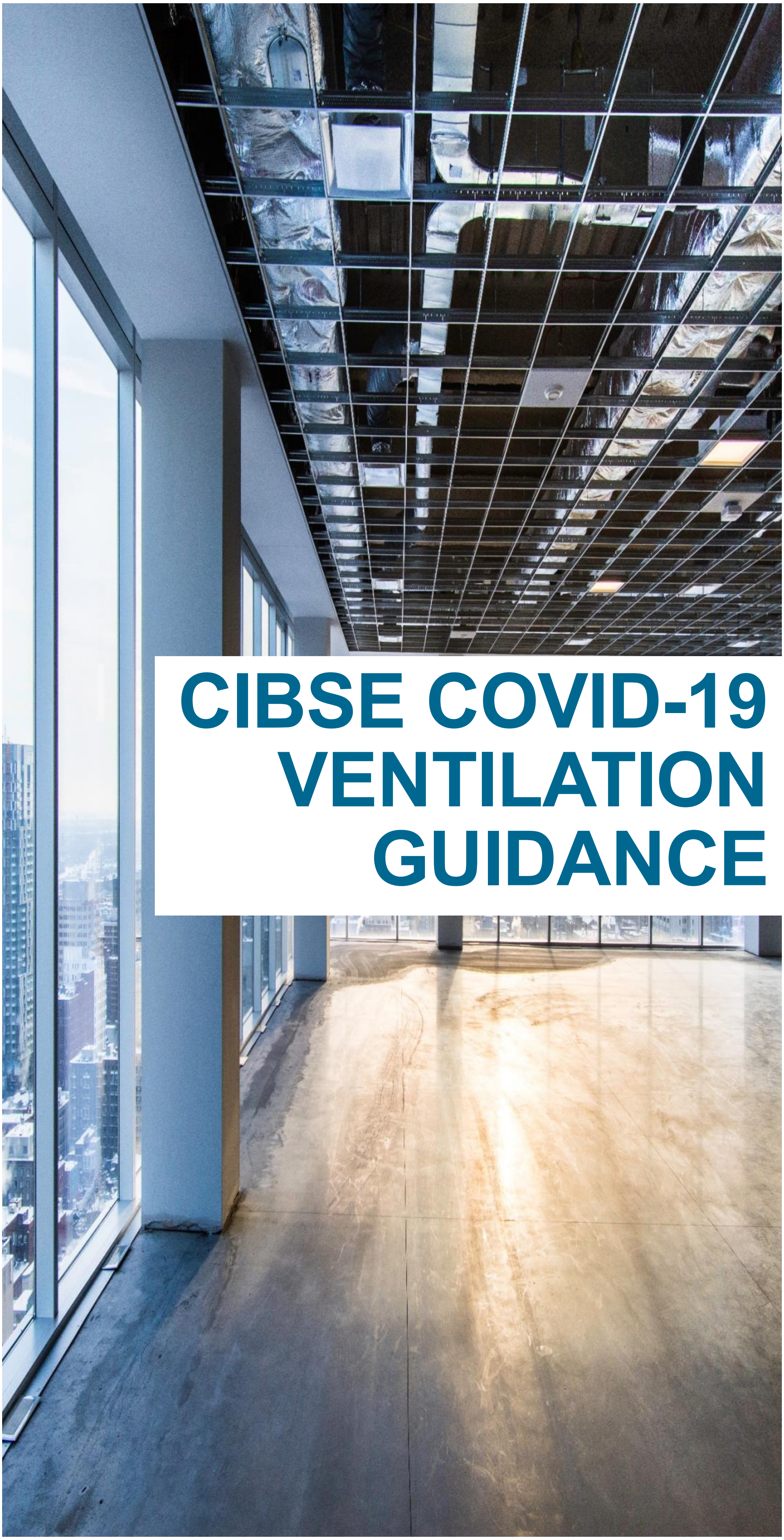

CIBSE COVID-19 VENTILATION GUIDANCE

CIBSE

Version 4

23 October 2020

Introduction

CIBSE initially published COVID-19 Ventilation guidance on 9th May, followed by Version 2 on 12th May and Version 3 on 15th July, in response to the CIBSE position, taken in April, that there was the potential for airborne aerosol transmission of SARS-CoV-2. The World Health Organisation (WHO) updated its guidance to acknowledge the possibility of airborne transmission on 9th July.

Public Health England[1] updated its guidance to note the possibility of airborne transmission particularly in poorly ventilated indoor spaces. The Centers for Disease Control[2] in the US recognise that transmission appears to have occurred when there is inadequate ventilation.

This guidance adopts a precautionary approach with the objective of ventilating spaces as much as reasonably possible with outside air as one measure to reduce transmission risk.

On 23rd October the government issued a paper prepared by the Environment and Modelling Group of the Scientific Advisory Group for Emergencies (SAGE-EMG) assessing the 'Role of ventilation in controlling SARS-CoV-2 transmission'.[3]

Evidence continues to suggest that in poorly ventilated indoor spaces airborne aerosols are a possible transmission route and the precautionary advice remains valid. Maintaining good levels of ventilation remains the key focus even in colder weather conditions, whilst minimising occupant discomfort due to draughts and lower indoor temperatures.

As businesses continue to manage the return of staff to work premises and the continuing operation of buildings through the pandemic, a number of issues need to be considered for the safety of those entering buildings. Government guidelines should be followed.

The UK government and devolved administrations have produced guidance for employers, employees and the self-employed to help them understand how they can work safely during the pandemic. For the UK as a whole the Health and Safety Executive, HSE, provides guidance on building safety in general and on air conditioning and ventilation in particular.

The government guidance reminds employers of their legal responsibility for the safety of all those entering workplaces:

'To help you decide which actions to take, you need to carry out an appropriate COVID-19 risk assessment, just as you would for other health and safety related hazards. This risk assessment must be done in consultation with unions or workers.'

Undertaking that risk assessment may require advice from competent persons, such as professionally registered engineers who are Chartered or Incorporated engineers registered with the Engineering Council.

This COVID-19 ventilation guidance is intended to give business owners and managers an outline of ventilation systems commonly encountered in buildings to assist in the preparation to re-open workplaces and how they can be used to reduce the risks of airborne infection. It will help building managers and those who operate and maintain building systems to identify those areas of a building and elements of ventilation systems that may need particular attention to reduce the risks to the building occupants.

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[1] Public Health England, COVID-19:epidemiology, virology and clinical features, http://tiny.cc/cbczsz October 9th 2020.
[2] CDC, Scientific Brief: SARS-CoV-2 and potential airborne transmission, https://www.cdc.gov/coronavirus/2019-ncov/more/scientific-brief-sars-cov-2.html October 5th 2020.
[3] https://www.gov.uk/government/publications/emg-role-of-ventilation-in-controlling-sars-cov-2-transmission-30-september-2020

This guidance will inform considerations of safe working practices and the provision of ventilation in non-residential buildings. It is intended primarily for offices, schools, educational buildings, retail and industrial buildings where occupants are mainly sedentary. Further consideration and more specialist advice may be needed for healthcare, food production, other specialist buildings and indoor spaces where activities known to increase respiratory aerosols take place, eg singing, loud talking, aerobic exercise.

