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Ventilation strategy – a selected bibliography

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– a selected bibliography

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PREFACE

International Energy Agency

In order to strengthen cooperation in the vital area of energy policy, an Agreement on an International Energy Programme was formulated among a number of industrialised countries in November 1974. The International Energy Agency (IEA) was established as an autonomous body within the Organisation for Economic Cooperation and Development (OECD) to administer that agreement. Twenty-one countries are currently members of the IEA, with the Commission of the European Communities participating under a special arrangement.

As one element of the International Energy Programme, the Participants undertake cooperative activities in energy research, development and demonstration. A number of new and improved energy technologies which have the potential of making significant contributions to our energy needs were identified for collaborative efforts. The IEA Committee on Energy Research and Development (CRD), assisted by a small Secretariat staff, coordinates the energy research, development and demonstration programme.

Energy Conservation in Buildings and Community Systems

The International Energy Agency sponsors research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is sponsoring various exercises to predict more accurately the energy use of buildings, including comparison of existing computer programs, building monitoring, comparison of calculation methods, etc. The differences and similarities among these comparisons have told us much about the state-of-the-art in building analysis and have led to further IEA sponsored research.

Annex V Air Infiltration Research

The IEA Executive Committee (Building and Community Systems) has highlighted areas where the level of knowledge is unsatisfactory and there was unanimous agreement that infiltration was the area about which least was known. An infiltration group was formed drawing experts from most progressive countries, their long term aim to encourage joint international research and to increase the world pool of knowledge on infiltration and ventilation. Much valuable but sporadic and uncoordinated research was already taking place and after some initial groundwork the experts group recommended to their executive the formation of an Air Infiltration Centre. This recommendation was accepted and proposals for its establishment were invited internationally.

The aims of the Centre are the standardisation of techniques, the validation of models, the catalogue and transfer of information and the encouragement of research. It is intended to be a review body for current world research, to ensure full dissemination of this research and based on a knowledge of work already done to give direction and a firm basis for future research in the Participating Countries.

Current participants in this task are Belgium, Canada, Denmark, Finland, Federal Republic of Germany, Netherlands, New Zealand, Norway, Sweden, Switzerland, United Kingdom and United States of America.

INTRODUCTION

Ventilation may be needed for any combination of the following reasons to meet physiological needs

- to remove contaminants and odours from the indoor environment
- for moisture control
- to maintain a desired temperature and air movement.

Over-ventilation wastes energy while under-ventilation may lead to odour and moisture problems[1] or to the build-up of an unacceptably high level of pollutants. The problems that may arise will depend to a large extent on the individual characteristics of each building considered - what contaminant sources it contains, the number of occupants and their lifestyles, and the external environment. As the contaminant sources and occupancy effects may vary considerably over a building's lifetime, it is impossible to define exactly how much ventilation is necessary, but guidelines for minimum ventilation rates exist in several countries[2].

The potential for energy saving in ventilation therefore comprises a reduction of the amount of ventilation air supplied and the adoption of the best strategy for supplying this quantity of air in order to achieve maximum ventilation performance without the discomfort of draughts or the creation of zones where the minimum ventilation rate is not achieved. To realise this goal, four major design strategies should be considered[3]. They are

1. to extract contaminants at source.
2. to ventilate for the worst pollutant.
3. to avoid by-passing of the supply and extract air.
4. to control the flow route.

In general, these strategies are applicable to all buildings - domestic, commercial and industrial. Goodfellow and Smith[4] have presented a major review of all uses of ventilation for industrial processes. The contaminants created by industrial processes are usually specific to the process concerned and sometimes highly dangerous, so specialised ventilation techniques are often necessary (such as air jets, air curtains, recirculation of filtered air, etc.). Dietze[5] outlines the foundations for designing natural ventilation systems for heat intensive factories and Billings and Vanderslice[6] discuss the use of mechanical ventilation for contaminant control, particularly of hazardous contaminants. The underlying principles of ventilation for industrial buildings are the same as for any other building.

For residential and commercial buildings, the basic choice to be made is between natural ventilation and mechanical ventilation. Often the choice is predetermined - in moist, temperate climates such as Britain's, the structure of houses is usually so leaky that mechanical ventilation is considered to be uneconomic. Widespread adoption of mechanical ventilation in housing in these regions would require a complete rethinking of the methods of house construction. Mechanical ventilation is usually reserved for commercial buildings and, even then, natural ventilation is traditionally preferred. In colder climates, such as those of the Scandinavian countries and Canada, it makes sense to build both housing and commercial buildings as airtight as possible to conserve heat. In this case, natural ventilation is often unable to provide adequate ventilation for odour or contaminant removal, therefore mechanical ventilation is necessary to guarantee minimum ventilation rates. This is also true of the warmer regions, where buildings are made airtight to reduce energy consumption during cooling rather than primarily during heating.

However, as advances are made in building technology, the traditional assumptions about ventilation strategy are called into question and attempts have been made to put the choice between natural and mechanical ventilation on a more scientific basis.

COMPARISON BETWEEN NATURAL VENTILATION AND MECHANICAL VENTILATION

Natural ventilation is subject to the vagaries of the weather and has been observed to vary by a factor of 5 with changing weather conditions[7]. Its total dependence on temperature and wind conditions is its most serious disadvantage, giving unsatisfactory ventilation in warm weather or too much air when there is a low temperature outside[8]. If a natural ventilation system is designed to give the correct rate under average conditions, high wind will cause excessive ventilation and possibly draught. If ventilation rates are reduced too much in a situation where moisture production is maintained, the risk of condensation and mould growth is increased[9].

Installation of an open-flued appliance, taking air from the room, provides a ventilation opening that promotes increased ventilation - ventilation rates can be more than doubled. Tipping et al[10] found that when an open-flued appliance was operating, ventilation rates were increased by both stack effect and the wind. If there is no appliance, a means of overcoming the problem is the installation of a flue for ventilation to replace the chimney[11]. This is common in Holland, for example. It extracts air by virtue of the pressure differences caused by wind and the stack effect in the same way as an open-flued appliance.

The advantages of natural ventilation are that there is no maintenance except for cleaning, no running costs and the initial installation costs are low.

Mechanical ventilation,on the other hand, can be controlled to the required level and thus has the potential to provide adequate ventilation in all weather conditions with minimum heat loss. Energy conservation goals can be met by providing a heat recovery system on the mechanical ventilation exhaust[12].

The main choice is between extract only ventilation and balanced supply/ extract systems. The former approach creates a small negative pressure in the building which induces air flow through openings in the building's envelope to replace that extracted by the ventilation system. Extract ducts are placed in the rooms or areas where pollution is most likely to be generated, thus minimising the risk of cross contamination. Heat recovery is possible by extracting heat from the exhaust air using a heat pump. Balanced systems comprise an additional mechanical supply network to complement the extract system. Heat recovery is possible by using an air-to-air heat exchanger to extract heat from the exhaust air and pre-heat the supply air[13].

