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Satbayev University

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CONTENTS

D.K. Akhmetkanov, M.Zh. Bitimbayev, V. Lozynskyi, K.B. Rysbekov, B.B. Amralinova
NEW VARIANTS FOR WIDE OREBODIES HIGH–CAPACITY MINING SYSTEMS
WITH CONTROLLED AND CONTINUOUS IN–LINE STOPING....6

F.A. Akhundov, M. Sarbopeeva, R. Bayamirova, A. Togasheva, A. Zholbasarova
ON THE ISSUE OF PREPARING THE WELLBORE FOR ITS FASTENING....22

A.M. Baikadamova, Y.I. Kuldeyev
GEOLOGICAL STRUCTURE OF THE ZHARKENT THERMAL GROUNDWATER DEPOSIT
BY THE EXAMPLE OF WELL 3-T....35

A.A. Yerzhan, P.V. Boikachev, B.R. Nakisbekova, Z.D. Manbetova, P.A. Dunayev
METHOD OF SYNTHESIS OF MATCHING TELECOMMUNICATION DEVICES BASED
ON THE METHOD OF REAL FREQUENCIES FOR 5G ANTENNAS IN A DISTRIBUTED
ELEMENT BASIS....47

K.S. Zaurbekov, S.A. Zaurebkov, A.V. Sladkovsky, D.Y. Balgayev
HYDRODYNAMIC SIMULATION OF THE STEAM-ASSISTED GRAVITY DRAINAGE
METHOD FOR DIFFERENT RESERVOIR THICKNESSES USING ECLIPSE....60

A.T. Ibrayev, D.A. Aitimova
A METHOD FOR ACCOUNTING THE IMPACT OF ERRORS ON THE QUALITY
OF ANALYTICAL INSTRUMENTS AND OPTIMAL CONTROL SYSTEMS....70

I.G. Ikramov, G.I. Issayev, N.A. Akhmetov, SH.K. Shapalov, K.T. Abdraimova
RECYCLING OF PRODUCTION WASTE AND ENVIRONMENTAL IMPACT ASSESSMENT....80

J.A. Ismailova, A.R. Khussainova, Luis E. Zerpa, D.N. Delikesheva, A.A. Ismailov
A NEW PREDICTIVE THERMODYNAMIC MODEL OF PARAFFIN FORMATION WITH THE
CALCULATION OF THE MATHEMATICAL ORIGIN OF THE POYNTING CORRECTION FACTOR....96

Zh.S. Kenzhetaev, K.S. Togizov, A.K. Omirgali, E.Kh. Aben, R.Zhalikyzy
INTENSIFICATION OF INHIBITOR-ASSISTED URANIUM ISL PROCESS....108

M.A. Li, T.T. Ibrayev, N.N. Balgabayev, B.S. Kali, D.A. Toleubek
SIMULATION AND OPTIMIZATION MODELING OF WATER USE MANAGEMENT
IN IRRIGATION SYSTEMS....119

A.S. Madibekov, L.T. Ismukhanova, A.O. Zhadi, A. Mussakulkyzy, K.M. Bolatov
RANKING THE TERRITORY OF THE ALMATY AGGLOMERATION ACCORDING
TO THE DEGREE OF POLLUTION....120

E.K. Merekeyeva, K.A. Kozhakhmet, A.A. Seidaliyev
CHARACTERISTICS OF THE STRUCTURAL UPLIFTS OF KURGANBAI AND
BAYRAM-KYZYLADYR LOCATED WITHIN THE ZHAZGURLI DEPRESSION....149

R.N. Moldasheva, N.K. Shazhdekeyeva, G. Myrzagereikyzy, V.E. Makhatova, A.M. Zadagali
MATHEMATICAL FOUNDATIONS OF ALGORITHMIZATION OF WATER POLLUTION
MODELING PROCESSES....164

Y.G. Neshina, A.D. Mekhtiyev, A.D. Alkina, P.A. Dunayev, Z.D. Manbetova
HARDWARE-SOFTWARE COMPLEX FOR IDENTIFICATION OF ROCK
DISPLACEMENT IN PITS....180

