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SOLAR ASSISTED NATURAL VENTILATION WITH HEAT PIPE HEAT RECOVERY

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SYNOPSIS

Natural passive stack ventilation (PSV) consumes no power and so produces no harmful emissions, has no running cost, no noise of operation, requires little maintenance and because it involves no moving parts, operation is reliable. However, virtually all PSV systems are designed and constructed without incorporating heat recovery, leading to wasteful heat loss. The goal of the research reported here, is to develop a passive stack ventilation system with heat recovery for use in naturally ventilated buildings.

The heat recovery unit is based on the heat-pipe principle. A recovery unit having a sufficiently high efficiency and a very low pressure drop is aimed at. The drawback of an efficient heat recovery is, that it reduces the stack pressure by reducing the temperature difference between the supply and exhaust air flows, which can cause the ventilation system to fail. To avoid this problem, a solar chimney and a wind generator driven fan are integrated into the system to assist the air flows and to maintain them on a sufficient level from the viewpoint of indoor air quality. On the other hand, for the air flows not to be too high, a control unit is added to the system. A pilot plant shall be constructed, where all above mentioned features are included and this plant shall be monitored for six months to find out its performance.

Until now several versions of the heat recovery unit have been tested. The highest effectiveness has been around 55% with two banks of heat pipes and a flow velocity of 1 m/s. With the same velocity the pressure loss through a two bank section is 4.5 Pa. The solar chimney has been studied both theoretically and experimentally. According to computations, the performance of the chimney is not very sensitive to small changes in direction on both sides of the south. Measurements indicate a 47 % increase in air flow compared to a conventional stack. The air flow control unit has been developed and tested. It works well according to a control strategy specified for the PSV system. The work continues by designing and optimisation of the pilot plant.

INTRODUCTION

Natural ventilation is being applied to an increasing number of new buildings across Europe to minimise reliance on mechanical ventilation and so reduce emission of greenhouse gases. The stack pressure created by the temperature difference between the indoor and outdoor air provides a driving force for natural ventilation and stack-driven ventilation has been applied to a wide range of modern buildings, including offices, schools and houses [1, 2]. Natural passive stack ventilation (PSV) consumes no power and so produces no harmful emissions, has no running cost, no noise of operation, requires little maintenance and because it involves no moving parts, operation is reliable. However, virtually all PSV systems are designed and constructed without incorporating heat recovery, leading to wasteful heat loss. It has been estimated that this heat loss amounts, depending of the location in Europe, to 3 - 15 GJ per annum for a small family residence and much more for larger buildings, e.g. offices, which employ natural ventilation [2].

Table 1. An estimate of the annual ventilation energy consumption of a small European family residence equipped with different types of ventilation systems (η_{heat}=0.80, $\eta_{electri}$ =0.30)

Ventilation system	heat recovery efficiency [%]	consumption of heat [GJ]	electricity for fan operation [GJ]	total energy consumption [GJ]	primary energy consumption [GJ]
Mechanical exhaust, no heat recovery	0	9.79	0.78	10.6	14.8
Mechanical supply and exhaust with heat rec.	70	2.94	1.55	4.49	8.86
Passive stack ventilation, no heat recovery	0	9.79	0	9.79	12.2
Passive stack ventilation with heat recovery	50	4.90	0	4.90	6.12

According to the simple calculation presented in Table 1, the passive stack ventilation system with heat recovery (PSVH) would be a very attractive solution, especially from the primary energy point of view. There is obviously a need for appropriate and efficient heat recovery in natural ventilation systems to minimise waste of energy.

The SAVEHEAT research project, funded partly by the Commission of the European Union, aiming at a novel PSVH system, has started in January 1996. Following are described some features and ideas of the developing work as well as some results produced until now.

