Heat pumps

Heat pumps are used for transforming free heat from sustainable sources: air, water, ground and waste heat at a relatively low temperature (0-10 °C), to a useful temperature level (typically 30-50°C). They are used for residential and commercial rooms for heating, cooling and domestic hot water heating as well. A high number of different heat pumps exist and they vary in size, price and efficiency depending on its purpose. Most are electrically driven, but the latest developments include natural gas driven heat pumps.

Heat pumps for heating and cooling purposes in buildings can be divided into four main categories depending on their operational function:

- Heating-only heat pumps, providing space heating and/or water heating.
- Heating and cooling heat pumps, providing both space heating and cooling.
- Integrated heat pump systems, providing space heating, cooling, water heating and sometimes exhaust air heat recovery.
- Heat pump water heaters, fully dedicated to water heating.

It is considered that using heat pumps can significantly reduce CO2 emissions. In some European Countries heat pumps are treated as a renewable energy source. This allows obtaining some donation from environmental funding. A heat pump does not require chimneys or gas or oil installations, and it does not produce any pollutions or wastes in the nearby environment.

The heat pump is a machine, which can change heat from a low level of temperature to a higher one. As a low level temperature heat source the following are usually used: ground (vertical or horizontal heat exchangers), ground and surface water (open or close loop), outdoor and exhaust air. A good idea may be to use waste heat as a low temperature heat source, where the heat is transformed to a higher level of temperature by the heat pump. The heat is usually released to a central heating system or/and domestic hot water. It is also possible to make a reversible operation with the heat pump in cooling mode.

Below are shown two kinds of heat pumps: heat pump using heat from the ground and a heat pump using heat from the outside air. The last mentioned are popular in holiday cottages and patios. The one shown on the picture is connected to a small PV-plant producing the necessary electricity for running the pump.

Fig. Heat pump producing heat for 8 apartments using heat from the ground.

In the heating mode, the external fluid returns from the ground and passes through the heat exchanger. Within the heat exchanger the internal fluid is allowed to expand and change state into a gas (vaporization) drawing the heat of vaporization from the external fluid. This gaseous fluid is then pumped to the compressor which compresses and liquefies the fluid releasing the heat of vaporization into the heat sink (heating system, domestic hot water etc.). The cooled external fluid is then pumped back into the pipes running outside the house, where its temperature is lower than the temperature of the surrounding soil. It once again absorbs the heat from the ground and the cycle repeats.

In the cooling mode, indoor air is drawn through a heat exchanger where the internal fluid is allowed to expand and evaporate absorbing the heat of vaporization from the air. The gaseous fluid is then pumped to the compressor where it is compressed back into a liquid releasing the heat of vaporization into the external pipes via a second heat exchanger. The fluid in the external pipes is then pumped out into the heat field where its temperature is higher than the temperature of the surrounding soil. The soil absorbs the heat and the cooled fluid returns to the house to repeat the cycle.

Nowadays there are also heat pumps with direct evaporation and accumulation in a vertical tank. This can reduce the number of heat exchangers, pipe's connections and length of installation. This type of heat pumps usually consume less energy for pumps and compressors, gives heat at higher temperature level and because of less cost became quite popular especially in single family houses.

It can be formulated following limitation in heat pomp using:

- Because a heat pump operates most effectively when the temperature difference between the heat source and heat sink (distribution system) is small, the heat distribution temperature for space heating heat pumps should be kept as low as possible during the heating season. For example replacing conventional radiators (60/50°C) with floor heating (35/30°C) may increase COP from 2.5 to 4.0. For

more information see description of technology B.12. Low Temperature Heating System.

- It is quite difficult to control working of heat pumps. In most cases it is only possible to use an on/off kind(?) of control strategy. This is the reason for additional requirements for central heating and/or domestic hot water systems.
- Continuous access to low level temperature heat source should be provided. In some cases it may be difficult (large ground area for horizontal ground heat exchanger, lack of pond, river or lake) or expensive (cost of energy consumption of ground water pump, cost of constructing low level temperature heat exchanger).

Refrigerants should have as low environmental impact as possible - ozone depletion and global warm potential.

COP coefficient

The heat delivered by a heat pump is theoretically the sum of the heat extracted from the heat source and the energy needed to transform the heat from low temperature level to higher one. The steady-state performance of an electric compression heat pump at a given set of temperature conditions is referred to as the coefficient of performance (COP). It is defined as the ratio of heat delivered by the heat pump and the electricity supplied to the compressor (and shows how much heat is delivered by using one amount (kWh) of energy). The COP of a heat pump is closely related to the difference between the temperature of the heat source and the output temperature of the heat pump. The COP drops with the increasing of condensation temperature.
As the heat pump uses electricity it might be necessary also to take into account the amount of energy used for producing the electricity. With a factor 2,3 used for the production of electricity a heat pump with a COP of 3,0 will have a resulting energy efficiency of 1,3 (3,0/2,3). This number is called the PER or Primary Energy Ratio. This is an important aspect to consider when calculating the energy efficiency of the house and might be demanded by implementation of EPBD.

The COP of a (theoretical) ideal heat pump is determined by the condensation temperature and the difference between condensation and evaporation temperature. This number is theoretically the highest efficiency of any heat pump operating at these temperatures. The ratio of the actual COP of a heat pump and the ideal COP is defined as the Carnot-efficiency. The Carnot-efficiency varies from 0.30 to 0.5 for small electric heat pumps and 0.5 to 0.7 for large, very efficient electric heat pump systems.

Performance

The operating performance of an electric heat pump during the season is called the seasonal performance factor (SPF). It is defined as the ratio of the heat delivered and the total energy consumed over the season. It takes into account the variable heating and/or cooling demands, the variable heat source and difference in sink temperatures over year, and includes the energy demand, for example, for defrosting. The SPF also takes into account the energy use for pumps, fans, electronics etc. The SPF can be used for comparing heat pumps with conventional heating systems (e.g. boilers), with regards to primary energy saving and reduced CO_2 emissions. However SPF is very useful in practice it is quite difficult to obtain.

The performance of heat pumps is affected by a large number of factors. For heat pumps in buildings these include:

- the climate - annual heating and cooling demand and maximum peak loads;
- the temperatures of the heat source and heat distribution system;
- the auxiliary energy consumption (pumps, fans, supplementary heat from peak load heating system etc.);
- the technical standard of the heat pump;
- the sizing of the heat pump in relation to the heat demand and the operating characteristics of the heat pump;
- the heat pump control system.