Determination of optimal oil pumping plans

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ABSTRACT

This paper presents the results of determining the optimal plans for pumping oil through the main oil pipelines of Kazakhstan. The calculation methodology is based on determining the minimum unit cost of pumping depending on oil flow rate. Oil pumping energy-saving modes are determined under optimal operating conditions of pumping units and heating furnaces at stations. Determination of the optimal pumping plan is implemented as a separate module of the SmartTranPro software. Pumped oil volumes on the oil pipeline sections were determined on the basis of the automated system of control and metering of electrical energy data of KazTransOil JSC. Optimal pumping plans for monthly oil volumes in the Kalamkas – Karazhanbas and Dzhumaguliev – Atasu pipeline sections for cold and warm periods were calculated on the basis of the found dependence of the pumping unit cost. For each range of oil mass flow rate, specific costs for oil pumping and a list of operating pumps at oil pumping stations located along the pipeline section are indicated.

Keywords: oil pipeline, flow rate, optimal pumping plan, energy-saving mode, unit cost.

Introduction

Increasing energy consumption efficiency when transporting oil by main pipelines mostly depends on the system of organization and management of technological modes of oil pipeline operation and is achieved by modeling optimal conditions of its operation [1, 2, 3, 4].

Optimizing the process of pipeline transportation of oil is of great practical importance, and a number of works are devoted to the problem of optimizing distribution of cargo flows through the system of main pipelines [5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17].

When considering this problem, the question of choosing rational volumes of pumped oil naturally arises. Pumping units must be able to pump the amount of oil that is required according to optimal operation of the oil pipeline. Therefore, associated with the problem of choosing rational oil volumes along oil pipeline routes is the problem of choosing the most effective modes of operation of pumping and power equipment for reliable operation of the main oil pipeline.

Management of energy-saving modes is determined under optimal operating conditions of equipment of oil pumping stations and technological modes of oil pumping through main oil pipelines. Determination of energy-saving modes of pumping is important for estimating the efficiency of operation of main oil pipelines.
The optimal pumping mode is considered to be such the mode in which the least amount of financial costs is consumed for given performance. Oil pumping costs are the sum of electricity expenses consumed by pumps and fuel for operation of heating furnaces.

The problem of finding the optimal pumping mode of a given volume of oil is as follows: $G$ is the total volume of oil (in tons), which must be pumped optimally over a period of time $T$; $Q_i$ is the capacity (in t/h) of the pipeline at the mode No. i without using a pressure regulator (PR) or a variable frequency drive (VFD); $t_i$ is the total operating time of the pipeline in the mode No. i during the period $T$; $E_i$ is the unit costs per unit of time (in tenge/h) when pumping oil in the mode No. i. $Q_i^\text{min}$ is the minimum specified capacity (in t/h) of the pipeline at the mode No. i, which can be achieved using a PR or a VFD.

Each optimal plan is represented by one of the following three cases:

1) The mode No. i with shutdowns, i.e. the plan consists of alternating states: pumping in the mode with the capacity $Q_i$ (total $t_i$ hours) and stopping pumping (total $(T-t_i)$) hours:

$$Q_i t_i = G, \ t_i \leq T$$

2) The combination of modes No. i and No. j, i.e. the plan consists of alternating states: pumping in the mode with the capacity $Q_i$ (total $t_i$ hours) and in the mode with the capacity $Q_j$ (total $t_j$ hours):

$$Q_i t_i + Q_j t_j = G, \ t_i + t_j = T, \ E_i t_i + E_j t_j \rightarrow \min$$

3) The mode No. i with the selection of rotor speed:

$$Q_{VFD} = \frac{G}{T}, \ Q_i^\text{min} \leq Q_{VFD} \leq Q_i$$

In this case, the pumping plan consists of one mode with the constant capacity $Q_{VFD}$. Required pump rotor speed is determined based on the value of $Q_{VFD}$.

The energy efficiency of oil transportation can be estimated by specific electric energy consumption according to the work performed [18]:

$$E_p = \frac{W}{G \cdot H_{loss}}$$

where $W$ is the amount of consumed electricity, kWh; $G$ is the volume of pumped oil, t; $H_{loss}$ is the required head for pumping the volume of oil $G$ through the pipeline, m.