This CIBSE COVID-19 ventilation guidance is under continued review.

It is preferable not to recirculate air from one space to another. But in certain weather conditions closing the recirculation dampers in some systems may make the supply air unacceptably cold and cause a reduction in the rate of supply of outside air to the occupied spaces below the recommended minimum (10 l/s/person for typical offices) in order to maintain an acceptable temperature. In these instances, there is a balance between two risks: the greater risk arising from recirculating some air of cross-contamination between rooms or zones, which is relatively low risk, against the risk of increasing contaminant build-up as a result of not maintaining adequate provision of outside air, which poses higher risks. Recirculation should be considered if this is the only way of maintaining adequate provision of outside air to occupied spaces without causing undue occupant thermal discomfort. Guidance on recirculation is given in section 4.2.2.

For naturally ventilated spaces, windows and vents are often the mechanism for providing outside air. In the colder months, the natural forces that drive air through these openings, wind and indoor/outdoor temperature difference are greater, so they do not need to be opened as wide. Opening just the high level vents can enable more mixing of the outside air with air in the space and also warms the incoming air before it reaches the occupied zone. This allows more colder outside air to be introduced to the space without causing significant discomfort. It is better to open all the windows or vents a small amount to aid mixing and warming. If natural ventilation openings are the only mechanism for delivering outside air into a space it is important not to completely close them when the spaces are occupied as this can result in very low ventilation rates and increased risks of airborne viral transmission.

Nondispersive infrared (NDIR) CO_2 sensors are useful devices to help assess whether adequate ventilation is being provided to an occupied zone. Indoor ventilation dilutes exhaled CO_2 from occupants and so the CO_2 concentration in a space is often used to help indicate ventilation rates. CO_2 concentrations regularly greater than 1500ppm are indicative of poorly ventilated spaces and attention should be given to improving the outside air provision to such spaces. For more information see Section 5.2.

eCO_2 sensors (or '*equivalent CO_2*'sensors) should not be used. These devices can only measure volatile organic compounds (VOCs) and make an estimate of CO_2 concentration based on the concentration of VOCs in the air. They do not directly measure the indoor CO_2 concentration.

Germicidal ultraviolet (GUV) devices have been proposed for air cleaning. They use light in the UV-C spectrum and have been shown to inactivate coronaviruses. There is significant emerging evidence of the efficacy of UV-C sources at a wavelength of 254nm to deactivate SARS-CoV-2. There are currently still uncertainties about a variety of factors affecting UV performance including dosage and exposure time, and how these might depend upon the ventilation rate of outside air. In addition, consideration will need to address the specific room and system configuration, air flow, distribution and humidity as well as the safe deployment of UV for occupants and building operations personnel. An additional section of this version of this guidance addresses the potential use of UV and important safety considerations, see section 6.

CIBSE are also working closely with other institutions to provide guidance for ventilation of more specialist indoor spaces.

Increased ventilation is one of several recommendations to reduce the risk of SARS-CoV-2 transmission indoors and therefore should be used in conjunction with other government advice including working from home, social distancing, wearing of face coverings, good hygiene practices, workplace cleaning and test and trace.

Principal changes to version 4

This version of the CIBSE guidance contains a revised introduction which addresses questions about adapting ventilation arrangements during the heating season and includes updated information about the use of UV technology. The guidance reflects the onset of cooler conditions in the UK and includes additional guidance on the use of natural ventilation openings, recirculation and thermal wheels. New chapters on natural ventilation and the potential applications and safety considerations for UV technology are also included.

Registered charity number 278104

This document is based on the best knowledge available at the time of publication. Due to the rapidly evolving nature of the COVID-19 epidemic this guidance should be read in conjunction with the relevant government guidance, in particular that relating to 'Working safely during coronavirus (COVID-19)'

Ventilation

The advice in this document is for building owners and managers, operators and those maintaining buildings. It is relevant both for reopening buildings after a period of inactivity and for continuing operation of buildings during the pandemic. It considers the requirements for achieving adequate ventilation, including particular consideration of ventilation provision during the cooler months. It is to be read in conjunction with any information available through ‘Working safely during coronavirus (COVID-19)’ or other government websites.

This guidance is written in the context of a temperate oceanic climate as experienced in the UK and will outline the main actions you should take regarding your ventilation. However, the principles of providing adequate ventilation generally and identifying poorly ventilated spaces will be relevant outside the UK. This guidance is relevant to all types of building ventilation system, whether natural ventilation, mechanical ventilation or full air conditioning.

Section 1 explains the importance of ventilation in relation to COVID-19. Section 2 explains what can be done to reduce risks related to building ventilation. Section 3 explains different building ventilation systems and their key operating characteristics, Section 4 explains how to operate these different ventilation types to reduce SARS-CoV-2 transmission risk. This includes preparing ventilation systems for re-occupation of buildings and consideration of ongoing operation and maintenance. Section 5 considers how to optimise use of natural ventilation in winter and Section 6 considers the use of UV disinfection and air cleaners.

In some cases the occupancy of a room or zone may be reduced due to social distancing criteria and ordinarily this might result in a reduction of the ventilation airflow required. However, in order to reduce risks associated with viral transmission the ventilation rate should be increased as much as reasonably possible. Sensors which automatically reduce the ventilation rate during lower occupancy may need to be disabled or reset to prevent this.

It is primarily intended for application in non-domestic buildings excluding health care and hospital buildings where NHS and PHE guidance should be sought.

If a confirmed case or case(s) of COVID-19 has been identified in a building user or visitor then please consult current Government advice.

The advice contained in this document specifically concerns the ventilation provision in indoor spaces and presents advice as to what can be done to reduce the risk of viral infection transmission indoors. It should be read in conjunction with advice on personal hygiene practices, social distancing and occupancy, cleaning, face-coverings, reducing exposure times and other building management advice.

The key actions are:

- Understand your ventilation system
- Understand where you may have poorly ventilated spaces or areas
- Increase the ventilation rate as much as reasonably possible; this may require changes to CO_2 set points (for both mechanical ventilation and automated windows)
- Avoid recirculation/transfer of air from one room to another unless this is the only way of providing a sufficient rate to all occupied rooms
- Recirculation of air within a single room where this is complemented by an outside air supply is acceptable as this helps to provide more outside air to occupants and can help to maintain thermal comfort.
- Where thermal (or enthalpy) wheels are installed to recover heat, then a competent engineer/technician should check that the configuration and operating conditions are such that any leakage across the device is from the supply side to the extract side, to minimise the risk of transferring contaminated air into the supply.

This CIBSE COVID-19 ventilation guidance is under continued review.

Contents

1 Why indoor ventilation is important to reduce COVID-19 cases

Building ventilation is always an important part of a healthy building environment as it brings a stream of outside air into the building and removes stale air. Stale air includes body odours and exhaled breath and airborne pollutants such as smells from cleaning products and furniture.

Ventilation is also a very important way of diluting any airborne pathogens and there is good evidence showing that room occupants are more at risk of catching an illness in a poorly ventilated room than in a well-ventilated room. This is because in a poorly ventilated room occupants are exposed to a higher concentration of airborne pathogens, and the risk will increase with a greater amount of time spent in such an environment.