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GEOLOGICAL STRUCTURE OF THE ZHARKENT THERMAL GROUNDWATER DEPOSIT BY THE EXAMPLE OF WELL 3-T

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Abstract. Geothermal energy resources, as well as other types of renewable sources of energy, have the ability to satisfy almost any consumer in terms of potential and quality of energy. The utilization of geothermal sources is always based on a geological study. In order to determine whether a particular location has the potential to supply geothermal heat for industrial and domestic needs, a preliminary search is required. This feature is one of the main differences between geothermal energy and other renewable energy sources. Prospecting and exploration for geothermal groundwater was carried out in the Zharkent basin area in order to assess the exploitable reserves of thermal groundwater. On the territory of Zharkent geothermal field there are several wells, which are of interest for use as a source of energy. Two promising geothermal wells were identified — No. 1RT and 3T, for which research was conducted.

Keywords: thermal water, well, Zharkent, artesian basin, hydrodynamic research, geochemical research

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ЖАРКЕНТ ТЕРМАЛДЫ ЖЕР АСТЫ СУЛАРЫНЫҢ КЕН ОРНЫНДА ҰҢҒЫМАЛАРДЫ ЗЕРТТЕУ (3-Т ҰҢҒЫМАСЫ)

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Аннотация. Геотермалды энергоресурстар басқа жаңартылатын энергия көздері сияқты потенциалы және энергия сапасы бойынша кез келген тұтынушыны

қанағаттандыра алады. Геотермалды көздерді пайдалану әрдайым геологиялық зерттеуге сүйенеді. Нақты мекенжайдың өнеркәсіптік және тұрмыстық қажеттіліктер үшін геотермалды жылуының потенциалын анықтау үшін алдын ала іздеу-барлау рәсімін іске асыру керек. Бұл ерекшелік — басқа жаңартылатын энергия көздерінен геотермалды энергияның басты ерекшеліктерінің бірі. Жаркент бассейнінің жерінде термалды жер асты сулардың эксплуатациялық қорларын бағалау үшін геотермалды жер асты суларына іздеу-барлау жұмыстары өткізілді. Жаркент геотермалды кен орнында энергия көзі ретінде пайдалану үшін бірнеше ұңғымалар анықталды. Зерттеу өткізілген екі келешегі бар перспективті геотермалды №1РТ және 3Т ұңғымалар анықталды.

Түйін сөздер: термалды су, ұңғыма, Жаркент, артезиан бассейні, гидродинамикалық зерттеулер, геохимиялық зерттеулер

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ОБСЛЕДОВАНИЕ СКВАЖИНЫ ЖАРКЕНТСКОГО МЕСТОРОЖДЕНИЯ ТЕРМАЛЬНЫХ ПОДЗЕМНЫХ ВОД (СКВАЖИНА 3-Т)

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Аннотация. Геотермальные энергоресурсы, так же как и остальные виды возобновляемых источников энергии имеют возможность удовлетворить практически любого потребителя по потенциалу и качеству энергии. Эксплуатация геотермальных источников всегда основывается на геологическом исследовании. Для того, чтобы определить, имеет ли определенная местность потенциал снабжения геотермальной теплотой для промышленных и бытовых потребностей, необходим предварительный поиск. Эта особенность — одно из главных отличий геотермальной энергии от других возобновляемых источников энергии. На участке Жаркентского бассейна были проведены поисково-разведочные работы на геотермальные подземные воды с целью оценки эксплуатационных запасов термальных подземных вод. На территории Жаркентского геотермального месторождения расположены несколько скважин, представляющие интерес для использования в качестве источника энергии. Были определены две перспективных геотермальных скважины — №1РТ и 3Т, по которым проводились исследования.

Ключевые слова: термальная вода, скважина, Жаркент, артезианский бассейн, гидродинамические исследования, геохимические исследования

Introduction

This paper analyzes the hydrogeological exploration of thermo-mineral waters in the Usek area located in the central part of the Zharkent artesian basin. Exploration area is

located 36 km southwest of Zharkent (Panfilov District of Almaty Region, sheet K-44-II), on the right bank of the Ili River, on the lake plain (Plekhanov et al., 2012).

