the correct pressure cascade.

- 12.133 Particle counting should be carried out at a specified number of test positions in order to determine the individual cleanroom classification in accordance with ISO EN 14644 and ISO 17141.

- 12.134 Control system checks should ensure that the system operates as specified.

- 12.135 Microbiological sampling should check the air quality.

Test and measuring conditions

- 12.136 While validating the aseptic preparation facility, the conditions in the cleanrooms should be stable and within the given ranges.

Temperature: 19–23°C dry bulb.

Humidity: 30–70% relative humidity.

Test and measuring equipment

- 12.137 Any test or measuring equipment used should have a certificate to prove that its calibration has been checked within the previous 12 months at a facility using traceable national standards.

Supply terminal EPA or HEPA filter seal leak test

- 12.138 The test will confirm that there is no unfiltered air bypassing the EPA or HEPA filter seal.

- 12.139 Each EPA or HEPA filter seal should be scanned using a light scattering airborne particle counter (LSAPC) to prove that there are no leaks.

- 12.140 A spot reading will be taken at the face of the filter to determine the background particle level. A leak is defined as a significant and repeatable rise above the background level.

Terminal (EPA or HEPA) filter media leak test

- 12.141 The test will confirm that the terminal filters have not sustained damage while being installed.
- 12.142 The face of each terminal filter should be scanned using an LSAPC to prove that there are no leaks.
- 12.143 A leak is defined as a significant and repeatable rise above the background level.

Cleanroom particle count

- 12.144 The test will confirm the number and size of particles present and therefore the classification of the cleanroom in terms of ISO 14644 or EUGGMP as specified in the project brief.
- 12.145 The number of test positions is determined by reference to Table A.1 in ISO 14644-1.
- 12.146 The complete test methodology will be as set out in ISO 14644.

Cleanroom biocontamination control

- 12.147 BS EN 17141 gives details on cleanroom biocontamination control.

Radiopharmacy aseptic preparation facilities

- 12.148 Validation will be as for a pharmacy aseptic preparation facility.
- 12.149 Additional radiological tests as specified in the project brief will be required. These will be carried out and/or witnessed by the client's appointed specialist.

Inspection, assembly and packing (IAP) rooms in central decontamination units

- 12.150 Validation will be as for the standard practice described in paragraphs 12.1–12.33.
- 12.151 The pressure cascade and associated automatic monitoring sensors and alarms should be tested for correct operation in accordance with the design specification.

Note: The detail of the sealing between the instrument washers, transfer hatches and sterilizers that penetrate the walls of the IAP room will be critical in attaining the specified room pressure.

- 12.152 Following the satisfactory validation, the IAP room should be physically cleaned using specialist contractors. Particle counts at locations related to the floor area as set out in table A.1 of ISO 14644 Part 1, along with instructions from ISO 17141 will then be used to establish whether the room achieves a Class 8 cleanroom standard.

Containment level 3 laboratories

- 12.153 Validation will be as for the standard practice described in paragraphs 12.1–12.33.
- 12.154 The room will be subject to a permeability test as set out in paragraph 12.17.
- 12.155 The pressure cascade and associated automatic monitoring sensors and alarms should be tested for correct operation in accordance with the design specification.

Isolation rooms

- 12.156 Validation will be as for the standard practice described in paragraphs 12.1–12.33.
- 12.157 See Scottish Health Planning Note 4 Supplement 1 for details of the test regime.

Microbiological sampling

- 12.158 It is essential that all parts of the validation test specified above have been successfully completed and the areas thoroughly cleaned prior to any microbiological sampling.
- 12.159 Microbiological sampling will not normally be required for either general or local exhaust ventilation (LEV) systems unless otherwise specified within the contract.
- 12.160 The procedure for carrying out microbiological sampling in cleanrooms is set out in ISO 17141.

Microbiological sampling conventional theatres

- 12.161 The level of airborne bacteria introduced by the supply air can be checked by closing all doors and leaving the operating room empty with the ventilation system running for 15 minutes. An active air sampler set to 1 cubic metre and mounted on the operating table should then be activated remotely. Aerobic cultures on non-selective media should not exceed 10 bacterial and/or fungal colony forming units per cubic metre (CFU/m³).
- 12.162 The results should be examined to establish the broad category of organisms present. A high preponderance of fungal organisms may be an indication of inadequate filtration for the particular installation. Precise guidance is inappropriate and will depend on local circumstances.
- 12.163 It may be appropriate to carry out a check of airborne bacteria during a surgical operation. If required, this should be carried out as soon as possible after handover. Unless there are unusually high numbers of personnel or extensive activity in the room, the number of airborne bacterial and/or fungal CFU averaged over any five-minute period, would be unlikely to exceed 180 per cubic metre.
- 12.164 Information on the microbiological testing of UCV Operating suites is given in clauses 12.124 and 12.125.

13. Information

Records required

- 13.1 There is a requirement under the Building Regulations to provide documentary evidence of the design, commissioning and subsequent performance of ventilation systems as well as recommended maintenance routines (Building Regulations. 2010, Part 8, Paragraph 39).
- 13.2 Electronic records should be in a format that is compatible with the client's archive and retrieval system.

Handover

- 13.3 The following general information is required at plant handover:
- “as fitted” drawings of the plant showing the location of all items and listing the size of ducts, grilles and diffusers together with their factors;
 - “schematic” drawing of the air distribution system showing design and actual airflows from all outlets together with the design and actual airflows in each duct. The duct centre correction factors should be given and the grille factors;
 - the location of all volume control dampers should be marked on the “as fitted” and “schematic” drawings;
 - a floor plan of the area served by the plant showing all doorways, hatches, transfer grilles, pressure relief dampers, pressure stabilisers, supply and extract terminals. The total supply and extract volumes should be shown for each room served by the plant. The volume flow and direction of flow through transfer grilles, pressure relief dampers and pressure stabilisers should also be shown, together with the room pressures in pascals measured with regard to atmospheric pressure. For operating suites the “key” door should be identified;
 - a fire plan of the area served showing the fire zone and location of all fire and smoke dampers and detectors. An explanation of the ventilation strategy in the event of an in-zone fire, adjacent zone fire or smoke being drawn into the airhandling unit from an outside source should be provided.
 - wiring diagrams for all electrical equipment associated with the air handling systems including motor control circuit details and any interlocking and safety devices such as emergency stop buttons adjacent to the item of plant;
 - manufacturer's operating instructions and “setting to work” guidance for all specialist components incorporated in the systems;
 - a schematic of the control system showing the location of all plant sensors;
 - control algorithm(s) of the actual plant operation and the set points entered during commissioning together with the control panel access codes and keys.

Plant design information

- 13.4 The following plant design information is required at plant handover:

- a simple statement of the design intent;
- a description of the plant's intended mode of operation;
- winter outside design temperature in °Cdb;
- winter outside design humidity in % saturation;
- winter room supply air design temperature in °Cdb;
- winter room supply air design humidity in % saturation;
- winter inside design temperature for each room in °C;
- winter inside design humidity for each room in % saturation;
- summer outside design temperature in °Cdb;
- summer outside design humidity in % saturation;
- summer room supply air design temperature in °Cdb;
- summer room supply air design humidity in % saturation;
- summer inside design temperature for each room in °C;
- summer inside design humidity for each room in % saturation;
- winter psychrometric chart showing the condition of the air between all items of plant and the design outside, supply and room air conditions;
- summer psychrometric chart showing the condition of the air between all items of plant and the design outside, supply and room air conditions;
- the design mass airflow rate used to size the plant in kg/s;
- the design volumetric flow rate in m³/s.

Individual equipment information

Heater-batteries including energy recovery

13.5 The following information concerning heater-batteries is required at plant handover:

- the size of the battery, number of passes and fin spacing;
- the design flow and return temperatures and flow rate in L/s;
- the pressure drop across the water side of the battery in Pa;
- the number of phases, supply voltage, current drawn and number of steps if electric;
- the maximum rated capacity of the battery and actual design rating in kW;
- the design and actual face velocity in m/s;
- the pressure drop across the air side of the battery in Pa;
- the design on and off coil air temperature and humidity at winter and summer design conditions

Cooling coils

13.6 The following information concerning cooling coils is required at plant handover:

- the size of coil, number of passes and fin spacing;
- the design flow and return temperatures and flow rate in L/s if chilled water;
- the pressure drop across the water side of the coil in Pa;
- the supply pressure and mass flow rate if direct expansion;
- the maximum rated capacity of the coil and actual design rating in kW;
- the contact factor;
- the design sensible and latent cooling loads in kW;
- the design and actual face velocity in m/s;
- the pressure drop across the air side of the coil in Pa;
- the design on and off coil air temperature and humidity at summer design conditions.

Humidifiers

13.7 The following information concerning humidifiers is required at plant handover:

- the size of the humidifier and number of lances;
- the supply pressure and mass flow rate of the steam;
- the number of phases, supply voltage, current drawn and number of steps if electric;
- the maximum rated capacity of the humidifier and actual design rating in L/hour;
- the design and actual face velocity in m/s;
- the design upstream and downstream air temperature and humidity at winter design conditions

Filters

13.8 The following information concerning filters is required at plant handover:

- the size of the filter and number in bank;
- its grade;
- the design and actual face velocity in m/s;
- the initial pressure drop across the filter when clean in Pa;
- the final pressure drop across the filter when dirty in Pa;
- the manufacturer's name and filter identification code.

Fans

13.9 The following Information concerning fans is required at plant handover:

- the size of the fan and its type;
- the fan curve;
- speed and direction of rotation;

- the drive motor frame size;
- the number of phases, voltage and maximum design and actual current drawn;
- the design and actual delivered air volume in m³/s;
- the fan suction pressure at high and low speed in Pa;
- the fan delivery pressure at high and low speed in Pa;

Attenuators

13.10 The following information concerning attenuators is required at plant handover:

- the size of the attenuator and number in bank;
- the design and actual face velocity in m/s;
- the initial pressure drop across the attenuator in Pa;
- the upstream sound level in dB(A); the downstream sound level in dB(A).

System information

13.11 The preservation of information and records of ventilation systems and their performance is a legal requirement. It is therefore essential that when new systems are completed, full information as to their purpose, design, layout and actual commissioned performance are handed on to the client. If any derogations were agreed from this standard, they should be noted and the reason for them explained. The system information if electronic (for example, BIM model) should be in a form that is compatible with the client's IT standard and can be accessed and searched by it.

13.12 In new "green field" developments an inventory of the installed ventilation systems should be compiled. In existing developments the client will normally have an inventory of their installed systems, and all new systems should be added to it.

13.13 The inventory will be subdivided into the following categories:

- local exhaust ventilation systems (LEV) – note these are statutory items;
- critical healthcare ventilation systems (CHV).

(These are systems the loss of which would seriously limit the delivery of healthcare – for example, operating suite, SCBU, critical care areas, interventional imaging suite, aseptic preparation facility.)

- general ventilation system [supply and extract] (GVS);
- general extract systems (GES);
- systems installed for smoke clearance in the event of a fire, classed as smoke and heat exhaust ventilation systems;
- – (SHEVS) (for example, smoke extract fans in stairwells, automatic smoke clearance dampers in atria).

Note: During the design and contract process, ventilation systems are often given "construction" codes for drawing reference and site identification purposes. It is

imperative that prior to handover the actual identification codes and labels affixed to the systems conform to the inventory in use at the site or desired by the client. Each system code should be unique and conform to the categorisation format for the client's inventory given above.

For ease of future reference, a list of design and construction references for drawings and plant, cross-referenced to the client's building designations and plant inventory codes, should be produced.

13.14 For each ventilation system the inventory should contain the following details:

- a unique system identification code (for example, LEV 001; CHV 001) as appropriate;
- the location of the ventilation fan unit or supply and extract AHU(s);
- the location of the fresh air inlet;
- the location of the extracted air discharge;
- the specific area(s) served by the system;
- the date the system was installed;
- the date the system was validated and accepted by the client.

13.15 Each ventilation system should have a logbook (physical or electronic) that contains the following information:

- the unique system identification reference;
- purpose of the system;
- date of installation;
- details of the installed equipment and ductwork layout;
- detail of the fire plan and location of fire and smoke dampers;
- design performance parameters (for example, airflow rates, air-change rates, pressures);
- commissioned date and performance;
- record of the system validation and acceptance;
- records of the annual inspection and verification;
- maintenance records and plant information (for example, fan specifications and filter sizes).

13.16 The records should be linked to the inventory and stored in such a way as to be readily available in the event of plant breakdown or other incident.

13.17 Every ventilation system should be clearly identified with a permanent label. The label should show in lettering 100 mm high the inventory reference code of the AHU and clearly identify the area that it serves. The label should be mounted with screws or rivets in an easily visible place near the fan of the unit adjacent to the local electrical isolator. The system control panel should have a duplicate label. Any subsystems and the principal branch ducts should be similarly labelled.

- 13.18 The nature of air and direction of flow should be clearly marked on all ducts using the symbols given in BS 1710.
- 13.19 All airflow test-points should be clearly identified with a permanent label and the design information given (for example, TPS 1 – Anaesthetic supply; 400 × 300; Design 185 L/s).
- 13.20 If two ventilation systems supply a common room or an outlier from another zone, the room identification label should state the relevant ventilation identification codes, for example: Theatres 5&6 Utility; [CHV 012 and CHV 015], as should the labels on their individual AHUs.
- 13.21 Any ventilation system that conveys a hazardous substance or is affected by a hazardous radiation must be clearly marked with the appropriate symbol.

Fire and smoke dampers

- 13.22 A complete schedule of dampers fitted, their location and unique identification code should be provided.
- 13.23 A statement of when they were tested and by whom should be included.

Spares

- 13.24 Unless otherwise agreed with the site maintenance department, spares should be stored on a rack in the entrance of the relevant plantroom and preserved from casual damage or contamination.
- 13.25 The scale of spare fans to be provided should relate to the number of AHUs using fans of the same size. The spare fans should be pre-wired with power and control connectors so that when used they are plug and play.
- 13.26 A complete set of new filters should be handed over.
- 13.27 A complete set of any other consumable item installed in the installation should be handed over.

BIM status

- 13.28 If the installation was modelled using BIM during construction, the BIM model should be brought up to date and all asset tags incorporated prior to handover.
- 13.29 Training for estates staff who will be tasked with keeping the BIM model in date should be given, ideally while the original BIM team is available.

Maintenance routines

- 13.30 Any product or installation-specific maintenance routines should form part of the handover documentation and, if necessary, training.
- 13.31 Information on routine inspection and maintenance is given in Part B of Scottish Health Technical Memorandum 03-01.

Expected service life

- 13.32 Air handling units (AHUs) have an expected service life of 20 years. Part B of this SHTM states that ventilation systems should be taken out of service, deep cleaned, their controls renewed and recommissioned after 10 years. The handover information will both assist this process and help inform the selection of replacement plant.

