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Effect of Labor Management on Production Programme Implementation at a Drilling Enterprise

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***Abstract* — Production management is a system of measures that ensures harmonious development of production, implementation of new and use of existing equipment and other production resources, and improvement of production efficiency combining elements and production stages in space and time. Evaluation of drilling enterprise production program performance aims at identifying available reserves to be used to increase the rate of drilling operations. One of these reserves is a shorter cycle of well construction. It can be reduced by rational management of well construction. Production management requires focusing on a drilling time balance, unproductive losses of working time, since one of the main reserves for increasing the rate of drilling operations is reduction of the overhead time caused by accidents and downtime. Efficient production management is based on a number of principles: continuity, rhythm, and proportionality. To assess the performance of the production program of a drilling enterprise, we analyzed coefficients characterizing production continuity, rhythm and proportionality. Calculations showed that the continuity coefficient is 0.71, the rhythm coefficient is 98.2% and the proportionality coefficient is 0.64. The authors suggest monitoring the coefficients of continuity, rhythm and proportionality in order to optimize production management at the drilling enterprise**

Keywords* — *continuity, rhythm, proportionality, drilling enterprises, well construction, production organization

I. INTRODUCTION

Production management is a tool for managing the production process, regardless of the type of a finished product (goods, services, information, knowledge). To create any economic product, you need to use various resources (labor, equipment, raw materials, information and money) that are limited and rare [1]. That is why the main task of production management is effective use of these resources as well as optimal management of the employees and technological capacities by monitoring the production technology.

The well construction technology involves step-by-step performance of the following operations: site preparation, platform installation, well drilling, well testing. To assess performance of the production program of the drilling enterprise, we analyzed the coefficients of continuity, rhythm and proportionality of production [2, 3].

Table 1 shows the well construction cycle for a conditional enterprise.

TABLE I. WELL CONSTRUCTION CYCLE

Indicator	Total, days	Including, days			Constructed wells	Cycle speed, m/c months.
		construction	*drilling*	*development*		
2017						
Total cycles	90.3	9.5	32.8	48.0	142	588
including						
-operation	66.6	9.1	31.6	25.9	133	798
development	439.4	14.9	51.4	373.1	9	120
2018						
Total cycles	112.1	13.3	36.9	61.9	128	474
including						
operation	84.7	12.4	35.2	37.1	118	626
development	436.6	25.1	57.1	354.4	10	126

The structure of the well construction cycle is shown in Figure 1.

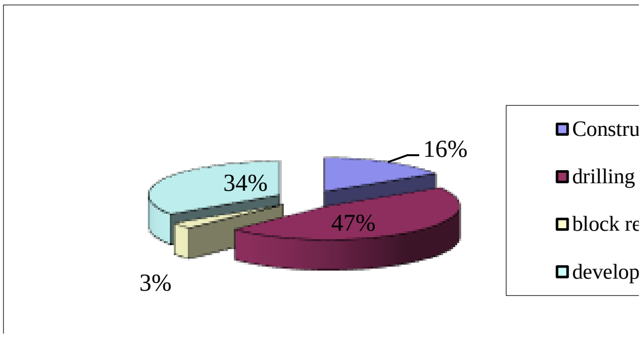

Fig. 1. Structure of the well construction cycle for 2018

The well construction cycle is growing which is due to the increasing duration of the construction works. This is mainly due to organizational reasons (waiting for the crew, drilling, block removal). As can be seen from Table 2 and Figure 2, each well is idle waiting for works for 23.7 days. (including waiting for drilling - 5.8 days, waiting for development - 5.7 days, removing the block - 2.2 days, waiting for the development team - 8.5 days, well abandonment - 1.5 days) which decreases the cyclic speed by 19.4%.

