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Energy Saving Possibilities for Swimming Pools

Bohumil Šťastný[1], Kateřina Slavíčková[2] Blanka Ježková[3]

[1] Associate Professor, Czech Technical University in Prague, Faculty of Civil Engineering, Department of Sanitary and Ecological Engineering, Czech Republic

[2] Dr., Czech Technical University in Prague, Faculty of Civil Engineering, Department of Sanitary and Ecological Engineering, Czech Republic

[3] P.G. Student, Czech Technical University in Prague, Faculty of Civil Engineering, Department of Sanitary and Ecological Engineering, Czech Republic

stastny@fsv.cvut.cz

Abstract

Swimming pools and aqua parks are big consumers of energy. This article deals with energy saving methods and renewable energy sources which it is possible to use at swimming pools and aqua parks. The main possibilities in energy savings are associated with heating of swimming pool water and also with heat losses prevention. An example of renewable energy source, the heat pump which is used for warming the water for swimming pool is discussed in this article. It is air-source heat pump which uses a waste heat from an engine room. The influence of this heat pump on engine room temperature and energy savings are evaluated in this article.

Keywords: energy saving, swimming pool, heat pump.

Introduction

The process of water treatment for swimming pools, pumping of the water, warming the water and optimal heating of the objects need big amount of energy. The energy-saving design and operation can save the costs of the swimming pool.

Energetic management and optimization can help to decrease the energy consumption and it leads to lower costs. The consumption of electric energy, due to the water pumping, represents important part of consumed energy - the use of optimal pump can enable the reduction of energy consumption, together with optimization of the pumping operational procedures. Technologies which are used during water treatment can influence the energy consumption and also the costs. If a reconstruction of the technology is planned, it is important to compare the possible solutions according to the investment costs but also according to the operational costs. The use of new more effective technologies is important but in some cases the optimisation of the whole treatment process can lower the consumption of chemicals and energy and also the costs. Application of monitoring and control system can lower the costs of treatment process. Energetic management and optimization is also important for all parts of water treatments plant for swimming pools.

Energy savings suitable for pools are for example in lowering the loss of heated swimming pool water by covering it when the pool is not used because the greatest influence on the loss has water evaporation enhanced by airflow over the surface of a pool. It is important to consider durability, ease of taking on and off, price, warranty, material transparency, insulation value, storage need, and safety when choosing a cover. Energy gained from renewable sources can be used to partially cover the need of swimming pool. Photovoltaic panels are used for the direct conversion of sunlight into electricity. They can be installed on rooftops and other surfaces in swimming pools or aqua parks.

Water micro power plants (water turbines) and small hydropower plants can be installed in water systems and use energy of water for the production of electricity. Hydropower can be obtained in places where is falling stream of water with two necessary assumptions - the flow and momentum. Small hydro capacity is usually in the range from 20 to 500 kW.

Wind turbines enable to generate electricity using wind energy but this method of obtaining renewable energy for swimming pools and aqua parks is not very

common, because wind turbines need suitable conditions for their installation.

The heat pump (HP) is known as an energy- saving equipment with higher investment costs, but more inexpensive operation. This device uses the thermal energy of low- heat accumulated in the environment in air, water or soil, or uses waste heat from used water or air and this unusable low-temperature thermal energy is transformed into usable forms with higher temperature. These pumps operate on the principle of adsorption heat at one location, its transfer and release in another place.

Renewable energy sources like solar energy or heat pumps at swimming pools can be used for heating the swimming pool water, water for showers and heating of the objects. The energy consumed by the operation of the pool is used for four main purposes - heating and ventilation, water heating, transport and technological processes of treatment of pool water and lighting.

Brookhaven National Laboratory (BNL) conducted a study, for National Grid to measure the performance factors associated with gas-fired and electric heat pump swimming pool heaters in order to assess the relative energy, environmental and economic consequences of using one technology in comparison to the other. It has illustrated the measurable operating energy cost reductions with the use of heat pumps in comparison to gas-fired units. [1]

The energy efficiency of heat pump swimming pool heaters is measured by coefficient of performance (COP). The higher is the COP number, the more efficient the heat pump is. However, there is no standard test for measuring the COP. Therefore, it is not really possible to compare the COPs of different models unless we know that the manufacturers used the same test for each model. For example, the same heat pump will operate at a higher COP when the outside air temperature is higher. [2]

Energy savings during swimming pool water heating by heat pump

The aim of experimental part of this article is to show measurement of profitability of water heating by heat pump that uses the waste air from the engine room. It covers suitable heat pump choice and its location in engine room, measurement of temperature drop in engine room and evaluation of the results of the measurements and cost savings. The measurements were realized at Aqua park Aquadream in Prague.