Sherman and Grimsrud[14,15] use a simple calculation to compare ventilation (energy) load in a typical tight house for natural ventilation (including use of stacks), balanced mechanical ventilation systems with air-to-air heat exchangers and mechanical exhaust ventilation with and without heat pumps under average weather conditions. A single-zone infiltration model was used to compare the effect on total ventilation that each of these systems would have on a structure having $2x10^{-2}m^2$ of leakage area. Natural ventilation was far below the target of $0.55m^3/s$, giving possible problems with indoor air quality. The mechanical ventilation systems gave adequate ventilation. The stack ventilator did not meet the target for mild conditions because it was completely dependent on natural driving conditions and was therefore the most affected by the weather. The exhaust system was the least affected by the weather due to its pronounced effect on internal pressure. The additional ventilation (energy) load was, in decreasing order, ventilation stack, exhaust without recuperation, exhaust with heat exchange, air-to-air system, and exhaust with heat pump. This is also probably the order of increasing cost. The stack ventilator performed relatively poorly under extreme temperature differences, making it unattractive for cold climates. Under moderate weather conditions, the heat pump system was a net producer of energy; under more extreme conditions the net load of the heat pump system approached that of balanced air-to-air systems. When the envelope leakage was increased to $5x10^{-2}m^2$, the air-to-air heat exchanger system became less attractive in terms of ventilation load. For a very loose envelope of $0.1m^2$ leakage area, natural ventilation was sufficient for all except the calmest conditions.

The ventilation load for the balanced system was independent of leakage area, but additional load for any of the unbalanced systems decreased with increasing leakage area. Therefore, the balanced system is to be preferred in tighter structures and the unbalanced systems in looser structures. The choice of system is thus critically dependent on envelope leakage. The economic choice depends on climate, system performance, existing HVAC plant, fuel type and costs.

However, when Freeman et al[16] studied the individual room ventilation rates in a 2-storey, brick-built, detached test house, natural ventilation was found to possibly have certain advantages in that, roughly speaking, the individual room rates followed the same pattern as whole house rates. The ventilation efficiency was almost constant throughout the house with or without heating. The overall ventilation rate with a mechanical extract system remains relatively constant, but there may be wide variations in individual rooms. In the test house, extraction points were in the kitchen, bathroom and toilet. The bathroom and kitchen were found to have widely fluctuating fresh air entries, whereas the other rooms remained constant. This may be due to the relatively large leakage areas associated with these two rooms and their positions in the house.

The extract only ventilation system has other disadvantages because of the methods of fresh air supply. In winter there can be draughts from windows and dirt entering from outside. Control of the airflow through the dwelling is not complete[17]. For greater control, a balanced extract and supply system is preferable. Some 25% of new houses built in Sweden have a balanced ventilation system. An example of this type of system is a conventional exhaust system, including a smoke ventilator in the staircase, and a supply system with fresh air preheated to about 15°C and filtered in a make-up unit and ducted to supply nozzles situated behind radiators. Actual flow rate of air extracted will be decided on the basis of capital cost, noise levels and ventilation heat loss.

NATURAL VENTILATION

Natural ventilation is the movement of air through openings in the building fabric, due to pressures created by wind and by differences in temperature between the interior and exterior of the building (stack effect). Wind speed, direction and temperature will not only affect the rate of fresh air supply but will also determine whether any opening will act as an inlet or outlet for the air space, and hence the path that the air takes within the building[18].

Natural ventilation has always been the preferred choice in housing and many other buildings in moderate climatic areas, such as the UK, but it has tended to be chosen by default. It is only as building construction has become more energy-conscious that ventilation energy loss has gained in importance and a conscious decision has been taken regarding ventilation strategy. The main advantages of natural ventilation are its low capital cost and ease of maintenance. It uses no power and is generally silent in operation[19].

Natural ventilation efficiency is affected by the degree of insulation of the building, the ventilation openings, the outdoor climate and occupant behaviour[20]. The problems to be overcome are:

1. guaranteeing an adequate air supply for air quality under all conditions,

2. keeping the ventilation energy loss to the minimum, and

3. ensuring that the air enters in a way that minimizes draughts and short circuiting.

Etheridge[21] suggests that a possible way of reducing variations due to weather is to minimize the effects of wind. This can be done by maximizing buoyancy effects by maximizing the height between purpose-provided openings, i.e. low level vents on the ground floor and high level vents on the upper floor. In some European countries, vertical ventilation ducts have been adopted. Trees and other vegetation can be used to form windbreaks which reduce wind pressure on the shielded building. "Constant flow" vents, which in some way prevent high flow rates, could be considered. Other possibilities include the siting of vents relative to prevailing wind directions. However, Etheridge considered that leakage is probably one of the most important design parameters. General background leakage areas cannot easily be controlled (other than by their complete elimination). Nominally identical buildings can have different leakages and the leakage of the building can change, particularly during its early life. Another problem, he suggests, is leakage distribution. Theoretical calculations showed that two buildings with identical leakage but very different distributions can have ventilation rates that differ by 50%. However, Howarth[22] et al have found that a system of controllable ventilators, separate from but perhaps included in window openings, can have a beneficial effect.

Nevrala and Etheridge[23] have studied the siting of heat emitters and their response to varying ventilation rates, which is important when considering natural ventilation. Higher levels of insulation have resulted in smaller heat emitters being required, resulting in increased sensitivity to ventilation. Hence the variation in air change rate,which can arise as a result of variations in wind speed and direction, could lead to large changes in the heat demand of the house. Preliminary studies indicated that the mean air change rate in a tight house was higher than conventional calculations suggest, as background infiltration has to be taken into account. They also noted that control of the whole building heating system by a thermostat in a single room leads to considerable disparity between rooms. Under certain conditions, the bulk of fresh air may be entering from one particular side. Then the overall air change rate may be irrelevant for individual rooms and individual room flow rates become all the more important because, with higher values, draughts may be caused. Simulation of a typical room showed that, for the design ventilation rate, the required temperature was attained but air flowing out resulted in a degree of overheating, while air flowing in created conditions that would cause thermal dissatisfaction.

Designing a ventilation system for a naturally ventilated energy efficient house is not simply a matter of designing methods for reducing whole-house ventilation rates, but also of ensuring that individual spaces have adequate ventilation and, for this, air flow patterns must be measured and understood. O'Sullivan and Jones[24] suggest the use of trickle ventilators for a better distribution of ventilation, leading to a reduction of condensation. Suitable design criteria for a naturally ventilated house would be to have infiltration reduced by tight construction and open areas re-introduced to the external walls of the house in the form of trickle ventilators. The required air distribution can be achieved by using the stairwell as a main distribution duct or, if the internal design does not allow this, by introducing ducting to obtain the necessary (possibly fan-assisted) air distribution.

Carne[25] found that a ventilation flue was also effective. In a house of typical construction and condition, a vertical flue with a base opening of $96.77 \times 10^{-4} m^2$ was, on average, as effective as a $322.58 \times 10^{-4} m^2$ wall vent in facilitating natural air change in an unheated room with closed windows and doors. Ventilation by vertical flue was approximately constant for all wind directions, but if an air vent was used, ventilation was greater when the opening was on the windward side. In a building of tight construction, for uniform ventilation, one needs:

1. a flue terminating outside the region of eddy motion in the wind stream,

2. an opening between the room and the well of the building, and

3. an opening between the well of the building and the exterior in each of two opposite walls.

