Alternating, Decentralized, Regenerative Ventilation System

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ABSTRACT: My invention is an innovative ventilation system to provide the necessary fresh air with a simple, energy-saving and economical method containing two co-operated ventilation flues integrated in the external wall (which is made from hollow burnt loam brick masonry blocks) wherein the controlled fans ensure the proper airflow. One of the ventilation flues operates as an extraction unit, whereas the other is the inlet unit, but these functions are alternated from time to time. In the winter season, the first phase of the operation of one unit extracts and discharges the warm air of the room, and in the meantime heats up the ventilation flue also serving as heat-storing and heat-exchanger unit. After a certain period of time, the second phase – with a reversed direction of airflow – blows the external, cold air through the formerly heated ventilation flue heating up the air and cooling down the flue, and then the air enters the room. The other ventilation flue performs the same process in a reversed phase. The efficiency of the heat recovery is higher then 80% which results in a considerable energy saving. At the same time the indoor air quality is considerably improved.
Keywords: ventilation, indoor air quality, energy saving, regenerative heat exchange, innovation

NECESSITY OF AIR EXCHANGE AND KNOWN SOLUTIONS IN DWELLINGS

In buildings constructed with traditional wall structures (small bricks, B30, Porotherm, Ytong…) and conventional doors and windows of low air tightness (box-type, Tessauer windows …), there is no problem posed by the removal of the several liters of daily generated internal humidity under normal use in the heating period. The most part of this humidity, at least 95%, leaves the room with an air change rate (ACH) 1…1.5 1/h, by natural ventilation, via the gaps of doors and windows, while the remaining part via the wall structures, by vapour diffusion. The wall insulation has almost no influence on this process [1].

Therefore, ventilation has a key role on the humidity transport in the winter, and in case of very low ACH values (0.1–0.15 1/h [2]), the wall structure cannot take over this function. One well-known consequence – if no ventilation is provided in any other way– is the accumulation of the relative humidity of internal air, which in extreme cases leads to vapour condensation on the wall corners with thermal bridges, and then directly to mould growth.

Mould is difficult to remove, and in the lack of proper ventilation it re-emerges in a short while. It is not simply unaesthetic, but hazardous to health, as well. In the lack of appropriate ventilations, naturally, the indoor air quality also tends to deteriorate; it may be enough to refer to the increase of the CO_2 concentration and the accumulation of undesired smells.

Naturally, there are considerable benefits accompanying the use of doors and windows with high air-tightness: reduced heat load in winter-time (or cooling load in the summer), decrease in external noises, blocking of dust, while ventilation is not “spontaneous”, but can be performed wherever and however one likes – yet, it calls for carefully designed, installed and operated mechanical ventilation.

With some exaggeration, it can be claimed that windows featuring highly air-tightness are not designed for ventilation! They still can be used for ventilation purposes when opened manually, but definitely they cannot ensure proper ventilation for the building and its users.

In order to avoid condensation and the resulting mould growth with doors and windows of high air-tightness, and provide for the penetration of fresh air needed for health purposes, there have been several solutions worked out and applied. Naturally, when letting the external, cold ventilation air in it should be heated in some (possibly energy-saving) way, which requires heating energy, and therefore entails significant costs. It is especially true in the light of the associated requirements, as with the application of bounding structures (walls, floor structures, doors and windows …) with improved heat transmission coefficients the transmission heat demand of buildings tends to decrease, and concurrently the proportion of ventilation heat demand rises; in passive houses it is indeed the only real heat demand.

Without giving details for their advantages and disadvantages, four of the widely-known solutions should be mentioned here:

- Purmo Air System, the so-called “ventilation radiator” [3],
- (hygro-controlled) air inlet structures (e.g. Aereco, Kamleithner…),
- central ventilation systems (e.g. Aldes, Helios, Rosenberg…),
- decentralized ventilation systems (e.g. Reznor, “inVENTer®” Öko-Haustechnik inVENTer GmbH [4].

This latter “inVENTer” solution is to be highlighted here, because it is almost unknown in Hungary, and thus is not in use. I myself encountered it at an international professional exhibition, and having seen its innovative functioning I was immediately prompted, infatuated with the idea – and eventually it has become the line of thinking that has led me to the fundaments of my invention.