Risk is a function of exposure and duration exposed. The risk of airborne infection to the individual can therefore be reduced by:

- Reducing time spent in the location
- Reducing airborne exposure concentration of infectious material
- Reducing risk of contact spread through regular handwashing and surface cleaning.

Ventilation rate and how it is delivered influence both airborne exposure and deposition rate.

1.1 COVID risks

The main risk for SARS-CoV-2 transmission is from asymptomatic or pre-symptomatic people who occupy a building without knowledge that they are shedding viral particles. Current government advice should be consulted for reducing risks posed by symptomatic individuals.

Evidence is mounting[4] that the SARS-CoV-2 virus which causes COVID-19 can be spread by very small particles – called aerosols – which are released by an infected person when they cough, sneeze, talk and breathe, alongside the larger droplets that are released. Larger droplets fall by gravity, which has influenced the development of the 2m social distancing measure to reduce spread.

However, fine aerosols can remain airborne for several hours. Although difficult to definitively prove airborne aerosol transmission, our knowledge of this transmission in similar viruses (eg SARS-CoV-1) and emerging evidence showing high rates of infection in poorly ventilated rooms suggests that this is a potential transmission route. Measures to reduce the risk that these small particles may be breathed in and cause infection are therefore recommended.

These aerosols are at the highest concentration in the exhaled puff and 2m social distancing helps reduce exposure to this. Aerosols that are small enough to remain airborne become diluted in the indoor air and without suitable ventilation they can build up, increasing the risk of exposure for susceptible individuals. Ventilation can play an important role in minimising the build-up of aerosols in a space and will reduce exposure risk. Other interventions to minimise aerosol generation include face coverings and minimising respiratory activities known to generate more aerosols, such as singing.

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[4] See https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7413047/
https://www.bmj.com/content/370/bmj.m3206

As our understanding of the significance of the various transmission routes of SARS-CoV-2 develops, we recommend increasing the rate of supply of outside air to occupants wherever it is practical as a pre-cautionary measure.

This is particularly important in poorly ventilated areas. Increasing the ventilation rate helps dilute any airborne contamination and reduces the risk of exposure for building users.

During the heating season it will be necessary to balance the benefits of increased ventilation rates against the need to maintain the thermal comfort of the occupants.

This guidance takes a risk averse approach to reducing indoor pollution without significant capital cost and is subject to change as transmission routes become more clearly defined.

2 Minimise risks

To minimise the risks of far-field airborne aerosol transmission of SARS-CoV-2 the general advice is to increase the air supply and exhaust ventilation, supplying as much outside air as is reasonably possible. The underlying principle is to dilute and remove airborne pathogens as much as possible, exhausting them to the outside and reducing the chance that they can become deposited on surfaces or inhaled by room users. Recirculation or transfer of air from one room to another should be avoided unless this is the only way of providing adequate ventilation rates to all occupied rooms.

The risk of airborne transmission is greatest in poorly ventilated areas. These are often smaller rooms with limited outside air supplies. Spaces that are often stuffy or smelly are also likely to be poorly ventilated. It is particularly important to increase the supply of outside air to these spaces. It is recommended that occupancy density is reduced where possible.

In rooms and zones where there is no direct supply of outside air then consideration should be given to limiting access to these spaces by building users, especially where it is likely that they would be occupying such a space for considerable lengths of time (longer than 30 minutes). This may include basement rooms or storage areas which rely on infiltration of air from other spaces.

Ventilation should be balanced against other factors, particularly thermal comfort. It is recommended that the ventilation strategy should at least achieve the equivalent minimum ventilation rate for the space over the occupancy period as defined in current standards. In naturally ventilated buildings, strategies such as intermittent airing and partial window opening to complement background ventilation may enable this to be achieved. When it is reasonable to do so, ventilation rates should be increased as much as reasonably possible without compromising thermal comfort.

The key actions are:

- Understand your ventilation system
- Understand where you may have poorly ventilated spaces or areas
- Increase the ventilation rate as much as reasonably possible; this may require changes to CO_2 set points (for both mechanical ventilation and automated windows)
- Avoid recirculation/transfer of air from one room to another unless this is the only way of providing a sufficient rate to all occupied rooms
- Recirculation of air within a single room where this is complemented by an outside air supply is acceptable as this helps to provide more outside air to occupants and can help to maintain thermal comfort.
- Where thermal (or enthalpy) wheels are installed to recover heat, then a competent engineer/technician should check that the configuration and operating conditions are such that any leakage across the device is from the supply side to the extract side, to minimise the risk of transferring contaminated air into the supply.

3 Understanding your ventilation

It is important to establish what kind of ventilation provision exists in the building and how the ventilation rates can be increased. Section 3 is designed to help the reader identify the ventilation system or systems present, noting that there may be different regimes in different rooms of the building. Some rooms may have more than one type of ventilation provision, so first familiarise yourself with the ventilation types below and then establish the ventilation provision in your building on a room by room (zone by zone) basis. In order to minimise risks of aerosol transmission follow the advice in Section 4 for the ventilation type identified in each room/zone to maximise the delivery of outside air into those rooms and reduce the risks of aerosol transmission beyond the 2m social distance, helping to protect building users

3.1 Natural ventilation

The term natural ventilation is used to describe ways that outside air can enter the building without using fans or other mechanical means. For example, airflow through openings in the building envelope such as windows, doors, wind catchers and other vents.

3.1.1 Mixing boxes

A relatively new technology, these systems use a fan to mix outside air entering a room through natural ventilation openings with some of the air already in the room. This is a useful energy saving system in the heating season as it warms the cooler outside air before it enters the room, reducing the heating in the room and reducing cold draughts.

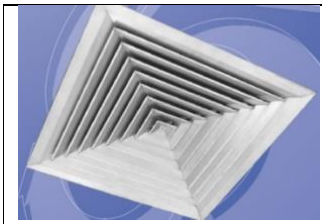
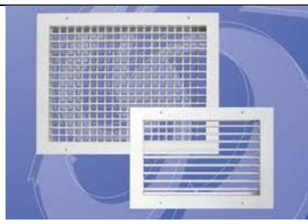
3.2 Mechanical ventilation

Mechanical ventilation is used to describe the means of bringing air into a building by mechanical means, for example fans. Often air is moved through ductwork to deliver outside air into a building and there are several ways in which this can be achieved.

Some ventilation strategies use both natural and mechanical ventilation within the same space; this is often termed mixed-mode ventilation. Typically mechanical ventilation may be the primary means of delivering outside air into the room year round, with the additional benefit of openable windows to provide more outside air to help cooling during the summer or to purge the room, for example from a smell caused by a spillage.

3.2.1 Supply and Extract

The main principle in this type of mechanical ventilation is a series of ducts and inlet grilles which deliver outside air into a space, with another set of ducts which extract stale air out of the room and exhaust it to the outside. There are a number of different systems which use this method and the grilles which deliver the incoming air can be located in the ceiling, on the wall or in diffusers on the floor. For the system to provide adequate outside air it is essential to keep these grilles free from blockages.