Also, some thought should be given to the orientation of the building in order to gain the required effect from prevailing winds.

While most of the research on natural ventilation strategy has been concerned with residential buildings, attention has been focused recently on other buildings such as office blocks, auction halls and agricultural buildings. For example, Knoll and de Gids[26] discuss the principles for naturally ventilating an auction hall. Meteorological wind speed and direction do not give information on actual speeds and directions of air flows around the halls. These air flows are influenced by obstacles in the neighbourhood and by the shape of the halls. These factors together determine the wind pressure distribution on the surrounding walls of the halls. The choice of position of the ventilating devices depends on the layout of the building - the most favourable locations are ones between which the greatest wind pressure differences occur - and, of course, cost considerations of the ventilating devices applicable at different sites. The height difference between ventilating devices should be as great as possible and, for a reduction of local differences in air change rates, a good distribution over the hall is desirable. The most appropriate places for ventilating devices were found to be on both sides of the roof, in the case they studied.

Occupancy Effects

Once a natural ventilation system is in use in a building, one of the major influences on its functioning is occupancy behaviour. This is particularly true for residential buildings. Brundrett and Poultney[27] attribute half of ventilation energy loss to window opening habits. Window opening is primarily a function of external air temperature; at high values, relative humidity and wind speed also become influential[28]. External temperature was said to account for over 70% of the observed variance, with a further 10% attributed to wind speed[29]. The air leakage value of an open window was found to be equal to twenty times the value of a ventilation duct or fifty times the value of cracks, etc. in the outside facade[30].

Designing appropriate windows and ventilation units can make a significant contribution to reduction in heat loss due to ventilation. Hauser[31] recommends windows which can be shut tight when the room is not in use, as one of the essential prerequisites. Intermittent ventilation by window opening is to be preferred to continuously having a window open, since the latter generally results in unnecessarily high rates of air exchange. Dickson[32] found that the amount of open window required for sufficient ventilation is much less than the minimum for which most window catches are designed. Ventilation by opening windows can easily cancel the advantages of high levels of thermal insulation. It is obvious that occupant window opening behaviour must be taken into account when considering natural ventilation.

MECHANICAL VENTILATION

One of the advantages of mechanical ventilation is that it removes much of the motivation to open windows by providing constant ventilation which is more or less independent of the weather[33].

In order to ensure adequate ventilation, mechanical ventilation must be considered. However, de Gids et al[34] found that designers frequently opt for mechanical ventilation in large buildings with a lack of insight into the ventilation process and a lack of means of calculating the ventilating effect as a function of wind speed, wind direction and temperature difference. They describe the use of mechanical extraction with fresh air supplied through natural ventilating devices such as vents, open windows and cracks and joints. This leads to the building being subjected to an underpressure with respect to the atmosphere or neighbouring buildings. Opening an outer door or connecting door can cause an undesirable air flow. Another aspect they discuss is air movement due to ventilation. Air extraction does not greatly influence the internal air movement, but the supply air can have an overwhelming effect. Thus must be taken into account so far as the internal distribution of pollutants and heat is concerned.

The extent to which ventilation is effective in controlling indoor contaminant concentrations was found by Offermann et al[35] to depend largely on the reactivity of the contaminant, its outdoor concentrations and its concentration in the exhaust airstream. If the contaminant reactivity is high relative to the air change rate in a well-mixed space, increasing or decreasing ventilation will have little effect. However, in the experiment which they conducted in nine tight houses, use of mechanical ventilation increased the air change rate by 80% (from 0.35 to 0.63 ach) and affected the contaminant concentration in the following way: average indoor radon concentration decreased by 50%, HCHO by 21% and relative humidity from 39% to 35%. The NO_2 level increased from 7 to 9 ppb. Inhalable particle concentrations were reduced on average by 30%. Extracting air from the basements gave a reduction in radon level that was greater than predicted.

Having opted for a mechanical ventilation system, the basic choice to be made is between extract only, supply only or a combined supply and exhaust system. However, all three systems will exceed the design air change rate when operated in an unsealed building. Etheridge et al[36] classed the combined system as the worst in this respect, giving rates about double the design value. The extract system was the least unsatisfactory, with rates about 50% greater than the design value. Application of moderate sealing only improves the situation by a small amount. Dickson[37] agreed that mechanical ventilation is only viable if installed in a relatively airtight house. He went on to describe various ventilation strategies. The simplest system is an extract fan in the kitchen for residential buildings. This may be supplemented by extract fans in the WC and bathroom perhaps, with controls so that they operate only when required. Ventilation is not controlled when the fans are off, which is most of the time. For a relatively tight dwelling, provision of extracts in the kitchen, bathroom and WC, together with air inlets in living rooms and bedrooms, will ensure adequate fresh air supply. He warned that, in this case, fortuitous leaks in the building structure must be much smaller than the air inlet slots, otherwise short-circuiting may occur,leaving some rooms unventilated. A good system can also be achieved using a central fan connected to a cooker hood and ceiling extracts in the bathroom/WC by ducting. Shaw[38] found exhaust-only systems to be relatively insensitive to both wind and temperature difference, in comparison with balanced systems. This was especially true for higher exhaust rates. However, all of the heat in the extracted air would be wasted unless it was recovered using, for example, a heat pump.

In a study by Sandberg[39], the extract system was found to give a relative ventilation efficiency rather independent of the nominal ventilation rate, where ventilation efficiency is a measure of the ability of a ventilation system to remove or control the level of internal pollution. The efficiency was higher in the supply room than in the extract room.

In theory, a building with mechanical extract ventilation can be made sufficiently airtight to ensure a permanent negative pressure but, in practice, this will have consequences for the indoor climate[40]. Problems associated with high velocity draughts and back-draughting can occur at quite small underpressures. Collet[41] recommends that, in order to ensure a reasonable distribution of the fresh air change rate when mechanical exhaust is applied, ventilation openings in the house envelope must be more than 250 - 300 x $10^{-4}m^2$ and they must have a relevant room distribution. It is possible to direct the fresh air into different rooms as required by means of appropriate ventilation openings if the inner doors are not tight and major leaks, such as front doors, are well sealed.

The supply only system is less common. Sandberg[42] found that it gave a much larger efficiency difference between the supply and exhaust rooms. This was due to the fact that the supply of air was now concentrated at the supply register. Overpressures developed by this type of system can force moisture into the fabric of the building causing serious damage.

Sandberg[43] concluded that the combined or balanced ventilation system gave the highest ventilation efficiency of all the systems. These systems have become popular in several countries because they give good air circulation and, also, waste heat from the exhaust air can be recovered and used to pre-heat supply air. This system has no influence on the overall pressure structure within the building and therefore the problems associated with underpressure do not arise. The disadvantage is that the influence of climatic conditions on air infiltration is not diminished. Therefore, for energy efficiency, a high degree of airtightness is required. Liddament[44] has calculated that the energy demands to achieve an air change rate of 0.5 ach in a tight building are 15.5 GJ for a building in the UK and 19.4 GJ for a Swedish location. Use of a heat exchanger with a typical efficiency of around 70% would reduce energy demands to 8.5 GJ and 11.4 GJ respectively.