Additional end user information

- 13.33 The information itemised above is intended to fulfil the contract requirement and provide a record for the client and their appointed operational management and maintenance teams. There is also a need in some circumstances to provide the end-user with information as to the role that them and their patients from airborne contaminants.
- 13.34 In operating suites and interventional imaging suites of any type, a simplified plan of the suite showing the principal direction of air movement should be displayed at the entrance to the suite. The following bullet points should be appended to the plan:
- the air supplied to each room is intended to dilute any airborne contaminants;
 - the airflow between rooms will ensure that contaminants do not enter;
 - people are the main source of airborne contaminants; they disperse such contaminants as they move around: the more people, the more movements, the more airborne contaminants;
 - optimum conditions exist when all doors are closed;
 - in order to ensure that the system operates correctly and efficiently:
 - routine checks should be carried out of the system performance;
 - the system should be taken out of use periodically to carry out essential maintenance.
- 13.35 The VSG should advise if other applications require similar explanatory information.

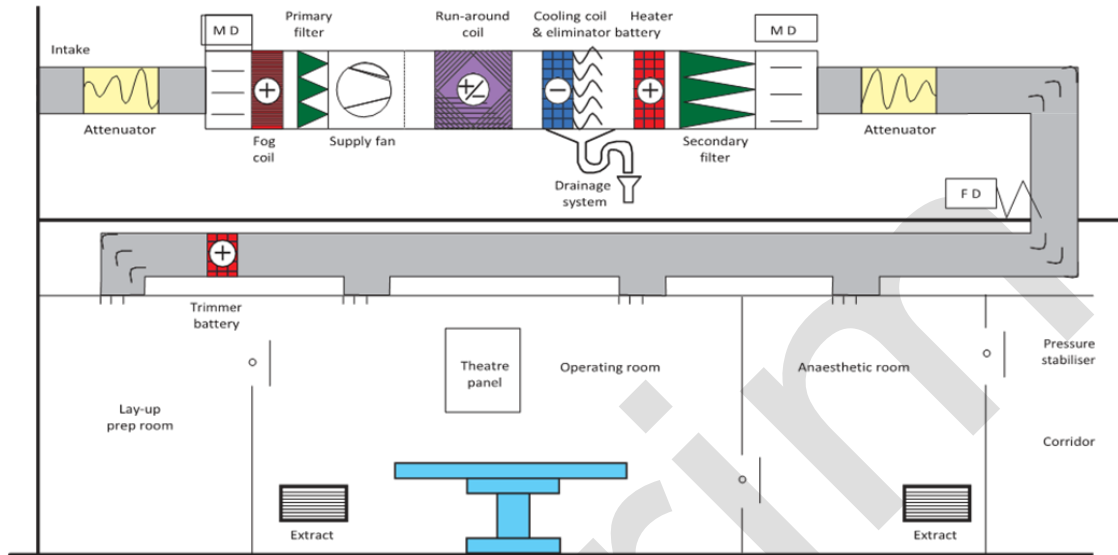
Staff training

- 13.36 On completion of the project, training in the correct use, operation and routine maintenance of the installed systems should be given as appropriate to the following staff groups:
- the end-users;
 - those who will operate and maintain the installed systems.

Appendix 1: Typical AHU Plant Layouts

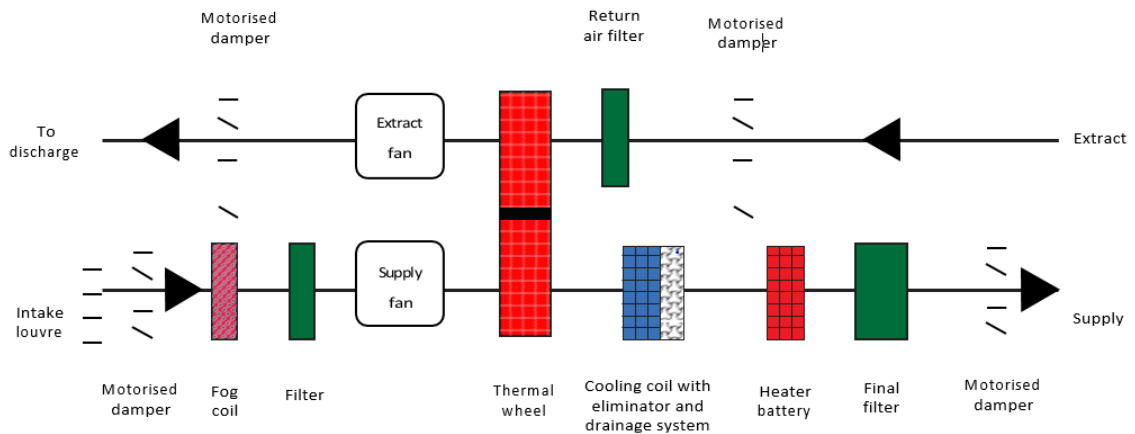
Supply AHU with remote extract unit

Figure A1: Schematic of typical operating suite AHU with energy recovery by run-around coil from a remote extract fan unit



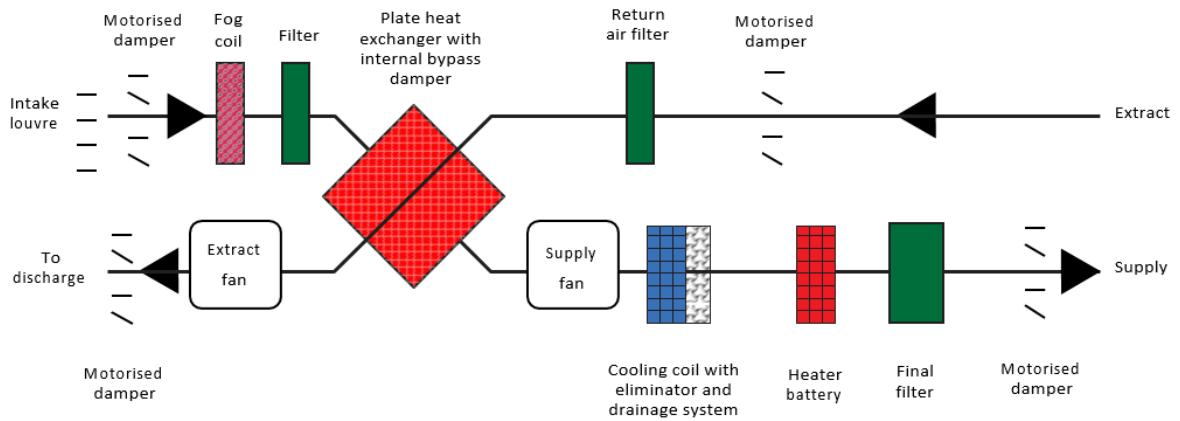
Double-stacked supply and extract AHU

Figure A2: Schematic of typical double-stacked AHU with energy recovery by thermal wheel



Note: Other configurations are possible

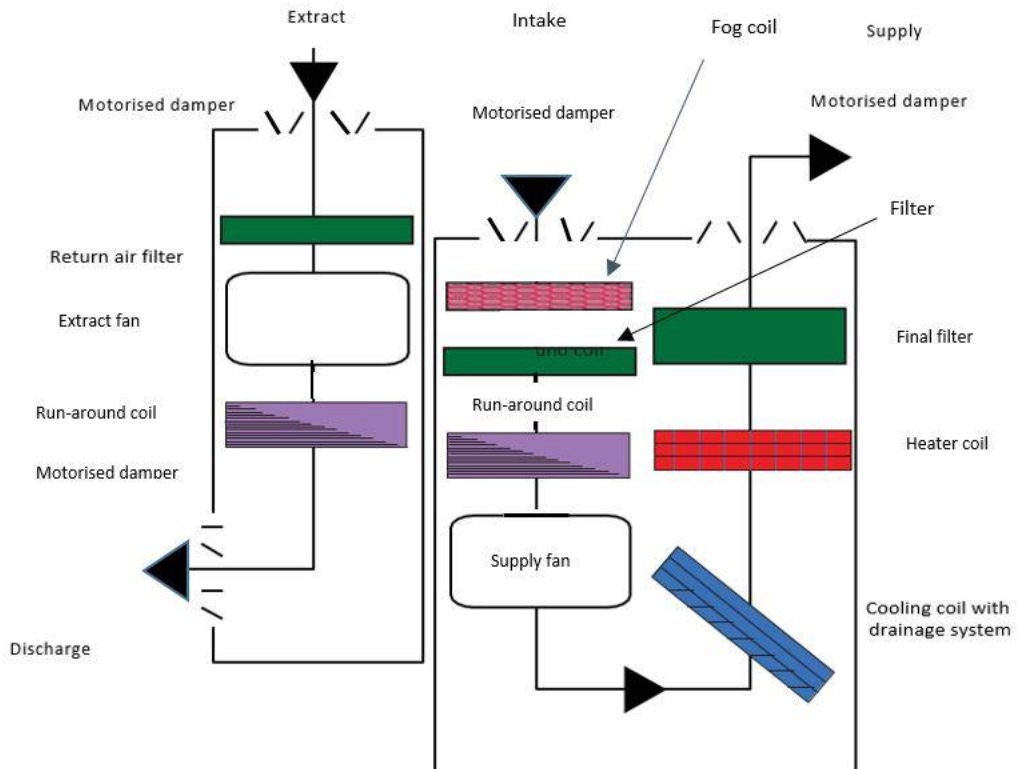
Figure A3: Schematic of typical double-stacked AHU with energy recovery by plate heat exchanger



Note: Other configurations of the fan positions are possible

Cabinet AHU

Figure A4: Schematic of typical cabinet-style AHU with energy recovery by run-around coil



Note: Other types of compact vertical AHUs are possible

Appendix 2: Summary of design conditions

Table A1 Design conditions for miscellaneous rooms

Application	Ventilation	Air-change rate (ac/h)	Pressure (Pascal Pa)	Supply filter grade (BS EN 16798 or BS EN 1822-1)	Noise (dB(A))	Temp (°C)	Comments (for further information see Chapter 8)
General ward (level 0 and 1 care)	S/N	6	–	SUP2	35	18–28	
Communal ward toilet	E	6	–ve	–	45	–	
Single room	S/E/N	6	0 or –ve	SUP2	35	18–28	
Single room WC	E	>10	–ve	–	45	–	
Clean utility	S	6	+ve	SUP3	45	18–22	
Dirty utility	E	6	–ve	–	45	–	
Ward isolation room (PPVL)	S	10	Lobby +10 Room 0	SUP2	35	–	See Scottish Health Planning Note 4 (Supplement 1)
Infectious diseases isolation room	E	10	–5	SUP2	35	–	See Table 4
Neutropaenic patient ward	S	10	+10	E12	35	–	See Table 3
Critical care areas (Level 2 and 3 care)	S	10	+10	SUP1	35	–	Isolation room may be –ve pressure or PPVL. See Table 3
Birthing room	S & E	10	0	SUP2	45	20–25	See Table 5
NICU/SCBU	S & E	10	+ve	SUP1	35	20–28	Isolation room may be –ve pressure
Operating department recovery room	S & E	15	0	SUP2	45	18–25	Provide clean airflow path
Catheterisation room	S & E	10	+ve	SUP2	45	18–22	
Interventional or non-interventional Imaging room of any type	S & E	10	+ve	SUP2	48	–	Stable conditions as specified for the imaging equipment
Sedation recovery room as in paragraph 8.16	S & E	15	S/E	SUP2	45	18–28	
Endoscopic procedure room	S & E	15	-5	SUP2	40	20–25	See Table 2
Endoscope reprocessing wash room	E	10	–ve	–	45	–	
General treatment room	S & E	10	Neutral	SUP2	45	20–25	See Table 2
Emergency department waiting area	S & E	6	–	SUP2	–	18–25	See Table 2

Application	Ventilation	Air-change rate (ac/h)	Pressure (Pascal Pa)	Supply filter grade (BS EN 16798 or BS EN 1822-1)	Noise (dB(A))	Temp (°C)	Comments (for further information see Chapter 8)
Containment level 3 laboratory	#	>20	#	H14*	–	18–22	# See ACDP guide; *Filter in extract See Table 4
Post-mortem room	S & E	S = 10 E = 12	–ve	SUP2	45	18–22	Provide clean airflow path
Specimen store	E	–	–ve	–	–	–	Fan accessible from outside of store

Notes:

For general and UCV operating suites and associated rooms, see specific guidance in Chapter 8 and typical design solutions in Appendix 7

Waiting and circulation areas should be directly or indirectly ventilated to provide a comfortable environment and control airborne contamination and odours.

18–22°C indicates the range over which the temperature may float.

18-22°C indicates the range over which the temperature should be capable of being controlled at any point within that range.

S = Supply

E = Extract

N = Natural ventilation where possible where natural ventilation is used the design must reflect clauses 5.2 to 5.9

SUP refers to the supply air quality as defined in BS EN 16798

Appendix 3: Hierarchy of cleanliness

Table A2 Hierarchy of cleanliness

Class	Room	Nominal pressure (Pa) ^a	Airflow rate for bacterial contaminant dilution Flow in or supply (m ³ /s)	Flow out or extract(m ³ /s)
Sterile	Preparation room	35	See standard schemes in Appendix 7 and detailed calculation process in Appendix 8 for recommended design values	
	lay-up	25		
	sterile pack store	25		
	Operating theatre Scrub bay	25		
Clean	Sterile pack store Anaesthetic room	+ve 15c	6 ac/h	–
	Scrub room	15	The greater of 15 ac/h or 0.15 –	The greater of 15 ac/h or 0.15 0.10 mind
Transitional	Recovery room	0	15 ac/he (See note f) (See note f) 7 ac/h	15 ac/he
	Clean corridor	0		7 ac/h
	General access corridor	0		7 ac/h
	Changing rooms	3		7 ac/h
Dirty	Service corridor	0	–	(See note g)
	Utility room	–5 or 0	–	0.40 or 0.10

Notes:

Nominal room pressures are given to facilitate setting up of pressure-relief dampers, the calculation process, and the sizing of transfer devices. In practice, the resultant pressures are not immutable provided the desired airflow rates and movement directions are achieved.

An open or semi-open bay is considered to be part of the operating theatre; a low-level extract under the scrub trough is required. (See Chapter 8 paragraph 8.45 onwards and “Note” for more information.)

For design purposes, anaesthetic should be assumed to be at 15 Pa. When commissioning, equal to or greater than 10 Pa is considered suitable.

May need to be increased if scrub is large to promote scouring.

15 ac/h is considered necessary for the control of anaesthetic gas (see Appendix 9).

Supply airflow rate necessary to make up 7 ac/h after taking into account secondary air from cleaner areas.

