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HEAT PUMPS WITH INTERNAL COMBUSTION ENGINES USING NATURAL GAS AS AN ALTERNATIVE TO ELECTRIC HEAT PUMPS

***Martina Janovcová**
University Science Park, University of Žilina,
Univerzitná 8215/1
Žilina 01026, Slovak Republic

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** Corresponding author: Martina Janovcová, University Science Park, University of Žilina, Univerzitná 8215/1, Žilina, Slovak republic, Phone: 00421 513 2856,*
E-mail address: martina.janovcova@uvp.uniza.sk

ABSTRACT

The subject of this article is to analyze the heating performance of the heat pump driven by an internal combustion engine for natural gas in the system of the air / water. In recent years, increased attention has been paid to gas heat pumps in heating, ventilation and air conditioning due to its advantage and to reduce power consumption during heating and cooling. Gas heat pumps have significant advantages over electric heat pumps, although do not reach a significant coefficient of performance. The advantage of gas heat pumps is the ability to use the waste heat from the engine cooling and exhaust gas while saving fossil fuels in connection with the production of energy from renewable sources - air.

INTRODUCTION

Increasing energy consumption and rising energy prices force us to think and constantly develop new energy facilities that are more efficient and more environmentally friendly.

In the light of declining fossil fuel reserves are brought into awareness of renewable energy sources. In order to realize the ambitious targets for reducing the consumption of fossil fuels and reducing greenhouse gas 141 countries signed the Kyoto Protocol. Also, the European Parliament adopted a directive on the use of renewable energy sources. This Directive aims at determining share of energy from renewable energy sources. The Directive recognizes aerothermal, geothermal and hydrothermal energy as a renewable source of energy and heat pumps also classifies among alternative energy sources. Heat pumps are started recently been heavily deployed in heating systems, especially in low-energy buildings in Slovakia. Largely deployed heat pumps are heat pumps with vapor compression cooling cycle. Heat pumps powered electric compressor can on the basis of thermodynamic transition at low energy to acquire 100% of useful thermal energy consumption of about 80-85% of primary energy (energy supplied). Although heat pumps have a COP 3-4, electricity is produced with an efficiency of about 34-40%, so the total transformation of primary energy is then at about 85%. From the previous analysis, efficient transformation of primary energy into heat can be achieved by using a heat pump with compressor powered internal combustion engines using natural gas. In this case, obtaining not only the heat from the cooling circuit, but also in engine cooling and exhaust. To obtain 100% of useful energy is consumed only about 65-70% of primary energy. Even though the natural gas distribution network in Slovakia covers about 92% are established only a few pieces. Gas heat pumps are new to our market and yet there is very little information on the operation and effectiveness of these sources of heat and cold.

ELECTRIC HEAT PUMP VS. GAS HEAT PUMP

Heat pumps are among the alternative sources of energy and using energy from the low-potential source (air, water, ground) for their function. The heat pump consists of four basic components (compressor, condenser, expansion valve and evaporator) interconnected to the circuit in which circulates the working fluid - refrigerant. Gas heat pumps are identical constructionally with electric heat pumps, the difference is that the electric motor to drive the compressor is replaced by a gas combustion engine with its own cooling circuit and the exhaust system as show in figure 1 and 2. GHP work only in system air - water, but obtained heat not only from renewable energy sources, but also the engine cooling and exhaust system are participating of the total production of heat. Based on current analysis, it appears that transformation of primary energy into heat more effective in GHP.

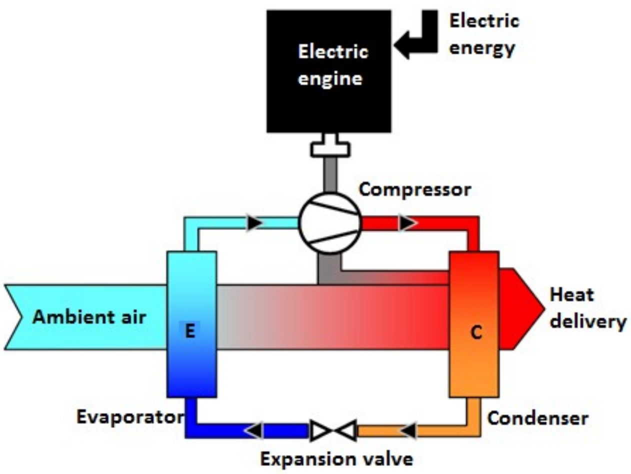

Fig. 1 Electric heat pump (www.spp.sk)

