Air Infiltration Review

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Browsing for Building Energy Efficiency

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Introduction

The Internet information highway is rapidly expanding, providing a conduit to almost limitless sources of information. Databases, reports, photographs, sound recordings and moving images are all to be found. A brief exploration of the Internet shows that the Building Energy Efficiency sector is well represented with a wide range of information being readily obtainable. While the Internet has been available to universities and large institutions for some time, it is only recently that accessibility to small organisations and individuals has become practicable. The purpose of this primer is to illustrate the range of information available and to show how, in just a short time, it is possible to become connected and operational on the Internet. In most cases, connection should cost no more than the price of a local phone call and a small monthly internet provider fee.

What services are provided?

The Internet offers a wide range of services. From a professional viewpoint, the most valuable of these are e-mail and the ability to tap into vast sources of data. It is also possible to establish your own information databases for either general or restricted access. The Internet service has been transformed by the development of the 'World Wide Web' (WWW). This can be likened to a vast network of information sources that is interconnected by countless paths.

The 'Web' is entered through a 'Browser' which operates in the well established 'Windows' environment of a 'PC', Macintosh, Unix or Main Frame computer. Each information source consists of a 'home page' comprising introductory information in which 'key words' are either underlined or are coloured blue. By pointing the computer mouse and 'clicking' at these keywords, further information screens are recovered containing more detailed information and yet further keywords. 'Browsing' is simply the process of 'pointing' at keywords and 'clicking'. This searching approach may take you deeper into the same information source or transfer you to a related source on the other side of the world.

In this issue

How is the Internet accessed by small organisations and individuals?

Becoming established on the Internet is a little tricky because commercial solutions are still being developed. Nevertheless a full World Wide Web connection can be established in a matter of hours by following the instructions presented below. Fortunately all the software needed to establish a WWW connection should be provided by your Internet provider is available free of charge from the internet itself. The installation instructions presented refer to an IBM compatible 'PC' although virtually identical instructions apply to other computing systems. To establish a connection the following are needed:

Computer: The minimum specification is usually a '486' DX series computer with 8Mb of RAM and at least 20Mb of available hard disk space.

Telephone Line: An ordinary 'voice' telephone line is needed to establish an internet connection. This line only remains open when connected to the Internet. It is not necessary to install a high quality ISDN line or a permanent line for casual Internet use. All the examples presented in this primer are based on a voice line connection.

Modem: A 'modem' converts computer and Internet information into signals that can be transmitted along a telephone line. The minimum speed specification must be 14400 Baud. Many internet systems are currently transferring to a new 'V34' Standard 28800 Baud speed which effectively doubles the information transmission rate at no extra charge. Suitable V34 modems now very inexpensive (e.g. £150 UK).

Internet Provider: The Internet Provider is a commercial organisation that connects your computer to the Internet System. Several providers exist and it is essential to find one that gives you the correct range of services. Without defining the jargon, you need a provider that can give you a 'PPP' or 'SLIP' connection and your own Internet (IP) address. You will also be allocated an e-mail address. Ideally you need a provider with a local 'Point of Presence' (PoP). This simply means that the Internet connection is made through a local telephone exchange and hence only a local call charge is incurred. A local connection also reduces the risk of line noise. As a guide, a good Internet provider offers unlimited connect time for a very low monthly fee (e.g £10 UK).

Software: Software refers to the computer programs you need to enter Internet through the World Wide Web. Provided you have selected the correct Internet provider, you will already have been supplied with all the tools necessary to run e-mail and to download WWW software from the Internet. 'Downloading' is undertaken using the 'File Transfer Protocol' (FTP) and 'get' commands. These tools are very easy to use and are described in your Internet provider manual. The software you need to download from the Internet are:

(i) Chameleon sampler: This software is included as a disk in reference (1) but is also obtainable by 'ftp'. It contains many useful tools but the all important programme for a WWW connection is 'winsock.dll'. This makes a 'Windows' connection into Internet.

(ii) mos20b1.exe: This is the WWW Browser software itself and is known as 'MOSAIC'. The significance of MOSAIC is described in more detail in Reference (2). This version of MOSAIC is obtained by 'ftp' to the Internet Address: "ftp.ncsa.uiuc.edu" .

(iii) w32sOLE.exe : This programme may be obtained from the same source as MOSAIC. It is needed to get MOSAIC to work on Windows 3.1. It is not needed if you use Windows for Workgroups v3.11 or intend to use Windows 95.

(iv) lviewp1a.zip: Also available from (ii) above are a range of software 'viewers'. The particular viewer recommended enables images to be downloaded at spectacular resolution, including those transmitted by the Space Shuttle and the Hubble Telescope. Other viewers for sound and video clips can be downloaded from the same source. Some

Air
Infiltration
Review

Editor: Janet Blacknell

Air Infiltration Review has a quarterly circulation of 3,500 copies and is currently distributed to organisations in 40 countries. Short articles or correspondence of a general technical nature related to the subject of air infiltration and ventilation are welcome for possible inclusion in AIR. Articles intended for publication must be written in English and should not exceed 1,500 words in length. If you wish to contribute to AIR, please contact the Air Infiltration and Ventilation Centre. Please note that all submitted papers should use SI units.

information sources include special viewers for converting data files into full-colour print ready reports.