 Ceiling diffuser	 Floor diffuser	 Wall diffuser

Typical examples of air supply inlets

Images courtesy of Gilberts (Blackpool) Ltd

3.2.2 Heat recovery

Some mechanical ventilation systems use heat recovery to extract heat from the warmer stale exhaust air and use that heat to warm the incoming outside air. This has energy saving benefits in the heating season as it helps to reduce the heating needed to warm the room. Some heat recovery systems work on a room/zone by room/zone basis and mix some of the exhaust air with the incoming outside air and therefore recirculate a portion of the air back into the room.

There are some exceptions where air is recirculated within a space, so if you have this type of system please read the recirculation actions carefully in section 4.2.2

3.2.3 Extract only

In this system a fan is used to extract air from the room direct to the outside and air enters the room to replace the extracted air through infiltration – for example via gaps under the door. These systems are typically employed in toilet blocks and wet room facilities.

3.2.4 Air Conditioning

Ducted air conditioning systems typically use the mechanical ventilation system. Outside air is first ‘conditioned’ before being moved along ductwork to the room. This conditioning can include warming of the air in winter or cooling of the air in summer as well as adjusting the humidity of the air.

Some systems that are commonly known as ‘air conditioning’, or ‘air conditioning units’ only condition the air in a room – i.e. warm the air or cool the air but are not part of a wider ventilation system. They are often referred to as ‘comfort cooling’ or ‘comfort heating’. These systems take air already in a room and warm or cool it before releasing it back (recirculate it) into the room. It is important to understand that these systems are not delivering outside air and are therefore not diluting any airborne pathogens.

3.2.4.1 Split air conditioning systems

A split air conditioning system has two main parts: an outdoor compressor with an outdoor cooil and an indoor air-handling unit (hence the term split – it is in two units. A conduit carries the power cable, refrigerant tubing and a condensate drain between the outdoor and indoor units. They are typically wall or ceiling mounted, and are quite common, but do not supply any outside air into a room.

3.2.4.2 Fan coil units

These units are usually ceiling mounted or installed in raised floors. A fan passes air over either a heating or cooling coil and into the room. Fan coil units generally have a chilled water coil for cooling and either a hot water coil for heating or an electric heating element. They may be connected to ventilation ducts from the air handling unit to provide outside air or they recirculate room air.

3.2.4.3 Chilled beams

These are installed near to the ceiling to provide cooling and come in two forms.

Active Chilled Beams – these form part of the ventilation system and are used to chill incoming outside air as it passes into a room from a ducted supply.

Passive Chilled Beams – these cool the air already in a room by absorbing the heat and are not responsible for bringing outside air into the room. They will create air mixing due to convection currents caused by the beam cooling air at high level, which then falls to the floor, creating airflow.

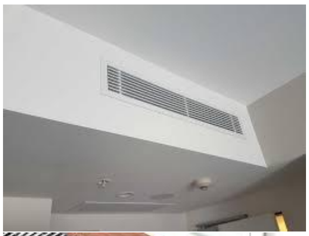
3.3 Specialist localised exhaust ventilation

In some settings specialised extract ventilation is used to remove lots of air from a specific location, for example; cooker hoods in kitchens, local exhaust on workshop machinery and fume hoods. Although these systems generally remove large volumes of air, it is important to ascertain where the replacement air is coming from which replaces that exhausted from the room. It may come directly from outside through windows/doors, or air may enter from other rooms/zones e.g. adjacent corridors or adjoining rooms. In the case of large factory floors replacement air is likely to be from the outside. Specialised local exhaust ventilation is the subject of specific workplace regulations and the Institute of Local Exhaust Ventilation Engineers provide more specialist advice and practitioners who have particular expertise in these systems.

3.4 No obvious ventilation strategy

Some spaces may not have an identifiable ventilation system. For example, it is common for there to be no ventilation in corridors or staircases as these are deemed to be transient spaces and they rely on air infiltration from neighbouring spaces. Where staircases, lobbies or common areas are used by a significant number of occupants, possibly from multiple building tenants or ‘user bubbles’ and have no obvious continuous ventilation then it is important to purge these areas regularly. How this is done will need to be considered on a building by building basis taking account of the fire strategy for the building.

Rooms or zones that are occupied routinely without any obvious ventilation strategy are going to be a significant risk and the ventilation provision should be addressed. Until adequate ventilation is provided it may not be appropriate to use the room or zone other than for very short durations.

System	Image	Outside air or recirculated?
Split air systems	 	Only recirculates room air
Fan Coil Units	  	Can be connected to ventilation ducting from the air handling unit to provide outside air or recirculates room air with a fan.
Chilled beams -Passive Chilled beams		Recirculates room air via convection
-Active Chilled Beams		Connected to ducting to condition incoming outside air

4 Recommended actions to improve ventilation

4.1 Natural ventilation

4.1.1 Opening windows

Openable windows and vents should be used more than normal as long as security is considered and the open windows do not cause a hazard to anyone moving outside. If possible windows should be open at least 15 minutes prior to room occupation. In warmer weather opening windows is a typical behavioural response, however it is important to that windows are kept open, even if only by a small amount, when it is cooler outside. It is important to balance the need to minimise the risk of airborne infection against the need for occupants to be comfortable. In cooler weather even a small opening can deliver significant ventilation flows to minimise the risk to occupants of the space.

Opening windows can result in draughts that can cause occupant discomfort. Where possible discomfort should be mitigated by ensuring building users are not located directly in a draught for long periods, for example by moving desks and other room furniture. Current requirements for distancing may make this more feasible. Relaxing dress codes so that warmer clothes may be worn is highly desirable.

Where there are both high level and low level openable windows in a room then it is recommended to open the high level windows during cooler weather in the first instance, as incoming air will be warmed as it flows down into the room thereby reducing cold draughts. This also improves mixing of the outside air with air in the room before reaching the occupied zone. To maximise airflow when draughts are not a concern, both high and low windows should be opened. This does not just increase opening area but creates a more efficient flow, thereby increasing the dilution of pollutants.

If it is windy, cold or raining then it may not be practical to fully open the windows/vents, however they should be open as far as reasonably possible without causing discomfort. Section 5 provides further guidance on managing air flow through natural ventilation openings under these conditions.

During cooler weather, it may be necessary to have the room heating on more than normal. This will incur energy penalties; however, these are deemed acceptable as the increased ventilation will help remove any airborne virus particles from the building.

During warmer weather and on brighter sunny days it may not be appropriate to have the heating on during the cooler mornings as this may exacerbate overheating in the afternoon.

4.1.1.1 Single sided ventilation

Where a room only has one side that has openable windows/vents then consideration should be given to areas within the room where air may become stagnant. It is generally considered that rooms can be well ventilated by single sided ventilation if the depth of the room is less than twice the height, or in the case of a single side ventilation with both high and low level windows if the depth of the room is less than 2.5 times the height. In deeper plan rooms it is advisable to use a local recirculation unit or fan at the back of the room to enhance air disturbance and hence reduce the risk of stagnant air. This is particularly important where a small room has multiple or transient occupancy, and when assessing the future occupancy of a space then the ventilation mechanism should be considered as well as achieving the simple 2m separation that is required.

