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Energy saving by using natural energy from the shallow ground depths – many years operating results

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Abstract. We pay back more and more larger attention on solutions which saving energy produced from conventional fuels. This is possible to obtainment in significant quantities in fields in which use up the large quantities of energy. The formation the microclimate of interiors is an example of such situation. Especially in the case air conditioning, heating and mechanical ventilation. There is, however, a possibility of energy saving as well as considerable reducing the pollution coming from combustion of raw materials by utilising the natural renewable energy from the shallow ground. In the paper the results gained during several year of continuous measurement on the exchanger were presented. In summer periods an air cooling occurs 10–12 K, e. g. from +30 °C to +20 °C. In winter on the other hand, a preparatory preheating of the air is possible, e.g. from -18°C to about ± 0°C. It is then possible to obtain for the air conditioning system the total energy needed for cooling purposes at the summer periods, or up to 50% of the ventilation heat energy in winter picks.

1 Introduction

There is a widespread aspiration that the energy needs of the world are increasingly met by renewable resources. Maintaining the current way of producing energy mainly from fossil fuels is not sustainable in a long period of time. At least for two reasons: one is the depletion of these resources, and the second is the need to protect our natural environment. More and more often we notice that the environment is no longer able to absorb the residue of combustion processes, especially CO_2, SO_2, NO_x, which the most damaging effects are acid rain and global warming. In the Central European climate for the purpose of shaping the microclimate is 40% of total energy production and so much pollution is getting into the environment. Environmental cleanliness requirements are still growing. For the health and well-being of residents and building users a good microclimate is essential. Optimal microclimate promotes full and rapid regeneration of the body. It is also indispensable for proper reception of artistic experiences (e.g. At concerts, opera, theatre). With the increase in quality also increase the cost of manufacturing and maintaining the appropriate microclimate of the premises. Technology is changing in new buildings. Buildings are increasingly tight. Where there was sufficient heating and gravity ventilation in the past, today, well-ventilated mechanical ventilation or air conditioning is required. Mechanical ventilation systems allow for a better microclimate and, at the same time, reduce operating costs, favoring especially energy savings. An example of saving energy for heating and cooling in small and medium-sized ventilation systems is a diaphragm ground heat exchanger.

2 The solution idea

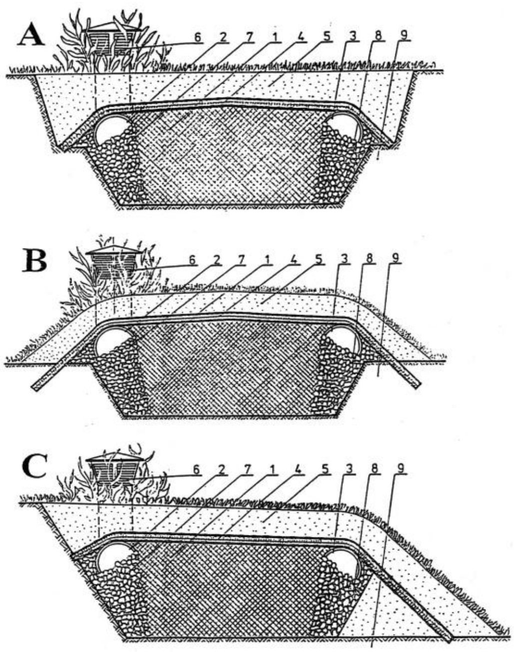

Fig. 1. Various proposal of heat exchanger design: A – recessed, B – partially recessed C – elevated above the level of the existing terrain and located on the slope. 1-accumulating (actual) bed; 2 conducting channel; 3-collecting channel; 4-heat-moisture insulation; 5-covering blanket; 6-drawing air inlet; 7-air distributing bed; 8-air collecting bed; 9-native ground.

The idea of the solution consists in the thermal energy from a depth of 4–5 m below the ground. At this depth in the Mid-European climate prevails almost a constant temperature of +10°C (± 1.5°C). The thing is to utilize a part of the practically unlimited stock of the heat energy contained at this depth. However, getting the outside air through a gravel bed placed 4–5 m below the ground surface level would be very troublesome and expensive, and often simply impossible, because of relatively high level of the underground water or rocky ground. It was thus decided to replace the thermal resistance of the ground layer by that of an insulating layer of a value corresponding to that of the 5 meter thick layer of wet ground. This way the isotherms corresponding to a deep ground layer are brought up to a higher level, just below the insulating layer. Such a solution enables to locate the heat exchanging gravel bed at a smaller depth (half recess), or even at a ground surface level, e.g. at an scarp. In the figure 1 is shown the intersection through the typical medium size ground exchanger. The effects are very close to those of 4–5 m depth. The heat exchanger can be located next to the building, under the lawn or even beneath the building between

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the structural elements. The plants can be planted in a suitable coarse soil layer above the exchanger.