Choice and principle of a heat pump which is used for experimental measurements

The heat pump works on the principle of a closed cooling circuit, wherein a suitable refrigerant is used for power transmission. Heat is collected on one side and on the other is transmitted. It is based on the fact that the boiling point (or condensation) of different substances depend on the pressure. This process is provided by four basic parts of the cooling circuit: an evaporator, compressor, condenser and expansion valve. The primary medium (in this case it is air, but it can be also water) heats the liquid refrigerant in the evaporator, where it evaporates due to the low pressure. The refrigerant in the gaseous state goes to the compressor driven by an electric motor which delivers an additional energy to refrigerant by compressing it and also heats it. Subsequently, the refrigerant enters the condenser, where it is cooled and it transfers the heat during the condensation to other medium, for example the swimming pool water. The refrigerant pressure is then reduced by the expansion valve to the default value for the re- transfer of energy in the last part of the circuit. [3]
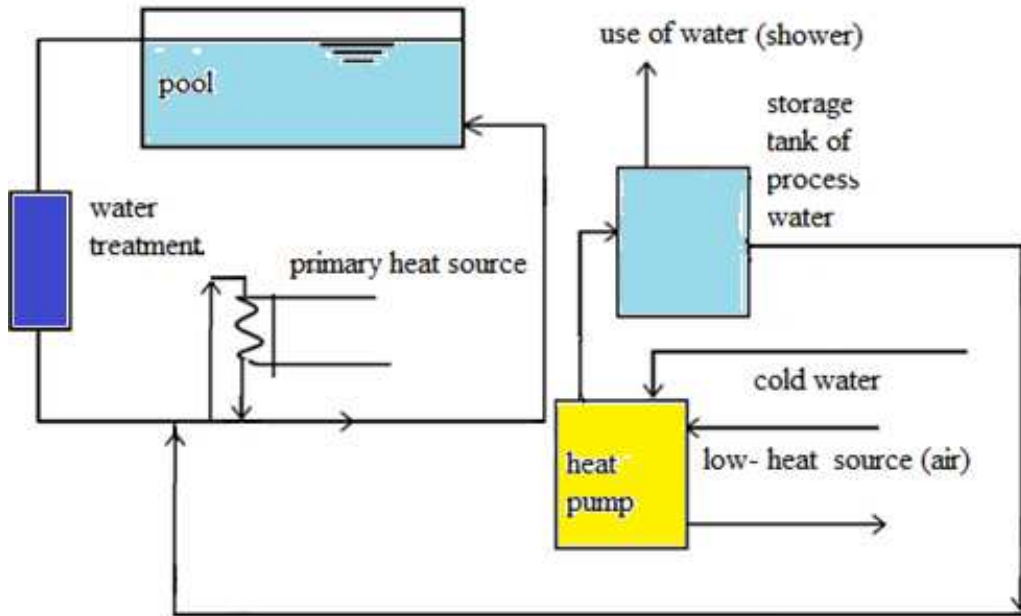
Figure 1. Scheme of swimming pool water heating and process water heating by heat pump

An example of swimming pool water heating and process water heating with the use of heat pump in combination with central heating with heat exchanger is at Figure 1. Two locations for heat pump optimal placement in the engine room were tested and temperatures were measured. The placement of heat pumps is at the Figure 2
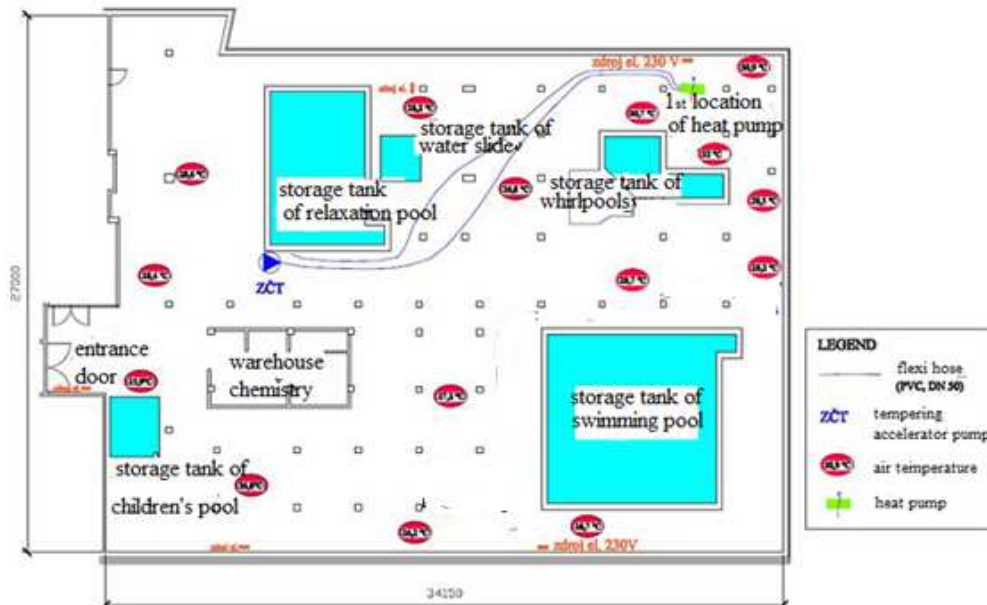

