

RESULTS AND INTERPRETATIONS OF HOT AND COLD WATER INJECTION EXPERIMENTS ON PAUZHETKA WATER-DOMINATED GEOTHERMAL FIELD IN KAMCHATKA

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ABSTRACT

An early injection experiment has been conducted in attempt to evaluate of possibilities of waste disposal and of influence degree of reinjection on thermo and hydro regime of field.

Changing of temperature profiles, fluid enthalpy, pressure, well's output and chemical test data in more than 30 injection, exploitation and observation wells has been analyzed and interpreted.

Results have allowed to define of structure and resources of geothermal field more accurately, to determine of rational reinjection strategy and to restart of reinjection in 1994.

INTRODUCTION

The thermal water of Pauzhetka geothermal field contains some toxic components such as boron, arsenic and others. From the very beginning of commercial exploitation of the field, waste condensed geothermal steam and separated water were disposed in surface waterways. In the period of 1978 through 1988 the injection experiments were conducted for determination of waste water injection possibility. The main aim of proposed injection was to reduce environmental impact of geothermal development. The injection experiments were stopped after 1988.

The injection experiments were conducted by Pauzhetka division of Kamchatskburgeotermia Head Enterprise. There were three directions in experiments' conduction: 1. cold (from near-by Pauzhetka and Bystry rivers) water injection - for determination of cooling process velocity due to injection; 2. in-field hot (separated geothermal) water injection - for determination of well's injectivity and thermal response of exploitation wells; 3. boundary field injection - for determination of possible field resources recharge.

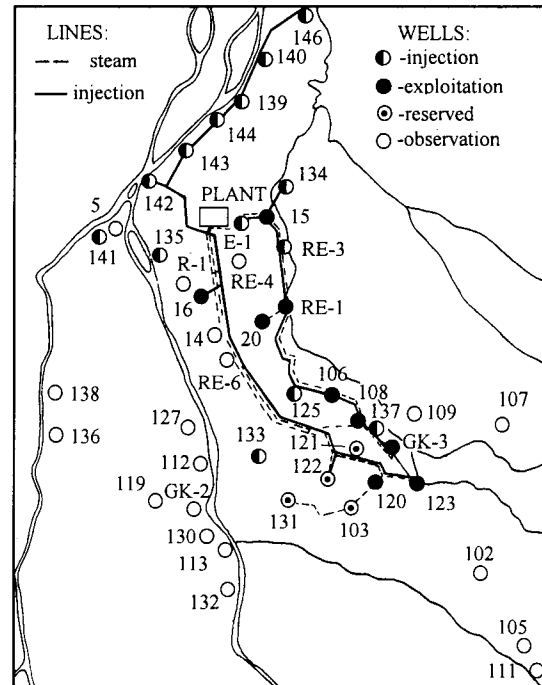


Fig.1 The Pauzhetka field exploitation scheme

Early analysis of injection experiments results has conducted by Mahalkin Yu.L. et al. (1988). Detailed analysis of injection influence on heat and exploitation field regime is in (Pashkevich R.I., 1993, 1995).

COLD WATER INJECTION

Results of cold injection are presented in Table 1. As turn out, wells 142 and 144 increased their injectivity during injection period. This effect was caused by geothermal water density drop inside the reservoir and by fractures thermal opening. The injection water arrival in the zones of wells 142, 143, 145 was determined during injection in well 135 (fig. 2, 3). The average temperature in these observation wells was lowering on 20-30°C.

