Торайғыров университетінің хабаршысы
ҒЫЛЫМИ ЖУРНАЛЫ

НАУЧНЫЙ ЖУРНАЛ
Вестник Торайгыров университета

Торайғыров университетінің ХАБАРШЫСЫ

Энергетикалық сериясы
1997 жылдан бастап шығады

ВЕСТНИК Торайгыров университета

Энергетическая серия
Издается с 1997 года

ISSN 2710-3420

№ 2 (2023)

Павлодар

НАУЧНЫЙ ЖУРНАЛ
Вестник Торайгыров университета

Энергетическая серия
выходит 4 раза в год

СВИДЕТЕЛЬСТВО
о постановке на переучет периодического печатного издания,
информационного агентства и сетевого издания
№ 14310-Ж
выдано
Министерство информации и общественного развития
Республики Казахстан

Тематическая направленность
публикация материалов в области электроэнергетики, электротехнологии, автоматизации, автоматизированных и информационных систем, электромеханики и теплоэнергетики

Подписной индекс – 76136

https://doi.org/10.48081/ABAC7746

SRSTI 44.31.41

https://doi.org/10.48081/PCLP1059

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THE POTENTIAL OF GEOTHERMAL SOURCES IN SOUTHERN KAZAKHSTAN FOR HEAT SUPPLY TO RURAL CONSUMERS, THE CASE OF THE ZHAMBYL REGION

The article presents the characteristics of geothermal deposits in the south of Kazakhstan and the analysis of the potential of geothermal waters of the Zhambyl region. Moreover, the study carries out the review of various types and methods of using geothermal water for household and its needs. Consequently, it outlines information on thermal boreholes. During the elaboration, manufacture and testing of these combined power units, several scientific and technical issues, such as the choice of the optimal low-boiling working fluid for heat and hot water supply systems were solved. An overview of the refrigerants and vapor compression fluids currently available have been made. The classification and characteristics of secondary heat carriers of various types and temperatures of their use are given. Therefore, it is proposed to use non-azeotropic binary mixtures as working bodies of a closed heat-power circuit. Moreover, an analysis was carried out on the use of non-azeotropic mixtures for heat pumps. It is proposed to use mixtures of refrigerants as working bodies for the second circuit. The specific characteristics of refrigerants are outlined. As a result, a description of the operation scheme of a steam compression heat pump operating in the mode of heat and hot water supply is highlighted.

Keywords: groundwater, geothermal resources, refrigerating gas, heat pump, propane, liquefied carbon dioxide.

Introduction

According to the results of studies of hydrogeothermal resources of Kazakhstan, more than a hundred exploration wells have been drilled for more than forty years, in which thermal waters with standard characteristics of flow rate, temperature and salinity, gas chemical composition, as well as prospects for use have been found. The use of geothermal energy potential is determined. 3,544 underground water deposits have been registered in the republic, their reserves amount to more than 42 million cubic meters of water per day. Groundwater reserves are replenished naturally due to precipitation or river runoff.

Based on the research, five characteristic geothermal zones have been identified for the territory of Kazakhstan:

- up to 20 °C – cold water;
- 20...40 °C – thermal, suitable for balneology, greenhouse and greenhouse farms;
- 40...75 °C – thermal waters suitable for district heating;
- 75...100 °C – thermal waters suitable for district heating, and at high pressures and costs – for electricity generation;
- >100 °C – thermal waters suitable for complex use of steam and hot water [1–2].

The object of the study is geothermal sources that have sufficient potential for heat supply of adjacent residential buildings and small settlements.

The objective of the study is to assess the potential of wells in the Zhambyl region, the possibilities of using secondary heat carriers in heat pumps for efficient heat supply.

Materials and methods

2.1. Research area

In order to assess the potential of hydrogeological wells of the Zhambyl region, which is geographically located at coordinates 44° N.L 72° E.L surveys of hydrogeological wells were carried out with measurements of the flow rate, temperature and pH of water, sampling of water for laboratory studies. The duration of the stage is about 25 days.

204 hydrogeological wells were identified in the studied territories, of which 137 are self-draining (Table 1, Fig.1), in 23 wells the groundwater level is below the earth’s surface, a submersible pump is installed in 19 wells, and in 25 wells the trunk is abandoned with stones and foreign materials. For clogged wells, cleaning the trunk with an airlift unit or drilling new wells is required. As the survey shows, 90% of self-draining wells are located within the Merke district [3].