Recently in the territory of Zharkent Depression a large factual material on thermal waters of Cretaceous sediments was obtained. Zharkent Depression has a huge reserve of natural thermo-mineral resources, which are not rationally applied commercially. Utilization of thermal waters is urgent in the conditions of development of alternative energy generation and during the transition of the Republic to the rails of "green economy". (Mukhamedjanov et al., 1995).

The purpose of the research is to assess the exploitable reserves of thermal waters of Zharkent Depression for their industrial exploitation.

The object of research is Zharkent artesian basin, which is located within the sheets K-44-II, K-44-III, the northwestern part of sheet K-44-VII, and by administrative division is part of the Uygur and Panfilov Districts of Almaty Region. Major population centers are the city of Zharkent and the settlement of Chunja (Franco et al., 2016; Absametov et al., 2018).

The eastern part of the Ili Depression, corresponding to the Zharkent Depression, is almost universally covered by Quaternary formations. Ancient sedimentary rocks come to the day surface on the northern and southern parts of the depression rim. The mountain frame is represented by volcanogenic-sedimentary and metamorphosed Paleozoic formations. They compose isolated blocks within the Ulken-Boguty and Ketmen mountains in the south and in the Katutau, Dolantau and Tyshkantau mountains in the north. The rocks of the transitional, middle-upper Paleozoic complex are represented by weakly dislocated strata of effusive-sedimentary formations of the Carboniferous and Permian, deposited with deep erosion on the underlying strata (Mukhamedjanov et al., 1990).

The carboniferous system is represented by three divisions - lower, middle, and upper.

The lower section (Ketmen and Kungei Formations) is composed of basaltic, andesite and dacite porphyrites and their tuffs of dark gray and light gray color, transiting into effusives of acid composition (felsite porphyries, dacite porphyries, etc.) These formations are overlain by massive gray limestones with brachiopod and foramenifer fauna.

The Middle Carboniferous is represented by limestones and sandstones and is identified only in the northeastern part of the Zharkent Depression.

The Upper Carboniferous deposits are represented by effusives of the basic composition of dark color. They were uncovered only in well 4-T on the Koybin structure.

The upper section of the Carboniferous system, the lower section of the Permian system is represented by pinkish-gray quartz porphyries and is penetrated by the reference well 1-G in the central part of the Depression.

The *Permian system* is represented by interstratification of coarse-grained sandstones and mixed-pebble conglomerates in the lower part of the section, passing then to bluish-gray clays, mudstones and siltstones with interlayers of sandstones. Triassic deposits

were uncovered in wells 1-T, 2-T, and 3-T of the Usek area on the right bank of the Ili River, as well as in wells 3-G and 7-G on the extreme southeast of the Depression.

The *Jurassic sediments* were studied by cores from wells of the Usek area, as well as deep wells 3-G, 6-G, 7-G in the left bank part of the Depression. The Lower Jurassic is represented by light gray coarse-grained sandstones transitioning to siltstones and mudstones. The sediments are light to dark gray in color. There are thin interlayers of brown coals. In the vicinity of well 3-G, the thickness of deposits is 308 m, to the west — within the Usek area 107–170 m, and in the vicinity of Cis-Ili area the Jurassic deposits are completely absent.

The *Middle Jurassic* is represented by sandstones, siltstones, sandy mudstones and clays with interlayers of coal. They are uncovered by boreholes in the Usek area.

Upper Jurassic — Cretaceous sediments – kaolinized clays and siltstones are 20–35 m thick.

The rocks of the Jurassic system in the Pijima stage are represented only by the Upper Jurassic sediments, unconformably deposited on the rocks of undivided sediments of Permo-Triassic age. They are represented by kaolinized siltstones and argillite-like clays of pinkish-white and yellowish-pink color, 16-22 m thick (wells 6-T, 7-T, 8-T).

Cretaceous deposits are exposed in small local areas in mountain outcrops of Aktau, Malaysary, Kalkan (southern side of Zharkent Depression). Characteristics of deposits are given by the results of drilling deep wells.

