A BSRIA Guide

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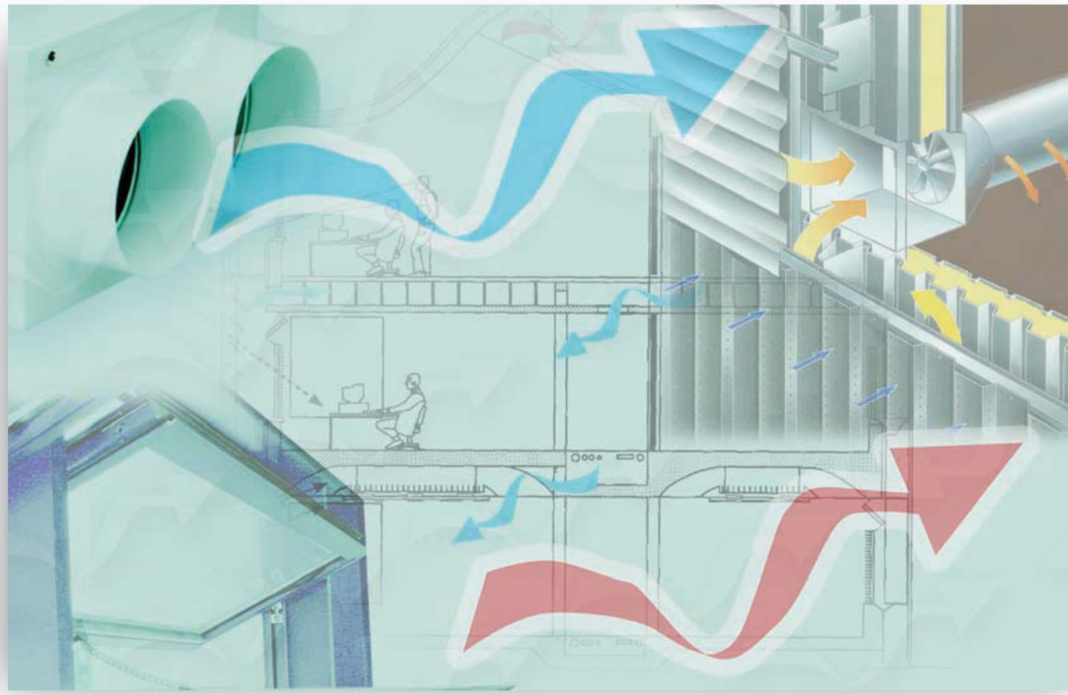
The Illustrated Guide to Ventilation



Compiled by Kevin Pennycook

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INTRODUCTION

Effective ventilation, whether provided by mechanical or natural means, is crucial to provide a comfortable, healthy and ultimately productive working environment. This new guide addresses the design and performance issues of the three main types of ventilation:

- Natural ventilation
- Mechanical ventilation
- Mixed-mode ventilation.

The effective ventilation of buildings has always been a primary design requirement. But in recent times more stringent energy conservation standards have sought to improve the thermal performance of building fabric and reduce levels of uncontrolled infiltration. Among other things this has put greater emphasis on the correct design of windows and mechanical ventilation systems. No longer can designers expect natural infiltration to help maintain air quality. What you specify and what you procure will almost wholly determine what you'll get.

Correct specification, careful detailing, accurate installation, thorough commissioning and diligent post-handover fine-tuning are now of equal importance in order to achieve a satisfactory ventilation system. They are all of equal ranking. Skimp on any one, and a ventilation design can be fatally compromised.

This guide therefore not only describes the basics of ventilation, with copious pictures and illustrations to show how things work and the often subtle differences between components, but also points out key design checks that are necessary to achieve a high quality system. Inevitably, the guide is often more geared to the skilled designer than the lay client, but such guidance is rarely read in isolation from other members of the project team. BSRIA is also available to help its Members understand the more complex issues that the Guide sometimes raises. It's BSRIA's view that it's better to provide too much information than leave readers with begged questions.

Note that while the information in this Guide relates primarily to non-domestic buildings, the basic information is relevant to all types of buildings, particularly in terms of the usability and maintainability of ventilation systems.