AN INNOVATIVE METHOD: WALL-INTEGRATED VENTILATION SYSTEM WITH REGENERATIVE HEATH RECOVERY

The solution has originated from the comparison of the ceramic heat-storing and heat-exchanger element of “inVENTer” and the common hollow burnt loam brick, the masonry block type that is the most frequently used for the masonry works of the external bearing walls of buildings nowadays. Both of them have a multi-holed, hollow structure and ceramic base, and therefore the hollow brick should be fundamentally – without any need of alteration – suitable for attending the above-described heat-storing and heat-exchanger function provided that air is conducted to the inside of the bricks – even with alternating airflow.

On the other hand, such a solution is not too customary, and moreover during the masonry works vertical air ducts are usually closed with a cc. 1–1.5 cm bedding mortar layer to ensure the proper bonding of the masonry blocks, which blocks natural airflow in conventional walls.

However, technology has been changing in this professional field, as well: manufactured with a ±0.5 mm height tolerance, the so-called “polished” bricks (e.g. Wienerberger Porotherm N+F Profi, Porotherm HS Profi) have been used in Western European countries for a while, and are in the phase of introduction in Hungary. When used for masonry works, only a 1 mm horizontal mortar layer is applied to these bricks to ensure proper bonding only on the peripheries and the internal ribs, but not to close the vertical air ducts. As a consequence, even “normal” masonry works give rise to flue consisting of parallel, vertical small air ducts in the wall along the entire headroom of the premises from the floors (or intermittent floor structures) to the ceiling – without looking for any special solution for the development of the flues.

If with any of the applicable methods the vertical flue running in the external walls of the building is opened to the outdoor space on the bottom, and to the indoor space on the top, such a ventilation flue will be available wherein fans, air grills and filters can be installed as required to develop a regenerative ventilation unit in a very simple manner. The heat-storing and heat-exchanger element is provided by the material of the wall itself in an inexpensive and simple design, developed in a single and concurrent operation with the masonry works – moreover, in a fully hidden way requiring no space in rooms neither in dwellings, nor installation accessories or special works. There are always two of these ventilation flues operated simultaneously (but in certain intervals with a reversed direction of airflow: either for air extraction, or for air inlet), and thus they concurrently ensure well-balanced ventilation.

The details of the invention are presented in (Fig. 1), showing the theoretical outline of the alternating, decentralized, regenerative ventilation equipment in a vertical section being perpendicular to the external wall, via one of the ventilation flues.

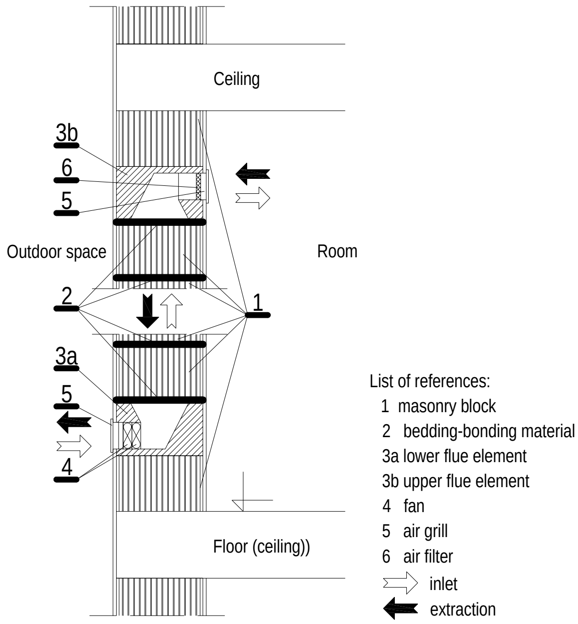

Figure 1: Schema of the ventilation system

As it can be seen, in the wall the ventilation flue is formed by lower and upper flue elements connected to the outdoor and indoor space. Both in the inside and outside, they enclose a belt not affected by airflow within the wall (thus these belts still function as heat insulations), while in the inside of the wall a vertical air channel is formed where the ribs of the bricks bordering of the elemental air channels function as heat storing and heat exchanging units.