Table 1. Results of cold water injection

well no.	rate, kg/s	t, °C	WHP, atm	level, m	Injectivity, kg/s (atm) m
gk-2	17-26.7	2	5.1-3.8	-	7.0-3.3
134	8.9-9.6	19-15	0.8-2.4	-	5.1-2.7
135	8.0-15	1	10-16	-	0.9-0.8
144	25-35*	3.8-6.2	-	1.85	3.6-2.6
143	25-35	5-11	2.2-0.6	-	18.8-9.4
142	16.8	3-7	3.3-1.2	-	7.6-3.9
141	4.1-5.0	8-12	2.0-3.4	-	1.5-1.0
136	8.9-1.0	7-9	5.7-6.4	-	0.7
136	2.4-3.2	4-6	1.9-3.4	-	1.0-0.6
138	12.5-1.0	3-5	9-17	-	0.7-0.4
143	50-60	6-10	2.2-2.3	-	17.2-16.7
139	15-16	6	5.0-3.3	-	3.6-2.6
135	70-60	3-10	-	12	23.3-20
140	8.3	7-12	6.2	-	1.2
146	11-10	12-15	2.0-2.5	-	3.5-3.0
144	27.5-14.4	6-10	-	6-6.3	13.8-7.2
	35-16.5	5-16	2.1-3.2	-	8.3-6.1
141	18-18.5	4-8	2.5-2.7	-	5.2-4.9
140	3.0-3.5	12-15	3.6-3.8	-	0.7
146	12-14.5	5-12	3.4	-	3.3-2.7
142	21-22	0.5-4	1.2-1.3	-	9.8-9.3
142	30-40*	-	-	12	2.8-2.1

*- lowering of well water level

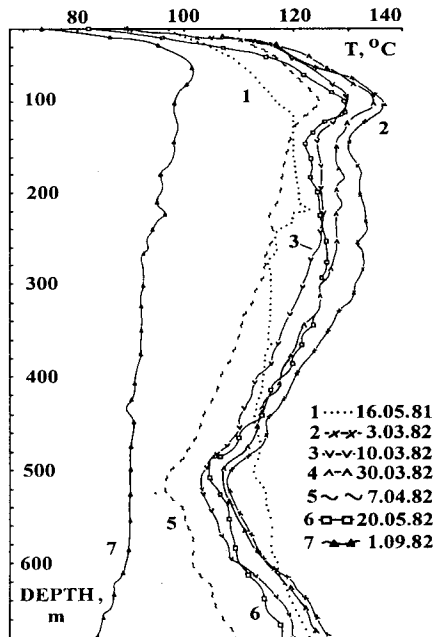


Fig. 2. Changing of water temperature in 142 well during cold water injection in 143 well (2-6) and in 135 well (7). 1 - standing up after drilling.

The injection water return was determined in the experiment of injection in well 144 with

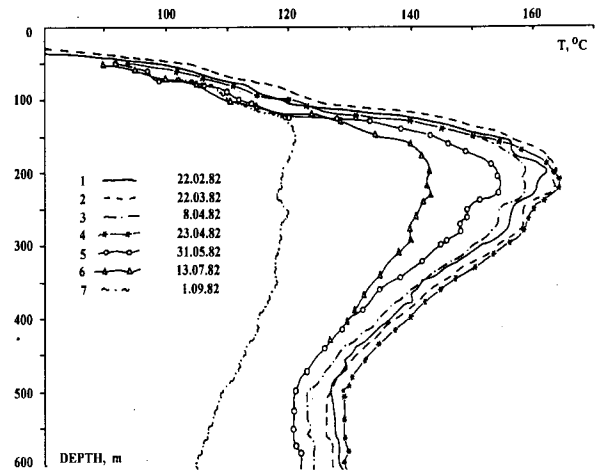


Fig.3. Changing of water temperature in 145 well during cold river water injection in 135 well.

simultaneous self-discharge of well 139. The temperature logging data analysis defined that injection water mainly filtrates through fractured boundary between porous tuff and tuffite layers of reservoir (fig. 4, 5). This result is confirmed by analysis of logging in injection wells. All the observation wells showed of level rise during injections.

The correlations of water mineralization and temperature changes during injection were determined (see for example fig.6).

HOT WATER INJECTION

Results of hot water injection is presented in Table 2.