It is not desirable for readers to consider the various forms of ventilation in isolation from allied subjects, such as passive design, use of thermal mass, and controls. Inevitably these subjects are co-related and often co-dependent. The guide therefore touches upon the minimising of cooling loads, the contribution from thermal massing, the control of ventilation, the commissioning of systems, and the maintenance and upkeep of ventilation systems.

The best example one can give is the humble window handle. It is not unusual for far more design attention to be paid to the glazed element than to the window handle and the friction stays that are needed to keep window open. Clients and designers therefore need to keep a very watchful eye on the specification of ancillary items. They may be small, but they are not trivial. A few pennies shaved during the value engineering exercise can result in less than robust handles and stays, premature failure of which will seriously weaken the performance of a ventilation strategy.

Controls can also ultimately dictate the success or failure of a ventilation system. Like the window handle, the issue of controls (particularly override controls for occupants) is often lost in the bigger picture.

For example, motorised windows are often a packaged subcontract item, which includes the suppliers' dedicated wall-mounted override controls. These are often generic controls that are rarely tailored to a specific context. Result: the controls are not discussed by the architect's or services engineer, and end up being put in by the specialist sub-contractor, as part of the package subcontract, without anyone on the design side overseeing their usability. Subsequently, the building's users may not know what the controls do, and when to use them. Even the building's architects and designers can be flummoxed, which will be embarrassing. By that time, it's too late to do anything about it.

It follows that ease of commissioning and maintenance become vital to the performance of any ventilation system, whether natural or mechanical or a mix of the two. In the end it comes down to designing for managability and maintainability. There are a host of BSRIA guides that give advice on these issues, and the relevant ones are given in the bibliography. BSRIA Members can download these guides in PDF from the BSRIA Bookshop, while non-members can purchase printed versions on-line.

In conclusion it is worth quoting the old adage: build tight, ventilate right. Do that – and provide well-designed and fully-commissioned controls – and you won't go far wrong.

Roderic Bunn
BSRIA January 2009

The Illustrated Guide to Ventilation

The latest addition to BSRIA's series of illustrated guides is intended to assist technical dialogue between the client and the design team during the briefing process, and help clients to identify and raise technical questions that they feel are relevant to their organisation's specific needs. For construction professionals, the guide provides a quick reference to effective ventilation, whether provided by means of mechanical, natural or mixed-mode systems, to provide a comfortable, healthy and ultimately productive working environment.

Other guides in the series include *The Illustrated Guide to Electrical Building Services,* and *The Illustrated Guide to Renewable Technologies*.

All of these guides are available from the BSRIA Bookshop
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ALPHABETICAL LIST OF SYSTEMS AND EQUIPMENT

