NatVent™ EUROPEAN PROJECT: GUIDANCE ON TECHNICAL SOLUTIONS FOR LOW ENERGY VENTILATION IN OFFICE BUILDINGS

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ABSTRACT

NatVent™ is a seven nation pan-European project which aims to reduce primary energy consumption (and consequently CO_2 emissions) in buildings by providing solutions to barriers which prevent the uptake of natural ventilation and low-energy cooling in countries with moderate and cold climates. It also aims to encourage and accelerate the use of natural ventilation and 'smart' controls as the main design option in new-designs and major refurbishments of office-type buildings. This paper reports on the current findings of the task to provide solutions by developing 'smart' natural ventilation technology systems and component solutions to overcome the identified technical barriers. This includes the investigation of strategies and components to control the incoming air flow, to minimise overheating, to recover heat, to attenuate the effects of urban pollution and noise and to integrate ventilation strategies. The paper also outlines the preliminary structure of a guidebook which will describe and summarise the findings. The guidebook aims to increase confidence of how to achieve Indoor Air Quality (IAQ) and Comfort in office buildings using low energy ventilation strategies for the designers and his client.

Keywords: low energy ventilation, natural ventilation, office buildings, technical solutions, smart components, heat recovery, urban pollution, summer overheating.

INTRODUCTION

There has been a recent increase in the number of purposely built naturally ventilated buildings in the UK [1] and across Europe which have set a precedent for the application of the technology. The main goal of the built examples is to produce buildings with low operating budgets that respond to user needs and therefore are most appealing to owner occupiers and companies with an environmental image. There is still a resistance to the uptake of the natural ventilation technology by developers and big owners, especially for speculative buildings, although surveys suggest that occupiers prefer naturally ventilated buildings. There are a number of reasons why natural ventilation can be rejected at the stage of brief requirements, which include financial and institutional barriers. In addition, there exist technical shortfalls in the technology which can introduce an increased risk for the designer and the developer of not achieving the specific design-values in the occupied buildings. NatVent™ [2] is a research project which aims to overcome some of these technical barriers and reduce the risk. The project is being carried out by a consortium of nine partners, across seven European countries: Great Britain, Belgium, Denmark, the Netherlands, Sweden, Norway and Switzerland. The full title of the project is 'Overcoming technical barriers for the application of low energy ventilation to office-type buildings in cold and moderate climates' and it aims to achieve three major tasks:

a) identify perceived barriers to the application of natural ventilation, through an in-depth study among leading designers, architects, building owners and occupants,
b) assess current practice by monitoring the ventilation performance of twenty buildings purposely built to incorporate natural ventilation strategies, and
c) provide solutions by developing 'smart' natural ventilation technology systems and component solutions to overcome the identified technical barriers.

This paper describes the objectives and current state of research for the third task activities, namely:

- control of incoming air flow,
- overheating,
- natural heat recovery,
- urban pollution and noise, and
- integration of ventilation strategies.

Simple design tools will be developed on the above problems to help designers at the early concept stage and the design stage to address these issues. In addition available components (existing or new) will be identified to help in the specification stage of the design process. A guidebook will be produced to describe and summarise the findings. The aim of the guidebook is to increase confidence of how to achieve Indoor Air Quality (IAQ) and Comfort in office buildings using low energy ventilation strategies and it is aimed at the architect and client sector of the construction industry.

CONTROLLED AIR FLOW INLETS

During the winter, the purpose of efficient ventilation is to provide fresh air to ensure IAQ without compromising energy consumption. In naturally ventilated buildings this may be achieved with purpose built ventilators which usually do not control the air flow. Therefore, variable air flow is delivered in the space, depending on external temperature and wind conditions. This could lead to complaints about stuffiness or drafts for some periods of the year. To overcome this, several types of controlled air inlets are available in the European market mainly developed in France, Scandinavian countries and the Netherlands. The NatVent™ project aims to identify and specify conditions under which these newly developed smart natural ventilation controlled air flow inlets can provide acceptable IAQ and comfort and contribute to energy savings in office buildings. To-date, the types of controls available on air flow inlets are:

- pressure controlled inlets from France and the Netherlands; there exist few applications, mainly in residential buildings. Their applicability in office buildings is potentially high but price might be a consideration.
- humidity controlled inlets from France; these are particularly suitable for residential buildings where moisture from domestic activities is the primary pollutant of concern.
- pollutant controlled inlets from France and the Netherlands; depending on the controlled pollutant these can have applications to houses, offices, schools, theaters, shopping malls,

congress halls, parking lots etc. CO_2, CO and smoke control inlets are presently available but calibration requirements might be a consideration.