The positions of the air supply and exhaust are obviously a point to be considered and various studies have been undertaken to decide where the most appropriate locations may be.

Skaret and Mathisen[45] found that, for best ventilation efficiency, the air supply just below the ceiling and the exhaust near the floor was suitable for a warm air ventilation system. The reverse situation should thus be best for a cool air ventilation system. In other words, diagonal schemes seem to be the most efficient - more efficient than having complete mixing. This principle has been successfully applied in some industrial plants in Scandinavia.

Shaw[46] compared a basement supply and roof exhaust with a basement supply and exhaust, both with a nominal forced ventilation rate of 0.5 ach. Similar results were found for both, leading to the conclusion that the location of exhaust outlets has less effect on a balanced system than on an exhaust-only system. He found that the air change rate increased with temperature difference for wind speeds up to $6.945 ms^{-1}$. At moderate temperature differences, the air change rate increased with wind speed, but the influence of wind was diminished by large temperature differences. To provide a desired air change rate of 0.5 ach, a balanced system would only require a forced ventilation rate of 0.3 to 0.4 ach.

Sandberg[47] found that the balanced system gave, apart from the lowest ventilation rate, the highest ventilation efficiency of all systems. Various locations for the system were tested in two rooms. Both supply and exhaust in the one room gave the highest ventilation efficiency in that room, but the other room was also found to have surprisingly high efficiency. With the door between the two rooms closed, the efficiency became strikingly higher in the supply room. The air was only transferred from room 1 to room 2 and not vice versa. This implies that the dwelling was now ventilated 'in sequence' with quick removal of gas. This illustrated that a ventilation system's main purpose should be to remove the pollutant as quickly as possible and not to dilute the contaminant.

In the same experiment, a warm air ventilation system was also tested in various locations. With both supply and exhaust above the occupied zone, short-circuiting typically occurred. Ventilation efficiency decreased when ventilation air flow was increased. With the exhaust at floor level and supply above, ventilation efficiency was considerably improved. A combined high nominal air change rate and high over-temperature gave an exceptionally high ventilation efficiency, due to buoyancy effect and the placing of the register. The resulting air flow was similar to a plug flow. With supply air at floor level and the exhaust in the middle of the ceiling, an undirectional flow was obtained, blown vertically up the wall. The ventilation efficiency was low, probably due to short-circuiting as the supplied air partly travelled as a wall jet directly to the extract air register. With the supply air blown along the floor, in the case of cooling, ventilation efficiencies were much improved. This can be ascribed to the buoyancy effect and the position of the registers.

Boman[48] compared three different locations of the supply register - above the door, above the door with a slot under the door and with a slot under the door only. The first option gave a ventilation efficiency of only 79% due to short-circuiting, the second gave a satisfactory mean ventilation efficiency of 124%, and the simplest arrangement (the slot under the door) resulted in the highest mean ventilation efficiency of 127%.

With supply and extract registers located in the ceiling, and the supply air blown horizontally against the centre of a room heated with panel radiators under the windows, temperature differences of -1.8°C and 3.0°C gave respectively 89% and 68% efficiency. With panel heaters under the windows, and the supply and extract registers on the opposite wall, very uniform ventilation efficiency was achieved at isothermal conditions (no heating on). This shows that the location of the register is important even at isothermal conditions and that air motions caused by radiators do not always prevent short-circuiting effects due to a higher supply air temperature.

Various novel ventilation strategies have also been developed. For example, Muller and Balkowski[49] describe the use of waste air ventilated windows for offices. The design principle is that part of the exhaust air of external areas of a building is passed through a gap between two layers of window, ducted in an upward or downward direction. The decision on the flow direction is determined by the air flow in the room - upwards when supply and extract air openings are positioned in the ceiling, because during pre-heating the required temperatures at floor level are more quickly attained, and downwards in winter because this is parallel with the natural air flow, so an upward flow would create turbulence. Waste air ventilated windows can:

1. increase thermal comfort by minimizing temperature differences between room air and window surface,

2. reduce energy consumption for heating and cooling, and

3. increase sound insulation.

In an actual office situation, the air flow was directed through the window into a separate discharge duct for each storey of the building. This proved better on space utilisation and with respect to heat losses and formation of condensation than a centralized discharge system. The required volume of waste air was generally below 4.167 - 13.89 dm^3s^{-1} per m^2 of window area. A high air change rate gave improved heat insulation in summer, a lower air change rate gave higher heat recovery values in winter.

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ABSTRACT
Ventilation is a key factor in low energy housing and in temperate maritime climates such as Britain's moisture is a major factor in determining ventilation needs. Outlines necessary levels of humidity for both people and buildings. Summarises sources of moisture. Discusses control of humidity by either mechanical ventilation or heat pump dehumidification.
KEYWORDS
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ABSTRACT
Reviews technical progress being made in the industrial ventilation field by different investigators throughout the world. Subjects reviewed and updated include natural ventilation, local exhaust ventilation, specialised ventilation techniques (dilution, air jets, air curtains, recirculation of filtered air, tracers for ventilation studies) and mine ventilation. Presents typical applications of the new technology to solving industrial ventilation problems, and identifies areas requiring further research and development.
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ABSTRACT
Outlines the foundations for calculating and designing natural ventilation: conditions for the building unit: technological prerequisites: components: sound insulation: calculation methods: fields of application: combination of mechanical and natural ventilation: and models for optimization of new buildings and for reconstructing factories.
KEYWORDS
natural ventilation, mechanical ventilation, design, factory, sound insulation, theoretical modelling, empirical models

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ABSTRACT
Identifies alternative methods available to control indoor air pollutant exposures. Describes the performance characteristics of ventilation systems and of air cleaning devices used in mixed modes for ventilation of occupied spaces. Reviews models for predicting effectiveness of several alternative modes, with field trial validation results cited where available. Briefly reviews previous confined-space studies as points of departure for consideration of necessary air quality, ventilation and air cleaning.
KEYWORDS
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ABSTRACT
In a modern residence with reduced air infiltration, a problem may arise if the fresh air requirement is left to natural leakage. The article discusses this problem, and describes techniques for measuring air leakage and typical results. The contaminants which define the need for ventilation are described and the case for controlled ventilation systems (and possibly heat recovery devices) is made. Areas for further research are recommended.
KEYWORDS
air infiltration, tight house, ventilation needs, controlled ventilation, heat recovery, measurement technique,

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= British Gas Corporation Translation no.T5269 in English
ABSTRACT
Outlines necessary ventilation rates for an occupied room. Discusses natural ventilation of a room through openings in the ceiling. Discusses natural draught ventilation for single family houses, combined natural draught and mechanical ventilation, mechanical fresh air ventilation based on a central duct, fortuitous ventilation caused by air infiltration and leakage. Compares natural and mechanical ventilation. Considers supply air systems for single family houses, warm air heating and possibilities for heat recovery.
KEYWORDS
air change rate, humidity, temperature difference, mechanical ventilation, house, heat recovery, natural ventilation,