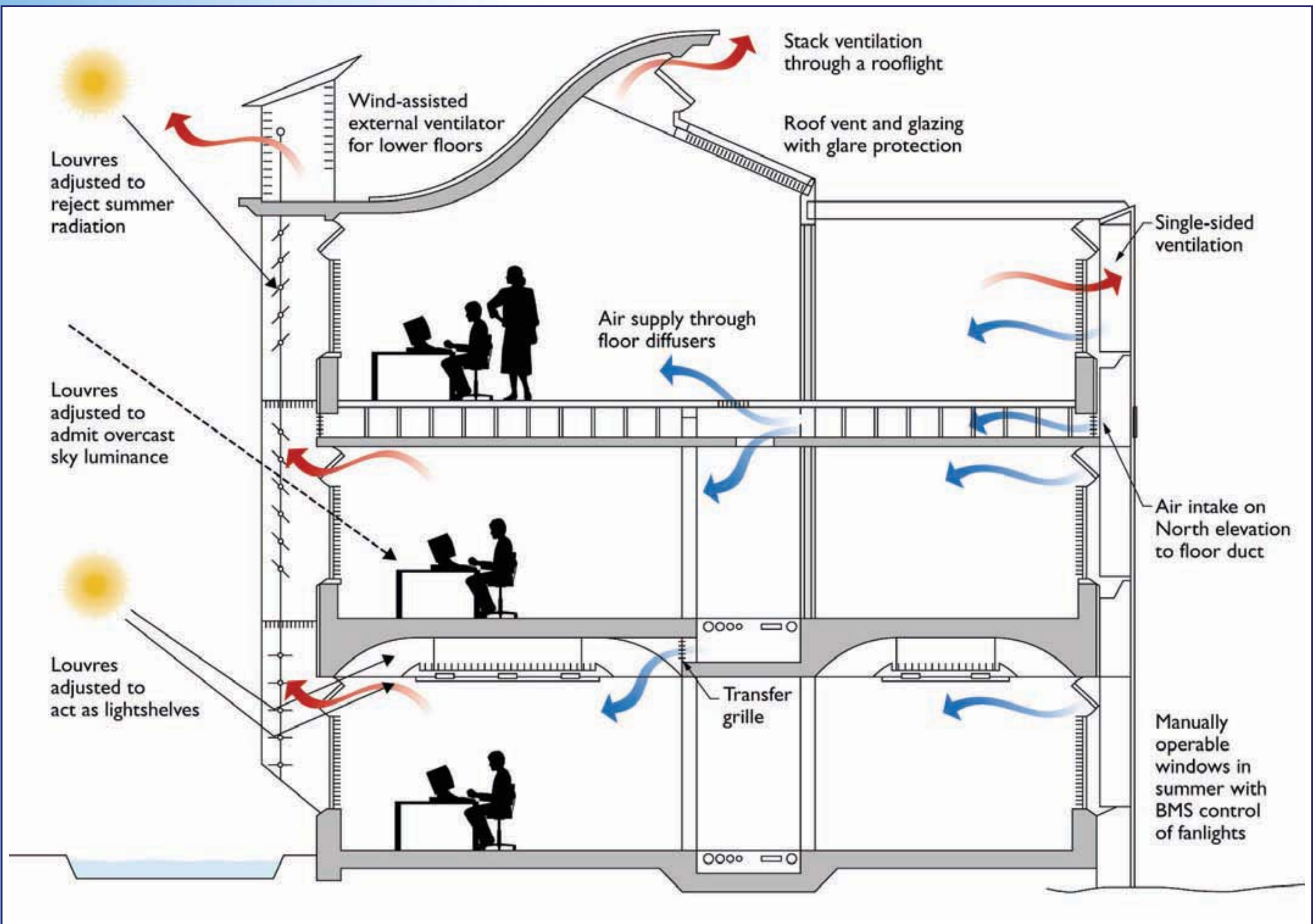
TYPES OF NATURAL VENTILATION

Natural ventilation makes use of the forces of wind and differences in air to move air through a building. There are a number of different natural ventilation air flow paths in buildings, the three main ones being:

- Cross ventilation
- Single-sided ventilation
- Passive stack ventilation.

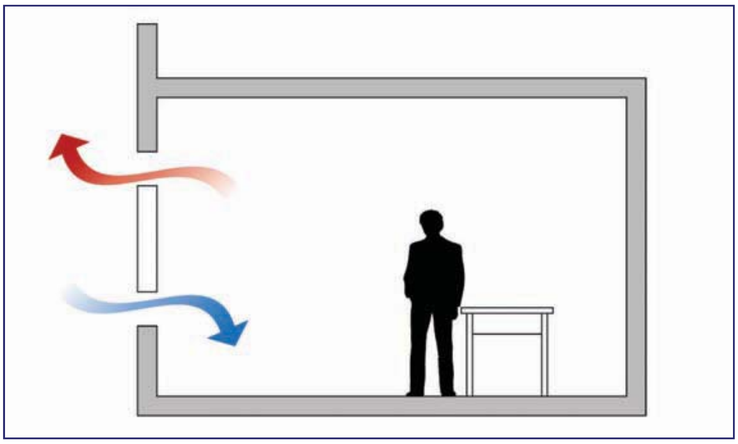
The latter relies on the temperature difference between the outside and inside of a building to drive air movement.

Natural ventilation enables occupants to make their own decisions on trade-offs between ventilation rate, external noise, draught and views out. It is often better and more energy efficient to provide people with tolerable conditions, and the means to change them, than with better conditions with no means of control.



A schematic showing the various natural ventilation strategies described in the chapter on natural ventilation systems.

Single-sided ventilation



Schematic showing the principle of single-sided ventilation.

Cross-ventilation of some spaces may not be possible due to fixed or structural partitioning. Where this is the case, single-sided ventilation may be appropriate. If windows are designed with this in mind, a room depth of up to 6 – 7 m can be satisfactorily ventilated in this way.

