BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LXI (LXV), Fasc. 2, 2015
Secția
CONSTRUCȚII DE MAŞINI

EXPERIMENTAL INVESTIGATION OF AN AIR-TO-WATER HEAT PUMP

BY

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Received: July 22, 2015
Accepted for publication: October 14, 2015

Abstract. An air-to water heat pump was implemented in a school placed in rural area near Galați. This facility was monitored for two years period. This study presents an experimental study of this type of heat pump, but in the same time some possibilities for improving the system performance. The implementation of the heat pump was considered because there is no heating or natural gas network in the village.

Key words: renewable energy; alternative individual heating system; air-to-water heat pump.

1. Introduction

Following the European commitment of reducing 20% of the emissions by 2020, energy waste from residential space heating and domestic hot water have been identified as the possible reduction targets.

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Air-to-water heat pumps (ASHP) are considered as renewable energy technology compared to heating systems dependent on fossil fuel or non-efficient electrical heating. They are now considered as ideal solutions for space heating and domestic hot water. Newly produced air source heat pumps can provide heat energy from outdoor air at temperature as low as −20°C. As a result they could be utilized during most days of the year. The drawback of air source heat pumps is the reduction in efficiency as the outdoor air become colder, resulting in lower heat supply in times when it is most needed. Although there is an inverse relationship between heat pump efficiency and outdoor temperature, in the last three years, the air source heat pumps were most installed alternative heating systems.

Because the old heating system of the school presented a lot of technical problems, especially due the quality assurance and supply conditions with GPL, the local authorities decided to install a heat pump. Few years ago, the superior energy efficiency of brine-to-water heat pumps justified the complex installation associated with them. But in the last period, the air-to-water heat pump technology was critically improved (Zhu *et al*., 2012). The new generation of air-to-water heat pumps presents some convincing advantage concerning both technical performances coupled with the requirement of minimal space and minimal installation effort - especially when installed outdoors (Danielski & Frölinga, 2012). This means that, even in existing renovated buildings with conventional radiators, good seasonal performance factors can be achieved. Maximum flow temperatures of 55°C and thus high heat outputs can be reached, even at external air temperatures as low as −25°C.

2. Heating System Configuration

The heating load of the building was established to be 74 kW. The new heating system consists in two units of air-to-water heat pumps, each of them having a nominal capacity of 40 kW. Because of project condition and lack of money, the old heating system distribution, with static radiators, was maintained. This despite the dimensioning of radiators for temperature input/output of 90/70°C, while the heat pump can provide hot water with 55°C.

Two LA 40TU air-to water heat pumps (produced by Dimplex Company) were selected. These are heat pumps for heating purposes for outdoor installation, with wall-mounted WPM EconPlus heat pump manager and two screw compressors for output reduction when operating at partial load. Some technical characteristics of this pump are (Dimplex. LA 40TU technical data):

− refrigerant – R410A;

− sensor for monitoring of the refrigerating circuit for energy-efficient defrosting;

− integrated thermal energy metering (display of the thermal energy volume for heating and domestic hot water preparation on the WPM Econ Plus heat pump manager).

The Econ Plus controller also monitors the heat pump's operation and provides all of the functions of a modern heating regulation system, such as connection to a building management technology system and timing programmes for heating and domestic hot water preparation.

Heat pump 1 is used for heating and domestic hot water preparation, while heat pump 2 is used just for heating purpose.

In Fig. 1 the heat pumps circuit diagram is presented, while the Fig. 2 presents a picture of the heat pumps outdoor location.