9. Johnson K.A. Pitts G.
#NO 1045 Experiments with a passive ventilation system.
3rd AIC Conference "Energy efficient domestic ventilation systems for achieving acceptable indoor air quality" September 20-23 1982 UK p.9.1-9.12 3 figs. 4 refs. #DATE 20:09:1982 in English AIC
ABSTRACT
Describes a simple method of controlled ventilation comprising an extract system and air inlets. The extract system is effectively a flue connecting to vents in the kitchen and bathroom and relying on thermal differences and the wind to create air flow, air enters the house via slot vents over windows. The proposed system has been installed in a timber framed house. Air has been extracted through the system up to the equivalent of 0.3 ac/h for the house volume, but this is less than expected.
The house needs to be tightly constructed, the extract tubes need to have very low air resistance and care is needed in siting the inlets for efficient operation. The effect of wind has not been measured, but a device may be necessary to prevent over-extraction. Modifications to the system are proposed for future work.
KEYWORDS
controlled ventilation, tight house, flue, natural ventilation,

10. Tipping J. et al.
#NO 36 Ventilation: design considerations
British Gas Corpn/IHVE Ventilation of housing symposium February 1974.
= Bldg. Serv. Engr. September 1974, 42, (9), 132-141, 9 figs, 9 refs. #DATE 01:03:1974 in English BSRIA j = in 'Ventilation of Domestic Buildings' #AIC 492.
ABSTRACT
Outlines basic requirements for a fresh air supply to a dwelling, which include health, comfort and air for combustion appliances. Discusses feasibility of achieving these requirements by natural and mechanical means.
KEYWORDS
ventilation needs, residential building, air quality,

11.Johnson, K.A., Pitts, G.
(see reference 9 above)

12.Johnson, K.A., Pitts, G.
(see reference 9 above)

13.Bagge, J.J.
(see reference 8 above)

14.Sherman M.H. Grimsrud D.T.
#NO 1044 A comparison of alternative ventilation strategies.
3rd AIC Conference "Energy efficient domestic ventilation systems for achieving acceptable indoor air quality" September 20-23 1982 UK p.7.1-7.21 9 figs. 7 refs. #DATE 20:09:1982 in English AIC
ABSTRACT
Examines several ventilation strategies in tight houses for both impact on the total ventilation and effect on the energy balance of the system. Uses the single-zone infiltration model developed at LBL as part of the calculation of total ventilation load. Strategies covered include natural systems such as ventilation stacks as well as mechanical systems such as air-to-air heat exchangers and exhaust fans with and without heat pumps. Concludes that the best ventilation strategy for a building depends on the envelope leakage, the balanced systems being favoured in tighter structures and the unbalanced systems in looser structures.
KEYWORDS
tight house, natural ventilation, mechanical ventilation,

15.Sandberg M. Warren P. Sherman M. Grimsrud D.
#NO 1101 Air Control.
Building Services January 1983 p.35-42 #DATE 01:01:1983 in English #AIC 672
ABSTRACT
Gives a series of short articles on air quality, air infiltration, and the ventilation needs of low energy buildings. These are -
1. Sandberg M. Quantifying the pollution. Defines the quality of ventilation
2. Warren P. Predicting infiltration rates. Explains BRE's method of predicting air infiltration in houses
3. Getting close to zero. Describes the low energy EKONO office complex
4. Sherman M. Grimsrud D. Which ventilation system? Shows that the choice of the economically optimum ventilation system depends on the tightness of the building.
KEYWORDS
air quality, air infiltration, prediction, ventilation efficiency, office building,

16.Freeman J. Gale R. Sandberg M.
#NO 1068 The efficiency of ventilation in a detached house.
3rd AIC Conference "Energy efficient domestic ventilation systems for achieving acceptable indoor air quality" September 20-23 1982 UK p.15.1-15.22 9 figs. 2 tabs. 3 refs. #DATE 20:09:1982 in English AIC

ABSTRACT
Uses the SEGAS "Autovent" constant concentration apparatus to measure the fresh air entering and the local ventilation rate in each cell of a multi-celled dwelling with both natural and mechanical extract ventilation. Measures fresh air entry into each cell using tracer gas constant concentration and decay techniques. Conducts decay tests without artificial mixing, and interprets them by computing the area under the decay curve to obtain local ventilation rates. Compares the 2 measurements, giving the ventilation efficiency of each cell and an idea of air quality in each room of the house. Traces the pathways of air movement around the house by injecting an amount of tracer gas into one room and following the transfer to all other rooms of the house.
KEYWORDS
tracer gas, decay rate, constant concentration, ventilation efficiency, natural ventilation, mechanical ventilation,

17.Tipping, J. et al
(see reference 10 above)

18.British Standards Institution
#NO 667 B.S.I. Code of Practice for design of buildings : ventilation principles and designing for natural ventilation.
British Standard BS 5925:1980 24p. 10 figs. 13 tabs. 27 refs. #DATE 01:01:1980 in English BSRIA
ABSTRACT
Presents code of practice which supersedes CP3:chapter 1(c):1950. Deals with ventilation of buildings for human occupation. Outlines main reasons for provision of ventilation and gives recommended quantitative air flow rates. Shows that these form the basis for air supply recommendations for different types of buildings, and rooms characterised by usage. Gives basis for choice between natural and mechanical ventilation. Provides guidance on design of natural ventilation systems. Chapter headings are: General, General principles of ventilation, natural ventilation, appendices.
KEYWORDS
standard, natural ventilation, building design,

19.Holt J.E.
#NO 701 Problems in commercial and industrial ventilation.
CIBS Symposium "Natural ventilation by design" London, 2nd. December 1980 p.35-44 15 figs. 7 refs. #DATE 02:12:1980 in English #AIC 318
ABSTRACT
Briefly reviews factors to be taken into account in considering natural ventilation in commercial and industrial buildings. These factors include the location of the building, surrounding buildings, activity within the building and results required of the installation. Notes some of the problems and possible advantages of combining natural and fan powered systems.
KEYWORDS
natural ventilation, industrial building,

20.Adamson B.
#NO 341 Energy management and ventilation.
Lund Institute of Technology, report 1977 15p 1 fig, 1 tab, #DATE 01:01:1977 in English #AIC 129.

ABSTRACT
This paper is a general survey of work done on natural ventilation of dwellings. Discusses ventilation of houses with both natural and mechanical ventilation. Reviews experimental investigations, quoting air change rates found. Discusses ventilation requirements and methods for investigating different factors. Outlines suggested experimental method for investigating air infiltration of mechanically ventilated houses.
KEYWORDS
air infiltration, natural ventilation,residential buildings,

21. Etheridge D.
#NO 1093 Domestic ventilation system design - changes in the wind?
Watson House Bull. 1982 vol.46 no.3 p.12-16 3 figs. #DATE 01:01:1982 in English #AIC 666
ABSTRACT
Examines the possibilities of achieving energy-efficient ventilation systems in naturally ventilated homes (which include the use of intermittent extract fans in individual rooms). Discusses factors affecting energy efficiency. Treats general design requirements for mechanical and natural ventilation systems. Discusses the characteristics of natural ventilation systems, including leakage, weather and window opening. Compares natural and mechanical systems. Provides suggestions for natural ventilation design.
KEYWORDS
ventilation efficiency, natural ventilation, mechanical ventilation,

