**Summary**

In today's low-energy houses, the high degree of heat insulation has reduced the transmission heat requirement for buildings to such an extent that the ventilation heat requirement is steadily gaining in importance. This makes up about 35-40 % of the total heat requirement in modern low-energy houses.

A major step in reducing the ventilation heat losses is the installation of mechanical ventilation system with heat recovery in the dwelling. The heat recovery unit consists of a plate-type heat exchanger, a compact heat pump or a combination of plate-type heat exchanger with downstream compact heat pump. In these systems, the high degree of enthalpy in the exhaust air, which is cooled down to 1°C in the latter variant, is used to heat the incoming air.

An additional possibility for reducing the ventilation heat losses is the installation of a ground heat exchanger. In the winter, the thermal energy stored in the ground is used to preheat the outside air. This thermal energy is clearly accumulated solar energy, since the geothermal heat flow is negligible in the upper layers of the soil.

In the summer, the low ground temperature level is used to cool the outside air. Since it is possible here that the temperature on the inside wall of the ground pipe falls below the dew point, condensation arises, which dries the outside air in addition. This process should not be underestimated with regard to comfort, since incoming air which is cooler and drier than the outside air is very pleasant in summer.

The test ground heat exchanger, which was made for a one-family house in southern Germany, was designed with practical

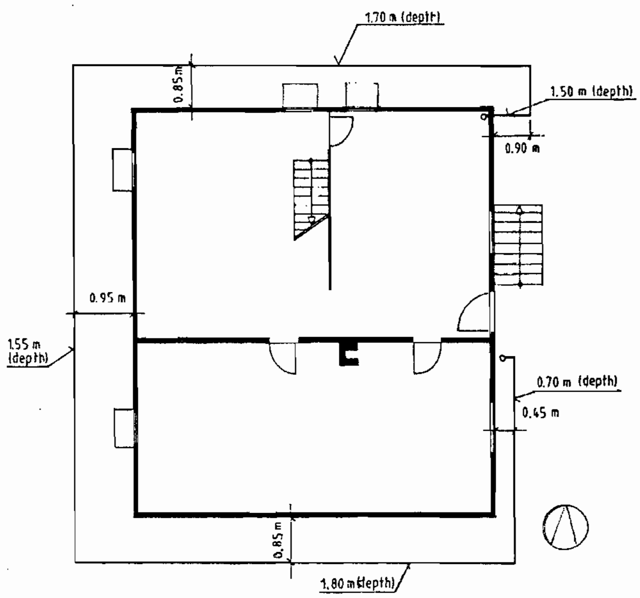


**Fig. 1 Scheme of the ground heat exchanger**

considerations in mind. Foremost among these is the minimisation of production costs. In order to avoid the need for an additional trench and the related extra cost, the ground heat exchanger was laid on the bottom of the building trench around the house. This gave a ground pipe with a length of 42 m. To take off the condensate arising in summer, a smooth, folded spiral-seam pipe was used for the ground heat exchanger, and not a ribbed pipe. It was laid at an incline of 2 %. The inside diameter of the pipe is 125 mm, and the wall thickness 0.8 mm. The position of the ground pipe with details of laying depth and the distance to the house can be seen in Figure 1.