Lower Cretaceous deposits are composed mainly of conglomerates with rare interlayers of clays and siltstones. Conglomerates consist of pebbles and gravel of effusive rocks on clay-carbonate cement. Within the Usek area, Lower Cretaceous conglomerates are present in all three wells. Depositional thickness ranges from 59 m in the north (Well 4-T) to 172 m within the Usek area.

Research stages. The following main types of work were carried out in the basin:

– plotting well survey routes;

– assessment of the wellhead equipment condition;

– laboratory survey;

– office work.

The results of the above types of work should solve the following main tasks:

– to determine the technical condition of the wells uncovered geothermal water;

– determine qualitative and quantitative parameters of geothermal waters, their temperature in order to assess the possibility of their use for various purposes;

– select the most promising areas of geothermal water distribution in Zharkent artesian basin;

– substantiate technological schemes for the extraction and use of geothermal water, taking into account the flow rate and temperature of wells, the chemical composition of geothermal water (Satpayev et al., 2009).

During the route survey of the Zharkent artesian basin 15 wells (№№ 1t, 2t, 3t, 5t, 9t 1tp, 2tp, 11a, 1040, 1046, 1597, 1487, 1478, 963, 963a) specially drilled for geothermal water were identified. The temperature of self-discharging groundwater reaches up to 92°C. This index for geothermal water was fundamental, and all of these identified

wells were subject to a route studies (Figure 1). Two additional wells were identified during the collection of actual artesian basin materials. Thus, a total of 17 wells were investigated for the area — Nos. 11a, 9t, 5t, 3t, 1t, 2t, 1tp, 2tp, 1040, 1046, 1597, 1487, 1478, 963, 963a, 3g and 1g. Of interest to us are the two wells 1RT and 3T. Wells are located from each other at a distance of 45 km and have the same flow rate: 40 kg/sec. Water temperature in well 1RT is 92°C, and in well 3T -66°C (Murtazin et al., 2014).

Fig. 1. Map of the route studies of geothermal wells of Zharkent artesian basin

Well №3T was drilled in 1982 to a depth of 3281 m. Cretaceous thermal-water-bearing complex, represented by coarse- and medium-grained sandstones, was penetrated in the interval 2270–2350 m [1]. Thermal waters with temperature 68–73°C are self-discharged with output 33 l/s at overpressure at the wellhead — 22 atm. Mineralization of thermal water is 0.5 g/l, water composition is sodium bicarbonate-sulfate. The well was not operated for many years, thermal water was discharged into an open pond (Vyalov et al., 2014).

Since 2012, experts of the Institute of Hydrogeology and Geoecology named after U.M. Akhmedsafin have been carrying out scientific and applied research at the site of well №3T. The works are being carried out under the scientific and technical program "Scientific and technological support of the energy sector development of the Republic of Kazakhstan" (renewable energy sources, energy saving) to justify and select technologies of integrated development of thermal energy potential of the well as a demonstration model at the EXPO - 2017 "Future Energy" and under the TFP program "Development of clean energy sources of the Republic of Kazakhstan for 2013–2017 years" under the project "Creating a complex of thermal and electric power generation". (Plekhanov et al., 2012).

Experimental production at the site of the well №3T of the Usek area was carried out in the period from June 16 to August 22, 2015, its total duration was 64 days. Initial self-discharge flow rate of the well was 20.0 l/sec. The water temperature at the wellhead was 67°C and the piezometric level was set at +216 m above the ground surface.

Before the beginning of experimental works the well was inspected. The pressure at the wellhead, at the time of the survey, was +216 m, i.e., there had been no level change since 1985.

After the survey, the well was equipped to carry out pilot filtration works. A second sample pressure gauge was installed at the wellhead. In addition to the existing one, another high-pressure gate valve was installed and a 1000-litre measuring vessel was installed at the outlet.

Upon completion of this work, pilot production was started from well No. 3T

1. The purpose of experimental works was to determine the nature of dependence of the well flow rate on water level lowering, to identify hydrogeological parameters, to identify the pattern of changes in the level, flow rate, temperature and water quality over time (Mukhamedjanov et al., 1992).

It was envisaged to carry out the discharge at two stages of lowering. Flow rate control during outflows was achieved by opening one or simultaneously two gate valves of the fountain equipment.

