HybVent

Control Strategies for Hybrid Ventilation in New and Retrofitted Office Buildings

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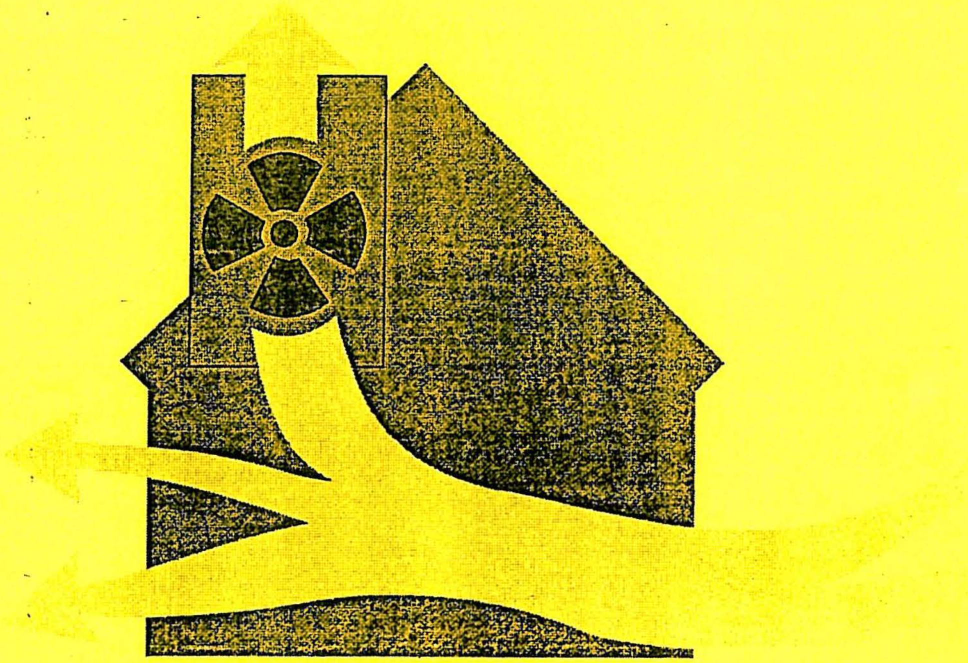

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HybVent
Control Strategies for Hybrid Ventilation in New and Retrofitted Office Buildings

Proposal for a new IEA-ECB&CS Annex

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Background

Soon after the energy crisis in 1973 everybody focused their attention on thermal insulation, airtightness of buildings and heat recovery to decrease energy consumption for heating (and cooling) of buildings. Buildings were designed to be isolated from the outdoor environment with an indoor environment controlled by artificial lighting, mechanical ventilation and heating and cooling systems.

Today, in the design of new buildings and retrofit of old buildings, the attention has been turned towards a more integral energy design with focus not only on thermal insulation, airtightness and heat recovery but also on optimal use of sustainable technologies as passive solar gains, daylight and natural ventilation. The buildings are designed in an interplay with the outdoor environment and are utilizing it to create an acceptable indoor environment whenever it is beneficial.

The extent to which sustainable technologies can be utilized depends on outdoor climate, building use and building location and design. Under optimum conditions sustainable technologies will be able to fulfil the demands for heat, lighting and fresh air, while in some cases supplementary mechanical systems will be needed and in other cases it will not be possible to use sustainable technologies at all.

In well thermally insulated office buildings, which are more and more frequent in IEA countries, ventilation (and cooling) account for more than 50% of the energy requirement, [1], and a well-controlled and energy-efficient ventilation system is a prerequisite to low energy consumption. Natural ventilation and passive cooling are sustainable, energy-efficient and clean technologies as far as they can be controlled, (that is if well modelled and understood). They are well accepted by occupants and should therefore be encouraged wherever possible.

Unfortunately, the design of energy-efficient ventilation systems in office buildings is often turned into a question of using either natural ventilation and passive cooling or mechanical ventilation and cooling. This prevents a widespread use of sustainable technologies because a certain performance cannot be guaranteed under all conditions. In fact in the large majority of the cases a combination of systems would be beneficial depending on outdoor climate, building design, building use, and the main purpose of the ventilation system.

The number of office buildings to be retrofitted in most IEA countries is now much larger than the potential for new buildings. In many cases there is a large potential for use of sustainable technologies either as a supplement to the existing mechanical systems or as the main part of solutions in cases where classic ventilation systems are impossible to install in an existing building. Innovative hybrid ventilation systems should be developed or improved for that purpose.

Suitable design tools are not available for sustainable ventilation systems as it is the case with mechanical systems. Valid design tools would give architects and engineers the necessary confidence in system performance which in many cases is the decisive factor for choice of system design.