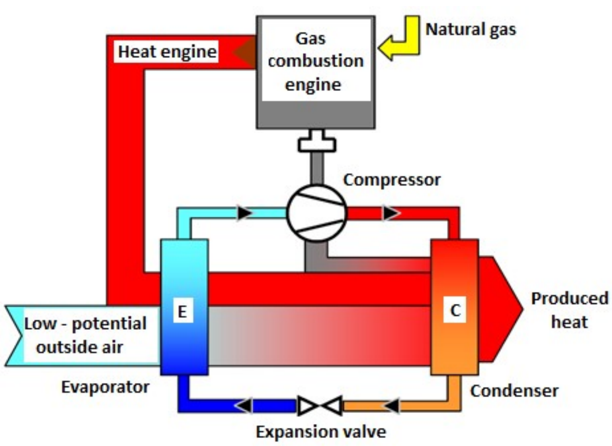

Fig. 2 Gas heat pump (www.spp.sk)

ENERGY EFFICIENCY OF HEAT PUMPS

Energy efficiency heat pump can be determined on the basis of two factors COP and PER. The COP (Coefficient of Performance) compares the ratio of the generated heat (supplied to the heating) and the energy required to drive a heat pump which can be either an electric or energy produced by combustion of gas.

$$COP = \frac{Q_{OUT}}{G_{HP,drive}} \tag{1}$$

where Q_{OUT} [kW] is heating power at temperature T_{OUT}, $G_{HP,drive}$ [kW] is energy supplied to the heat pump (electric power or energy contained in natural gas).

For systems rated coefficient of performance is valid, higher COP achieve energy-efficient. To compare the energy efficiency on the basis of the COP factor is important that the systems were compared with the same type of primary energy. It is therefore not appropriate to compare GHP and EHP on the basis of the factor of primary energy rate.

Primary Energy Rate (PER) compares the efficiency of energy systems with different types of fuel and energy productivity. PER is generally the ratio of all the available energy in the system of the useful energy produced. The system, which has a lower value PER thus consume a smaller amount of primary energy per unit of useful energy and thus the system is more energy efficient.

$$PER_{PTČ} = \frac{G_{HP,drive} + \frac{E_{HP,drive}}{\eta_{el}}}{Q_{OUT}} \tag{2}$$

where G_{HP} is the energy of gas supplied to the heat pump (kWh), E_{HP} is the electricity supplied to the heat pump (kWh), η_{el} is the efficiency of electricity production (35%), Q_{OUT} is heating power produced by heat pump (kWh).

CHARACTERISTIC OF EXPERIMENTAL DEVICE

Heat pumps are installed at the area of University of Žilina in Slovakia. Measuring of the energy efficiency of GHP and also EHP was realized in time from 02/19/2013 - 02/24/2013. Because heat pumps work in system air - water, it was necessary to measure the weather data by the meteorological station (Fig. 3) at the time. The greatest impact on performance of HP air - water has outside temperature of low potential heat source.

