# VENTILATION AND DRAUGHT PROOFING IN HISTORIC CHURCHES

Draught proofing sounds like a simple thing to undertake, and one with which we are all familiar. Get it right and you can make a building feel more comfortable and be more energy efficient. Get it wrong and you can make a building feel stuffy and cause salt damage to masonry, cracking of woodwork and mould outbreaks.

The aim of this guidance document is to take those who have responsibility for the care of a church building through the process of understanding how ventilation works, where restricting ventilation (draught proofing) is likely to have either a positive or negative effect, and the way in which this can be safely and effectively achieved. In a shorter guidance document of this type, the information is necessarily limited, however, references are provided at the end on more detailed technical information, as well as where to find further advice.

### Executive Summary

In order for our church buildings to be comfortable and energy efficient, as well as for their effective long-term conservation, they need to be maintained in the best possible condition. This requires ensuring that the building envelope is well maintained that the rainwater and drainage functions effectively, and that air exchange with the exterior only occurs where it is necessary.

For effective draughtproofing, it is important to understand the source of uncomfortable draughts, why they are occurring, and whether they serve any beneficial purpose, before finally designing control measures. These measures can often be simple and low cost and can be an excellent way of improving comfort and energy efficiency. However, preventing ventilation in the wrong location can lead to condensation issues, timber rot, mould outbreaks and other problems which cause long term and expensive damage.

## Conservation and Ventilation

In broad terms, effective conservation of the building fabric and the furnishings requires stable environmental conditions without an elevated level of relative humidity (RH). Large fluctuations in RH can cause timber furnishings to expand and contract, sometimes leading to cracking and splitting. If the timber is painted, such as on a ceiling or a rood screen, this can cause flaking and loss of the paint layer. Painted hatchments suffer from the same risks, with expansion and contraction of the canvas causing separation from the paint layers. High RH can also lead to mould growth on textiles, timber and books. On stone and plaster, and on wall paintings, large fluctuations in RH can cause salt activity leading to powdering, flaking and loss.

*Damage to a painted ceiling and salt deterioration on masonry due to unstable environmental conditions.*

Therefore, when considering measures for ventilation and draught proofing it is important to also consider the impact on the conservation of the fabric and furnishings, alongside improvements to comfort and energy efficiency. In all cases, there is a balance to be struck, but in general, the need to maintain stable conditions for effective conservation is best served through minimising air exchange with an unstable space (typically outside), while ensuring that there is not a build-up of humidity in enclosed spaces through the employment of good air movement or circulation.

## Building Condition, Draughts and Humidity

The concern with draughts is generally that they make people feel cold and uncomfortable. However, comfort is influenced by the temperature and humidity in a building and air movement simply exacerbates other factors that are already causing discomfort. In other words, a draught in a dry and well-maintained building is far less of a problem than a draught in a wet and poorly maintained building. Therefore, ensuring that the building envelope and rainwater disposal system are in good condition and that the building is dry should always be considered to be as important as draughtproofing, or it may transpire that measures to control air movement have had little or no effect on comfort within the building.

As seen above, ventilation is an important tool in controlling build-up of moisture that can cause damage to the historic building. Thus, in a poorly maintained and wet building, it is often necessary to have greater levels of ventilation to manage the damp conditions than in a dry, well maintained building. For the same reason it is often easier to implement effective and safe draughtproofing in a dry, well-managed building because the risk of creating conservation issues is considerably reduced.

## What is Ventilation?

The term ventilation generally refers to two separate but connected facets: *air movement* and *air exchange*.