In practice, in addition to specific electric energy consumption $E_p$, specific electric energy consumption by pipeline capacity is used:

$$E_{\text{cap}} = \frac{W}{G \cdot L}$$

where $L$ is the oil pipeline length, km; $E_{\text{cap}}$ has the dimension of kWh/(thousand tons km).

The energy-saving mode of main oil pipeline operation is estimated by specific electric energy consumption for pumping one ton of oil. Specific electric energy consumption in kWh/t is found by the formula [18, 19]:

$$E_{\text{sp}j} = \frac{1}{\rho Q_j} \left( N_{\text{cons}jn} + \sum_{i=1}^{n_{Hj}} N_{\text{cons}ij} \right)$$

where $N_{\text{cons}jn}$ is the power consumed by electric motors of booster pumps of the head pumping station (PS) when operating in the j-th mode; $N_{\text{cons}ij}$ is the same for electric motors of mainline pumps of the i-th PS; $n_{Hj}$ is the total number of mainline pumps at stations in the j-th mode.

Power consumed by the pumping unit when operating in the j-th mode is found from the expression [18, 19, 20]:

$$N_{\text{cons}j} = \frac{\rho g H_j Q_j}{\eta_{1j} \eta_{2j} \eta_{3j}}$$

where $H_j, Q_j, \eta_{3j}$ are the head, the flow rate and the efficiency of the pump, respectively, when operating in the j-th mode, $\eta_{1j}$ is the efficiency of the electric motor in the j-th mode, $\eta_{2j}$ is the efficiency of the mechanical transmission, for the mechanical clutch can be taken $\eta_{2j} = 0.99$.

Pump efficiency is calculated by the formula [18, 19]:

$$\eta_{3j} = c_0 + c_1 Q_j + c_2 Q_j^2 + c_3 Q_j^3$$

where $c_0, c_1, c_2, c_3$ are the empirical coefficients, which are determined for each type of rotor.
The efficiency of an electric motor is expressed by the formula [19]:

\[ \eta_{ij} = \left[ 1 + \frac{1 - \eta_{\text{nom}}}{2 \eta_{\text{nom}} k_{\text{load}}} (1 + k_{\text{load}}^2) \right]^{-1} \]

where \( \eta_{\text{nom}} \) is the efficiency of an electric motor at nominal loading, \( k_{\text{load}} \) is the operation factor of an electric motor.

Thus, to assess the efficiency of energy-saving modes of pumping oil blends along oil pipeline routes, it is possible to use specific electric energy consumption (3), specific electric energy consumption for the work performed (1) or specific electric energy consumption for cargo turnover (2).

**Calculation results**

Determination of the optimal pumping plan is implemented as a separate module for the SmartTranPro software package [21]. The software module selects the most optimal combination of pumps for each flow rate \( Q \) in the interval \((10, Q_{\text{max}})\) with a step of 0.5 t/h and calculates specific energy consumption \( E(Q) \).

Using this module for the Kalamkas – Karazhanbas and the Dzhumagaliev – Atasu oil pipeline sections, optimal modes of pumping oil and oil blends were calculated. According to production data, the lowest ground temperature value is observed in March, and the highest – in September, therefore calculations were carried out for these two months.

To calculate financial costs, tariffs for electricity and fuel in respective regions for 2020 were used. Pumped oil volumes on considered sections of oil pipelines were determined on the basis of the ASCAPC (Automatic System for Commercial Accounting of Power Consumption) system data of KazTransOil JSC.

The following data were used as initial parameters:
- average monthly values of soil temperature along the pipeline;
- an actual value of the pumped oil volume during the month.

When carrying out optimization calculations, the following restrictions are taken into account, which are necessary for safe operation of oil pipelines:
- maximum allowable pressure at the station outlet;
- maximum allowable pressure at the oil pumping station outlet (up to the PR);
- minimum allowable pressure at the pump inlet;
- a safe range of pump flow rate;
- minimum allowable rotor speed.

For listed sections of oil pipelines, dependences of the minimum unit cost of pumping on capacity were plotted. Based on the found dependence, optimal pumping plans were calculated for various values of monthly planned volumes.

Optimal pumping plans are presented in a tabular form, which displays a list of ranges of monthly planned volumes with corresponding optimal pumping modes.

