

# Thermal-Steam Cyclic Processing Technology of Development Objects In Karazhanbas Kazakhstan Field

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## Abstract

**Background:** This paper investigates the Karazhanbas oil field, according to the development condition and with application of impact thermal methods on layer. For this purpose, simultaneous application of thermal-steam cyclic wells processing are utilized. **Methods:** At the first step, geological structure data are provided on new wells. Then various indexes such as in homogeneity, filtration and capacitor properties of layer-collectors, physical and chemical properties analysis and petroleum composition are evaluated. **Results:** The statistical analysis on wells processing is conducted and the main factors which has the most effects are specified. On the basis of the analysis, the optimum mode of carrying out Thermal-Steam Well Processing (TSWP) is determined. Results demonstrate that productions with water content are optimal. Finally technological and economic effects of carrying out processing are proposed. **Conclusion:** The payback period of TSWP costs is about 1 year, in other words, the extra initial costs are covered over a year.

**Keywords:** Karazhanbas Field, Thermal Methods of Layer Impact, Thermal-Steam Well Processing (TSWP)

## 1. Introduction

According to Strategy of Kazakhstan development till 2050 and Strategy of industrial-innovative development by 2030, the republic intends to develop bodily oil branch to help it enter the world market of energy resources. *These technologies are improved due to oil and gas projects of the international oil monopolies and large investments.*

The theory and practice of high-viscosity oil layers development and world experience show that the most perspective direction of these layers development is thermal methods. Improvement of existing and invention of more efficient ways of impact on these layers, with application of thermal ways and with lowering the material expenses, is

the actual scientific and technical direction for oil industry of the world in general and Kazakhstan in particular<sup>1,2</sup>.

Primal problem of field development regulation process for the purpose of carrying out thermal-steam cyclic processing of layers is realizations of geological and technical actions.

The mechanism of reservoir naphtha extraction when pumping in layer of gaseous steam is based on ability of naphtha properties change and water containing in productive layer as a result of increase in formation temperature. *Increasing the formation temperature density, viscosity and the phase relation of naphtha decreases are favorable for oil recovery.*

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## 2. The Characteristic of the Geological Structure taking into Account Data on New Wells

Oil field Karazhanbas was opened in 1974. The pioneer of this field was the structural and search well of K-12, where gushing inflow of naphtha from the Lower Cretaceous deposits was received.

*At the 01.01.2014, 3421 wells were drilled on the field.*

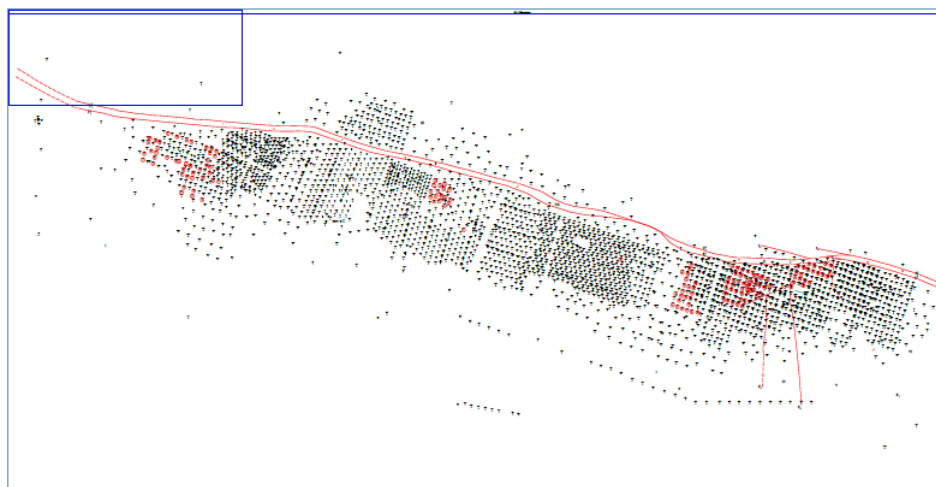
*During 2013 on the field 154 wells were drilled; among them in the 1 block 44 wells were in the western part, 19 wells were located in the central part, 69 wells were in eastern part and 22 wells were in the 5 block.*

Oil-and-gas content of the field in the Middle Jurassic and Lower Cretaceous deposits were established for which

the productive horizons of Yu-I (the top, average and lower layers), Yu-II (the main and lentiform) and the emitted layers A1, A2, B, B, G, D1, D2.