## Air Movement

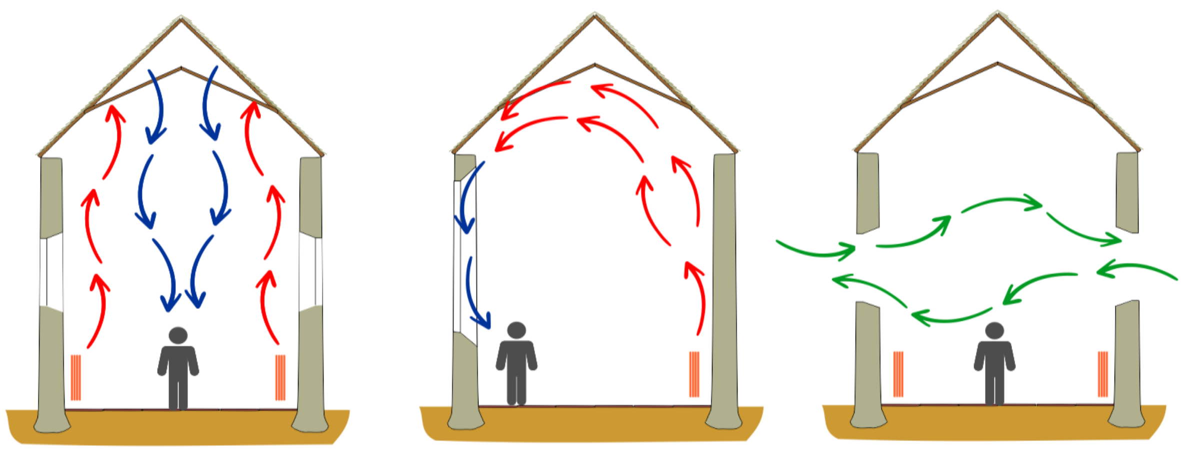
Air movement is exactly as it sounds – air moving around a space – and can be generated by wind blowing through an open window or around a loosely fitting door, or by mechanical systems such as fans. Moving air causes moisture to evaporate at a faster rate than static air (clothes on a line dry more quickly on a breezy day), and can cause surfaces to reduce in temperature as energy (in the form of heat) is lost to the moving air.

Air movement or *air circulation* can be used to improve comfort when there is a high temperature, and the cooling and evaporative effect is welcome. When the temperature is low, however, this same air movement causes discomfort and is generally what is referred to as draughts.

The simplest way to achieve air movement is often through opening windows and doors, allowing external air into the building, but this also results in *air exchange* with the exterior, which can have both positive and negative effects.

Air movement is often used in an attempt to improve drying in wet buildings due both to its ability to increase the rate of evaporation from wet surfaces and in order to bring in drier air through *air exchange*.

Air movement can also be caused as a result of poor heating design, with warm buoyant air rising from radiators to the high, cold, upper part of a church, where it cools beneath the uninsulated roof and then falls back down causing uncomfortable cold draughts for the people below. In winter, a similar situation can occur due to large church windows as, when warm air touches the cool glass, it becomes colder and less buoyant, with a resulting flow of cold air moving downwards.



*Air movement and air exchange from cross ventilation and heating; while internal air movement alone recirculates air within a space, air movement from another space causes air exchange.*

## Air Exchange

The other aspect of ventilation is air exchange, in other words, swapping air between different spaces. These might be two internal rooms (leaving the bedroom door open so the room does not become stuffy) or internal/external change (opening the window to a bathroom to reduce the humidity following use of the shower).

Air exchange can also take place in a single space, such as when dry air in the middle of a room is encouraged to move into wet corners or enclosed spaces behind panelling, in order to reduce the buildup of static damp air. In combination with the evaporation from *air movement*, as discussed above, this can be an effective drying tool.

The key thing to understand is that, by exchanging air with another space, you are also introducing all the environmental elements of the new air. Thus, by introducing external air into a building, you will also be introducing either wet, dry, hot or cold air, depending on the prevailing conditions outside. This may have positive or negative consequences for the building fabric and furnishings.

The other thing to consider with external air is that the temperature and humidity is unstable, so the air coming in through an open window at 8am will be very different to that at 1pm, and likewise, external air in winter will be very different to external air in summer.


*External temperature and humidity are far more unstable than internal conditions.*

In a well maintained church, on a typical sunny spring day, the humidity and temperature inside the church is generally relatively stable, varying by less than 10% relative humidity and 2°C, which is beneficial for the conservation of the fabric and monuments. In contrast, external air may fluctuate by more than 50% and 10°C. Therefore,  the introduction of this unstable air into the church will almost inevitably increase the conservation risks to the historic fabric and furnishings (see below).