Control issues

The success of a natural ventilation strategy will not be determined purely by technical specifications. Reality may not match the modelled assumptions about the extent and timing of window or vent opening and closing, as the variables that determine occupants' response to their conditions are many and varied. Workgroup size is also a factor.

Ventilation effectiveness may be less determined by floor depth and free window area, and more by seemingly minor but critical things such as the robustness and usability of window handles, stays, and controls. Windows that fail to stay open in breezy conditions may either remain closed or be left propped open. Motorised windows that are noisy when they operate will be regarded as nuisance technology that disrupts concentration. Facilities managers may intervene to reduce complaints, but in so doing compromise ventilation effectiveness. A night cooling strategy may fall into disuse.

Openable windows and vents therefore need as much care and detailing as any mechanical ventilation or air-conditioning system. This means that a high level of attention should be paid to the specification of windows, motors and actuators. The same goes for glare control devices, which must operate effectively throughout their range without adversely affecting ventilation rates.

It is a false economy to buy the cheapest components. In general, where motorised elements are concerned, it is always best to procure an integrated system from a single source, rather than assemble the components – window/vent, actuator, motor and linkage – from many suppliers, as they may not match up properly. A weak link in the chain can fatally compromise the ventilation strategy, leading to overheating, stuffiness and occupant discomfort.

All ventilation devices, particularly those operated by occupants, need to be robust and intuitive to use, and enable trade-offs to be managed between ventilation rate, glare, noise, draughts, and views out. However, even the most intuitive user control will benefit from clear explanation. This can be achieved through good design, careful specification and proper labelling. It is also important to locate the control devices near to the elements they are supposed to control. User familiarisation and training during the initial period of occupation is also desirable. These issues also apply to cross-ventilation and stack ventilation.

Single-sided ventilation

Benefits

- The simplest form of natural ventilation
- Good occupant control for cellular spaces with workgroups of between 6-10 people
- Windows should be tall, ideally with top and bottom openings
- A space which can be daylit by perimeter windows on one side is generally suitable for single-sided ventilation up to a depth or around six to seven metres
- Low cost

Limitations

- Dependent on the presence of wind for good ventilation
- Inappropriate window design or positioning and poor control of opposite elements can lead to occupier discomfort
- Inadequate control over ventilation, either due to poor automation or unusable manual controls, can lead to windows being opened while heating is on, wasting energy
- Not suitable for deep-plan spaces
- May not be appropriate for noisy, polluted environments
- Motorised windows can be noisy and distracting, and prone to illogical operation
- Activators and motors for automated windows are not fit-and-forget items, and can require regular maintenance

A typical outward opening fanlight (sometimes called a clerestorey window, depending on the location in the building).

A typical high-quality bottom-hung inward opening window. These types of window are better with mid-pane blinds. Also see page 41.

Cross ventilation

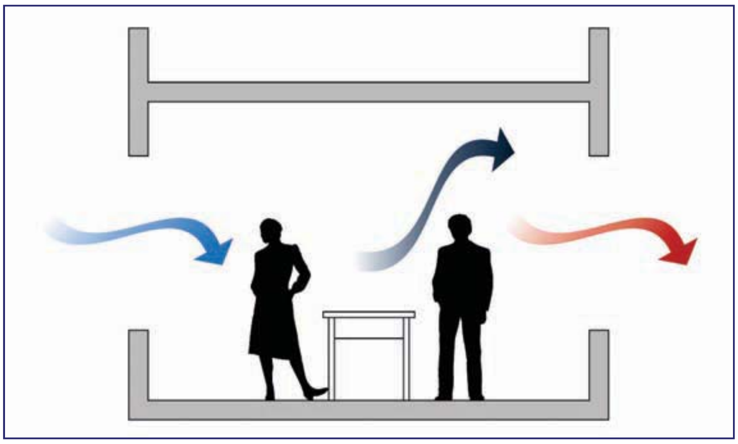
Benefits

- A high rate of ventilation is possible under favourable weather conditions
- Cross ventilation can be used in relatively deep-plan spaces with two or more perimeter walls containing windows that can be opened
- Good occupant control
- Low cost
- Cross ventilation can be designed to link with thermal mass