Proceeding from geological structure of the field, the collection properties characteristic, layers collectors, within productive thickness of the field 3 objects of development are allocated. The first includes naphtha deposits, bound to A1, B and B layers, the second – to layers G and D1 and the third – all deposits, bound to D2, Yu-I and Yu-II horizons<sup>3</sup>.

The data received as a result of new wells drilling allowed to specify the tank structure of east and western field part, filtration and capacitor properties of solids-collectors were also specified.



**Figure 1.** The scheme of the drilled new wells arrangement.

On three objects of development 350 wells are drilled totally (Figure 1), which did not make changes to the adopted OWC provision<sup>1</sup>.

## 3. The Physical and Chemical Properties Analysis of Petroleum and Gas Composition taking into Account Results Research of Naphtha and Gas Tests from New Wells

In 2013 the JSC Karazhanbasmunay made selection and researches of naphtha tests from deep wells 414,

2484, 2960, 3008, 3659, 4677, 5277, 5376, 6024, 6562. Researches were conducted in Alstron LLP according to OST «39-112-80 Naphtha. Standard research of reservoir naphtha»<sup>4</sup>.

In this section physical and chemical characteristics of the reservoir, decontaminated naphtha and composition of Karazhanbas field petroleum gas on condition of study as of 01.01.2014 remain at acceptable level in SDP.

### 3.1 Properties of Reservoir Naphtha

The characteristic of reservoir naphtha in development objects and layers of Noncomian and Jurassic productive deposits of Karazhanbas field, accepted in the Specified Development Project (SDP)<sup>4</sup> is presented in Table 1, received by research results of the deep tests

which selected more than from 40 wells during investigation and development of the field.

Researches were carried out by the companies CLKNGR, Ros NIPItemneft, KazNIPIneft, JSC NIPIneftegaz, Alstron LLP.

On deep tests the complete research complex according to OST 39-112-80 «Naphtha. Standard research of reservoir naphtha».

On deep tests average parameters of reservoir naphtha on 1 and 2 - to objects of development (layers A, B, B, G, D, D2) - on northern, western, central and east sites and on 3 object of development (the horizons of Yu-I, Yu-II) - on the western, central and east sites are received.

The parameters of reservoir naphtha accepted in SDP<sup>4</sup> are presented in Table 1.

**Table 1.** Average parameters of reservoir naphtha on development objects and the allocated sites accepted in SDP

Name	Quantity of exemplars		Change diapason	Average value
	of wells	ex.		
<b>1-object - (Layer A - North)</b>				
Pressure saturation, MPa	3	4	1,10-2,96	1.85
Gas content, m <sup>3</sup> /g	3	4	6,49-12,00	9.09
Volume coefficient in Rpl, p. shares.	3	4	1,007-1,016	1.013
Viscosity of reservoir naphtha, mPa*sec	3	4	304-500	411
Density of reservoir naphtha, g/cm <sup>3</sup>	3	4	0,8904-0,9388	0.9211
<b>1-object - (Layers A, B - Central site, West)</b>				
Pressure saturation, MPa	9	11	1,14-2,19	1.72
Gas content, m <sup>3</sup> /g	9	11	3,60-8,20	5.97
Volume coefficient in Rpl, p. shares.	8	10	1,003-1,028	1.014
Viscosity of reservoir naphtha, mPa*sec	8	10	182-576	378
Density of reservoir naphtha, g/cm <sup>3</sup>	8	10	0,9160-0,9389	0.9282
<b>1-object - (Layers A, B, B - East)</b>				
Pressure saturation, MPa	5	10	1,18-2,09	1.59
Gas content, m <sup>3</sup> /g	5	10	2,42-7,74	5.29
Volume coefficient in Rpl, p. shares.	5	10	1,007-1,016	1.012
Viscosity of reservoir naphtha, mPa*sec	5	10	311-805	541
Density of reservoir naphtha, g/cm <sup>3</sup>	5	10	0,9235-0,9373	0.9292
<b>2 object - (Layers G, D - Central site, West)</b>				
Pressure saturation, MPa	14	18	1,20-2,42	2.03
Gas content, m <sup>3</sup> /g	14	18	3,90-10,09	7.07
Volume coefficient in Rpl, p. shares.	13	17	1,001-1,035	1.020
Viscosity of reservoir naphtha, mPa*sec	11	14	171-663	449
Density of reservoir naphtha, g/cm <sup>3</sup>	14	18	0,9140-0,9560	0.9304
<b>2 object - (Layers G, D - East)</b>				
Pressure saturation, MPa	8	14	1,59-2,27	1.87
Gas content, m <sup>3</sup> /g	8	14	5,95-12,15	8.21
Volume coefficient in Rpl, p. shares.	8	14	1,014-1,024	1.019
Viscosity of reservoir naphtha, mPa*sec	8	14	387-600	448
Density of reservoir naphtha, g/cm <sup>3</sup>	8	14	0,9184-0,9301	0.9234

