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Transformation of heat by gas heat pump depending on primary energy sources

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ABSTRACT
This article deals with the use of the heat pumps in different types of primary energy. The heat pump is an energy system that can efficiently transform otherwise unusable low potential energy into higher potential energy. In order to save primary energy is emerging gas heat pump is most suitable alternative for obtaining the thermal energy

Nomenclature

COP *coefficient of performance,*
GHP *gas heat pump,*
EHP *electric heat pump,*
AWS *air-water system,*
EU *European Union,*
RES *renewable energy source,*
LPG *liquefied petroleum gas,*
CO_2 *carbon dioxide,*
HP *heat pump,*
PE *polyethylene,*

1. Introduction

Discussion about reducing supplies of fossil fuels and high level of pollution leads our planet to think what will be the further development of energy policy in the world. A large amount of fossil fuels are used to produce electricity and thermal energy. For this reason, high CO_2 production has a huge impact on the greenhouse effect and our climate. Based on these circumstances, the EU focuses its policy to support renewable energy sources (RES). Therefore, heat pumps are getting into the leading positions, which receive heat from renewable sources and transform it into thermal energy with a higher potential.

Heat pumps are not new in the market for energy resources. The principle of operation of these devices is well known for over 100 years. The basic idea of the heat pump principle was already expressed in 1852 by Lord Kelvin in his second thermodynamic statute. The first heat pump was constructed by the American inventor Robert C. Webber at the end of the 40th the last century, but it was just a coincidence.

Only few people know that the first designer of the functional heat pump was a Slovak physicist Aurel Stodola. One of his heat pumps from 1928 has been used even today. It heats town hall in Geneva. It uses water from Lake Geneva as a low potentional heat source.

Heat pumps are increasingly becoming part of a residential, multifunctional buildings, and industrial buildings, not only in terms of efficient conversion of low potential energy to heat respectively to cold. Based on the increasing demands of people in comfort environment in which they live and work and while continually rising energy price developments suggest that the heat pumps are a good alternative to effectively reach these requirements.

Millions of these devices are working around the world, today. The largest number of installed heat pumps are in the USA, Canada, Japan and Scandinavia. About 1100 heat pumps are annually sold in Slovakia.

2. Primary energy sources and their use in heat pump systems

General distribution of heat pumps depends on the type of primary energy source (air, water, ground) and the transfer of heat to the heating or cooling system (air, water). Table 1 provides the primary energy source with the applicable temperature range of heat pump systems. As mentioned above, the heat pump acts as a transformer of low-potential heat for heat with a higher potential, which passes the heating

system, hot water and in summer mode for cooling buildings. The availability of the primary heat source and itself the price of heat pump along with costs associated with its implementation are critical factors in choosing the type of heat pump.

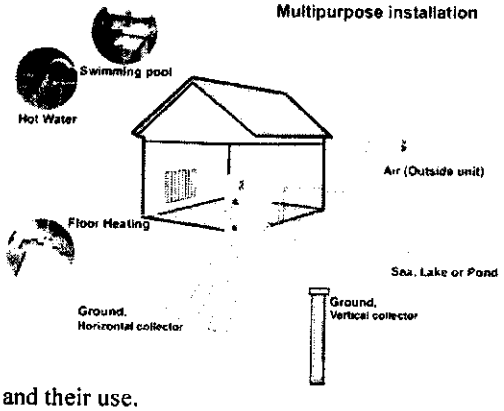

Fig. 1 Primary energy sources and their use.

Tab. 1 Characteristics of primary energy sources.

Heat source	Outdoor air Waste heat	Ground water Surface water	Ground
Temperature range	-20 to 35 °C	7 to 12 °C 2 to 15 °C	-5 to 17 °C
Realization	HP air – air HP air – water	Two wells Set of PE pipes	Ground collector Ground lead
Advantages	Availability of the heat source The cheapest alternative	Stabile heat source Higher heating performance	Stabile heat source Long life
Disadvantages	Temperature fluctuations The need for supplementary heat source	Higher investment costs Availability of the heat source High demands on water	Higher investment costs Availability of the heat source

3. Diversification of heat pumps according to drive of compressor

Electricity is the most often used for drive of compressor or it is driven by gas combustion engine which fuel is natural gas or LPG. The gas heat pump is constructionally almost identical compared to electric heat pump. The difference is that the electric motor is replaced by a gas combustion engine with its own cooling circuit and exhaust system. The heat of combustion of natural gas in gas engines can be used in heating systems or hot water. GHP is able to provide domestic hot water even when working in cooling mode.

3.1. Comparison of primary energy consumption in the EHP and GHP

The analysis of different energy systems have shown the importance of heat pumps in terms of primary energy savings.