No other software is needed. In all cases, the software listed contain 'README' files explaining how the programmes need to be set-up. For the items described, this turns out to be very straightforward and is no more complex than installing any other type of Windows software.

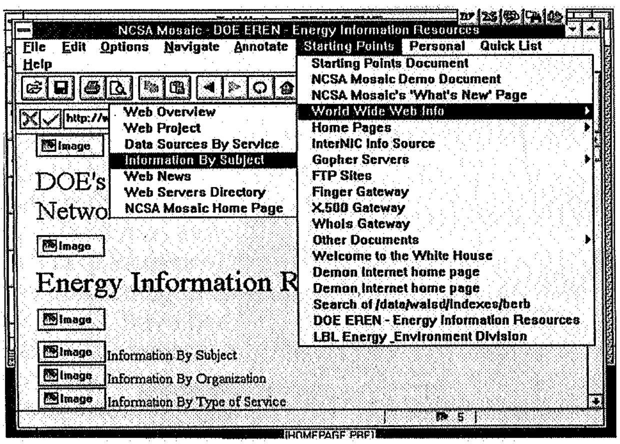
Initiating a Session

If you are lucky, a WWW connection will be established at the first attempt. If installation has failed, a range of help and frequently asked question pages will assist you in solving your problem.

A session is initiated by running 'Chameleon' to establish a 'windows' link between your PC and Internet; this puts you 'on-line'. MOSAIC is then initiated (normally by double clicking an icon) to give you a default 'home page'.

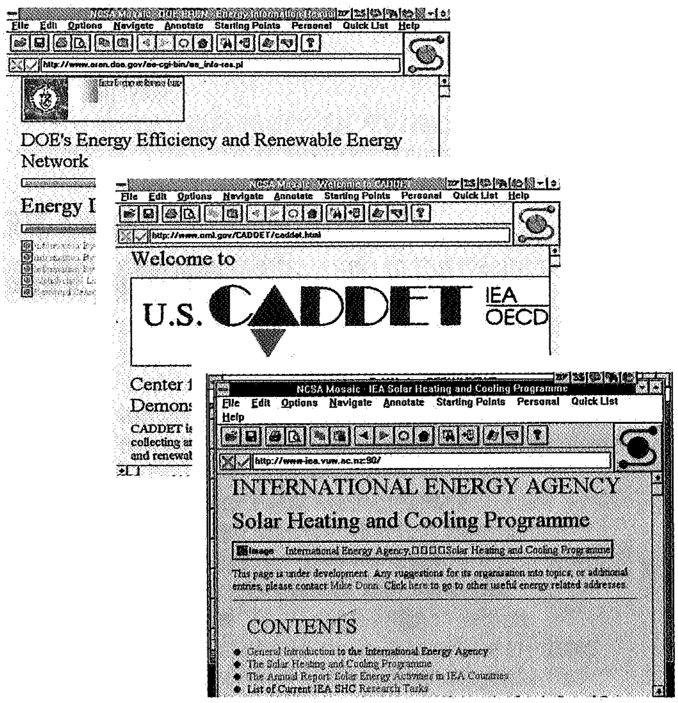
'Browsing the Internet'

One way to begin browsing is to point and click the on 'Starting Points' of the home page 'tool' bar (see attached figures). This yields a 'drop down' menu from which 'World Wide Web Info' may be selected. Then, from the next displayed menu, 'Information by Subject' can be tried. From here the field is wide open. Fruitful information can be obtained by 'clicking' on 'energy', 'engineering', 'environment', 'government departments' and a whole range of other subjects. The address of any interesting source of information can be stored at a 'click' for instant retrieval at a later date.



Some of the information retrieved in only a few minutes of browsing is illustrated in the attached figures.

- From the US Department of Energy came a comprehensive buildings energy bibliographic data base. References and abstracts could be located by 'free text retrieval' or by searching specific fields (e.g. author search).
- Access to the European THERMIE programme yielded details of newsletters and other reports, many of which are available by direct downloading.
- The International Energy Agency CADDET provided information about their demonstrated energy end use programme.
- Other IEA projects included the Solar Heating and Cooling Programme.



All the information recovered could be searched and downloaded without charge.

It is also possible to locate commercial home pages through which information can be reached via a pricing structure. Commercial pages are used to market books, products and services.

An inexpensive start for anyone considering general or commercial exploitation of the Internet is to insert your own 'Home Page' on the Web. This, again is possible at very little expense (£25/month UK), through your Internet Provider. An example of the AIVC Home Page is also attached.

Conclusion

By following the instructions outlined in this primer, it is possible to enter the Internet system and find considerable information related to building research and application. Also included is a comprehensive e-mail system and the opportunity to put your own information on the World Wide Web. For more information contact Martin W. Liddament at martin@aivc.demon.co.uk.

References

The following references provide a g
to the Internet.

(1) 'Navigating the Internet' by Richard J. Smith and Mark Gibbs, Sams Publishing, ISBN No. 0-672-30485-6, Price £26.95.
This book provides a good background to the Internet and includes a 'Chameleon' software disk, enabling Windows based e-mail, 'ftp' and other forms of Internet Access.