3 object – (Yu-I horizon – West)				
Pressure saturation, MPa	1	1	-	1.12
Gas content, m <sup>3</sup> /g	1	1	-	4.70
Volume coefficient in Rpl, p. shares.	1	1	-	1.011
Viscosity of reservoir naphtha, mPa*sec	1	1	-	500
Density of reservoir naphtha, g/cm <sup>3</sup>	1	1	-	0.9329
3 object – (The horizon of Yu-I, Yu-II – Central site)				
Pressure saturation, MPa	1	2	-	7.15
Gas content, m <sup>3</sup> /g	1	2	-	530
Volume coefficient in Rpl, p. shares.	1	2	-	2.16
Viscosity of reservoir naphtha, mPa*sec	1	2	-	1.011
Density of reservoir naphtha, g/cm <sup>3</sup>	1	2	-	0.9228
3 object – (The horizon of Yu-I, Yu-II – East)				
Pressure saturation, MPa	5	9	1,50-2,27	1.94
Gas content, m <sup>3</sup> /g	5	9	6,79-12,15	9.07
Volume coefficient in Rpl, p. shares.	5	9	1,014-1,024	1.019
Viscosity of reservoir naphtha, mPa*sec	5	9	387-600	458
Density of reservoir naphtha, g/cm <sup>3</sup>	5	9	0,9184-0,9277	0.9232

As we can see from the table, physical and chemical properties of reservoir naphtha on the horizons and sites are close among themselves. Reservoir naphtha of the Jurassic horizons 3I object) differs a little from naphtha of cretaceous layers (1 and 2 object) by properties. Karazhanbas is naphtha heavy, of high-viscosity and is poorly sated with gas.

On separate wells of cretaceous and Jurassic layers (1, 2 and 3 objects of development) experiments were made on differential reservoir naphtha de-gassing allowing to estimate changes of the main reservoir naphtha properties at pressure decrease from formation to atmospheric<sup>1</sup>.

### 3.2 Component structure of petroleum gas

Component structure of Karazhanbas field petroleum gas is estimated at SDP<sup>4</sup> by results of over 60 tests researches on single-pass de-gassed reservoir naphtha (Table 1). In 2013 single-pass de-gassing gas tests (research of the deep naphtha tests) selected from the above wells were investigated.

Petroleum gas of all development objects has practically identical structure. Its principal component is methane – over 93% moln, the content of ethane is 1,90% moln and propane – under 1,15% moln. From non hydro-carbonic gas components in solution there is nitrogen

– under 3,96% moln. and carbon dioxide – no higher than 0,7% moln.

The component structure of the free gas is presented by gas selected from the well 106 punched in the gas cap range. The free gas of Karazhanbas field by structure practically does not differ from gas in solution<sup>5,6</sup>.

### 3.3 Properties and Composition of the Decontaminated Naphtha

In this section physical and chemical properties of the decontaminated Karazhanbas field naphtha 1, 2 and 3 development objects are presented on 142 tests, which are selected for the entire period of development and operation of the field.

After drawing up<sup>2</sup> the new researches of 10 decontaminated naphtha tests received after deep de-gassing of naphtha tests were conducted. Researches of the decontaminated naphtha were conducted in laboratory of limited liability partnership ALSTRON in 2013.