No dilution requirement. Temperature control requirements only.

Appendix 4: Leakage flows in m³/s through closed door gaps

Pressure difference (Pa)

Table A3 Leakage flows through closed door gaps

Type	5	10	15	20	25	30	35	40
Single door	0.03	0.05	0.06	0.06	0.07	0.08	0.09	0.10
Single door + half	0.04	0.06	0.07	0.08	0.09	0.10	0.11	0.12
Double door	0.05	0.08	0.10	0.11	0.12	0.13	0.14	0.15

Designers' notes:

The door gaps assumed are 4 mm along the bottom, 3 mm at the top and sides, and 2 mm between double leaves.

If doors are fitted with cold smoke seals, these will significantly reduce the door leakage rate when new and undamaged. It is therefore recommended that provision for the design leakage be factored into the size of the appropriate transfer grille or pressure stabiliser. Failure to do this will result in air-gap whistles and doors being held partially open by air pressure.

Factory-assembled door-sets with a steel frame and pre-hung leaves are becoming common. There is effectively no leakage across these doors when closed. Therefore, when this type of door assembly is fitted, the door leakage can be ignored and the design airflow into the room reduced accordingly. The design airflow would then become that required either (i) for open door protection (Appendix 5), or (ii) to achieve the specified air-change rate – whichever is the greater.

Appendix 5: Recommended airflow rates in m³/s through a doorway between rooms of different cleanliness to control cross-contamination

Table A4 Flows through doorways

Room class		Dirty	Transitional	Clean	Sterile
Sterile	Hatch Single door	0.3	0.24	0.18	
	Double door	0.47	0.39	0.28	0 or 0.28a
Clean	Single door	0.39	0.28	0 or 0.28a	
	Double door	0.75	0.57	0 or 0.57a	
Transitional	Single door	0.28	0 or 0.28a		
	Double door	0.57	0 or 0.57a		
Dirty	Single door	0	Open single door = 0.80 m x 2.01 m high	Open single door = 0.80 m x 2.01 m high	Open single door = 0.80 m x 2.01 m high
	Double door	0	Open double door = 1.80 m x 2.01 m high	Open double door = 1.80 m x 2.01 m high	Open double door = 1.80 m x 2.01 m high

Designers' notes:

The degree of protection required at an open doorway between rooms is dependent on the degree of difference in cleanliness between them.

Flow-rate required between rooms within the same class tends to zero as class reduces.

If two rooms are of equal cleanliness, no flow is required (in practice there will be an interchange in either direction) and the design of the air movement will assume zero airflow. In certain cases, however, interchange is not permitted, and a protection airflow of 0.28 is assumed in the design – for example, in the case of a preparation room used as a “lay up”.

Appendix 6: Typical approximate pressures in an operating suite when a given door is open

Typical approximate effect on other rooms

Table A5 Pressure in room with open door

Door open between	Typical approximate resultant	Room	Pressure (Pa) pressure in these rooms (Pa)
Operating theatre and corridor or Scrub bay and corridor	0	Anaesthetic Preparation – lay-up Utility Preparation – sterile pack store	0 12 -6 5
Operating theatre and anaesthetic room (or other series room with double doors)	17	Preparation – lay-up Utility Preparation – sterile pack store	26 -9 22
Operating theatre and Utility room or Operating theatre and preparation room	25	No change	
Anaesthetic room and corridor (or other series room with double doors)	0	Preparation – lay-up Utility Operating theatre Preparation – sterile pack store	30 -6 20 25
Preparation room and corridor or Utility room and corridor	0	No change	
Utility room and outer corridor	0	No change	

Notes:

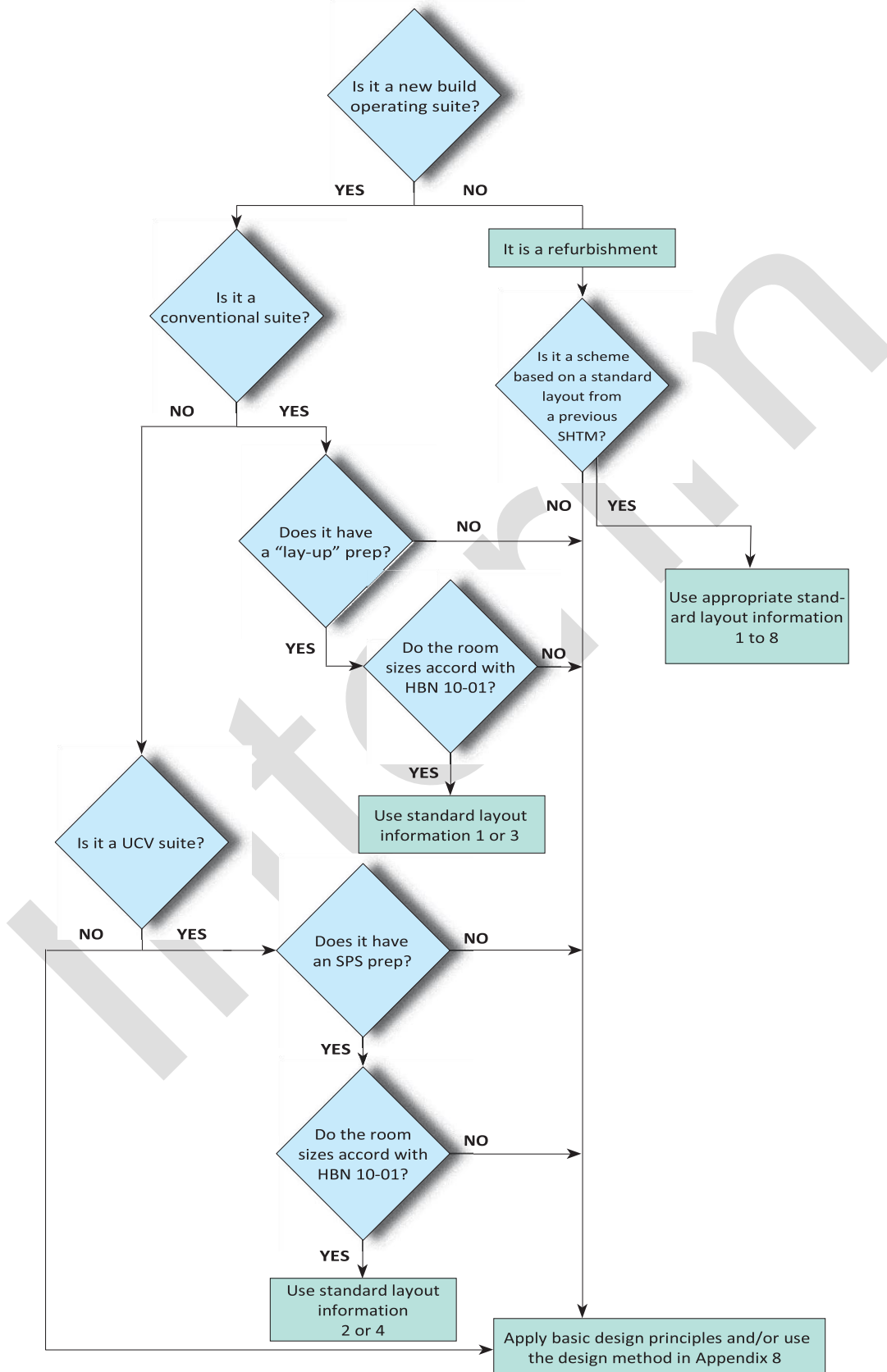
The room differential pressure protects against reverse flows when the door is closed.

The flow of air through a doorway protects against reverse airflow when the door is open.

Pressure stabilisers control flow and ensure a known airflow path between rooms when doors are closed and also reduce backflow between rooms when doors to other rooms are open.

Appendix 7: Operating suite design logic

Figure A5 Operating suite design logic



Standard layout 1 – Two-corridor conventional operating suite with “lay-up” prep

Table A6 Two corridor conventional operating suite with “lay up” prep design criteria

Room	Size (m3)‡	Air-change rate (ac/h)	Nominal pressure (Pa)	Flow rate (m3/s)
Theatre	165	≥22	25	Primary = 0.73 From Prep = 0.28 Total = 1.010
Anaesthetic	57	15	Design 15 Commissioned ≥10	0.24
Lay-up prep	36	≥22	35	0.28**
Scrub	*	–	25	–

Notes:

‡ Derived from Health Building Note 10-01 (2021). If room sizes differ from those given, recalculate the design air flows to achieve the air change rate or door protection.

*This is a separate scrub and is not considered as being part of the theatre volume.

**Interchange is not permitted between the theatre and lay-up prep; therefore, as in Appendix 5, an airflow protection of

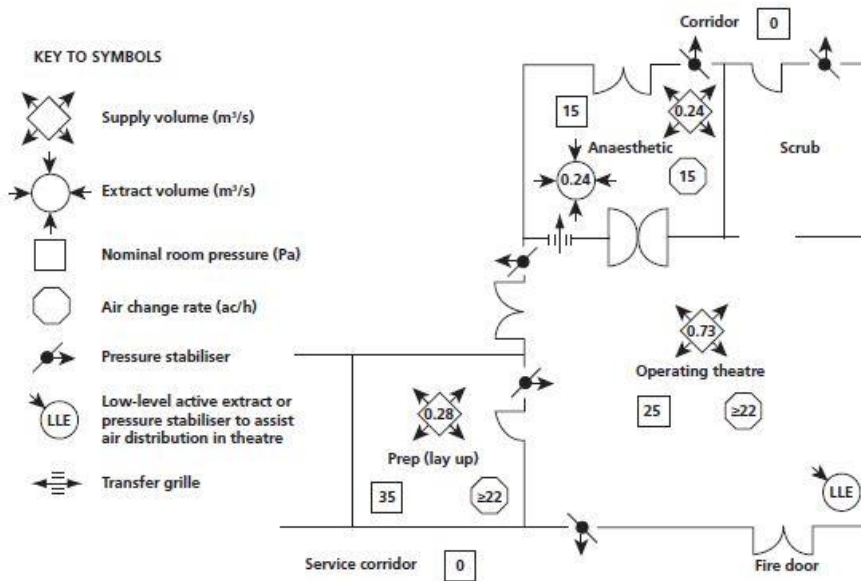
0.28 m3/s is required as a minimum (but see also the “designers’ notes” in Appendix 4).

N.B.If the lay-up prep also has a door or hatch to the corridor, its supply airflow volume would increase to 0.35 m3/s

The volume of air to be extracted from the theatre should be determined by subtracting the airflow required for door protection at the key door from the total air entering the space. The balance should be equally divided between the passive or active extract locations.

The extracts within the theatre and scrub may be either passive and fitted with pressure stabilisers or active and connected to the extract system. They should where possible be located at low level and positioned to promote the active ventilation and scouring of all areas of the space (see paragraph 8.92). Air transfer from theatre to anaesthetic room may be by pressure stabiliser or transfer grilles (see paragraphs A8.51 and A8.52 in Appendix 8). The anaesthetic room extract will be at low level (see Appendix 9).

Figure A6 Two corridor conventional operating suite with “lay up” prep, schematic layout



Standard layout 2 – two-corridor UCV operating suite with SPS prep

Table A7 Two corridor UCV operating suite with SPS design criteria

Room	Size (m3)‡	Air-change rate (ac/h)	Nominal pressure (Pa)	Flow rate (m3/s)
Theatre	165	≥22	25	# 1.01
Anaesthetic	57	15	Design 15 Commissioned ≥10	0.24
Sterile pack store prep	36	10	25	0.10
Scrub	*	–	25	–

Notes:

‡ Derived from Health Building Note 10-01 (2021). If room sizes differ from those given, recalculate the design air flows to achieve the air change rate or door protection.

* This is a separate scrub and is not considered as being part of theatre volume.

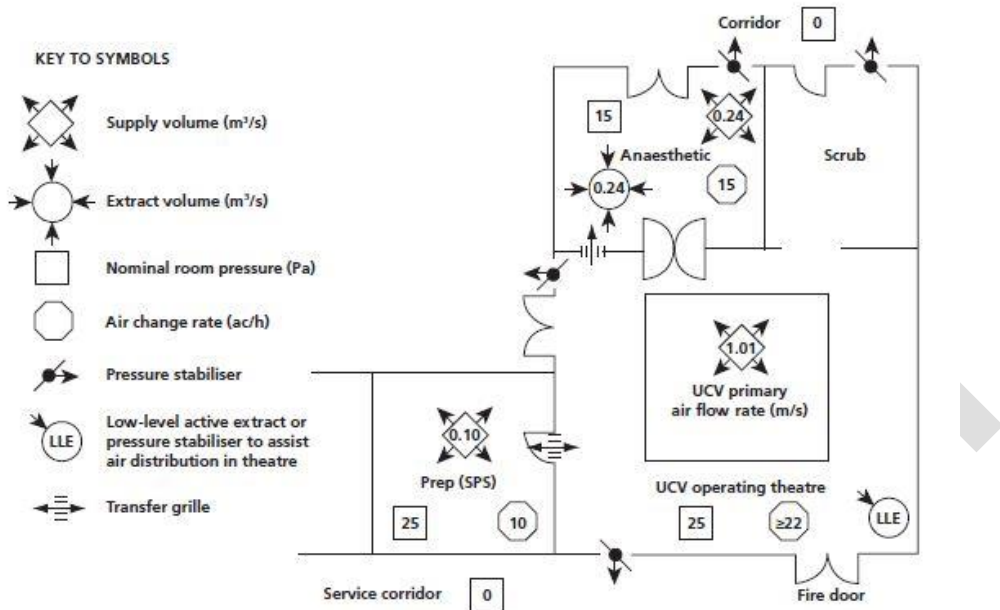
Primary fresh-air volume to UCV canopy only or ≥22 or door protection

The volume of air to be extracted from the theatre should be determined by subtracting the airflow required for door protection at the key door from the total air entering the space. The balance should be equally divided between the passive or active extract locations.

The extracts within the theatre and scrub may be either passive and fitted with pressure stabilisers or active and connected to the extract system. They should where possible be located at low level and positioned to promote the active ventilation and scouring of all areas of the space (see paragraph 8.92). Air transfer from theatre to anaesthetic room may be by pressure stabiliser or transfer grilles (see

paragraphs A8.51 and A8.52 in Appendix 8). The anaesthetic room extract will be at low level (see Appendix 9).

Figure A7 Two corridor UCV operating suite with SPS schematic layout



Standard layout 3 – single-corridor conventional operating suite with “lay-up” prep

Table A8 Single corridor conventional operating suite with “lay up” prep design criteria

Room	Size (m ³)‡	Air-change rate (ac/h)	Nominal pressure (Pa)	Flow rate (m ³ /s)
Theatre	165	≥22	25	Primary = 0.73 From Prep = 0.28 Total = 1.01
Anaesthetic	57	15	Design 15 Commissioned ≥10	0.24
Lay-up prep	36	≥22	35	0.35**
Scrub	*	–	25	–
Utility	36	–	–5	0.40

Notes:

‡ Derived from Health Building Note 10-01 (2021). If room sizes differ from those given, recalculate the design air flows to achieve the air change rate or door protection.