- temperature controlled inlets from Sweden and Finland; their applicability is mostly in cold climates where the outside temperatures can be relied upon as the main ventilation driving force.

At present, pressure and temperature control air inlets seem to have the most practical chances for application in office type buildings; some of the pressure controlled inlets are promising in terms of indoor air quality, comfort and energy.

Pressure controlled inlets could be passive or active. In most cases, in passive devices a vane rolls over a curved support, and as the pressure increases the vane tilts downwards, hence closing the inlet opening. Active inlets contain a device which measure the pressure difference across it. With the help of a small motor the grid of the inlet is controlled. Temperature controlled inlets contain a bi-metal sensor which by bending closes the inlet. The measured performance of such controlled inlets is shown in Fig 1. It should be noted that large differences can be found in the capacity or sizes of available air inlets due to different requirements in the building regulations across Europe. Also, the difference in response pressure is large as the pressure at which air flow rate has reached an almost constant level differs from 1 to 20 Pa. For a typical building environment, the pressure differences across air inlets are in the range of 0 to 50 Pa. However, statistical analysis of weather data show that inlets which only act at pressure differences higher than about 15 Pa will only control the flow for a few percent of the year. The same applies to temperature controlled air inlets.

In order to help investigate the issues mentioned above such as regulation requirements for IAQ, ventilator characteristics etc, in the early design stage, a design tool is being developed which will predict the IAQ using the minimum of input variables. In this way, realistic design values can be set and agreed with the client.

COMBATING SUMMER OVERHEATING

While during winter controlling the incoming air flow rate is very important to maintain an acceptable internal environment and ensure energy savings, the opposite is almost true for the summer. The control of internal temperate is the parameter of importance and in temperate climates, where usually external temperatures are lower than internal, the more incoming air the better. However, an element of control is necessary in order to avoid draught problems and possible overcooling. Ventilation for cooling can be used during the day when internal temperatures are higher than external and during the night when the cool air can be used to flush out heat stored in the building structure during the day. Night ventilation cooling is particularly applicable to office buildings which are usually unoccupied during the night so relatively high air flow rates would not disturb occupants. In many European countries the research and application of natural ventilation with night cooling in office buildings is gaining momentum and many naturally ventilated buildings with natural or fan assisted night-time cooling are being realised. An example of the effect of night ventilation for different internal heat gains, thermal mass and ventilation rates for London weather data is shown in Figure 2 and further findings are reported in [3,4].

In order to apply successful night ventilation for cooling there is a requirement for exposed thermal mass, suitable control to avoid overcooling and weather influence (rain, high wind etc) and appropriate ventilation hardware which provides security and weather protection. However, market research has revealed that there is lack of suitable hardware to facilitate this. In addition associated control is not coupled with the system in many situations. Within NatVent™, some systems have been reviewed and

1992-1995 were taken for five potentially poor pollution sites and analysed. It was assumed that this would mirror polluted urban locations in other European cities. This work is reported in detail in [8] where the location of inlets is also discussed. The aim of this activity is to specify and test a noise attenuating and air pollution 'filtering' system or design strategy which could be used in urban offices.