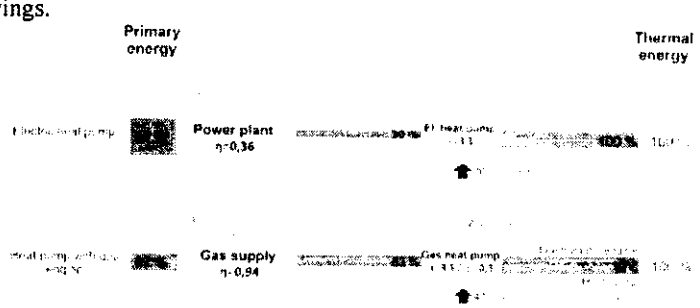

Fig. 2 The consumption of primary energy using heat pumps with different types of driving energy.

From Figure 1 it is evident that the heat pump with electric drive compressor produces 100% of the required heat energy consumption of 84 % of primary energy. More preferably transformation of primary energy by heat pump with gas engine that consume approximately 67 % of primary energy to convertion. It can take advantage of waste heat from engine cooling.

4. Heat pump coefficient of performance COP

Energy efficiency in the production of thermal energy is expressed as the coefficient of performance COP and represents the ratio of produced thermal energy and consumed energy.

$$COP = \frac{\text{produced heat energy}}{\text{consumed energy}} \qquad (1)$$

The greater coefficient of performance is achieved, the more useful thermal energy is produced and thus the system achieves greater efficiency. Comparing heat pumps based on coefficient of performance is possible only in the heat pump systems with same fuel energy.

In the heat pump is produced heat from combustion of natural gas in engine used together with the heat obtained from the environment. In comparison to electric heat pumps is the COP of gas heat pumps lower (approximately 1,3). This is a logical consequence that the EHP coefficient of performance in the calculation does not include the efficiency of production of primary energy - electricity. Electricity in the Slovak Republic is produced and distributed with efficiency around 30 % mainly in water, coal and nuclear power plants.

If the efficiency of primary energy production should be included in COP calculation then the COP of heat pumps with electric drive was in range from 0.6 to 1.2.

Tab. 2 COP of heat pumps with a different type of drive.

Type of heat pump	COP
Compressor circulation, Electricity	3,5 – 5
Compressor circulation, Gas combustion engine	1,1 – 2,3

5. Advantage and disadvantage of gas heat pumps

GHP is characterized mainly by using heat from the environment (" free energy"), which ca n efficiently convert the heat transmitted to the heating system or hot water. GHP has a large number of advantages in comparison with other energy systems:

+ Low operating costs
+ Minimal maintenance equipment
+ Save up to 80 % on energy costs
+ Independence from energy price
+ Ecological operation
+ Quick return on investment
+ Low energy consumption
+ High efficiency equipment

The only disadvantage of PTC is its higher cost and initial investment costs associated with implementation.

6. Experimental device

Based on the knowledge of heat pumps will be realized a unique experimental device that will be used in the modification of gas heat pumps in two modes (air - water and water - water), making it possible to find a suitable kind of primary energy for the real climate conditions in the Slovak Republic. In both cases is available utilization of heat from the engine cooling via an electromagnetic valve. On the primary side will take heat from the ambient air or from two 150 m deep boreholes made at the University of Žilina (Fig. 3).

The secondary side of a gas heat pump technology is the unit AWS (air-water system) that is used to transfer heat from the refrigerant circuit to the water. It is a separate device with heat exchanger, pump and control system. Part of the gas heat pump is "hot water kit", consisting of water-water heat exchanger placed in the engine cooling circuit. Obtained heat can be used in case of the limit values of water temperature in the engine cooling circuit (75 °C).

Part of hot-kit are relevant sensors and electronic circuits validating the utilization of heat from this source. Water from AWS as well as hot-kit is distributed by the distributor for its further use (heating, hot water). The system will be managed automatically using solenoid valves according to preset parameters.

7. Conclusion

The aim of experiment is to find a suitable energy source in the Slovak Republic and to monitor and evaluate the dependence of COP experimental gas heat pumps for a variety of primary heat source. Realization of this project will be installed a unique experimental device, which allows obtaining a large database of relevant data on the conversion of primary energy consumption of natural gas to heat in the gas heat pumps taking low potential energy from the ambient air, groundwater and ground in a deep borehole. The obtained experimental data can be input into a reliable analysis of the economic returns of these new and modern heat sources. The knowledge about the transformation of primary energy consumption of natural gas to heat will have an impact on the popularization of the use of natural gas as a source of heat and cold with sophisticated technology the most efficient transformation of primary energy into heat.

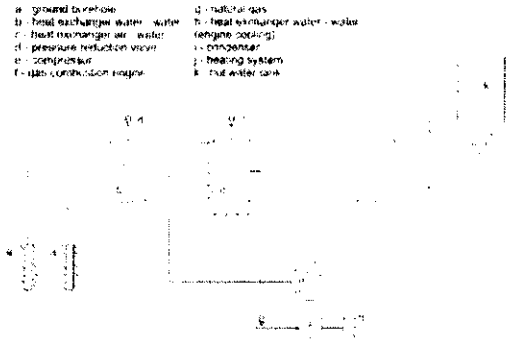

Fig. 3 Testing experimental device.

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