International Journal of Latest Research in Science and Technology **ISSN (Online):2278-5299**
Volume 4, Issue 2: Page No.6-10, March-April 2015
https://www.mnkpublication.com/journal/ijlrst/index.php

GEOTHERMAL WATER TEMPERATURE AND ITS EFFECT ON CHARACTERISTIC PARAMETERS AND PERFORMANCE OF A HIGH-TEMPERATURE HEAT PUMP

[1]Milovan Jotanović, [2]Goran Tadić, [3] Vladan Mićić, [4] Darko Goričanec
[1] University of East Sarajevo, Faculty of Technology Zvornik, Bosnia and Herzegovina
[2] University of East Sarajevo, Faculty of Technology Zvornik, Bosnia and Herzegovina
[3] University of East Sarajevo, Faculty of Technology Zvornik, Bosnia and Herzegovina
[4]University of Maribor, Faculty of Chemistry and Chemical Technology Maribor, Slovenia

Abstract- The paper presents the results of the research into the exploitation of geothermal water using a high-temperature heat pump. Recovery of heat from geothermal water in the region of the town of Bijeljina for the purpose of additional district heating involved using a single-stage high-temperature heat pump with the following refrigerants: water, R717ammonia, R407c mixture and R600a isobutane. Evaporation and condensation temperatures were varied depending on the technical demands of heat users. The effect of entrance temperature of geothermal water on the basic parameters of a high-temperature heat pump, such as heating value, coefficient of performance COP and pressure ratio was analysed depending on the condensation temperature. The results of the research recommend the use of a a single-stage high-temperture heat pump with R600a refrigerant which can raise the temperature of the water in the district heating up to 85°C. The efficiency of a heat pump expressed by the coefficient of performance COP depends on the difference between the evaporation and condensation temperatures of the refrigerant. The smaller the difference the greater the efficiency. After observation of the energy potential of geothermal water in the region of the town of Bijeljina it can be concluded that using a high-temperature heat pump for the purpose of district heating is a promising method from the aspect of technology, economy, energy and environment protection.

Key words - geothermal water, high-temperature heat pump, energy utilization, renewable energy resources, district heating

I. INTRODUCTION

In the last decades of the twentieth century we witnessed immense pollution of the environment and disturbance of ecological balance caused by the use of fossil fuels. Today, at the beginning of the new century, people have to understand that the mistakes from the past that reoccur in the present may bring humanity to the verge of destruction. This is the reason why people have started searching for the sources of energy that are sufficient, renewable, environmentally friendly and cheap at the same time.

In this respect, the authors of the paper investigated the exploitation of heat from geothermal water for district heating of towns using a high-temperature heat pump.

The sources of geothermal energy in the region of Semberija in Republic of Srpska are abundant enough and can be used for the purpose of district heating of residential areas, spas, greenhouses, etc. The heat energy that would be produced using geothermal water from drill holes in the vicinity of the town of Bijeljina can be used for district heating. For direct use, by means of direct heat exchange, gethermal water of 50°C to 90°C can be used. The heat from geothermal water whose energy was already exploited whose temperature is below 50°C can be exploited additionally using a high-temperature heat pump with the coefficient of performance *COP*>5. This additional exploitation of the heat from geothermal water is possible up to the temperature of 20°C. After that, geothermal water returns to the ground using a reinjection drill hole. In this way it is possible to increase energy utility even two times, which results in saving of the investment by at least two exploitation network hot water pipline systems.

Since geothermal water is a cheap, renewable, domestic, environmentally friendly source of energy, it is possible to apply high-temperature heat pumps to exploit low-temperature sources of geothermal water of 30°C to 60°C for the purpose of district heating. This can be achieved because a high-temperature heat pump can raise the temperature of water even to 85°C which is sufficient for the system of high-temperature radiators.