22. Howarth A.T. Burberry P.J. Irwin C. I'Anson S.J.
#NO 1039 Ventilation and internal air movements for summer and winter conditions.
3rd AIC Conference "Energy efficient domestic ventilation systems for achieving acceptable indoor air quality" September 20-23 1982 UK p.6.1-6.8 2 figs. 1 ref. #DATE 20:09:1982 in English AIC
ABSTRACT
Distinguishes the problems of designing natural ventilation systems for summer and winter conditions and discusses in detail the objectives, methods and some field studies directed towards the solution of winter ventilation problems.
Describes experimental work conducted in a low-energy house equipped with adjustable slot ventilators in the window frames. Both tracer gas decay methods and pressurization tests indicate similar increases of air flow when the ventilators are opened.
KEYWORDS
natural ventilation, controlled ventilation,

23. Nevrala D.J. Etheridge D.W.
#NO 24 Natural ventilation in well-insulated houses.
Unesco International Seminar, Heat Transfer in Buildings, Dubrovnik 1977, 3, 14pp, 10 figs, 2 tabs, 10 refs. #DATE 01:01:1977 in English BSRIA bk = in 'Ventilation of Domestic Buildings' #AIC 492.
ABSTRACT
Points out that ventilation heat loss can account for 50% of total loss in a well-ventilated house. Presents analysis of mechanics of natural ventilation. Describes computer-based model developed by British Gas Corporation for predicting ventilation patterns in houses.

Uses calculations applying the method to illustrate basic reasons why natural ventilation is likely to cause problems in heating well-insulated dwellings. Discusses these problems in detail. Treats how ventilation could affect sizing of appliances and indoor thermal environment. Presents results of computer simulation of thermal behaviour of a well-insulated dwelling.
KEYWORDS
computer, modelling, natural ventilation

24. O'Sullivan P. Jones P.J.
#NO 1046 The ventilation performance of houses - a case study.
3rd AIC Conference "Energy efficient domestic ventilation systems for achieving acceptable indoor air quality" September 20-23 1982 UK p.10.1-10.21 7 figs. 7 tabs. 5 refs. #DATE 20:09:1982 in English AIC
ABSTRACT
Describes a programme of ventilation measurements performed on a group of energy efficient houses built in the mid-1970's and situated in Abertridwr, S.Wales. Pressurization, tracer decay and British Gas autovent techniques were employed. Results show satisfactory whole-house ventilation rates (0.5 ac/h), but the living room and bedrooms had very low ventilation rates. Some cases showed serious condensation. "Trickle" ventilation installed in 18 of the houses improved internal ventilation patterns and condensation levels were substantially reduced. Reports on a design methodology for naturally ventilated energy efficient dwellings derived from the measurement programme.
KEYWORDS
natural ventilation, tight house, ventilation efficiency, air change rate,

25. Carne J.B.
#NO 360 The natural ventilation of unheated closed rooms.
Jnl. of Hygiene vol.44 p.314-325. 8 figs.7 refs. #DATE 01:01:1945 in English #AIC 142
ABSTRACT
Reports investigation of the relative effectiveness of wall gratings and flues as means of naturally ventilating unheated closed rooms. Ventilation rates of several rooms were measured using carbon dioxide as tracer gas and wind speed and direction were recorded. Presents results and finds for the flue, ventilation increased with wind speed irrespective of direction. For grating, ventilation rate increases slowly with size of grating and is dependent on both wind speed and direction. Concludes flue with base opening of 15 sq.ins. is as efficacious as grating having 50 sq.ins. in free area.
KEYWORDS
flue, grating, natural ventilation, tracer gas, carbon dioxide,

26. Knoll B. de Gids W.F.
#NO 938 Natural ventilation of auction halls in Bleiswijk, the Netherlands.
Verwarming en Ventilatie March 1982 vol.39 no.3 p.181-190 15 figs. 1 tab. 12 refs. #DATE 01:03:1982 in English #AIC 558
ABSTRACT
TNO Research Institute for Environmental Hygiene have developed a mathematical model (based on an electrical analogue model) for

deciding on the best ventilation system (natural v. mechanical) for a building while it is still at the design stage. This model has been applied to an auction complex situated at Bleiswijk to deduce the best ventilation system for the building. Conclusions are that a natural ventilation system can be realized by placing ventilating devices exclusively in the roof. The ventilation is then chiefly provided by the differences in wind pressure caused by the shape of the roof.
KEYWORDS
auction hall, mathematical modelling, natural ventilation, mechanical ventilation, wind pressure

27. Brundrett G.W. Poultney G.H.
#NO 1026 Use of natural ventilation.
3rd AIC Conference "Energy efficient domestic ventilation systems for achieving acceptable indoor air quality" September 20-23 1982 UK p.2.1-2.12 8 figs. 1 tab. 14 refs. #DATE 20:09:1982 in English AIC
ABSTRACT
Outlines ventilation needs to show that odour dilution and moisture control are the major winter factors. Detailed studies on 24 well insulated houses show that window opening habits are clearly linked to outdoor temperature, more windows being opened in milder weather. Shows from energy input analysis that space heating only provides a quarter of the total heat, the remainder coming from casual sources. Analysis of energy loss suggests that a third of the losses are attributable to ventilation, the remainder through the building fabric. This ventilation loss is equally divided between infiltration and window opening. Average house seasonal ventilation rate is half an air change per hour.
KEYWORDS
occupancy effects, window opening, ventilation needs, heat loss,

28. Conan G.
#NO 1029 Variations in householders' window opening patterns.
3rd AIC Conference "Energy efficient domestic ventilation systems for achieving acceptable indoor air quality" September 20-23 1982 UK p.3.9-3.20 35 figs. 2 tabs. #DATE 20:09:1982 in English AIC
ABSTRACT
Describes a window opening survey concerned with identifying the objective correlates of window opening. Finds that the variation between households in terms of their total daily window opening is greater than that within households. Householders may adopt consistent window opening patterns. Hypothesises that although window opening is primarily a function of external air temperature, relative humidity and windspeed are influential at high values. Also suggests that all households follow a similar curve of window opening against increases in temperature but that the threshold temperature marking the foot of the curve varies from one household to another.
KEYWORDS
occupancy effects, window opening,

29. Dick J.B. Thomas D.A.
#NO 131 Ventilation research in occupied houses
J.Inst. Heat. Vent. Eng. vol.19 p306-326 #DATE 01:10:1951 in English.
#AIC 694

ABSTRACT
Gives results of measurements of air-change rates and heat loss in occupied and unoccupied houses on two sites, one exposed and the other sheltered. Observations of the wind pressures on the houses and of the window-opening habit of the occupants are discussed. These are used in conjunction with the results of a regional survey of the temperatures maintained and the window-opening habits in local authority houses to extend the application of the results of other housing. Estimates that average rate of heat loss by ventilation will be from 6 to 8 therms per week corresponding to air-change rates of between 2 and 3 per hour.
KEYWORDS
air change rate, house, occupancy effects, wind,