1.1 Output with one gate valve open (1st stage)

At the initial moment after the start of output the dynamic level dropped within five minutes to +106 m with a static level of +216 m. Further, during 10 minutes the hydrodynamic regime was unstable. Level fluctuations within +106.5 - +108.0 m were observed. Well flow rate during this period also fluctuated, in the initial period it was 19.8 l/sec and then changed from 19.7 to 20.2 l/sec.

Water temperature at the wellhead during this period gradually rose from 66 to 67°C.

On the second day after the start of output, fluctuations in dynamic level and flow rate ceased, with a gradual increase in temperature. The flow rate was 20,1 l/s with a level drop of 75,5 m and dynamic level +140,2 m.

As was established by further observations, for 5 days, the above values of flow rate and pressure were stable.

At the beginning of output and at the end, water samples were taken for full chemical analysis. The results of the analysis show that the hydrochemical regime was also stable. Water salinity was 0.42 g/l at the beginning and 0.41 g/l at the end of outlet.

At the end of the test output the well was closed and level recovery observations were carried out, which continued for 8 hours until full recovery of the static level (+216 m).

Analyzing the process of level recovery, we can note that almost in the first 5 minutes there was an abrupt level recovery to the mark of +179.0 m. During the next 11 minutes there was a gradual rise of the level to the initial static level (+216 m) and further during 7 days its rise was not observed.

1.2 Outflow with two open gate valves (2nd stage)

After observing the level recovery two gates of gushing valves were opened and the second stage of experimental-operational output at maximum flow rate approached to operational one started.

After opening the well, the piezometric level at the wellhead decreased sharply during the first minute, to +102.4 m, and then, in 1.5 hours, it dropped to +80 m. At the same time, the well flow rate decreased slightly from 36.75 to 37.67 l/sec. Further,

during 33 days, there was a gradual decrease of the level from +80 to +78 m. and the flow rate from 36.67 to 36.3 l/sec. Water temperature at the wellhead was gradually increasing and reached 67.5°C. During this period of time a water sample was taken and its analysis showed constancy of chemical composition and mineralization (0.41 g/l) during experimental production. Further, during 20 days, no changes in flow rate and dynamic level were observed. Water temperature by the end of the experiment increased up to 67.5°C due to heating near borehole space.

Thus, at the end of the test the flow rate of the well was 36.3 l/s at 138 m lowering and the specific flow rate was 0.263 l/s.

2. Monitoring observations of Usek area wells can be divided into two stages

The first stage continued from 1985 to 1998. At that time the borehole was annually inspected by a field team of the Institute of Hydrogeology and Hydrophysics and then by employees of Ystyk-Su (Mukhamedjanov et al., 1995). The natural regime of thermal waters was investigated, as during this period water withdrawal from the well was not carried out. In the process of research, water samples were taken for full chemical analysis, spectral analysis, determination of micro-components and gas composition of water. The well flow rate, static level and water temperature were determined. These studies showed that there are no changes in hydrodynamic, hydrochemical and temperature regime of thermal waters in undisturbed conditions over time (Mukhamedjanov et al., 1992).

At the second stage, after the beginning of experimental hydrogeological works on the well №3T, the regime in disturbed by pumping conditions was studied. Monthly flow rate and water temperature were measured during regime observations. Once a month water samples were taken for chemical analysis. Chemical analyses were carried out according to the mineral water scheme, including determination of gas composition. Analyzing the results of these observations we can conclude that there are no changes in chemical, gas composition and flow rate in the process of long-term pumping. Water temperature at the beginning of the experiment was 67.1°C and at the end, three months later, it increased to 67.8°C, which is explained by heating near the borehole space.

Thus, obtained materials on thermal water regime both in natural and disturbed conditions allow to speak about stable character of investigated thermal water parameters and, hence, they can be used for determination of design parameters.

The table presents a comparative characteristic of the main hydrogeological indicators.