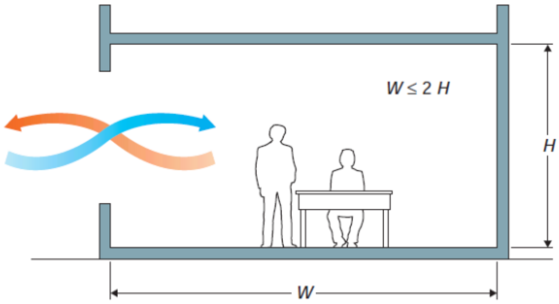


Figure 2.18 Single sided ventilation, single opening

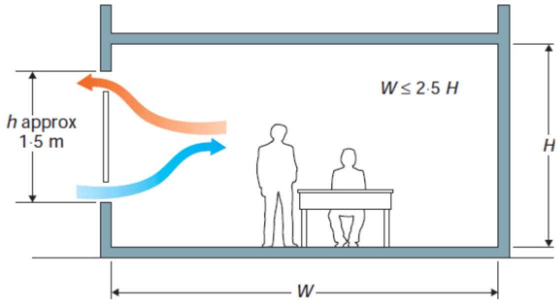


Figure 2.19 Single sided ventilation, double opening

4.1.1.2 Cross ventilation

Greater air flow can be achieved when windows/vents can be opened on different facades to allow air flow through a room. This can also include layouts where cross ventilation occurs by air entering through the external façade, traveling across the floor plate to a central atrium where it is exhausted up and out through vents at roof level.

It is generally recommended that cross ventilation flows should not exceed 15m or 5x floor to ceiling height (whichever is the smallest) as it is known that air pollutants become more concentrated at the leeward side of the room, where the air exhausts, compared to the windward side where outside air enters the room. However, in the case of reducing the risk of COVID-19 transmission this consideration can be relaxed as cross ventilation will increase the outside airflow and consequently increase the dilution and removal of any airborne pathogens.

Cross ventilation pathways where air travels from one occupied room/zone into another should be avoided if possible by keeping internal partition doors closed, unless opening such partitions significantly increases the total volume flow rate of outside air. Fire doors should not be kept open unless fitted with approved automatic closers so that they function as fire doors in the event of an alarm or fire.

4.1.1.3 Roof turrets

Roof turrets should usually open proportionally in response to air quality and temperature in the space in their normal operation mode if they are correctly set up. If the space with roof turrets has a high occupancy, for example during lunch in a school hall, then it is advisable to use the manual boost to temporarily increase the ventilation rate. Manual boost should also be used if the occupants are undertaking activities that can increase aerosol generation eg aerobic exercise, singing or talking loudly. It should be noted that if activities that increase aerosol generation are to be undertaken the latest Government advice should be considered. Manufacturer's may also provide product specific guidance.

4.1.1.4 Automated windows/vents

Some windows and vents are controlled automatically and open in response to indoor air quality and temperature. For more frequent window opening (for example when the external conditions are favourable to increasing ventilation rates) either use manual override or adjust the CO_2 setpoint to a lower value. Ventilation should be balanced against other factors, particularly thermal comfort. It is recommended that the ventilation strategy should at least achieve the equivalent minimum ventilation rate for the space over the occupancy period as defined in current standards and therefore CO_2 setpoints should be adjusted to open vents to at least deliver these flow rates. As it may take some time for CO_2 concentration to increase to the setpoint value it may be appropriate to use manual override to open the windows a little to provide some background ventilation initially.

4.1.1.5 Windows in toilet blocks

If windows are the only means of ventilating the toilet block then they should be left open (in winter they do not need to be open as wide as in the summer) as long as reasonably possible, and windows in adjoining rooms should also be open.

In internal toilets blocks with passive stack or mechanical exhaust systems, the principle of this ventilation system is that air will flow into the toilet block as the door to the block is opened, thus ensuring that contaminants and odours are kept within the toilet block and do not enter adjacent rooms. Opening windows in toilet blocks with mechanical extract ventilation may reverse the air flow when doors open allowing contaminated air to flow from the toilet block into the adjacent room – which is to be avoided. Therefore, in internal toilet blocks with mechanical extract ventilation the extract ventilation should remain constantly on and windows in the toilet block remain closed. A notice may be required on the toilet doors/walls to explain this and discourage opening.

For external toilet blocks with no adjoining rooms, open windows can supplement the mechanical ventilation and can be left open.

It is important to keep toilet doors closed so that the ventilation dilutes and removes any pollutants rather than recirculating them to the rest of the building.

4.1.1.6 Window Restrictors

Restrictors will reduce the opening area of your window, and therefore the potential for ventilation. They may be essential for safety and security of occupants. Removal of restrictors to boost air flow should only be done after a risk assessment considering the risk of clashes with people outside walking past open windows (on the ground floor) and the risk of falls from upper floors.

4.1.1.7 Security considerations for open windows

There are security issues to consider with respect to leaving windows open, especially when the building is not occupied. A walk-round may be required to ensure that all windows that pose a security issue are closed before the building is vacated, and windows reopened as early as possible before reoccupation by the majority of the building users. Where leaving windows open does not cause a security issue it is recommended to do this overnight on warm/hot days to maximise purge of the room air. On cold days and nights this may cause over cooling and significant discomfort so should be avoided.

4.1.2 Open external doors to boost ventilation

For small buildings with limited ventilation openings such as small shops or offices within a secure compound, external doors may be used to increase ventilation as long as care is taken over security. Opening doors for ventilation provision is not ideal as they are not easily adjusted and alternative ventilation strategies should be considered in the medium to long term. Keeping open internal doors may be appropriate where it delivers a significant increase in air movement and ventilation rate. It is important to note that fire doors should not be kept open unless fitted with approved automatic closers so that they function as fire doors in the event of an alarm or fire.

4.1.3 Mixing boxes

These devices are designed to supply air to a single room or zone, so the mixing mode can still be used if this enables more outside air to be supplied to the room and reduces draughts when the outside air temperature is low. However, to maximise outside air provision the device should be used in full outside air mode if reasonable to do so.

4.2 Mechanical ventilation

4.2.1 Supply and Extract

In buildings with mechanical ventilation systems extended operation times are recommended. Change the clock times of system timers to start ventilation at nominal speed at least an hour before the building usage time and switch to lower speed an hour after the building usage time. In demand-controlled ventilation systems change CO_2 setpoint to a lower value if this assists in maximising the reasonable flow of outside air (for example in favourable seasons), in order to maintain the operation at nominal speed. Refer to manufacturer's guidance for help. Relative humidity should be kept above 40% wherever possible.

4.2.2 Heat recovery

There are several methods by which heat recovery can be achieved; the manufacturer's literature for the system installed should provide information on what method is employed. For buildings completed since 2002 the building log book should also provide information on the ventilation system and how it is intended to operate.

4.2.2.1 Twin coil unit or plate heat exchange

This system keeps the supply air and the extract air streams physically separate; just the heat energy is transferred and the air streams never mix. On this basis the heat recovery device can remain online, but the unit should be inspected to ensure there are no leaks (which might lead to transfer of air from exhaust duct to supply duct).

