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INVESTIGATION OF THERMAL CONDITIONS IN SOLAR AIR COLLECTORS UNDER NATURAL CONVECTION

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Summary: *The paper deals with the experimental investigation of the performance of solar air collectors in the Eco-house VÚES in the village of Podolí, 10 kilometers east of the city of Brno. In the first stage the thermal conditions inside the solar air collectors under natural convection have been studied. The attention was aimed at the correlation between the global solar irradiation and the temperature difference at the inlet and outlet of the solar collectors.*

1. INTRODUCTION

Solar air collectors present the non-expensive way of solar energy utilization [1], [2]. Solar preheated air can be utilized for warm air heating or ventilating. A dependence of solar air collector performance on global solar irradiation and outdoor air temperature is very important for the design, application, and operation of solar air systems. The paper deals with the experimental investigation of the performance of solar air collectors in trial operation.

2. DESCRIPTION OF THE EXPERIMENTAL BUILDING

The performance of solar air collectors, installed in the Eco-house VÚES in the village of Podolí 10 kilometers east of the city of Brno, has been investigated. The Eco-house (Fig.1, 3) is an experimental building, which was built with the aim to demonstrate the possibilities of exploitation of renewable energy sources, especially the various ways of solar energy utilization.

There are several solar systems installed in the building, like photovoltaic panels, solar air collectors with rock heat storage, solar water collectors with water heat storage, heat pumps, etc. Thanks to these systems the building is nearly self sufficient from the point of view of consumption of energy.

The solar air collectors (Fig.2, 4) were designed with the aim to utilize solar energy for preheating of supply ventilation air and warm air heating on sunny days in spring and autumn. The preheated air can be supplied directly to the ventilated space or to the rock heat storage beds (see Fig.3). The heat storage enables to utilize the solar heat when ventilation system is not in operation.

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The stored heat can be used for preheating of supply air during the time, when solar radiation is not available.

The solar air collectors employed in the Eco-house are quite simple. The building contains a solar wall. Additional glazing was supplemented to this wall so that two vertical slots were created (Fig.4). The glazing between these two slots contains absorption film SDI-SUN GARD (SOLAR-MAX, USA).

Three types of absorption films, HP 50G/D, HP 20G/D, HP 05G/D, with different absorption factors were used. Ambient air from the main hall enters the solar collectors on the lower side. On the upper side the solar air collectors lead to the duct of the ventilation system. The ventilating unit is located in the attic. As mentioned above, the air preheated in the solar air collectors can be supplied either directly to the building or to the rock heat storage. The ventilation system fan is equipped with a frequency changer, which