3 Experimental results

Obtained in the extruded and operating heat exchanger for many years, the results confirm the validity of the above assumptions. In the warm season, on gravel storage beds located below the surface, air is cooled by up to 10÷12K, for example from +30°C to +20°C. In addition, drying of the flowing air stream is also often added. Rarely, when the relative humidity of external air is less, drying is also rare. Conversely, in cold weather, the air stream passing through the bed is pre-heated for example from -18°C to 0°C or a temperature of several degrees above zero while moisturizing the flowing air.

In the case of obtaining air temperatures exiting the heat exchanger at +16 – +20°C for many days in the summer, it is possible to obtain even the total cooling demand for the air conditioning [4]. In winter the share of energy saved by the preheating of the air on the bed can reach up to 50% (for temperature conditions of -18°C). Figure 2 shows an exemplary design of a single ground heat exchanger. Where a larger airflow is required, a two-bed double exchanger may be used. Double heat exchangers are also applicable to the projected alternating bed operation. It is advantageous in the case of continuous operation of the ventilation system and allows for the self-regeneration of the beds. Switching mode can occur automatically or in a simple manual version.

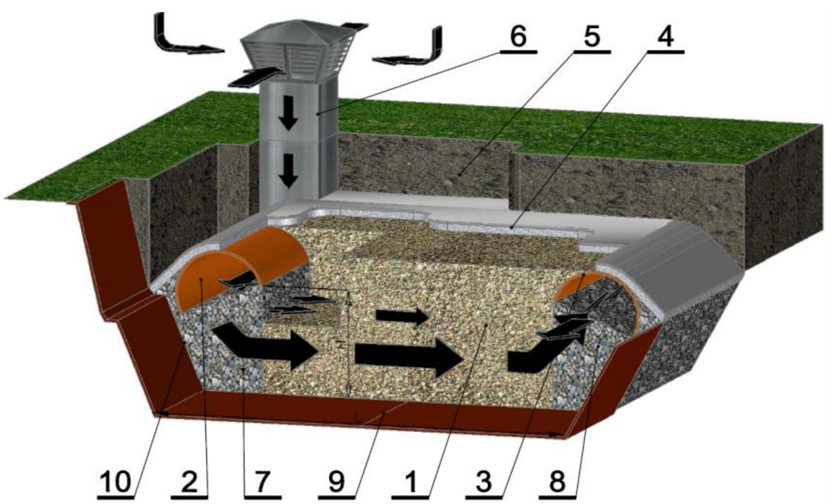

Fig. 2. Exemplary performance of ground heat exchanger: description of elements just like at fig. 1 (1-accumulating (actual) bed; 2-conducting channel; 3-collecting channel; 4-heat-moisture insulation; 5-covering blanket; 6-drawing air inlet; 7-air distributing bed; 8-air collecting bed; 9-native ground, 10 – geotextile [3].

The heat exchanger bed has the characteristics of the storage bin, both in short periods of work – several days as well as seasonal work. This means that the parameters of leaving air stream are very slow to follow the rapidly changing parameters of external air stream in the intake of the heat exchanger.

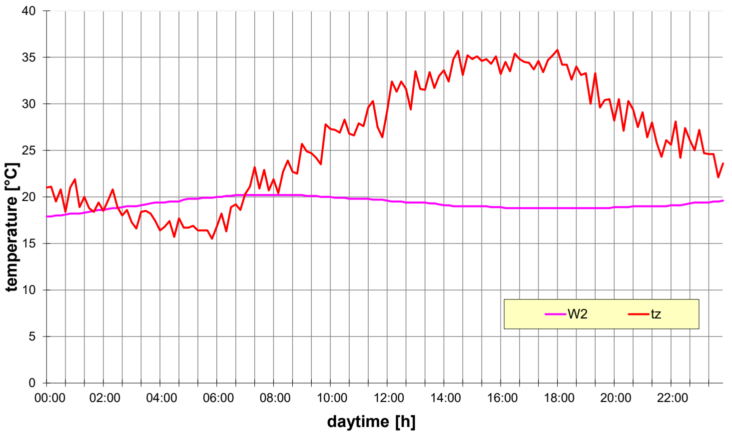

Fig. 3. Experimental results in the example summer period.

