WATER TRIPLE POINT HEAT PUMPS FOR DANISH HOUSES

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Abstract
Heat pumps and more efficient power stations can reduce fossil fuel used for heating Denmark. Conventional lawn evaporator heat pumps are not cheap. Forcing triple point water to vapor and slush ice can make a better system. A numerical model of a modern house was combined with meteorological data from July 2003 to June 2004. Result from simulation was that approximately 17 tons of slush ice was stored somewhere in garden in February and would have melted in April if ambient air velocity had been 0.5 meter/s or more. Technology level of the heat pump will be comparable to modern vacuum cleaners and not very expensive. Coefficient of Performance can be ~5 over a year and this can make water triple point heat pumps (WTPHP) a cheap way to heat Danish Houses.

Key Words: ***Water triple point, vapor compression, heat pump***

Introduction. Roughly one fifth of fossil fuel used in Denmark in 2003 was expensive distillate oil and natural gas used for heating houses, schools and farms, that could not be supplied from the numerous district heating systems around power stations. Oil and gas can be used for more rewarding purposes and CO2 emission is an issue making more heat pumps a must and not an option. Figure 1 shows outside air temperature from July 2003 until June2004 every hour close to the city of Aalborg.

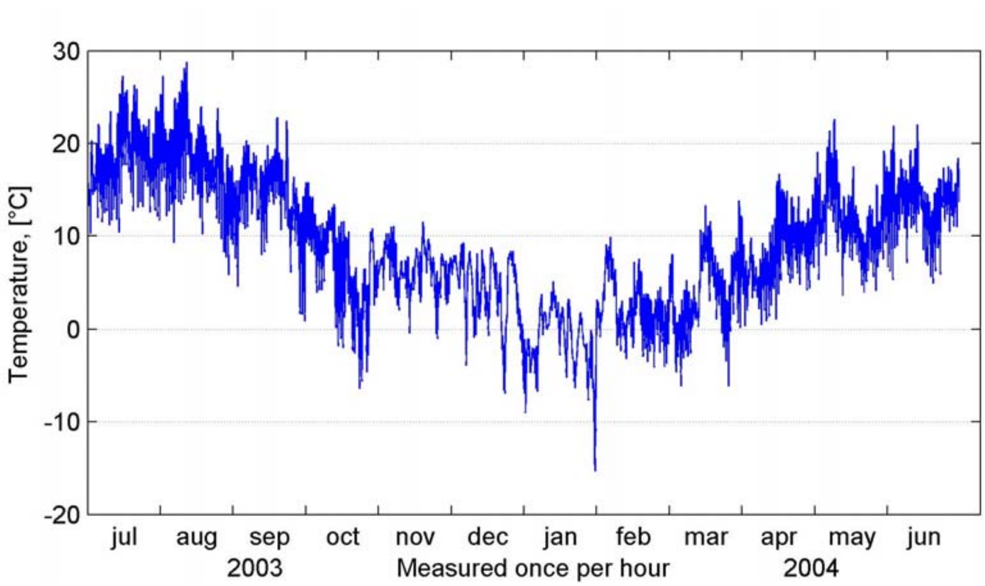

Figure 1 Air temperature at Tylstrup (Danish Metrological Institute)

Danish winters are dark, wet and windy but not very cold.

Building power stations, high-tension lines and heat pumps for the few frost hours will be overkill. It is better to design for zero °C outside and add extra heat with Liquefied Petrol Gas (LPG) burners when temperature goes under this. LPG can also be used for warming hot tap water (120 kg per day) from whatever the heat pump can supply up to 45 °C. Most new Danish houses are built with floor heating systems and the regulations concerning insulation make it normal that 4 kW supplied as 26 °C water can keep an average new Danish house comfortable when outside temperature is zero. Analysis of district heating station outputs shows that outside temperature and to a small extent solar radiation are the only necessary inputs for numerical simulation of heat demand of Danish houses.

1 WATER TRIPLE POINT HEAT PUMP IN AUGUSTENBORG

Mr. Villadsen received a patent (DK priority 1653/81) in the early eighties for a heat pump cycle where small water drops are divided (by removing surrounding vapor) from triple point condition into slush and water vapor .A 2MW test plant was built as first stage of a gas motor driven Freon 12 heat pump plant for the district heating system of Augustenborg.

The slush was pumped back to the Fjord from where the feed water came and melted with no measurable effect on the nature.

The water vapor was compressed to 4 °C pressure. The ensuing condensation of water vapor evaporated Freon 12. The plant was scrapped 2004 due to some strange tax reasons but was the most efficient natural gas consuming heating system in Denmark during its existence. Vapor was only compressed to 4 °C because turbo compressors for higher-pressure ratios were unavailable. The selected radial compressor came from a desalination company in Israel.

