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1. Péter KORZENSZKY, 2. Gábor BÉRCESI, 3. László BENSE, 4. Gábor GÉCZI

IDEAL OPPORTUNITIES FOR AIR TO WATER HEAT PUMP APPLICATION

1-2. Szent István University, Gödöllő, Faculty of Mechanical Engineering, Institute of Process Engineering, Department of Metrology, HUNGARY
3. Szent István University, Gödöllő, Faculty of Mechanical Engineering, Institute of Mechanics and Machinery, Department of Agricultural Machinery and Food Engineering, HUNGARY
4. I Szent István University, Gödöllő, Faculty of Mechanical Engineering, Institute of Environmental Systems, Department of Environmental Engineering, HUNGARY
2100, Gödöllő, Péter k. u. 1, HUNGARY

Abstract: The air to water heat pumps require more place on the market. They are even able to heat a flat or an office building in winter time, or produce the needed amount of hot water supply. The extension of heat pump applications is happening because we recognized the fact that it is based on a renewable energy source. At least at the COP value (*Coefficient of Performance*) it is operating at. At Hungarian climatic conditions swimming pool technology and fish farming is searching for energy sparing solutions for pool heating and tempering. Thermal water can be a good solution in both cases, but its utilization has territorial obstacles. Sun collector utilization is not a safe solution taking the Hungarian meteorological conditions. Natural gas and electricity is available everywhere in the country, but its usage has economic aspects. In case of swimming pool technology the usage is more convenient with application of heating system. This way the risk is decreasing at fish farming, and the breeding possibility is increasing as well at water tempering. In this paper we present ideal opportunities for the application of air to water heat pump by analysis of COP and energy consumption.
Keywords: heat pump, COP, swimming pool, fish farming

1. INTRODUCTION

Renewable energy source utilization can be found in education and in practice at the Faculty of Mechanical Engineering, Szent István University (*Gödöllő, Hungary*). In 2005 a 9.6 kW photovoltaic power plant based on a 150 m^2 surface solar cell was installed. In 2012 the new multifunctional education building the Knowledge Transfer Centre was opened and supplemented with a new heat pump heating system (Gergely et al., 2013; Seres et al., 2009).

The Central European researches of the last years prove that solar systems are the most popular at individual heating systems out of other applicable renewable energy sources (Ostrowska et al, 2013; Rózycka, 2009; Zelena, 2013). Besides the solar systems, the geothermal energy consumption is gaining more popularity for heating of houses and for hot water supplies (Hepbasli and Kalinci, 2009; Milenic et al., 2010; Naár et al., 2013; Rózycka, 2009; Rybach and Sanner, 2000). There are ongoing researches for waste heat utilization in mixed fuel boiler (Chinese et al., 2005; Piecuch et al., 2009; Tillman, 1991). Those results have to be mentioned as well, which do not exclude the effective utilization of electricity (Dudkiewicz et al., 2013; Szkarowski and Kolienko, 2013). Practically heat pumps can be put in this group.

The heat pump is actually a refrigerator, because we distract heat from our medium, but the most important is that we utilize this heat. At heat pump utilization the heat distraction happens from the lower temperature place (soil, water, air). The heat is transferred to a higher temperature place. This can only be done with energy investment. (Dexheimer, 1985; Randy et al., 2011; Reay and Macmichael, 2008; Sanner et al., 2003).

Air to water heat pumps utilizes the heat of ambient air (evaporator cools ambient air). On condenser side heat utilization prevails, which is used for heating water (Dexheimer, 1985; Lund, 1988; Reay and Macmichael, 2008). The efficiency and conformance of heat pumps can be defined with the performance factor (COP). The COP is the ratio of heat performance, $\dot{Q}_h$ [W] and used electrical performance P_w, [W].

$$COP = \frac{\dot{Q}_h}{P_w} \quad (1)$$

The value of COP is defined by vaporization and condenser temperature. In our case it can be described with environmental air and pool water temperature. It is evident that at lower air temperature and/or higher water temperature the efficiency of the heat pump is lower as well. The proportion of this lower performance cannot be defined by COP value (mostly defined for ideal cases by the manufacturers).

With taking water temperature into consideration specific heat c_p, [J·kg^{-1}·K^{-1}] and density ρ, [kg·m^{-3}] values can be defined from specific tables. The volume flow $\dot{V}$, [m^3·h^{-1}] and water temperature difference of heat pump $\Delta T_{heatpump} = T_{out} - T_{in}$, [°C] can be measured. On the basis of that the current heat performance can be defined:

$$\dot{Q}_h = c_p \cdot \dot{V} \cdot \rho \cdot \Delta T_{heatpump} \quad (2)$$

We show the current COP values on Table 1. as a function of ambient air and water temperature. The results state the known principle: the decrease of ambient air temperature and/or the increase of pool water temperature results in lower current COP value. However, it can be seen that if we want to ensure 20 to 25°C water temperature that it can be reached in the spring and autumn period also effectively utilized by the air-water heat pump.