Exploitation of geothermal water from thermal upper-cretaceous and triassic limestones and dolomites can be performed rationally with the drill holes up to 2500 m deep. Intensive exploitation of geothermal water can be achieved using an exploitation and a reinjection drill hole which serves to return the water whose energy was used into the ground. For the purpose of district heating of the town of Bijeljina, and due to higher thermal efficiency of the potential of the drill hole obtained using a high-temperature heat pump, the investment is reduced from the planned

Publication History

Manuscript Received	:	*23 March 2015*
Manuscript Accepted	:	*2 April 2015*
Revision Received	:	*25 April 2015*
Manuscript Published	:	*30 April 2015*

seven drill holes (five exploitation and two reinjection) to only three (two exploitation and one reinjection) [1].

II. HIGH-TEMPERATURE HEAT PUMP

Development of heat pumps began in the second half of the twentieth century when people started paying attention to a rational consuption of energy. The principle of operation of classic heat pumps is based on removing heat from the environment with lower temeperature level and transfering it on the fluids of a higher temperature level. A heat transfer pump needs a refrigerant (operating fluid), which changing its state transfers the heat from the environment into the system. A refrigerant is a substance that evaporates at lower temperatures, between 0°C and 30°C for example. Recently the focus has been on the suitable type of refrigerant to be chosen, particularly due to their negative effect on the ozone layer and the fact that they cause the greenhouse effect. That is the reason why the use of certain refrigerants is forbidden (chloro-fluoro-carbons, for instance). A classic compresion heat pump consists of evaporator, compressor, condenser and expansion valve [2,3].

So far classic available heat pumps have been used only in low-temperature heating systems (between 20°C and 50°C), which makes their application restricted mainly to the buildings with under floor heating, balneological purposes and greenhouses. The aim of the research is the possibility of installing a high-temperature heat pump for achieving a high-temperature heat flow of 0.5 to 10 MW and high temperatures (up to 85°C). This would enable industrial exploitation of low-temperature, used, recovered geothermal sources.

A high-temperature heat pump was developed only in 2010 under the EUREKA project in cooperation between the Faculty of Chemistry and Chemical Technology of University of Maribor and a Japanese company called MAYCOM. A high-temperature heat pump is an innovative approach in this area and can be applied in high-temperature systems of district heating of residential and commercial buildings. This pump is a completely new, innovative device in the world, [4].

III. RESULTS OF THE CALCULATIONS OF CHARACTERISTIC PARAMETERS OF A SINGLE-STAGE HIGH-TEMPERTURE HEAT PUMP

Modelling of the heat pump process and the calculation of operation parameters of mainly classic models is the topic of reseacrh of many scientists and experts who publish their results in journals and international conference proceedings [5-9].

The following types of high-temperature heat pumps were analysed regarding the temperature of geothermal water, the available capacities of high-temperature heat pumps and economic justifiability:

- A single-stage high-temperature heat pump,
- A two-stage high-temperature heat pump with an expansion tank, and
- A two-stage high-temperature heat pump with a heat exchanger.

Calculation of different construction variants of high-temperature heat pumps and the efficiency of different refrigerants was done using “Mathcad 2001 Professional“. This programme enables a fast and efficient calculation of operation parameters for different conditions in which a heat pump opertes. The results of the calculations were then inserted into the Aspen Plus programme where it is possible to check both material and energy balances of the heat pump. Physical properties of refrigerants and their mixtures were calculated using “Refprop 7“ programme. In their earlier works the authors presented the methods, the procedure and the results of mathematical models of high-temperature heat pumps of different constructions, [10,11].

Calculation of a single-stage heat pump involved using four refrigerants: H_2O, NH_3, R407c and R600a. MS Excel programme calculations were used to draw characteristic curves for each refrigerant. They show the dependance between characteristic parameters of the high-temeperature heat pump and the exit temperature of geothermal water.

Figure 1 shows the results of the calculations of a single-stage high-temperature heat pumpusing water as a refrigerant. Figures 2 and 3 show ther value of the coefficient of performance and the pressure ratio of the compressure depending on the exit temperature of geothermal water and condensation temperature.

The following symbols a were used in the diagram:

P – compressor power (W),

Q_c – condenser heat transfer (W),

Q_r – evaporator heat transfer (W),

t_k – condensation temperature (C) and

t_{g1}– entrance temperature of geothermal water (42°C).