SAIC' Navigator' by Paul Gilster, Wiley
g, ISBN No. 0-471-11336-0, Price

This book provides all the information you need to download MOSAIC software and become operational on the 'World Wide Web'. It also provides simple 'home page' software and guidance on how to establish your own home page.

Air Infiltration and Ventilation Centre is now on the World Wide Web

Web Site (URL): http//www.demon.co.uk/aivc

The AIVC now has full Internet access on the World Wide Web. Contact our Web page to review our work programme and download reports.

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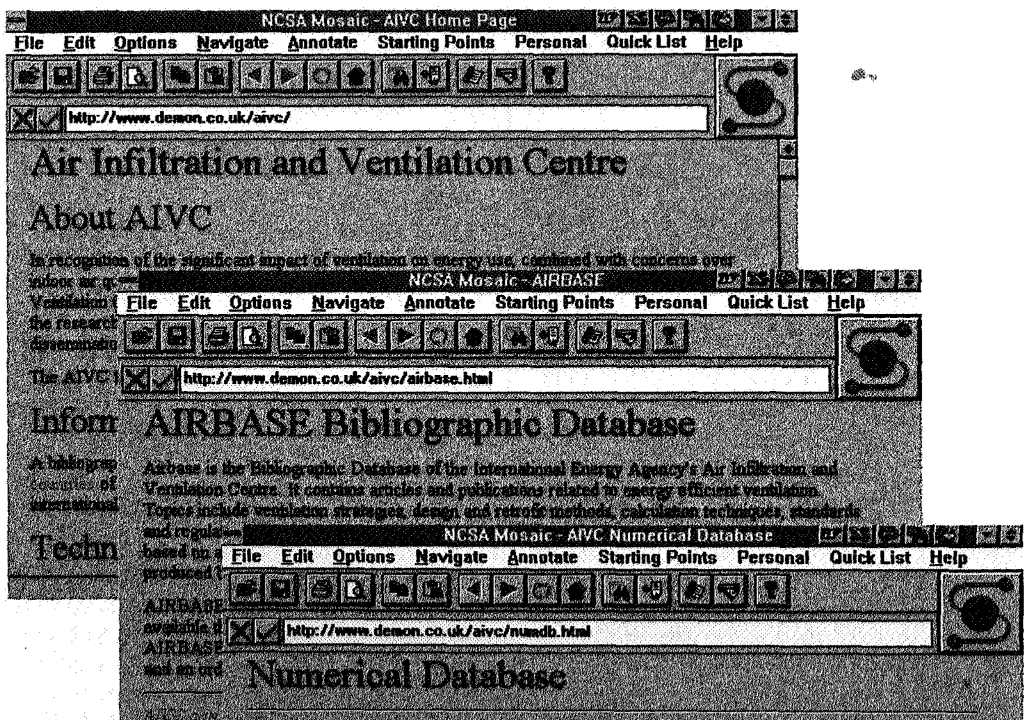
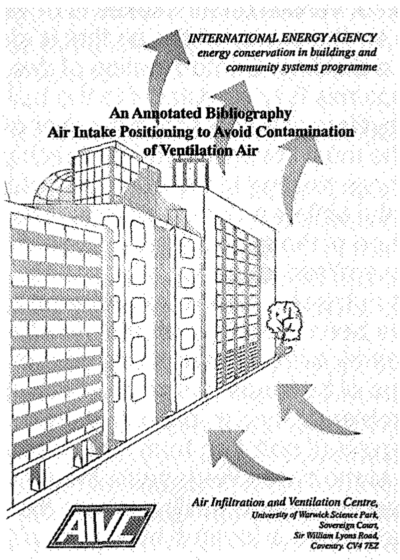


New AIVC Publication

Air Intake Positioning to Avoid Contamination of Ventilation Air - An Annotated Bibliography

by Mark J Limb, Scientist, AIVC

A new annotated bibliography is now available from the AIVC. Below the author gives a brief summary of its content.



The positioning of fresh air intakes is a vital element in the design and installation of ventilation systems. It is from these point that outside air is drawn into a building for ventilation. In the literature outdoor air is often termed "fresh air". However, while this air may not have been previously circulated throughout the building, it may already be contaminated. Pollutants can become entrained in this air because of the airflow characteristics around the building or intake, or indeed may simply be drawn in through the choice of intake location. Despite the fact that guidelines for the positioning of air intakes, to avoid such pollution incidents, have been put forward by CIBSE and ASHRAE, several authors discuss buildings where, for one reason or another, such guidance has not always been followed. This bibliography based on current research, attempts to demonstrate various ways in which the pollution at air intakes can be minimised at the design stage. Also for those buildings which have become polluted, it discusses what actions are then available, to reduce the contamination of the indoor environment.