Figure 2. Scheme of the heat pump (air/water) location in aqua park engine room

Relaxation pool circuit has second greatest water circulation volume – in total 259 m3 with constant average temperature about 30 °C (between 29-32 °C). Circulating water is vulnerable to temperature lost, that can reach up to 7.2°C per day (0.3°C/hour). The losses are mainly caused by two water slides, that are in operation 12 hours a day and by other attractions that cause evaporation and therefore temperature transfers to hallway area.

The heating is provided either by heat pump or by heat exchanger. The heating is operated manually, by valves on primary heating water circuit. Heat pump is connected to the outer circuit (bypass) of pool-water heating system. So it is substituting heat exchanger, which function is to transfer heat between „heating water" (heat gradient 90/70 °C), from central heat supply, and pool water.

If we compare output of installed heat exchanger, 209 kW and heat pump maximum possible output 30 kW, we will see that heat pump will have pre-heating function. But because the power of the acceleration pump for tempering the pool water on the bypass is weak for the serial connection of heating by the heat pump and by current plate heat exchanger, the heat pump will substitute the heating and if there is a need for additional heating of pool water then heating by heat pump will be switched off and central heating via a heat exchanger will be used.

Heat exchanger from SWEP with output 209kW was installed for standard swimming pool water heating. It consists of thin steel profile plates, which create channel areas between each other.

Temperature of water in relaxation pool changes in the range 29-32 °C. Because of the day temperature losses that are higher than night loss (the area is closed), the effort is to have at 8:00 A.M. the water temperature on 32 °C, sustain it during the day on average temperature 30°C, and during the night heat the water so at the start of opening hours the temperature is 32 °C.

Materials and Methods

For computation of total energy (and therefore economy) savings, it was necessary to determine real coefficient of performance (COP) of installed heat pump, which is influenced by air temperature in engine room (average 26°C) and temperature of warmed up water (average 31°C).

At first coefficient of performance for individual days of measurement in relaxation pool was computed. Average coefficient of performance then served for determination of advantages of application of heat pump.

Coefficient of performance (COP) is the most important parameter of a heat pump, it expresses its efficiency. It´s sign is εT. It compares electricity consumption for operation of heat pump (compressor, ventilator) with amount of gained heat.

The output of heat pump comes from sum of energy gained from surroundings (about 70%), electric power delivered for driving unit of the pump (about 30%) and losses. Coefficient of performance doesn´t take heat gained from surroundings into consideration, and therefore we can say that efficiency of the heat pump is always more than 100%. Value of the coefficient of performance is usually between 2-5

Equation for computation of coefficient of performance (1):

$$\varepsilon_T = \frac{Q}{E} \qquad (1)$$

Where:

ε_T –Coefficient of performance [-]
Q – Output of heat pump [kWh]
E – Power input [kWh]

TF equation (1) shows that is important to determine output Q and input E for heat pump.

Power input in kW comes from electric power consumption, deducted from electro- meter for each operating time of heat pump. It is average hourly input (kW) of heat pump for each date.

Output of heat pump comes from equation (2)

$$Q = v \cdot \Delta T \cdot 1,163 \qquad (2)$$

Where:

Q – Output of heat pump [kW]
v – Flow rate of pool-water (v = 143,1 l/min → v= 8,6 m3/hour) (from flow meter)
ΔT – Temperature difference between input and output of heat pump [°C] (from data logger)

Results and Discussion

Final values of coefficients of performance for measured days are in the Table 1 and Figure 3. Figure 3 was calculated from the average of power consumption and heat factor.