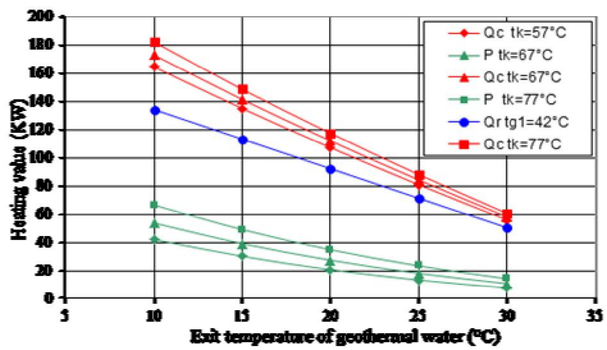

Figure 1. A single-stage heat pump with H_2O refrigerant

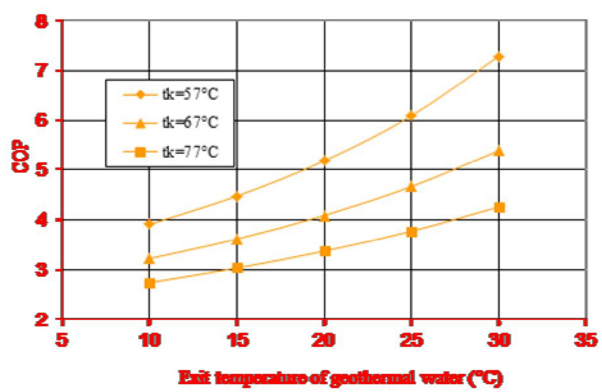

Figure 2. The coefficient of performance of a single-stage heat pump with H_2O refrigerant

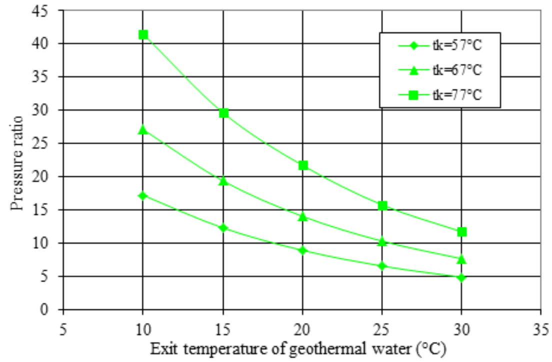

Figure 3. The pressure ratio of the compressor in a single-stage heat pump with H_2O refrigerant

These results show that in a single-stage high-temperature heat pump using water as a refrigerant, the increase of condensation temperature increases the power necessary for the operation of the compressor as well as the amount of heat (heating value) produced in the condenser. The heating value in the evporator increases depending on the exit temperature of geothermal water. Coefficient of performance *COP* of a single-stage high-temperature heat pump increases with the increase of the exit temperature of geothermal water and drops with the increase of condensation temperature. Coefficient of performance for the exit temperature of geothermal water of 10°C is in the interval of 3 – 4.2. An important parameter for deciding on the type of the refrigerant and compressor is the pressure ratio of the compressor which has to be lower than 5 for a single-stage high-temperature heat pump (Figure 3.). It can be seen that for a single-stage high-temperature heat pump using water as a refrigerant, the pressure ratio is considerably greater than it was calculated previously. That is the reason why, due to technical limitations, this pump using water as a refrigerant is not recommended.

Figure 4 shows the results of the calculations of characteristic parameters of a single-stage high-temperature heat pump using ammonia as a refrigerant. The dependance between the coefficent of performance and the pressure ratio on one hand and the change of the exit temperature of geothermal water at different condensation temperatures on the other is shown in the diagram (Figures 5 and 6).

