Air heating systems for low-energy buildings

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Central Europe is, especially in the residential sector, a region using mainly hydronic systems with static heat transfer surfaces, which operate noiselessly and with slow air movements. Cooling is – as yet – not required. This implies that air-heating systems are not very common in Austria. However, new improved building standards may change this situation, because the specific heat load is significantly reduced. In the building sector, both energy savings and a reduction in CO_2 emissions can be achieved relatively quickly.

Current situation

Since the two oil crises, significant improvements have been achieved in the thermal insulation standard for buildings in Austria: Heat transmission values have been reduced to 0.35 W/m^2K for walls, 1.4 W/m^2K for windows, 0.25 W/m^2K for ceilings, and 0.5 W/m^2K for the basement floor. For single-family houses with heated areas of 130-180 m^2, this results in a specific heat load of approximately 60 W/m^2. With a ground-coupled heat pump – in Austria usually a direct-evaporation unit – in combination with a low-temperature floor heating system using supply temperatures below 35°C, a seasonal performance factor (SPF) of 4 or even higher can be achieved.

However, these energy-efficient buildings have one problem: air ventilation. In the past, buildings were supplied with fresh air via natural ventilation, through leaks in the building envelope. The windows usually constituted the main leaks, whereas in new buildings windows are sealed. This means that windows need to be opened periodically to exchange sufficient stale air for fresh air. As Pettenkoffer stated in 1858, people will not become ill from lack of ventilation, but they will become less resistant to other types of disease.

In the Nordic countries this problem is solved by regulations which require a controlled ventilation system with heat recovery in new buildings. These regulations are based on health care and energy conservation. In Austria such regulations do not yet exist.

Further improvements in specific heat load can be made by reducing the transmission losses through the building envelope. This results in a specific heat load of approximately 40 W/m^2, consisting of 23-28 W/m^2 ventilation losses (assuming an air exchange rate of 0.8-1.0/h, as required for hygiene reasons) and only 12-17 W/m^2 transmission losses.

Heat recovery methods

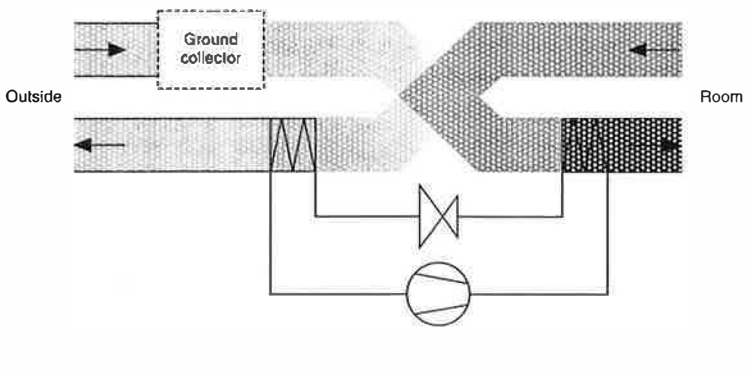
A further reduction of this load can be achieved by introducing a controlled ventilation system with heat recovery. There are generally two methods of exhaust air heat recovery:

- heat exchangers which reduce the ventilation losses by 50-90%, depending on the heat exchanger type used;
- heat pumps.

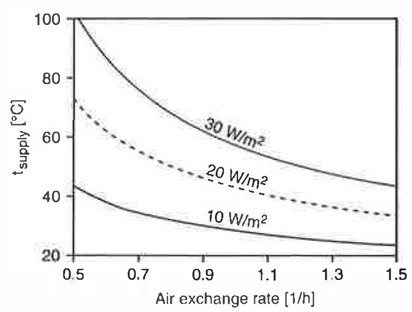
The optimum is a combination of a heat exchanger and a heat pump (see **Figure 1**). The warm exhaust air is first cooled down in the heat exchanger and then used as the heat source for the heat pump. The fresh air is preheated in the heat exchanger and then heated by the heat sink side of the heat pump.

