SHORT TIME UNDERGROUND HEAT STORAGE FOR VENTILATION

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ABSTRACT

The paper presents the new original concept of utilization of the ground for heat storage in ventilation systems.
The idea of presented solution is based upon the construction of the Membraneless Heat and Mass Exchanger elaborated at the Technical University of Wroclaw.
The mathematical model of heat transfer within the bed of gravel with air flowing through it is also presented. Results of computer simulation of the system and the results of experiments are shown on diagrams.
Presented system of heat storage in a bed of gravel placed under the ground allows to reduce up to 80 % of heat demands for ventilation in winter. It also makes it possible to cool down the air stream in summer, covering 100 % of cool demands.

INTRODUCTION

Almost 40 % of the overall thermal energy production in Poland is consumed for heating, air conditioning and domestic hot water purposes. Development and wide range application of energy saving solutions in these systems would allow for the significant reduction of energy consumption. Beside the economical aspect, the savings of the energy are closely connected with the environment protection. Reduction of the energy consumption may be achieved by rationalization of use of the fuels, utilization of the unconventional energy sources and the certain solutions on the field of recycling of once produced energy i.e. its accumulation.

DESCRIPTION OF THE PROPOSED SYSTEM

The system of heat accumulation under the ground may be applied both in ventilating and air heating installations. It allows for effective utilization of the thermal energy of the exhaust air for preheating or heating of the supply air stream in winter. Additionally the supply air may be cooled down in hot summer days. Application of the proposed system makes possible the whole year temperature control inside the ventilated rooms with almost no additional energy consumption connected with air treatment.
The idea of the Membraneless Ground Heat and Mass Exchanger elaborated at the Technical University of Wroclaw has been applied for the construction of the heat accumulator.
Scheme of such heat exchanger is presented in Figure 1.

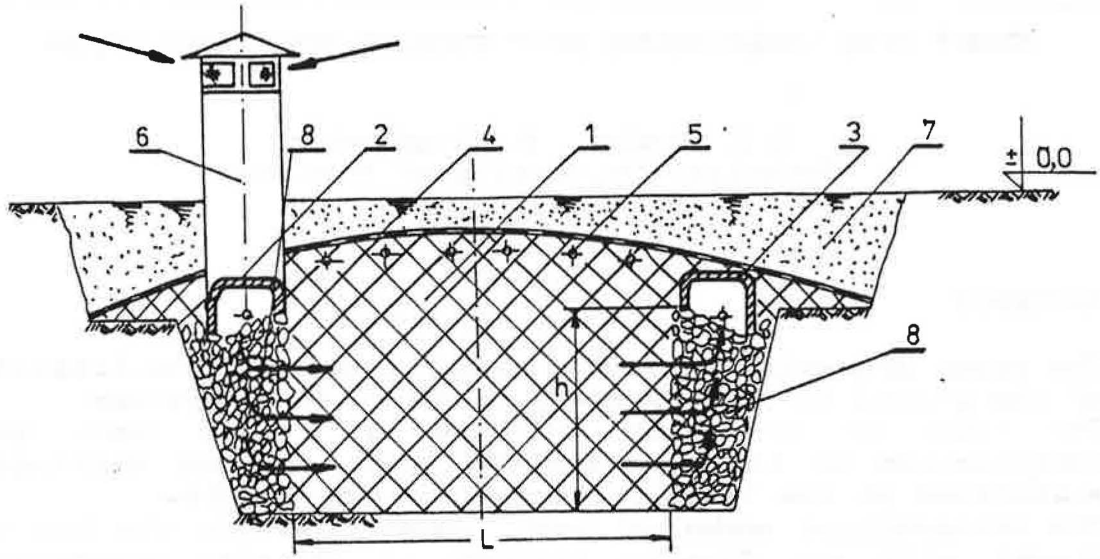

FIGURE 1. Scheme of the membranless ground heat and mass exchanger. 1- accumulative layer, 2- distributing channel, 3- gathering channel, 4- insulation, 5- showering installation, 6- air inlet, 7- covering soil.