Table 1. COP of Microwell HP700 as a function of ambient air and water temperatures

COP		T_{air} [°C]		
		15	20	24
T_{water} [°C]	15	5.34	5.81	6.29
	20	5.12	5.50	5.73
	25	4.83	5.21	5.55

Source: Microwell Hungary Ltd.

At Hungarian climatic conditions the outside swimming pools of hotels, pensions and family houses can only be comfortable with heating them in spring and autumn time. The heating of pools makes appropriate conditions for fish farming as well. In outside pools (ponds) the breeding period can be shifted, better possibilities can be provided for the fish. On the basis of the two mentioned examples in 2013 we examined the heating up and tempering of pool water with an air to water heat pump. With our research we would like to prove that the utilization of air to water heat pumps is favorable in energetic aspects and a gives cost efficient and environmental friendly solution.

2. MATERIALS and METHODS

The measurements were carried out in Budapest at an 8.0 x 4.0 x 1.40 meter overflow system private pool at the start of the season just a few days after filling the pool. There are two alternative solutions in use for the heating of the water. One of them is a solar cover, where the heating effect is caused by the improved absorption of solar radiation and the inhibition of evaporative heat loss. The other is a HP700 type air to water heat pump (7 kW nominal heat output), which is installed on the filter-circulation system. It is capable of ambient air cooling and heating of the pool water.

he pool technology is presented in Figure 1. We indicate the measurement points, which make it possible to determine the actual COP value. The COP can be calculated with equation 1. The heat output can be determined from the change in water temperature (eq.2). It can be measured immediately before and following the heat pump directly.

The water temperatures were measured in the pool and before and after heat pump with an ALMEMO 2590-9 temperature measuring instrument (Ahlborn, Holzkirchen, Germany) and K type NiCr-Ni thermocouple. The volume flow ($\dot{V}$ = 6m^3·h^{-1}) was set by opening of the bypass line and checked by measuring the amount of water. The specific heat c_p=4.182 – 4.184kJ) and density values (ρ = 997.5 – 998,5 kg·m^{-3}) were obtained from table of literature as a function of temperature of the water (T_{water}=18.5 – 22.1°C). The electrical power consumption (P_w=1.41±0.03kW) was measured with an Actaris SL7000 (Ganz Mérőgyár Kft., Gödöllő, Hungary) ower meter.

On the Department of Aquaculture of Szent István University, Gödöllő we heated 10 m^3 water with the before mentioned HP700 (Microwell, Šaľa, Slovakia) equipment to the desired 20°C and we tempered water temperature on this desired temperature for a month in October, 2013. During the experiments we used the before mentioned ALMEMO 2590-9 (Ahlborn, Holzkirchen, Germany) measurement and data collector system and collectable sensors.

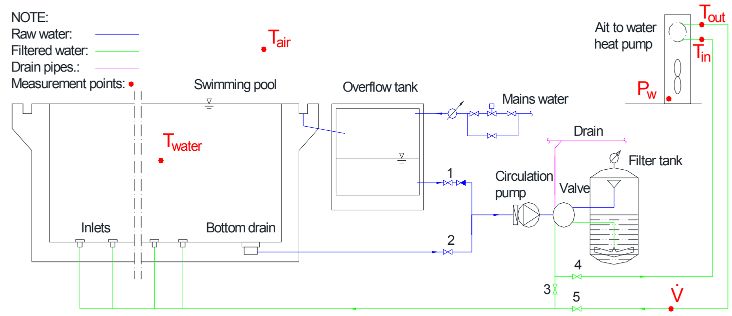

Figure 1. Technology flow diagrams. Source: Kerex Óbuda Ltd.

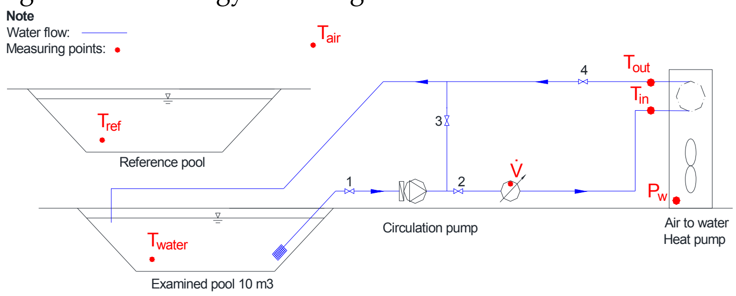

Figure 2. Tempering of outside pool with 7 kW heat pump

Similarly to the swimming pool examination, pool water temperature T_{water} [°C] and environmental air temperature T_{air} [°C] was continuously measured. Inner and outer water temperature T_{in} and T_{out} [°C] and water volume flow was measured as well for the description of heat pump efficiency. In this case the volume flow was measured by ARAD Woltman Silver Turbó (WST model, Arad Hungária, Miskolc, Hungary) mechanic flow meter and was adjusted to $\dot{V} = 65$ l/min with the closing of the returning branch. The water was kept at a constant temperature. We measured the current (I_c, A) and on the basis of the value heat pump operating time can be described as well.