Limitations

- Effective cross-ventilation requires a relatively clear path for air to flow across the space
- Partitions should be kept under 1·2 m, and tall cupboards should be placed between windows on the perimeter wall
- Natural ventilation is dependant on the presence of wind for good ventilation
- Inappropriate window design and positioning may result in disruptive draughts, and papers being blown off desks
- Opening windows during cold weather can waste a significant amount of heating energy, but this needs to be considered against the electrical energy that would otherwise be used to power fans
- May not be appropriate for noisy polluted environment such as town centres

Cross ventilation



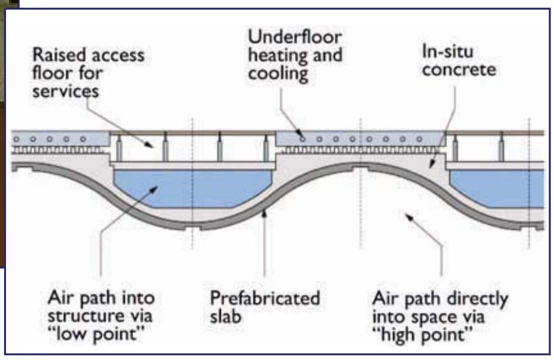
Schematic showing the principle of cross ventilation.

In its simplest form, cross ventilation drives air through open windows on the windward side of the building. Wind-induced pressure differences drive the air across the building. Open windows on the opposite side allow the stale air to escape.

Cross ventilation can achieve high air change rate, and ventilate a deeper floor plate (five times the floor-ceiling height) than single-sided ventilation.

Cross ventilation requires the windows to be carefully designed. A motorised upper window or clerestorey may be controlled by a building management system (bms) to ensure adequate ventilation, particularly on windy days when the occupier may shut a manually-operated lower window. The incoming air through the clerestorey window can also be entrained across the exposed thermal mass for cooling the air (at night, the same principle can be used to purge the room of heat build-up during the day).

Cross-ventilation from a fanlight has been aided by providing a route through an exposed slab (which also serves to control the temperature of the incoming air). See diagram.



How the building's structure in the picture opposite was designed to help cross-ventilation between offices and corridors.

In order to work, cross-ventilation may require transfer grilles to enable ventilation air to move from a room to a corridor. In this primary school classroom a transfer grille has been incorporated into the top of a storage cabinet.

A more simple transfer grille linking the room air with the return air path of an adjacent air handling unit.

NATURAL VENTILATION KEY DESIGN AND APPLICATION CHECKS

- Natural ventilation is unlikely to cope with heat gains exceeding 40 W/m^2. Reduce heat gains where possible or consider the use of exposed concrete ceiling slabs and/or night ventilation/cooling or mixed-mode strategies
- Be realistic about system performance and achievable internal conditions. A naturally ventilated open-plan office cannot be controlled in summer to stable temperatures typical of a mechanically, air-conditioned space
- Check that the air-change rate will be sufficient to provide satisfactory outside ventilation air and internal temperatures for occupants. Natural ventilation is intrinsically variable – always check performance under a worst-case scenario, such as on a warm day with no wind, as part of the design assessment
- Check room air distribution patterns and air velocities in the occupied zone for both summer and winter
- Check external noise and pollution levels to assess whether natural ventilation is feasible. Consider noise attenuation strategies
- Assess the security arrangements and risks associated with opening windows
- With a building depth of over 15 m, the ventilation strategy can be very complex, with a 6 m depth often the limit for single-sided ventilation
- The effective depth for natural ventilation systems varies from twice the floor to ceiling height for single-sided openings, to five times the floor to ceiling height for cross-flow or stack ventilation. However, occupier satisfaction may be dependent on other factors, such as the degree of control occupants can exert over ventilation devices. The use of an atrium can allow greater floor depth depending on design
- Driving pressures for natural ventilation can be very low. As a result, natural ventilation will not be efficient where there are obstructions to the flow path or resistance to airflow, such as partitions, furnishing, and changes of direction
- Cross ventilation is most effective with an open plan. Any partitions should be kept low, preferably under 1·2 m in height. Tall furniture should be placed perpendicular to the perimeter wall to present the least resistance to airflow in the room
- For cross ventilation with full-height partitions, such as central corridor and perimeter rooms, windows in the internal walls or transfer grilles in walls or doors can be used, although the resistance of these to air flow must be considered
- Tall windows, or windows with top openings can promote cross ventilation at high level without inducing draughts at desk heights
- Passive stack-ventilation can be used when cross ventilation and single-sided ventilation cannot provide a sufficient air-change rate
- Consider the use of trickle ventilators for permanent background ventilation in winter