The ambient air is drawn through the inlet 6, distributing channel 3 and distribution layer 8 into the accumulative bed of loose mineral particles 1, in which the main heat transfer process occurs. After being treated the air is gathered in channel 3 and blown into the ventilated room. On top of the accumulative layer the showering installation is placed 5. The accumulator is then covered with the thermal and water insulation 4 and the layer of the soil 7. Showering installation is provided due to periodical washing or disinfection of the bed. However after a few years of operation, no need of such activity has arisen.
In the system of heat storage the accumulative layer is split into two equal parts. They are reversely charged with an exhaust air and discharged with an ambient air counter currently in winter making the heating of the ambient air possible.
In summer both parts of the accumulator are utilized in exchanger mode which enables significant cooling of the ambient air.
Due to enable the investigation of the different accumulators working in the same conditions the mathematical model of it has been created and solved by Kowalczyk (1). The differential equations and the boundary conditions are presented below.

MATHEMATICAL MODEL OF THE ACCUMULATOR OF THERMAL ENERGY

It has been verified experimentally (2), that the conditions for equivalence of two and one phase models given by Vortmeyer and Schaefer (3) are fulfilled for the gravel bed accumulator of heat with air stream flowing through it.

Thus the differential equation of heat transfer within the bed of gravel and the boundary conditions can be written as follows :

$$(1-\varepsilon)\rho_s c_s \frac{\partial T}{\partial t} = \lambda_a^e \frac{\partial^2 T}{\partial x^2} - w_o \rho_p c_p \frac{\partial T}{\partial x} \qquad (1)$$

$$T(0,x)=f(x); \qquad T(t,0^+) - \frac{\lambda_a^e}{w_o \rho_p c_p} \frac{\partial T(t,0^+)}{\partial x} = T_1;$$

$$T = \text{cons} \quad \text{for} \quad x \longrightarrow \infty$$

This model has been solved analytically for the initial bed temperature distribution and the inlet air temperature approximated with the elements of parabolas (1).
Presented model has been verified experimentally (4). In Figures 2 and 3 examples of the results of the verification both for charging and discharging modes are presented. Points represent measured values of the temperature of the bed and flowing air at different distances from the inlet : TII - 0.27 m, TIII - 0.72 m, TIV - 1.27 m, TV - 1.90 m.
The solid lines represent results of the computer simulation of the accumulator operational mode at the same distances from the inlet.
Analysis of presented figures proves the validity of taken assumptions and the applicability of the presented mathematical model for the simulation of the operation of the accumulator of thermal energy with gravel bed, charged and discharged with the air.