* This is a separate scrub and is not considered as being part of the theatre volume.

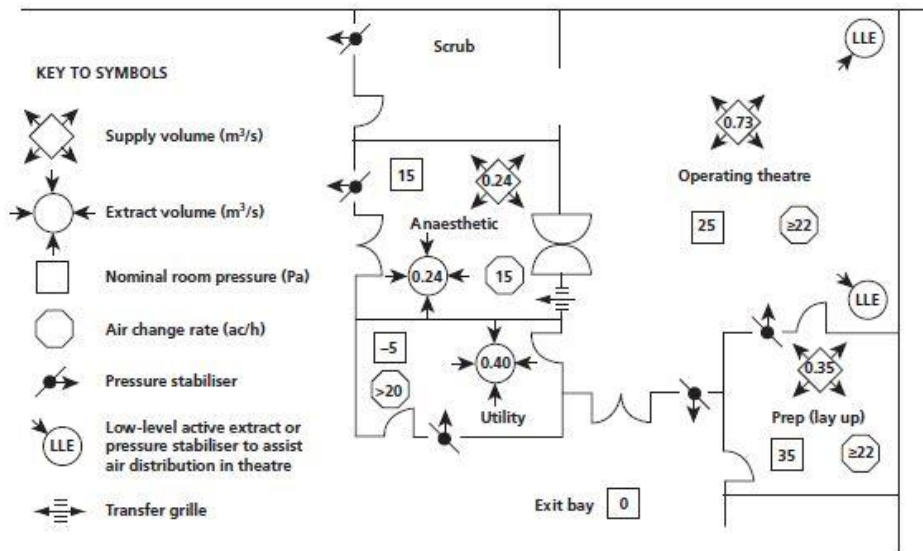
** Interchange is not permitted between the theatre and lay-up prep; therefore, as in Appendix 5, an airflow protection of 0.28

+ 0.07 closed-door airflow is required as a minimum (but see also the “designers’ notes” in Appendix 4).

The volume of air to be extracted from the theatre should be determined by subtracting the airflow required for protection at the key door from the total air entering the space. The balance should be equally divided between the passive or active extract locations.

The extracts within the theatre and scrub may be either passive and fitted with pressure stabilisers or active and connected to the extract system. They should where possible be located at low level and positioned to promote the active ventilation and scouring of all areas of the space (see paragraph 8.92). Air transfer from theatre to anaesthetic room may be by pressure stabiliser or transfer grilles (see paragraphs A8.51 and A8.52 in Appendix 8). The anaesthetic room extract will be at low level (see Appendix 9).

Figure A8 Single corridor conventional operating suite with “lay up” prep schematic layout



Standard layout 4 – single-corridor UCV operating suite with Lay-up prep

Table A9 single-corridor UCV operating suite with Lay-up prep design criteria

Room	Size (m ³)‡	Air-change rate (ac/h)	Nominal pressure (Pa)	Flow rate (m ³ /s)
Theatre	165	≥22	25	#1.01
Anaesthetic	57	15	Design 15 Commissioned ≥10	0.24
Sterile pack store prep	36	≥22	35	0.35**
Scrub	*	–	25	–
Utility	36	–	–5	0.4

Notes:

‡ Derived from Health Building Note 10-01 (2021). If room sizes differ from those given, recalculate the design air flows to achieve the air change rate or door protection.

* This is a separate scrub and is not considered as being part of the theatre volume.

** Interchange is not permitted between the theatre and lay-up prep; therefore, as in Appendix 5, an airflow protection of 0.28

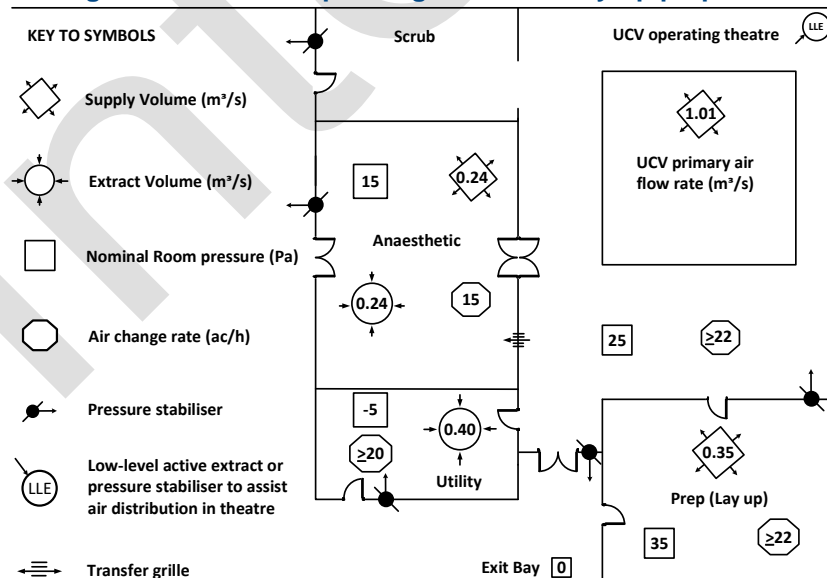
+ 0.07 closed-door airflow is required as a minimum (but see also the “designers’ notes” in Appendix 4).

Primary fresh-air volume for the UCV canopy or ≥ 22 ac/h or door protection

The volume of air to be extracted from the theatre should be determined by subtracting the airflow required for protection at the key door from the total air entering the theatre space. The balance should be equally divided between the passive or active extract locations.

The extracts within the theatre and scrub may be either passive and fitted with pressure stabilisers or active and connected to the extract system. They should where possible be located at low level and positioned to promote the active ventilation and scouring of all areas of the space (see paragraph 8.92). Air transfer from theatre to anaesthetic room may be by pressure stabiliser or transfer grilles (see paragraphs A8.51 and A8.52 in Appendix 8). The anaesthetic room extract will be at low level (see Appendix 9).

Figure A9 single-corridor UCV operating suite with Lay-up prep schematic layout



Standard layout 5 – (ex SHTM 2025 Plan 1b): single-corridor conventional operating suite with “lay-up” prep

Note: This layout and data is for historical purposes only. The information is to be used for the evaluation of existing systems, the fitting out of existing shell schemes or rebalancing of such systems following cleaning.

Table A10 (ex SHTM 2025 Plan 1b): single-corridor conventional operating suite with “lay-up” prep design criteria

Room	Size	Air-change rate (ac/h)	Nominal pressure (Pa)	Flow rate (m3/s)
Theatre	* See Notes below	≥22	25	# See Notes below
Anaesthetic	* See Notes below	15	Design 15 Commissioned ≥10	~ Supply and extract to achieve the air change rate
Lay-up prep	* See Notes below	≥22	35	0.35**
Scrub	* See Notes below	–	25	–
Utility	* See Notes below	>20	–5	0.40

Notes:

* Existing theatre suite rooms to be measured on site

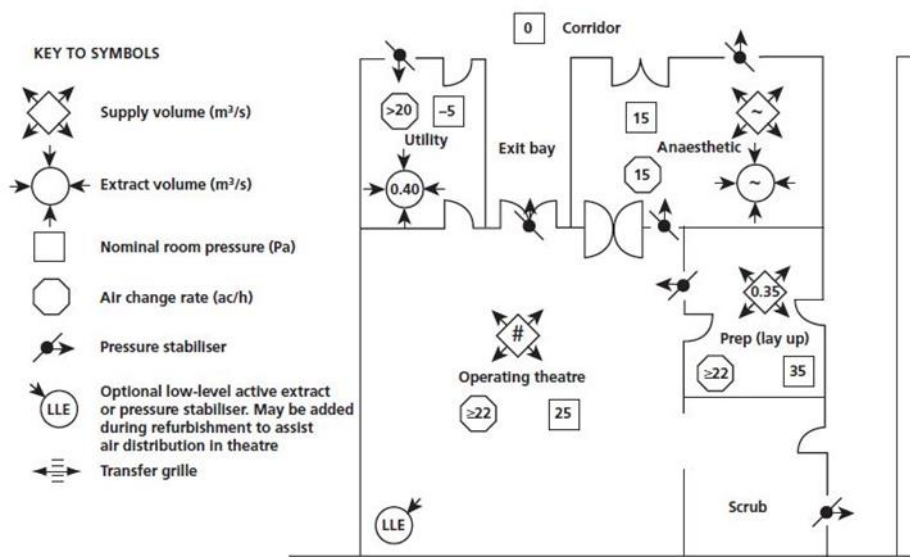
Total airflow related to volume of theatre to give ≥22 ac/h or door protection value = primary theatre supply + 0.28 m3/s from the Lay-up Prep pressure stabiliser

** See the “designers’ notes” in Appendices 4 and 5.

The utility layout design figures will remain the same if a hatch is fitted instead of a door onto the service corridor.

The extracts within the theatre and scrub may be either passive and fitted with pressure stabilisers or active and connected to the extract system. They should where possible be located at low level and positioned to promote the active ventilation and scouring of all areas of the space (see paragraph 8.92). Air transfer from theatre to anaesthetic room may be by pressure stabiliser or transfer grilles (see paragraphs A8.51 and A8.52 in Appendix 8). The anaesthetic room extract will be at low level (see Appendix 9).

Figure A10 (ex SHTM 2025 Plan 1b): single-corridor conventional operating suite with “lay-up” prep schematic layout



Standard layout 6 – (ex SHTM 2025 Plan 1a): single-corridor UCV operating suite with SPS prep

Note: This layout and data is for historical purposes only. The information is to be used for the evaluation of existing systems, the fitting out of existing shell schemes or rebalancing of such systems following cleaning. If difficulties are experienced with entrainment around the periphery of the UCV, adding a low-level active or passive extract in the location indicated will usually resolve the problem.

Table A11 (ex SHTM 2025 Plan 1a): single-corridor UCV operating suite with SPS prep design criteria

Room	Size	Air-change rate (ac/h)	Nominal pressure (Pa)	Flow rate (m3/s)
Theatre	* See Notes below	≥22	25	# See Notes below
Anaesthetic	* See Notes below	15	Design 15 Commissioned ≥10	~ Supply and extract to achieve the air change rate
Sterile pack store prep	* See Notes below	10	25	0.1
Scrub	* See Notes below	–	25	–
Utility	* See Notes below	–	–5	0.4

Notes:

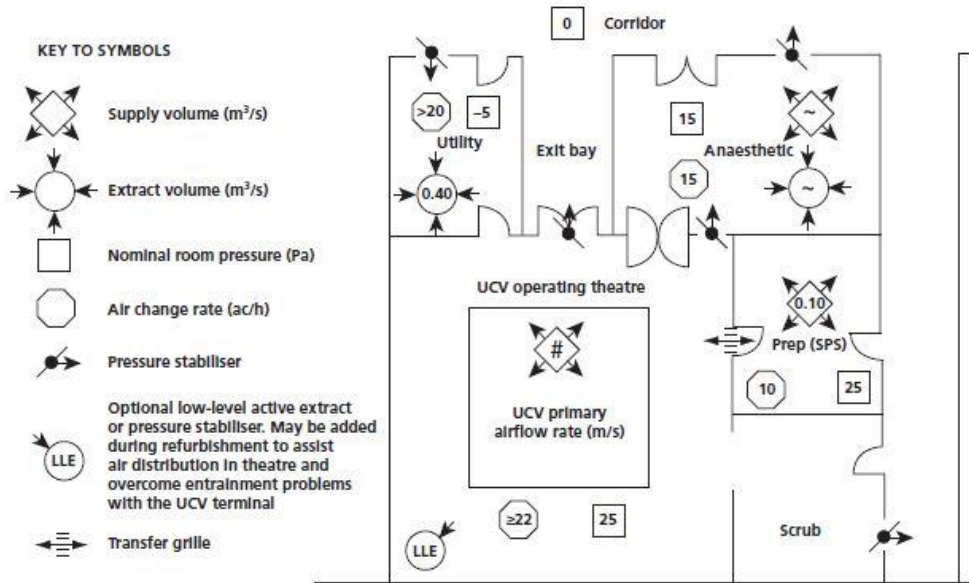
* Existing theatre suite to be measured on site

Theatre total airflow related to volume of theatre to give ≥22 ac/h or door protection value

The utility layout design figures will remain the same if a hatch is fitted instead of a door onto the service corridor.

The extracts within the theatre and scrub may be either passive and fitted with pressure stabilisers or active and connected to the extract system. They should where possible be located at low level and positioned to promote the active ventilation and scouring of all areas of the space (see paragraph 8.92). Air transfer from theatre to anaesthetic room may be by pressure stabiliser or transfer grilles (see paragraphs A8.51 and A8.52 in Appendix 8). The anaesthetic room extract will be at low level (see Appendix 9).

Figure A11 (ex SHTM 2025 Plan 1a): single-corridor UCV operating suite with SPS prep schematic layout



Standard layout 7 – (ex SHTM 2025 Plan 5b): two-corridor conventional operating suite with “lay-up” prep

Note: This layout and data is for historical purposes only. The information is to be used for the evaluation of existing systems, the fitting out of existing shell schemes or rebalancing of such systems following cleaning.

