Floor cooling and air-cooling, the effects on thermal comfort of different cooling systems

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ABSTRACT

One of the research areas of the Energy research Centre of the Netherlands (ECN) concerns the built environment. Several facilities to conduct research activities are at ECN's disposal. One of these facilities, are five research dwellings located on the premises of ECN. Measured data from these facilities together with weather data and computer models are used to evaluate innovative energy concepts and components in energy systems. Experiments with different cooling systems in ECN's research dwellings are executed to evaluate their effective influence on both energy use and thermal comfort. Influence of inhabitants' behaviour is taken into account in these experiments. The thermal comfort is indicated by the Predicted Mean Vote (PMV) as defined by P.O. Fanger. For this paper, the results of measurements with a floor cooling and air cooling system are assessed. Effects on the PMV measured during experiments with the two different cooling systems will be presented.

1. INTRODUCTION

Due to the increasing demand of thermal comfort, domestic cooling becomes more and more an issue in the Netherlands and other European countries. In the Netherlands an annual growth of the penetration of air conditioners between 10% to 15% is expected [1], resulting in an overall penetration of around 3.5%, in 2010. Standard compression cooling can supply comfort, but has the disadvantage of using relatively a lot of energy and large peaks on the grid. Decreasing the coolant temperatures results often in a decreasing efficiency of a cooling machine and thus an increasing energy use. The produced low temperature is often used to cool air, which is blown into the rooms that need cooling. Another way to provide cooling to a room is to use the produced low temperature to cool walls, floors, ceilings etc. This is often achieved by hydraulic circuits that can also provide space heating during the winter season.
Two ways to provide cooling to a room are mentioned:
1.) Air cooling 2.) Floor/wall cooling
Measurements in one of the research dwellings at ECN with both cooling systems, made comparison of energetic and comfort aspects possible. Main research questions to be answered by means of these measurements are:
- Which of the above mentioned ways to provide cooling to a room is more efficient?
- Which of these systems provide equal thermal comfort with higher coolant temperatures?

2. COOLING SYSTEMS AND DWELLING

The air-cooling system that is used for the measurements consists of an absorption cooler, providing coolant temperatures between 6°C and 9°C. The coolant is fed into a water-air heat exchanger, cooling the airflow to the dwelling. Because of the relative low temperature of the coolant, condensation of water vapor in the airflow will result in dehumidification of air. To be able to provide enough cooling to the dwelling, the airflow is increased by recirculation of air. The floor cooling system consists of a floor heating system that is fed with cold water from an earth heat exchanger. The cold supply water that is fed into the floor systems varies from 18°C to 23°C. A temperature below 18°C can result in condensation of water vapor on the floor and is not desirable. Both cooling systems deliver an average cooling power of around 1.5 kW. The research dwelling represents an average concrete Dutch single family house, built around 2000 [2]. Inhabitant's behavior is kept similar during measurements with the cooling systems and is based on 'the average family'. Only heat production by people, their electricity use and water demand is taken into account in the inhabitant's behavior. The thermostat was set at 21°C. Sun shading is not used during both experiments.

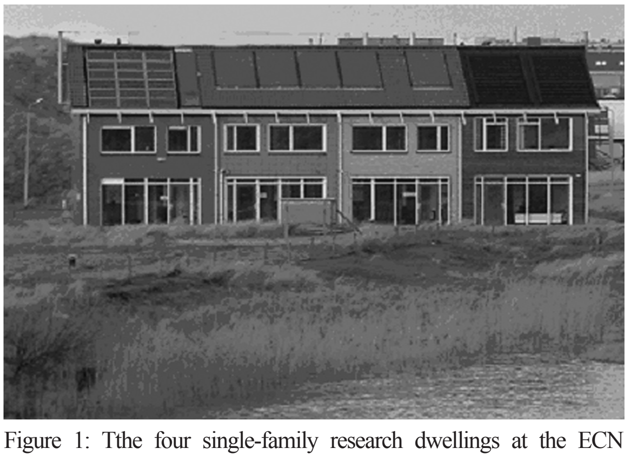


Figure 1: Tthe four single-family research dwellings at the ECN premises. The second house from the left is used for these experiments.

3. THERMAL COMFORT

The theory of Fanger [3] is used to evaluate thermal comfort. In this theory, the so called Predicted Mean Vote (PMV) is used as indicator. Inputs for the calculation of the PMV are; mean radiation temperature, relative humidity, air temperature, metabolic rate, clothing and air velocity. Details concerning the calculation of the Predicted Mean Vote, are explained in [3]. It is not within the scope of this article to explain this in more detail. Temperatures and relative humidity needed for input for the calculation is provided by measured data. The other inputs are assumed according Table 1.