Table. 1. Coefficient of performance of heat pump during measurement in relaxation pool

| Date	Time of heat pump use	Temperature difference ΔT	Electricity consumption for heat pump	Power input „E"	Output of heat pump „Q"	Coefficient of performance „εT"
	[hour]	[°C]	[kWh]	[kW]	[kW]	[-]
2.11.2010	8	1.4	38,1	4,8	13,8	2,9
3.11.2010	12	1.6	27,5	4,8	16,0	3,3
4.11.2010	9	1.4	42,0	4,7	14,0	3,0
8.11.2010	12	1.6	55,9	4,7	15,8	3,4
12.11.2010	13	1.7	62,6	4,8	17,0	3,5
14.11.2010	12	1.5	55,8	4,7	15,1	3,3
15.11.2010	5	1.4	23,9	4,8	14,0	2,9
Average	**10**	**1.5**	**48.1**	**4.7**	**15.1**	$\varepsilon_T=3,2$
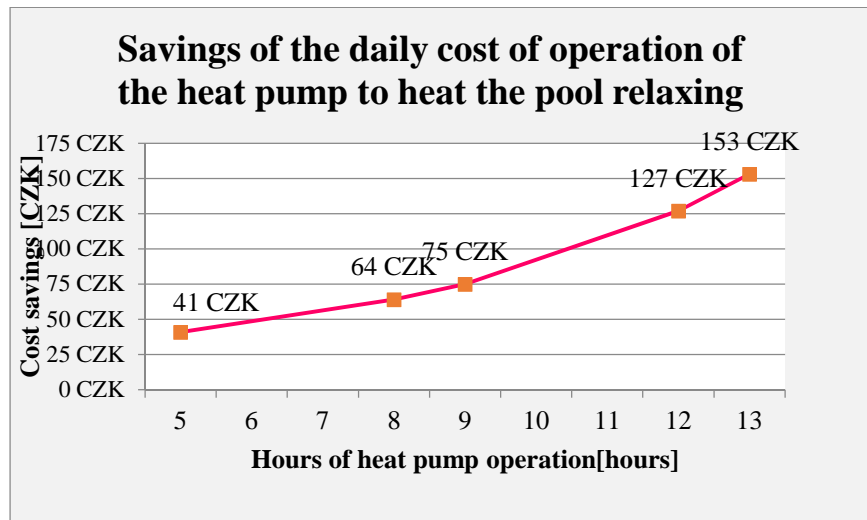
Figure 3. *Savings according to the daily cost of operation of the heat pump to heat the pool relaxing*

According to the type of the use of a heat pump it is necessary to design the appropriate performance of the heat pump. It is important to ensure that the heat pump consume only a portion of heat gain of engine room and the engine room is not cooled too much, because it would result in an increase of heat loss .

Therefore, it was necessary to find a heat sources respectively heat gains, which affect the high temperature in the engine room and the engine room heat load balance, which is composed of heat losses and gains. Results of temperature drop measurement realised at engine room are at figure 4.

Figure 4. *The map of the cooling of aqua park engine room - heat pump (air/water) is located under the relaxation pool*

The measurements presented here were done for one of suitable locations for heat pump in engine room – under the relaxing pool and whirlpool. Also the most suitable regime of operation of heat pump in combination with central heating of water which uses the heat exchanger was tested.

Annual cost savings for two variants of heat pump operation and central heating were evaluated. The cost savings are the highest during continuous operation of the heat pump. The cost savings are for relaxation pool which has a large consumption of energy around 10.3% of the total annual financial costs of standard pool water heating. Financial return computed on the base of these cost savings and installed heat pump price is for relaxation pool 1.5 years. This calculation is affected by the energy prices which were considered according to local operating conditions (1kW = 1.92 CZK; 1GJ = 343,5 CZK) [4].

Conclusions

The results of the measurement realised in swimming pool plant show that warming of swimming pool water by heat pump which is placed in inner area of engine room and which use the waste heat from engine room is economically more convenient than warming the water with the use of plate heat exchanger with heating water from the central heating.

The cost savings are the highest during continuous operation of the heat pump. The cost savings are for relaxation pool around 10.3% of the total annual financial costs of standard pool water heating. Financial return computed on the base of these cost savings and installed heat pump price is for relaxation pool 1.5 years. The annual energy savings are for the relaxation pool 84 490 kWh, which is saving of 13.7 % of energy in comparison with consumption of classical heating by central heating.

The appropriate placement of heat pump is in engine room under the pool which water is warmed by the heat pump. The best conditions are in places with the highest air temperature. It is also important to direct the heat pump that way which ensure that the cooled air from it will not be blown directly from a small distance to the pipe. Detected rate of air cooling in engine room is relatively low - in average around 2 ° C. It shows that there is a possibility to put more than one heat pump into the engine room if appropriate distance between them is designed.

According to the measurement results it can be stated that the heat pump (air / water), which use air directly from the engine room can be used for energy savings in public pools.

Acknowledgement

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