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THE INVESTIGATION OF THE PROPERTIES OF THERMAL WATER "KHACMAZ" (p, ϱ, T) IN KHACMAZ DISTRICT, AZERBAIJAN

M. M. BASHIROV
Baku Engineering University, Hasan Aliyev str., 120, Khirdalan, AZ0102, Azerbaijan
mbashirov@beu.edu.az

N. D. NABIEV
Baku Engineering University, Hasan Aliyev str., 120, Khirdalan, AZ0101, Azerbaijan
nnabiyev@beu.edu.az

N. S. RZAYEV
Baku Engineering University, Hasan Aliyev str., 120, Khirdalan, AZ0102, Azerbaijan
nrzayev@beu.edu.az

A. M. NAMAZOVA
Technical Humanitarian Lisey, Azerbaijan, Baku, Nasimi r, 20 January str.60, AZ 1102
aytan_namazova@yahoo.com

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ABSTRACT

The experimental laboratory, in which the properties of thermal water "Khachmaz" (p,ρ,T) in Khachmaz district, Azerbaijan were investigated, was air-conditioned at a constant temperature of T=293.15 K. The results obtained for the aqueous solution of water, toluene and NaCl (m=2.96661 $mol{\cdot}kg^{-1}$) were compared with the data given in various sources. The obtained results are presented graphically in the figures. In article, the dependence of the density of Khachmaz thermal water of the Khachmaz region of Azerbaijan on the temperature of $\rho/(kg \cdot m^{-3})$ was measured in the high-precision temperature range T = (278.15-468.15) in a tubular densimeter 5000M Anton-Paar DSA. Using experimental values at selected temperatures, analytical relationships of thermal water were established. The obtained values are described by mathematical equations.

1. Introduction

There are various geothermal technologies in the world with different levels of development, which are widely used in district heating systems, greenhouses and other applications. The technology of generating electricity from naturally high-conductivity hydrothermal tanks is also considered reliable. The majority of the geothermal power plants currently in operation in the world are based on dry steam turbines or "flash" devices (single, double and triple) and are used at 180 °C above hot water sources. Furthermore, new technologies are presently being developed, such as Enhanced Geothermal Systems (EGS)

Another option for a geothermal power plant uses natural geothermal resources, such as, water heated to a high temperature as a result of natural processes. However, the scope of such resources is limited. For example, in Russia, Kamchatka and Caucasian mineral water regions are among them. Otherwise, as a result of high geological pressure, water itself freely rises through a specially dug hole. This is a general operating principle that is applicable to almost all types of geothermal power plants.

Also, the substantial work is being carried out in this direction in Azerbaijan. By decision of the Republic of Azerbaijan dated October 21, 2004, the Ministry of Energy was instructed to ensure the implementation of the provisions of the State Program on "the Use of Alternative and Renewable Energy Sources". The State Program reflects the applications of energy sources that are convenient for our republic in this area, such as the use of wind energy, solar energy, geothermal waters, hydroelectric power of mountain rivers, canals, as well as the use of biomass energy. There are also fundamental possibilities of using the internal heat from the Earth's subsoil. According to the temperature, water or steam-water mixture can be used for hot water supply and heat supply, for the production of electrical energy, or for all of these purposes simultaneously. High-temperature heat of near-volcano areas and hot dry rocks are preferably used to generate electricity and heat. The potential total operating capacity of global geothermal power plants lags behind that of most other power plants using renewable energy sources. However, the high energy intensity of individual geographical regions where fuel and minerals are not available or relatively expensive, as well as government programs are developing in this direction.

2. The problem statement and solution

From 1950 to the present, the works of all researchers in Azerbaijan contain a lot of diverse and valuable information about the sources of mineral waters in different regions of the republic. Also, many questions of their formation and genesis are still insufficiently worked out and require in-depth study. This issue depends on solving the problems of prospecting and rational use of hydro-mineral resources. In hydrochemical and hydrodynamic approaches, the transition zone from less mineralized water to saline water, which is of greater interest in terms of the detection of different types of mineral waters, has not been studied yet.

The temperature of the mineral waters of Azerbaijan fluctuates between 4-65^{0}C. This applies only to natural water sources. At the same time, water with a temperature of 95°C is extracted from the bowels of the earth in Azerbaijan.