Table 1: assumed constant inputs for PMV calculation

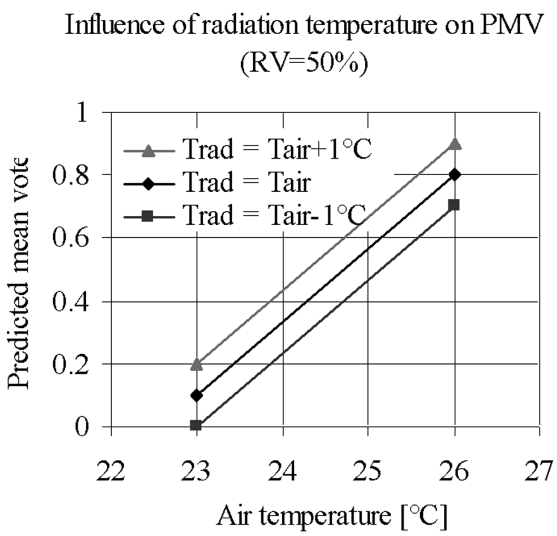
Input	Value
Metabolic rate (Domestic work)	1.7 [MET] = 98.6 [W/m^2]
Clo factor (nude=0, summer = 0.4, winter = 1)	0.4 = 0.062 [(m^2.K)/W]
Air velocity	0.12 [m/s]

The following thermal sensations are coupled to the PMV value;

Table 2: PMV and thermal sensation

-3	-2	-1	0	1	2	3
cold	cool	Slight cool	neutral	Slight warm	warm	hot

The parameters with the strongest influence on the PMV are clo-factor and metabolism. Because they are kept constant in this calculation, only radiation temperature, air temperature and relative humidity influence the PMV. The influence of these parameters on the PMV is given in Figure 2. From the measured parameters, the air temperature has the biggest influence on PMV.



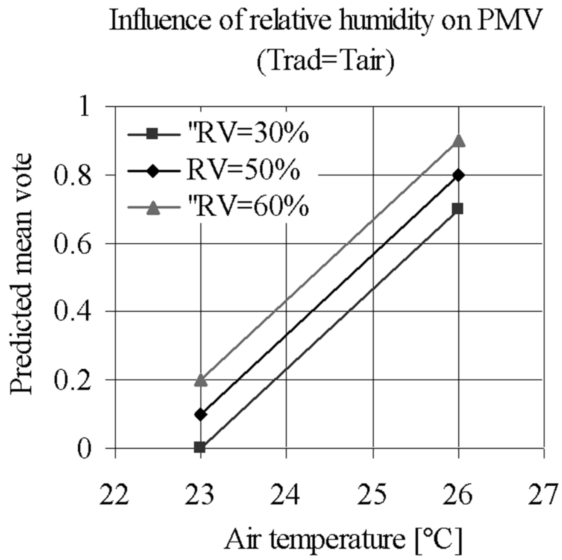


Figure 2: Influence of measured parameters on the PMV

4. MEASUREMENT RESULTS

The measurements with floor-cooling are executed in June 2004. Only one day, ambient temperatures above 25°C were measured as the graph in figure 3 illustrates.

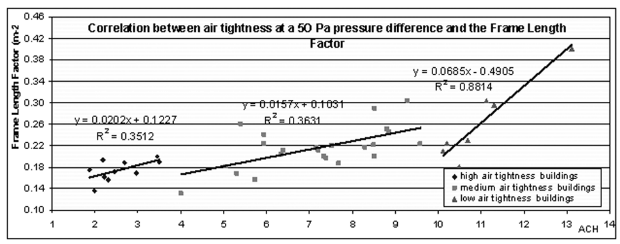


Figure 3: Solar irradiation on the south facade and ambient temperature during measurements with floor cooling

The cooling power andcoolant temperatures that were measured are shown in the graph in figure 4. During moments that the temperature reached the thermostat settings, the cooling is switched off. The same measured results with air cooling are presented in figure 5 and 6. The measurements with air-cooling are executed during September 2006. Ambient temperatures and solar irradiation were higher during this period compared to the measurements with floor cooling in June 2004. The air cooling has run continuously with supply temperatures between 6°C and 9°C.

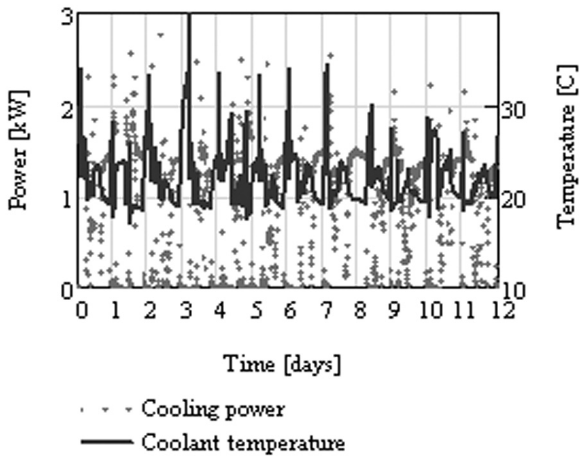


Figure 4: Cooling power and coolant temperatures during the measurements with floor cooling