Table 2. Results of hot water injection

well no.	rate, kg/s	t, °C	WHP, atm	level, m	Injectivity, kg/s (atm) m
125	5.0	70	-	62.0	1.3
	14.3-15.4	70-73	-	-	*
	23.0-25.0	-	-	-	3.7-2.6
145	7.3	22-36	2.2-0.9	-	3.8-2.3
E-1	6.2	97	-	4.15	1.6
137	23-27	98-99	-	132	0.8-0.7
E-1	10-12	-	1.0-3.0	-	5.5-4.8
R-3	30-31.5	126	1.5-1.8	-	12.3-11.0
134	6-8	-	2.7	-	2.2-1.6
133	29.3-35.7	98	-	105.3	0.8-0.7
143	71-79	125	7.4-7.8*	-	8.9-8.5

*- lowering of well water level

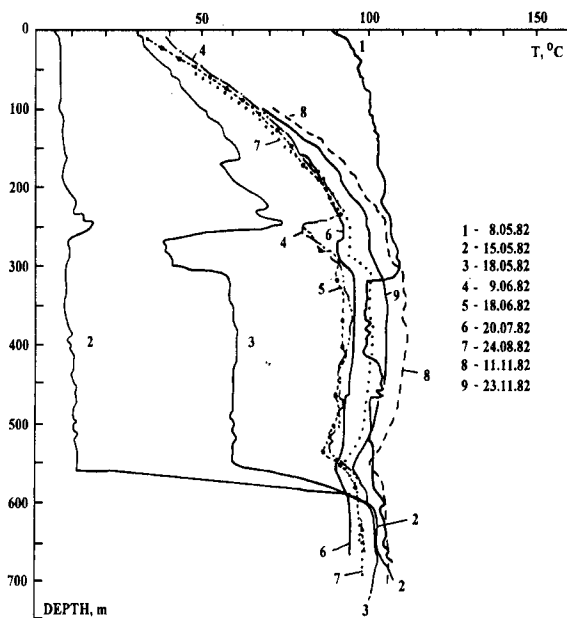


Fig 4. Changing of water temperature in 139 well before (1) and after (2-9) cold river water injection.

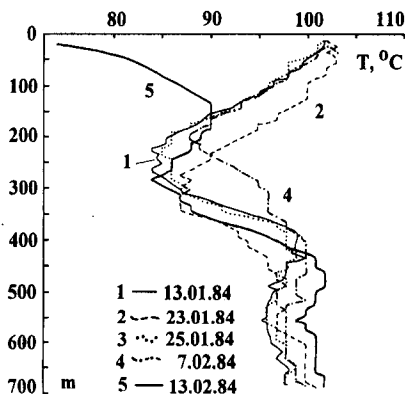


Fig. 5. Changing of water temperature in discharging 139 well during cold water injection in 144 well by drilling pump.

HOT WATER IN-FIELD INJECTION

The injection of 98°C separated geothermal water in well 137 during 3 month did not significant influence on exploitation regime of near-by exploitation wells 106, GK-3, 120. The same results were in the case of 70°C water injection in well 125 during 1 year.

The well 133 98°C injection during 2 years also did not influence on exploitation wells regime.

Nevertheless this injection had led to the average temperature decrease of 25°C in observation wells on the boundary of the field. That result caused of piesometric down injection flow in south-east direction.

HOT WATER BOUNDARY FIELD INJECTION

The injection of separated water form wells 106 and 108 in group of wells 134, RE-3, E-1 during more than 3 years had shown the injection water return in exploitation well 15. The experimental measured flash level in that exploitation well increased during injection period and was depended on injection rate and increased as well as well head pressure during injection. The enthalpy of steam-water mixture on the well 15 head had decreased on 10 kCal/kg during injection. The steam fraction correlated with injection rate (fig. 7).

The group injection has led to decrease of output of exploitation wells 16 and 20 due to inject return, as showed chemical test of produced water. In addition, the lowering of temperature in 135 well was occurred during this experiment.

The injection of separated 79°C water in well 143 during 8 month showed inject arrival in well 142 zone (fig.8).