A research project aiming at a better knowledge of the use of sustainable ventilation technologies and focusing on development of control strategies and design tools for hybrid ventilation in new and retrofitted office buildings is proposed.

Hybrid ventilation is ventilation systems where mechanical and natural forces are combined in the ventilation of buildings. It covers a wide range of systems as for example mechanical ventilation with openable windows, mechanical ventilation with natural night cooling, systems with natural ventilation in intermediate seasons and mechanical ventilation during midsummer and midwinter, natural ventilation supplemented by mechanical exhaust and systems with controlled vents from the outside and mechanical exhaust.

Control strategies are ways to control hybrid ventilation dependent on building design, internal loads, natural driving forces, outdoor conditions and season to fulfil the immediate demands to the indoor environment in the most energy-efficient manner.

OBJECTIVES

Objectives of the project are:

1) To develop control strategies for hybrid ventilation systems in new and retrofitted office buildings.
2) To develop methods to predict ventilation performance in hybrid ventilated buildings and promote the use of the new methods in performance assessment. To improve measurement techniques for diagnostic purposes to be used in buildings with hybrid ventilation systems.
3) To promote energy and cost effective hybrid ventilation systems in office buildings.

PRODUCTS

1) Guide for practical use and design of hybrid ventilation, including solutions and guidelines for efficient, energy and cost effective hybrid ventilation systems in new and retrofitted buildings. The guide will contain recommendations on control strategies, pilot studies and description of diagnostics.
2) Detailed design tool for hybrid ventilation optimization requiring a minimum amount of input data and predicting the performance and potential cost and comfort benefits of sustainable ventilation technologies.
3) Detailed description of improved measurement techniques for diagnostics and commissioning of hybrid ventilation systems.

APPROACH

The following tasks will be carried out in order to reach the objectives:

1) State-of-the-art review of sustainable ventilation technologies, of control strategies and algorithms being used in natural/hybrid ventilated buildings both in dependence of differences in climate (including seasonal differences) and building design, and assessment of the potential for sustainable ventilation retrofit in IEA countries.
2) Development of control strategies for hybrid ventilation in new and retrofitted office buildings.
3) Theoretical studies of performance, energy and environmental impact of hybrid ventilation. Development of detailed design tools.
4) Gain of expertise and demonstration of the applicability of hybrid ventilation through experiments and pilot studies.
5) Reporting.

These tasks can mostly be performed simultaneously, except task 5, which should be finished some time after the others. They are discussed in more detail below.

"State of the art" review

A state-of-the-art review of the potential and usefulness of sustainable ventilation technologies (natural ventilation and passive cooling) and hybrid ventilation systems will be carried out. The review will among other things focus on the impact of differences in climate (including seasonal differences as winter heating and summer cooling), building design, building use and internal loads on energy performance, indoor air quality and comfort. The review will provide examples of existing systems and will serve as a basis for general guidelines for use of sustainable ventilation technologies including hybrid ventilation. It will show solutions to specific problems (fresh air supply, excess heat removal, etc.) in a particular office building type located in a certain outdoor climate.

The review will include a study of the existing office building stock in each participating country and will classify it according to its potential for low energy ventilation. In this way the viability of sustainable ventilation technologies and hybrid ventilation systems in both new and retrofitted buildings can be demonstrated.

A market survey will be carried out on commercially available natural and low energy ventilation components. In addition, a review of control strategies and algorithms being used in naturally ventilated buildings will be carried out together with a critical view of their integration in the building energy management system (BEMS). A parametric analysis will be carried out to examine the effects of local versus building driven control of the various natural ventilation components.

Development of control strategies

Integration of sustainable ventilation technologies and classic mechanical systems in a common hybrid ventilation system requires development of new control strategies. By these strategies the hybrid ventilation system should at any time and for a certain combination of internal loads, outdoor conditions and comfort requirements be able to fulfil the immediate demands to the indoor environment in the most energy-efficient manner. The demands to the indoor environment also include the ability of the hybrid ventilation system to create optimum air flows and air flow patterns in the building. Different control strategies will be developed dependent on climate and main purpose of the ventilation system (IAQ, cooling). The control system should be intelligent and self-learning based on the preceding and the present situation, be capable of predicting the future needs and make the appropriate adjustments. Control strategies should also take safety measures into account as bad weather, noise, fire hazards, burglars etc.

The cost effectiveness of different ventilation and control strategies will be investigated by comparing capital and operational costs against a typical refurbishment or new build in each participating country.

Theoretical studies and design tool development

A better understanding and a better control of the natural ventilation process is a prerequisite for successful hybrid ventilation.