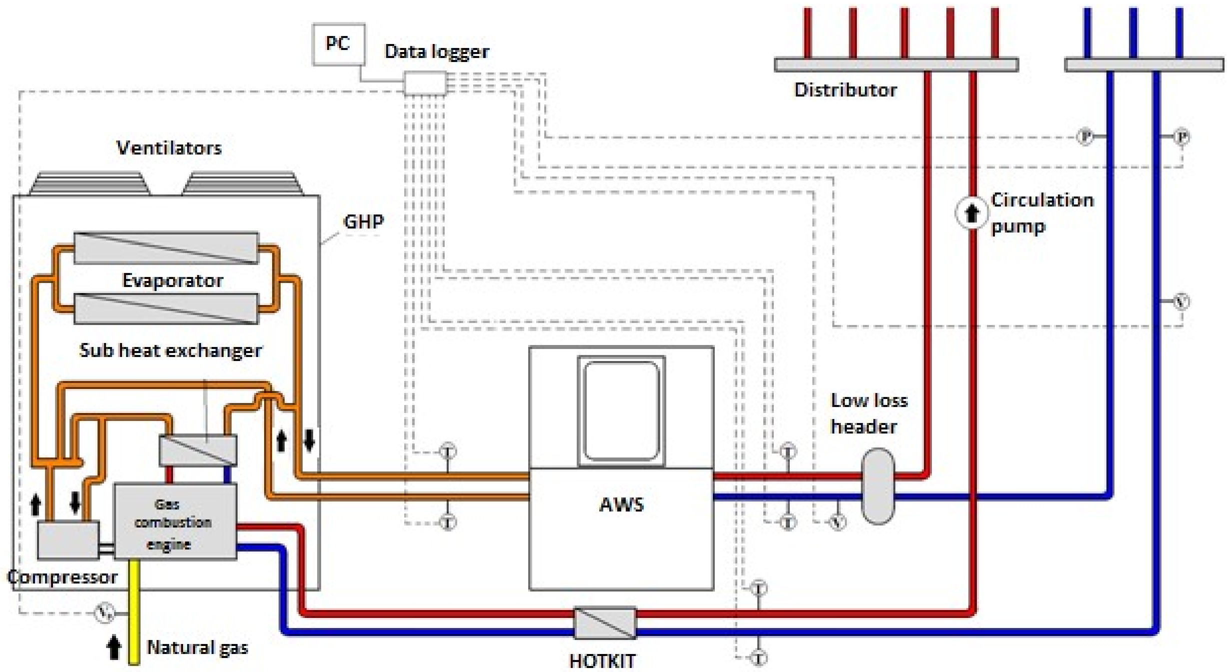

Fig. 4 Schematic diagram of gas heat pump air – water

Table 1 Basic data on the performance of experimental heat pumps

Experimental device	Electric heat pump	Gas heat pump
Model	DAIKIN ALTHERMA	Toyota AISIN 10HP
Rated heating capacity (kW)	8	33,5
Rated cooling capacity (kW)	5	28

Fig. 3 Weather station

In Table 1 are presented models of experimental equipment - electric heat pump and gas heat pumps and their performances.

Figure 4 shows the connection diagram of the gas heat pump, and the figure 5 and 6 show the outdoor unit and indoor unit of GHP.

In Figure 7 and 8 show the actual electric heat pump connected.

The outdoor unit consists of a heat exchanger air / coolant, a compressor, a combustion engine and a heat exchanger for preheating the coolant, included in the cooling circuit of the engine. Orange color shows the refrigerant circuit GHP, using R410A refrigerant. The inner side is called technology unit AWS (from the English Air - Water System), consisting of a plate heat exchanger is used to transfer heat from the refrigerant circuit to the water serving for heating, hot water, respectively, in reversible mode for cooling. Part of heat pump is a so-called. HOTKIT (from the English Hot Water kit) consisting of plate heat exchanger water - water added to the cooling circuit of the engine. Water from the AWS and the HOTKIT distributes into a distributor is used to heat or cool a laboratory.

Fig. 5 Outdoor unit of GHP

Fig. 6 Indoor unit of GHP

Fig. 7 Indoor unit of EHP

Fig. 8 Outdoor unit of EHP

RESULTS AND DISCUSSION

Throughout the measurement period were measured to determine the necessary parameters COP and PER experimental facilities, while also the meteorological data measured at one-minute intervals. Average daily temperatures were in the range -6.1 to 4.9 ˚C. The outlet water temperature of the heat pump was set at 45 degrees Celsius. After evaluation of all parameters were determined PER of both heat pumps shown in Figure 9. The number of COP electric heat pumps are reached 3-5, for gas heat pump COP is in the range of 1.2 to 2.4. Electric heat pump achieved during measurements of performance figures COP = 2.61 to 3.13, gas heat pump but does not exceed a value of 1 (Fig. 10). The graph indicated the course of daily average temperatures in the measured period. Since the comparison of the COP is not objectively because heat pumps are of a different power and the type of fuel to be recognized that electricity as primary energy, but is made with effect 0.35 to 0.4%. Therefore, to properly compare the two systems, the value PER, which incorporates the efficiency of primary electricity. In our case, was used for electricity generation efficiency of 0.35%. The higher the value the lower the PER system is more efficient and produce the required heat output using less primary energy.