4.2.2.2 Regenerative rotary air to air heat exchangers (also known as enthalpy or thermal wheels)

These heat recovery devices have a risk of air leakage and moisture transfer between the supply and exhaust air streams at the rotary heat exchanger. Any leakage and its magnitude will vary depending on the installed configuration of the fans, and the relative pressures in the supply and extract ducts. Where properly configured direct air leakage passes from the supply to the extract duct and is therefore not a concern. Actual configuration and pressure balances should be checked by an engineer, and poorly configured or balanced systems should be remedied or else must be bypassed.

There is the possibility that viral material could become adsorbed on the surfaces of the wheel and be transferred into the supply air flow, but there is no evidence of this happening, and the risks of such viral transfer are outweighed by the need to maintain ventilation rates. However, if adequate ventilation rates with suitable thermal comfort can be provided without use of the regenerative rotary heat exchanger then it is advisable to bypass the system if provision is available, or if no bypass is available then the rotor should be turned **off**.

The heat recovery function is usually integral to the system design in terms of simultaneously delivering adequate air flow and meeting heating or cooling demand. If the only way to provide adequate and safe outside air flows is by using the thermal wheel then it is advisable to turn the rotor **on.** Not doing so will result in a greater build-up of any indoor viral contaminant. The expected reduction in dilution of any potential indoor viral source with inadequate ventilation flow rates is considered to be a greater risk for viral transmission than the potential for viral transfer across the thermal wheel. Turning the rotor on will also improve thermal comfort conditions and has the added benefits of maintaining the energy efficiency of the system and helping to maintain appropriate humidity levels in the building.

In summary the benefits of maintaining high outside air rates to dilute internal viral contaminants outweigh the risks of viral particles being transferred via a correctly configured thermal wheel. Systems should be checked for configuration and correct operation by a competent engineer. Personnel should adopt the usual safety procedures for dusty work and should wear appropriate personal and respiratory protective equipment.

4.2.2.3 Recirculation sectors in centralised air handling units

Recirculation within central air handling units serving multiple rooms or zones may increase the risk of cross-infection. There is some evidence of viral material being detected in air handling units, although its viability is not known. Transfer of viral material from one zone to another poses as much lower risk compared to far-field airborne transmission in a single zone having an infected person, but to minimise the risk it is therefore preferable to operate with the recirculation dampers closed when reasonable to do so.

However, in certain weather conditions closure of the recirculation dampers may lead to unsatisfactory temperature conditions and consequently a reduction in the rate of supply of outside air to the occupied spaces to levels below that which is deemed adequate (10 l/s/person for typical offices). In these instances, there is a balance of risks to be considered with recirculation; the increased risk of cross-contamination between rooms/zones and the reduced risk of contaminant build-up as a result of maintaining adequate levels of provision of outside air. It is recommended that recirculation is used if this is the only way of maintaining adequate levels of outside air to occupied spaces. However, it should not be used if adequate levels of outside air can be reasonably (with due consideration to thermal comfort and energy use) provided with the recirculation dampers closed.

Some air handling units and recirculation sectors may be equipped with return air filters. These filters do not normally filter out particles with viruses effectively since they have standard efficiencies (G4/M5 or ISO coarse/ePM10 filter class) rather than high efficiency particulate air (HEPA) filter efficiencies. HEPA filters or other filter types which are able to filter out virus particles should only be used in systems that have been designed for use with higher efficiency filters otherwise there is a high possibility of air leaking around the HEPA filter due to the increased resistance of the unit. This will eliminate any benefit from installing the HEPA filter. The increased resistance of the filter may also reduce the rate of supply of outside air. It may also have unintended consequences in other parts of the system, for example placing excessive demand on fans. The advice of a competent engineer should be sought, and manufacturer’s guidance should be consulted before modifying installed filters or changing the grade of filter installed.

4.2.3 Duct cleaning

Duct cleaning does not reduce risk of infection since any viral particles encapsulated in aerosols that settle in ductwork will become unviable over time, unlike other pathogens such as bacteria and fungi which can continue to multiply in such environments, viruses require a host cell for replication. Therefore, no changes are needed to normal duct cleaning and maintenance procedures. In kitchens and catering facilities normal duct cleaning is required for fire safety and to meet other public health requirements and should be conducted as normal with appropriate precautions in place.

4.2.4 Outside air filters

Outside air is not seen as a high-risk source of SARS-CoV-2 viral aerosols. Therefore, it is not necessary to modify or alter the grade of existing outside air filters and replace them with other filter types. They should be changed in line with the standard maintenance regime requirement.

For a fuller explanation of filters and the relevant standards commonly applied in the UK see https://www.cibsejournal.com/technical/understanding-hepa-filters/.

4.2.5 Changing filters

Filters must be replaced according to normal procedure when pressure or time limits are exceeded, or according to scheduled maintenance intervals. Clogged filters are not a contamination source in this context, but they reduce supply airflow which has a negative effect on the ability to remove and dilute concentrations of contaminant. Thus,

HVAC maintenance personnel may be at risk when filters (especially extract air filters) are not changed in line with standard safety procedures. Filters may have active microbiological material on them, including viable viruses, particularly in any building where there has recently been an infection. Filters should be changed with the system turned off and technicians must use appropriate PPE including gloves and eye protection, overalls and personal respiratory protection. Used filters must be disposed of in a sealed bag in the appropriate waste stream.

4.2.6 Extract only

If the ventilation provision is extract only and the make-up air (the air that enters the room to replace that exhausted) is outside air from infiltration through the building fabric (i.e. gaps) then this is unlikely to present an increased risk of viral transmission. However, if the main make-up airflow pathway is from another room or zone then it will increase the risk of spreading any airborne viral particles between zones.

For extract ventilation in toilet blocks please see section 4.1.1.5, windows in toilet blocks. In toilet blocks with mechanical extract ventilation the extract ventilation should remain constantly on and windows in the toilet block remain closed. A notice may be required on the toilet doors/walls to explain this and discourage opening. Airflow through windows can change pressure differences in the toilet block and could encourage airflow out of the toilet block into adjacent spaces.

4.2.7 Split air conditioning systems

Within a room or zone these systems are good at providing thermal comfort by warming or cooling the indoor air and the air movement they provide can help prevent stagnant areas of air within a room. However, it is important to understand that they do not provide any outside air into the room or zone and without a dedicated source of outside air supply into a room they could be responsible for recirculating and spreading airborne viral particles into the path of socially distanced building users. If there is no source of outside air provision from either natural or mechanical ventilation when these units are in operation then the space should only be used for short periods of time.

4.2.8 Fan coil units

If there is a good outside air ventilation supply (either mechanical or natural) to the room or zone then the action of the fan coil unit fan will help de-stratify the air and reduce the chance of pockets of stagnant air, helping to dilute any airborne pathogens.

If a room or zone has no or very little outside air ventilation provision then the action of a fan coil unit could create air movement that is likely to spread any airborne viral particles throughout the room and the advice is to turn off the fan coil unit fan.

4.2.9 Chilled beams

Active Chilled Beams – these form part of the ventilation system and are used to chill incoming outside air as it passes into a room. These can operate as normal.

Passive Chilled Beams – cool air already in a room by absorbing the heat. They do not bring outside air into the room. They will cause air mixing due to convection currents, but as with fan coil units, if there is a good supply of outside air these can still be operated and do provide comfort.