2 WATER TRIPLE POINT HEAT PUMPS FOR DANISH HOUSES

Compressing 4 kW steam from triple point to 26 °C is a high volume/low-density job best done by turbo-machinery. Axial turbo-compressors can be designed but are not easy to manufacture. This leaves radial compressors as the type of choice. Available materials for radial turbo-machinery can tolerate a tip speed around 500 meter/s. This means that a single stage radial compressor for water vapor can give a pressure ratio around 2.4. The pressure ratio from triple point to 26 °C is (3360Pa/611Pa) ~ 5.5. Two radial compressors working in series can do the job and Figure 2 shows a possible system.

Compressor isentropic efficiency is needed to estimate the performance and an expert recommended 0.68 for this application. Efficiency of the electric motors is likewise set to 0.85. This gives a COP of ~5 for a year including water circulation and vacuum pumps.

Switched reluctance electric motors are used in novel vacuum cleaners where power level and RPM is comparable to the present task. Their integrated power electronics make it easy to vary RPM and thus the power and temperature of the heat pump output. The first compressor stage can be made of aluminum like the air compressor in a diesel turbocharger. The second compressor delivers superheated steam at over 200 °C and material must be more heat resistant than aluminum. It is only 80 mm in diameter and it is probable that cost of the heat pump core parts and power electronics will be less than the cost of three vacuum cleaners and the volume is not much bigger than two.