Causes of Air Intake Contamination

Causes of air intake contamination include the following:

- Environmental Wind Flows Around Buildings

The two main problems associated with outdoor air pollution around buildings relate to the height of the chimney stacks, which should be sufficiently high to ensure that the exhaust plume clears the immediate buildings, and the emission of pollutants in the wake regions of buildings. It is necessary to determine the resultant concentrations which will occur at air intakes and at street level. Such problems are often site specific and thus it is difficult to give any generalised guidance. According to one author even the old rule-of-thumb that to be really effective a stack should be twice as high as adjacent buildings, cannot be quoted as a certain way to avoid problems. A number of studies exist in which analytical and wind tunnel models have been used and developed to predict such dispersal patterns around buildings. This section of the document outlines these investigations, dealing first with the height and relative position of exhaust stacks to intake locations and then moving on to consider studies which focus on pollution exhausted into wake regions. A number of the studies use both wind tunnel and empirical models in their invesigations, the compared results of which are discussed by the authors.

- The Problem of Short Circuiting

Short circuiting is a major cause of contamination of fresh air intakes, and can result from pollutants being entrained into the ventilation intake, simply by the natural airflow around the building, or because of poor design, which has led to the building ventilation intake and exhaust being in the same vicinity. Despite the existence of design guidance warning against short circuiting, it is still a common problem. Several authors discuss examples where this is a recurring problem, a number of suggestions are made in order to combat these problems, including the re-routing of building exhausts and the provison of good engineering practice, which should be followed to avoid short circuiting occurring in the first instance.

- The Location of Air Intake Adjacent to Sources of Pollution

The outdoor air in a particular location should meet the required outdoor air quality standards. The National Ambient Air Quality standards for the United States are outlined by the US Environmental Protection Agency (1990), while the European air quality standards are dealt with in a number of EC Directives. Other guidelines are given by the World Health Organisation (WHO).

The design options available therefore depend upon the nature of the pollutant and of course, its location. Pollutants include dusts, fumes and smokes; mists and fogs or vapours and gases, etc some of which occur naturally and others are man made. Available guidelines actively discourage the location of air intakes adjacent to such sources of pollution. However, many examples exist which demonstrate that such problems do still frequently occur, some of which are outlined in this bibliography.

- Poor HVAC Maintenance

The hazards and dangers of poor HVAC maintenance and design, including short-circuiting of intakes and exhausts, the reduction in ventilation air to achieve greater energy conservation, and the interruption of fan operation to achieve greater energy conservation, have been highlighted by a number of researchers.

The HVAC system itself can become a source of pollution due to poor maintenance. However, the occurrence of dust in ventilation ductwork does not necessarily mean that the ventilation air is contaminated. However, dirt in the ductwork can allow the generation of microbes, fungi and pathogens, and depending on the amount and composition of the dust, it could in some systems be a potential risk, especially if the growing conditions are changed. Poor maintenance or design can lead to the entry of animals and insects, the faeces of which could be responsible for the growth and subsequent introduction of harmful bacteria into a building. The location of the air intake should be designed to minimise as far as possible the level of contamination from these sources.

- Design Guidance

ASHRAE and CIBSE give similar design guidance for the location of air intakes to minimise the contamination of ventilation air. This guidance includes ensuring that intakes are protected against the weather and that drains are included to allow the removal of any rain or snow that may penetrate. These drains also prevent the accumulation of stagnated water which would result in unpleasant odours within the building. Birdscreens should also be used to prevent the entry of birds or other large objects. Intake points should be located away from obvious sources of pollution, such as cooling towers, boiler flues, etc and care should be taken to ensure that any planned developments are considered at the design stage. If air inlets are located adjacent to discharge points then short-circuiting can occur. However, the airflow characteristics of the building will also determine whether short-circuiting is a major problem. Other brief guidance given by a number of other authors is also considered in this bibliography.

Conclusion

The location of ventilation air intakes is of vital importance to the quality of the air that is circulated throughout a building. Contamination of this air, even before it becomes fully ingested into the buildings ventilation system can occur for a number of reasons. The most important and far reaching of these are those relating to the complex nature of environmental airflow around buildings. The site specific nature of these problems make it difficult to produce generalised guidance. In response therefore, a number of analytical and wind tunnel models have been used to evaluate the effective height of nearby exhaust stacks, the contamination of wake regions of buildings (which can lead to short circuiting problems), and to provide ways of predicting levels of pollution from other nearby sources. In some cases inadequate thought for these problems has led to poor design, where the ventilation air intake is located near to an otherwise avoidable pollutant source, for example adjacent to a building's exhaust, be it its own or that of another building, or at street level, where vehicular pollutants can occur at specific times during the day. A further consideration is that of poor maintenance, which can result in air intakes becoming clogged, or themselves a source of pollution. The decomposition of animals, vegetation and other waste products can lead to the production of fungi, microbes and pathogens, which can then become entrained in the ventilation air and distributed throughout the building. Although these problems, can be avoided, or at least minimised if considered at the design stage, the quality of intake air ultimately depends upon the nature of the outdoor air in the first place.

The bibliography is aimed at researchers, designers and engineers who would benefit from an introductory overview of research into this subject. References quoted in this document are available, to participating countries, from the AIVC Bibliographic Database, AIRBASE. Copies of this bibliography are available upon request from the AIVC.

The Performance of Dynamic Insulation in Two Residential Buildings

by Jørn T Brunsell, Norwegian Building Research Institute, Oslo, Norway

Introduction

In the last two decades a lot of effort has been spent in order to reduce the heat loss from buildings. In particular two actions have been used in cold climate countries:

1. Increase the thickness of the insulation in the building envelope.

2. Reduce the ventilation rate in buildings.

One of the consequences of action 1 is a more expensive building. Building regulations in cold climate countries require U-values for the envelope which result in thicker and therefore often stronger constructions than needed for structural capacity.