TABLE II. CALENDAR TIME OF PRODUCTION WELL CONSTRUCTION

Indicator	Days	Days per well	Volume, %
Total	12168	105.8	100.0
including			
Construction works	1407	12.2	11.6
repairs	345	3.0	2.8
Waiting for drilling	326	2.8	2.7
drilling	4042	35.1	33.2
Waiting for development	653	5.7	5.4
Block removal	250	2.2	2.1
Waiting for the development crew	977	8.5	8.0
Development	2998	26.1	24.7
Waiting for commissioning	1003	8.7	8.2
Well abandonment	167	1.5	1.4

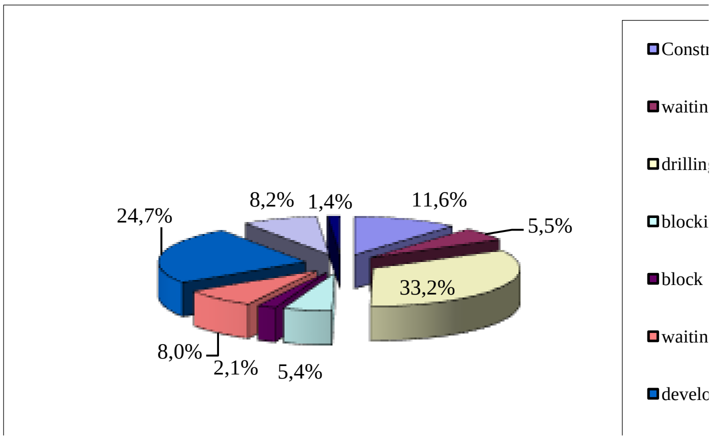

Fig. 2. Structure of the production well construction cycle

The degree of continuity of well construction is determined using the coefficient of continuity [4]:

$$K_n = \frac{T_{tech}}{T_к}, \qquad (1)$$

where T_{tech} и T_c are time for technological operations and the calendar time of all works

$$\mathrm{K_n} = \frac{8697}{12168} = 0.71.$$

Analysis of the coefficient of continuity shows that breaks make up 29% of the calendar time of well construction. The waiting for drilling time is 326 days, the waiting for development teams is 977 days, the well shutdown time is 653 days, the waiting for commissioning time is 1003 day, the well abandonment time is 167 days.

Despite the technological differences, the cycle elements are united by a common goal – on-time construction of the well with specified parameters. Therefore, one of the prerequisites for identifying the effectiveness of organizational options is a comprehensive analysis of all the processes [5], a detailed study of each process for improving efficiency.

The coefficient of continuity of construction works is

$$K_c = 1407 / 2078 = 0.68.$$

According to the standard, time for well repair is 2.5 days, downtime is 2 days. The plan coefficient is

$$K_c = 12.2 / (12.2 + 2.5 + 2.0) = 0.73.$$

To reduce downtime of the well waiting for the development team, it is necessary to plan distribution of development teams in order to ensure strict adherence to network schedules [6].

The coefficient of continuity of well development is

$$K_c = 3248 / 6048 = 0.54.$$

In 2018, downtime of wells waiting for drilling and development was 653 days. Reduction of downtime when waiting for development teams will be 977 days, or 8.5 days per well. Reduction of the waiting time for commissioning up to 3.0 days per well will save 658 days (5.7 days per well). Then the plan coefficient is

$$K_c = 26.1 / (5.7 + 2.2 + 26.1 + 3.0 + 1.5) = 0.68.$$

Let us calculate the coefficient of continuity of drilling production wells by formula (1)

$$K_c = 84785 / 89833 = 0.94.$$

Non-productive time is 6%. To reduce non-productive costs, it is necessary to minimize accidents and defects by following drilling rules.

There are three groups of organizational downtime:

- dependent on the contractor (waiting for workers, transport, tools, drill pipes, turbo-drills, cement, mud, equipment, bits, welders, etc.);
- dependent on the customer (waiting for electricity, water, orders);
- dependent on the subcontractor (waiting for grouting equipment, logging equipment).

Organizational downtime due to the fault of contractors is 2653 hours or 12.4 h per 1000 m. To reduce it, it is necessary to manage the central engineering and technological service and ensure uninterrupted supply of drilling crews.

Organizational downtime due to the fault of the customer and the subcontractor is 1061 hours or 5.0 h per 1000 m. To reduce it and cover losses, it is necessary to draw up downtime acts and file claims for compensation.