INTEGRATING AND MAINTAINING NATURAL VENTILATION

With the objective of helping implement the natural ventilation solutions and integrate them in the building envelope and internal environment, a simplified design tool in Visual Basic is being developed which can predict natural ventilation air flow rates and indoor air temperatures at the early design stage. The most important objectives while developing the program have been to create a robust underlying theoretical model and an easy-to-use interface. In order to reach the objectives a great deal of effort has been made in order to reach a stable iteration process, coupling the air flow model and the thermal model. The model takes into account both wind and temperature induced pressures on the building envelope. While minimizing the amount of input required, studies of the most significant parameters have been carried out in order to optimise the relationship between the amount of input and accuracy of the results. The aim of the user interface is to facilitate the use of the program by any building designer, architect or engineer at an early stage of the design. Therefore, the user interface inputs are simple to quantify. For more advanced users, there is an input option allowing for more detailed input. Evaluating results from an air flow calculation can be difficult. Therefore, a help file assists the user to analyse the results and to improve the design of the natural ventilation. A more detailed description of the program as it stands at present can be found in [9]. The final product will include new results as produced by the NatVent™ project. It is the intention that the program will contain information to evaluate the maintenance cost of buildings in comparison to fully air conditioned equivalent buildings as well as simplified checklists to help select suitable systems for a given building.

CONCLUSIONS - GUIDEBOOK

Based on the results of the research within task 3 of NatVent™, a guidebook will be produced to describe the recommended solutions. The guidebook is aimed at the architect and client end of the construction industry with the aim of supplying information to architects and informed clients on the possibilities of the application of natural ventilation in their buildings. The guidebook will contain information on the basics of natural ventilation design and will aim to clarify current misconceptions about the effect on the internal environment of certain passive ventilation features. For example, solar chimney and cowl design will be addressed as well as the effects of external landscape and internal/solar gains together with more specilised topics such as dynamic insulation. The main body of the book will be dedicated to the solutions to be provided by task 3 of the project. However, cross reference will be made to the case-studies examined by task 2 to illustrate specific points and demonstrate shortcomings or successes of purposely design naturally ventilated office buildings. It is anticipated that the guidebook will be available in late 1998.

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illustrated in [5]. The aim of this part of the project is to demonstrate the applicability of these systems and investigate the suitability of different control systems for a variety of external conditions.

ADVANCED NATURAL VENTILATION STRATEGIES

There are occasions when natural ventilation strategies are not an obvious choice. Research indicates that the main barriers in such cases are linked to extreme weather conditions (eg very cold weather), and to urban areas where external pollution and noise are high. NatVent™ aims to provide technical solutions to these in the form of hardware and give guidelines on how to design the system for such circumstances.

Heat recovery and the availability of natural driving forces

The possibility for heat recovery is one of the first considerations of a ventilation system for cold climates. It is used extensively with mechanical systems in which the available pressure drops between inlet and outlet are usually high. However, in natural ventilation systems, because of the nature of the driving force which depends on wind conditions and temperature difference, the first question is whether there is enough power to drive the heat recovery system in large buildings. This has been investigated within NatVent™ and the distribution of available driving forces has been calculated for some of the participating countries. In the calculations, it is assumed that 80% of the dynamic pressure of the wind can be utilised in a natural ventilating system and the thermal stack height is taken as 10 m. Fig 3 shows the distribution of the availability of driving force for the autumn and the spring heating periods which are the most critical of the year. As we can see the frequency of very low driving force is rather high. For example the frequency of a driving force of 10 Pa and lower ranges between 1050 and 2460 hours, lowest for Copenhagen and highest for Oslo. Increasing the stack height to 20 m shifts the distribution some 5 Pa to the right. However, the range between countries changes. The frequency of driving force, equal to and less than 15 Pa, ranges between 630 and 1560 hours, the lowest value for Sweden and the highest for Belgium. For a 10 m stack height the frequency of driving force less than 15 Pa, would be very high. Detailed calculations for a heat recovery system are not completed, but a driving force of 15 Pa is certainly on the lower side. This indicates that some sort of fan assisting ventilation will be required for some part of the heating season.

Based on these results and a critical review of different heat recovery systems [6], a prototype will be constructed and built in the laboratory which will demonstrate in detail the feasibility of natural ventilation systems with heat recovery for office buildings and will specify the characteristics of the required system.