In the lower part of flue, in the external side, two axial fans have been installed to face each other (12V DC cooling fans generally used in computers with their maximum power being 1.5W – but in the inlet operation mode it is also utilized as heating capacity), and in certain intervals their operation alternates. The air exchange is ~0.5 1/h and the flow rate is 20…22m^3/h in an average room. At the outlet points in the external and internal sides, there are air grills and air filters installed as required.

The ventilation equipment structured as described above consists of two ventilation flues in synchronized operations with controlled fans to provide for appropriate airflow. One of the two ventilation units functions as the extraction unit, while the other is the inlet unit – but these functions are changed in certain intervals. Therefore, in the winter the first phase of the operation of one unit extracts and discharges the warm air of the room, and in the meantime by utilizing the extracted “waste heat” it heats up the material of the flue, i.e. the brick ribs that also function as heat-exchanging and heat-storing units here. After a certain period of time, the second phase – with a reversed direction of airflow – blows the external, cold air through the formerly heated ventilation flue heating up the air and cooling down the flue, and then the air enters the room. The other ventilation flue performs the same process in a reversed phase. Thus, here heat exchange does not take place between simultaneously flowing media on the two sides of the bounding wall, but with a difference in time, by heating the ventilation flues also serving as the heat-storing and heat-exchanger units (storing the heat), and cooling the same down (extracting the heat), which is called regenerative heat exchange.

In the summer, the above-described ventilation is also suitable for the so-called “free cooling” mode, which means that at nights it uses the colder, external air for cooling or pre-cooling the rooms.

MEASUREMENT RESULTS OF THE PILOT EQUIPMENT

In the design described for the invention, I have built the pilot equipment in the heating laboratory of the Department of Building Services Engineering. The flues have been structured in a 38 cm thick Porotherm HS Profi and NF Profi brick wall so that from the entire thickness 24 cm has belonged to the flue, and a 7 cm insulation belts have been left both in the external and internal side. In the flues, the room and outside the room, temperature and relative humidity values have been measured at 13 points by data loggers. As a brief conclusion: the construction and operation findings, as well as measurement results have been convincing. With the ventilation flues integrated in the wall, the equipment could be developed in a simple, quick and cheap manner. The equipment has provided proper air exchange according to the relevant health requirements in the room, the two, alternating fans facing each other have ensured well-balanced air exchange, and in the winter it has reduced the humidity of indoor air to an extent required to avoid condensation; it has realized heat recovery in 70…85% efficiency under the various operating conditions, and has been running very silently: it has generated only a 0.3 dB(A) increase of sound level in the room. My associate, an electrical engineer has worked out a simple, so-called “PIC technology” based program control of the ventilation, which – with the use of a real-time clock and temperature sensors – ensures optimal automatic operations throughout the year, yet with the option of manual intervention at any time.

(Fig. 2) shows changes of the temperatures in winter – an example for the measurements performed – at 5 points of one of the flues, as well as in the indoor and outdoor side. (Fig. 3) reflects the typical processes under winter conditions in h-x diagram, as presented on the basis of the data of two measurement series.

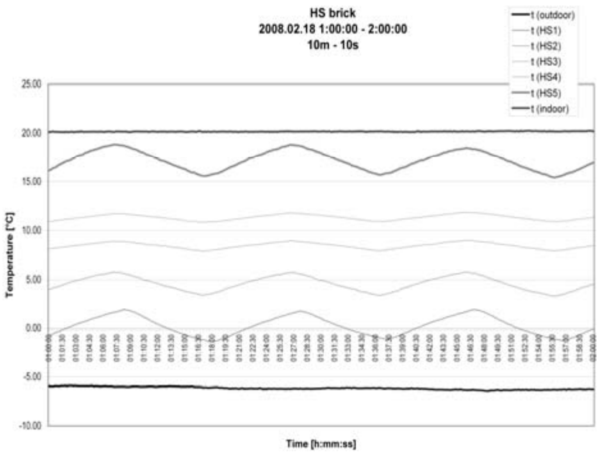

Figure 2: Variation of typical temperature values (Example 2, alternating interval: 10 minutes, the increasing values indicate measurements upward from the bottom of the flue by 50 cm intervals)