№	Period	T, C	Min-on, mg/l	pH	Debit, dm/s	Piez-ric level, m	Kurlov 's Formula
1.	The first	74,0	0,36	7,3	50	+190	$\frac{HCO_3 56 SO_4 27 Cl 12}{(Na+K)94 Ca6}$
	After	86,0	0,41	8,4	50	н. с	$\frac{HCO_3 49 SO_4 23 Cl 15}{Na90}$
	Change	+12,0	+0,05	+1,1	-	-	No change

3. Laboratory survey. Laboratory surveys during detailed exploration of the Usek thermal water well №3T were one of the main types of work. Sampling for chemical analyses and their submission to the chemical laboratory of the Institute of Hydrogeology and Geoecology were performed in accordance with GOST 23268.0.78 "Mineral drinking, therapeutic and natural table waters" (Acceptance rules and methods of analysis).

The following types of water and gas sampling and laboratory tests are included in exploratory works: water sampling at the wellhead for reduced, complete, balneological and bacteriological analysis, determination of microcomponents in water and reduced spectral analysis of dry residue, determination of phenols and naphthenic acids, determination of water aggressiveness.

In general, geothermal waters of Zharkent artesian basin are characterized as low- and slightly mineralized, soft and moderately soft in content of hardness salts, which do not form sediments even during a long condition. Mineralization of geothermal waters of Zharkent artesian basin in the range of 0.4–0.6 g/dm3 and by chemical composition are: by anions three-component — sulfate-chloride-hydrocarbonate sodium, sulfate-hydrocarbonate-chloride sodium (Kalugin et al., 2014).

Methodology of experimental research

Mobilization of the drilling rig, drilling equipment and field camp, the choice of laying point of an exploration well 3-T, construction of access roads and a platform for the drilling rig, installation of a drilling rig, drilling equipment of the field camp drilling of an exploration well, geophysical studies, equipping the wellbore with casing, perforating, disassembly of the drilling rig, drilling equipment and field camp, pilot issue by the hydrodynamic research (trial and pilot issue).

Expected results: conduction of prospecting and exploration of thermal groundwater in the Zharkent Depression of Panfilov District, Almaty Region. Consideration and approval of a report with the calculation of operational reserves of geothermal water in the Interregional Commission on Mineral Reserves of "Yuzhkaznedra" ID, Committee on Geology and Subsoil Use. Thermal water inflow was obtained with temperature of +103□, flow rate of 50.5□dm□^3/C, overpressure at the mouth of 2345 m. Groundwater salinity is 0.71 g/□dm□^3.

Experimental outtakes were carried out, which made it possible to obtain initial data on hydrogeological parameters for the estimation of operational groundwater reserves.

Calculation of operational groundwater reserves was carried out by the hydrodynamic method for the water intake, consisting of 5 wells of area location. For the approval in RoK State Reserves Commission on B+C_1 category are represented the operational reserves of underground waters of Upper cretaceous thermal and water-bearing horizon in an amount of 12960 m3/day (150□dm□^3/s) for the period of operation of 10000 days.

At present, quite an extensive material on geothermal waters of Kazakhstan has been accumulated, a number of research works dedicated to the conditions of their formation, distribution and prospects of use have been carried out.

For the first time geothermal waters were uncovered in the process of prospecting for oil and gas with drilling of deep wells.

In the second half of the XX century, targeted prospecting and exploration works were carried out, in particular, in the territory of the South Kazakhstan Region.

The results of experimental research

The purpose of the experimental research conducted in the Zharkent Depression, was the survey of the territory of the areas where the exploitation (controlled or uncontrolled) of the Upper Cretaceous thermal-water-bearing horizon is carried out for a long period of time. These are, first of all, wells No. 1-TP and No. 2-TP of Cis-Ili thermal groundwater deposit, as well as well No. 3T.

In the process of research the technical condition of wellheads, their bundling, as well as the geo-ecological situation of the adjacent territory were recorded. The degree of use of thermal groundwater is characterized. Groundwater temperature at the spout is measured. Sampling of thermal groundwater for laboratory research of its quality has been carried out in order to assess the degree of change in the quality characteristics and temperature of groundwater over a long period of operation.

Laboratory tests of thermal groundwater samples were carried out to assess the possibility of using this water for heating purposes, hot water power generation, intensive fish breeding, as well as for balneology and health-improvement procedures.