Table A12 (ex SHTM 2025 Plan 5b): two-corridor conventional operating suite with “lay-up” prep design criteria

Room	Size	Air-change rate (ac/h)	Nominal pressure (Pa)	Flow rate (m3/s)
Theatre	* See Notes below	≥22	25	# See Notes below
Anaesthetic	* See Notes below	15	Design 15 Commissioned ≥10	~ Supply and extract to achieve the air change rate
Lay-up prep	* See Notes below	≥22	35	0.35**
Scrub	* See Notes below	–	25	–
Utility	* See Notes below	–	0	0.1

Notes:

* Existing theatre suite to be measured on site

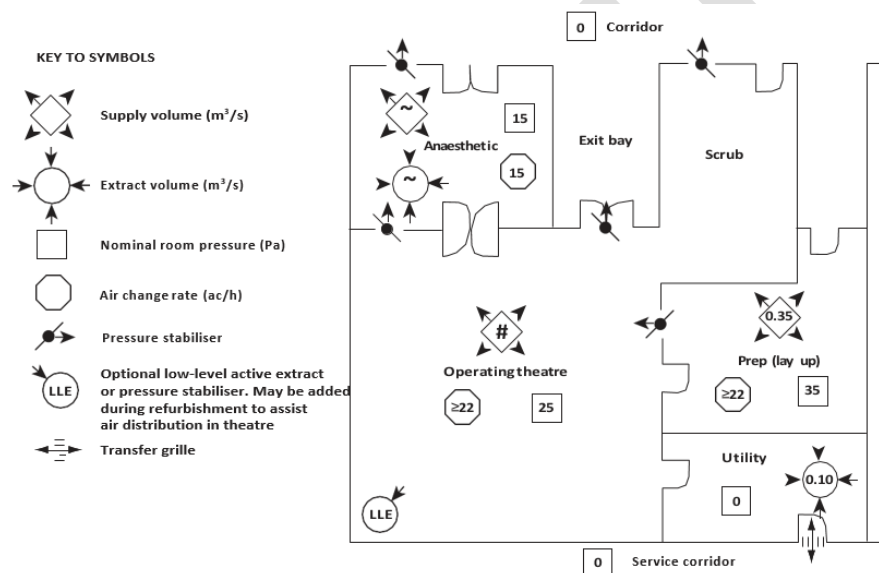
Theatre total airflow related to volume of theatre to give ≥ 22 ac/h or door protection
 = primary theatre supply + 0.28 m³/s from Lay-up Prep pressure stabiliser

** See the “designers’ notes” in Appendices 4 and 5

The utility design figures will remain the same if a hatch is fitted instead of a door onto the service corridor. Alternatively, if the operating department has a central waste processing station, the utility room may be omitted and replaced with a hatch between the theatre and service corridor.

The extracts within the theatre and scrub may be either passive and fitted with pressure stabilisers or active and connected to the extract system. They should where possible be located at low level and positioned to promote the active ventilation and scouring of all areas of the space (see paragraph 8.92). Air transfer from theatre to anaesthetic room may be by pressure stabiliser or transfer grilles (see paragraphs A8.51 and A8.52 in Appendix 8). The anaesthetic room extract will be at low level (see Appendix 9).

Figure A12 (ex SHTM 2025 Plan 5b): two-corridor conventional operating suite with “lay-up” prep schematic layout



Standard layout 8 – (ex SHTM 2025 Plan 5a): two-corridor UCV operating suite with SPS prep

Note: This layout and data is for historical purposes only. The information is to be used for the evaluation of existing systems, the fitting out of existing shell schemes or rebalancing of such systems following cleaning. If difficulties are experienced with entrainment around the periphery of the UCV, adding a low-level active or passive extract in the location indicated will usually resolve the problem.

Table A13 (ex SHTM 2025 Plan 5a): two-corridor UCV operating suite with SPS prep design criteria

Room	Size	Air-change rate (ac/h)	Nominal pressure (Pa)	Flow rate (m3/s)
Theatre	* See Notes below	≥22	25	# See Notes below
Anaesthetic	* See Notes below	15	Design 15 Commissioned ≥10	~ Supply and extract to achieve the air change rate
Sterile pack store prep	* See Notes below	10	25	0.1
Scrub	* See Notes below	–	25	–
Utility	* See Notes below	–	0	0.1

Notes:

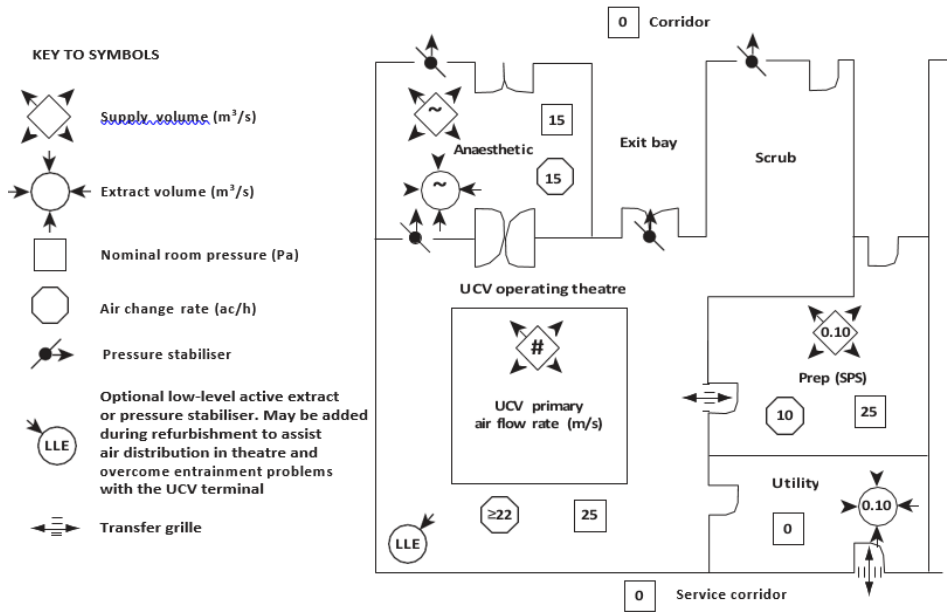
* Existing theatre suite to be measured on site

Primary fresh supply air for the UCV canopy is related to volume of theatre to give ≥22 ac/h or door protection

The utility design figures will remain the same if a hatch is fitted instead of a door onto the service corridor. Alternatively, if the operating department has a central waste processing station, the utility room may be omitted and replaced with a hatch between the theatre and service corridor.

The extracts within the theatre and scrub may be either passive and fitted with pressure stabilisers or active and connected to the extract system. They should where possible be located at low level and positioned to promote the active ventilation and scouring of all areas of the space (see paragraph 8.92). Air transfer from theatre to anaesthetic room may be by pressure stabiliser or transfer grilles (see paragraphs A8.51 and A8.52 in Appendix 8). The anaesthetic room extract will be at low level (see Appendix 9).

Figure A13 (ex SHTM 2025 Plan 5a): two-corridor UCV operating suite with SPS prep schematic layout



Appendix 8: Design of air- movement control schemes for operating theatres

General

- A8.1 Standard operating suite design solutions are given in paragraphs 8.27–8.74 and Appendix 7. If these standard solutions cannot be used, the following procedure should be adopted, which will result in an acceptable design. Note that the method employed may equally be used to provide a design solution to a ventilated suite of rooms for any application.
- A8.2 The method is concerned with the calculation of air-flow rates to ensure that correct air movement occurs between rooms when any one door is open. Under most circumstances, the air quantities required for air-movement control will approximate to those for either temperature control or bacterial contaminant dilution. This flow rate is sufficient to control the effects of any slight reverse flows occurring when a door is opened.
- A8.3 The progression through the design procedure is shown in the air-flow design procedure chart (Figure A24) and is supported by worksheets WS1 to WS7 described in paragraph A8.4. It is recommended that a plan of the suite and an air-flow network be made (Figure A23) to collate all information. Flow rates, air- transfer devices etc should be entered as required. The remainder of this Appendix may be treated as reference data to assist in the various steps. The following symbols are used:
- SS – supply air-flow rate for summer temperature control;
 - SW – supply air-flow rate for winter temperature control;
 - SD – supply air-flow rate for dilution of bacterial contaminants;
 - SL – supply air-flow rate for heat loss;
 - SG – supply air-flow rate for heat gain;
 - ED – extract air-flow rate for dilution of bacterial contaminants;
 - SF – final supply air-flow rates
 - EF – final extract flow rates;
 - SAMC – air-supply flow rate for air- movement control;
 - EAMC – air-extract flow for air- movement control;
 - LOUT – leakage air-flow rate outward;
 - LIN – leakage air-flow rate inward;
 - Σ OUT - total air-flow rate outward;

Σ IN total air-flow rate inward.

- A8.4 To simplify the procedure, standard worksheets (WS1 to WS7) have been devised. For each operating suite, a set is required comprising one each of WS1, WS3, WS5, WS6a, WS6b and WS7, one WS4 for each corridor and one WS2 to cover each peripheral room. WS2 has five versions:

WS2a single flow,

WS2b parallel/series multi-flow,

WS2c parallel multi-flow or series multi-flow (unbalanced);

WS2d series multi-flow (balanced); and

WS2e bay (semi-open).

Peripheral room type

- A8.5 The rooms in the operating suite other than the operating theatre and corridor are referred to as peripheral rooms. Peripheral rooms have been classified according to the flows in and out. These room classifications are defined in paragraphs A8.6–A8.11.

Single flow

- A8.6 This is a room with only one door and a net surplus of supply or extract air.

Parallel multi-flow

- A8.7 This is a room with two or more doors through each of which the air flows either outwards (high pressure) or inwards (low pressure) (for example the Prep (lay-up) in standard layout 5 in Appendix 7).

Parallel/series multi-flow

- A8.8 This is a room having a net surplus of supply or extract and with two or more doors. One or more doors will be to an area of equal cleanliness and need not be protected; hence, the flow may vary between inwards and outwards, the remaining door being to an area of greater or lesser cleanliness (for example the Prep (SPS) in standard layout 6 in Appendix 7).

Series multi-flow (unbalanced)

- A8.9 This is a room having a net surplus of supply or extract and with two or more doors. Air flows inwards through one or more doors and outwards through one or more doors.

Series multi-flow (balanced)

- A8.10 This is a room as in paragraph A8.9 above, but having either no mechanical ventilation or no net surplus of supply or extract (for example an anaesthetic room).

Bay

- A8.11 A room which has a permanent opening to the operating theatre may be considered as a bay off the latter (for example a scrub). Two categories exist:

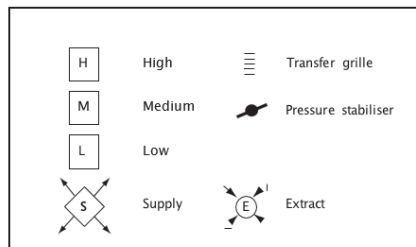
open bay – the opening is larger than a normal single door opening. The bay may be considered as part of the main room;

semi-open bay – the opening is no larger than a normal single door opening. In this case it is possible to protect the bay from the main room by provision of air supply or extract in the bay, or by passing air to or from another area.

Air-movement control in peripheral rooms

- A8.12 For the design of air-movement control, two types of air-transfer device are considered. These are transfer grilles and pressure stabilisers. Each has a particular field of application within the design, as described in paragraphs A8.34– A8.43. Air movement is controlled in each of the different room types described in paragraphs A8.13–A8.31.

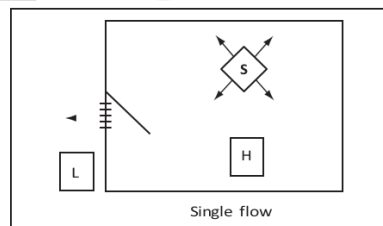
Figure A14 Key to symbols



Single flow rooms

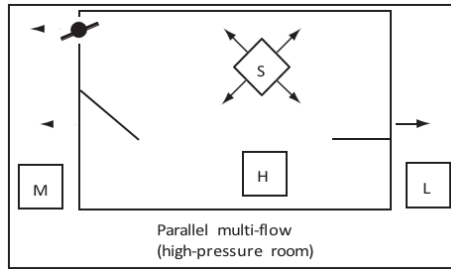
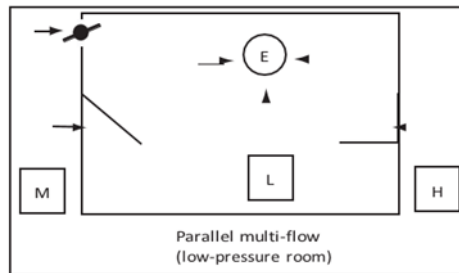
- A8.13 An appropriately-sized transfer grille should be located in or adjacent to the door of each single flow room to relieve the pressure differences across the door when closed.

Figure A15 Single flow room solution high–pressure room



Parallel multi-flow rooms

- A8.14 The pressure difference across the closed doors should be relieved, but transfer grilles are not appropriate where two doors lead to areas of different pressures, because reverse flow could occur when the other door is open. For this reason, pressure stabilisers are used.

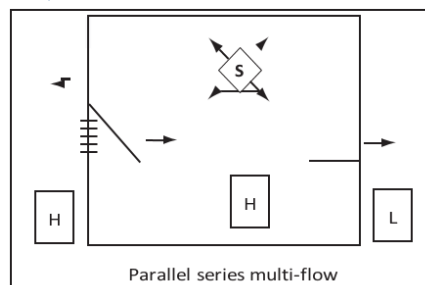
Figure A16 Parallel, multi-flow room solution high-pressure**Figure A17 Parallel, multi-flow room solution low-pressure**

A8.15 These rooms will be either high- pressure or low-pressure with respect to the adjacent areas (see preparation lay-up room and disposal room, respectively, in standard layout 5 of Appendix 7). The pressure-relief damper is always situated between the room and area, which results in the smaller differential pressure to ensure best use of air.

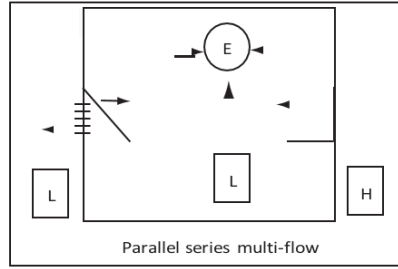
A8.16 Just as reverse flow can occur if transfer grilles are used, it can similarly occur via door gaps when the other door is opened. It is not possible to avoid this, except by using air locks, but due to the low flow rates and short durations involved, this is not considered to be of importance.

Parallel-series multi-flow rooms

A8.17 These rooms are similar to those in paragraph A8.14 above, but because the room is of equal cleanliness to one of the adjacent rooms, the nominal pressures will be equal and air may flow through the adjoining doorway in either direction (for example the Prep (SPS) in standard layout 6 of Appendix 7).

Figure A18 Parallel, series multi-flow room solution high-pressure

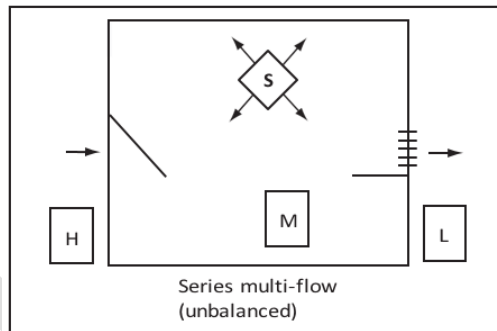
A8.18 Where the nominal room pressure equals that of the higher-pressure adjacent room, the best use of air is by supplying air required for bacterial dilution only and allowing this to exhaust via a transfer grille to the area of equal cleanliness. The doorway to the lower pressure area is protected by the combination of the supply air and the air that will flow inwards through the transfer grille from the area of equal cleanliness.

Figure A19 Parallel, multi-flow room solution low-pressure

- A8.19 Conversely, where the nominal pressure equals that of the lower-pressure adjacent room, extract ventilation and a transfer grille to the lower pressure adjacent room should be provided (for example the disposal room in standard layout 8 of Appendix 7).

