Information
Guide

Guide to Mixed Mode Cooling Systems

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Information Guide

This is an independent guide produced by Mitsubishi Electric to enhance the knowledge of its customers and provide a view of the key issues facing our industry today. The guide accompanies a series of seminars, all of which are CPD accredited. The changing face of construction in the 21st Century demands that designers, specifiers and suppliers work as teams to create better buildings - for occupants and the environment. Mitsubishi Electric aims to be a part of this by encouraging employees and customers to work together to increase their knowledge of the latest technology, legislation and markets.

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Mixed Mode –
Getting it Right Naturally

The mixed-mode cooling system, with its mix of natural ventilation and comfort cooling, is a servicing strategy with the benefits of lower energy use, alongside predictable and controllable indoor temperatures. The new Part L2 demands cuts in building energy use, as well as compliance with temperature guidelines – the mixed mode approach answers both these requirements.

In order to design an efficient mixed mode system, it's vital to ensure that the natural ventilation strategy operates to maximum effect. This means understanding the possible approaches to natural ventilation and passive design, before considering aspects of comfort cooling and air conditioning.

There are two main traditional natural ventilation strategies: cross flow or passive stack. Cross ventilation occurs where there are ventilation openings on both sides of a space. Air flows in one side of the building utilising wind driving forces only, and out of the other through a window or door. As air passes through an occupied space, it increases in temperature and picks up pollutants. This means that there is a limit on the distance air can be allowed to travel, before it's no longer providing effective air quality and cooling. The rule of thumb for a cross ventilation strategy (as recommended by CIBSE), is that the maximum distance between two facades is five times the floor-to-ceiling height.

This means that cross flow ventilation is best applied in narrow-plan buildings. It has also been used effectively on buildings based around a central courtyard. The main challenge is to ensure sufficient air flow. Resistance can be caused if windows are closed, or by internal partitions in office space (particularly where offices are created in an open plan layout).

Stack ventilation utilises both wind driving forces and the different densities of cool and warm air to create a flow across the space. Cool air is drawn across an occupied space and exhausts vertically, as the warm air is naturally buoyant. Since air is moving across the occupied space horizontally, the same rule of thumb height to width ratio applies.

Chimneys are one way of creating a stack ventilation system. The system performance can be increased by using a chimney that is warmed by the sun. Glazed solar chimneys can be seen on the BRE Environmental Building. The added advantage is that solar chimneys must face the sun, so fresh air is always being drawn in from the cooler side of the building.

In larger, deeper buildings, a central atrium can also be used to draw away warm air. Here, fresh air is brought into the building from both sides, with air exiting upwards through the atrium, at the centre. This doubles the plan width that can be naturally ventilated.

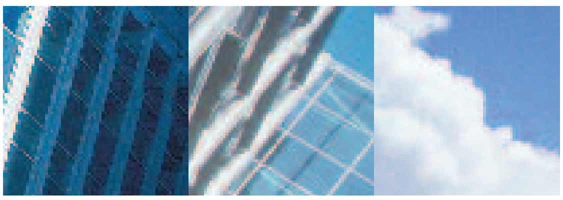
Since atria are also designed to let light into a building, they experience solar gains, and act as large solar chimneys. Unlike chimneys however, atria are not solely designed for the purpose of air extraction. They will often be occupied, with walkways at high level. Overheating can be an issue. Designers can use heat-absorbing materials above the occupied space to draw up the exhausted air, without causing occupant discomfort.

An important passive design strategy is night cooling ventilation, offering additional cooling without mechanical means. Naturally ventilated buildings can easily be adapted for night cooling ventilation through the use of automatic opening devices.

Night ventilation takes advantage of the lower night time temperatures in the UK to flush the building of warm air and pollutants stored during the day. Also, the temperature of the building fabric drops, which means that the overall building temperature is lower the next day. At night, the differences between internal and external temperature are greater, enhancing the effects of natural ventilation. This strategy usually reduces the peak internal temperature by around 2°C to 3°C the following day.

Entirely naturally ventilated buildings use less energy than those employing mechanical methods, and therefore produce fewer CO_2 emissions. However, in spite of their environmental credentials, naturally ventilated buildings can be prone to overheating. A natural ventilation system can usually deal with heat loads of around 40W/m^2 – often half the level experienced in a typical modern office building. Also, clients want to create a predictable indoor environment – which is more challenging to achieve with a naturally ventilated system.