Extract ventilation

Benefits
- Extraction of contaminated air is assured
- Localised extraction prevents contamination of adjacent areas

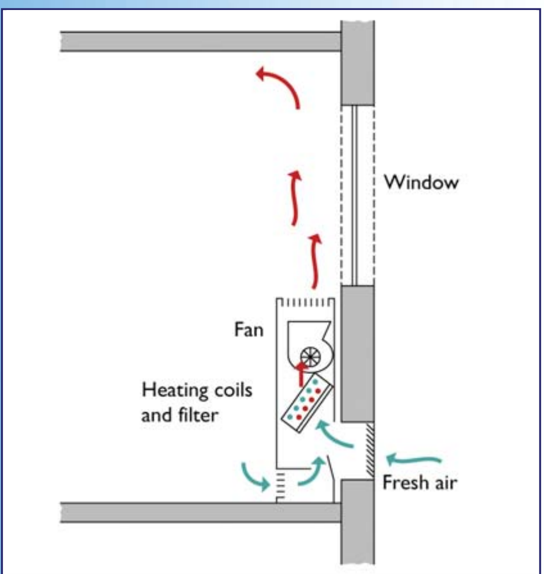
Limitations
- Make-up air entering the space cannot be heated or filtered
- Very limited control of air movement in the occupied space

Supply ventilation

Benefits
- Enables outside air to be filtered and heated
- Ensures adequate supply of outside air
- The pattern of air movement can be controlled

Limitations
- No control over the extraction of air from the space.
- No opportunity for heat recovery from exhausted air to improve energy efficiency
- Any points where air leaves the building may also be a source of draughts and external noise, and may need some form of control

An example of a high-level warm-air unit in a shopping centre.



A unitary perimeter fan-coil unit with a direct fresh-air supply through an external wall.

TYPES OF MECHANICAL VENTILATION

Extract ventilation

Extract-only systems are generally used in environments where air becomes directly contaminated by a particular activity or process. The main benefit of mechanical extract over natural ventilation is a constant and predictable ventilation rate. For many applications this is an essential requirement; the use of natural ventilation would not be appropriate. Examples of such systems are given below.

Commercial kitchens

Ventilation usually consists of a hood located over a range and is linked to an extract unit. Make-up air is drawn from the dining area, preventing cooking smells from leaving the kitchen.

Toilets and bathrooms

Most local authorities require non-residential toilets and bathrooms to have two extract fans with automatic changeover if one unit fails (often referred to as a twin fan unit).

Underground car parks

Where little or no natural ventilation is possible, a mechanical system is needed to ensure that carbon monoxide and any leaked flammable vapour is removed.

Factories or industrial buildings

Typically used in factories or light industrial buildings to extract warm air, dust and fumes. Fans can be mounted in a weatherproof casing and their speed controlled to vary the ventilation rate.

Localised industrial extraction

Used to remove hazardous process fumes or dust at source, preventing exposure to employees.

Supply ventilation

Supply-only systems have limited application, but are more suited to ventilating occupied spaces than extract-only systems. Supply-only ventilation can be used to filter and heat the fresh air. The pattern of air is also more controllable.

Typical applications for supply-only mechanical ventilation include roof-mounted warm air units, boiler house ventilation, and unitary perimeter fan-coil units with a direct fresh-air supply.

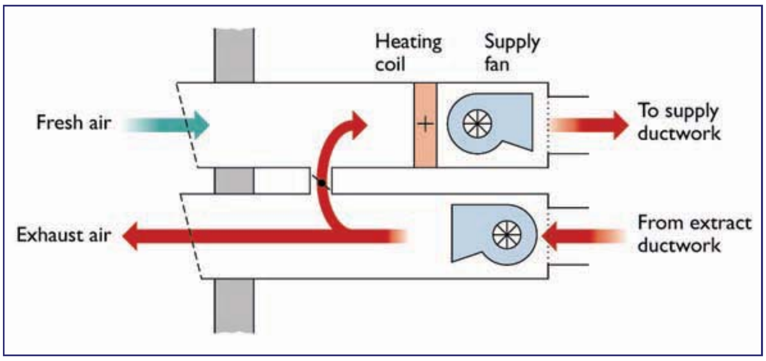
- **Roof-mounted warm air units**
  Roof-mounted warm air units are primarily used in high volume industrial and commercial buildings with a large floor to ceiling space. The units provide a mixture of fresh and re-circulated air that can be warmed in the winter to provide space heating. Mechanical extract and supply is also an option.
- **Boiler house ventilation**
  Used in boiler rooms to ensure safe and efficient plant operation where natural ventilation is not adequate.
- **Unitary perimeter fan-coil units**
  This type of fan coil is located on an external wall and draws outside air through an opening in the wall behind the unit. The fresh air is mixed with re-circulated room air before being heated or cooled. It is delivered to the occupied area by a supply fan.