30. De Gids W.F. Van Schijndel L.L.M. Ton J.A.
#NO 220 Wind tunnel and on-site pressure distribution measurements on a house and its effects on infiltration
ASHRAE trans 1979 vol 85 part 2 p411-427, 13 figs 17 refs. #DATE 01:01:1979 in English #AIC 7
ABSTRACT
Summarizes measurements made on a flat. These include inside to outside temperature and pressure differences, infiltration rates using helium as a tracer gas, duration of opening windows and doors and weather conditions. Also describes wind tunnel measurements made on a model of the building with and without obstacles and terrain roughness. Concludes that there is reasonable agreement between wind-tunnel and on-site pressure measurements, that opening two small windows on the windward side may increase the infiltration rate by a factor of two, that the length of time a window is opened is better correlated with temperature than wind.
KEYWORDS
air change rate, air infiltration, tracer gas, helium, wind tunnel, pressure difference, temperature difference, wind direction, wind speed, correlation, flat, shielding, window opening,

31. Hauser G.
#NO 258 Influence of the type of ventilating system on the loss of ventilating heat
Einfluss der Luftungsform auf die Luftungswarmeverluste von Gebauden.
Heiz. Luft. Haustech. vol.30 no.7 p.263-266 6 figs, 9 refs. #DATE 01:07:1979 in German BSRIA j.
= E.C.R.C. translation, in English #AIC 312
ABSTRACT
With improved thermal protection of buildings proportion of ventilation heat loss has grown until it now accounts for 50% and more of total building heat losses. Since ventilation cannot be reduced below certain limits for comfort and hygienic reasons, selection of appropriate type of ventilation system is increasingly important to control heat losses. Describes characteristics and consequences for heat energy consumption and hygiene of constant ventilation and abruptly increased ventilation such as window opening etc..
KEYWORDS
mechanical ventilation, health, occupancy effects,

32. D.J. Dickson
#NO 639 The case for controlled ventilation of houses
Proceedings R.E.H.V.A. Conference Clima-2000, Budapest Sept 17-19, 1980 Vol. 2, p 427-435, 4 figs, 2 tabs. #DATE 18:09:1980 in English
#AIC 1138
ABSTRACT
Fresh air requirements in individual rooms of an occupied house vary between 0.5 and 2 air changes per hour depending on the number and activity of the occupants. The most common method of ventilation control is by opening windows but measurements show that even quite moderate window opening results in air change rates greater than 2 air changes per hour throughout a house.
Reports measurement of the energy cost of window opening in a test house with a heat loss coefficient of 5 kWh/K day. Finds in a low energy house, controlled ventilation is essential. Reports tests of a mechanical ventilation system which gives a constant trickle ventilation, capable of being boosted locally. Compares energy cost with the alternative of relying on window opening for fresh air control.
KEYWORDS
window opening, heat loss, mechanical ventilation, air change rate, house

33. Brundrett G.W.
#NO 625 Electricity and comfort in the home.
Proc. International Conference on Energy Use in Buildings. Arizona October 1977 p.355-391 8 figs. 15 refs. #DATE 01:10:1977 in English
#AIC 238.
ABSTRACT
Outlines in general terms the ventilation characteristics of typical British houses. Discusses energy losses through conduction and ventilation. Shows that excess energy consumption over that predicted theoretically can be partly accounted for by the British habit of opening windows. Reports programme to investigate factors influencing the amount of window opening. Suggests new integrated approach to energy in the home.
KEYWORDS
natural ventilation, occupancy effects

34. De Gids W.F. Phaff J.C. Knoll B.
#NO 1254 An overview of ventilation research in large non-residential buildings.
4th AIC Conference "Air infiltration reduction in existing buildings" Switzerland, 26-28 September 1983 p.7.1-7.25 19 figs. 27 refs. #DATE 26:09:1983 in English AIC
ABSTRACT
A short treatment of the concepts and aspects that play a role in ventilation is followed by a brief description of the investigation methods employed. Gives a concise survey of the equipment and mathematical models used. Reviews the ventilation research carried out by the IMG-TNO. Covers factories, laboratories, hospitals, auction halls and similar buildings. Concludes that almost no research into local ventilation provisions has been carried out, the choice between natural and mechanical ventilation is a difficult one, and there is a lack of knowledge regarding the influence of turbulence on ventilation.
KEYWORDS
ventilation, mathematical modelling, measurement technique, factory, laboratory, hospital, auction hall,

35. Offermann F.J. Hollowell C.D. Nazaroff W.W. Roseme G.D.
#NO 1130 Low-infiltration housing in Rochester New York-A study of air-exchange rates and indoor air quality.
Proceedings of the International Symposium on indoor air pollution, health and energy conservation Amherst Mass. USA 13-16 October 1981 Environment International Special Issue "Indoor Air Pollution" vol.8 no.1 1982 p.435-445 2 figs. 4 tabs. 20 refs. #DATE 01:01:1982 in English #AICR US25
ABSTRACT
Studies a sample of 58 occupied homes in Rochester NY to assess 1. the effectiveness of construction techniques designed to reduce air leakage 2. the indoor air quality and air-exchange rates in selected airtight houses and 3. the impact on indoor air quality of mechanical ventilation systems employing air-to-air heat exchangers. Measures leakage using the pressurization technique. Finds house with vapour barriers and joint-sealing are 50% tighter than houses without these components. Measures air change rates and indoor concentrations of radon, formaldehyde, nitrogen dioxide and humidity in 9 tight houses for one week periods, with and without mechanical ventilation. Air change rates are low (0.2-0.5 ach) without mechanical ventilation, and yet indoor concentrations of Rn, HCHO and NO2 are below existing guidelines. Mechanical ventilation systems are effective in further reducing indoor contaminant concentrations.
KEYWORDS
tight house, air quality, mechanical ventilation,

36. Etheridge D.W. Martin L. Gale R. Gell M.A.
#NO 764 Natural and mechanical ventilation rates in a detached house : measurements.
Applied Energy vol.8 no.1 March 1981 p.1-18 9 figs. 8 refs. #DATE 01:03:1981 in English #AIC 407
ABSTRACT
Presents results of measurements of ventilation rates in the SEGAS test house. Describes the house and its heating and mechanical ventilation systems. Measurements of ventilation rates were made using helium as a tracer gas. Tests were made both with the house sealed to block obvious paths of infiltration and with it unsealed. Tests were also made with the house mechanically ventilated and with supply and extract systems working. Presents results of tests and examines the effect of variation in mean wind speed on ventilation rates. Discusses results and concludes that sealing the external windows and weatherstripping external doors reduces the air change rate by about a third. Finds that the mechanical ventilation systems exceed the design air change rate when the house is unsealed.
KEYWORDS
house, air change rate, tracer gas, helium, decay rate, mechanical ventilation, wind speed,

37. Dickson D.J.
#NO 864 Mechanical ventilation.
CIBS Symposium 'Developments in Domestic Engineering Services' 1st December 1981 p.14-19 2 tabs. 1 fig. #DATE 01:12:1981 in English #AIC 502
ABSTRACT
As insulation standards improve, heat loss by ventilation becomes a larger proportion of the total heat loss from a building. Ventilation control is therefore necessary to minimize heating energy consumption

in houses. States that while passive systems and those requiring occupant participation may give satisfactory results, only a mechanical system can provide predictable ventilation routes and rates at all times. An extract only system has low initial cost, but it is difficult to ensure fresh air ventilation throughout the rooms of the house. A complete supply and extract system with heat recovery is expensive to install and requires careful design to ensure convenient duct runs but the performance is predictable. Economics are attractive when compared with the energy loss caused by opening windows.
KEYWORDS
mechanical ventilation, energy conservation, heat exchanger,