HEAT RECOVERY

The heat recovery unit is based on heat pipe technology. A nominal air velocity of 1.0 m/s has been chosen for the dimensioning. A very small pressure drop in the recovery unit is essential. At Nottingham University four types of extended surfaces on the air side of the recovery unit have been tested: I) plain fins, II) spine fins, III) louvred fins and IV) wire fins. The effectiveness of heat recovery of the types I and IV are shown in Fig. 1. A high thermal performance usually means a higher pressure loss and for that reason certain compromises, when choosing the best alternative, have to be done. A more detailed description and results of the recovery unit are given in reference [3].

SOLAR CHIMNEY

The heat recovery reduces the pressure difference and the air flows of the PSVH system in two ways: first, because of its own pressure loss and second, because of reducing the temperature difference between the supply and exhaust air flows. The higher is the efficiency of the heat recovery, the smaller is the stack effect. This could lead to insufficient small air flows, moisture problems and a poor indoor air quality. The air flows can, however, be assisted using simple active solutions, such as directly heating the exhaust stack with solar energy or utilising wind energy as an additional driving force.

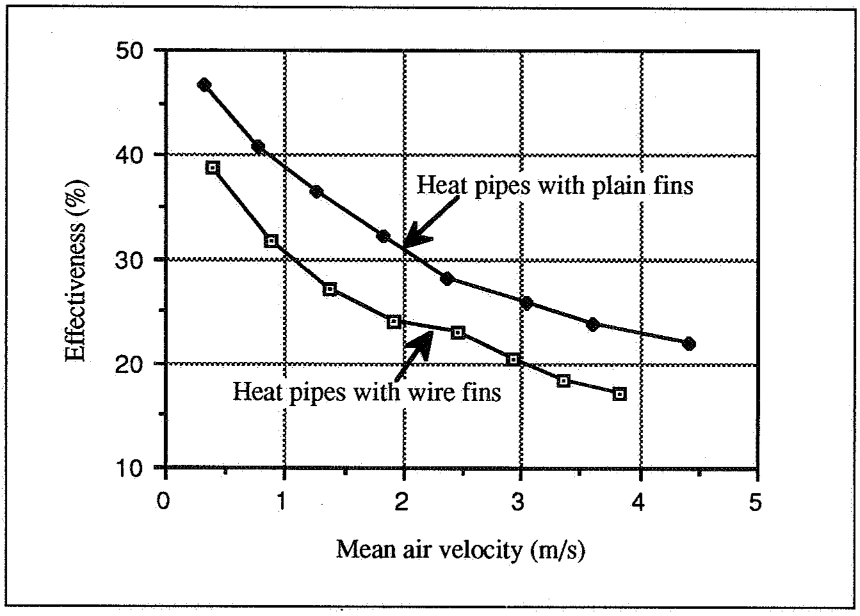

Fig. 1. Effectiveness of the recovery unit with plain fins and with wire fins.

Measurements of a solar chimney, to assist the natural ventilation, were carried out in a two zone test cell at University of Porto. The test rooms are identical, from a geometrical point of view, and each one was equipped with a heating facility, with a precise control of the inside air temperature. Both were provided an inlet and an exhaust air duct, through the roof. The exhaust chimneys have a similar geometry, but while one allows the collection of solar radiation (solar chimney), the other does not (conventional chimney). Both exhaust chimneys have an internal cross section of 0.2m x 1m and a height of 2m. The walls are made of brick (10 cm thick), with outside insulation (5 cm) for the solar chimney. In both rooms the air temperature is measured and controlled. The exhaust chimneys were fully instrumented with anemometers, thermocouples and fluxmeters.

Table 2. Air exchange rate of the rooms in the test cell.

	Sampling point	ACH (h^{-1})	
			Average
Room 1 (Convent chimney)	1	14.2	
	2	13.8	14.0
Room 2 (Solar chimney)	3	20.6	
	4	20.5	20.6

Fig. 2 shows the variation of the flow rate in the solar chimney during a day-night period. A comparison between the air exchange rate created by the solar chimney and the conventional chimney is shown in Table 2. As can be seen, the contribution of solar energy to the air exchange rate of the room with solar chimney is about 47%, for the measuring period.