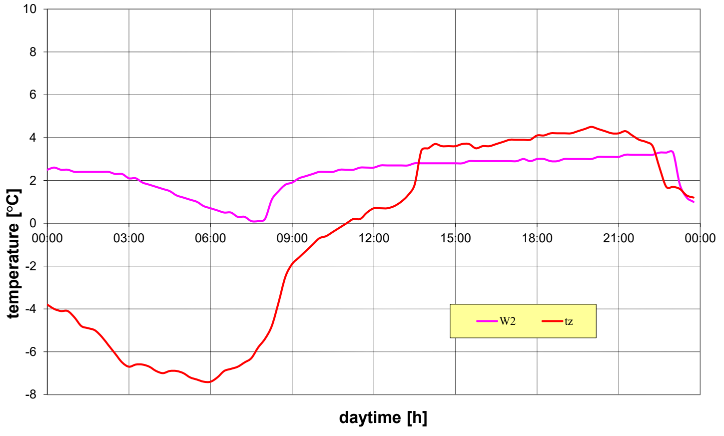

Fig. 4. Experimental results in the example winter period.

Seasonal changes of the air flow parameters from ground heat exchangers affect the cooling of the bed at the end of the winter season and heating at the end of the bed operation in the summer season. Consequently, different bed temperature is obtained in autumn and spring at similar external air temperatures. The variations in gravel temperatures in the ground heat exchangers in the whole year show figures 5–8 [3]. Based on the measurements, the expected air temperatures exiting the heat exchangers according to the different outdoor air parameters were graphed, dividing the year into the so-called the "climate quarters" as follows: December, January, February – I quarter, March, April, May – II quarter, June, July, August – III quarter, September, October, November – IV quarter.

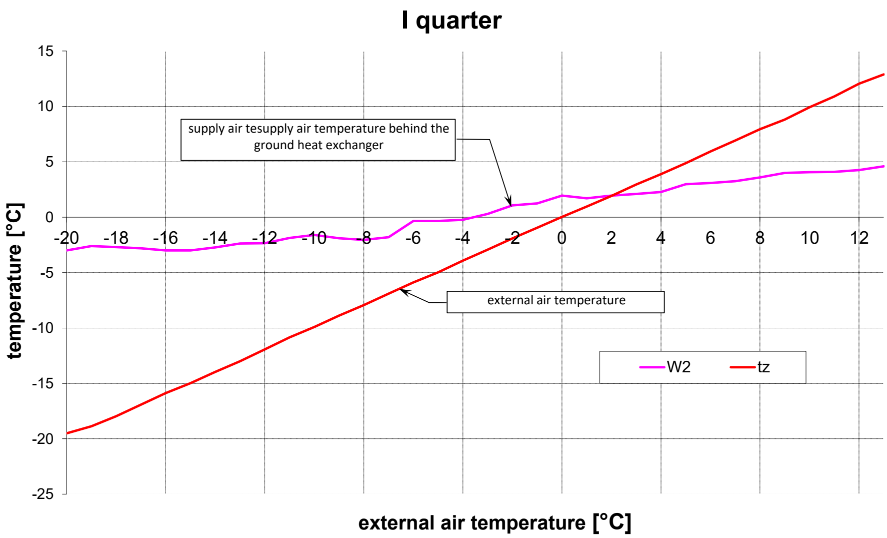

Fig. 5. Air temperatures exiting the exchanger as a function of outside air temperature for the first quarter (climate).