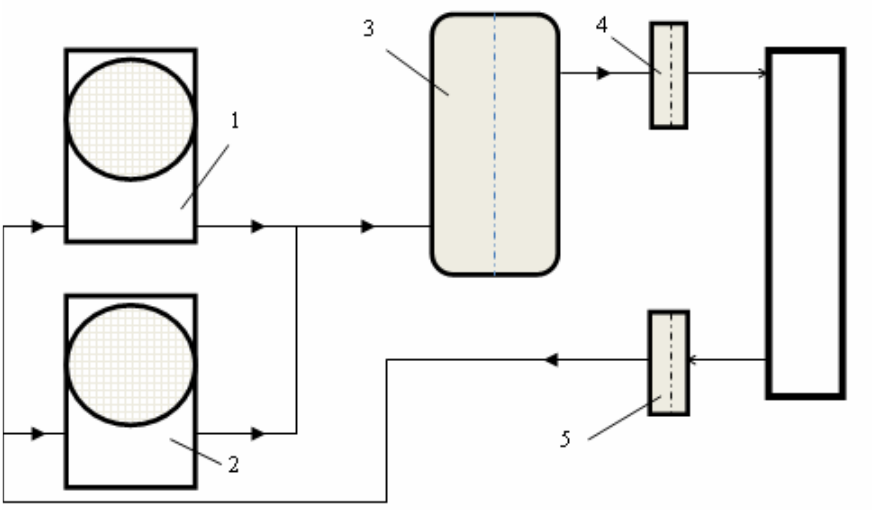

Fig. 1 − Heating system diagram:
1 – HP1, 2 – HP2, 3 – buffer storage tank, 4 – distributor, 5 – collector.

Fig. 2 − Front view of the air-to water heat pumps.

To offset the decreasing the thermal load at very low outdoor temperature, the buffer storage tank is equipped with three electrical heaters, each having 7.5 kW electrical power.

3. Heating System Analysis

The operation set of the heating system, in accordance with school activity program, is presented in Fig. 3.

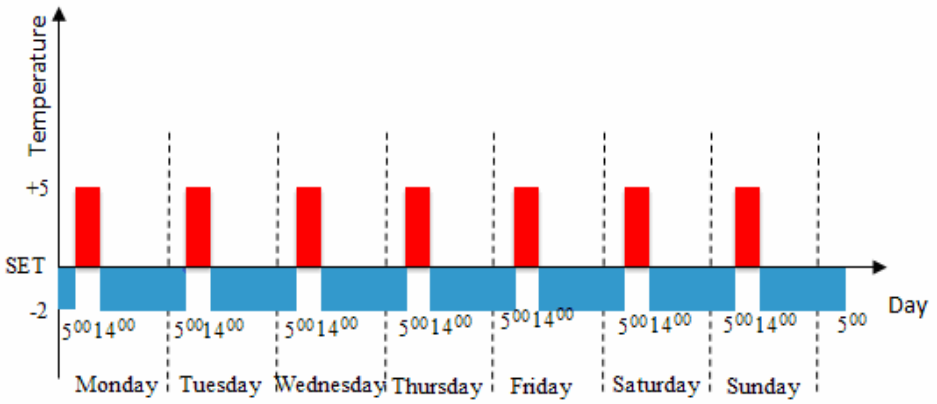

Fig. 3 − The operation system setting according the school activity program.

Using the thermodynamic characteristics of LA 40TU heat pump (Dimplex. LA 40TU thermodynamische) the setting temperature variation can be plotted, according to the outside temperature. This graphic is presented in Fig. 4.

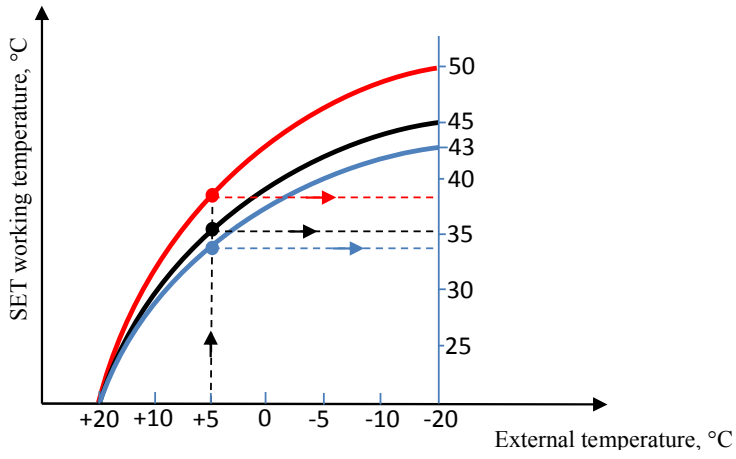

Fig. 4 − SET working system temperature *vs*. external temperature.