Air exchange to the exterior can occur through a single opening due to variations in internal and external air pressure. However, when there are two or more apertures open concurrently (such as an open door and an open window), the cross ventilation that is created can cause a far greater volume of air exchange, as well as a greater speed of airflow. In summer this might be viewed as welcome cooling, while in winter as an uncomfortable draught.

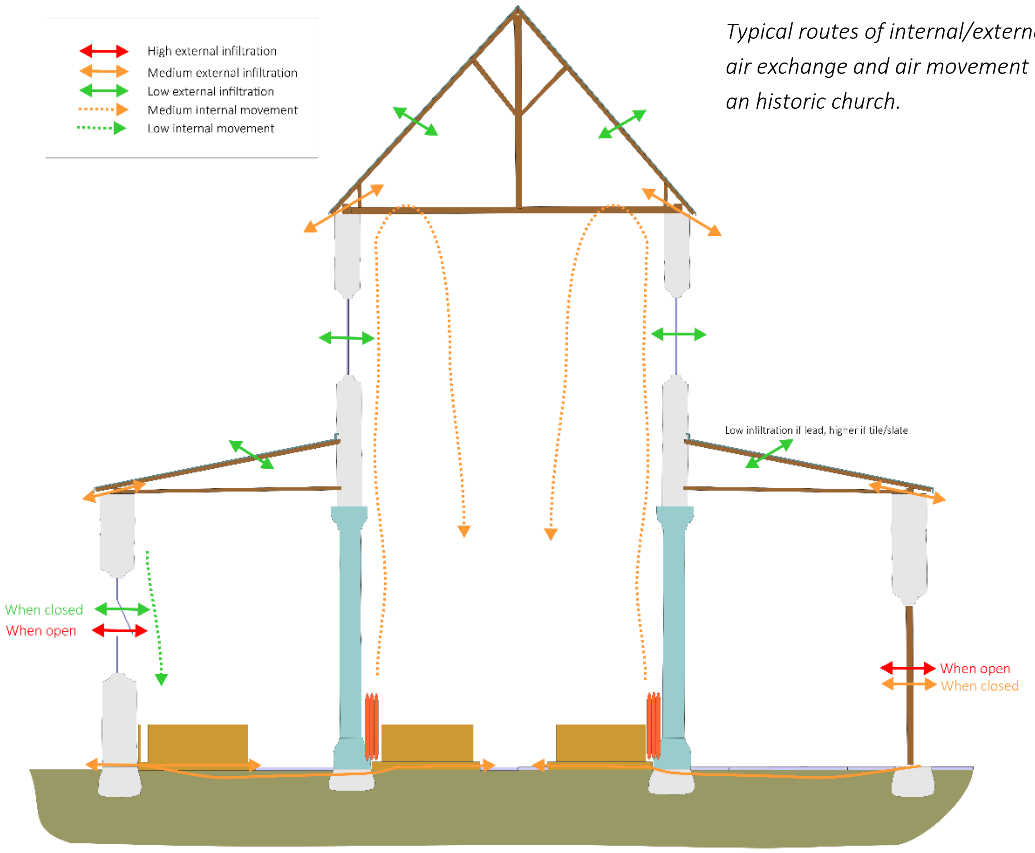
External air being used for ventilation is sometimes referred to as *fresh air*. This is generally in the context of carbon dioxide content (see below), but can be misleading in terms of building conservation if it gives the impression that external or *fresh* air is benign. External air is simply air from a different space which has different environmental conditions. The external air's attributions may have either positive or negative implications and its introduction needs to be evaluated on this basis.