The consequence of action 2 has been a lot of complaints from the users. The houses have been tighter which has reduced the infiltration rate. The controlled ventilation through the ventilation system has also been decreased in order to save energy. The total ventilation rate has therefore often been too low to control the contaminant level inside the houses. This action has certainly contributed to the diagnosis "sick building syndrome".

Dynamic insulation is an alternative to these actions. Dynamic insulation means a construction where the air is being forced through the insulation, usually from the colder outside air into the heated building. The theoretical U-value can be reduced towards zero and the conduction heat in the insulation is preheating the incoming air.

The Norwegian Building Research Institute has been engaged in evaluating 12 row houses built in the Oslo area with dynamic insulation used in the roof. This paper presents the main results from measurements in one occupied and one unoccupied house.

Theory

The air-flow is normally forced in the opposite direction to the conduction, thus the term "contraflux insulation". When the airflow has the same direction as the conduction, "proflux insulation", there is a risk of moisture condensation inside the construction. All the tests described in this paper are carried out with contraflux insulation.

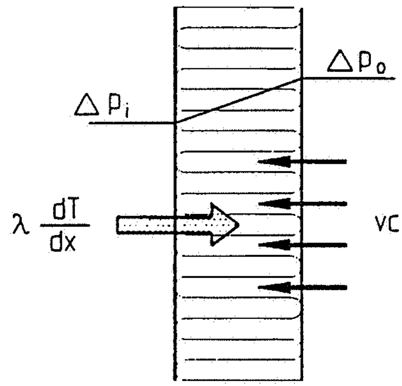


Figure 1: Direction of conduction and convection in a "contraflux insulation."

The conduction and the convection heat flow can be described mathematically as follows:

$$q_d = \lambda \frac{dT}{dx}$$

$$q_\upsilon = \upsilon \rho c_p (T - T_r)$$

In a steady-state situation Anderlind (1) first showed that the temperature distribution in a homogeneous insulation layer can be described as:

$$T = T_u + (T_i - T_u)\frac{e^{\frac{ax}{d}} - e^{-a}}{1 - e^{-a} + \frac{a}{b-a}}$$

where $a = \frac{d\upsilon \rho c_p}{\lambda}$ and $b = \frac{d\alpha_i}{\lambda}$

The concept "dynamic U-value" can be defined as the U-value of a construction with "static" insulation with the same heat loss as the construction with the dynamic insulation. For a homogeneous insulation layer the dynamic U-value in the steady state situation can be shown to be:

$$U = \frac{\lambda}{d} \cdot \frac{a e^{-a_1}}{1 - e^{-a} + \frac{a}{b-a}}$$

Anderlind has also presented curves where the dynamic U-value is a function of the air velocity and the thickness of the insulation (Figure 2).

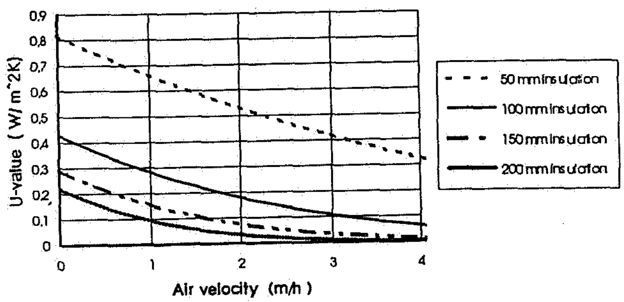


Figure 2: U-value for a construction with 50-200 mm dynamic insulation as a function of the air velocity.

Laboratory Experiments

In order to find the right permeability of the materials that were going to be used in the buildings described later, some laboratory experiments were carried out. The temperature distribution obtained from these measurements corresponds to the theoretical calculations.

Field Experiments

The construction of the 12 houses with dynamic insulation in the roof is shown in Figure 3. Several strategies can be used to force the air through the insulation. There can be established an overpressure in the attic, there can be an underpressure inside the house or there can be a combination. The necessary and acceptable pressure difference will also vary with the different strategies.

For the 12 row houses the following strategy was chosen:

The outside air is sucked into the attic and through the insulation by an underpressure inside the house.

The underpressure was planned to be 10 Pa. We considered 10 Pa to be the highest pressure difference that could be acceptable for the users (opening of windows and doors etc.). 10 Pa was also considered enough to avoid the wind causing a change of the flow direction through the roof or the walls more than 5% of the time. The velocity through the insulation with 10 Pa pressure difference should be 2 m/h which should give a ventilation rate alone of 0.8 ach. If the n_{50} value based on leakages from the rest of the house was less than 1.0 ach, about 0.3 ach would come through the leaks in the walls and the floor at a pressure difference of 10 Pa. Together this will give a total ventilation rate of 1.1 ach.