Series multi-flow (unbalanced)

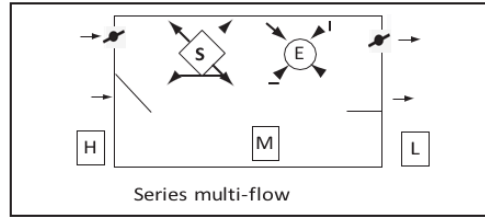
- A8.20 These rooms are somewhat similar to those in paragraph A8.15 above, but because the pressure lies between that of the rooms on either side, the back-flow problem does not exist.

Figure A20 Series, multi-flow room solution medium-pressure

- A8.21 Where the room has a net surplus of mechanical supply air, a transfer grille should be located in or adjacent to the door through which air flows outwards, and the mechanical supply flow rate to the room should be chosen to give protection when this door is open.
- A8.22 Where the room has a net surplus of mechanical extract air, a transfer grille should be located adjacent to the door through which the air flows inwards, and the mechanical extract flow rate to the room should be chosen to give protection when this door is open.
- A8.23 The grille should be sized for the protection requirement of the opposing door when open. When the room on the high-pressure side depressurises, there is a possibility of back-flow through gaps around the door, but this problem may be ignored.

Series multi-flow (balanced)

- A8.24 In these rooms, a transfer device adjacent to each doorway is required in order to provide a flow path for the air required to protect the opposing door when opened.

Figure A21 Series, multi-flow room solution medium-pressure

- A8.25 These transfer devices will normally be pressure stabilisers, although transfer grilles may be used where a large amount of excess air is to be exhausted from the operating theatre when all doors are closed (for example anaesthetic rooms).
- A8.26 The calculation procedure is to assume that pressure stabilisers are being used; then – if there is sufficient excess air – change to transfer grilles as described in paragraph A8.50.

Bay

Open bay

- A8.27 A bay of the open type (for example scrub-up) is considered to be part of the operating theatre. There should be an active or passive extract/pressure stabiliser under, or directly adjacent to, the scrub trough.

Semi-open bay

- A8.28 In a bay of the semi-open type, protection of one area from the other is possible (for example scrub-up).
- A8.29 As stated previously, the need for protection between operating theatre and scrub-room is not very great. Better use of air can therefore be achieved in this case by installing a pressure stabiliser between the scrub-room and clean corridor. This will allow a flow of air through the scrub-room at all times, except when a door is opened elsewhere in the suite. The pressure stabiliser will then close and the air will be diverted to the other door. When it is considered necessary to protect the scrub-room at all times, either a transfer grille to the corridor or mechanical extract in the scrub-room should be provided.

Operating theatre

- A8.30 Once the peripheral rooms have been considered, the operating theatre requirements may then be decided and the supply flow rate required for air-movement control calculated. This flow rate should be such that, with any one door open, the correct air movement directions are maintained. There will be one door in the suite that will require the largest supply flow rate to the operating theatre for protection when open. This is called the “key door” and is discussed separately in paragraph A8.33. Use of this concept avoids repetitive calculations for each door in turn. Having established the required supply flow rate, a relief route should be provided to the clean corridor for any excess air when the doors are closed. This would be via transfer grilles or pressure stabilisers through a series-flow room or via pressure stabilisers to the clean corridor directly.

Corridors

- A8.31 All surplus air from the suite, except that lost through structure leakage and any passing to the outer corridor, will arrive in the patient/staff corridor. Should this air be insufficient to achieve the required air- change rate (see Appendix 3), some additional air supply should be provided. (The air balance should take account of structural leakage.)
- A8.32 Whereas the resulting pressures are dependent on ductwork layout, room relationships and characteristics of the fan, the generalisations shown in Appendix 6 may be used to estimate the change in room pressure when a door is opened.
- A8.33 The “key door” will be the open double door which leaves the operating theatre at the highest pressure, and/or requires the largest air flow. This should be determined using the procedure in worksheet WS3.

Transfer grilles

- A8.34 These may be used to limit the pressure differences across the closed door of a single-flow room or, in some instances, for protection of a series-flow or parallel-series-flow room. They allow air flow in both directions and may not be suitable for all applications.
- A8.35 The free area of a grille is calculated from the following equation:

$$A = \frac{Q}{0.84\sqrt{\Delta P}}$$

where:

A is free area (m²)

Q is flow rate (m³/s)

P is pressure difference (Pa)

0.84 is the grille's resistance- correction factor.

- A8.36 The flow through a grille at a different pressure may be found from the following equation:

$$Q_2 = Q_1 \sqrt{\frac{\Delta P_1}{\Delta P_2}}$$

where:

Q₁ and P₁ are original flow and differential pressure

Q₂ and P₂ are new flow and differential pressure.

- A8.37 The transfer grille may be replaced by carefully proportioned door undercuts of the equivalent free area.

- A8.38 The function of the transfer grille is to provide a means of air-flow control by which the volume and pressure loss can be established. If a grille is used, it should have an easily removable core to facilitate cleaning.

Pressure-relief dampers

- A8.39 The functions of a pressure-relief damper are now carried out by pressure stabilisers. Accordingly, all mention of them has been removed from this document.

Pressure stabilisers

- A8.40 Pressure stabilisers can be adjusted to hold the pressure constant over a wide range of flow rates. They are used where requirements exist for accurate room- pressure control or rapid shut-off on pressure fall.
- A8.41 The installation of a grille or baffle in association with a stabiliser will alter the operating characteristics. It is recommended that a location be chosen to avoid the need for visual screening, for example, at high level. The location should be chosen to minimise the likelihood of damage.
- A8.42 The stabilisers used should be virtually silent in operation, adjustable on site, maintenance-free and of a type which cannot be wrongly inserted. They should not be used in external walls or where the pressure difference is less than 5 Pa. The required size of a pressure stabiliser is dependent on the design pressure difference across it and flow rate through it. The manufacturer should provide data relating pressure difference to mean velocity (or flow rate per unit area). From this, the required area can be calculated and then rounded-up to the nearest size manufactured or nearest combination of smaller sizes.
- A8.43 It is sometimes possible to arrange for a pressure stabiliser to perform two tasks. In an anaesthetic room, for example, the two pressure stabilisers may be made to pass the open door protection air, and also control the operating and anaesthetic room pressures with the door closed. To achieve this, the stabilisers are sized for the flow rate required with one of the doors open, but the pressure setting is adjusted to be the value required with the doors closed.

This is shown in Figure A22.

Door leakage flows

- A8.44 For an air-movement control scheme to work satisfactorily, it is essential that the estimates of door-gap leakage made at the design stage are closely related to those which are achieved in practice. The calculation of gap-flows is complicated by the fact that such flows generally fall into the transition region between laminar and turbulent flow and hence do not follow the normal flow equations. The gaps assumed are 4 mm along the bottom, 3 mm at the top and sides, and 2 mm between double leaves. Doors should not have wider gaps than these. Tighter gaps would result in lower flow-rate requirements and hence lower fan power, but care should be taken to ensure that all doors in the suite have similar gap dimensions. It may be possible to

ignore the door leakage and so reduce the air-flow requirement (see the “designers’ notes” in Appendix 4).

Room temperature estimation

A8.45 The air-flow rate required to prevent back-flow through an open door is dependent on the temperature difference across the door. The design figures shown in Appendix 6 are based on the temperature differences that will normally occur in practice, assuming heat gains and losses in accordance with Appendix 4.

A8.46 At step 11 of the air-flow design process, the temperature differences across the doors of all rooms classed as “sterile” are calculated. Worksheet WS6 is recommended for the calculations, using the following criteria:

- a. assume that the operating theatre is being controlled at 20°C and calculate the incoming air-supply temperature as shown on worksheet WS6;
- b. the calculation should be repeated for both summer and winter conditions, with an operation in progress;
- c. assume all doors are closed;
- d. use the room supply flow rates from WS1;
- e. use the inward air flows through air-transfer devices and closed door leakages from WS2a to WS2E;
- f. the formula used in worksheet WS6 is as follows:

$$T = \frac{(t_1 Q_1 + t_2 Q_2 + \dots + t_n Q_n) + 0.828H}{(Q_1 + Q_2 + \dots + Q_n)}$$

where:

Q = flow rate from source (m³/s)

t = the temperature of source (°C)

H = the room heat gain (kW).

A8.47 If the evaluated temperature differences between rooms do not exceed 2°C, the solution is satisfactory; otherwise proceed as follows:

- (i) check the assumption on which the heat gains are based;
- (ii) take steps to reduce the heat gains;
- (iii) if the door is to a corridor, the flow through the open door will be larger than the value given in Appendix 6. Calculate on WS3, assuming it is the “key door” with door-flow unknown, and the supply as known;
- (iv) if the door leads to a room with mechanical supply, install a trimmer heater in the supply to the room controlled by either a differential thermostat or a

thermostat slaved to the operating theatre thermostat to ensure that T is minimised;

- (v) if the door leads to a room with no mechanical supply, increase the door protection flow as follows:

$$Q_{\text{new}} = Q_{\text{old}} \frac{2}{[\Delta T + 1]}$$

- A8.48 These options should be considered in this order, and (i), (ii) and (iii) should be investigated thoroughly before proceeding to (iv) or (v). The mechanical supply may need to be increased in order to achieve the desired air-change rates.

Relief of excess air from operating theatre when all doors are closed

- A8.49 As the mechanical supply to the operating theatre is sized to provide an appropriate flow outwards through any door which is opened, it follows that when all doors are closed, there will be more air supplied to the operating theatre than can exit from it via leaks etc. This “excess” air can be relieved by either of the two methods described in paragraphs A8.50– 8.54.

By transfer devices via the anaesthetic room

- A8.50 The transfer device (pressure stabiliser or transfer grille) between the theatre and anaesthetic room needs to accommodate an air volume of 0.46 m³/s at 20 Pa (see Appendix 6) when the door between the anaesthetic room and corridor is open. An additional 0.11 m³/s will pass through the door gaps of the theatre to anaesthetic door to give a total door flow protection figure of 0.57 m³/s through the open door between the anaesthetic room and corridor. The optimum duty for this device with all the doors closed would be 0.33 m³/s at the room differential of 10 Pa. The following equation shows how this figure is arrived at:

$$\begin{aligned} Q &= \frac{Q_1}{\frac{(\sqrt{\Delta P_2})}{\Delta P_1}} \\ &= \frac{0.46}{\frac{(\sqrt{\Delta 20})}{\Delta 10}} \\ &= 0.33 \text{m}^3/\text{s} \end{aligned}$$

where:

Q = excess air to be vented with doors closed

Q₁ = airflow required for door protection through the transfer device

ΔP₁ = nominal differential pressure with door to operating theatre closed and door to corridor closed

ΔP_2 = nominal differential pressure between the operating theatre and anaesthetic room when the corridor door is open.

- A8.51 If the excess air is less than 0.33 m³/s, a pressure stabiliser is required to ensure that the correct pressure and protection airflow is available to pass through the door.
- A8.52 If the excess air is greater than 0.33 m³/s, a transfer grille is acceptable because at all times the airflow will exceed the flow required for pressure and door protection.

By pressure stabilisers to the corridor

- A8.53 If it is undesirable to pass all the extra remaining air volume through the anaesthetic room after the door flow- protection volumes have been achieved, it may be passed from the theatre directly to the corridor via a separate pressure stabiliser.
- A8.54 If there is sufficient excess air, the transfer grille solution at paragraph A8.52 should be adopted, as it provides the simplest solution and, once set up, will require no further maintenance. With less excess air, it is recommended that the air be passed through the anaesthetic room via the pressure stabilisers as at paragraph A8.51, thus keeping the number of pressure stabilisers to a minimum. Both these solutions increase the air-change rate in the anaesthetic room, but care should be taken to avoid passing excessive amounts through that would cause discomfort to the occupants.