Fig.1 The Eco-house VÚES in Podolí

Fig.2 Solar air collectors in the Eco-house VÚES

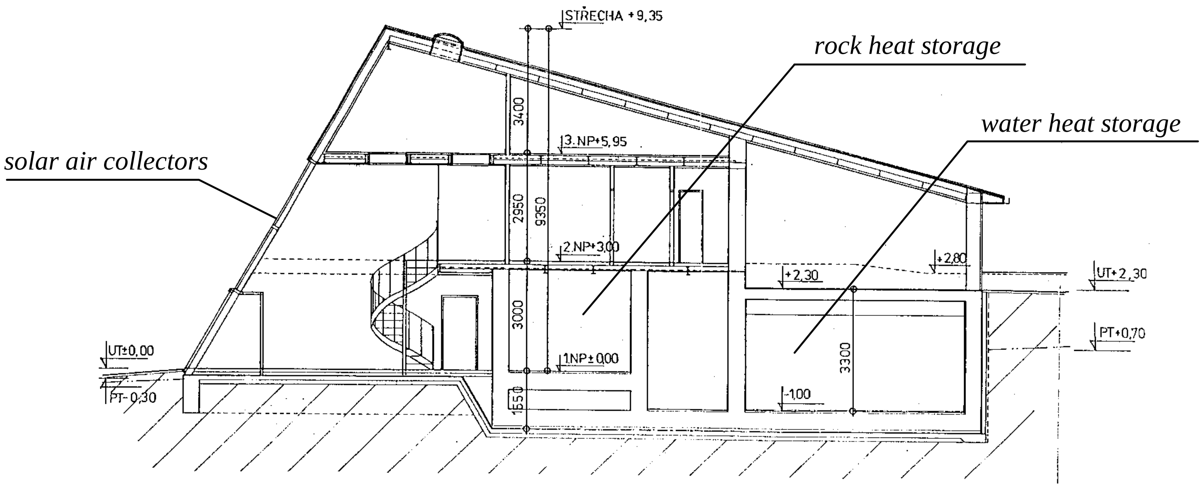

Fig.3 Schematic cross-sectional view of the Eco-house VÚES in Podolí

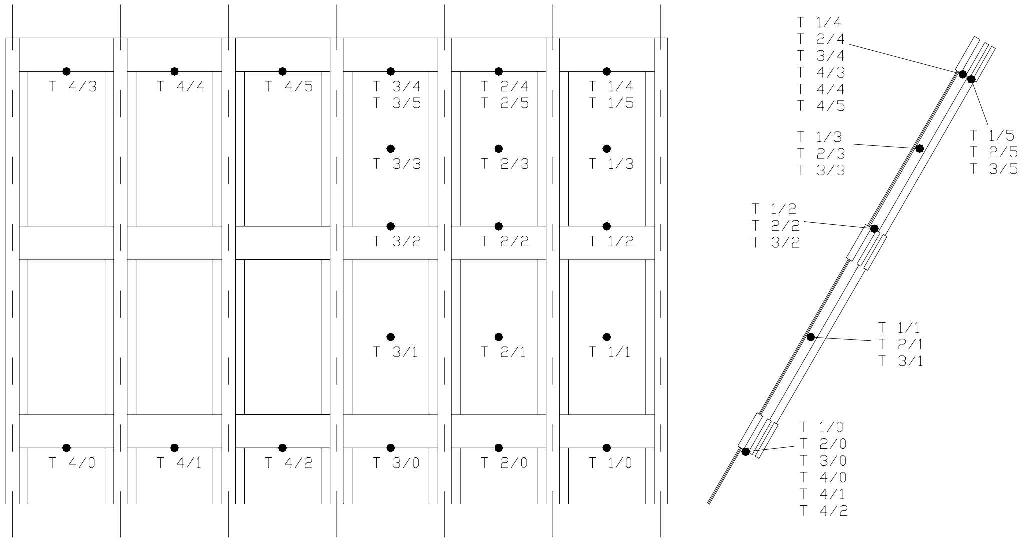

Fig.4 Schematic view of solar air collectors installed in the Eco-house VÚES

enables to control fan revolution. The flow rate through the solar air collectors can be controlled this way.

3. DATA ACQUISITION SYSTEM

A data acquisition system has been installed with the aim to investigate characteristics of solar air collectors. The system (shown in Fig.5) contains four modules ADAM-4018-D1 (Advantech, Taiwan), each with eight voltage inputs. The modules are connected to a PC via RS-485 serial bus and communication module ADAM-4520-D2. The temperature sensors AD-592 (Analog Devices, Taiwan) have been used for temperature measurements. The sensor locations are shown in Fig.4. At present there are 24 temperature sensors installed in solar air collectors.

The temperature sensors are installed in the outer slot of each of the three sections with different absorption films. Besides the inlets and outlets, the temperatures in three intermediate positions are monitored. Next, for the comparison of both slots, the outlet temperature in the inner slot is measured. In the left part of the solar collectors array, only the inlet/outlet temperatures have been monitored.