3. RESULTS and DISCUSSION

The measurement results of 10th May are presented on Figure 4. The surface of the pool was open, the solar cover was not used. The water circulation and heat pump operation started at 8:00 and lasted until 20:00. The measurement was not disturbed by rain and the average humidity was 50.52%. It can be seen in Figure 4 that the pool water temperature is constantly rising when the heat pump is operating. The change of the curve's slope shows the COP change, too.

The current COP – determined by measuring of parameters for equations 1 and 2 and counting – are shown on Figure 3. The current value varies between 3.54 and 5.56 depending on the environmental conditions. The HP700 heat pump can characterized as having $COP_{average}$=4.97 in the illustrated two times 12 hour period.

The examination of fish pool tempering was carried in October, 2013. The extreme weather helped to gather information at different outside conditions. Fig.6 shows the situation at 9–13 October. At the first day, 9th October, night time temperature was under 10°C and the daytime temperature reached 15°C. The second day was a rainy day, and after it the weather became warmer, maximum air temperature exceeded to 20°C. Heat pump operation is shown on Fig.6 on the basis of electricity consumption. The circulation pump was operating continuously, which meant 1.6 A current consumption. Beside the circulation pump, heat pump operation can be seen at 5.8 – 7.3 A current consumption. The evolved "saw" diagram shows spectacularly how many times and for what time interval heat pump operation was needed.

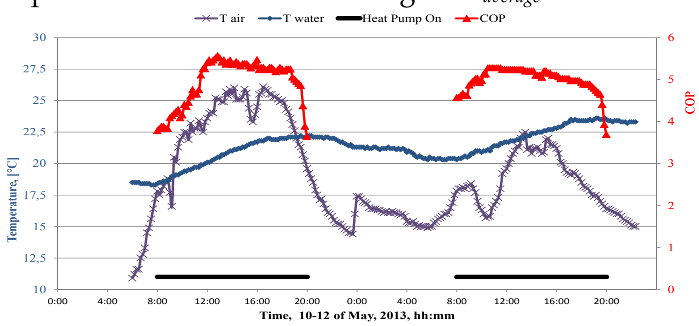

Figure 3. Air and pool water temperature as a function of time from 6 am until 22 pm

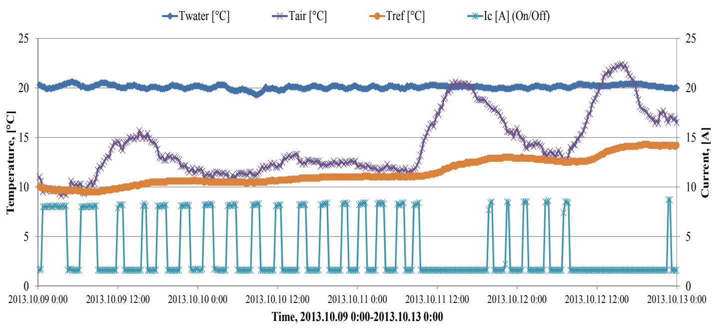

Figure 4. Changes in water and air temperature as a function of the time

For the presented 4 days it can be said that pool temperature can be kept on an average temperature 20.0±0.3°C at 14.3°C environmental temperature. (For comparison: the temperature of the reference pool was 9.5 – 14.9°C.) The heat pump switched on 23 times for 0.5 – 3.5 hours intervals, and it operated for 36 hours. This meant 49.68 kWh energy consumption by 1.38 kW mean electrical performance. The COP value was 3.62 – 4.51.

It is clear that the heating and tempering of pools is a surplus cost in case of the breeding and at comfort increasing. However, the larger fish production, the security or even the possibilities and comfort can be effective. In Hungary the utilization of air to water heat pumps means 30% cost saving against gas furnaces if the breeder chooses tempering. It must be mentioned that heat pump application means approx. 45% CO_2 emission decrease compared to fossil fuel usage. (Calculated emissions are at 0.56 $kgCO_2/kWh$ electric energy and at 1.96 $kgCO_2/m^3$ natural gas value. The heating performance of natural gas is $9.44 kWh/m^3$).

According to experiences up to the present, it can be stated that the ideal utilization field for air to water heat pumps are fish farming systems, pool technology and water tempering. In spring and in fall time, air temperature (evaporator temperature) is already/still (T ≈ 12-20°C) and pool temperature (condenser temperature) is ideal (T ≈ 20 – 24°C) for heat pump application.

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