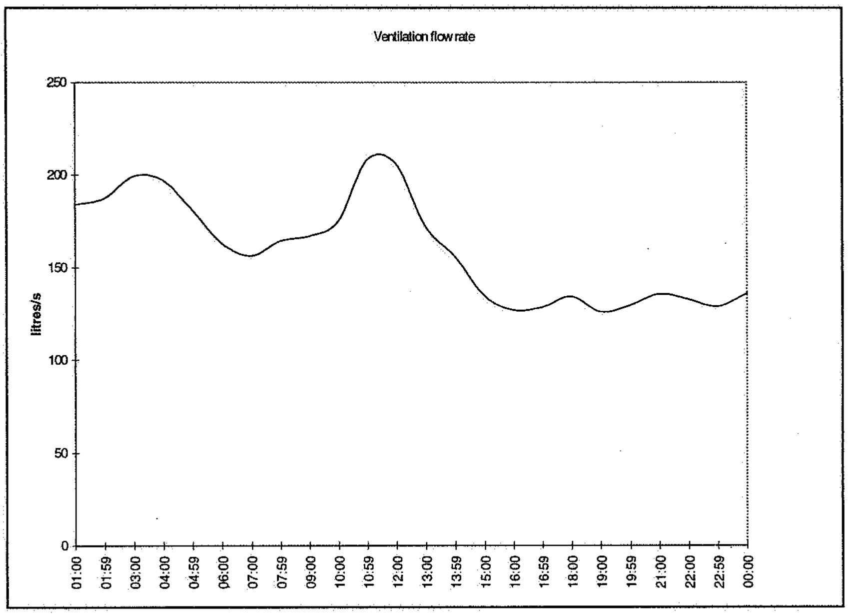

Fig. 2. Ventilation air flow rate with solar chimney, 15 Nov 96

WIND DRIVEN FAN

To further assist the ventilation flows in situations, when neither a temperature difference nor sun shine is available, a wind driven fan was constructed. A vertical axis wind generator was chosen. The purpose was to install it directly on the shaft of the fan. Preliminary modelling and computations were carried out to see what type of fan would match the generator and give the best performance. It was found out that a radial fan having forward curved blades would give roughly double air flow than an axial fan. This is a consequence of the better matching of the characteristics of the radial fan and the wind generator. Thus, a radial fan was chosen and combined with the generator to form a wind driven supply air unit.

CONTROLS

Because the PSVH system should work properly during different kind of conditions and in different climates, controls is needed. The main tasks of a control system would be to reduce the air flows in cases there is a too high driving force and to inactivate the heat pipe unit when there is no need for heat recovery. To accomplish this, a control strategy for the PSVH system was developed, Fig. 3.