Sampling was carried out on self-discharging wells from the water jet, as well as a deep water sample with a special sampler.

The following types of laboratory tests were performed:

–full chemical analysis according to SP 209 of 16.03.2015, TR approved by GD of RK №156 of 13.05.2008.

–determination of certain indicators;

–microbiological study of water;

–study of radioactivity of water;

–chemical and balneological conclusion.

№	Depth of occurrence of water rocks, m	The flow rate on the self-discharge dm/s	Pressure at the mouth of the kg/cm	Ion content mg/dm^3 %-экв						Dry residue g/dm^3
				Cl	SO^4	HCO^3	Na	Ca	Mg	
1.	2278-2344	50,0	19,5	20.0 12	61.0 27	162.0 56	101.0 94	5.0 5	1.0 1	0,33

Conclusions

Thus, for the time of regime observations changes in mineralization and chemical composition of thermomineral water were not noted. In Zharkent Depression highly promising for geothermal water extraction for various purposes is the territory of 12 thousand km2, including in its most part the area of artesian basin of the same name (Murtazin et al., 2014).

Based on the results of the work carried out:

– the carrier of geothermal energy is groundwater, which is widely distributed, constantly renewable, large reserves, availability of modern technical means and the possibility of their integrated use;

– The Zharkent geothermal water deposit has a significant energy potential. Natural heat reserves are 10,355 * 1012 kcal, and operational heat reserves — 27 218 649 * 103kcal/day;

– within the Zharkent artesian basin, 3 types of areas are distinguished by their energy potential: geothermal waters with temperatures of 65 -750C, 95 -1000C and 120-1500C, in accordance with this, various technologies for generating electricity should be used here;

– the temperature of groundwater is too low to ensure the operation of a conventional geothermal power plant. A feasible option for generating electricity from underground geothermal waters with a temperature of 65–96°C is a binary technology based on the use of the organic Rankine cycle (CRO).

The development of the deposit may consist of the creation of a powerful greenhouse-greenhouse complex using combined solar-geothermal installations that generate electricity for their own needs.

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CONTENTS

D.K. Akhmetkanov, M.Zh. Bitimbayev, V. Lozynskyi, K.B. Rysbekov, B.B. Amralinova
NEW VARIANTS FOR WIDE OREBODIES HIGH–CAPACITY MINING SYSTEMS
WITH CONTROLLED AND CONTINUOUS IN–LINE STOPING....6

F.A. Akhundov, M. Sarbopeeva, R. Bayamirova, A. Togasheva, A. Zholbasarova
ON THE ISSUE OF PREPARING THE WELLBORE FOR ITS FASTENING....22

A.M. Baikadamova, Y.I. Kuldeyev
GEOLOGICAL STRUCTURE OF THE ZHARKENT THERMAL GROUNDWATER DEPOSIT
BY THE EXAMPLE OF WELL 3-T....35

A.A. Yerzhan, P.V. Boikachev, B.R. Nakisbekova, Z.D. Manbetova, P.A. Dunayev
METHOD OF SYNTHESIS OF MATCHING TELECOMMUNICATION DEVICES BASED
ON THE METHOD OF REAL FREQUENCIES FOR 5G ANTENNAS IN A DISTRIBUTED
ELEMENT BASIS....47

K.S. Zaurbekov, S.A. Zaurebkov, A.V. Sladkovsky, D.Y. Balgayev
HYDRODYNAMIC SIMULATION OF THE STEAM-ASSISTED GRAVITY DRAINAGE
METHOD FOR DIFFERENT RESERVOIR THICKNESSES USING ECLIPSE....60

A.T. Ibrayev, D.A. Aitimova
A METHOD FOR ACCOUNTING THE IMPACT OF ERRORS ON THE QUALITY
OF ANALYTICAL INSTRUMENTS AND OPTIMAL CONTROL SYSTEMS....70

I.G. Ikramov, G.I. Issayev, N.A. Akhmetov, SH.K. Shapalov, K.T. Abdraimova
RECYCLING OF PRODUCTION WASTE AND ENVIRONMENTAL IMPACT ASSESSMENT....80