Table 1 – Results of hydrogeological wells survey (2021)

No.	Administrative region	Total inspected well	With well-spring	Without well-spring	With pump	Clogged by stones
1	Merke	182	132	22	5	23
2	Shu	5	5	-	-	-
3	Korday	17	-	1	14	2
Total		204	137	23	19	25

Figure 1 – Administrative research areas

The flow rates of self-draining wells vary from 0.1 l/s to 40 l/s. The water level is at a depth of 0.1–10 m, in some wells a submersible pump is used to take water for domestic drinking water supply. The water temperature in the wells varies from 10.0 °C to 32.0 °C. The reaction (pH) of water is 7.5–9.5 (Table 2) [4].

Table 2 – Example of description of hydrogeological wells in the studied areas from 08/20/2021

Well No.	Geographic coordinates		Brief description of wells	Flow rate, l/sec	Photo of wells
	Northern latitude	East longitude			
2	42° 52' 42.84"	73° 5' 50.91"	Spouting well is located opposite the Aktogan village. t of water in the well is 17.7 °C pH=8.0	5	

9	42°52' 54.55"	73° 25' 12.31"	Spouting well is located at the entrance of Makhanda village. t of water in the well is 11.9°C, pH=8.3	20	
60	42°53' 3.10"	73° 28' 40.30"	Spouting well is located to the north of Kyzylkistak village, 1.2 km. t of water in the well is 15.0°C, pH=8.6	25	
22	42°58' 55.68"	73° 17' 15.05"	Spouting well is located in the territory of Sypatay Batyr enterprise. t of water in the well is 17.8°C, pH=8.5	30	
43	42°50 '2.50"	73°24' 42.80"	Wellbore clogged by rocks and foreign materials	-	

2.2. The use of secondary heat transfer medium for the efficient use of geothermal waters

As can be seen from the review, there are many explored deposits of geothermal waters with temperatures above 40 °C in the south of Kazakhstan. But there are a large number of sources with water temperatures below 40 °C, which are poorly used or ignored. In this regard, we suggest using geothermal water from 20–40 °C for heat and hot water supply according to the following scheme. To do this, we willneed geothermal water at its normal temperature and a second additional liquid with a lower boiling point than water, bothpassed through a heat exchanger. The heat of geothermal water evaporates the second liquid, the vapors of which drive the turbines. Since this is a closed system, there are practically no emissions into the atmosphere. During the development, manufacture and testing of these combined power units, it is necessary to solve a number of scientific and technical issues, such as choosing of a working fluid with a low boiling point of the second circuit, determining the lowest temperature, the condensate cooling temperature and choosing the optimal method for obtaining non-condensing gases from the condenser-evaporator.

As is known from the principle of operation of a closed-cycle compression heat pump, for the efficient operation of a closed circuit, a heat pump needs an additional fluid that converts geothermal water into steam. These liquids are also called: freon, freon, refrigerants. These working will ensure stable operation and high efficiency of the heat pump with the specified parameters. Traditionally, the most common working fluidsfor heat pumps are refrigerants: R11, R12, R13, R113, freon (R-134a), isobutane, freon, propane, etc. We determine the working fluid for the pump [5].

From the analyzed group of refrigerants, three refrigerants can be selected that are acceptable in terms of environmental characteristics. It is proposed to use non-azeotropic binary mixtures R32/R134a and R32/R152a as working bodies of a closed heat-power circuit. The most environmentally safe refrigerant is R152a. The working substance R152a is a medium-pressure refrigerant for the average operating temperature range of heating systems. The thermophysical characteristics are close to those of R12 and R134a refrigerants. Although hladon R152a is a good substitute for hladon R12, however, in its pure form it is not used because of its combustibility. R152a is used mainly in non-combustible mixtures of refrigerants. Refrigerant R152a is toxicologically safe, thermally and chemically stable, which contributes to the favorable operation of hot water supply [6].

Based on the analysis carried out on the use of non-azeotropic mixtures, we propose for heat pumps to use mixtures of refrigerants R32/R134a and R32/R152a as working bodies with a percentage of components of 30 to 70 %.

The higher values of the conversion coefficient of a heat pump operating on hot water supply, compared with the results obtained in the combined mode of heating + hot water supply, are explained by the fact that the difference between the boiling point and condensation in the hot water supply mode is smaller. Accordingly, the compression work is less.And, as a result, a higher conversion coefficient is obtained. In reality, the mode in which the heat pump works simultaneously for the needs of heating and hot water supply is more profitable. Since in such a cycle, the heat of the condensate is more fully used and the temperature of the water going for heating is higher than in the hot water supply mode [7–8].

The conversion coefficient obtained on R152a refrigerant exceeds R12 at various condensation temperatures from 2 % to 3 %, and the higher the condensation temperature, the more efficient the use of R152a refrigerant. Therefore, the best option for a secondary coolant for this scheme of operation of a steam compression heat pump is hladon R152a.