Figure A22: Pressure stabilisers performing two tasks

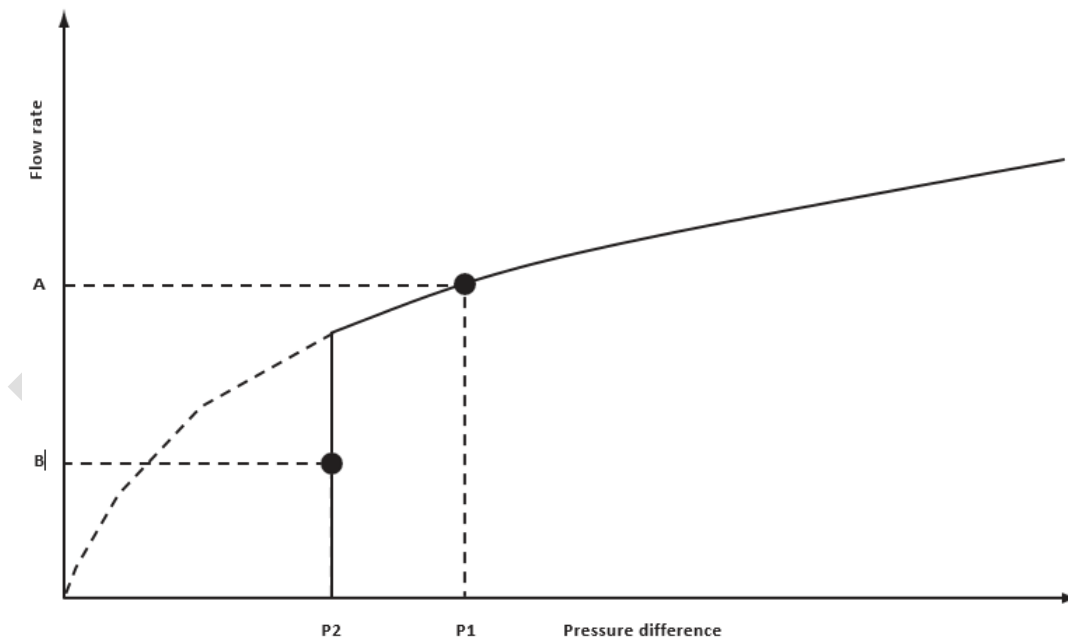


Figure A23: An example of an air-flow network

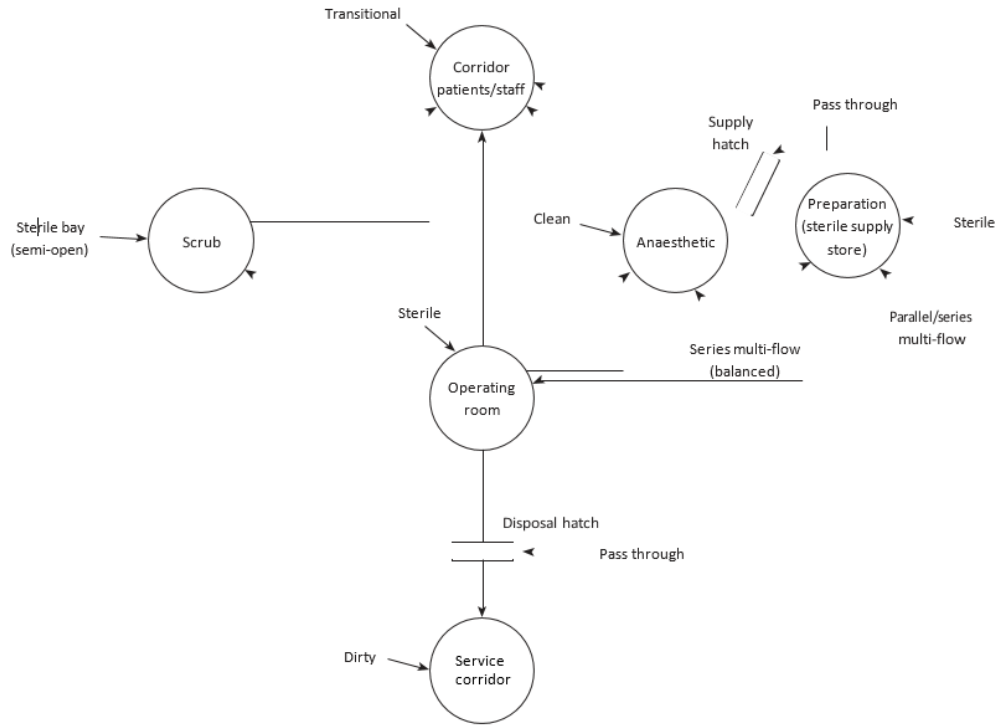
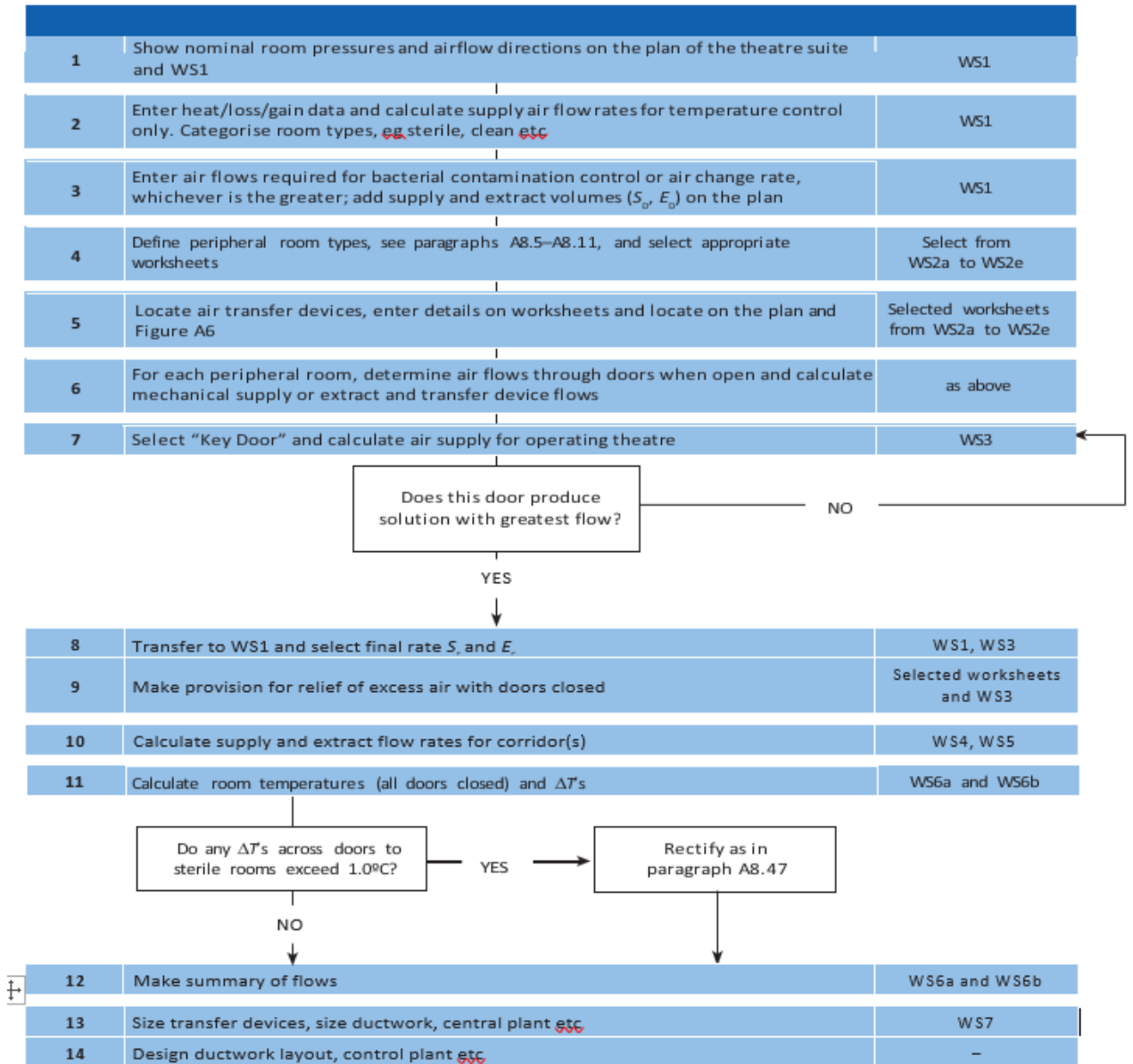


Figure A24: Air-flow design procedures



Calculation sheet for flow rates

Worksheet WS1

Reference:

Room name					
1. Summer temperature control Heat gain	kW				
2. Acceptable Δt	°C				
3. Air flow rate (S_G) = $\frac{\text{Gain}}{\Delta t \times 1.2}$	m ³ /s				
4. Winter temperature control Heat loss	kW				
5. Acceptable Δt	°C				
6. Air flow rate (S_L) = $\frac{\text{Loss}}{\Delta t \times 1.2}$	m ³ /s				
7. Dilution of bacterial contaminants Air flow rate S_D or E_D	m ³ /s				
8. Desired air change rate $\frac{\text{AC/hr} \times \text{room volume (m}^3\text{)}}{3600}$	AC/hr				
	m ³ /s				
9. Maximum of S_G , S_L , S_D or E_D or air change rate from step 8	m ³ /s				
10. Air movement control Air flow rate for air movement control S_{AMC} or E_{AMC} (from WS2, WS3 or WS4)	S m ³ /s				
	E m ³ /s				
11. Final supply flow rate (S_P)	m ³ /s				
12. Final extract	m ³ /s				
13. Total supply		m ³ /s			
14. Total extract		m ³ /s			

Designer Date

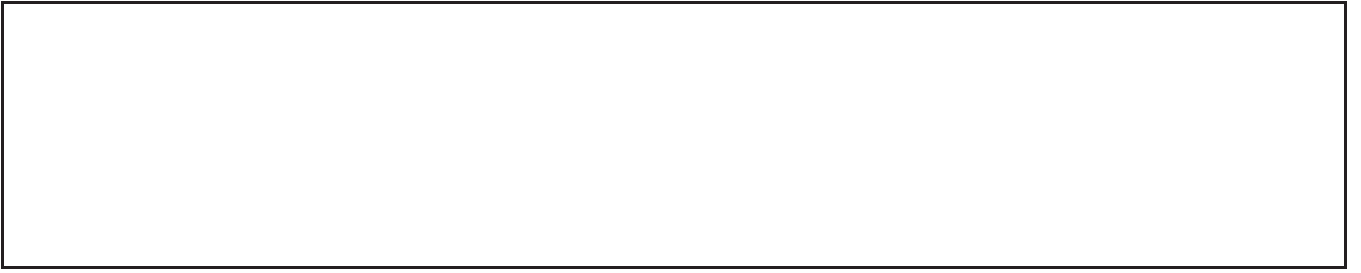
Template A1 Worksheet WS1

Air movement control Peripheral room type, parallel/series multi-flow			Worksheet WS2b Reference:		
			Nominal pressure: _____ Pa		
Door from this room to (room of equal cleanliness) is not to be protected. A transfer grille is located in, or adjacent to, this door					
Consider other door to open. Room pressure now becomes _____ or _____ or _____ Pa (see Appendix 6)					
			Air flow, m3/s		
			Out	In	Remarks
Flow required through doorway to give protection					
At above pressures leaks through closed doors	Pa	ΔP			
Mechanical supply or extract (S_r/E_r)					
Total					
$X (\sum_{OUT} - \sum_{IN})$			or $Y (\sum_{IN} - \sum_{OUT})$		
Transfer grille required from high-pressure zone Flow = X or _____ at _____ ΔPa to low-pressure zone Flow = Y Size of transfer grille (free area) A1 _____					
Consider doors and hatch closed – room pressure becomes			Pa (nominal)		
Closed door leakage from Appendix 4 (assuming no transfer grille)	Pa	ΔP	Out	In	Remarks
Mechanical supply or extract					
Total					
Air flow required through transfer grille = IN – OUT = Z' or OUT – IN = Z'' _____					
Transfer grille required flow Z' or Z'' _____ @ _____ ΔP					
Size of transfer grille (free area) A2 = _____					
Select larger of A1 or A2 _____					

Designer Date

Template A3 Worksheet WS2b

Air movement control Peripheral room type, parallel multi-flow high/low or series multi-flow (unbalanced)			Worksheet WS2c Reference:			
			Nominal pressure: _____ Pa			
Consider door from this room to open. Room pressure now becomes _____ or _____ or _____ Pa (see Appendix 6)						
Flow required through open doorway to give protection			Air flow, m ³ /s			
			Out	In	Remarks	
At above pressures leaks through closed doors are:			Pa	ΔP		
Total						
$S_1 (\sum_{OUT} - \sum_{IN})$			or $E_1 (\sum_{IN} - \sum_{OUT})$			
Consider door from this room to open. Room pressure now becomes _____ or _____ or _____ Pa						
Flow required through open doorway to give protection			Out	In	Remarks	
At above pressures leaks through closed doors are:			Pa	ΔP		
Total						
$S_2 (\sum_{OUT} - \sum_{IN})$			or $E_2 (\sum_{IN} - \sum_{OUT})$			
Consider doors closed. Closed doors leakage from Appendix 4						
Door to:	Pa	ΔP	Out	In	Remarks	
Total						
Return S_f and E_f from WS1 _____ Flow through transfer device outward ($S_f - L_{OUT}$) or _____ to Flow through transfer device inward ($E_f - L_{IN}$) Transfer grille _____ Pressure relief damper _____ from						



Designer Date

Template A4 Worksheet WS2c

Interim

Flow through transfer device (TD1) to protect
door 1 = $Q1$ _____ at resultant
 ΔP

Flow through transfer device (TD2) to protect
door 2 = $Q2$ _____ at resultant
 ΔP

Designer Date

Template A5 Worksheet WS2d

Interim

Air movement control Peripheral room type bay (semi-open)			Worksheet WS2e Reference:		
			Nominal pressure: _____ Pa		
<p>Note: If the room is of the open bay type (ie opening is larger than normal single doorway), the room should be considered part of the main room. No air movement control considerations need then be made, and this sheet can be discarded. Supply and/or extract flow will be based on air distribution considerations.</p>					
Consider permanent opening					
			Air flow, m3/s		
			Out	In	Remarks
Flow required through opening to give protection					
Leaks through closed doors to:	Pa	ΔP			
Total					
E_{AMC} _____ or flow outward through transfer device ($\sum_{IN} - \sum_{OUT}$) _____					
Transfer S_{AMC} or E_{AMC} to WS1					
Transfer device – transfer grille _____					
– pressure stabiliser _____					
Size select transfer device for flow rate _____ @ ΔP _____					
<p>Note: A door from the bay is considered with the peripheral room to which it leads or, if it leads to the corridor, it is considered with the main room</p>					

Designer Date

Template A6 Worksheet WS2e

Air movement control Operating room			Worksheet WS3 Reference:		
			Nominal pressure: _____ Pa		
Note: To avoid considering each door open in turn, the "key door" concept is introduced. This is the door which requires the greatest mechanical flow when open. See paragraph A8.33					
Select "key door" (see above). Consider this door open – room pressure now becomes _____ Pa (see Appendix 6) See Appendix 7 for room pressures					
			Air flow, m ³ /s		
			Out	In	Remarks
Flow required through doorway to give protection					
Air flow "out" or "in" via doors, transfer devices etc	Pa	ΔP			
Mechanical extract					
Total					
$S_{AMC} (\sum_{OUT} - \sum_{IN})$ _____ transfer S_{AMC} to WS1					
Consider all doors closed. Return S_F from WS1 _____ Room pressure now _____ Pa (nominal)					
Air flow "out" or "in" via door leakage, transfer devices etc	Pa	ΔP	Out	In	Remarks
Mechanical extract and supply					
Total					
Flow ($\sum_{IN} - \sum_{OUT}$) through transfer device _____ @ ΔP _____ to					
For final selection of transfer device see paragraphs A8.50–A8.54					

Designer Date

Air movement control Corridor			Worksheet WS4 Reference:		
			Nominal pressure: _____ Pa		
Consider all doors closed					
			Air flow, m ³ /s		
			Out	In	Remarks
Flow required through doorway to give protection					
Leaks through closed doors, transfer devices, permanent openings etc	Pa	ΔP			
Total flow inwards (S_1)					
Add mechanical input (S_2) if necessary to increase S_1 to give 7 AC/hr					
Total flow outwards and inwards					
$S_{AMC} = (\sum_{OUT} - \sum_{IN} + S_2)$ _____ Transfer to WS5					
or $E_{AMC} = (\sum_{IN} - \sum_{OUT} + S_2)$ _____ Transfer to WS5					

Note: this sheet to be used for each individual operating theatre suite (or pair of suites if they share a preparation room)

Designer Date

Template A8 Worksheet WS4

Air movement control	Worksheet WS5 Reference:	
Summary of air supply and extract for an operating suite		
Air flow to corridor	All doors closed	Anaesthetic (key door open)
	m ³ /s	m ³ /s
From preparation		
From operating theatre		
From scrub		
From anaesthetic		
Total (a)		
Air flow to corridor		
From utility		
From other source		
Total (b)		
Other room supplies Total (c)		
Total air supply (a) + (b) + (c)		
Consider corridor ventilation (see Appendix 3) and calculate air volume required, based on 7 AC/hr (see Note 1)		
Air flow required to ventilate corridor (m ³ /s)		
Air flow required to ventilate service corridor (see Note 2) (m ³ /s)		
If the air flow from the operating suite (a) and (b) is greater than the calculated required volume, no further supply air is necessary		
Additional air to ventilate corridor (m ³ /s)		
Additional air to ventilate service corridor (see Note 2) (m ³ /s)		
Air extract (m ³ /s)		
The size of the extract plant should be of the order of 10% below the supply to assist in maintaining the department under positive pressure relative to the outside departments		
Extract plant = Supply less leakage (m ³ /s)		
Less 10% of supply		
Total extract (see Note 3)		