If a room or zone has no or very little outside air ventilation provision then the chilled beams may generate air movement that is likely to spread any airborne viral particles throughout the room and the advice is to turn off the chilled beams.

4.2.10 Room air cleaners

Room air cleaners effectively remove particles from air, but do not remove CO2, odours, gaseous pollutants and volatile organic compounds from the air. To be effective, air cleaners need to have HEPA filters or other filter types which are able to filter out virus particles and to have a substantial proportion of room air pass through them.

Because the airflow through air cleaners is limited, the floor area they can effectively serve is normally quite small, typically less than 10 m^2, and the appropriate location of these is essential. The cleaner must not be located in a stagnant zone; an air cleaner located in the centre of the room will clean more of the room air in most cases due to the air circulation passing it. Locating the air cleaner close to the breathing zone is an alternative, however this requires an air cleaner per person.

Special UV cleaning equipment for room air treatment is also effective at killing bacteria and inactivating viruses but this is normally only a suitable solution for health care facilities. See section 6 for further information on the use of UV equipment.

4.3 Specialist localised exhaust ventilation

Specialist localised exhaust ventilation is provided for workplace and process specific safety reasons and should continue to be operated as normal. The Institute of Local Exhaust Ventilation Engineers, which is a division of CIBSE, provide more specialist advice and practitioners who have particular expertise in these systems.

It is worth considering where make-up air into the room with specialised ventilation is coming from; ideally the make-up air should come from outside air rather than from adjacent rooms.

4.4 No obvious ventilation strategy

If there is no obvious ventilation strategy in a room or zone then building users should be discouraged from using these spaces. If they are used only transiently e.g. stairwells, corridors, then more robust cleaning regimes for these locations should be implemented.

5 Natural Ventilation in Winter

The amount of outside air that can be reasonably provided during winter is likely to be less than in the summer due to the impacts on indoor air temperature and occupant comfort. Poorly ventilated spaces are highly likely to increase the risk of SARS-CoV-2 transmission via aerosols at distances greater than 2m. It is therefore important that all reasonable steps are taken to avoid poor ventilation of indoor spaces as far as possible.

Approved Document F (ADF) to the Building Regulations in England[5] sets out what, in ordinary circumstances, may be considered as reasonable provision of '*adequate means of ventilation provided for people in a building*' (Requirement F1(1) of the Building Regulations 2010). At the very least it is important that adequate ventilation is provided year round as poor indoor air quality also negatively impacts health, wellbeing and productivity. For further discussion of the evidence base for this see CIBSE TM40:2020, in particular chapters 3 and 9. Wherever possible, outside air flow rates should be increased to provide more than the minimum rates for adequate airflow for building regulations compliance, wherever it is reasonable to do so without causing undue thermal discomfort or a significant increase in energy usage.

Ventilation plays a key role in diluting airborne SARS-CoV-2 in respiratory aerosols. Poorly ventilated spaces increase the risk of transmission and the potential benefits of increasing ventilation to a poorly ventilated space are greater than for an already well-ventilated space. There is therefore a law of diminishing returns in increasing ventilation rates. Increased ventilation in winter may lead to unwanted occupant behavioural responses that result in ventilation provision being deactivated or minimised. For example, increased ventilation could result in colder indoor environments or cold draughts resulting in occupants closing, reducing or turning off ventilation provision, frustrating the goal of increased ventilation.

In winter, the driving forces for natural ventilation, pressure differences caused by wind and differences in temperature between indoors and outdoors, are usually greater and so, to deliver the same flow rate, openings do not need to be opened as wide in the winter as in the summer. What follows provides guidance for adjusting various ventilation openings to deliver adequate outside airflows whilst minimising occupant discomfort. Adjusting ventilation openings can be complimented with purging a space by opening windows or ventilators fully for several minutes during unoccupied periods, such as during breaks or between meetings.

5.1 Adjusting airflow through natural ventilation openings

5.1.1 A single set of high- and low-level openings:

Where a space has high and low level windows or ventilators it is preferable to open the high level vents first to provide outside air, and to open the low level windows to further maximise airflow when reasonable. The turbulent plume of cooler outside air entering through high level vents will mix with warm room air as it falls under gravity, tempering, or warming, the cooler air before it enters the occupied zone. A helpful draught plume calculator is available in the Department for Education Building Bulletin 101 calculation tools[6], which enables this effect to be measured. A safe means of opening and closing high level vents should be supplied in workplaces.

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[5] Each of the Devolved Administrations has similar guidance.
[6] https://www.gov.uk/government/publications/classvent-and-classcool-school-ventilation-design-tool

5.1.2 Multiple openable windows and/or vents:

Where a room has multiple openable windows or vents, it may be possible to deliver adequate ventilation through just one opening. However, it is usually possible to create a more comfortable indoor environment, with respect to draughts, if the airflow is achieved through opening all the vents by a smaller amount than that required for a single opening as described above.

If there are openable vents at both high and low level, then the principle of opening as many high level vents should initially be considered (see 5.1.1).

5.1.3 Sash windows:

As with high and low level windows, it is better to open the high level sash to provide openings at the top of the vent to encourage entrainment of outside air with the warm indoor air in the first instance. Opening the bottom sash will further increase outside airflow.

5.1.4 Other vents:

In addition to windows, there are other ventilators and louvre systems that can be modulated and operate in a similar way to windows, the principles of opening high level vents and multiple vents a small amount should be considered in the first instance.

5.2 CO_2 Sensors:

Measurements of elevated CO_2 levels in indoor air are an effective method of identifying poor ventilation in multi-occupant spaces. However, in low occupancy or large volume spaces a low level of CO_2 cannot necessarily be used as an indicator that ventilation is sufficient to mitigate transmission risks.

Multi-occupant spaces that are used regularly and are poorly ventilated (below 5 l/s/person or above 1500ppm CO_2 for prolonged periods) should be identified and prioritised for improved ventilation rates.

Spaces with low occupancy or where enhanced aerosol generation is likely (e.g. through singing, loud speech, aerobic activity) should aim to ensure ventilation is sufficient to maintain CO_2 concentrations below 800ppm (typically 10-15 l/s/person), and should also include additional mitigations such as reduced exposure (occupancy) times, face coverings for audiences and restricting the size of groups and duration of activities. The latest Government advice should be sought with respect to undertaking high aerosol generating activities indoors.

If CO_2 sensors are to be deployed they should be Non-dispersive Infra-red (NDIR) CO_2 sensors, which actually detect CO_2 in the space, rather than the less expensive e\co sensors that do not detect CO_2 and infer a CO_2 concentration by measuring room volatile organic compound (VOC) concentrations instead.

5.2.1 Occupant Comfort

A person's sensation of warmth is influenced by the following main physical parameters, which constitute the thermal environment:

- air temperature,
- mean radiant temperature,
- relative air speed,
- humidity.

Besides these environmental factors there are personal factors that affect thermal comfort:

- metabolic heat production
- clothing.

It is possible to adjust the personal environmental factors to improve occupant comfort, particularly where outside air supply may decrease occupant comfort. CIBSE Guide A describes the predictive mean vote (PMV) method of measuring occupant thermal comfort, which can be used to see how changes to apparel and metabolic activity can improve occupant thermal comfort.