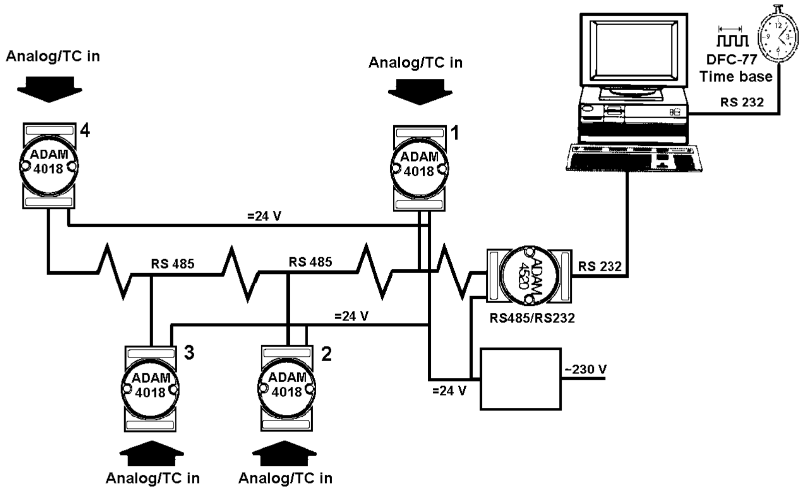

Fig.5 Data acquisition system of solar air collectors

Weather conditions at the location of the Eco-house (global solar irradiation, outdoor air temperature) have been monitored by the data acquisition system of the VÚES Brno. The pyranometer Kipp&Zonen CM 05 has been used to measure global solar irradiation. Both data acquisition systems contain time bases DFC-77, which are used for the time synchronization of the measurements.

4. DETERMINATION OF GLAZING PROPERTIES

Optical properties of the materials applied to solar air collectors were determined in cooperation with the Faculty of Natural Sciences of the Masaryk University in Brno. Various combinations of glazing and absorption films, with regard to the combinations applied to the solar collectors, were examined. Some of the results are shown in Tab.1. Spectral characteristics of absorption films are shown in Fig.6.

Tab.1 Optical properties of selected glazing arrangements

No.	Glazing system	Optical parameters		
		reflectance [%]	transmittance [%]	absorptance [%]
1.	film only: HP 05G/D	7,9	4,9	87,2
2.	HP 20G/D	13,3	20,3	66,4
3.	HP 50G/D	19,7	68,5	11,8
4.	whole collector: HP 05G/D	21,1	3,2	75,7
5.	HP 20G/D	22,3	13,1	64,6
6.	HP 50G/D	26,6	46,7	26,7