Results and discussion

The heat pump has three main units (evaporator, condenser, and compressor) and three circuits (cold, low-potential water source and water heating). Figure 4 shows the scheme of operation of the heat pump.

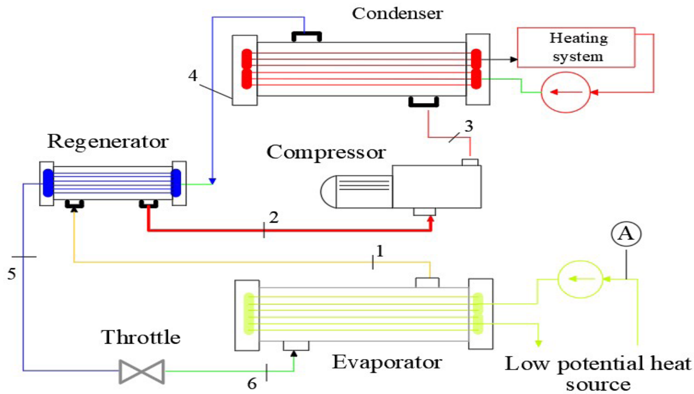

Figure 2 – Scheme of operation of a vapor compression heat pump

"The scheme works as follows: when low-potential heat is supplied to the heat pump's evaporator, the working fluid boils, transforming into a gaseous state (point 1). Next, the dry saturated steam enters the regenerator (point 2). Steam overheating occurs in the regenerator, and the superheated steam enters the 2nd compressor. Due to the compressor's work, the working fluid's enthalpy and temperature increase (point 3). In the condenser, the refrigerant condenses and turns into a liquid state, transferring heat to the process coolant. The liquid refrigerant enters the regenerator and shares part of the heat with the dry saturated steam before entering the compressor (point 4). Liquid refrigerant (point 5). under pressure enters the evaporator through a throttling device (temperature-regulating expansion valve) (point 6), and the cycle repeats.

In this scheme, R134a and R152a were used as refrigerants. Water from a well with a water temperature of 24 °C is used as a low-potential source. For calculations, the boiling point of the refrigerant in the heat pump evaporator is assumed to be 19 °C. The overheating of the refrigerant after the evaporator is set to 3 °C.The vapors of the refrigerant formed during boiling are sucked in by the compressor, so that the evaporator always maintains a low pressure and, consequently, a low temperature. Further, in the compressor, the refrigerant vapors are compressed and pumped into the condenser, where, condensing, it gives its heat to water. From the condenser, liquid refrigerant enters the super cooler, where it gives part of its heat to water. After passing through the throttling device, the refrigerant enters the evaporator and the working cycle repeats [9–10].

Table 2 – Comparison of the conversion coefficient φ for different refrigerants

Parameter	Modes					
	Heating		Hot water supply		Heating+Hot water supply	
	R134a	R152a	R134a	R152a	R134a	R152a
t_0, ^0C	19					
t_k, ^0C	75		55		75	
i1', kJ/kg	409,08	519,56	409,08	519,56	409,08	519,56
i1, kJ/kg	412,00	523,19	412,00	523,19	412,00	523,19
ic, kJ/kg	442,08	572,00	432,75	556,34	442,08	572,00
i2', kJ/kg	446,00	578,36	434,17	558,61	446,00	578,36
i3, kJ/kg	313,14	341,23	279,32	300,13	313,14	341,23
i4, kJ/kg	310,22	337,60	276,4	296,50	276,80	304,89
i1- i1',kJ/kg	2,92	3,63	2,92	3,63	2,92	3,63
i3- 4,kJ/kg	2,92	3,63	2,92	3,63	36,34	44,32
Alð, kJ/kg	34,00	55,17	22,17	35,42	34,00	55,17
$q_к$, *kJ/kg*	135,78	240,76	157,77	262,11	169,20	281,45
φ	3,99	4,36	7,12	7,40	4,98	5,10

From Table 4, you can see that

1 The conversion coefficient under the same initial conditions is higher for a heat pump running on R152a from 2.4 to 8.4 % than on R134a freon.

2 The compression performance of a compressor running on R152a freon is up to 38 % higher than on R134a.

Conclusion

Based on the conducted research, it can be stated that the geothermal waters of our republic are not used effectively, their potential and capabilities for providing heat and hot water supply are not sufficiently investigated. There are no promising research projects in this area in Kazakhstan. The proposed heat pump scheme can be used in almost all modern hot water and heating systems, which will provide hot water and heat supply to nearby villages and farms. The effective use of geothermal sources will save on combustible fuel and create conditions for ensuring environmental safety. The experience of using geothermal waters in developed countries shows their unlimited possibilities for generating heat and electricity.