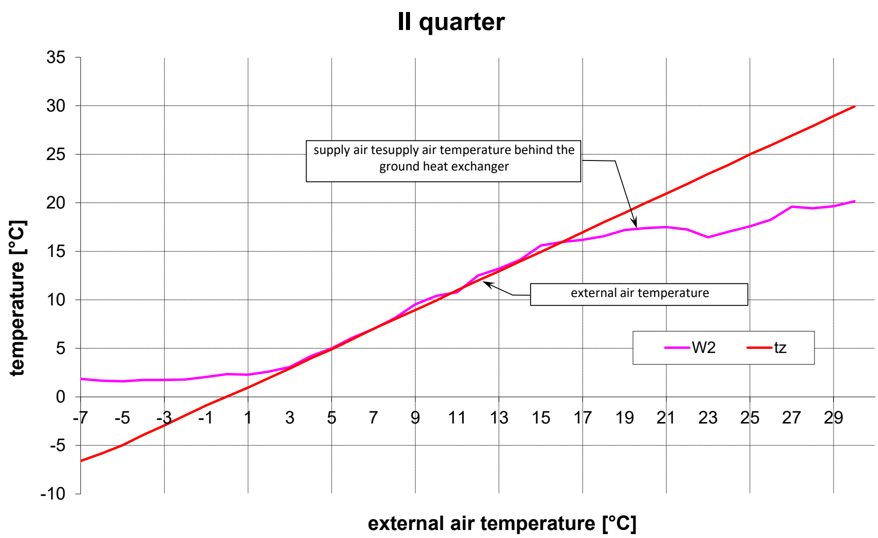

Fig. 6. Air temperatures exiting the exchanger as a function of outside air temperature for the second quarter (climate).

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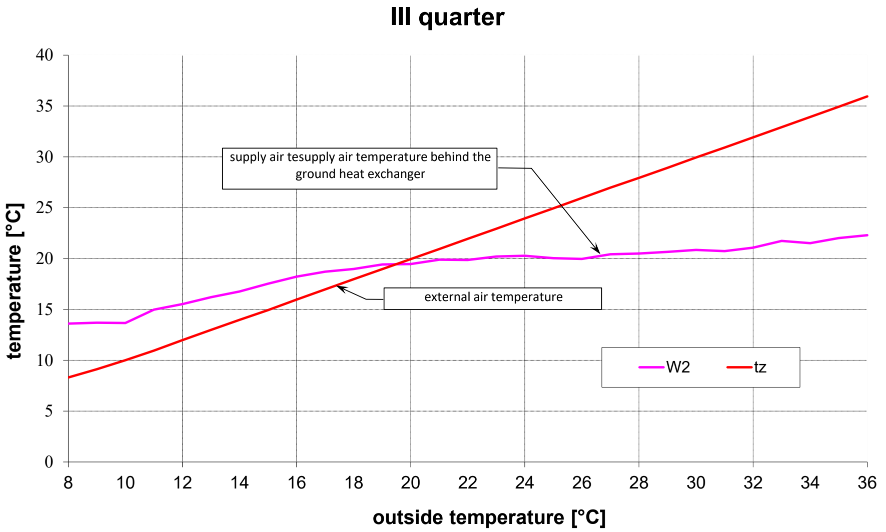

Fig. 7. Air temperatures exiting the exchanger as a function of outside air temperature for the third quarter (climate).

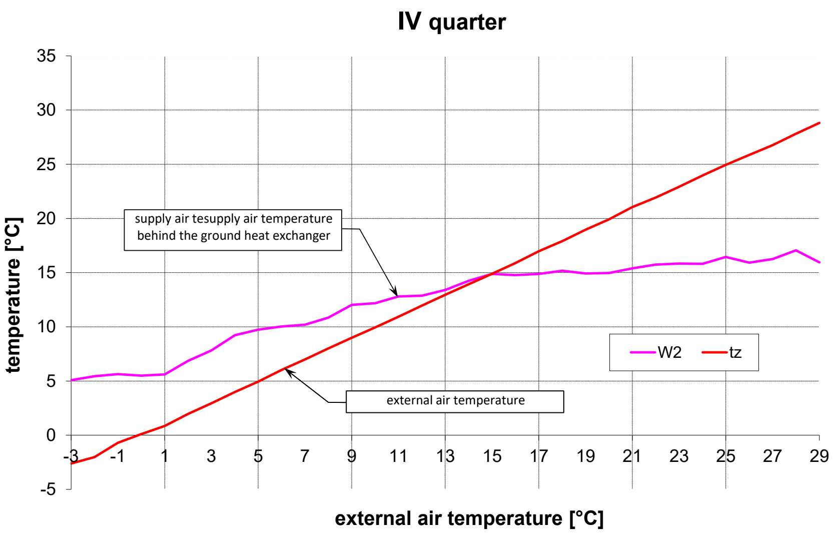

Fig. 8. Air temperatures exiting the exchanger as a function of outside air temperature for the fourth quarter (climate).