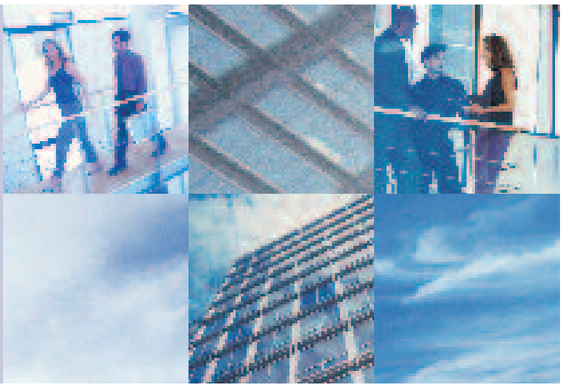
For these reasons, and others, the mixed-mode method can bring all the advantages of natural ventilation, with the benefits of air conditioning. Our next feature looks at mixed mode systems, and how they can create energy efficient comfortable working environments.



The Best of Both Worlds – Making Mixed Mode Work

While natural ventilation offers energy-saving benefits, it also has its limitations. Its performance is less predictable than air conditioned systems. Clients often specify space temperatures and it can be difficult to meet such targets using a natural ventilation strategy alone - there can be issues with over heating.

Mixed mode offers an excellent solution for clients who want the benefits of a lower-energy approach to ventilation and cooling via natural means, backed up by the predictability of comfort cooling. Mixed mode strategies have proved popular in office buildings due to their associated high internal office heat gains. A natural ventilation system cannot always control temperatures within a comfortable range at peak loads. It is not uncommon that even during winter, the cooling system will be operational due to high internal heat gains in offices.



As ventilation and cooling account for more than 50% of energy use in a well-insulated office building, a well controlled and energy efficient ventilation system is a prerequisite for a low-energy building. Mixed mode can be an excellent option, offering the benefits of air conditioning and natural ventilation.

There are two main types of mixed mode strategy: changeover and concurrent. Changeover occurs when a building is usually cooled (and heated) mechanically, but in mild seasons it can revert to natural ventilation only. In this way, occupants are protected from extremes of heat in the summer months. Such systems can still use night cooling to provide extra heat extraction when the building is unoccupied.

Concurrent means that the natural ventilation and comfort cooling systems work in parallel, and move from one form of cooling to another throughout the day.

It should be noted that mixed mode refers to a natural ventilation strategy which employs any kind of additional mechanical input. For example, in stack ventilation systems sometimes fans can be used to draw air more steadily through a space. Even if there is no extra cooling element, this would still be a mixed mode strategy. However, the latest forms of mixed mode also offer the benefits of comfort cooling.

For any type of mixed-mode strategy to realise its full potential, a key element is the control system. The aim of mixed mode is that at any time the operating method should reflect the external environment and take advantage of the ambient conditions. Software must be used which can track external and internal conditions to select the optimum systems settings.

The control system must record the immediate and past internal and external environments. Wind algorithms (including wind speed and direction) should also be included so that facade device opening positions are altered to ensure a steady flow through the space.

Without well-planned controls, there can be serious problems with the systems fighting one another. For example, in very hot weather energy wastage may occur if mechanical cooling is provided as part of a concurrent system, since excess natural ventilation may impose an unnecessary fresh air load. So it is vital that the natural and mechanical cooling system can communicate with each other effectively.

Ideally, any mixed mode strategy will be adopted at the early stages of a new building design. In this way, natural ventilation can work at maximum efficiency because the building has been created to take advantage of such a system. However, it is also possible to introduce a mixed-mode system into refurbishment projects. In such cases, the addition of comfort cooling is a great advantage, as the natural ventilation elements will not be working in a specially designed space. Our next feature shows how mixed mode can operate successfully even in the most challenging of projects.

Case Study – Mixed Mode in Action

Originally built in the early 1900's, the Brooklands Road office building was refurbished in the 1980's. However, without any mechanical ventilation, the increased use of technology and a growing number of occupants resulted in uncomfortable indoor temperatures during the summer months.

CIBSE recommends that internal temperatures should not exceed 25°C for more than 5% of the occupied period; and that they should not rise above 28°C for more than 1% of the occupied period. Thermal modelling showed that with passive stack natural ventilation at Brooklands Road, temperatures rose above 25°C for 13% of the occupied time. They also exceeded 28°C for 3% of the occupied time. Summer mornings were a particular problem, with internal temperatures rising quickly, as there was no way of removing warm air from the building at night – studies showed that one day in July saw office temperature rise to 31°C.