Tables show lists of pump operating modes in ascending order of obtained performance. A performance range corresponds to each individual table mode. If, opposite to the performance range in the list of operating pumps, any pump is indicated "with a VFD" (for example, "mainline pumping unit (MPU) No. 1 with a VFD"), it is assumed that any performance value from the corresponding range can be obtained by adjusting rotor speed of the specified pump. If, opposite to the performance range in the list of operating pumps, no pump is indicated "with a VFD", it is assumed that any performance value from the corresponding range can be obtained using a VFD at the starting station, or by creating backpressure at the inlet to the terminal station. In addition, if names of pumps are indicated in a cell on one line, then this means that given pumps operate in parallel, if on different lines of one cell, then sequentially.

**The Kalamkas - Karazhanbas oil pipeline**

At the Kalamkas – Karazhanbas section (Fig. 1) of the Kalamkas – Karazhanbas – Aktau main oil pipeline, Buzachi oil with constant physical and chemical composition is pumped [22]. Optimization calculations were carried out using the actual data of the SCADA system [23].

Initial parameters for performing optimization calculations are given in Table 1. At 0.6 km and 23 km of the Kalamkas - Karazhanbas pipeline, there are associated oil pumping points of Buzachi neft LLP and Arman JV. Based on the archival data of the SmartTranPro database for 2019, monthly pumping volumes from Buzachi neft LLP and Arman JV are 15-16 thousand m³ and 10-12 thousand m³, respectively. Therefore, in order to take this fact into account, monthly average values of pumping flow rate were used as the initial calculation parameter.

Figure 2 shows the dependency curve of unit costs for pumping oil for the Kalamkas –
Karazhanbas oil pipeline section from performance obtained for the cold period. Tables 2 and 3 show optimal pump operation modes for different performances and optimal pumping plans for different monthly volumes for the Kalamkas – Karazhanbas oil pipeline.

As a result of the calculation, two optimal pump operation modes were selected for this section: in the range of mass flow rate values 100–231 t/h, the pipeline can operate in the mode No. 1 with shutdowns, in the range of flow rates 232–740 t/h – in the mode No. 2 with the selection of required rotor speed.

![Diagram and profile of the Kalamkas - Karazhanbas pipeline section](image)

**Figure 1** – Diagram and profile of the Kalamkas - Karazhanbas pipeline section

**Table 1** – Initial parameters for calculating unit costs in the section of the Kalamkas – the Karazhanbas

| Parameter names                              | Parameter value            | March   | September |
|----------------------------------------------|----------------------------|---------|-----------|
| Initial oil temperature, °C                  |                            | +52.5   | +54       |
| Initial pressure, bar                         |                            | 0.5     | 0.5       |
| Flow rate of pumping from "Buzachi neft" LLP, t/h |                            | 20      | 20        |
| Flow rate of pumping from "Arman" JV, t/h    |                            | 14      | 14        |
| Residual pressure at the inlet of the terminal station, bar | 1.2 | 1.2 |
| Soil temperatures, °C                        |                            | +9.2 (0 km) | +24.8 (0 km) |
|                                             |                            | +10.6 (62 km) | +25.5 (62 km) |
| Electricity tariff, kWh/tenge                |                            | 19.49   | 19.49     |

![Dependence of unit costs on capacity in the Kalamkas – Karazhanbas section for March](image)

**Figure 2** – Dependence of unit costs on capacity in the Kalamkas – Karazhanbas section for March
Table 2 – Optimal operating modes of pumps for various performance values of the Kalamkas – Karazhanbas section

| Mode No. | Flow rate, t/h | Costs, thousand tenge/h | Unit costs, tenge/t | Operating pumps |
|----------|----------------|-------------------------|---------------------|-----------------|
| 1        | 100 - 231 (March) 100 - 242 (September) | 1.6 - 1.8 (March) 1.6 - 1.8 (September) | 15.8 - 7.7 (March) 15.8 - 7.4 (September) | booster pump unit (BPU) No. 1 |
| 2        | 232 - 740 (March) 243 - 750 (September) | 1.8 - 14.7 (March) 1.8 - 14.9 (September) | 7.6 - 19.8 (March) 7.4 - 19.8 (September) | BPU No. 1 MPU No. 3 with a VFD |

Table 3 – Optimal pumping plans at different monthly volumes for the Kalamkas – Karazhanbas section

| Pumping volume, t | Required modes |
|-------------------|----------------|
| 0 – 171000 (March) 0 – 174000 (September) | Mode No. 1 with shutdowns |
| 171000 – 550000 (March) 174000 – 540000 (September) | Mode No. 2 with the selection of required rotor speed |

The Dzhumagaliev – Atasu oil pipeline

For optimization calculations of the Dzhumagaliev – Atasu section (Fig. 3) of the Pavlodar – Atasu main oil pipeline, parameters of Aktobe oil at the outlet of the Pavlodar - head oil pumping station (HOPS) were used.