38. Shaw C.Y.
#NO 1217 The effect of mechanical ventilation on the air leakage characteristic of a two-storey detached house.
NRCC Building Research Note no.204 July 1983 #DATE 01:08:1983 in English #AIC 768
ABSTRACT
Measures air change rates in a 2-storey detached house with operation of various types of mechanical fresh air ventilation systems. Studies 4 systems, including 2 balanced systems and 2 exhaust-only systems. The forced ventilation rate is controlled at 0.15, 0.25, 0.4, or 0.5 ach. Develops expressions for the test house relating the house air change rate under winter conditions to the forced ventilation rate and the infiltration rate due to wind and temperature difference.
KEYWORDS
air change rate, mechanical ventilation, detached house, temperature, wind,

39. Sandberg M.
#NO 1048 Definition of ventilation efficiency and the efficiency of mechanical ventilation systems.
3rd AIC Conference "Energy efficient domestic ventilation systems for achieving acceptable indoor air quality" September 20-23 1982 UK p.13.1 - 13.22 10 figs. 5 refs. #DATE 20:09:1982 in English AIC
ABSTRACT
Discusses air quality and the related definitions of ventilation efficiency. Suggests a definition of efficiency for ventilation systems in residential buildings that takes into consideration how ventilation air spreads within a dwelling. Measurements of the efficiency for exhaust, supply and combined systems show that for combined and supply systems the highest efficiency occurs in those parts where the air is supplied. For these systems efficiency is sensitive to ventilation flow rate, while for the exhaust system the relative efficiency is more or less independent of ventilation flow rate. Finds that in warm-air systems the ventilation efficiency is affected by the positioning of the supply and exhaust registers, the ventilation flow rate and the relative difference between supply air temperature and room air temperature.
KEYWORDS
ventilation efficiency, residential building, mechanical ventilation,

40. Liddament M.W.
#NO 1235 Modelling the influence of ventilation strategies on air distribution and heat loss in a single family dwelling.
Proceedings of the 2nd International Congress on Building Energy Management 30 May-3 June 1983 Iowa USA 11pp. 7 figs. 8 refs. #DATE 30:05:1983 in English #AIC 783

ABSTRACT
Uses a validated multi-cell mathematical model of air infiltration to analyse the influence of various ventilation strategies on air distribution and energy demands. Assesses the performance of both natural and mechanical systems for two sets of climatic conditions and for two levels of airtightness. Shows that natural ventilation rates are highly dependent on climate. Additionally, air movement is a function of wind direction and stack effect. Mechanical ventilation provides good air distribution but climatic conditions have an important influence on its potential for cost effectiveness.
KEYWORDS
modelling, air infiltration, natural ventilation, mechanical ventilation,

41.Collet P.F.
#NO 1247 Measurements of air infiltration rates in dwellings with only exhaust ventilation.
"Energy conservation in buildings - heating, ventilation and insulation" Proceedings Contractors Meetings Brussels 14-15 Dec 1981 6-7 May, 24,28 and 30 September, 21 October 1982 #DATE 21:10:1982 in English #AIC 793
ABSTRACT
Measures the air change rate in 2 atrium houses and in 6 terrace houses. Examines the possibility of allocating the air change to particular rooms by correctly placed and operated exhaust ventilation and ventilation openings. Concludes that in dwellings with mechanical exhaust the fresh air change rate only depends slightly on the ventilation openings being opened or closed, and that it is possible to direct fresh air flow into different rooms if the doors within the house are not tight. In the dwellings with natural ventilation only concludes that ventilation openings are too small for adequate ventilation rates. States that for natural and mechanical ventilation, openings must exceed 250-300 cm2 and be reasonably distributed.
KEYWORDS
air change rate, house, natural ventilation, mechanical ventilation, air flow,

42.Sandberg, M.
(see reference 39 above)

43.Sandberg, M.
(see reference 39 above)

44.Liddament, M.W.
(see reference 40 above)

45.Skaret E. Mathisen H.
#NO 985 Ventilation efficiency.
International Symposium on Indoor Pollution, Health and Energy Conservation, Massachusetts 13-16 October 1981 18 pp. 16 figs. 1 tab. 5 refs. #DATE 13:09:1981 in English #AIC 591
ABSTRACT
Reviews a research project which has the objective of establishing:
1. Expressions for ventilation efficiency
2. Methods for measuring ventilation efficiency
3. Rules for achieving efficient ventilation.
Derives expressions for ventilation efficiency in a room by using

two-box theoretical model, assuming thermal stratification occurs. Measures ventilation efficiency by the tracer gas steady state method, using N2O and an infra red gas analyzer. Uses a series of probes placed in a vertical column and put in different positions in the room for gas detection. Sampling, analyzing and movement of the column are done automatically using a microprocessor. Tests show that the efficiency varies considerably between different ventilating systems. Finds that the best system for warm air ventilation is with the air supply located just below the ceiling and the air exhaust near the floor, and vice-versa for cool air ventilation. Therefore "diagonal schemes" seem to be the most efficient, and more efficient then complete mixing.
KEYWORDS
ventilation efficiency, tracer gas, modelling,

46. Shaw, C.Y.
(see reference 38 above)

47. Sandberg, M.
(see reference 39 above)

48. Boman C.A.
#NO 1069 Field trials of ventilation efficiency in buildings equipped with mechanical ventilation systems.
3rd AIC Conference "Energy efficient domestic ventilation systems for achieving acceptable indoor air quality" September 20-23 1982 UK p.14.1-14.12 7 figs. 2 refs. #DATE 20:09:1982 in English AIC
ABSTRACT
Gives results from field trials of the performance of various mechanical ventilation systems. Carries out measurements in buildings built during the seventies, using the tracer gas decay technique with N2O. Tests 3 cases:
1. Air supplied only through register above door
2. Air supplied both through register and the slot under the door
3. Air supplied only through slot under the door
Concludes that the slot under the door gives the highest ventilation efficiency. In another case, varies the temperature of the supply air to measure the effect on ventilation efficiency.
KEYWORDS
mechanical ventilation, ventilation efficiency, tracer gas, decay rate,

49. Muller H. Balkowski M.
#NO 1308 Waste-air ventilated windows for offices.
Heizung Luftung Haustechnik vol.34 no.10 p.412-417 October 1983 = OA Translation 2649 10 figs 1 tab 4 refs. #DATE 01:10:1983 in English #AIC 827
ABSTRACT
A large number of air-conditioned office blocks constructed in recent years in the FRG have been equipped with waste-air ventilated windows. Based on experience now available from planning, laboratory tests and practical operation, describes the different design principles and their technical characteristics. Bases the evaluation on window designs which have been used in 11 office buildings totalling 10000sq.m useful floor area. The dependence of the heat protection effect during the summer and winter on the design parameters of the windows is shown on the basis of measurements and calculations.
KEYWORDS
window, office building, mechanical ventilation,

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