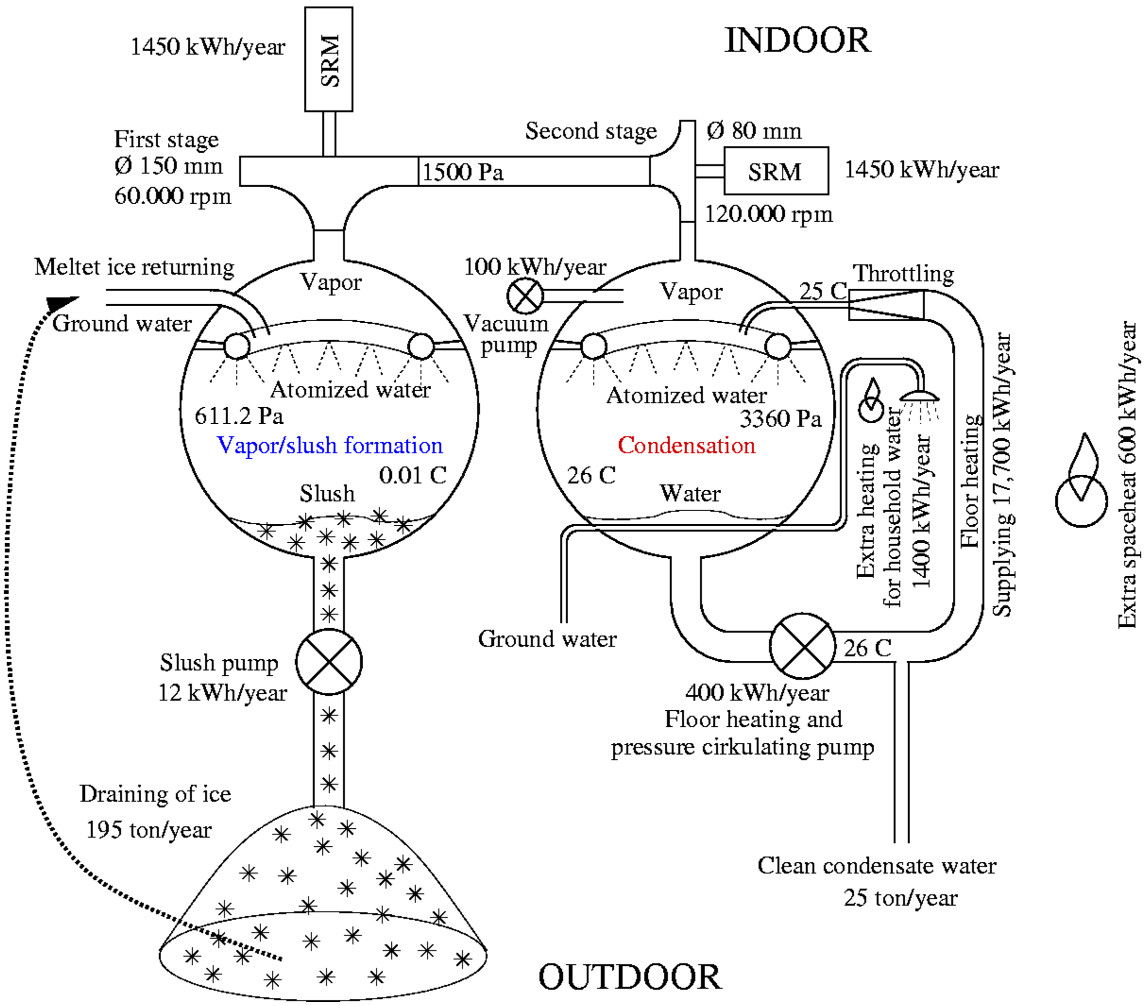

Figure 2 Water triple point heat pump

3 SLUSH IN GARDEN

Figure 2 shows that a Danish house with a WTPHP generates approximately 195 tons slush ice and 25 tons of very clean condensate per year.
It will also burn approximately 160 kg of LPG for extra tap water and space heating.
An experiment showed that 0.9 kg of slush melts per hour/m2/°C when air blows over with more than 0.5 meter/s. The re-melted water can either be fed to the heat pump again or used for toilets, washing machine etc.
A Danish family uses around 120 tons of clean groundwater per year but fertilizers and pesticides are making much of it unfit for drinking. The condensate from Augustenborg was remarkably pure considering that feed-water came from a brackish fjord surrounded by efficient and industrious farmers. Condensate from a WTPHP (25tons/year) will be fit for drinking, cooking and dishwashing if calcium, fluor etc is added for taste and health reasons. Slush from the heat pump will be pumped out to the garden and placed as a round pyramid with a height equal to one third of the diameter and figure 3 shows amount of accumulated slush during a year if air blown with at least half a meter per second (when outside temperature is higher than zero).

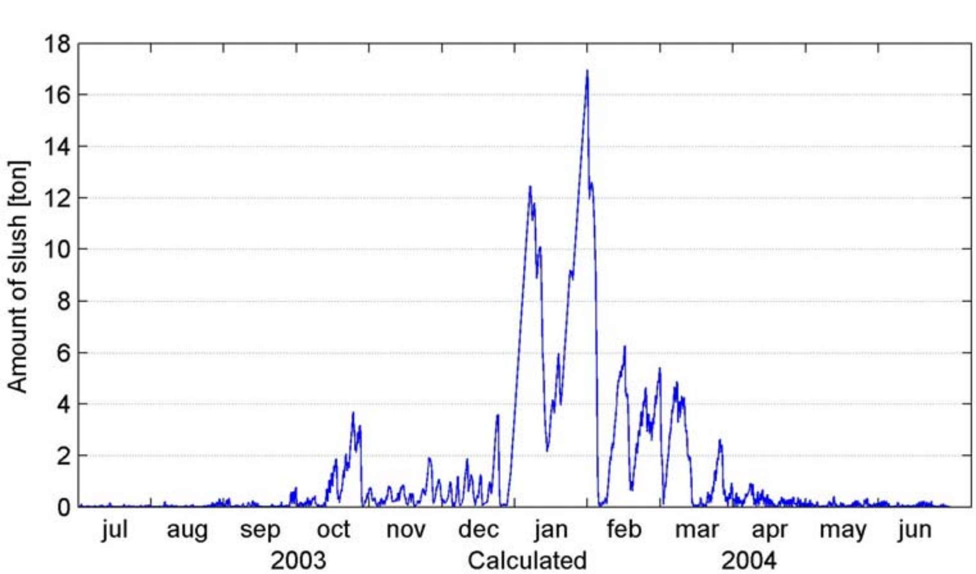

Figure 3 Amount of un-melted slush in garden of a modern Danish one family house

4 CONCLUSION

Combining the temperature data shown in figure 1 with a demand of 4kW at zero °C and 120 liters of 45 °C water per day (July 2003-june2004) and assuming 0.9 boiler efficiency makes 1700 kg oil worth € 490 necessary.

The heat pumped house would have drawn electricity from a coal-fired power station having an efficiency of 0.45 and through a grid that wasted 7 % .The corresponding values are (950 kg coal +160 kg LPG) worth € 133.

Prices are January 2005 without tax and give a true picture of cost to Danish society. Danes pay roughly 10 times the raw cost for electricity but do not care too much about getting old, ill or lonely. It is totally misleading to compare merits of different technical solutions based on prices with Danish taxes but the real money going out of Denmark for fossil fuel is the single most dangerous threat to our welfare-system. Denmark was very close to being bankrupt in 1982 and was only saved by collapse of the OPEC production limit agreements and because oil and gas was found in the Danish part of the North Sea. This oil and gas will be gone in 10 to 15 years and at any rate deserves better than being burned in houses.

One future course is to build 5 kW nuclear power capacity/transmission lines and electric heating panels and another is to have 1 kW nuclear power generating capacity/transmission lines and floor heating/WTPHP per house. Five kW of nuclear power station is worth € 8745. Five kW Danish transmission grid is worth € 8755 and five kW electric heating panel is € 500. Fuel cost is insignificant and maintenance costs of the systems are comparable. Conclusion is that a WTPHP and floor heating system must have an untaxed cost of less than € 14500 per house to be an option.