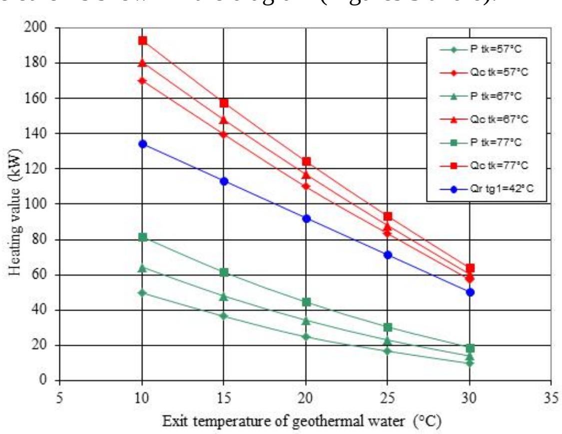

Figure 4. A single-stage heat pump with NH_3 refrigerant

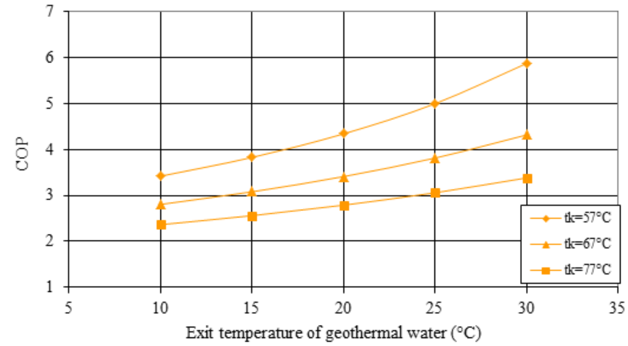

Figure 5. The coefficient of performance of a single-stage heat pump with NH_3 refrigerant

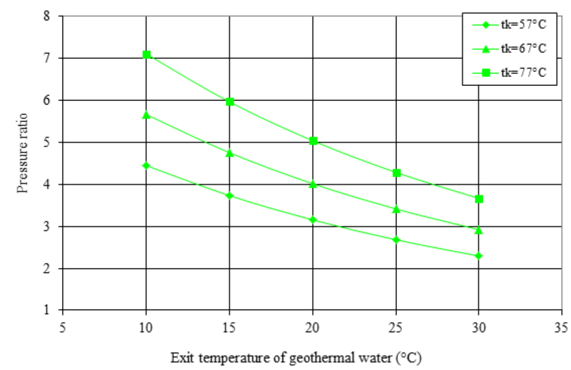

Figure 6. The pressure ratio of the compressor in a single-stage heat pump with NH_3 refrigerant

The results shown in the diagrams above suggest that the increase of temperature in the condenser increases the necessary power and heat transfer of the condenser. Coefficient of performance of a high-temperature heat pump varies in the interval of 2.46 – 3.41. On the other hand, the pressure ratio is still high.

The results of the calculations for a single-stage high-temperature heat pump using R407c mixture as a refrigerant are shown in diagrams (Figures 7, 8 and 9).

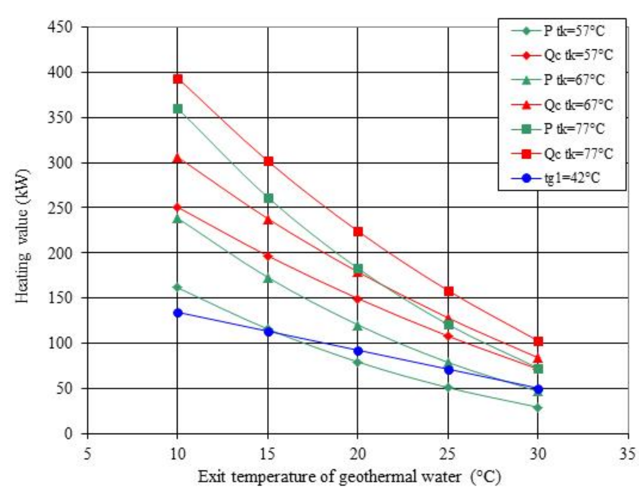

Figure 7. A single-stage heat pump with R407c refrigerant

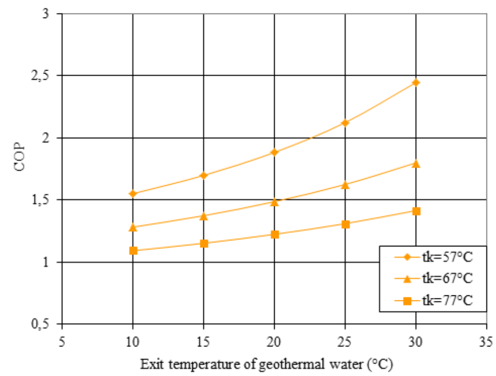

Figure 8. The coefficient of performance of a single-stage heat pump with R407c refrigerant