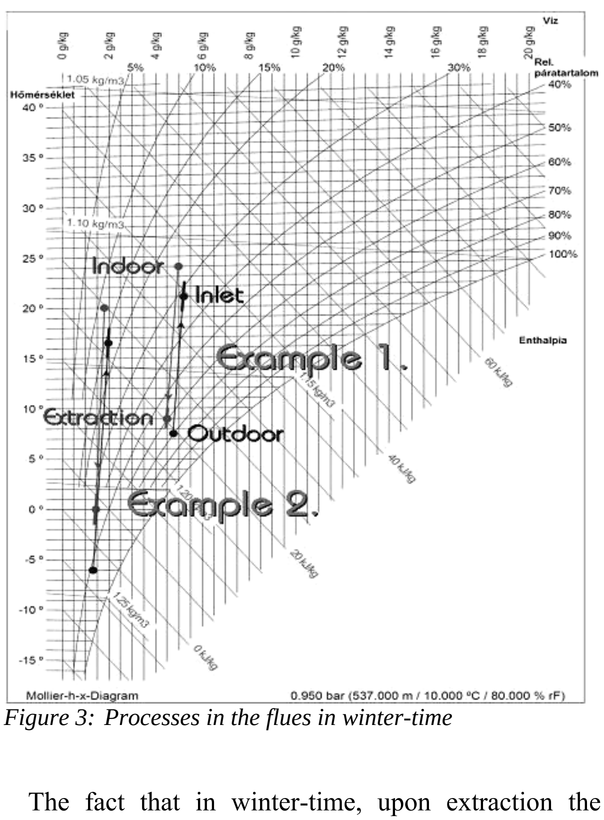

Figure 3: Processes in the flues in winter-time

The fact that in winter-time, upon extraction the absolute humidity of air drops (without any condensation in the flue) proves that the porous material of the brick ribs store small volumes of vapour, and gives back it to the dry, external supply air in the inlet phase – i.e. there is a regenerative humidity exchange also in the flue. Therefore, in comparison with fresh air ventilation, this type of ventilation equipment (may be equipped even with plate-type heat exchanger) removes excess humidity having been generated in the room, yet it dries less the internal air, which can be considered as more favorable from human comfort point of view.

No condensation was detected in the flues, yet during the measurements the lowest, permanent external temperature was -7°C, but in reality much colder conditions – rarely and in general for short periods – may as well occur. Avoiding the condensation in the flue is a relatively simple calculation after assuming the external and internal basic air conditions. This means in fact the determination of the appropriate thermal resistance of external insulating wall belt of the flue. In this context, with the similar dimensioning of the internal insulating wall belt of the flue (towards the room), the internal surface temperature of the wall can as well be established. With this pilot equipment the internal surface temperature of the wall at the flue has been just 0.5°C lower on average than in the parts of the wall without thermal bridges, which poses no threats in terms of thermal comfort.

The "free cooling" operation mode in summer nights is shown in (Fig. 4); in this mode, the fan of the first flue blows the air inside continuously, while the fan of the second one extracts air – but only if external temperature is lower than internal temperature by a pre-defined value, e.g. 2°C.

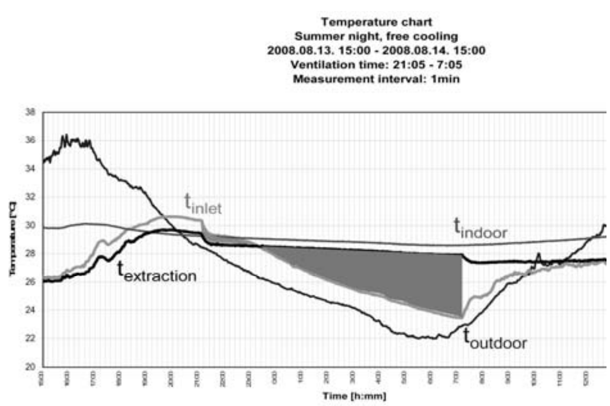

Figure 4: Summer night operation mode, free cooling (the highlighted area indicates useful cooling)