*The decontaminated naphtha of 1, 2 and 3 development objects by properties and structure is similar among themselves. Therefore the characteristic of physical and chemical properties of the decontaminated naphtha were presented in this section for the field, generally.*

On density the decontaminated naphtha falls into to type bituminous, range makes from 0,9230 to 0,9540 g/cm<sup>3</sup>. Dynamic viscosity at temperature of 20° C is ranging from 614,4 to 1849 MPa s, at temperature of 50° C – ranging from 53,95 to 350,7 MPa s.

Karazhanbas naphtha field should be referred to category of high-resinous, with asphaltic substances content from 18,0 to 34,6% mass. The maintenance of total sulfur in the field is in range from 0,90 to 2,40% mass. Mean values of total sulfur for 1, 2 and 3 objects make: 1,72% mass., 1,61% mass. and 1,68% mass. respectively, naphtha falls into the class of sulphurous naphtha.

According to the content of paraffin it is paraffinic, the content of high molecular weight paraffin hydrocarbons is in the range from 0,3 to 3,6% mass. Mean values of the paraffin content on 1, 2 and 3 objects make: 1,7% mass, 1,6% mass. and 1,8% mass. respectively. Set point of naphtha is in the area of below zero temperatures and makes change range from - 27°C to-5 °C. For 1, 2 and 3 objects set point of naphtha makes: -17 °C, -17 °C and -16,5 °C.

The decontaminated Karazhanbas naphtha field is poor for light distillates. Initial boiling point of naphtha is high and makes under 236 °C. The maximal exit of the light fractions which are boiling away at atmospheric pressure up to the temperature of 300 °C makes about 30% sp.. The maximal exit of the petrol fractions which are boiling away to the temperature 200 °C makes 4,5% sp.

Physical and chemical properties of naphtha characterize the decontaminated Karazhanbas naphtha field as bituminous, viscid, high-resinous, paraffinic, sulphurous, non stiffening and with a small exit of light fractions<sup>1</sup>.

Since 2008 the annual increase of oil production by 50 thousand tons average is observed. If in 2008 1 million 829 thousand tons of naphtha was extracted, in 2014 JSC Karazhanbasmunay got 2 mln. 132 thousand tons, being ahead of production schedule by 57 thousand tons. In 2015 the company plans to get 2 million. 100 thousand tons<sup>7,8</sup>.

## 4. Thermal-Steam Technology of Object Development Cyclic Processings of the Karazhanbas Field

### 4.1 Thermal-Steam Impact (TSI) on Karazhanbas field layer. Thermal influence in the way of forcing to steam layers on CRP Karazhanbas was begun in December, 1982

For this purpose 2 steam generating devices were let in operation on trade with efficiency of 60 t/h with pressure of 60 MPa s and desalination installations (Figure 2).

Where,  - production wells;  - injection wells

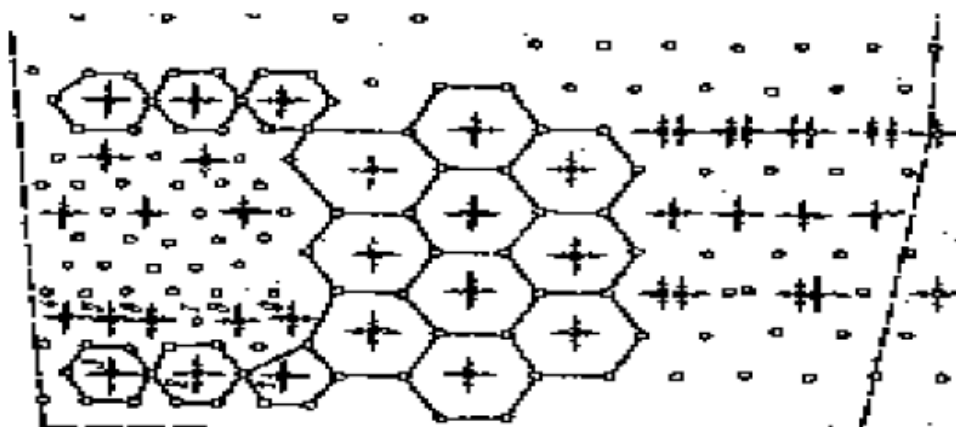


Figure 2. The scheme of well arrangement on STI.