Supply and extract systems

A supply and extract system comprises a central air handling unit (AHU), typically containing separate supply and extract fans, an air filter and/or a heating coil supplied with hot water from the building boiler system. A ductwork system is used to supply and extract air from around the building. A heating coil can provide the main source of heat for the building.

To save energy in cold weather, some systems are designed to re-circulate a portion of the warm extracted air back into the supply. This cuts down the amount of outside air that needs to be heated.

A heat recovery device can also be incorporated into the AHU. This takes heat from the exhaust air and transfers it back into the supply air without mixing the two air streams. This is important in some industrial and medical applications where contaminated extract air must not be reintroduced into the space.



An example of a double-deck air handling unit, showing the basics of a supply and extract system with re-circulation, where a proportion of the extract air can be mixed with incoming fresh air. This technique reduces the energy needed to heat supply air on cold days. The air handling unit may also include a cooling coil and a humidification system.

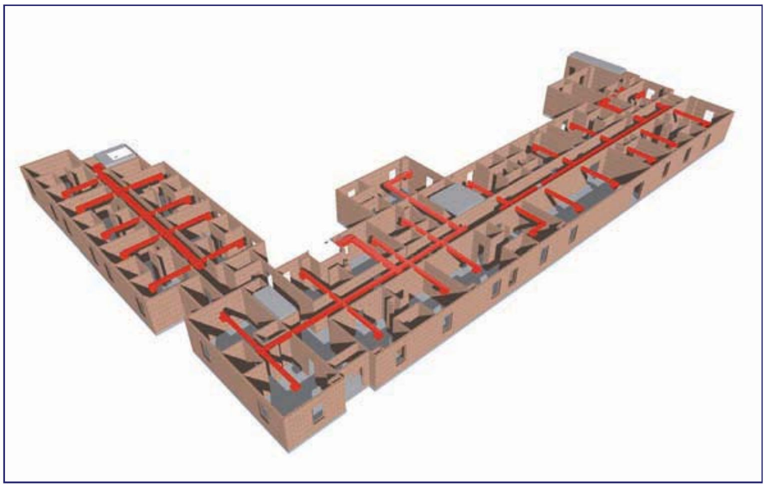
Supply and extract ventilation

Benefits

- A constant, reliable rate of ventilation is assured
- The volume of air entering and leaving a building can be controlled, and the ability to recover heat ensures good energy efficiency in cold weather
- Security and noise problems associated with openable windows are avoided
- Ventilation effectiveness will determined by automatic and manual control strategies
- The pattern of air movement in a space can be controlled to ensure even distribution
- Mechanical ventilation can be combined with natural ventilation to provide a mixed-mode ventilation system

Limitations

- Fans can consume a significant amount of energy, and fan motors can warm the air stream by up to 2°C. This may limit the effectiveness of night ventilation
- Occupants have less control over their environment in comparison to a natural ventilation system. Shortcomings in ventilation effectiveness and occupants' inability to alleviate any thermal discomfort by being able to open a window and trade off ventilation against other comfort criteria, such as external noise, may make them less tolerant of internal conditions
- The AHU and ductwork occupy potentially valuable space and require maintenance



A computer image showing how ductwork superimposes on building structure. The cross-sectional area of ductwork will reduce towards the end of a duct run, as the air volumes will be smaller. Ductwork can be square, round, oval, or flat oval.

An air handling unit located on a roof. This contains fans, filters, sound attenuation, heat recovery devices, and any hydraulic circuits for heating and cooling the incoming air.