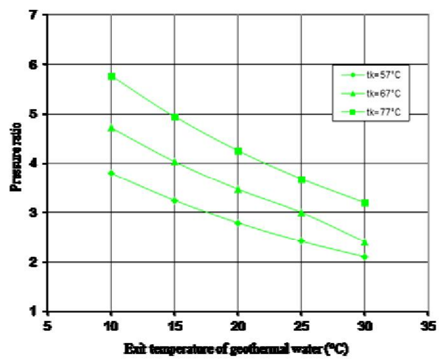

Figure 9. The pressure ratio of the compressor in a single-stage heat pump with R407c refrigerant

For a high-temperature heat pump using R407C mixture as a refrigerant, the necessary power in the compressor is additionally increased. What is also increased is the heat transfer of the condenser compared to the two prevoiusly discussed refrigerants. The coefficient of performance of the heat pump varies between 1.24 and 1.77. Moreover, the pressure ratio is above the average value.

Figure 10 shows the results of the calculations of the heat transfer of a single-stage high-temperature heat pump using R600a refrigerant (isobutane). Figures 11 and 12 show the values of the coefficient of performance and the pressure ratio in the compressor depending on the exit temperature of geothemal water at different condensation temperatures.

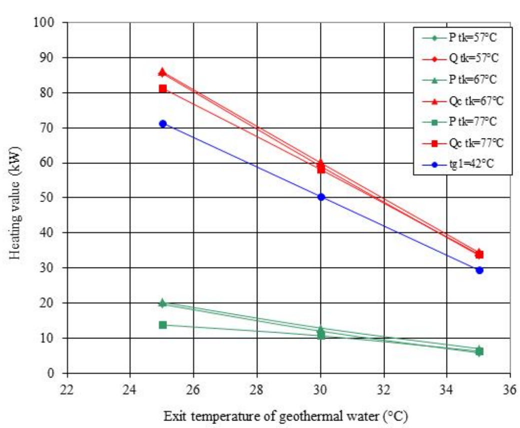

Figure10. A single-stage heat pump with R600a refrigerant

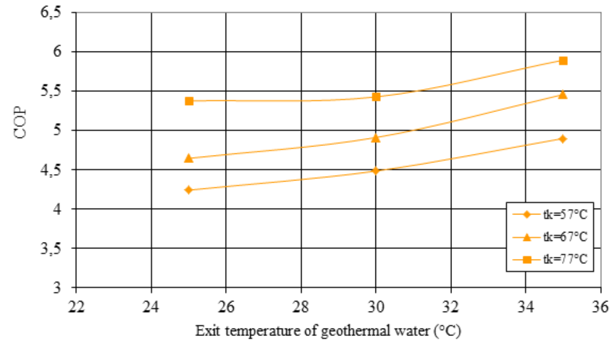

Figure11. The coefficient of performance of a single-stage heat pump with R600a refrigerant

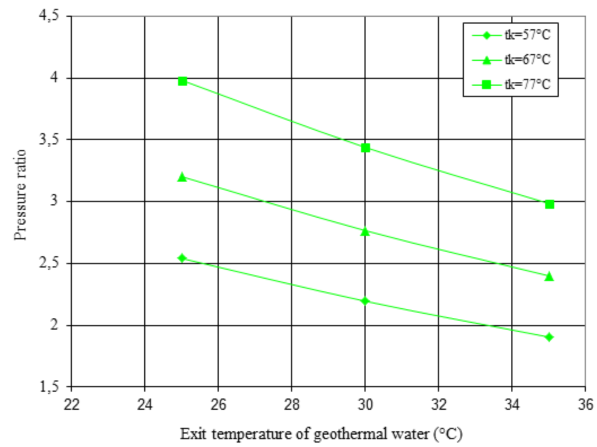

Figure12. The pressure ratio of the compressor in a single-stage heat pump with R600a refrigerant

If isobutane R600a is used as a refrigerant, the necessary power and the heat transfer of the condenser is decreased. The coefficient of performance is higher and varies in the interval of 4.3 – 5.5, whereas the pressure ratio is within the optimum range and amounts to 3.