The investigated thermal waters were taken directly from their exit zones and prepared for experimental purposes by various chemical processing methods. These areas are rich in nitrogen and hydrogen sulfide thermal and cold mineral springs. Sodium (Na) constitutes the majority of the chemical elements of the "Khachmaz" geothermal power resource in Khachmaz district, Azerbaijan. It accounts for approximately 72.41÷90.12% of all chemical substances of the "Khachmaz" geothermal power resource in Khachmaz district, Azerbaijan. Before conducting the main experiments, the operating capacity of the experimental device to be used was confirmed by conducting verification experiments with materials that have high-quality experimental data. Since this vibrating tube method needs to be calibrated with at least two substances, water and aqueous NaCl solutions, methanol, ethanol and toluene were chosen as the main substances used for the calibration for this purpose. The process of calibration was analyzed. After the calibration procedure, the calibrated items were repeatedly measured and the average error of the comparisons was analyzed. In a number of cases, the experiments were repeated 4-5 times at the same temperatures, and the operating capacity of the device was checked at different times, regardless of its charging difference and the experiment. The laboratory where the experiments were conducted was air conditioned at a constant temperature of T=293,15 K. The comparison of the results obtained for the aqueous solution of water, toluene and NaCl (m=2,96661mol·kg^{-1}) with the information given in the literature is shown in figures 1, 2 and 3.

3.Discussion of the research work and its results:

As shown in the figures below, the difference between the newly obtained density data and the data given in the literature does not exceed the estimated errors of the measurements on this device. Bi-distilled water was obtained in various laboratory facilities. NaCl, methanol and other reagents were purchased from Merck company (Germany). The results were always close to each other with small errors. All this testifies to the high accuracy of the developed experimental device.

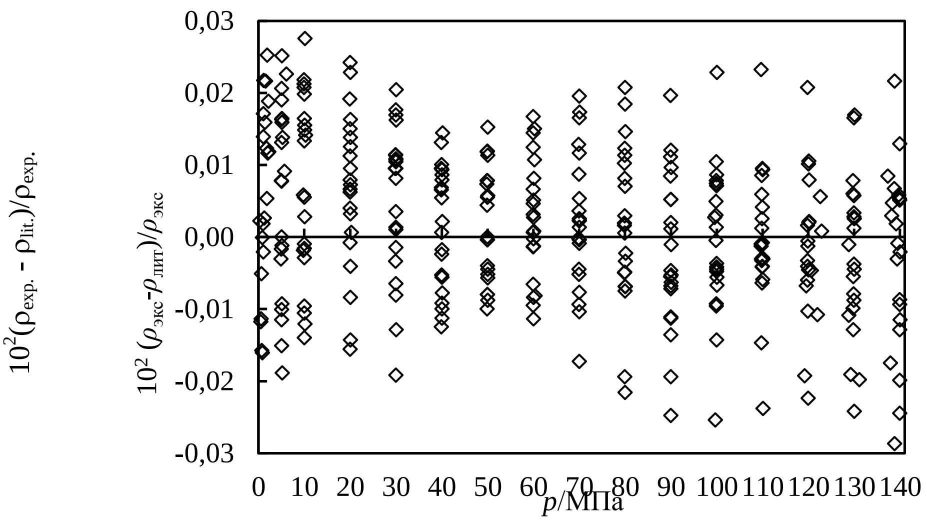

Fig. 1. Dependence of measured water density on pressure at temperature T=(278,15-468,15) K and difference from literature data IAPWS 95

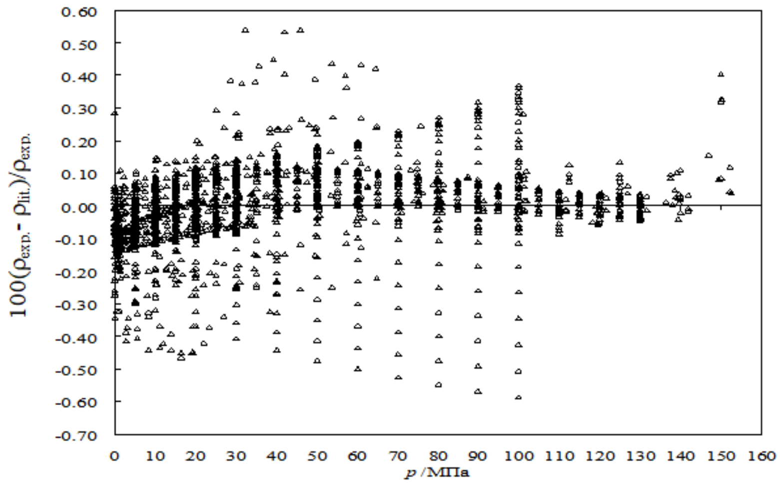

Fig. 2. Dependence of the measured density of toluene on pressure at a temperature of T=(278,15-468,15) K and the difference with data from various literature (data up to 2000).