J.A. Ismailova, A.R. Khussainova, Luis E. Zerpa, D.N. Delikesheva, A.A. Ismailov
A NEW PREDICTIVE THERMODYNAMIC MODEL OF PARAFFIN FORMATION WITH THE
CALCULATION OF THE MATHEMATICAL ORIGIN OF THE POYNTING CORRECTION FACTOR....96

Zh.S. Kenzhetaev, K.S. Togizov, A.K. Omirgali, E.Kh. Aben, R.Zhalikyzy
INTENSIFICATION OF INHIBITOR-ASSISTED URANIUM ISL PROCESS....108

M.A. Li, T.T. Ibrayev, N.N. Balgabayev, B.S. Kali, D.A. Toleubek
SIMULATION AND OPTIMIZATION MODELING OF WATER USE MANAGEMENT
IN IRRIGATION SYSTEMS....119

A.S. Madibekov, L.T. Ismukhanova, A.O. Zhadi, A. Mussakulkyzy, K.M. Bolatov
RANKING THE TERRITORY OF THE ALMATY AGGLOMERATION ACCORDING
TO THE DEGREE OF POLLUTION....130

E.K. Merekeyeva, K.A. Kozhakhmet, A.A. Seidaliyev
CHARACTERISTICS OF THE STRUCTURAL UPLIFTS OF KURGANBAI AND
BAYRAM-KYZYLADYR LOCATED WITHIN THE ZHAZGURLI DEPRESSION....149

R.N. Moldasheva, N.K. Shazhdekeyeva, G. Myrzagereikyzy, V.E. Makhatova, A.M. Zadagali
MATHEMATICAL FOUNDATIONS OF ALGORITHMIZATION OF WATER POLLUTION
MODELING PROCESSES....164

Y.G. Neshina, A.D. Mekhtiyev, A.D. Alkina, P.A. Dunayev, Z.D. Manbetova
HARDWARE-SOFTWARE COMPLEX FOR IDENTIFICATION OF ROCK
DISPLACEMENT IN PITS....180

M.B. Nurpeisova, Z.A. Yestemesov, V.G. Lozinsky, A.A. Ashimova, S.S. Urazova
INDUSTRIAL WASTE RECYCLING – ONE OF THE KEY DIRECTIONS
OF BUSINESS DEVELOPMENT.....193

B. Orazbayev, M. Urazgaliyeva, A. Gabdulova, Zh. Moldasheva, Zh. Amanbayeva
METHODS OF MULTI-CRITERIA SELECTION IN PETROLEUM GEOLOGY UNDER
CONDITIONS OF FUZZY INITIAL DATA.....206

B.R. Rakishev, A.A. Orynbay, A.B. Mussakhan
AUTOMATED FORECASTING OF THE PARTICLE SIZE COMPOSITION OF BLASTED
ROCKS DURING BLASTHOLE DRILLING IN HORIZONTAL UNDERGROUND
WORKINGS.....222

Y.Sh. Seithaziyev
GEOCHEMICAL STUDIES OF CONDENSATE, GAS AND CORE SAMPLES DERIVED
FROM GAS-CONDENSATE FIELDS IN THE MOYNKUM SAG (KAZAKHSTAN).....242

E.Yu. Seitmuratova, R.T. Baratov, F.F. Saidasheva, V.S. Goryaeva, M.A. Mashrapova, Ya.K. Arshamov
TO STUDY THE RING STRUCTURES OF CENTRAL AND SOUTHERN KAZAKHSTAN
AND THEIR ORE CONTENT.....262

J.B. Toshov, Sh.R. Malikov, O.S. Ergashev, A.K. Sherov, A. Esirkepov
IMPROVING THE EFFICIENCY OF THE PROCESS OF DRILLING WELLS IN COMPLEX
CONDITIONS AT GEOLOGICAL PROSPECTING SITES.....282

V.A. Tumlert, Zh.K. Kasymbekov, R.A. Dzhaisambekova, E.V. Tumlert, B Sh. Amanbayeva
INFLUENCE OF THE HYDROGEOLOGICAL MODE OF OPERATION ON THE CHARACTER
OF COLLATING OF THE FILTER AND THE FILTER ZONE OF SEASONAL WELLS.....295

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