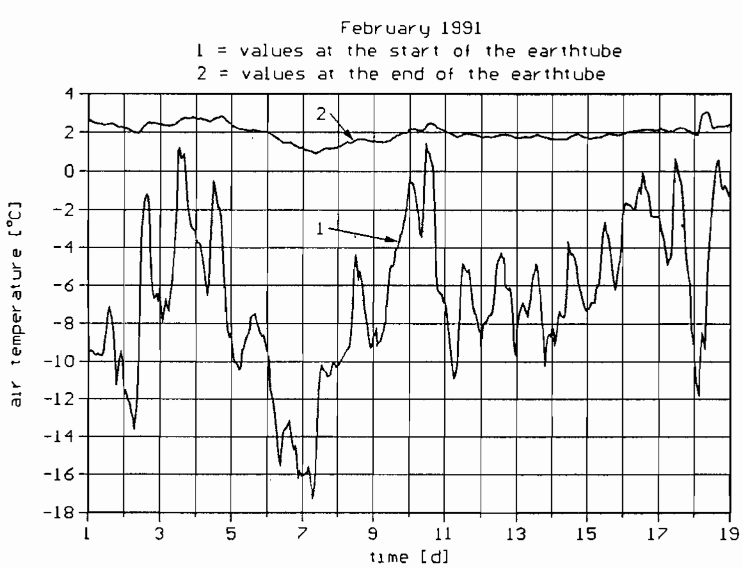


**Fig. 2 Temperature chart upstream and downstream of the ground pipe**

The functioning of the ground heat exchanger is highlighted by charts of the incoming air temperature plotted upstream and downstream of the ground heat exchanger. Figure 2 shows this for the coldest month of the past year's winter. Thanks to the high thermal capacity of the ground, an almost

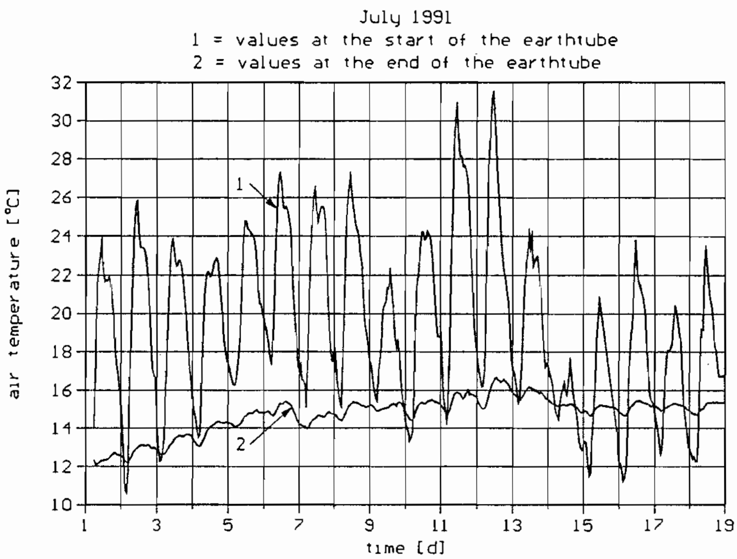


**Fig. 3 Temperature chart upstream and downstream of the ground pipe**

most constant incoming air temperature is obtained even with extreme fluctuations in the outside air temperature. In the summer (Figure 3) the picture is the same. Once again an almost constant incoming air temperature is obtained as compared with the outside air temperature. When cooling the incoming air, it is necessary to distinguish between two effects. On the one hand, this relates to the reduction of the incoming air temperature, in other words a perceptible cooling performance. On the other, when there are extremely high outside air temperatures, this leads mainly to a temperature below the dew point and hence to a drying of the incoming air (latent cooling performance).

In order to dimension ground heat exchangers as simply as possible, an analytical solution is obtained of the ground temperature field with ground-laid pipe. With this analytical approximation solution, it is possible to design the ground heat exchanger for any given project in an optimum fashion and with simple means. It is also possible to give information on the mean monthly or annual heat and cold gain. Furthermore, something can be said about the maximum and minimum incoming air temperatures downstream of the ground heat exchanger.

Many parameters which influence the heat and cooling capacity of the ground heat exchanger are fixed by the location, size and use of the house for which the heat exchanger is planned. These parameters are the temperature and heat conductivity of the ground, the outside temperature chart and the volumetric flow rate of the incoming air. Of the freely selectable parameters, only the laying depth and the length of the ground heat exchanger have an appreciable effect on the heat or cooling capacity. The investigations yield the following main design criteria.

The first criterion involves the existence of an optimum laying depth which maximizes the annual heat and cold gain of the ground heat exchanger. The fact that there is such an optimum is caused by the continuation of the fluctuations in the outside air temperature in the ground as an attenuated oscillation. This oscillation displays an increasing phase displacement as the depth increases. The optimum laying depth for the ground heat exchanger depends on the thermal properties of the ground.

The second major design criterion says that the optimum pipe length is determined by the requirement that, in winter, the incoming air temperature downstream of the ground heat exchanger should always be greater than 0°C, even with short-term, extremely low outside air temperatures. This requirement is of great importance for the serviceability of the heat recovery technology. Incoming air temperatures below 0°C would lead to an icing up on the exhaust side in the plate-type heat exchanger used for heat recovery. This would in turn considerably disturb the functioning of the ventilation system.