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Material received on 20.06.23.

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Португалия Республикасы, Порту қ.
Материал 20.06.23 баспаға түсті.

ЖАМБЫЛ ОБЛЫСЫ МЫСАЛЫНДА, ОҢТҮСТІК ҚАЗАҚСТАННЫҢ ГЕОТЕРМАЛДЫ КӨЗДЕРІМЕН, АУЫЛДЫҚ ЖЕРЛЕРДЕГІ ТҰТЫНУШЫЛАРДЫ ЖЫЛУМЕН ЖАБДЫҚТАУ

Мақалада Қазақстанның оңтүстігіндегі және Жамбыл облысының геотермалды суларына талдау берілген. Тұрмыстық және шаруашылық қажеттіліктер үшін геотермалды суды пайдаланудың әртүрлі түрлері мен әдістері қарастырылды. Осы біріктірілген энергетикалық жүйелерді әзірлеу, өндіру және сынау барысында жылу және ыстық сумен жабдықтау жүйелері үшін қайнау температурасы төмен оңтайлы жұмыс сұйықтығын таңдау сияқты бірқатар ғылыми-техникалық мәселелер шешілді. Қазіргі уақытта қолжетімді хладагенттер мен бу компрессорлық сұйықтықтарға шолу берілген. Сондықтан тұйық контурлы күштік жылу тізбегінің жұмыс сұйықтығы ретінде азеотропты емес бинарлы қоспаларды пайдалану ұсынылады. Екінші контур үшін жұмыс сұйықтығы ретінде хладагент қоспаларын пайдалану ұсынылады. Сонымен қатар хладагенттердің жалпы сипаттамалары берілген. Нәтижесінде жылу және ыстық сумен жабдықтау режимінде жұмыс істейтін бу-компрессорлық жылу сорғысының жұмыс схемасының сипаттамасы берілген.

Кілтті сөздер: жер асты сулары, геотермалдыкөздер, хладон, жылулық сорғы, пропан, сұйытылған көмірқышқыл газы.

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ПОТЕНЦИАЛ ГЕОТЕРМАЛЬНЫХ ИСТОЧНИКОВ ЮЖНОГО КАЗАХСТАНА, НА ПРИМЕРЕ ЖАМБЫЛСКОЙ ОБЛАСТИ, ДЛЯ ТЕПЛОСНАБЖЕНИЯ ПОТРЕБИТЕЛЕЙ СЕЛЬСКОЙ МЕСТНОСТИ

В статье приводится характеристика геотермальных месторождений юга Казахстана и анализ потенциала геотермальных вод Жамбылской области. Выполнен обзор различных видов и способов использования геотермальной воды для бытовых и хозяйственных нужд. Следовательно приведены сведения по термальным скважинам. В ходе разработки, изготовления и испытания данных комбинированных энергоблоков решен целый ряд научно-технических вопросов, таких как выбор оптимального низкокипящего рабочего тела для тепла и системы горячего водоснабжения. Произведен обзор по существующим на сегодняшний день хладагентов и парокомпрессионных жидкостей. Дана классификация и характеристика вторичных теплоносителей различных видов и температуры их использования. Следовательно в качестве рабочих тел закрытого теплосилового контура предложено использовать неазеотропные бинарные смеси.Более того проведен анализ по использованию неазеотропных смесей для тепловых насосов. В качестве рабочих тел для второго контура предлагается использовать смеси хладагентов. Далее приведены оновные характеристики хладагентов. В результате приводится описание схемы работы парокомпрессионного теплового насоса, работающего в режиме тепла и горячего водоснабжения.

Ключевые слова: подземные воды, геотермальные ресурсы, хладон, тепловой насос, пропан, сжиженный углекислый газ.

Теруге 20.06.2023 ж. жіберілді. Басуға 30.06.2023 ж. қол қойылды.
Электрондық баспа
17,5 Mb RAM
Шартты баспа табағы 22,67. Таралымы 300 дана. Бағасы келісім бойынша.
Компьютерде беттеген: А. Мыржикова
Корректор: А. Р. Омарова
Тапсырыс № 4103

Сдано в набор 20.06 2023 г. Подписано в печать 30.06 2023 г.
Электронное издание
17,5 Mb RAM
Усл. печ. л. 22,67. Тираж 300 экз. Цена договорная.
Компьютерная верстка: А. Мыржикова
Корректор: А. Р. Омарова
Заказ № 4103

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