Notes:

1. In the case of a multi-theatre operating department, the air balance for the corridor should be considered as a separate exercise, taking into account the final dispersal of excess air.
2. Omit these if only one corridor in operating suite.
3. The extract volume includes 0.24 m³/s from the anaesthetic room for a balanced condition

Designer Date

Template A9 Worksheet WS5

Room temperature – winter	Worksheet WS6b Reference:
----------------------------------	----------------------------------

Find winter supply temperature $T_{sw} = 20 - 0.828H(O/R)$ _____
 $= T_{sw}$ _____ °C
 $Q(O/R)$ _____

Note: the temperature of a space may be calculated from

$$T = \frac{t_1Q_1 + t_2Q_2 + \dots + t_nQ_n + (0.828H)}{Q_1 + Q_2 + \dots + Q_n}$$

Where t_1 is temperature of source 1 (°C)
 Q_1 is flow from source 1 when all doors are closed (m³/s) H is heat gain in space (kW)

Room	Heat gain kWh	Supply		Flows inwards										Temperature °C T		
		Q	T _{sw}	From		From		From		From		From				
				Q	t	Q	t	Q	t	Q	t	Q	t			

Check doors to sterile areas

Door between	Calculated room ΔT (°C)	Maximum ΔT permitted	Remarks

Designer Date

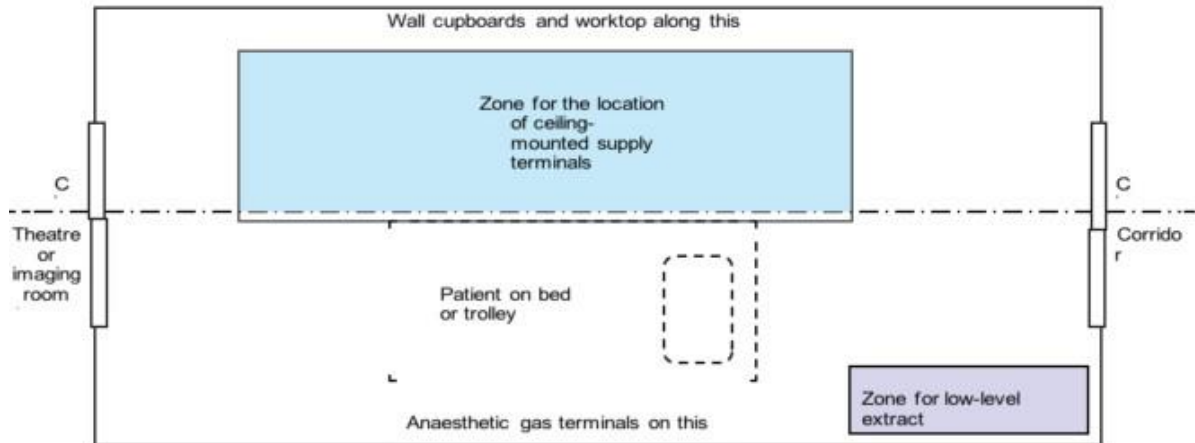
Transfer grilles, pressure relief dampers and pressure stabilisers							Worksheet WS7
							Reference:
Transfer grilles – see paragraphs A8.34–A8.38							
No	Location	Pressure difference Pa	Flow rate m ³ /s	Free area m ²	Model	Resultant Δp Pa	Remarks
Pressure relief dampers – see paragraph A8.39							
No	Location	Pressure difference Pa	Flow rate m ³ /s	Free area m ²	Pressure setting Pa	Remarks	
Pressure stabilisers – see paragraphs A8.40–A8.43							
Note: where a stabiliser is acting both as series room door protection and operating pressure control, “pressure difference” and “flow rate” are from WS2; “pressure setting” is from WS3							
No	Location	Pressure difference Pa	Flow rate m ³ /s	Free area m ²	Pressure setting Pa	Remarks	

Designer Date

Appendix 9: Design of air- movement control scheme for anaesthetic room

General

Figure A25 Schematic of suitable supply and extract solution



The above shows the typical zones for the positioning of ceiling-mounted supply and low-level extracts in an anaesthetic room. The objective is to comply with the COSHH Regulations and SHTM 03-01 Part A by providing a clean airflow path for staff working in anaesthetic rooms and so reduce their risk of casual exposure to waste/leaking anaesthetic agents.

Note 1: Supply terminals should not be positioned above wall-mounted cupboards as this will prevent their output being measured directly with a balometer. It will also negatively impact on the air distribution within the room.

Note 2: See photographs below for details of the recommended low-level extract installation.

Note 3: Low-level extracts should have a spring-clip-retained pull-off grille face for ease of cleaning.

Low-level extract installation

Traditional installation (not recommended)

- Low-level extract easily obstructed by equipment
- Extra corners to clean around

Figure A26 Low level extract traditional installation (not recommended)**Recommended installation**

- low-level extract cut back at 80° and stops short of the floor;
- no added detail to floor covering or coving;
- no additional corners to clean around;
- not easily obstructed by equipment;
- pull-off grille face for ease of cleaning;
- grille still accessible for airflow measurement.

Figure A27 Low level extract recommended installation

The photograph is for illustrative purposes only and shows a cutback of approximately 65°. This was found to make airflow measurement quite difficult, hence the change to an 80° cutback so that measurement can be easily taken with a balometer.

Operating theatre to anaesthetic room air-transfer device

The air-transfer device between an operating theatre and anaesthetic room may be either by a transfer grille or pressure stabiliser. The choice will be determined by the volume of air to be transferred.

Paragraphs A8.51 and A8.52 in Appendix 8 give details.

Appendix 10: Example cause-and-effect check-sheets

Example cause-and-effect check-sheet for general theatre or imaging suite

Site			Date		
Area served			System ID		
Test	AHU Checks	Y/N	TCP Indication	Y/N	
1	AHU Off	Supply and extract dampers closed		Red	
2	Switch AHU "On"	Supply damper open		Red	
		Extract damper open			
		Supply fan start and run		Red	
		Extract fan start and run			
		Prove airflow		Green	
3	Switch AHU to "Set Back"	Supply fan slows Extract fan slows		Red	
4	Switch AHU to Operational speed	Supply fan speeds up Extract fan speeds up		Green	
5	End of day <u>10 minute</u> warning that system will switch to "Set Back" (Not all TCPs have this facility)			Yellow display information box	
	Do nothing	System goes to "Set back"		Red	
	Reset to full speed			Green	
6	End of day <u>10 minute</u> warning that system will switch to "Set Back" (Not all TCPs have this facility)			Yellow display information box	
	Press "Continue"	System stays at full speed for 1 hour		Green	
7	Supply fan fail	System shuts down		Red	
	Reset system to normal			Green	
8	Extract fan fails	Warning on TCP and BMS. AHU locks out if fault not rectified by following day		Yellow display information box	
	Reset system to normal			Green	
9	Theatre/Imaging room temperature to be stable at 20°C at the start of this test.				
	Reduce set point temperature to lowest possible on TCP	Chiller battery valve opens fully Record min temp reached and time taken to stabilise.		Set temp: °C Measured: Ind (TCP) Time taken	°C °C mins
	Increase set point temperature to highest possible on TCP	Heater battery valve opens fully. Record max temp reached and time taken to stabilise.		Set temp: °C Measured: Ind (TCP) Time taken	°C °C mins
	Reset set point to 20°C			Green	
11	Switch AHU "Off"	Extract fan stops Supply fan stops Extract damper closes Supply damper closes		Red	

Template A13 Example cause-and-effect check-sheet for general theatre or imaging suite

Example cause-and-effect check-sheet for ultra-clean theatres

Site		Date			
Area served		System ID			
Test	AHU/UCV Checks	Y/N	TCP Indication	Y/N	
1	AHU Off	Supply and extract dampers closed		Red	
2	Switch AHU "On"	Supply damper open Extract damper open		Red	
		Supply fan start and run Extract fan start and run		Red	
		Prove airflow UCV "Off"		Red	
3	Switch AHU to "Set Back"	Supply fan slows Extract fan slows		Red	
4	Switch AHU to Operational speed	Supply fan speeds up Extract fan speeds up		-	
5	AHU at operational speed	Switch UCV on in "Low speed"		Amber = "Conventional Theatre mode"	
	Press "UCV mode"	UCV goes to "Full speed"		Green "UCV Theatre Mode"	
	Press "Conventional Theatre mode"	UCV goes to "Low speed"		Amber	
6	Switch AHU to "Set Back"	UCV goes to "Low speed" or "Off"		Red	
	Reset system to normal	UCV stays in "Low speed"		Amber	
7	Switch UCV "Off"	UCV fans stop		Red	
	Reset system to normal with UCV at full speed			Green	
8	Fail each UCV quadrant fan in turn and Coanda fans (4 + 2)			Red	
	Reset system to normal with UCV at full speed			Green	
9	Trigger HEPA filter high pressure switch			Green plus Blue light	
10	End of day 10 minute warning that system will switch to "Set Back" or "Off" <i>(Not all Theatre Control Panels have this facility)</i>			Yellow display information box	
	Do nothing	AHU & UCV go to "Set back" or "Off"		Red	
	Reset to full speed including UCV			Green	
11	End of day 10 minute warning that system will switch to "Set Back" or "Off" <i>(Not all Theatre Control Panels have this facility)</i>			Yellow display information box	
	Press "Continue"	System stays at full speed for 1 hour		Green	
12	Supply fan fails	System shuts down. UCV to "Low speed or Off"		Red	
	Reset system to normal			Green	
13	Extract fan fails	Warning on TCP and BMS.AHU locks out if fault not rectified by following day		Yellow display information box	
	Reset system to normal and UCV to full speed			Green	
Site		Date			
Area served		System ID			

Test	AHU/UCV Checks	Y/N	TCP Indication	Y/N
14	Theatre temperature to be stable at 20°C at the start of this test.			
	Reduce set point temperature to lowest possible on TCP	Chiller battery valve opens fully Record min temp reached and time taken to stabilise	Set temp: °C Measured: °C Ind (TP) °C Time taken mins	
15	Increase set point temperature to highest possible on TCP	Heater battery valve opens fully Record max temp reached and time taken to stabilise	Set temp: °C Measured: °C Ind (TP) °C Time taken mins	
	Reset set point to 20°C		Green	
16	Switch AHU "Off"	Extract fan stops Supply fan stops Extract damper closes Supply damper closes UCV drops to "Set back"	Red	
Note any additional tests or checks below				

Template A14 Example cause-and-effect check-sheet for ultra clean theatre

Appendix 11: References

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Note: In all cases the most recent version of any Legislation, Regulation, Standard or Guidance document should be consulted

Appendix 12: Abbreviations used in this document

Table A15: Abbreviations and their meanings

Abbreviation	Meaning
ac/h	Air changes per hour
ACDP*	Advisory Committee on Dangerous Pathogens*
ACOP	Approved Code of Practice
AE(V)	Authorising Engineer (ventilation)
AGP	Aerosol-generating procedure
AHU	Air handling unit
AP(V)	Authorised Person (ventilation)
BESA	Building Engineering Services Association
BIM	Building Information Model
BMS	Building Management System
BEMS	Building Energy Management System
BS EN	British Standard European Number
BSRIA	Building Services Research and Information Association
CCA	Critical care area (Level 2 & 3 care)
cfu	Colony forming unit
CIBSE	Chartered Institution of Building Services Engineers
COSHH	Control of Substances Hazardous To Health
CP(V)	Competent Person (ventilation)
CT	Computed tomography (imaging)
DIPC	Director of Infection Prevention and Control
DOP	Dispersed oil particles
DX	Direct expansion (refrigeration cycle)
EC	Electronically commutated (fan)
EPA	Efficiency particulate air filter (E10 to E12)
ErP	Energy related products
EU GGMP	European Guide to Good Manufacturing Process (pharmacy)
GRP	Glass reinforced polymer
HBN	Health Building Note
HEPA	High efficiency particulate air filter (H13 to H14)
HIS	Healthcare Infection Society
SHTM	Health Technical Memoranda
IAP	Inspection, assembly and packing (room)
ISO	International Standards Organisation
Level 0 care	Patients whose needs can be met through normal ward care in an acute hospital
Level 1 care	Patients at risk of their condition deteriorating, or recently relocated from higher levels of care, whose needs can be met through normal ward care with additional advice and support from the critical care team.

Abbreviation	Meaning
Level 2 care	Patients requiring more detailed observation or intervention, including support for a single failing organ system or post-operative care and those 'stepping down' from higher levels of care.
Level 3 care	Patients requiring advanced respiratory support alone or monitoring and support for two or more organ systems. This level includes all complex patients requiring support for multi-organ failure.
LEV	Local exhaust ventilation
LSAPC	Light scattering airborne particle counter
MDR-TB	Multi-drug-resistant tuberculosis
MRI	Magnetic resonance imaging
NICU	Neonate intensive care unit
PFI	Private Finance Initiative
PPVL	Positive pressure ventilated lobby (isolation room)
PVC	Polyvinyl chloride
RH	Relative humidity
SCBU	Special care baby unit
SPATA	The Swimming Pool and Allied Trades Association
SUP	Supply air quality
SVHSoc	Specialised Ventilation for Healthcare Society
TB	Tuberculosis
TCP	Theatre control panel
UCV	Ultra clean ventilation
ULPA	Ultra low particulate air filter (U15 to U17)
UV	Ultraviolet
VAV	Variable air volume
VCD	Volume control damper
VSG	Ventilation Safety Group
WEL	Workplace exposure limit

Table A16: Symbols

Symbol	Meaning
°C(db)	Degrees centigrade (Dry bulb) temperature
K	Kelvin (temperature difference)
% RH	Percentage relative humidity
L/s	Litres per second
µm	Micrometres, microns
ePM1, 2.5, 10	Particle size in micrometres
≥	Equal to or greater than

* ACDP Containment levels

Category 1 biohazard: a biological agent unlikely to cause human disease

Category 2 biohazard: a biological agent that can cause human disease and may be a hazard to employees; it is unlikely to spread to the community and there is usually effective prophylaxis or effective treatment available.

Category 3 biohazard: a biological agent that can cause severe human disease and presents a serious hazard to employees; it may present a risk of spread to the community, but there is usually effective treatment or prophylaxis available.

Category 4 biohazard: a biological agent that causes severe human disease and is a serious hazard to employees; it is likely to spread to the community and there is usually no effective prophylaxis or treatment available.

Note: This publication can be made available in a number of other formats on request.

Interim