Air And Noise Pollution In Urban Areas

Air and noise pollution in urban areas is a major barrier against the use of natural ventilation. However, there is evidence that there may be a natural filtration mechanism in large office buildings which can provide a reduction in externally generated air pollution levels in the building [7]. In order to understand the mechanism and provide design solutions, as part of NatVent™, information on guidelines and standards for air pollutants and noise levels for all the participating European countries has been reviewed and existing systems used for filtration of external pollutants and noise reduction have been evaluated.

Before natural ventilation systems can be incorporated into office buildings in potentially 'polluted' urban locations, it was felt essential to identify the extent of the external pollution problem on the indoor environment and periods when external pollution levels reach unacceptable values. Since the UK has a national air pollution monitoring network, data for NO_2, SO_2, CO, O_3 and PM_{10} for the years

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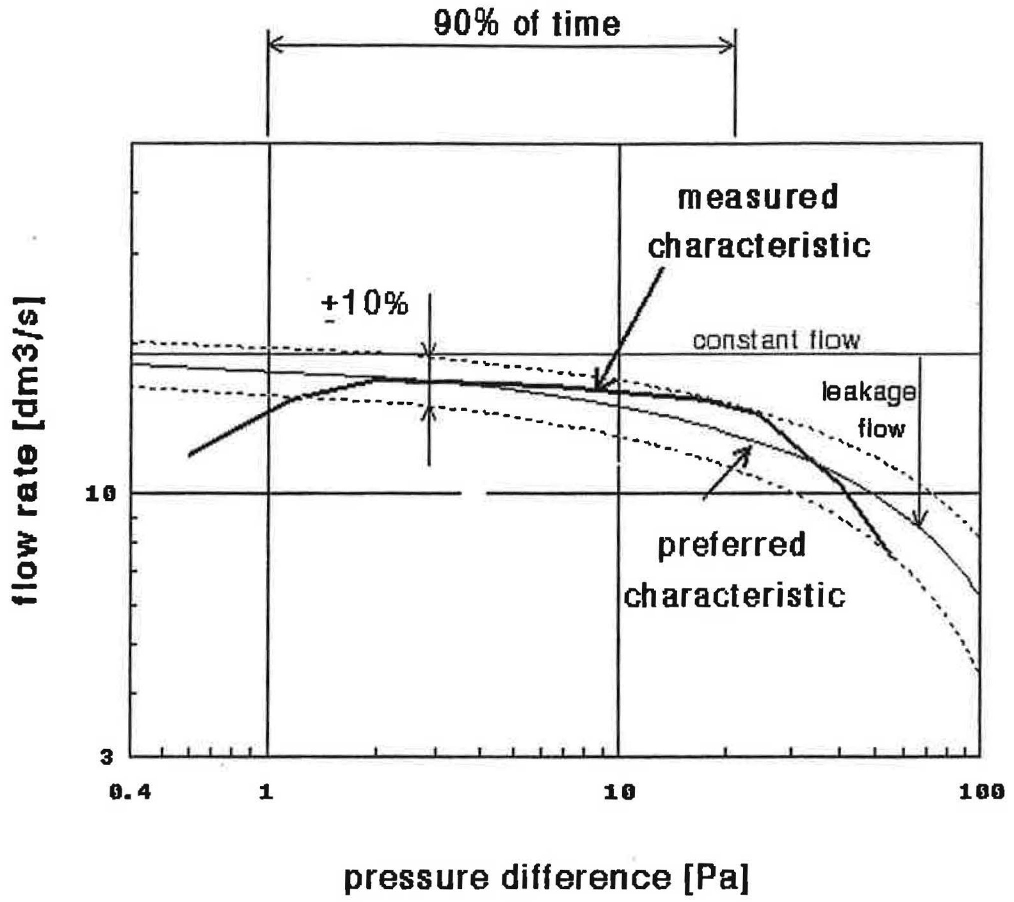

Figure 1: An example of the performance of a passive pressure controlled inlet from the Netherlands