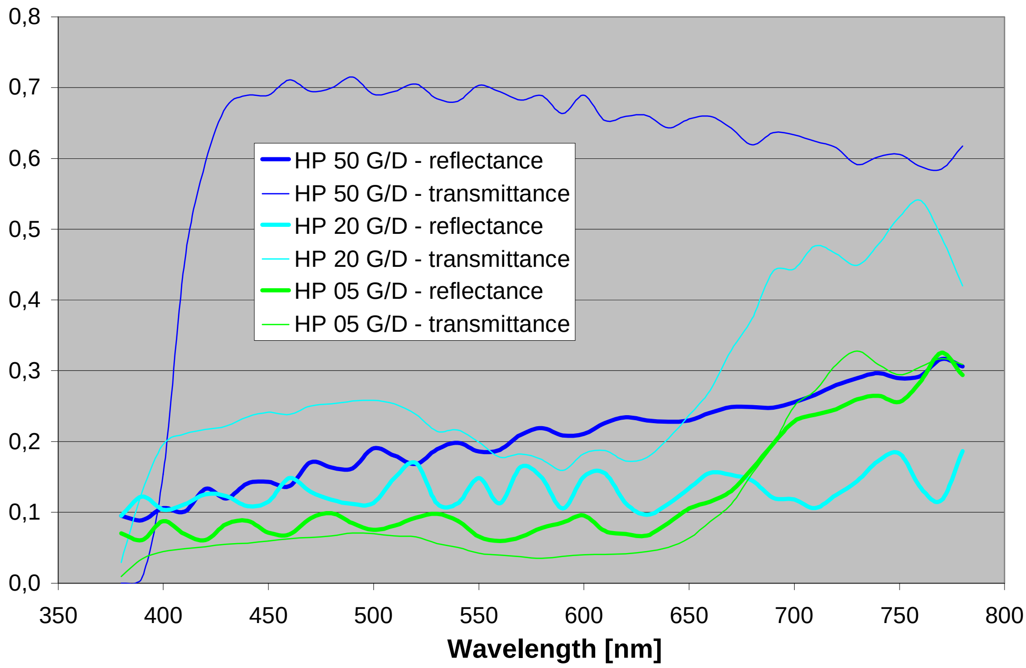

Fig.6 Spectral characteristics of the absorption films

5. RESULTS AND DISCUSSION

Since the ventilation system has not come into operation yet, the measurements were carried out only under natural convection in solar air collectors. The attention was aimed at the correlation between the global solar irradiation and the temperature difference at the inlet and outlet of the solar collectors.

A typical example of temperatures in the solar collector on a sunny day in autumn is in Fig.7. The chart shows that the outlet temperatures follow, with a small delay, the changes of global solar

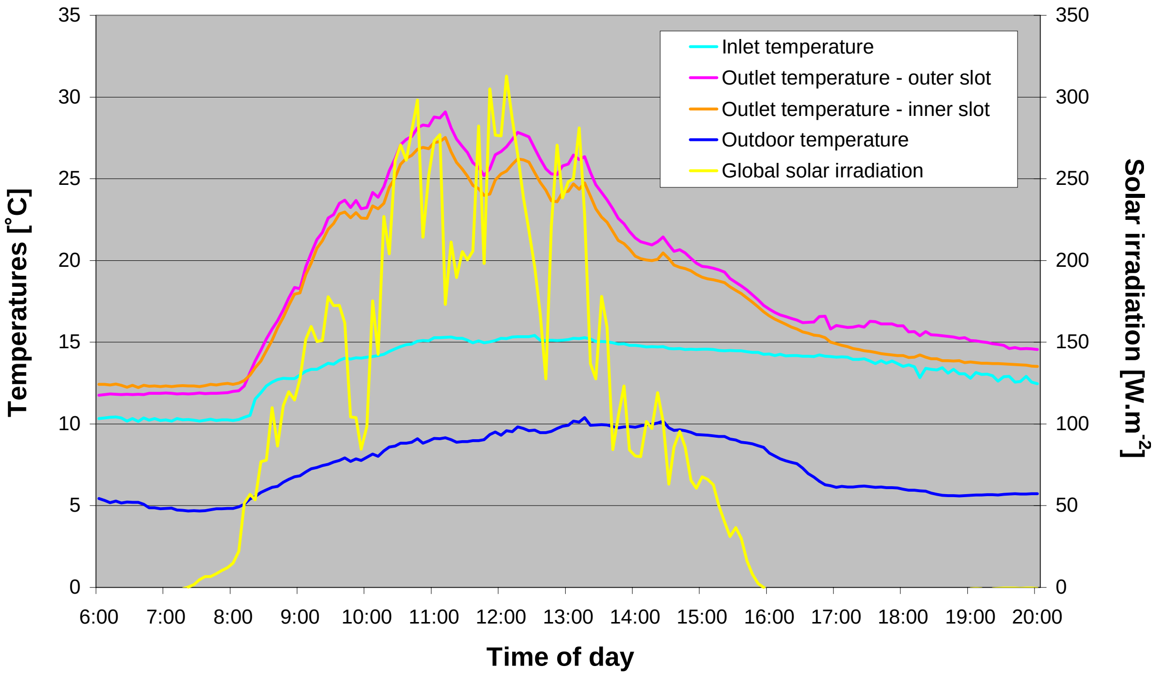

Fig.7 Solar air collector temperature history typical for a sunny autumn day (measured on November 24, 2000)