It was clear then that a natural ventilation-only system couldn't provide occupants with the comfort they needed to work productively. However, switching to an entirely air conditioned environment would have created higher energy costs, which the client wanted to avoid.

The answer to this problem is a combination of passive ventilation with spot comfort cooling. Also, by using night cooling to flush the office space of hot air once occupants have gone home, the system has reduced annual energy use by over 41% for the whole building when compared to a full mechanical system – 19% of which is due to night cooling..

The mixed mode system works by sensing internal air temperatures. As daytime temperatures rise, passive ventilation is used to draw external air into the office space. At a certain point, temperatures inside the building start to rise further and the building energy management system will automatically switch on the spot cooling. As late afternoon temperatures fall again, the comfort cooling turns off and the building returns to passive ventilation mode.

Night cooling has played a large part in achieving the outstanding energy reductions. By utilising the natural external air temperature drops experienced at night, on a typical day in mid-July, there is a 57% reduction in energy consumption – 39% of this is directly attributed to night cooling.

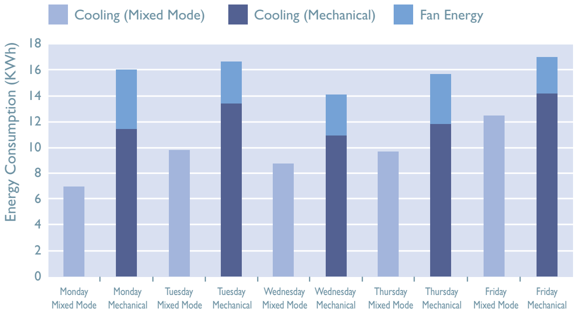
The natural ventilation system uses the plenum of the ceiling void, and discreet passive Aircool vents above the windows to allow outdoor fresh air into the building in a controlled way. Exhaust air is removed from the building by the natural stack effect via roof mounted terminals. No mechanical component is used in the system for ventilation – yet still fresh air remains within minimum recommended levels. By reducing the mechanical elements in the system, energy is saved as are maintenance costs.

The air conditioning system also makes a large contribution to the overall energy efficiency of the mixed mode system, as it uses inverter driven technology. The night cooling effect also means that it can work at part load most of the time, where this technology has proved particularly successful. By reducing the amount of time the spot cooling is on, the building energy management system keeps energy use to a minimum. Night cooling means that the air conditioning system isn't on before occupants arrive, which is often the case in overheated buildings. As well as reducing energy costs, the system creates a better internal environment for occupants. It also reduces CO_2 levels, maintaining CO_2 parts per million below the recommended 1000 ppm level.

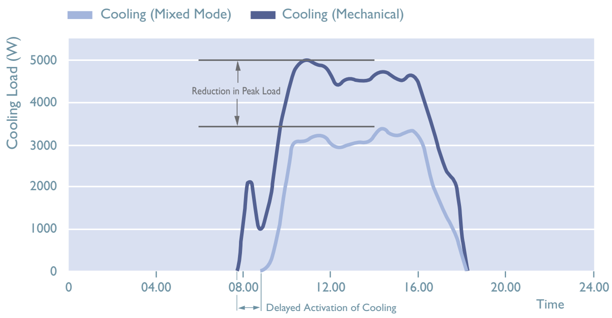
This use of a mixed mode system demonstrates that natural ventilation can work in an existing building - the most challenging environment for any cooling strategy. In this case, ensuring that the air conditioning equipment selected is energy efficient, even at part loads, has ensured that building energy use is minimised.

The following charts demonstrate the energy consumption and load profiles of the mixed mode systems when compared to mechanical systems.

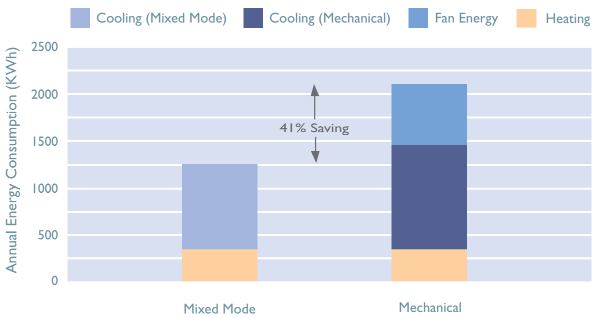
Energy Consumption for Mixed Mode Vs Full Mechanical System
(Typical Cooling Season Week Mid July)



Cooling Load Profile for Mixed Mode Vs Full Mechanical System
(Typical Cooling Season Day Mid July)



Annual Energy Consumption for
Mixed Mode Vs Full Mechanical System



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