Initial data for optimization calculations are given in Table 4: initial oil temperature, pressure at the inlet of the booster pump at the Dzhumagaliev HOPS, residual pressure at the inlet of the Atasu oil pumping station (OPS), soil temperature values at main points and electricity tariffs.

Table 4 – Initial parameters for calculating unit costs in the Dzhumagaliev – Atasu oil pipeline section

| Parameter names | Parameter value |
|-----------------|-----------------|
| Initial oil temperature, °C | +10  +24 |
| Initial pressure, bar | 0.6  0.6 |
| Residual pressure at the inlet of the terminal station, bar | 1  1 |
| Soil temperature, °C | +4.3 (0 km) +1.4 (175.7 km) +3.3 (267.6 km) +2.7 (427.3 km) +22.1 (0 km) +18 (175.7 km) +19.2 (267.6km) +16.4 (427.3km) |
| Electricity rate, kWh/tenge | 15.49 15.49 |

Figure 3 – Diagram and profile of the Dzhumagaliev – Atasu pipeline section

Figure 4 shows the dependency curve of unit costs on performance obtained for cold and warm periods of Dzhumagaliev – Atasu pipeline section operation. The zigzag change in specific energy consumption on the graph is explained by switching to another pump or a group of pumps.

Table 5 shows found optimal operating modes of pumps for various performance values of the Dzhumagaliev – Atasu section for the cold period. For each range of oil mass flow rate, specific pumping costs and lists of pumps that operated at oil pumping stations of the considered section.
(Dzhumagaliev HOPS and Barsengir OPS) are indicated. If the cell is empty, then this pumping station is not turned on. In accordance with obtained modes for the Dzhumagaliev – Atasu pipeline section, optimal plans for pumping oil were found at various monthly volumes.

Table 6 shows data on optimal pumping plans for the cold period. For example, in the range of monthly oil flow rates from 738,000 to 1,066,000 tons, the most optimal for energy saving is the use of a combination of modes No. 4 and No. 13 when pumping oil in this section.

**Table 5 – Optimal operating modes of pumps for various performance values of the Dzhumagaliev – Atasu oil pipeline section in the cold season**

| Mode No. | Flow rate, t/h | Unit costs, tenge/t | Operating pumps |
|----------|----------------|--------------------|-----------------|
|          |                |                    | Dzhumagalieva HOPS | Barsengir OPS |
| 1        | 200 - 658      | 82.6 - 30.1        | BPU No. 1        | 4 |
|          |                |                    | MPU No. 1 (Q=0.5) | 5 |
| 2        | 659 - 715      | 39.4 - 36.9        | BPU No. 1        | 3 |
|          |                |                    | MPU No. 3        | |
| 3        | 716 - 718      | 39.5 - 39.4        | BPU No. 1        | 465mm |
| 4        | 719 - 993      | 47.4 - 38.5        | BPU No. 1        | 3 |
|          |                |                    | MPU No. 1 (Q=0.5) | |
| 5        | 994 - 1069     | 44.5 - 42.5        | BPU No. 1        | 3 |
|          |                |                    | MPU No. 1 (Q=0.5) | |
| 6        | 1070 - 1076    | 42.6 - 42.5        | BPU No. 1        | 3 |
|          |                |                    | MPU No. 3        | |
| 7        | 1077 - 1078    | 44.0 - 44.0        | BPU No. 1        | 465mm |
|          |                |                    | MPU No. 3 (Q=0.5) | |
| 8        | 1079 - 1086    | 44.1 - 43.9        | BPU No. 1        | 1 |
|          |                |                    | MPU No. 1 (Q=0.5) | |
| 9        | 1087 - 1128    | 49.4 - 48.2        | BPU No. 1        | 465mm |
|          |                |                    | MPU No. 3        | |
| 10       | 1129 - 1172    | 48.3 - 46.9        | BPU No. 1        | 1 |
|          |                |                    | MPU No. 3        | |
| 11       | 1173 - 1174    | 48.4 - 48.3        | BPU No. 1        | 465mm |
|          |                |                    | MPU No. 1        | |
| 12       | 1175 - 1187    | 49.0 - 48.8        | BPU No. 1        | 3 |
|          |                |                    | MPU No. 3 (Q=0.5) | |

