DESIGN OF BUILDING HEATING SYSTEMS USING HEAT PUMPS

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Abstract. This thesis presents an overview of the design of building heating systems using heat pumps. Heat pumps are increasingly being utilized as an energy-efficient and sustainable alternative to traditional heating systems in buildings. This paper explores the principles of heat pump technology, including the different types of heat pumps and their working mechanisms. The design considerations for integrating heat pumps into building heating systems are discussed, including system sizing, equipment selection, and control strategies. The benefits and challenges of using heat pumps for building heating are also examined, with a focus on energy savings, environmental impact, and system performance. Overall, this abstract provides a comprehensive overview of the design aspects of building heating systems using heat pumps, highlighting the potential for energy-efficient and sustainable heating solutions in the built environment.

All heat pumps have a so-called refrigeration circuit, i.e. an evaporator, in which there is a liquid refrigerant with a low boiling point. The refrigerant is heated by environmental heat from the air, water, or ground and becomes gaseous and evaporates at very low temperatures. A heat pump uses technology similar to that found in a refrigerator or an air conditioner. It extracts heat1 from a source, such as the surrounding air, geothermal energy stored in the ground, or nearby sources of water or waste heat from a factory. It then amplifies and transfers the heat to where it is needed. Because most of the heat is transferred rather than generated, heat pumps are far more efficient than conventional heating technologies such as boilers or electric heaters and can be cheaper to run. The output of energy in the form of heat is normally several times greater than that required to power the heat pump, normally in the form of electricity. For example, the coefficient of performance (COP) for a typical household heat pump is around four, i.e. the energy output is four times greater than the electrical energy used to run it. This makes current models 3-5 times more energy efficient than gas boilers. Heat pumps can be combined with other heating systems, commonly gas, in hybrid configurations. The heat pump itself consists of a compressor, which moves a refrigerant through a refrigeration cycle, and a heat exchanger, which extracts heat from the source. The heat is then passed on to a heat sink through another heat exchanger. In buildings, the heat is delivered using either forced air or hydronic systems such as radiators or under-floor heating. Heat pumps can be connected to a tank to produce sanitary hot water or provide flexibility in hydronic systems. Many of the heat pumps can also provide space cooling in summer in addition to meeting space heating needs in winter. In industry, heat pumps are used to deliver hot air, water or steam, or to directly heat materials. Large-scale heat pumps in commercial or industrial applications or in district heating networks require higher input temperatures than in residential applications. The heat pump operation is based on a thermodynamic cycle. In cold weather conditions, the heat pump operates in heating mode, extracting heat from the air, water, or ground and going through the evaporator, compressor, condenser, and expansion valve to provide heating, hot water, floor heating, etc.

Functional scheme and thermodynamic cycle of mechanical compression heat pump

Mechanical vapor compression heat pump works by reverse Carnot cycle, placed in the water vapor domain, but situate above ambient temperature. Figure 1 shows the functional scheme and theoretical thermodynamic cycle of undercooling heat pump. To reduce loss caused by the lamination irreversibility, it recourses for inclusion of undercooled in the heat pump scheme with the role to reduce the temperature of saturated liquid refrigerant, below condensation temperature T_c.

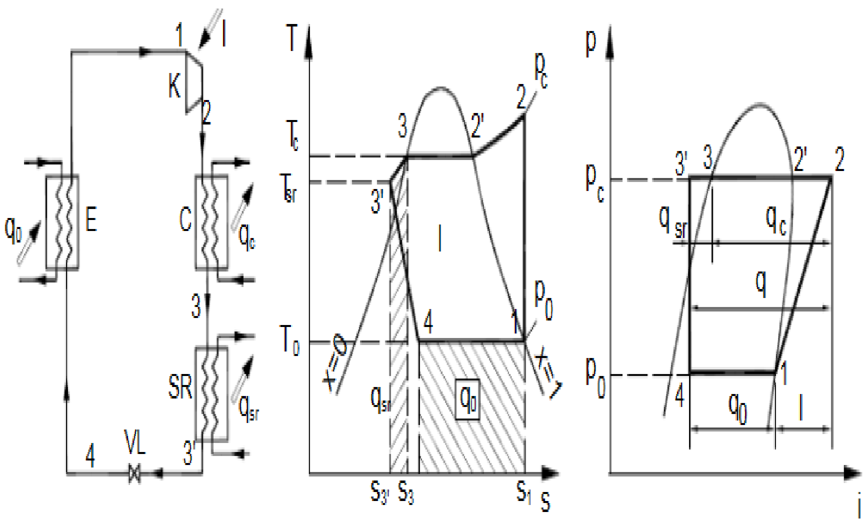

Figure 1. Functional scheme and thermodynamic cycle of heat pump with undercooling.

2-2’ – isobar cooling in the condenser C at pressure p_c from the temperature T_2 to T_2’= T_c;

2’-3 – isotherm-isobar condensation in the condenser C at pressure p_c and temperature T_c;

3-3’ – isobar undercooling in the under cooler SR at pressure p_c from temperature T_c at $T_{sr}<T_c$;

3-4’ – isenthalpic lamination in expansion valve VL, leading the refrigerant from 3’ state of the undercooled liquid at pc, T_{sr} in 4 state of wet vapor at p_0, T_0;

4-1' – isotherm-isobar vaporization in the evaporator E at pressure p_0 and temperature T_0.

In heat pumps the undercooling rank $\Delta T_{sr} = T_c - T_{sr}$ can be increased till the achievement of the ambient temperature of the refrigerant liquid, resulting a substantial reduction of loss caused by the irreversibility of the lamination process.

Calculation methodology

To calculate the design of a building heating system using a heat pump, several key factors need to be considered. These include the heating load of the building, the efficiency of the heat pump system, the COP (Coefficient of Performance) of the heat pump, and the required temperature rise. Here is an example calculation for designing a building heating system using a heat pump:

1. Determine the heating load of the building:
– let's assume the heating load of the building is 100,000 BTU/hr.
(BTU- British Thermal Unit)

2. Select a heat pump system:
– choose a heat pump system with a COP of 3.5.

3. Calculate the required heat output:
– Required heat output = Heating load / COP
– Required heat output = 100,000 BTU/hr / 3.5
– Required heat output = 28,571.43 BTU/hr

4. Determine the temperature rise:
– assume the desired temperature rise is -6.7°C.

5. Calculate the Power Input to the Heat Pump:
– Power input = Required heat output / COP
– Power input = 28,571.43 BTU/hr / 3.5
– Power input = 8,163.83 Watts

6. Check the energy efficiency:
– compare the energy input to the heat pump with the energy output to ensure efficiency.

This calculation provides a basic overview of how to design a building heating system using a heat pump. It's important to consider factors such as insulation, building orientation, climate conditions, and system controls when designing an efficient and effective heating system using a heat pump. Consulting with a professional HVAC engineer or technician can help ensure that the system is properly sized and optimized for the specific building requirements.

Conclusion

In conclusion, the design of building heating systems using heat pumps offers a sustainable and energy-efficient solution for meeting heating needs in buildings. By harnessing renewable energy sources, heat pumps can reduce carbon emissions and operating costs while providing reliable and consistent heating performance. Proper design considerations, such as system sizing, efficiency optimization, and integration with other building systems, are crucial for maximizing the benefits of heat pump technology. Overall, the design of building heating systems using heat pumps represents a forward-thinking approach to building sustainability and energy management.

References

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