It is important to note that the gas heat pump is burnt in order to drive natural gas compressors. The ratio of 1 kW fuel prices between natural gas and electricity in the long term holds in the ratio 1: 4 in favor of natural gas in Slovakia. By investing in PTČ as the sole source of heat and cold are reduced investment costs for creating the heating system in comparison with the building of two sources (heating - gas cooling - electricity).

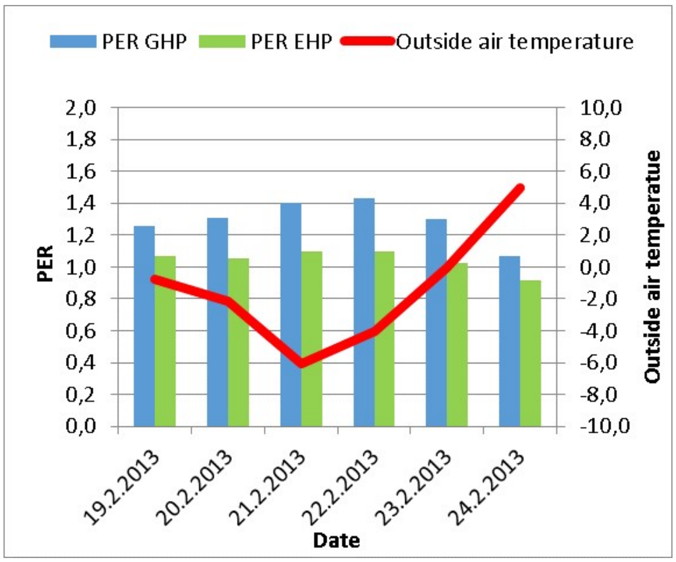

Fig. 9 Primary energy rate of GHP and EHP

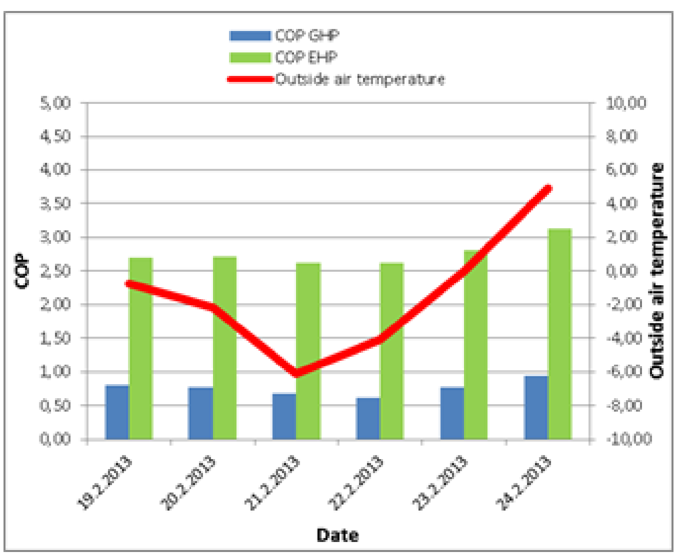

Fig. 10 Coefficient of performance of GHP and EHP

CONCLUSION

Measurement to obtain the relevant data on the gas heat pump in real conditions. The experimental measurements showed that the electric heat pump is more energy efficient under the same climatic conditions as compared to gas heat pump, the outdoor air temperature from - 6 ˚C to 5 ˚C. However, gas heat pump worked in a range of about 47 to 63% power, which was due to insufficient heat demand on the secondary side. Electric heat pump worked between 70-90% of the power. This meant that for low heat consumption on the secondary side of the gas heat pump to the total production of heat is not used heat from the engine cooling and exhaust.

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NOMENCLATURE

COP (Coefficient of performance),
PER (Primary Energy Rate),
GHP (Gas heat pump),
EHP (Electric heat pump),
Q_{OUT} [kW] is heating power at temperature T_{OUT},
$G_{HP,drive}$ [kW] is energy supplied to the heat pump (electric power or energy contained in natural gas),
G_{HP} [kWh] is the energy of gas supplied to the heat pump, E_{HP} [kWh]is the electricity supplied to the heat pump,
η_{el} is the efficiency of electricity production (35%).

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