The change of conditioned air obtained in operating heat exchangers in the winter seasons shows the phenomenon of taking up moisture by the air stream. Conversely, during the summer seasons there is noticeable drying of air flow. The relative humidity of the air stream exiting the ground exchanger is in the range of 75–85%, which is a limitation for air conditioning systems (in case of the need for significant drying of air) when the air temperature in bed is lowered to +16 – +18°C during the summer season. Sample air changes for the winter and summer period on i-x graph are shown in Fig. 9.

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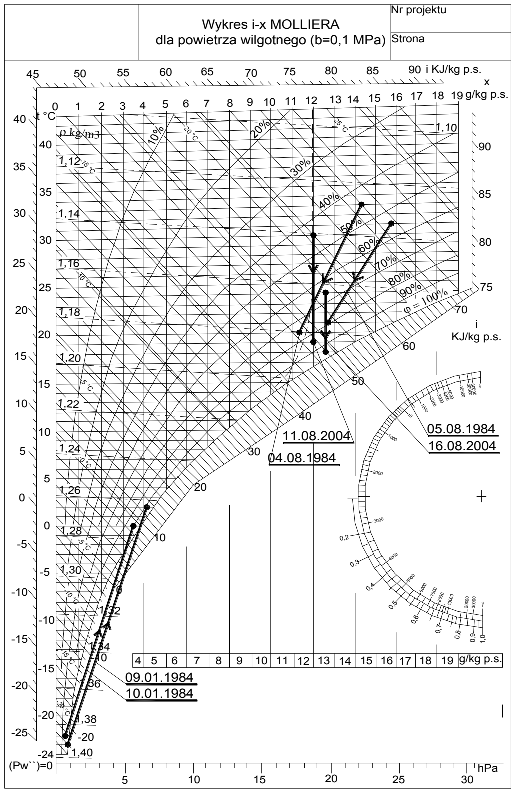

Fig. 9. The i-x graph: examples of characteristic of air flow in the heat exchanger.

3.1 The problem of air purity

After 14-years of non-stop exploitation an evaluation of the purity of air leaving the membraneless heat and mass exchangers was made. The investigation concerned the exchangers working in the Lab. of the Chair of Air Conditioning and District Heating at the Wrocław University of Technology since 1980. The investigations were carried out by the Provincial Epidemiological Station in Wrocław. The results are shown below in the tab. 1.

Table 1. Results of the investigations of air purity in ground exchangers in Wrocław.

No of. meas	**Meas. point**	**Total No. of bacteria**	**Number**				**Total No of fungi**
			Actinomycetales	**Pseudomonas fluorescens**	**Staphylococus Type of hemolysis**		
					α	**β**	
417	inlet	10615	3319	288	no incr.	no incr.	3485
418	outlet	680	157	no incr.	no incr.	no incr.	1231

The final conclusion is as follows: “In effect of the investigation carried out it has to be stated that the air – after passing through the heat exchanger – contains much less cells of micro-organisms than that contained at the inlet”. At this opportunity it should be explained that – on the average – the pure air contains 3000–5000 fungi in 1 m^3; the air containing 5000–10000 fungi in 1 m^3 is concerned as one possibly influencing negatively upon the environment, it is usually assumed that the air which may endanger the environment contains more than 10000 fungi per 1 m^3.

3.2 Recapitulation

Basing on the investigation results obtained during the many years exploitation one may conclude that:

- The introduction of BGWCiM allows extracting from the ground in winter periods, at the picks, up to 50% of ventilation heat energy, and in summer periods - the whole cooling energy for air conditioning.
- The energy inputs for overcoming the flow resistance are negligeable, because the ratio of energy input to the energy gained reaches a value of 1:40, whereas for example in the heat pump installations the average ratio is about 1:3.5.
- There are no contraindications as to locating the BGWCiM. They may be placed under a lawn, under a building or even on the ground surface with effects not much deviating from those obtained at 4–5 m depth.
- They may be built on to the existing ventilating systems.
- For the construction of the BGWCiM only low-cost materials are used, mainly gravel and natural stones.
- Refund of money spent for building the BGWCiM occurs after about 2–4 years, which speaks well about profitableness of such enterprises.

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