# Common Routes of External Air Exchange

Some of the common routes of external air exchange in churches are obvious, in particular:

- Open windows
- Open and/or loosely fitting doors

- External ventilation openings (often installed during 19th century construction or restoration)



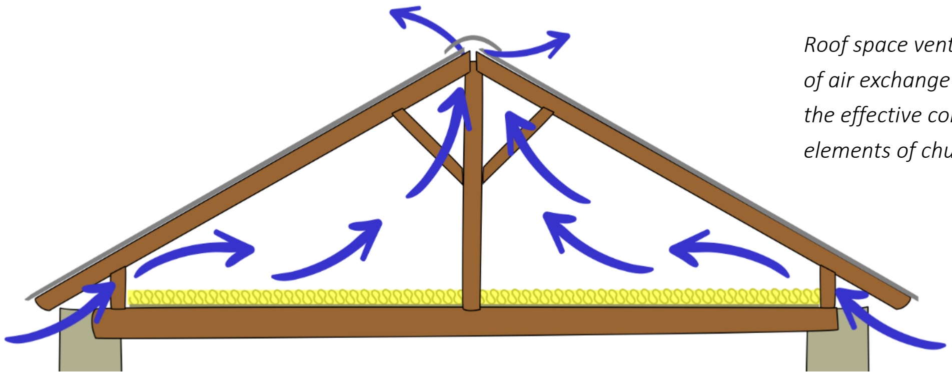

*Typical routes of internal/external air exchange and air movement in an historic church.*

There are also numerous routes that are less obvious:

- Leakage around door and window frames
- The junction between the wall heads and the roofs (where there is no ceiling)
- Directly through tiled roofs which have exposed sarking boards and no felt
- Cracks at the vertical junctions between walls (i.e. in the corners of the nave or chancel)
- Cracks in ceilings
- Cames in leaded windows (as the glass cement in the lead cames deteriorates)
- Suspended floors and pew platforms
- Open towers or loosely constructed tower room floors

# Beneficial or Damaging Ventilation

There is no such thing as good or bad ventilation, it is simply a question of what the use of ventilation is intended to achieve. In church buildings, some typical applications where external ventilation is used intentionally to positive effect are roof spaces and pew platforms where air exchange and movement can reduce moisture build up, which is a greater conservation risk than the instability that is caused by the introduction of external air.



*Roof space ventilation: high levels of air exchange are essential for the effective conservation of some elements of church buildings.*

It is possible that this type of ventilation might also cause uncomfortable draughts. However, it is essential for the protection of the building from long term damage, so that blocking up these ventilation routes is almost never a good solution. Nevertheless, it is important to consider the condensation risk in these hidden spaces (see below).

Following a flood or leak, external air exchange (and air movement) can be an effective tool as the need to dry the building temporarily outweighs the need to prevent uncomfortable draughts, prevent unstable conditions with conservation risks or to reduce energy efficiency. However, this should be regarded as a short term solution to a specific problem and not a long term approach.

## Air Exchange, Carbon Dioxide and Historic Pollutants

In occupied buildings there is a need to allow a level of air exchange to prevent the build-up of carbon dioxide, which results from human breathing and which can cause poor environmental health conditions. In modern buildings, which intentionally have a minimum air exchange rate (AER), systems need to be put in place to ensure that this air exchange is achieved by passive or mechanical means. However, in periodically used historic churches, the natural AER is generally well above that needed to control the build-up of carbon dioxide. Nevertheless, when considering draught proofing, the impact on $CO_2$ build-up should be taken into account, particularly in modern church buildings.

In a similar manner, in some 18$^{th}$ and 19$^{th}$ century churches, a complex system of manual ventilation was included in walls, ceilings and roofs in order to control the build-up of noxious gasses from gas or coal fired heating and lighting. However, this may have had a secondary effect of providing ventilation which benefitted the conservation of the building. Before removing or blocking up the remaining parts of systems of this type it is important to understand their current effect on the building environment and what the effects of their removal would be.

## Ventilation, Draughtproofing and Condensation

Warm air can hold more moisture than cold air. Condensation occurs when the air temperature falls to a level whereby it cannot hold the current volume of water vapour, the so-called dew point temperature. At this point, the water vapour will condense, either on a cold surface or in the air itself. The liquid water formed as condensation can be especially damaging to the conservation of the building fabric and furnishings.