STRATEGY scheme

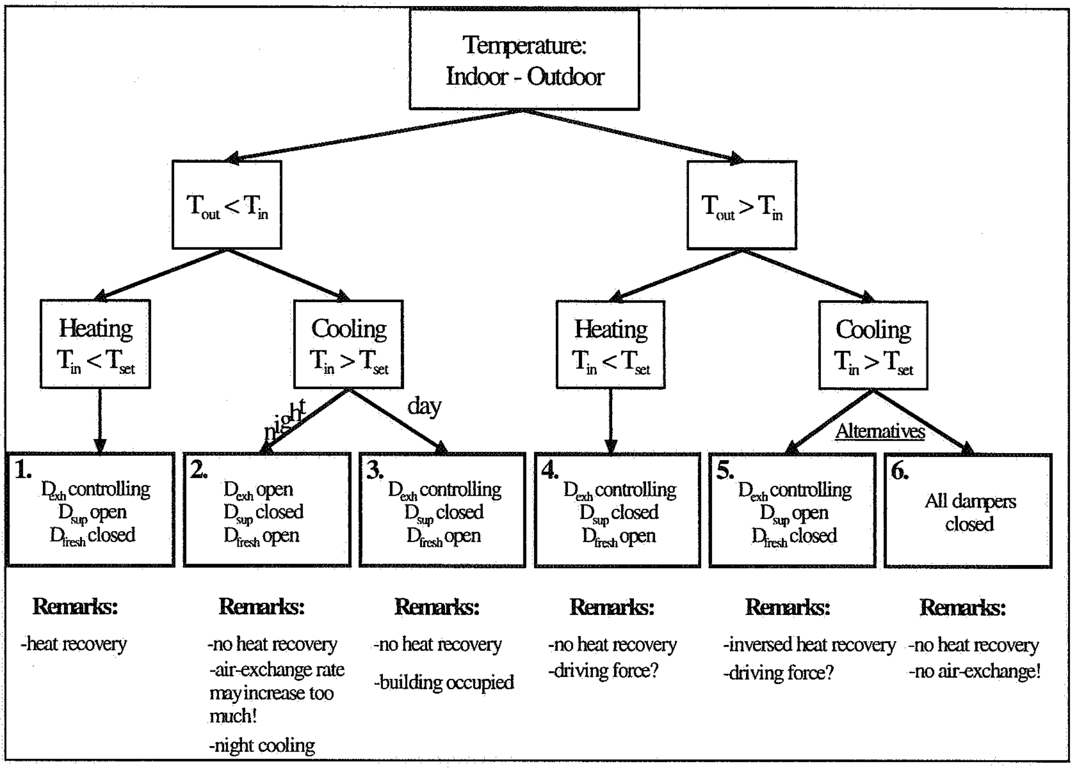

Fig. 3. Control strategy for the PSVH unit.

The control strategy is implemented using a modern programmable logic combined with conventional dampers, temperature sensors and a low velocity sensor measuring the air flow in the exhaust duct.

MODELLING

To prepare the selection of a test building for the installation of a pilot plant, the influence of some most essential parameters was investigated by a preliminary simulation. The computations were made with a simple aeraulic model describing the building and the passive stack system. The most important result of this exercise was, that the tightness of the building is crucial factor for the energy performance of the PSVH system. If the building is leaky, only a part of the air is guided through the heat recovery unit, thus greatly reducing the recovery potential.

Because the functioning of the PSVH system very much depends on the local weather parameters, different design for different climates has to be applied. Also the technical optimisation, where the minimum amount of primary energy is used maintaining the comfort conditions and the air quality at the same time, gives different results for different locations. To find out an optimal design for a specified location, a model describing the behaviour of the system is needed. A model consisting of the building structure, the ductwork, the recovery unit, the wind unit and the controls is at present under development. The developing environment, called IDA, is utilising the Neutral Model Format (NMF), has an efficient solver and is one of the most advanced simulation tools in the building/HVAC sector at present[4]. This model combination shall first be validated against measurement results from a pilot PSVH plant and after that used to look at the optimal design and performance in different European climates.

PILOT PLANT

A pilot plant of the PSVH system shall be built in an office building in Winterthur, Switzerland during the year 1997. The building, called SLM Building, is a five storey office with additional two basements and a technical level on the roof. It was completed in 1991 and is situated in a heavily urbanised part of Winterthur, with the main road to Zürich just in front of it. The area of the ground floor is 396 m2. The remaining four upper floors have the measures 37,8*19,8 m, giving 741 m2 to each of them. The building is planned for commerce and has approximately 180 workplaces.

An open office space in the building is prepared to serve as a test environment for the PSVH pilot plant. The space is isolated from the rest of the building to prevent the effect of the mechanical ventilation. The solar chimney will be built on the roof and the ductwork is guided in through one of the large windows. The plant will be equipped with a comprehensive monitoring equipment and monitored for a six months period to find out the performance of the pilot system.

CONCLUSIONS

A passive stack ventilation system including heat recovery, flow assistance and controls (PSVH) is under development and seems to have potential to be an alternative for the conventional ventilation systems.

The heat pipe based recovery unit has shown an efficiency of 55% and a pressure loss of 4.5 Pa at the same time.

The tests of a solar chimney indicate 47% increase in air flow compared to a conventional stack.

Preliminary modelling of the PSVH system show, that a good tightness of the building is essential for the energy performance of the system.

The work continues by the construction and monitoring of a pilot scale PSVH system.

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