irradiation. It can be seen that at night, the temperature in the outer slot was lower then the temperature in the inner slot, but when the sun was shining, the temperature in the outer slot was higher then the temperature in the inner one. It is not easy to explain this result. The temperature difference at night is logical, since the outdoor air temperature was lower then the temperature inside the building. The same situation would be expected during the day, because only the glazing between the slots contains the absorption film, and the film is on the side of inner slot. The cause of this phenomenon could be a different character of natural convection on the upper and lower side of the glazing between the slots. Next experiments should investigate, whether this state would remain also under the forced convection, when ventilation system is in operation.

Fig.8 shows the correlation between the inlet – outlet temperature difference and the global solar irradiation for the three types of absorption films. It can be seen that the higher is the absorption factor the higher is the temperature difference.

6. CONCLUSIONS

The solar collectors in the Eco-house are designed for the operation either in natural convection mode or in mechanical ventilation mode. In the first stage, the investigations of thermal conditions inside them under natural convection were carried out. The difference between temperatures at the inlet and outlet of solar collector was more then 15 K on sunny days. In the natural convection mode the collectors can be used only for heating of the lobby. In mechanical ventilation mode the preheated air can be supplied to all rooms in the building or to the thermal storage. This operation mode will be studied in the next stage. The results of the research will be valuable for investors and designers of such systems.

ACKNOWLEDGEMENT

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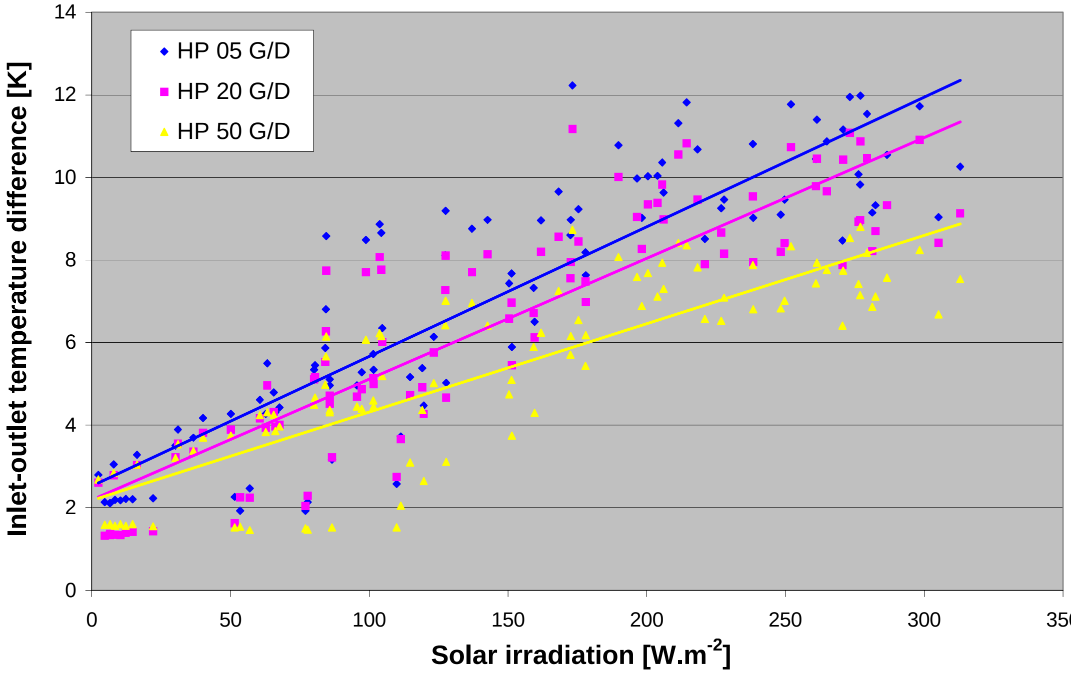

Fig.8 Correlation between solar irradiation and inlet-outlet temperature differences

7. References

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