The delivery and production wells located linearly in chessboard order so that if necessary it was possible to organize seven-dot elements with a delivery well in the center, to carry out block and cyclic thermal-steam impact of all production wells processing<sup>9</sup>.

STI was begun with the frontal replacement of naphtha from layer by creating thermal fringes and their subsequent advance on layer to production wells with non-heated water (Figure 3 and Figure 4).

Responses of production wells to the steam influence expressed by fluids output increase and stability of oil production on trade began with initial stage of steam forcing in 2-3 months. It influenced steady rise of production by well production that testifies to high performance of STI on Karazhanbas layer in the conditions of the field<sup>7</sup>.

Annual naphtha yield, th./tons, Annual fluid yield, th./tons, Additional developed wells fund.

Naphtha average daily production rate, Water cut.

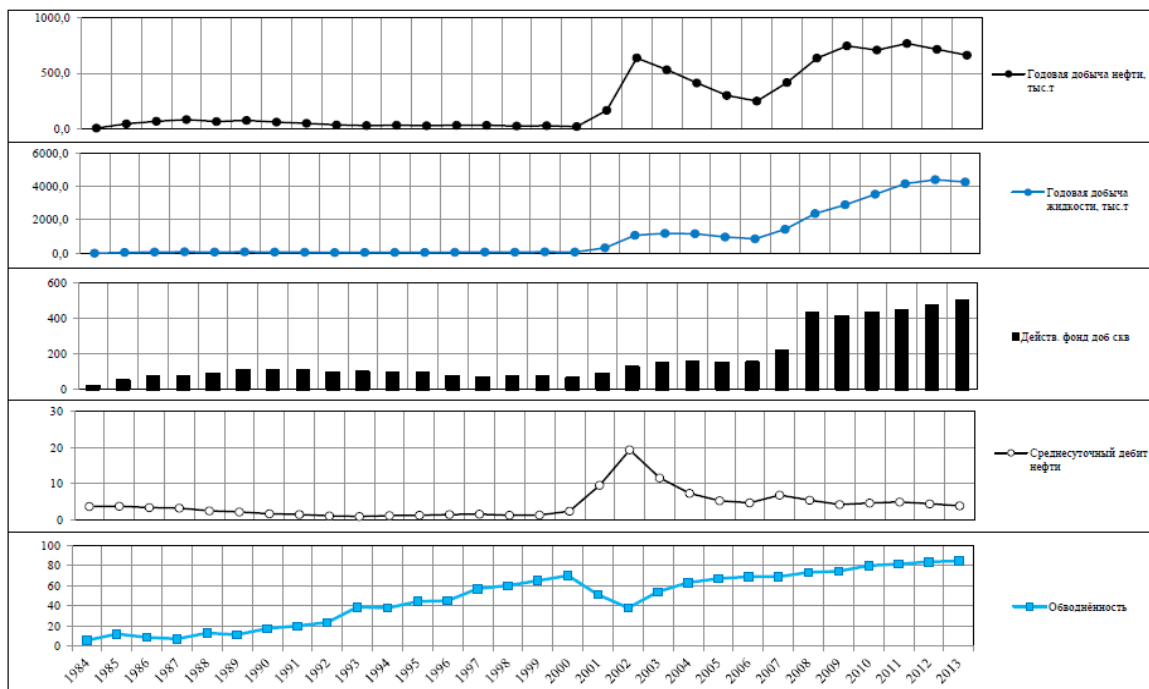


Figure 3. The 3 object. Dynamics of the main technological development indexes.

Steam, th./tons, Air, th./m<sup>3</sup>, Hot water, th./m<sup>3</sup>, Developed well fund.

Process of STI developed with high technological rates therefore oil production (from 1982 to 1984) increased with 24 to 430 thousand tons. (Oil production at the expense of STI made 235 thousand tons.), the average output of naphtha increased with 3,2 to 10 t/day. The steam-naphtha factor does not exceed 3 t/t that approximately corresponds to the extracted naphtha<sup>5</sup>.