## Fresh Air Condensation

Due to the potential differences between temperature and humidity conditions inside and outside a church, poorly controlled air exchange can lead to condensation, causing significant damage to the historic fabric and furnishings. This can occur at all times of year, but is most prevalent in the spring when the masonry structure of the church, which is comparatively thermally inert (i.e. it changes temperature slowly), has been chilled over the winter. Outside, as the spring air warms, there is a large increase in the moisture content of the air due to water evaporating from the ground. If windows and doors are opened, sometimes in order to "air the church", the warm, wet external air enters the building in large volumes. This air strikes the cold walls, decreasing in temperature until dew point is reached and condensation forms on the walls leading to the type of deterioration discussed above. Therefore, encouraging ventilation with external "fresh air" in these circumstances can be highly damaging.


*The introduction of warm, moist "fresh" air into a cold church can cause significant condensation and damage.*

## Condensation and Roofs

When the church is in use, the air moisture content generally rises as a result of people breathing out moisture (typically in the region of 70 g per hour) and evaporation of moisture from the building fabric caused by the increase in temperature, both from people (typically about 100 watts per person) and from heating used for their comfort. When this moist air strikes a cold surface, for instance the underside of the lead roof, the temperature will fall, particularly during nighttime or winter, until it reaches the dew point and condensation may form on the underside of the lead.


*An example of underside lead corrosion: poorly designed roofs with insufficient roof space  airflow can lead to severe condensation, resulting in underside lead corrosion.*

This is a common occurrence, however, if there is sufficient ventilation around the wet lead, the moisture can evaporate with little damaging effect. In the event of insufficient ventilation resulting from air exchange and movement routes being blocked up, the lead can remain wet, causing underside corrosion and, in the most serious examples, condensation may run onto the adjacent timber, which may then cause dry or wet rot.

High levels of roof condensation can also occur when the external weather is especially cold, or a church is in poor condition and internal humidity is especially high, even when the church is not occupied. For this reason a good system of ventilation is especially important for lead roofs.

## Condensation on Windows

In a similar way to condensation issues on roofs, this can also occur on church windows. Glass is generally more robust than lead, however historic stained glass is vulnerable to the effects of condensation, due both to the solubility of the body glass and the possibility of deterioration of the glass paint. The level of vulnerability of different types of stained glass varies depending on how it was made. In contrast to roofs, the surface of church windows are exposed, rather than being hidden behind sarking boards, and air exchange across the surface is generally good, which means that evaporation is easily achieved. Nevertheless, because there can be a significant accumulation of condensation on the relatively impermeable glass, this water can pool and run down the glass, causing damage to the masonry below.

*Severe condensation can form on cold surfaces, such as glass, causing damage to adjacent stonework.*

Environmental protective glazing (EPG) is sometimes used to protect sensitive historic glass from condensation. While this might also reduce ventilation and draughts, the system is carefully designed to control condensation and other risks. However, if standard secondary glazing is being considered to reduce draughts on non sensitive windows, care has to be taken with the design to ensure that the reduction in air movement does not increase the risk to the glass and masonry associated with condensation.

## Condensation in Hidden Spaces

Condensation on roofs and windows is expected and it is often recognised that some control measures may need to be put in place. However, in terms of building conservation, an area of significant risk is condensation in hidden spaces. These can be defined as poorly accessible spaces that are generally not considered, such as under pew platforms, behind panelling, at the back of cupboards or in unintended gaps in the building structure. These are spaces into which air from the body of the church can penetrate, but they are often poorly ventilated. The greatest condensation risk is usually in those hidden spaces that are against external walls, where the temperature can fall due to the external conditions. Warm, moist air generated during periods when the church is in use can leak into the space and condense on the cold surfaces, causing salt activity and microbiological growth, which often remains unseen until there is severe deterioration.