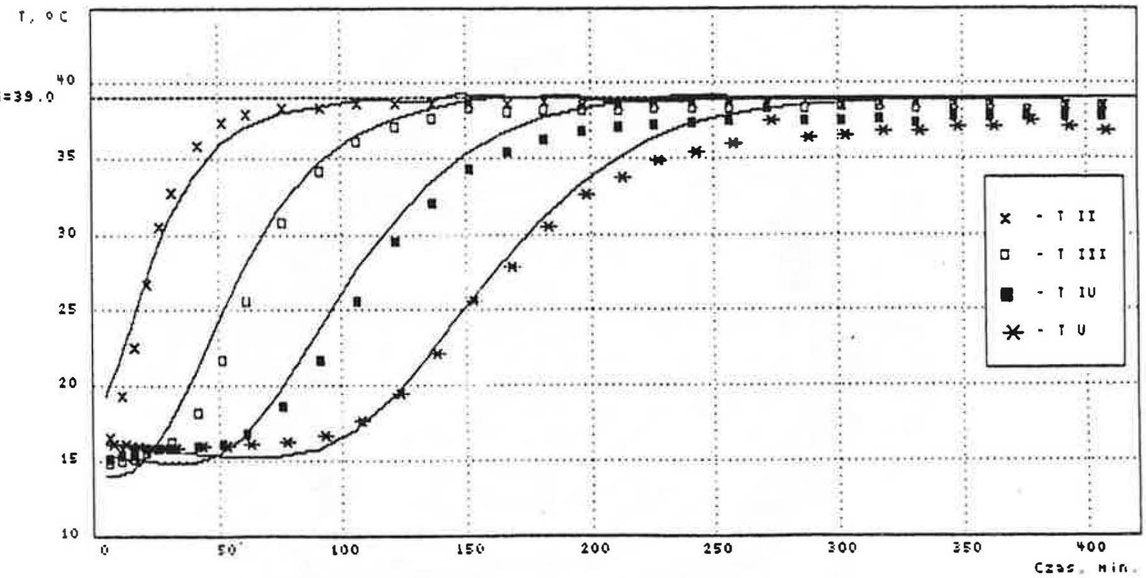

FIGURE 2. Temperatures of the flowing air at the different distances from the inlet as a function of time. Charging mode.
Air velocity - w_o=0.205 m/s. Inlet air temp. - T_{wej}=39.0 °C

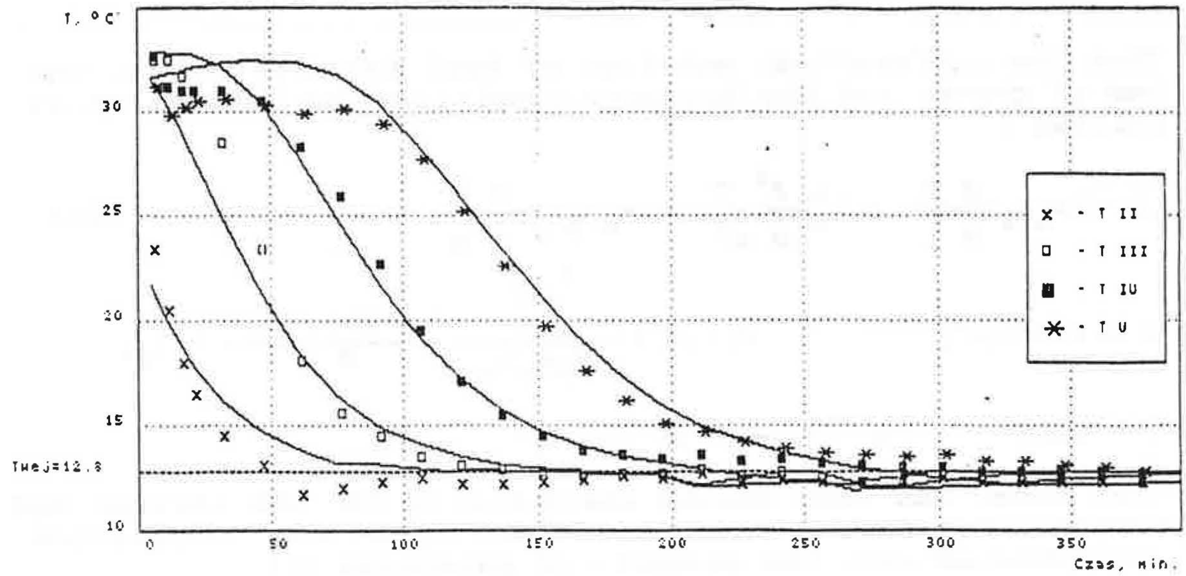

FIGURE 3. Temperatures of the flowing air at the different distances from the inlet as a function of time. Discharging mode.
Air velocity - w_o=0.205 m/s. Inlet air temp.- T_{vej}=12.8 °C

RESULTS OF FULL SCALE EXPERIMENTS AND COMPUTER SIMULATIONS

The Membraneless Ground Heat and Mass Exchanger has been first applied ten years ago in the ventilating system of the health-resort Polanica Zdroj, Poland. In the Figure 4, the results of investigations and the results of computer simulation are presented.