#### 4.2 The Deposit Thermal Condition Analysis on STI Application Sites

The Steam-Thermal Influence (STI) as well as is provided by the design document<sup>3</sup> is conducted on east and

northern sites of the field. On east site the pumping steam was begun in 2005 – in the 3 object of development, in 2007 – in 2, in 2011 – in 1. On the northern site the organization of cells for pumping steam in the 1 object was begun in 2011.

As of 01.01.2014 the pumping steam was carried out through 207 steam-injection wells: 193 wells of east site, 14 wells of northern site.

For the purpose of naphtha deposits thermal condition assessment on 01.01.14 maps of isotherms on development objects on sites of pumping steam (the East, the North) are constructed. For map creation data on formation temperature in 1242 wells, including 1045 – extracting and 197 – delivery were used. In 162 wells on various parts of deposits temperature measurement on a

well trunk through each 50 m (RPS-25 No. 8972 device) was carried out, in other wells temperature was measured in the calculated way, proceeding from temperature on ostium and temperature gradient. Temperature gradi-

ent was accepted equal to 3-40 C/100 m according to the actual measurements of temperature. Reference temperature of layer +30 ° C. Downloading temperature in steam-injection wells on made osmium +250-270 °C<sup>1</sup>.

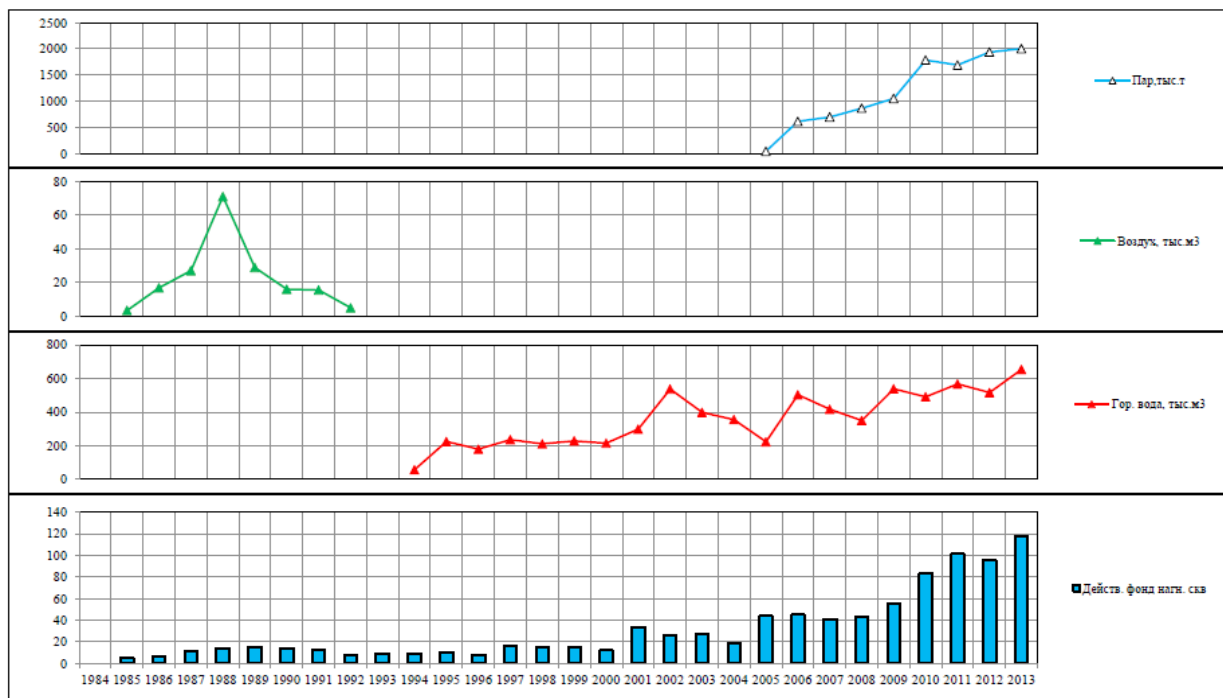


Figure 4. 3 development object. Pumping dynamics of working substances and operating delivery wells fund.

## 5. Technical and Economic Assessment of Carrying Out Thermal-Steam Well Processing (TSWP) on the Karazhanbas Field

The main calculated indicators of thermal-steam cyclic layer processing are the linear consumption of dry steam, layer enthalpy coefficient, well output after processing and expected effectiveness of processing.