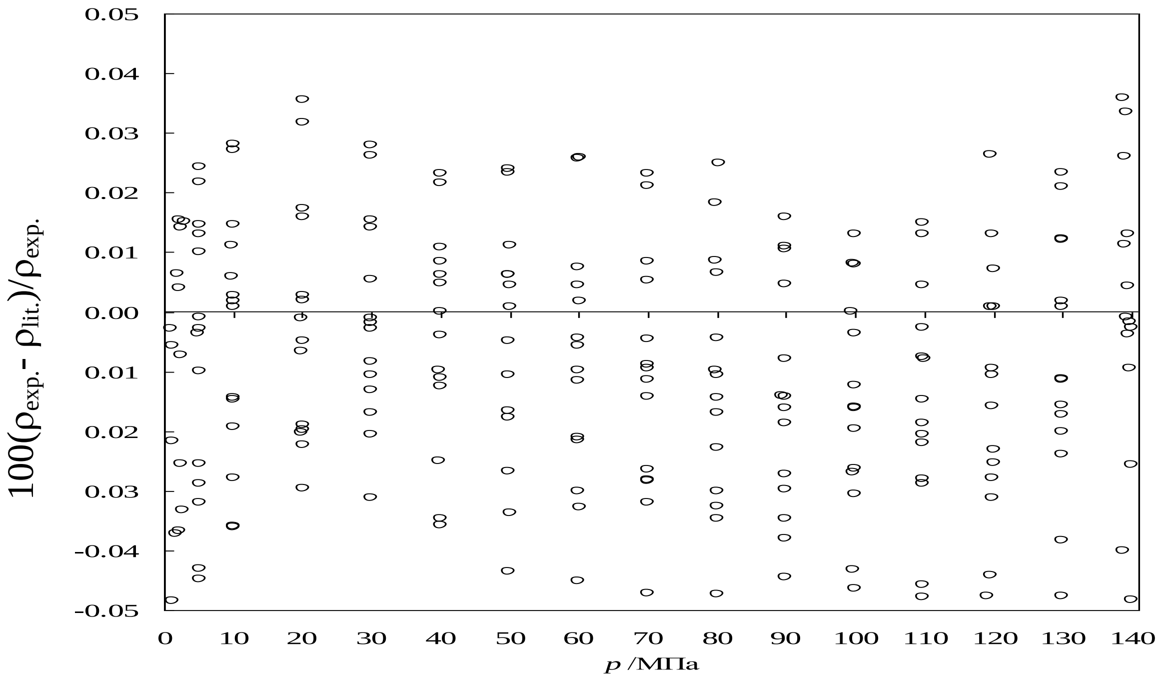

Fig. 3. Dependence of the measured density of aqueous NaCl solutions (m=2,96661 mol·kq[1]) at temperature T=(278,15-468,15) K and difference with data from different literature (data up to 2000).

After testing water, NaCl, methanol, ethanol and toluene (p, ϱ, T), dependences (p, ϱ, T) of thermal water in Khachmaz district of Azerbaijan, as well as high pressure and experimental device where vibration tube method is implemented at different temperatures were measured.When measuring the dependences (p, ϱ, T) in each equilibrium state, it was sought to create as low pressure values as possible in order to obtain highly accurate density values using graphical extrapolation at atmospheric pressure, which were compared with the values of density measured on the DMA 4500 device. The data obtained by these different methods are in good agreement within ±0.02%. Each isotherm experiment was performed with pressure intervals of approximately 5 MPa. Researches for all studied objects were conducted at temperatures starting from T=(278.15÷373.15) K and pressures up to p=40 MPa. The obtained experimental parameters (p, ϱ, T) are given in table 1.

Table 1. **Experimental values of the density of thermal water "Khachmaz" in Khachmaz district, Azerbaijan at various pressures and temperatures**

$\frac{p}{MPa}$	$\frac{\rho}{kg \cdot m^3}$	$\frac{T}{K}$	$\frac{p}{MPa}$	$\frac{\rho}{kg \cdot m^3}$	$\frac{T}{K}$
0.624	1004.04	278.15	1.160	989.32	328.02
5.004	1006.21	278.15	5.024	990.99	328.04
10.023	1008.65	278.16	10.079	993.00	328.17
15.012	1011.05	278.15	15.576	995.38	328.18
20.035	1013.43	278.14	19.985	997.22	328.19
25.036	1015.76	278.15	25.527	999.61	328.17
30.054	1018.07	278.15	30.023	1001.50	328.14
35.124	1020.37	278.14	35.513	1003.58	328.12
40.021	1022.56	278.15	39.978	1005.37	328.06
0.539	1002.59	288.14	0.846	981.22	343.15
5.006	1004.66	288.16	5.097	983.06	343.16