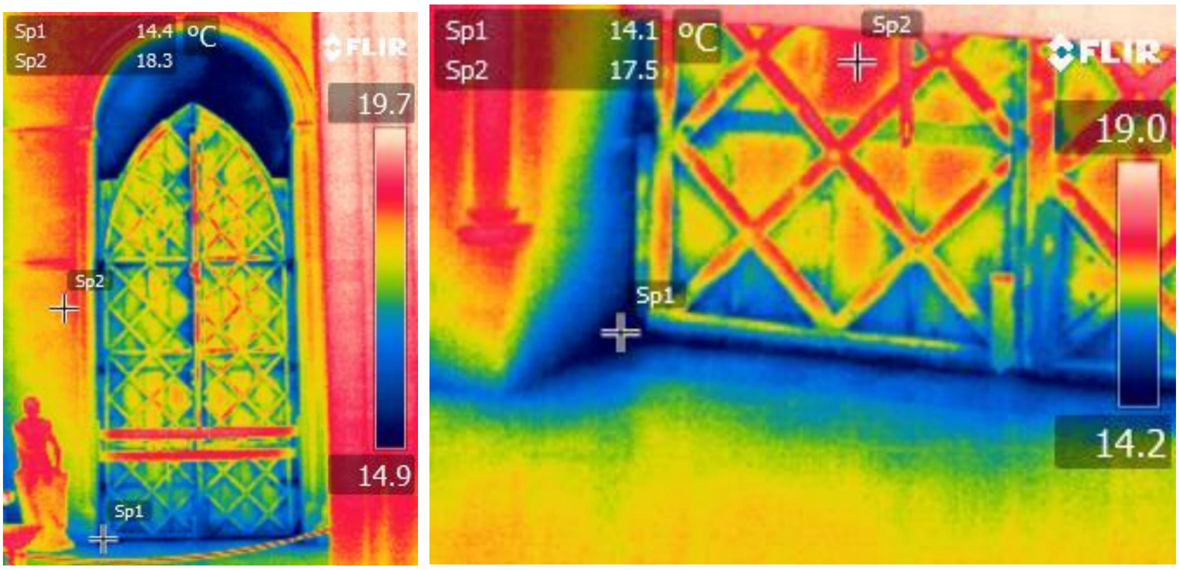
Traditionally, many of these spaces have been intentionally ventilated (external vents to under pew platforms and ventilation openings into wainscoting). However, many of these openings have been closed up either due to a misunderstanding of what they were for, or so as to prevent uncomfortable draughts.


*External and internal ventilation openings to under pew voids are designed to reduce moisture levels.*

# Energy Efficiency

Building heat loss (or gain) occurs largely as a result of radiation and convection. Radiation is the ability to allow the transmission of heat through the solid structure. Thick masonry walls allow limited radiant heat gain/loss, while windows, doors and uninsulated roofs allow high levels of radiant heat gain/loss. Convection refers to heat gain/loss through air exchange. A high infiltration rate building with multiple gaps will allow greater convective heat gain/loss than a well-sealed, low infiltration rate, building.

For new buildings, low air infiltration rates are specified in order to optimise energy efficiency, minimising heat loss through air leakage. Churches and other historic buildings have naturally far higher air infiltration rates, which makes them inherently less energy efficient in terms of air exchange. However, this same air leakage is often the ventilation which controls the build-up of damaging moisture. It is therefore always necessary to strike a practical balance between reducing air exchange to improve energy efficiency and maintaining air exchange to prevent damage.



*Thermal images demonstrating air leakage around poorly fitting church doors, which is both inefficient in energy terms and the cause of uncomfortable draughts.*

## Historic Draughtproofing

Historically, people have generally been far better at managing traditional buildings and making them more comfortable through passive means (without the use of mechanical systems) than we are today.

In the 19th century, a church would often have door curtains to block draughts, box pews, often upholstered, to create cosy, draught free spaces, and pew cushions and mats to reduce heat loss to the cold structure, thereby providing greater overall comfort. During the 20th century, as fashions changed, many of these features were removed from churches, making the building more vulnerable to draughts and sources of uncomfortable cold.


*Tower curtains and external door curtains can significantly reduce air movement and draughts.*

It is also worth noting that, as with many buildings of traditional construction, churches are inherently draughty buildings and throughout most of their history this has been an accepted feature. What we are now trying to do in terms of reducing air exchange and ventilation is to change the original performance of the building. While this might improve comfort and energy efficiency, it can also remove the beneficial effects of ventilation.