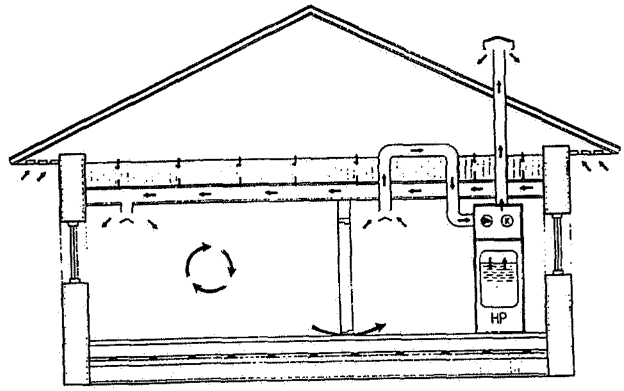


Figure 3:

The 12 row-houses have dynamic insulation in the roof. The outside air is sucked into the attic and then down through the insulation and into the house through inlets. The driving force is an underpressure inside the house created by fans in the heat pump which also transfer the heat from the exhaust air to the hot water supply. The houses were built without any influence from the evaluation group.

The following parameters were measured in the two houses:

- Temperature inside, outside and the profile through the insulation
- Pressure differences between outside, the attic, through the insulation and the inside
- Wind speed and wind direction
- Ventilation rate inside and in the attic
- Tightness and thermographic measurements of the houses

Ventilation rate measurements were carried out with the constant concentration method using Bruel and Kjaer equipment model 1302 and 1303. We had 6 channels for dosing and 6 for sampling. Values for the tracer gas measurements were logged every minute, then averaged values for 10 minutes were stored.

Values for temperature, pressure differences, wind speed and wind velocity were logged every 10th second and then the averaged values for 10 minutes were stored.

Results

Tracer gas measurements

House 1 was occupied by the owners, an elderly couple, during the measurements. After the termination of the measurements and all the equipment was removed, they informed us that they had tried to air out the tracer gas by opening windows and doors. The pressure difference across the thermal envelope disappeared of course during these periods. In addition we had some problems with the tracer gas equipment and therefore there are no results from these measurements in house 1.

House 2 was unoccupied during the measurement period which can be divided into two parts. During the first period we did only tracer gas measurements inside the house. During the second period we had tracer gas measurements in the attic and sampler tubes in the insulation, in the air inlet and inside the living room.

The ventilation rate for the whole House 2 the first period is given in Figure 4.

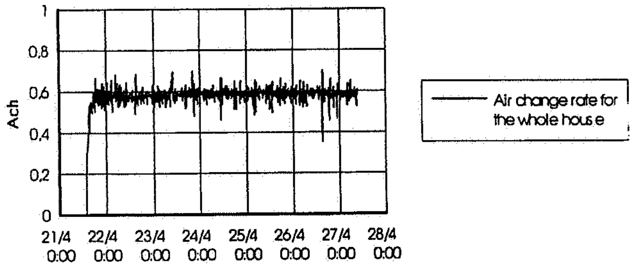


Figure 4: Ventilation rate for the whole House 2 the first period.

The ventilation rate for the whole house is rather constant as expected. With an underpressure of 6-7 Pa there must be a wind speed above 3-4 m/s towards a wall to change the flow direction through the leaks in the leeward wall and change the air change rate significantly.

In the second period two dosing tubes for the tracer gas equipment were moved up to the attic. Here the target concentration was set to be 5 ppm. Two sampling tubes were placed in the attic, two under the insulation, one in the inlet in the living room and one in 1.5 m height in the living room. The purpose of these measurements was to find the proportion of air coming from the attic through the insulation and into the apartment at different climatic conditions (mainly different wind speed).

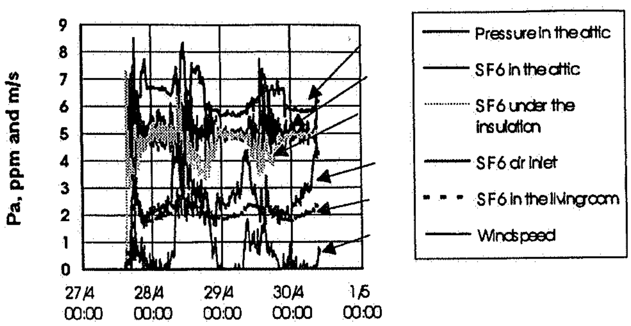


Figure 5

Concentration of tracer gas, SF_6, in the attic (average of 2), under the insulation (average of 2), in the air coming out from the inlet in the living room and at 1.5 m height in the living room. One can see the variation of the concentration and the pressure difference between the inside and the attic as a function of the wind speed.

There were two sampler tubes in the attic and under the insulation. The following values are the average concentration for the second period:

Attic 1: 5.02 ppm

Attic 2: 5.16 ppm

Under the insulation 1: 4.44 ppm

Under the insulation 2: 4.78 ppm

Inlet air to the living room: 2.54 ppm

Living room, 1.5 m height: 2.05 ppm

Although we had 3 fans to mix the gas in the attic, we had only 2 tubes for sampling the air in the attic. We can therefore not be sure we had a uniform concentration, especially along the edge where the air entered the attic. This might explain the big difference in the concentration from under the insulation and to the air coming through the inlet.

Pressure differences, temperatures and wind speed

These measurements were carried out in order to better evaluate the performance of the "dynamic construction".