9.855	1006.87	288.17	9.967	985.17	343.14
15.151	1009.25	288.17	15.525	987.55	343.15
20.064	1011.43	288.17	20.000	989.45	343.15
25.121	1013.64	288.16	25.586	991.82	343.14
30.103	1015.79	288.16	30.045	993.68	343.16
35.111	1017.92	288.16	35.514	995.98	343.15
40.145	1020.04	288.15	40.050	997.87	343.15
1.025	1000.15	298.27	0.846	974.29	354.24
5.079	1002.02	298.22	5.097	976.23	354.25
9.818	1004.22	298.22	9.967	978.33	354.27
15.593	1006.61	298.17	15.525	980.63	354.27
20.018	1008.46	298.13	20.000	982.58	354.27
25.104	1010.69	298.13	25.586	984.92	354.27
30.155	1012.85	298.12	30.045	986.83	354.28
35.089	1014.82	298.13	35.514	989.17	354.27
40.040	1016.88	298.13	40.050	991.07	354.27
0.898	995.52	313.08	1.626	962.02	372.90
4.995	997.25	313.10	5.059	963.59	372.90
9.972	999.20	313.15	10.042	965.73	372.96
15.563	1001.65	313.17	15.525	968.08	372.97
20.008	1003.42	313.20	20.014	970.00	372.99
25.534	1005.80	313.18	25.596	972.31	373.00
30.057	1007.65	313.19	30.001	974.44	372.90
35.586	1009.82	313.17	35.576	976.79	372.91
39.970	1011.52	313.15	40.013	978.53	372.92

Isotherms are plotted in p-ϱ coordinates in the pressure range of 0,1-40 MPa (Figure 4).

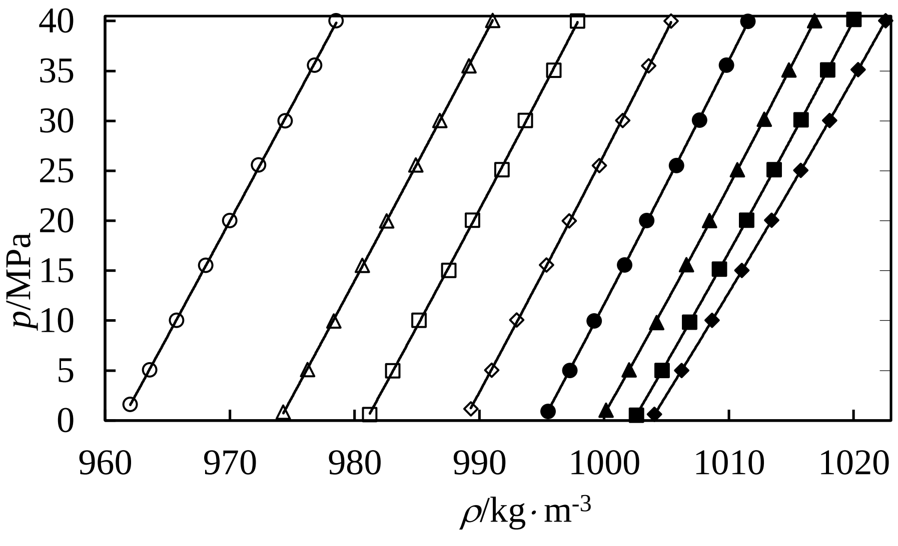

Fig. 4. Dependence of pressure (p) on density (ϱ) of thermal water "Khachmaz" in Khachmaz district, Azerbaijan, calculated according to formulas 1-2: ♦, 278,15 K; ■, 288,16 K; ▲, 298,17 K; •, 313,18 K; ◊, 328,18 K;□, 343,15 K; Δ, 354,27 K; ○, 372,96 K.

The measured density of thermal water "Khachmaz" in Khachmaz district, Azerbaijan was also calculated on the DMA 5000M device at atmospheric pressure with an accuracy of 0.01% (more precisely than at high pressures). This device allows accurate measurements at temperatures up to T = 363,15 K. The results obtained are written by the following equation of state:

$$p = A\rho^2 + B\rho^8 + C\rho^{12} \quad (1)$$

It is proved that with an increase in the third limit of the Akhundov-Imanov equation, the error in the description of experimental data decreases to $\Delta\varrho/\varrho=\pm(0.001\div0.003)\%$. The coefficients A(T), B(T) and C(T) depend on temperature in polynomial form:

$$A(T) = \sum_{i=1}^{3} a_i T^i,\ B(T) = \sum_{i=0}^{2} b_i T^i,\ C(T) = \sum_{i=0}^{2} c_i T^i \quad (2)$$

The values of the coefficients a_{ij}, b_{ij} və c_{ij} in equation (2) are given in table 2.

Table 2.

a_1= -3.9508587	b_0= 8322.6444921	c_0= -6583.286607275
a_2= 0.019210690563	b_1= -56.828468335	c_1= 45.23492762848
a_3= -0. 3685081337·10^{-4}	b_2= 0.103286734291	c_2= -0.07893862924

Equation (1) makes it possible to write down the experimental values of the dependence of thermal water "Khachmaz" (p, ϱ, T) with an average error of 0.007%, taking into account the values of the coefficients A(T), B(T) and C(T).

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