# Practical Draughtproofing

Safe and effective draughtproofing requires careful planning if it is intended to improve both thermal comfort and energy efficiency while avoiding creating risks to the conservation of the building. The basic steps for all well designed draughtproofing projects are as follows:

1. Establish very clearly what is intended to be achieved. This could be:

    a) Improved comfort

    b) Improved energy efficiency

    c) Improved building conservation

2. Establish the source of problematic draughts. Common sources are:

    a) Gaps in the external envelope

    b) Internal spaces ventilated between one another

    c) Air movement caused by heating systems or cooling from windows and roofs

3. Establish whether the air movement causing the discomfort serves a positive purpose and if stopping it could cause damage. Key questions are:

    a) Is the air movement/exchange intentional with conservation benefits?

    b) Is the air movement/exchange unintentional?

4. Consider temporal factors:

    d) Is the planned draughtproofing temporary or permanent?

    e) Is the draughtproofing intended to be used only during the cooler months or is there a need to reduce the air movement during the warmer months as well?

    a) Temporary draughtproofing measures (such as "sausage" draught excluders) can be simple, cheap and quick to apply, but they also have very little risk as they can be easily removed.

    Some common draught proofing measures are listed in the table below, along with the likely scale (and cost) of the project and its conservation risk.

| Intervention | Scale | Risk |
|---|---|---|
| Blocking gaps around church doors | | |
| Application of door curtains | | |
| "Sausage" draught excluders | | |
| Blocking ventilation openings on external walls | | |
| Repairing cracks in walls and ceilings | | |
| Sealing the tower ceiling | | |

| | | |
|---|---|---|
| Sealing doors to understairs cupboards | | |
| Blocking internal openings in pew platforms | | |
| Closing openings between the head of a wall and the roof | | |
| Repairing leaded windows | | |
| Application of secondary glazing | | |
| Temporary seals around window lights | | |
| Installation of a ceiling | | |
| Closing roof ventilation (intentionally or through insulation in eave openings) | | |

## Conservation and Statutory Issues

Alongside an evaluation of the conservation risks associated with the effects of draughtproofing, it is also important to consider the issues associated with making changes to, or applying fixtures to, the structure of a church building. Some draughtproofing measures will have minimal risks and require no permission, while some will require technical architectural advice and a List B or faculty permission.

Care also needs to be exercised when closing existing ventilation openings to ensure that this does not adversely affect protected fauna, including bats. If in doubt, advice should be sought from a qualified inspector.

The best starting point is a discussion with your church architect, who will be familiar with the conservation and faculty issues; they may have made similar changes in other churches and be able to bring that experience to the project. Another source of information is the Diocesan Church Buildings Team.

## Additional Information


Oxford Diocesan Church Buildings Team https://www.oxford.anglican.org/parish-support/church-buildings/

National Trust, The National Trust Manual of Housekeeping: The Care of Collections in Historic Houses Open to the Public, London 2005

Churchare, The practical path to net zero carbon for churches, https://www.churchofengland.org/resources/churchcare/net-zero-carbon-church/practical-path-net-zero-carbon-churches

Churchcare heating guidance https://www.churchofengland.org/resources/churchcare/advice-and-guidance-church-buildings/heating

Historic England Energy Efficiency and Your Home https://historicengland.org.uk/advice/your-home/energy-efficiency/

Historic England, Places of Worship https://historicengland.org.uk/advice/caring-for-heritage/places-of-worship/

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Brian Ridout, Ventilation and Conservation, Discovery, Innovation and Science in the Historic Environment, Historic England Research Report Series no. 12-2017, https://historicengland.org.uk/research/results/reports/6737/Ventilationandconservation

Tobit Curteis, St Botolph's Church, Hardham, West Sussex, Reinstating the Ceiling to Stabilise the Internal Microclimate, Historic England case study (Forthcoming, 2024)

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Tobit Curteis
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