This can be obtained by developing valid models for air flow rates in buildings. Such models should be able to predict statistical occurrences of heat and air flow rates as well as contaminant removal efficiency. Deterministic methods used in research are not well adapted to this task, and "qualitative" and statistical modelling should therefore be developed. A statistical model in this document is defined as a model in which data are input together with their uncertainties, and whose output is frequency distributions. There are several useful mathematical tools for this purpose.

The statistical model can be developed by combining physical models of the phenomena involved (air, heat and contaminant transfer, occupant behaviour, meteorological data, interaction between wind, environment and building, etc.) with stochastic models. The model will be validated according to the procedure developed within IEA-ECB&CS Annex 23. This procedure includes a sensitivity study and error analysis as well as comparisons with experiments and simulations with other models.

The work will result in a detailed design tool for hybrid ventilation optimization requiring a minimum amount of input data and predicting the potential of sustainable ventilation technologies as for example outdoor air flow rates and the passive cooling potential.

Experiments and pilot studies

Pilot studies will be monitored to collect data on the performance and environmental impact of hybrid ventilation systems and to evaluate corresponding control strategies. Pilot studies will include both retrofitted and new-built designs in all participating countries to highlight similarities and differences in climatic (including seasonal differences), institutional and cultural (developers and occupants), and technology transfer issues. The pilot studies will concentrate on success stories of hybrid ventilation but will also critically highlight problematic cases. These pilot studies can be used as a powerful tool to demonstrate to both legislators, developers, brief specifiers and occupants the relative merits of the applicability of sustainable ventilation technologies in hybrid ventilation in realized new-built and retrofitted projects backed-up by post-occupancy data.

New diagnostic measurement techniques may be developed for these experiments. These techniques will be reported.

Reporting

The aim of the reporting task is to deliver the final products mentioned above. This phase will start at the very beginning of the Annex in order to define clearly and precisely the final products on the basis of the actual participation in the Annex.

The hybrid ventilation guide will be drafted on the basis of experience gained as well as from previous research, from the investigation into strategies mentioned above, and from the monitoring studies.

DISCUSSION

Target Audience

The hybrid ventilation guide will be written for architects and engineers, and parts of it will be available for a large public. Therefore, architects should be in the editorial team. This guide will provide advice for good practice for application of sustainable ventilation technologies in new and retrofitted buildings. The emphasis will be on usual cases, which do not require specific studies ("ordinary" office buildings).

The reports and design tools will be available for engineering offices, helping them to provide advice to architects and to design systems, especially for cases not treated in the hybrid ventilation guide.

Integrated Approach

Good control of hybrid ventilation in new as well as retrofitted buildings requires a completely integrated approach to building design, its technical systems (lighting, heating), inhabitant behaviour, topography of surroundings, climatic and meteorological conditions, etc. Integrated approach is the basic strategy to be applied in this project.

In development of the design tool preference will therefore be given to combined models, describing as far as possible all involved phenomena to give realistic results, even if simplifying assumptions are required.

The fact that input data are not known with perfect accuracy will also be taken into account. It has no meaning to develop a sophisticated design tool if the uncertainty on input data results in output data which are not more reliable than output from a simpler tool.

Energy and Environmental Impact

In most cases, and especially when well planned, retrofitting of buildings uses less energy and loads the environment less than replacing the old building by a new one. This is also valid for ventilation systems. In many climates and in many buildings air-conditioning can advantageously be replaced or assisted by natural ventilation to avoid wasting energy as well as to improve comfort. Good control of natural ventilation, together with proper information and suitable design methods, should reverse the present tendency to install air conditioners without thinking in alternatives. Natural ventilation can provide very large air flows at very low energetic expenses. The main problem is its control, its even distribution in the building and the effect of the facade construction on the heating of the incoming outside air. The facade materials (colour) and the type of the solar protection can decrease the efficiency of natural ventilation substantially. Such effects are not well understood and are regularly coming up in practice.

Naturally ventilated buildings can typically consume less than half the delivered energy consumed in air-conditioned buildings [1]. Recent estimates suggest that cost-effective energy savings in the order of 20-30% are achievable in office buildings, with evidence of greater savings for major refurbishment projects at some sites, resulting in significant reductions in the energy consumed, the CO_2 emitted and avoidance of ozone-depleting refrigerants. Realistic savings of 10% of the ventilation related energy consumption have the potential to save 6 million tonnes of oil equivalent and 25 million tonnes of CO_2 emission every year, [2].

Natural ventilation can make a positive contribution to a sustainable environment by reducing electrical energy use for cooling and by reducing or even eliminating the need for refrigeration. The general arrangement of naturally ventilated buildings usually helps to increase the use of daylight and thereby minimizes the electrical costs still further.