IV. CONCLUSION

For reasons of both economic and technical nature, a single-stage high-temperature heat pump was used for exploiting geothermal water for the system of district heating. Refrigerants investigated were water, ammonia R717, R407c mixture and R600a isobutane. The evaporation temperature of the refrigerant and the condensation temperature were varied depending on technical demands for exploiting heat. The temperature of geothermal water at the entrance was 42°C , although, due to technical conditions, a higher value may be applied (up to 50°C), which would improve characteristic parameters of the operation of the heat pump entirely.

Due to operating limitations of the compressor (the pressure at the inlet side) and due to optimum characteristic parameters of a single-stage high-temperature heat pump, the refrigerant R600a is recommended. Based on the research conducted, using refrigerant R600a may cause a high-temperature heat pump to raise the temperature up to 85°C. The efficiency of a heat pump expressed by the coefficient of performance *COP*, depends on the difference between the evaporation and condensation temperatures of the refrigerants. The smaller the difference the greater the efficiency.

After observing the energy potential of geothermal water in the region of the town of Bijeljina, it can be concluded that using this water and its heat for the town's heating system is a promising concept from the aspect of technology, economy, energy and environment protection. Its exploitation is conditioned by its natural abundance and the location of the source, by potential utilization and transport to the users. Its potential as a form of renewable source of energy has a positive effect on the environment since it decreases the factors that cause pollution such as fossil fuels.

REFERENCES

[1] M. Jotanović, J. Krope, D. Goričanec, G. Tadić, V. Mićić, Korišćenje toplote niskotemperaturnih energetskih izvora sa visokotemperaturnom toplotnom pumpom, Tehnološki fakultet, Zvornik, 2012. (Projekat rađen za Ministarstvo nauke i tehnologije Republike Srpske).

[2] D.Malić, B. Đorđević, V. Valent, Termodinamika strujnih procesa, 2. izdanje, Građevinska knjiga, Beograd, 1980.

[3] Z. Rant, Termodinamika, Fakultet za strojništvo, Ljubljana, 2000.

[4] E. Torhač, D. Goričanec, S. Andrejevič, S. Saljnikov, J. Krope, New High Temperature Heat Pumps for Exploiting Low-temperature Sources, Res. J. Chem. Environ. **15** (2011) 1-6.

[5] J.Seasa, A. Pereiro, S. Bastos, J. A. Dopazo, Experimental Evoluation of Geothermal Heat Pump for Space Heating and Domestic Hot Water Simultaneous Production, Renewable Energy, **48** (2012) 482-488.

[6] H. Hucktemann, D. Müller, Simulation Study on Supply Temperature Optimization in Domestic Heat Pump Systems, Building and Environment, Available on line 5 september 2012.

[7] H. Lee, K. Saleh, Y. Hwang, R. Radermacher, Optimization of Novel Heat Exchanger Design for the Application of Low Temperature Lift Heat Pump, Energy, **42** (2012) 204-212.

[8] M. Kim, Y. J. Baik, S.R. Park, K. C. Chang, H.S. Ra, Design of a High Temperature Production Heat Pump System using Geothermal Water at Moderate Temperature, Current Applied Physics, **10** (2010) 117-122.

[9] S. Zhang, H. Wang, T. Guo, Experimental Investigation of Moderately High Temperature Water Source Heat Pump with Non-Azeotropic Refrigerant Mixtures, Applied Energy, **87** (2010) 1554-1561.

[10] M. Jotanović, G. Tadić, J. Krope, D. Goričanec, Analysis of Two-Stage High-Temperature Heat Pump Efficieney, International Journal of Systems Applications, Engineering & Development **6** (2012) 350-363

[11] M. Jotanović, M. Miščević, B. Kulčar, D. Goričanec, Optimal Proportion of Refrigerants in Single-Stage High-Temperature Heat Pump, International Journal of Systems Applications, Engineering & Development **6** (2012) 365-375