For this concept, the air supply temperatures required to meet the overall heat load can be calculated. **Figure 2** shows these temperatures depending on the specific transmission losses and the air exchange rate. Assuming 10 W/m^2 specific transmission losses and an air exchange rate of 0.8/h, the air supply temperature required to meet the total heating demand, at design conditions of -12°C, is around 32°C. When assuming 20 W/m^2, the required temperature is 50°C.

▼ *Figure 1: Exhaust air heat-recovery system with an optional ground collector.*



▼ *Figure 2: Air supply temperature depending on specific transmission losses and air exchange rate.*



This type of operation offers ideal conditions for a variable-speed heat pump with CO_2 as refrigerant. CO_2 is a safe refrigerant, and both direct condensation and direct evaporation can be applied. Furthermore, the temperature glide at the condenser side can be used to heat air to the required temperature level without high energy losses.

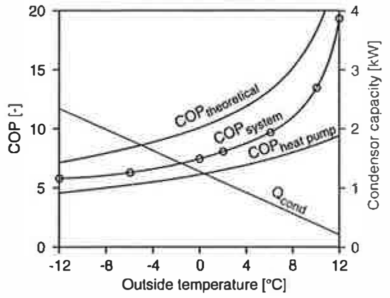
Simulations have been carried out based on specific transmission losses of 10 W/m^2 and an air exchange rate of 0.8/h. **Figure 3** shows the coefficient of performance (COP) of the heat pump unit alone, the theoretical and practical COP of the system (including the heat pump and air heat exchanger) and the condenser capacity depending on the ambient temperature. The system COP is over 5 at -12°C and around 19 at an ambient temperature of 12°C. With this type of system, seasonal performance factors (SPFs) close to 7 can be expected.

Ground collectors

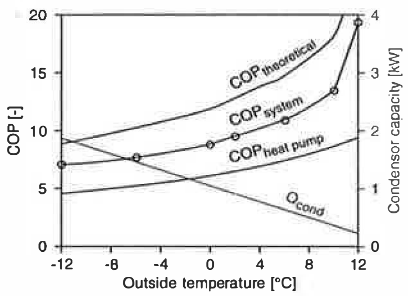
Using a ground collector would be another improvement. This type of air preheater primarily has to dampen the fluctuations of the ambient air temperature and preheat the fresh air at low outside temperature, thus reducing the heat load. For a single-family house, approximately 60 m of pipe (diameter 0.2-0.3 m) needs to be buried in the ground at a depth of approximately 1.5 m around the building. The exhaust air is cooled down first in the heat recovery heat exchanger, then in the evaporator of the heat pump. The fresh air is preheated first in the ground collector, then in the heat exchanger and finally at the heat sink side of the heat pump (as shown in Figure 1).

Figure 4 again shows the COP of the heat pump unit alone, as well as the COP of the system and condenser capacity depending on the outside temperature, this time for the improved system. The system COP is above 7 (at -12°C) and around 19 at an ambient temperature of 12°C. With this improved system, SPFs close to 8 can be expected and additionally the capacity of the heat pump can be reduced.

▼ Figure 3: Efficiency and condenser capacity of the heat pump air-heating system.



▼ Figure 4: Efficiency and condenser capacity of the heat pump air-heating system with a ground collector.



Both systems (with or without preheating in ground collectors) are suitable to meet the overall heating demand of a building by using the air flow produced by the controlled ventilation system only, without circulation air and without an auxiliary heating system. This also means a significant reduction in investment costs by omitting the conventional floor heating system. The cost savings can be used to install such a controlled ventilation system suitable for heating the building. Additionally, the internal air quality in the building will improve significantly compared to systems with natural ventilation.

Other important features of the new system are that it can be used for hot water production throughout the year, as well as for cooling, or at least dehumidification, during the summer. If this is implemented together with the hot water production, there will be no additional energy requirement.

Summary

Air-heating systems based on the controlled ventilation system with heat recovery via a heat exchanger and a heat pump seem to be the future solution for low-energy buildings. The high thermal insulation standard and controlled ventilation system provide excellent air quality, as well as high comfort levels for the consumer and a low energy bill.

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