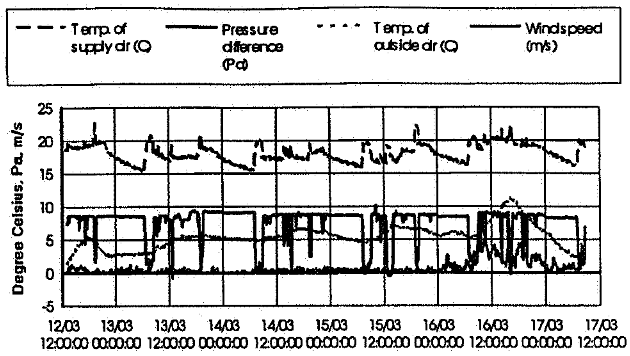


Figure 6

Temperature of supply air, pressure difference between the inside and the attic, temperature of the outside air and wind speed measured for House 1.

As can be seen from the figure the windows and/or the doors were kept open some parts of the day. The result is a drop to 0 of the pressure difference between the inside and the attic.

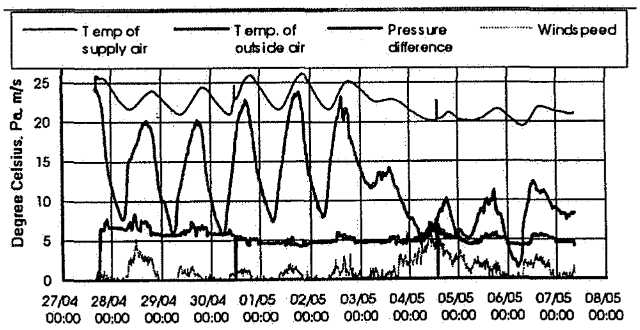


Figure 7

Temperature of supply air, pressure difference between the inside and the attic, temperature of the outside air and wind speed measured for House 2. The pressure difference is smaller than for House 1 but it is stable around 5-6 Pa.

For both the houses we had 2 columns with temperature sensors through the insulation. These sensors were installed to see how the curve of the temperature profile corresponds to the theoretical curve. The calculations carried out with the measured temperatures inside and outside are not yet completed.

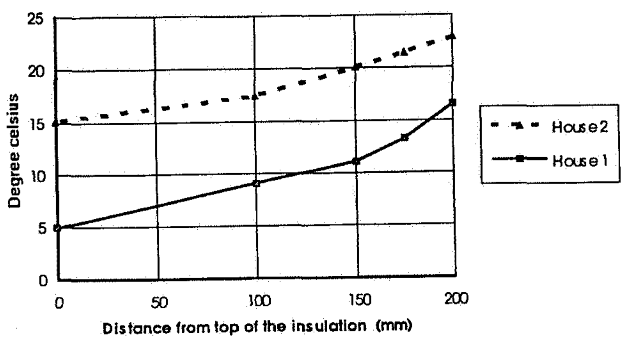


Figure 8

Temperature profile through the insulation for both House 1 and 2. The profiles are made out of the average temperatures for both columns in each point.

The characteristic curved profile can be seen for both of the houses. For some shorter periods the curved profile was more clear. Especially this is true during colder periods (House 2) and when the pressure difference was at the highest level (House 1).

Indoor air quality

Together with the tracer gas measurements some pollutants were monitored as well. The results do not indicate that outside air going through this kind of insulation brings pollutants from the insulation into the house as some have feared. This will not be discussed in this paper.

Discussions

From the measurements it is clear that a smaller proportion of the total ventilation rate is coming through the roof than planned. There are two reasons for this:

- The n_{50} value is higher than planned
- The volume flow through the outlets is smaller than planned (if there is an underpressure in the whole house it means that the volume flow through the outlets is equal to the total volume flow through the house)

The measurements also show that the total flow rate was smaller than planned even if the houses were leakier than planned.

The strategy for bringing in the air to the house has been to establish an underpressure inside. Since the houses are leakier than expected, more air will be sucked through the leaks. To avoid this, one action can be to establish an overpressure in the attic. This will give the possiblity also of cleaning the air before it enters the insulation.

We did not measure the total air flow rate through the two heat pumps which ventilate and supply hot water to 6 apartments each. The volume flow through the outlets was measured and this was smaller than planned. It corresponded however with the result from the tracer gas measurements in house 2 where the air change rate was 0.58 ach.

If we consider the measured concentration to be right, a much smaller proportion than planned is coming through the insulation from the attic:

$$Q_a.c_a = Q_t.c_i = n.V.c_i$$

$$Q_a = n.V.c_i / c_a = 0.58.168.2.05/((5.02+5.16)/2)$$

$$Q_a = 39\, m^3/h$$

The velocity through the insulation is then:

v = Qa/A = 39/70 (A = area of the roof in m^2)

v ≈ 0.6 m/h

If we go to figure 2 and use the curve which represents 200 mm insulation we will find that the velocity v = 0.6 m/h corresponds to a U-value of 0.12 W/m^2K.