5.2.2 Clothing

Clothing provides a layer of insulation that contributes to the occupant's perception of comfort and is dependent upon the material and fit. Typical winter wear would have a value of 0.8 to 1.0 clo, although studies in recent decades in Europe and the UK have found values generally at the lower end. This may be a result of occupants acclimatising to, and expecting, warmer indoor environments in the winter. For example, compare typical winter office clothing of the 21st Century, with that in vogue at the turn of the 20th Century. To improve occupant comfort, particularly in naturally ventilated indoor spaces, occupants should be encouraged to dress appropriately. Relaxation of dress codes should be considered if necessary to allow warmer clothes to be worn.

Notwithstanding the benefit of warmer clothes to improve occupant comfort, the heating design of naturally ventilated indoor spaces should include provision to temper the incoming air required for adequate ventilation. Whilst it would be expected that the indoor design air temperatures will be maintained, air temperature is only one component of thermal comfort and so warmer clothes will also be of benefit for comfort. For example, it is quite common to be comfortable in shorts and t-shirt early on a summer morning, when the air temperature may be 18°C, but to be uncomfortable wearing the same apparel in the winter when the room air temperature is also at 18°C.

5.2.3 Metabolic rate

Sedentary activities have a relatively low metabolic activity which can contribute to occupant thermal discomfort. Encouraging periods of activity, to move around the room, or partake in some light exercise, will help to improve thermal comfort – as well as aiding in meeting display screen equipment (DSE) regulations which require regular breaks or changes in activity when using DSE and recommendations for regular movement to improve health.

5.3 Position of occupants in relation to openable vents

Where possible, increasing the distance of occupants from openable vents gives more time for incoming cool air plumes to mix with warm room air prior to entering the occupied zone.

NOTE: Hybrid and mechanical systems are not covered – advice should be sought from the manufacturer as to recommendations on using their proprietary systems in delivering adequate air flows during cooler months.

6 UV disinfection

Ultraviolet germicidal irradiation, UVGI, is a long-established technology using UV-C light at wavelengths around 254nm. It appears to have considerable potential to inactivate SARS-CoV-2 and other pathogenic coronaviruses, as at the appropriate wavelength it disrupts the structure of the nucleic acids which form the virus genome. Early studies indicate that SARS-CoV-2 is relatively easily inactivated by UV-C light and when aerosolised the virus is likely to show a similar susceptibility to UV as other coronaviruses in air.

It may be possible to install UVC disinfection equipment within some mechanical ventilation systems. UV disinfection may be a viable solution to reducing levels of active viral material in spaces where it is difficult to provide good ventilation. UV disinfection should be seen as a supplementary measure for reducing the concentration of pathogens. It does not remove other contaminants and it is not an alternative to providing adequate ventilation. Where there is adequate ventilation the cost benefit of using UV may be limited.

UV systems take several forms:

- Upper room germicidal ultraviolet (UV) systems: may be installed in upper areas of a room, acting on the air above head height and relying on air mixing to enable it to be effective on the whole volume of air in the space over a period of time.
- In-duct UV: installed in the air distribution, disinfecting air as it passes through the system. The efficacy is a function of the size of the UV lamp and the velocity at which air is passed across the system.
- Room air cleaner: it can be part of a room air cleaner which passes air from the room through a combination of filters and UV radiation.

When specifying any UV installation it is necessary to consider the size and for upper room systems the height of the spaces to be served and the existing ventilation system, the flow rate through the device, duct or space, the location of the equipment, noise and any unintended effects on air quality. Some UV technologies can be hazardous to health if applied or operated incorrectly. Installation of UV will involve some capital cost.

6.1 Upper room Ultra-Violet Germicidal Irradiation

Upper room systems use UV light in the upper air of a room to deactivate viral material, relying on mixing in the space. It is not limited by the rate of airflow through a duct or cleaning unit. Initial assessments of the effectiveness of UV to deactivate similar viruses suggest that UV is effective against SARS CoV 2. Upper room UV is likely to be at its most effective in poorly ventilated spaces and can be installed reasonably easily at a low cost. Sizing a system is not always straightforward, and it is essential that they are installed by competent professionals who understand the safety requirements for UV-C radiation sources in occupied zones.

6.2 In-duct Ultra-Violet Germicidal Irradiation

These systems use UV-C lamps mounted in the return or supply air ducts of mechanical ventilation systems to disinfect the air. Although the lamps can be placed in either the return or supply air ducts, it is generally preferable to install them on the return air side of the air handling unit where they disinfect air that may be recirculated and also protect up-stream duct-work, filters and coils from becoming contaminated. It is important to design the installation appropriately for the volumes and air flow rates in the system.

6.3 UV Room air cleaners

UVGI room air cleaners are located in a room space and use UV-C lamps mounted inside an enclosure, with a fan to draw air through the irradiated zone. They may also employ filters, and can vary in size, but only disinfect the air that passes through the device.

6.4 Safety

Where the UV system is being relied on to reduce the risk of viral particles in the air, it is important that any such system `fails safe', so that building managers become immediately aware of any failures so that occupants can continue to be protected should the lamps fail.

This may be done by allowing some additional system capacity to cover some lamp failure, allowing maintenance and replacement to be undertaken out of hours when the system can safely be shut down if necessary.

UV-C light is highly biologically active and can damage human tissues. As this wavelength of light is invisible to humans, damage can occur without being noticed initially. Exposure to UV light can result in inflammation of the cornea of the eye (known to skiers and mountaineers as sun-blindness). Certified safety eye-wear for use with UV-C should always be worn when working on UV systems. UV-C light can also cause reddening of the skin similar to sunburn. A review by the International Commission on Illumination (CIE) concluded that upper-room UVGI air disinfection could be safely used without significant long-term risk.

Upper room UV systems are designed to operate whilst the room is occupied and must be installed so as to avoid exposure of occupants to UV light.

Any other form of UV air cleaning in rooms must only be operated when the room is vacant, and there must be robust means of preventing anyone entering the space during the time when the UV lamps are operating.

6.5 Summary

Each of these engineering control measures may be appropriate in certain circumstances, although all have both advantages and limitations, and none can entirely eradicate the risk of transmission. Upper room UV offers an approach to reduce the risk of transmission, particularly in poorly ventilated spaces. In duct systems may be effective where it is possible to manage duct velocity and radiation levels to achieve a high level of disinfection within the treated section of the system. Portable units may be effective, although careful attention is needed to size them.

In all cases it is essential to establish that the equipment is appropriate for the intended use, can be safely maintained and is tested and certified for the proposed use using recognised and accredited testing certification arrangements. Care should be taken with portable or in duct units to check the likely noise of the unit in use.

There is a need for better data and case studies on successful real-world applications to support all of these technologies.

Contributors to this guidance: The primary authors were Dr Chris Iddon, Dr Abigail Hathway, Prof Tony Day and Dr Shaun Fitzgerald, with contributions from Frank Mills, David Stevens and George Adams. Dr Hywel Davies co-ordinated the group. Further information on preparing and using buildings during the Covid-19 pandemic can also be obtained from other professional bodies and https://www.gov.uk/coronavirus.