**Figure 4 – Dependence of unit costs on performance at the Dzhumagaliev – Atasu pipeline section: a) cold period (March); b) warm period (September)**
| №   | Номер | Тип | Тип | Тип |
|-----|-------|-----|-----|-----|
| 13  | 1188 - 1434 | 54.0 - 48.3 | MPU No. 1 | MPU No. 1 (Q=0.5) |
|     |        |     |     | MPU No. 3 |
| 14  | 1435 - 1435 | 49.4 - 49.4 | MPU No. 1 | MPU No. 1 (Q=0.5) |
|     |        |     |     | MPU No. 4 (D=465mm) |
| 15  | 1436 - 1511 | 53.2 - 51.4 | MPU No. 1 | MPU No. 1 (Q=0.5) |
|     |        |     |     | MPU No. 3 |
| 16  | 1512 - 1518 | 51.9 - 51.8 | MPU No. 1 | MPU No. 3 (Q=0.5) |
|     |        |     |     | MPU No. 3 |
| 17  | 1519 - 1519 | 52.5 - 52.5 | MPU No. 1 | MPU No. 3 (Q=0.5) |
|     |        |     |     | MPU No. 4 (D=465mm) |
| 18  | 1520 - 1599 | 56.3 - 54.2 | MPU No. 1 | MPU No. 1 |
|     |        |     |     | MPU No. 2 |
| 19  | 1600 - 1600 | 55.0 - 55.0 | MPU No. 1 | MPU No. 3 |
|     |        |     |     | MPU No. 3 |
| 20  | 1601 - 1601 | 55.2 - 55.2 | MPU No. 1 | MPU No. 3 |
|     |        |     |     | MPU No. 4 (D=465mm) |
| 21  | 1602 - 1602 | 56.0 - 56.0 | MPU No. 1 | MPU No. 1 |
|     |        |     |     | MPU No. 3 |
| 22  | 1603 - 1685 | 57.0 - 54.8 | MPU No. 1 | MPU No. 1 (Q=0.5) |
|     |        |     |     | MPU No. 2 |
| 23  | 1686 - 1688 | 55.2 - 55.1 | MPU No. 1 | MPU No. 1 (Q=0.5) |
|     |        |     |     | MPU No. 3 |
| 24  | 1689 - 1753 | 58.6 - 56.8 | MPU No. 1 | MPU No. 1 (Q=0.5) |
|     |        |     |     | MPU No. 2 |
| 25  | 1754 - 1757 | 57.5 - 57.4 | MPU No. 1 | MPU No. 1 (Q=0.5) |
|     |        |     |     | MPU No. 3 |
| 26  | 1758 - 1766 | 57.7 - 57.5 | MPU No. 1 | MPU No. 1 (Q=0.5) |
|     |        |     |     | MPU No. 3 |
| 27  | 1767 - 1770 | 59.2 - 59.2 | MPU No. 1 | MPU No. 3 (Q=0.5) |
|     |        |     |     | MPU No. 4 |
| 28  | 1771 - 1828 | 61.1 - 59.4 | MPU No. 1 | MPU No. 1 |
|     |        |     |     | MPU No. 2 |
| 29  | 1829 - 1839 | 59.6 - 59.3 | MPU No. 1 | MPU No. 1 |
|     |        |     |     | MPU No. 3 |
| 30  | 1840 - 1843 | 60.4 - 60.4 | MPU No. 1 | MPU No. 1 |
|     |        |     |     | MPU No. 2 |
| 31  | 1844 - 1844 | 61.4 - 61.4 | MPU No. 1 | MPU No. 1 |
|     |        |     |     | MPU No. 3 |
| 32  | 1845 - 1848 | 62.5 - 62.5 | MPU No. 1 | MPU No. 1 |
|     |        |     |     | MPU No. 3 |
| 33  | 1849 - 1863 | 63.9 - 63.5 | MPU No. 1 | MPU No. 1 |
|     |        |     |     | MPU No. 2 |
Table 6 – Optimal pumping plans at different values of monthly volumes for the Dzhumagaliev – Atasu section for March