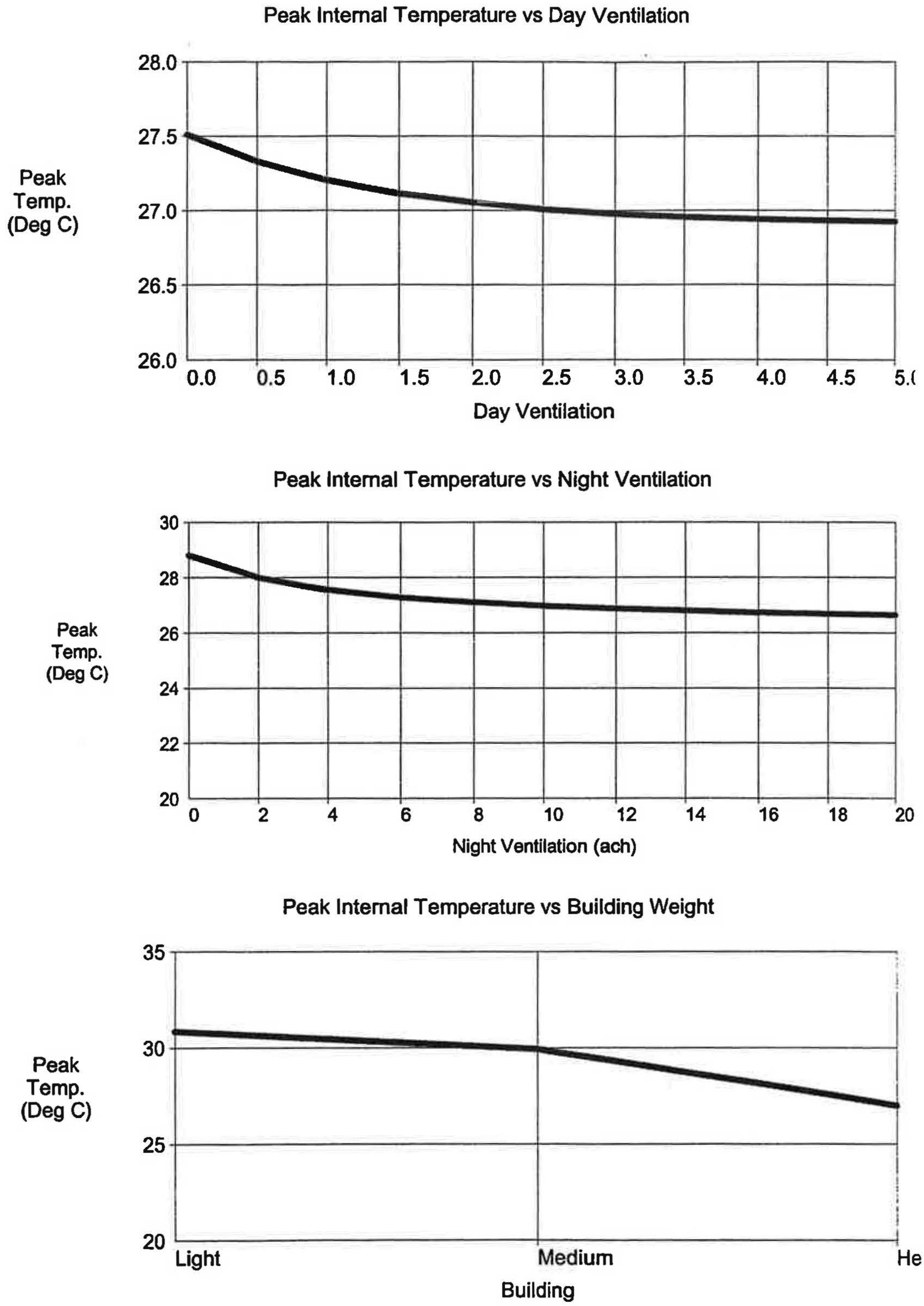

Figure 2: Parametric analysis of peak internal temperatures versus day ventilation, nigl ventilation and building weight. Internal heat gains were set to 25W/m^2 , glazi 0.4 with solar protection. External temperatures were set to 28°C max and 1ε for the last day, 26°C max and 16°C min for the previous day and 23°C max aı min for the previous five days, to simulate a slowly warming up week.