From the temperature measurements on both sides of the insulation and inside the insulation it is possible to calculate a “dynamic U-value” as follows:

$$U = \frac{q_d}{T_i - T_o}$$

The heat flow can also be written as:

$$q_d = \lambda \frac{dT}{dx}$$

The equation for the U-value is then:

$$U = \frac{\lambda \frac{dT}{dx}}{T_i - T_o}$$

From the measurements we have chosen the value (T_{100}-T_o) for dT. T_o is the temperature on the outside surface of the insulation and T_{100} is the temperature in the middle of the insulation, 100 mm from the outside surface.

The result from such a calculation will give a slightly higher U-value than correct because we assume that the temperature profile from the outside surface of the insulation and in to T_{100} follows a straight line.

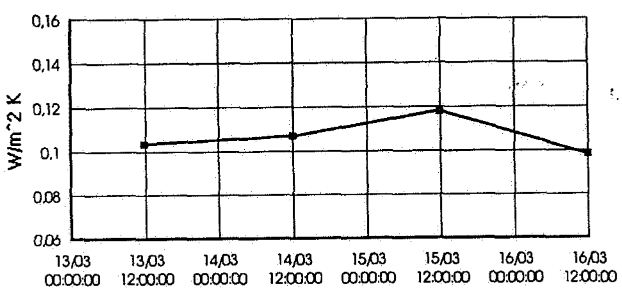


Figure 9
The calculated average dynamic U-value per day using the results from the temperature measurements for House 1.

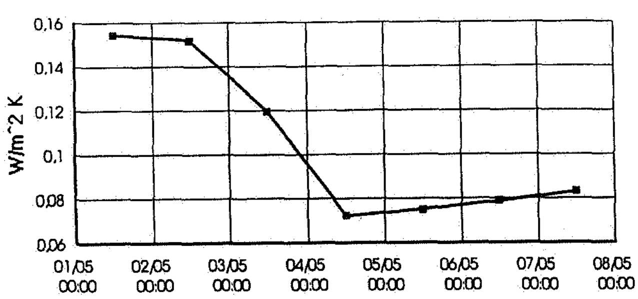


Figure 10
The calculated average dynamic U-value per day using the results from the temperature measurements for House 2. This is the period with the smallest variation of the outside temperature and therefore also the smallest variation of the U-value.

The variation of the dynamic U-value is a result of the variation of the temperature inside and outside and also because of the variation of the pressure difference across the insulation. The average U-values for the roof for the whole measured periods for the two houses are:

House 1 U = 0.10 W/m^2 Deg K

House 2 U = 0.06 W/m^2 Deg K

The periods are too short to find a representative U-value for the roofs. The values however, indicate that the heat loss through the roof has been reduced with 55% and 73% respectively for the two houses compared to the heat loss through a similar construction with static insulation. The U-value without any convection is U = 0.22 W/m^2 Deg K.

Conclusions

The following conclusions can be drawn from the field experiments on two residential buildings:

- Dynamic insulation can give ventilation without draught and the heat loss from the construction can be reduced to 0.
- Dynamic insulation is an interesting alternative way if insulating and ventilating residential buildings
- It is important to choose a strategy on how to get the right air flow rate into the house without influence of the weather condition, the air tightness of the house and the users.
- Field measurements of U-values have to be carried out over a long period of time with stable weather conditions.

A	Roof area	m^2
Q_a	Volume of air flow rate from attic to apartment	m^3/h
Q_t	Volume of total air flow rate through the apartment	m^3/h
T_i	Temperature inside	°C
T_o	Temperature outside	°C
T_r	Reference temperature	°C
U	Thermal permeance	W/m^2°C
V	Volume of the apartment	m^3
c_a	Concentration of tracer gas in the attic	ppm
c_i	Concentration of tracer gas in the apartment	ppm
c_p	Specific heat capacity	J/kg°C
d	Thickness	m
n	ventilation rate	h^{-1}
n_{50}	ventilation rate at 50 Pa pressure difference	h^{-1}
q_d	Conduction heat flow rate	W/m^{2}h
q_v	Convection heat flow rate	W/m^{2}h
v	Air velocity	m/h
α_i	Surface film coefficient for heat transfer	W/m^2°C
λ	Thermal conductivity	W/m°C
ρ	Density	kg/m^3

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Evaluation of Indoor Air Quality Models

Synopsis of a guide on model evaluation developed by ASTM

by Niren L Nagda, Ph.D, Energen Consulting Inc, USA

Although indoor air quality models have been used for some time, there is little guidance in the technical literature on the evaluation of performance of such models. ASTM has filled this gap by issuing a standard guide for statistical evaluation of indoor air quality models (D5157-91 published by the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103).

This guide provides quantitative and qualitative tools for evaluation of IAQ models. These tools include commonly used measures such as correlation coefficient and normalized mean square error (NMSE) for assessing the general agreement between predicted and observed values. For assessing the bias in model predictions relative to observed concentrations, tools such as fractional bias of the mean concentrations and fractional bias of the variance of concentrations are included. To assist the user, a range of values for indicating adequate model performance is presented in the guide. Guidance is also provided in choosing data sets for model evaluation.

This guide will be re-balloted during 1996. Any comments based on use of the guide or other comments should be conveyed to Dr Niren Nagda, Energen Consulting, Inc., 19900 Wild Cherry Lane, Germantown, MD 20874, USA, Phone: 301/540 1300 or Fax: 301/540 6924).

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