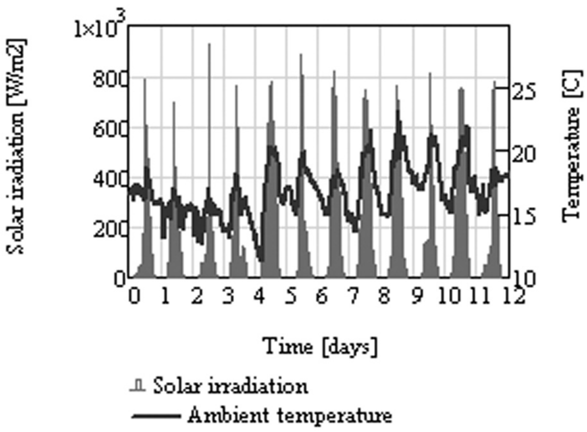


Figure 5: Solar irradiation on the south facade and ambient temperature during measurements with air cooling

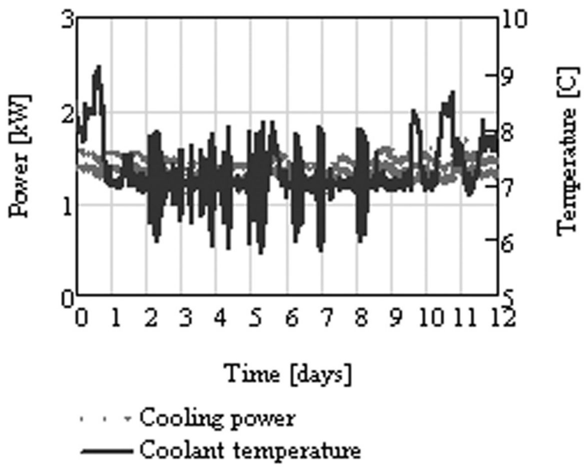


Figure 6: Cooling power andcoolant temperatures during the measurements with air cooling

5. ANALYSIS

A comparison between cooling power and coolant temperature of both cooling systems shows that floor cooling reaches comparable cooling power than air cooling, but with a 12°C higher coolant temperature. Figure 7 shows the cooling power versus coolant temperature of both systems. The higher temperature supplied to the floor cooling, shows that similar cooling power compared to air cooling can be reached. Still it is not clear if floor cooling results in more efficient thermal comfort compared to air cooling. Also, the measurements with floor cooling shows that the cooling is sometimes turned of as the air cooling has run continuously during the experiments.

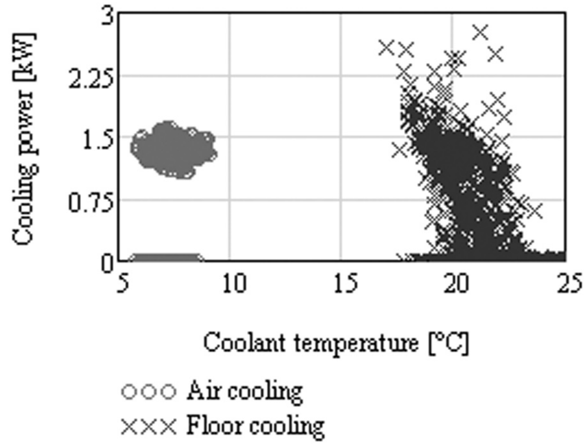


Figure 7: Cooling power and coolant temperature of both cooling systems during daytime in the living room

To examine which cooling system is more effective, measured PMV and air temperature in the living room are plotted in a graph shown in figure 8.

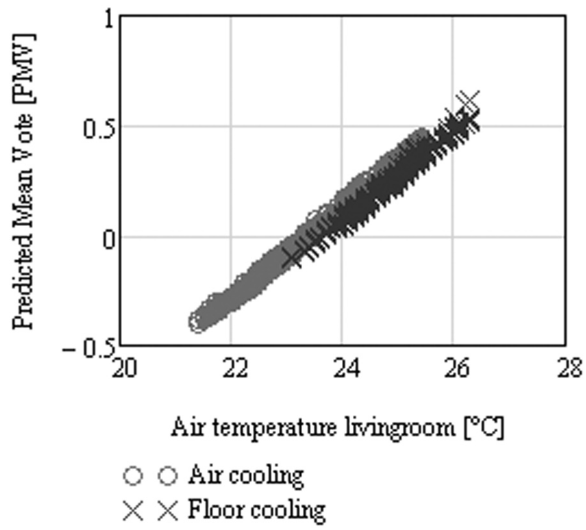


Figure 8: PMV and air temperature in the living room during daytime of both cooling systems

The graph shows that with similar air temperatures in the living room, floor cooling with a coolant temperature between 18°C and 23°C results in a similar effect on the PMV as air cooling.

6. CONCLUSIONS

Separate experiments with a floor cooling system and an air cooling system in a research dwelling that is representative for the situation in the Netherlands showed that:

- With floor cooling that is supplied with a coolant temperature that is around 12°C warmer than most air cooled systems, a similar cooling power of around 1.5 kW can be reached.
- The effect of both cooling systems on thermal comfort (Predicted Mean Vote) is similar.
- Floor cooling can reach similar thermal comfort (PMV) with a coolant supply temperature of around 19°C compared to an air cooled systems that is supplied with around 7°C.

With above mentioned conclusions, it is clear that in Dutch climate conditions, floor cooling provides similar thermal comfort compared to standard air cooled systems while it operates at much higher coolant temperatures.

REFERENCES

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