Knowledge Gap

Despite large research efforts these last years, there is still a lack of knowledge in modelling and measuring natural ventilation and its effects. Natural ventilation modelling was strongly developed within the PASCOOL project and the IEA-ECB&CS ANNEX 23. However, knowledge of input data is still limited, and models only predict air flow rates, not ventilation efficiency. Valuable measurement methods in mechanical ventilation diagnostics are not automatically applicable for natural ventilation systems. Measurements using tracer gas are in fact much better applicable to ventilation efficiency (age of air) measurements than to air flow rate assessment in natural ventilation.

In fact, the common knowledge of natural ventilation, based on building use and energy strategies which date back to times when energy and CO_2 release were not of great concern, is obsolete and no more applicable in today's buildings in which the envelope is much less permeable to air and where mechanical systems often interact with natural ventilation.

Related EU projects

JOULE II PASCOOL (ended in 1995) provided knowledge of passive cooling and a prototype planning tool (PASSPORT +) was developed, which may be of interest for the present project. A JOULE-THERMIE project is submitted to EU for dissemination of knowledge developed within PASCOOL.

JOULE-THERMIE OFFICE - “Passive retrofitting of office buildings to improve their energy performance and indoor working conditions” aims at developing global retrofit strategies, tools and design guidelines in order to promote successful and cost effective implementation of passiv solar and energy-efficient retrofitting measures to office buildings. HVAC redesign is one aspect among many others in the global retrofit strategies that this project addresses. This project is running now and will end in 1998.

JOULE-THERMIE NATVENT (started in 1996) aims at overcoming technical barriers preventing the use of low-energy ventilation in office-type buildings in moderate and cold climates. The barriers restricting the implementation of natural ventilation will be identified. Performance of naturally ventilated buildings will be evaluated, using pragmatic measurement procedures and protocols. Then, smart technology systems for natural ventilation will be developed, and component solutions to overcome shortcomings will be identified. The project covers mainly technical and component solutions and it appears to be a good complement to the present project, which mainly aims at developing and improving control strategies and design tools. In the JOULE-THERMIE NATVENT project interviews among leading designers, architects and consultants to identify the perceived barriers for implementation of natural ventilation revealed in all countries the lack of suitable design methods as one of the most important ones. One of the objectives of the present project is to develop such methods. The present project will not be restricted to moderate and cold climates but will develop design tools that can be used independent of climate and control strategies for all types of climate and problems (heating, cooling, IAQ). The NATVENT performance evaluation of naturally ventilated buildings will be used in the development of control strategies, and the computer design tool used to evaluate natural ventilation strategies in early design development could be the starting point for the development of a suitable engineering tool for detailed design of hybrid ventilation.

A project with similar (but more theoretical) objectives, the AIOLOS project, was submitted in 1995 to EU DG XII within the frame of the Joule-Thermie programme. Despite a generally good appraisal, and acknowledgement that it was an international project, AIOLOS was rejected by lack of financial support, with the following comment: "*In any way, the project should be developed and put through, either as a Joule project or as an IEA project.*" Another project with the same name, AIOLOS, started within the frame of the SOCRATES project. Its aim is mainly educational, and no research is included in this project.

Related IEA-ECB & CS annexes

ANNEX 5. The present proposal has been discussed at the AIVC SG meeting in Helsinki in March 1997 and later reviewed by members of the AIVC SG.

ANNEX 27. The objectives of Annex 27 are to develop tools to evaluate domestic ventilation systems, to validate the methods and tools by data obtained from measurements and to demonstrate and evaluate ventilation systems for different climates, building types and use of dwellings. The focus of the HybVent project is office buildings, and the developed evaluation tools from Annex 27 will be a valuable basis for the evaluation of control strategies and system performance of hybrid ventilation systems. The project ends in 1998.

ANNEX 28. The main objective of ANNEX 28 is to develop design tools for low-energy cooling technologies. One of these technologies is night cooling with natural ventilation, which can be used directly in the present project. One of the most important aspects of successful hybrid ventilation will be integration of low-energy cooling systems and the results of Annex 28 will therefore be very useful in the development of control strategies. The project ends in 1998.

Other related annexes are: Annex 11, 20, 21, 23, 26 and IEA Solar task 20.

No overlapping

The results from EU projects and IEA work mentioned above will be taken into account, and consequently any overlapping of work will be avoided.

References

[1] Moss, S.A. Energy consumption in public and commercial buildings. Building Research Establishment Information Paper IP 16/94. 1994.

[2] Kolokotroni, M.; Kukadia, V.; Perera, M.D.A.E.S. NATVENT - European project on overcoming technical barriers to low-energy natural ventilation. CIBSE/ASHRAE Joint National Conference 1996.