CONCLUSION

As injection experiment's results had shown, more rational strategy of reinjection on Pauzhetka field is boundary field injection. The reinjections conducted in past volume had not essentially influenced on exploitation regime of reservoir. Just that strategy had used in Project of Pauzhetka field Development, issued by Kamchatsky Complex Department of NIPGeochem Institute (Pashkevich R.I. et al. 1995). In 1994 the reinjection on Pauzhetka field was restarted with the injection well 142, rate ~ 20 kg/s. Since the December of 1995, the 143 and 144 injection wells have been included and reinjection rate has been increased to 54.4 kg/s. Now the whole separated water from 120 and 122 production well is reinjected. In the future total injection has projecting.

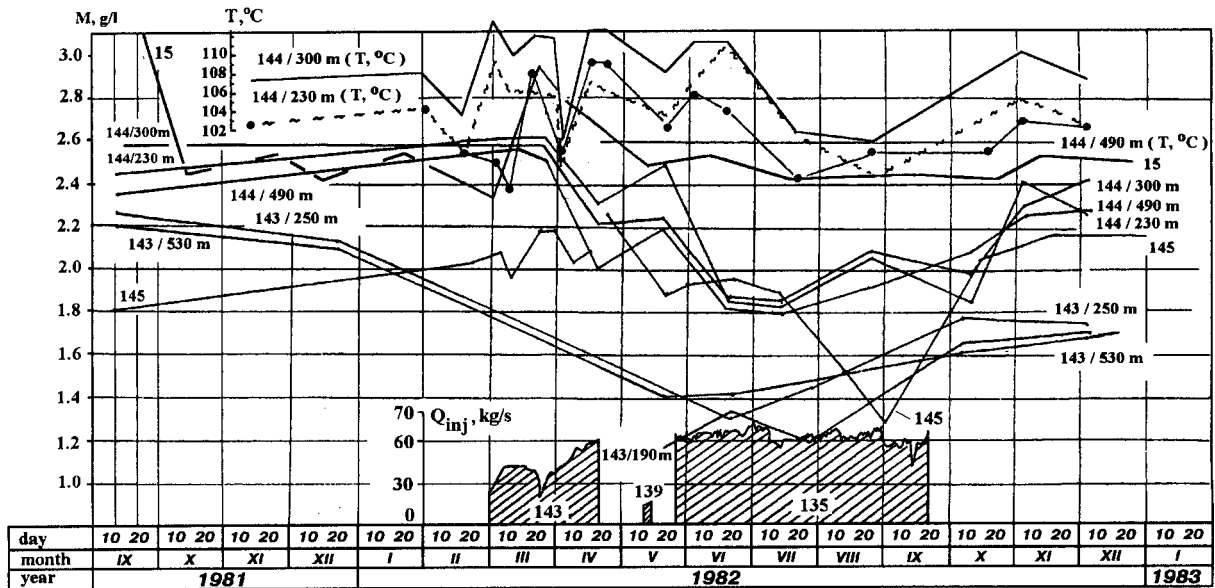


Fig. 6. Correlation of changing of mineralization of water in 144 and 143 observation wells and of separated water from production well 15 (by Mahalkin Yu.L. et al., 1988) with changing of water temperature in 144 and 145 wells (2,3) during the injection of cold river water in 143, 139 and 135 wells (Pashkevich R.I., 1993,1995). M - mineralization; T - temperature. Q_{inj} - injection rate. Number after (/) indicates depth of mineralization and temperature determination.