In case of two rooms side by side, the system can be operated in a way that both flues of the first room deliver air, while the flues of the other room extracts air, and in this case between the two rooms – for instance – a door without a door step ensure the proper air flow. A particular advantage of the system is that cooling is implemented with all the windows closed, without any noise – with filtered air. In comparison with the winter conditions, due to the much smaller differences of the external and internal temperature values, as well as the much shorter periods of operation, savings on cooling are just the fractions of savings on heating, may be some 1/10…1/30 of them, yet they are not insignificant at all.

The efficiency of the heat recovery of regenerative ventilation depends on the duration of the heating and cooling period, i.e. the reverse time of fans (in addition to several other heating and flowing characteristics, e.g. the specific heat and weight of the heat storage unit, the flow rate of air, dimensions…). If inlet and extraction periods are set to 4…8 minutes, based on the processed data from laboratory measurements, the efficiency of heat recovery are higher than 80%, which can be considered very good, and in fact exceeds my expectations.

In (Table 1) the basic data of the calculation can be seen for the (Table 2) which summarizes the values of considerable savings on heating capacity, energy, natural gas and operational costs of the ventilation equipment in an average room under average circumstances and with the currently average European gas prices.

Table 1: Basic data of the calculation for (Table 2)

Area of room	16	m^2	Indoor temperature	20	°C
Height of room	2.5	m	Outdoor temperature	3.6	°C
Volume of room	40	m^3/h	Specific gas net price	0.024	€/MJ
Air change rate	0.50	1/h		0.80	€/m^3
Specific density of air	1.195	kg/m^3	Heating capacity of gas	34.1	MJ/m^3
Heating days	183	day/year	Yearly efficiency of boiler	90	%
Heat recovery efficiency	80	%	VAT	20	%

Table 2: Savings on heating capacity, energy, natural gas and costs in average conditions

Results		
Heat demand of air inlet	110	W
Heat recovery	88	W
Heating energy saving	483	kWh/year
	1.7	GJ/year
Specific heating energy saving	30	kWh/m^2,year
Gaz consumption economy	55	m^3/year
Expense economy	57	€/year

(Fig. 5) shows the ventilation equipment during the construction of an implemented building, and hopefully I will be able to perform measurements under more realistic, built-up circumstances.

Figure 5: Ventilation equipment of a family house during construction

APPLICATION POTENTIALS IN PASSIVE HOUSES AND LOW ENERGY BUILDINGS

As in passive houses, indeed only the heating of the external cold air carries real heat demand, this should be treated in any, possibly energy-saving manner. Due to the approximately 80% efficiency of heat recovery, the solution described in my invention requires just a few times of ten watts heating capacity for each flue. This demand can be covered in a relatively simple, easily controllable manner with small, separate (for instance electric) heating units integrated in the flues. Furthermore such appliances would also function as safety heating units. In view of control, comfort and operating safety a particular advantage is that the system can also be operated separately in each room.

CONCLUSIONS

This innovative way of ventilation – though it is not fully comparable with central ventilation systems in all its parameters (it cannot be combined with soil heat exchangers) – ensures such appropriate, highly energy-saving and well-balanced ventilation for buildings and their users, which may be regulated room by room according to individual demands. As it provides good indoor air quality, it offers appropriate protection against the accumulation of pollutants, reaching relative humidity, as well as mould growth. During masonry works, it can be constructed in a very simple and quick manner by the integration of some special elements in the wall, and the same applies to planning. The ventilation equipment integrated in the walls is almost invisible, does not occupy any space in the room or apartment, and special installation materials or works are not needed. Its construction and operating costs remain well under those of central ventilation systems, while its noise level is lower beyond all comparison. With central or individual, room-based regulation, its operation is adapted to the continuously changing external and internal air conditions with fully automatic control, yet also ensures the option of manual intervention in the light of individual demands.

This innovative ventilation system based on my invention is very environment friendly in terms of materials used; construction and operation also, and therefore it can contribute to the spread of the so-called sustainable or green building qualification.

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