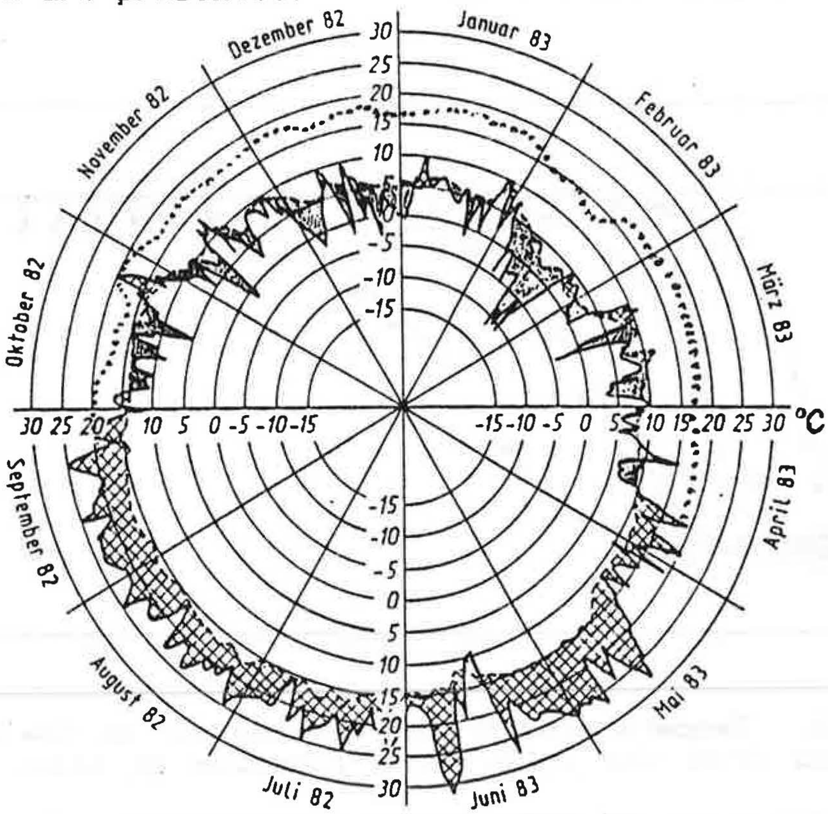

FIGURE 4. Yearly opperating parameters of the ground heat exchanger and the results of the computer simulation.

The solid line represents the ambient air temperature, dashed line - measured outlet air temperature and the dot line - results of computer simulation in cold periods. The calculations have proved, that up to 80% of heat demands for ventilation in winter can be recycled in the system. In summer, in the mid european climate the whole cool demand is covered

CONCLUSIONS

Presented system of heat accumulation in the gravel bed placed under the ground is the effective tool for the reduction of the consumption of energy in ventilating systems. It also allows for creating the microclimate of the ventilated rooms throughout the year with no need of use of energy consuming cooling devices. Applicability of this system is practically unlimited. It can be utilized in small installations, as for instance in single family houses, as well, as in huge industrial ventilation plants. The only limitations may raise from the underground infrastructure in the neighbourhood of the ventilated building and from higher radon concentration, which did not occurred in the plants which have up till now been built in Poland.

NOMENCLATURE

Symbols

- c - specific heat at constant pressure, $Jkg^{-1}K^{-1}$
- f - functions of temperature distribution
- L - length of gravel bed, m
- T - bed temperature, $^{\circ}C$
- T_1 - inlet air temperature, $^{\circ}C$
- t - time, s
- w_o - overall air velocity, ms^{-1}

Greek Symbols

- ε - bed porosity
- λ_a^{*} - effective heat transfer coefficient with air flow, $Wm^{-1}K^{-1}$
- ρ - phase density, kgm^{-3}

Indexes

- f - fluid phase
- s - solid phase

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