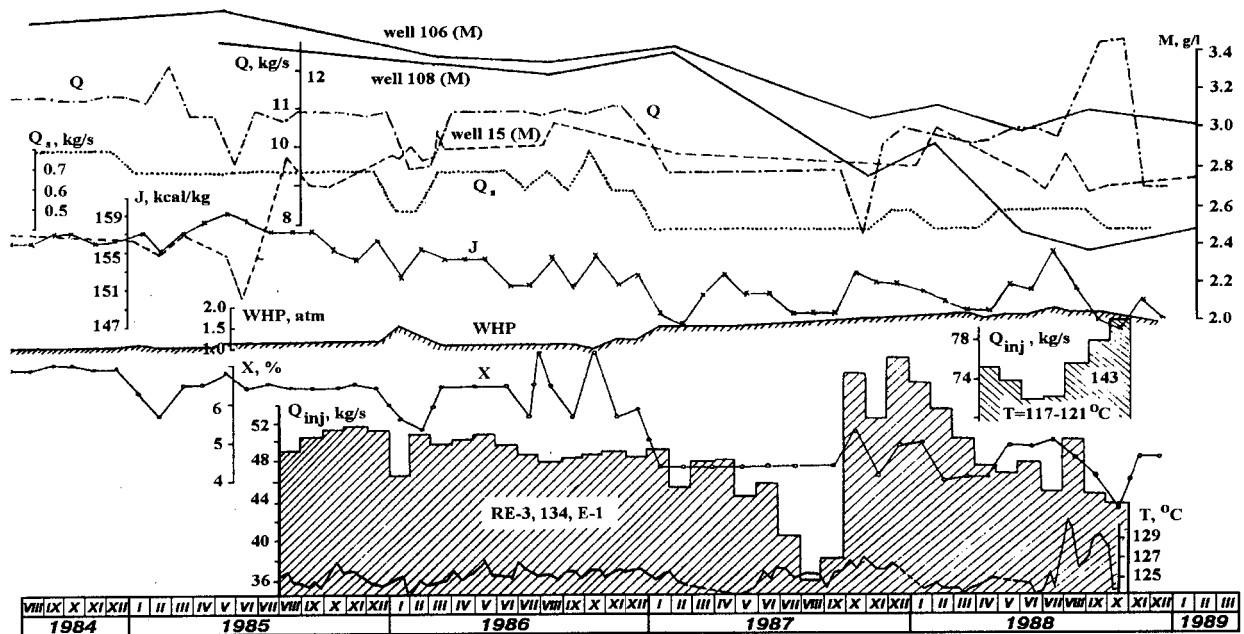


Fig. 7. Correlation of changing of well 15 production parameters during the injection of separated water from 106 and 108 wells in group of RE-3, 134, E-1 wells and during injection of separated water in 143 injection well. Q - steam-water mixture rate; Q_s - steam rate; J - enthalpy of production steam-water mixture; WHP - wellhead pressure; X - steam ratio; Q_{inj} - injection rate; M - mineralization of separated water from production wells 106, 108, 15; T - injected water temperature.

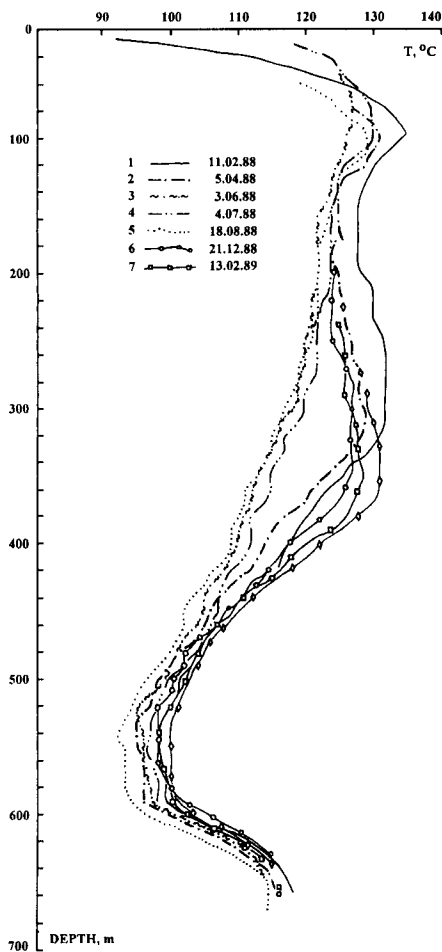


Fig. 8. Distribution of water temperature in 142 well before (1,2), during waste thermal water injection in 143 well (3-5), and after injection stop (6,7).

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