The experimental study was performed for four years running period of heating system. In this paper the experimental values are presented for the coldest operation period analysed, from October 22, 2011 to April 4, 2012 respectively.

The values recorded by systems controllers are presented in Table 1.

Table 1
Recorded Values for Heating System

Element			Value
Number of hours of operation of the system			3960 h (165 days)
Total thermal energy produced			96,695 kWh
Thermal energy produced by HP1	heating		40,867 kWh
	DHW		1,440 kWh
Thermal energy produced by HP2	heating		54,388 kWh
	DHW		0
Operating hours for compressors	HP1	C1	1486 h
		C2	1592 h
	HP2	C1	2048 h
		C2	1846 h
Operating hours for fans	HP1		2219 h
	HP2		2716 h
Operating hours for pumps	HP1	HP	3459 h
		DHW	96 h
	HP2		3788 h
Operating hours for additional electric resistances			274 h

From Table 1 result:

1. Thermal power hourly delivered was:

$$P_{HP} = \frac{Q_{produced}}{N_{hours}} = \frac{96,695}{3,965} = 24.42 \text{ kW} \quad (1)$$

2. COP of the heat pumps (unfavourable estimation):

$$COP = \frac{Q_{produced}}{P_{el.consumed}} = \frac{96,695}{39,600} = 2.44 \quad (2)$$

This is an unfavourable estimation of COP, because we considered the maximum electricity consumption for heat pump, in conformity with technical data (Dimplex. LA 40TU technical data).

This value of COP can be considered very well, if it is compared to the average COP indicated by manufacturer (Dimplex. LA 40TU technical data):

$$COP_{average}\,(t_{ext} = +7°C/+2°C/+10°C) = 3.93$$

This is because in the analysed period there are at least 8 days with an exterior temperature down −21°C.

A comparative study regarding the cost of heating energy produced with different fuels was conducted. The value of this heating energy was considered being 96,695 kWh. According with a study elaborated by Linz University, the price of 1 kWh was considered:

− For an air-to-water heat pump: 0.0350 euro/kWh;
− For natural gas: 0.0479 euro/kWh;
− For liquefied petroleum gas: 0.0916 euro/kWh.

The heating energy costs were being:

− Air-to water heat pump: 3,384 Euro;
− Natural gas: 4,631.69 Euro;
− Liquefied petroleum gas: 8,857.26 Euro.

It can be seen that the most economical solution for heating is the heat pump.

4. Conclusions

This presented experimental study show that air-to-water heat pumps became a good alternative heating systems, even in cold areas. In the same time, this alternative heating system is considered renewable energy. Because the improvement in their technology allows using these devices at external temperature up to −25°C, the air-to-water heat pumps became more attractive that water-to-water heat pumps.

The system presented can be improved by replacing static radiators mounted in the heating space by underfloor heating system or using fan coil units.

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STUDIUL EXPERIMENTAL AL UNEI POMPE DE CĂLDURĂ AER-APĂ

(Rezumat)

Prezentul articol analizează din punct de vedere experimental un sistem de încălzire folosind două pompe de căldură aer-apă, montat la o şcoală situată în zona rurală a oraşului Galaţi. Acest sistem a fost monitorizat pe o perioadă de patru sezoane reci consecutive, analiza efectuându-se pentru sezonul cu regimul de temperaturi cel mai scăzut din acest interval. Rezultatele obținute au permis calculul COP al pompei de căldură în condiții reale. Valoarea obținută pentru acest coeficient de performanță, calculat pe baza datelor monitorizate, conduce la concluzia că această soluție de încălzire a spațiilor este viabilă, în special în zonele în care nu există rețea centralizată de încălzire sau distribuție de gaze naturale.