| Pumping volume, thousand tons | Required modes |
|-------------------------------|----------------|
| 0 – 489000                    | Mode No. 1 with shutdowns |
| 489000 - 738000               | a combination of mode No. 1 and mode No. 4 |
| 738000 – 1066000              | a combination of mode No. 4 and mode No. 13 |
| 1066000 – 1304000             | a combination of mode No. 13 and mode No. 24 |
| 1304000 – 1368000             | a combination of mode No. 24 and mode No. 29 |
| 1368000 – 1386000             | a combination of mode No. 29 and mode No. 33 |

Thus, for each range of monthly flow rates, the most optimal pump operating modes were determined for the coldest and warmest periods of time for the Dzhumagaliev – Atasu oil pipeline section.

Conclusions

With the use of the control module of optimal oil pumping modes of SmartTranPro SP for the Kalamkas – Karazhanbas and the Dzhumagaliev – Atasu oil pipeline sections:
1. dependences of the minimum unit cost of pumping on performance for warm and cold periods were plotted;
2. on the basis of the found dependence of the unit cost, optimal pumping plans were calculated for various values of monthly planned volumes for warm and cold periods of time.

Conflicts of interest. On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Мұнай айдаудың оңтайлы жоспарларының анықтау

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ТҮЙІНДЕМЕ
Бул мақалаға Қазақстандық магистральдық мұнай құбырлары арқылы мұнай айдаудың оңтайлы жоспарларының анықтау нәтижелері келтірілген. Есептеу әдістемесі мұнай шығынына байланысты айдау бірлікің минималды меншікті құнын анықтауға негізделген. Мұнай айдаудың энергия унемдеу режимдері стационарларында сорғы қондырғылары мен жылыту пештерінің оңтайлы жұмыс жағдайларында анықталады. Айдаудың оңтайлы жоспарының анықтау SmartTranPro бағдарламалық пакеті үшін және модуль ретінде жүзеге асырылды. Мұнай құбырларының учаскелері арқылы айдалатын мұнай көлемі «ҚазТрансОйл» АҚ АСКУЕ жұмысынан құрылыс директорлары бойынша анықталады. Айдаудың оңтайлы жоспарының анықтау SmartTranPro бағдарламалық пакеті үшін және модуль ретінде жүзеге асырылды. Мұнай көлемі арқылы жоспарлар жылытуның есептелді. Бұл жоспарлар жылыту әдісін әрекет етеді. Айдаудың барлық құрылыс орнанық өзінен айдаудың энергиясын өмір сүретін және сезимдік қәсіпті айдаудың түрлі типтерін анықтады. Түйін сөздер: мұнай құбыры, массалық шығын, оңтайлы айдау, энергияны унемдеу режимі, меншікті шығындар.

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Определение планов оптимальной перекачки нефти

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АННОТАЦИЯ
В данной статье приведены результаты определения оптимальных планов перекачки нефти по магистральным нефтепроводам Казахстана. Методика расчета основана на определении минимальной удельной стоимости перекачки в зависимости от расхода нефти. Энергосберегающие режимы перекачки нефти определяются при оптимальных условиях работы насосных агрегатов и печей подогрева на станциях. Определение оптимального плана перекачки реализовано в виде отдельного модуля для программного комплекса SmartTranPro. Объемы перекачиваемой нефти по участкам нефтепроводов были определены по данным системы АСКУЭ АО «КазТрансОйл». На основании найденной зависимости удельной стоимости от расхода были рассчитаны оптимальные планы перекачки для месячных объемов нефти на участках «Каламкас – Караанбас» и «Джумагалиева – Атасу» для холодного (март) и теплого (сентябрь) периодов времени. Для каждого диапазона расхода указаны удельные затраты на перекачку нефти и перечень работающих насосов на перекачивающих участках, расположенных вдоль участка нефтепровода.

Ключевые слова: нефтепровод, массовый расход, оптимальный план перекачки, энергосберегающий режим, удельные затраты.

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