It is necessary to define beforehand the linear consumption of  $q_{c.n.h}$  and dry steam coefficient characterizing specific enthalpy of layer  $\varphi$ .

The linear consumption of dry steam:

$$q_{c.n.h} = \frac{q_{c.n}}{h} \quad (1)$$

Where  $q_{c.n} = 8000 \text{ kg / (h m)}$  – consumption of dry steam. Consequently:

$$q_{c.n.h} = 8000 / 20 = 400 \text{ kg / (h m)}$$

Layer enthalpy coefficient:

$$\varphi = \pi \left[ m(1 - S_b) \rho_{H.n} X_{\pi} + (1 - m) C_M \frac{t_{\pi} - t_{\pi n}}{i_{\pi}} + m S_b C_K \frac{t_{\pi} - t_{\pi n}}{i_{\pi}} \right] \quad (2)$$

Where  $X_{\pi}$  – dryness of steam on face, equal to 0,624;  
 $\rho_{c.n}$  – density of dry steam, equal to 19,69 kg/m<sup>3</sup>;  
 $\rho_{H.n}$  – density of saturated steam, is determined by formula:

$$\rho_{H.n} = \frac{1}{\frac{X_{\pi}}{\rho_{c.n}} - \frac{1 - X_{\pi}}{\rho_b}} = \frac{1}{\frac{0,624}{19,69} - \frac{1 - 0,624}{1000}} = 31,3 \text{ KT / M}^2$$

Here  $\rho_b$  – water density.

Having substituted these values in (2), we will receive:

$$\varphi = 3,14 [0,4(1 - 0,5)31,3 \cdot 0,624 + (1 - 0,4)2000 \frac{523 - 303}{1735} + 0,4 \cdot 0,5 \cdot 3950 \frac{523 - 303}{1735}] = 742$$

Knowing values  $q_{c\Pi n}$ ,  $r_t$  and  $\varphi$ , determine duration of steam forcing in a well  $\tau_{\Pi}$  by a nomogram of  $t_{\Pi} = 2,85$  days. Similarly the average output of well after processing is defined as equal to ;

$$q_{cp} = 1.9; q_0 = 1,9.4,7 = 8,93 M^3 / CYT$$

Well running time with the raised output as a result of processing we will determine by a formula:

$$\tau_{3,0} = \frac{\pi r_t^2 h c \Pi}{q_{cp} c_s} \ln(t_{\Pi} - 273) = \frac{3,14.4^2 \cdot 20.2310}{8,93.3350} \ln(523 - 273) = 111 \text{ day.}$$

Economic return on thermal-steam processing of wells:

$$O = \Delta K / \dot{Y} \quad (3)$$

Where  $O$  – the period of payback, years;  $\Delta K$  – padding capital investments in a year;  $\dot{Y}$  – annual economic efficiency.

At application of mobile steam generating caravan padding capital investments on one well will decrease to 1193790,9 t/y. in a year and economic efficiency will increase to 1062964,5 t/y. Therefore, the payback period of expenses will make:

$$O = \frac{1193790,9}{1062964,5} = 1.1 \text{ Year}$$

## 6. Summary

So, as it was noted above, response of production wells to STI began in 2-3 months, namely: significantly naphtha outputs increased, production of well production increased. All this signifies about high performance of STI on layer under conditions of Karazhanbas field, which allows to recommend application of STI in simulated geological field condition. The calculated payback period (1,1 years) allows to draw a conclusion on high economic efficiency of layer impact this method.

## 7. Conclusion

We analyzed the development condition of 1-3 operational objects on sites (central, east, west, north) and on the field in general.

The analysis of statistical data on well processing is made and the factors influencing the result in the greatest degree are revealed on the basis of the above the optimum mode of carrying out TSWP on object wells, for which water content of production is high, was recommended. Calculation of technological and economic effect of carrying out processing is made. The result indicates possibility of carrying out TSWP; therefore by calculation we will receive the raised average output of well after processing (4,7-8,93), and the payback period of TSWP costs is calculated ( $O = 1.1$  years).

## 8. Conflict Of Interest

The author confirms that the presented data do not contain the conflict of interests.

## 9. Acknowledgments

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