One of the ways for increasing the rate of drilling operations is to reduce unproductive time due to accidents and defects [7]. In 2018, there were 23 accidents and 1 defect at the conditional enterprise. The total time spent on elimination of accidents and defects is 2056 hours. Table 3 shows the accident rates for 2017–2018.

TABLE III. ACCIDENT AND DEFECT ELIMINATION

Indicator	2017			2018		
	Total	*Operation*	*Development*	*Total*	*Operation*	*Development*
Drilling distance, m	225022	212426	12596	213623	196848	16775
Calendar time, h	104049	93777	10272	104719	89833	14886
Number of accidents, defects	8 -	8 -	- -	23 1	18 1	5 -
Costs of accident and defect elimination, h	1600 -	1600 -	- -	1876 180	1733 180	143 -
Losses of working time due to accidents and defects, h	1600 -	1600 -	- -	1876 180	1733 180	143 -
Decrease in the drilling distance due to accidents, defects, m	3235 -	3235 -	- -	3076 297	3018 297	58 -
Losses, rubles due to accidents, defects, rubles	2210660 -	2210660 -	- -	2121320 203540	1959620 203540	161700 -

In 2018, the number of accidents increased. The time spent on elimination of accidents increased by 28.5%, and per 1000 meters, penetrations increased from 7.1 hours to 9.6 hours. Table 4 shows that 19 out of 23 accidents are drilling tool failures caused by wear of equipment and factory defects. One accident happened due geological reasons. Elimination of this accident took 264 hours. Violation of drilling technology and negligence of workers caused two accidents.

TABLE IV. CAUSES OF ACCIDENTS AND DEFECTS

Cause	2017	2018
Technical, accidents per hour	-	19/996
Technological, accidents per hour	8/1600	2/610
Geological, accidents per hour		1/264
Customer fault, accidents per hour		2/186
Total, accidents per hour	8/1600	24/2056

Having analyzed the causes of organizational downtime, accidents and defects, we see that it is possible to reduce the unproductive time due to the fault of the contractor to 4259 hours or 19.9 days per well, due to the organizational downtime – to 2,653 hours (12.4 hours per 1000 meters) and due to accidents and defects – to 1606 hours (7.5 h per 1000 m).

The continuity coefficient is

$$K_c = 30.7 / 31.3 = 0.98.$$

Under the condition that the downtime depending on the contractor will be reduced to one day or 25 days per well, the total plan continuity coefficient is

$$K_c = 69.0 / 80.8 = 0.85.$$

The actual and plan continuity coefficients are summarized in Table 5. Actual and design-possible coefficient of continuity.

TABLE V.

Indicator	Actual	Plan	Variance, +,-
Continuity of production	0.71	0.85	0.12
including			
Construction works	0.68	0.72	0.04
drilling	0.94	0.98	0.04
development	0.54	0.68	0.32

As can be seen from Table 5, the enterprise has reserves for reducing time-dependent costs. This must be taken into account when developing the production program for 2019.

II. EXPERIMENT

Rhythm means the production of the same or plan volume of products at equal intervals [8].

Production rhythm is estimated by average fluctuations of actual values of production relative to the planned value or by average values. Several indicators characterizing rhythm are used.

The initial data for solving the task are the plan and actual indicators of a monthly drilling distance presented in Table 6.

TABLE VI. IMPLEMENTATION OF THE DRILLING PLAN AT THE CONDITIONAL ENTERPRISE FOR 2018

Month	Plan, m	Actual, м	Variance, +,-	Actual/Plan, %
January	11088	11037	-51	99.5
February	13526	12698	-828	93.9
March	16977	17896	919	105.4
April	17300	18450	1150	106.6
May	19062	19108	46	100.2
June	17292	17338	46	100.3
July	18585	19961	1376	107.4
August	21195	21288	93	100.4
September	18613	19356	743	104.0
October	16258	17198	940	105.8
November	21972	21277	-695	96.8
December	18527	18016	-511	97.2
Total, year	210395	213623	3228	101.5

The fluctuation index is calculated by formula:

a) in absolute terms

$$K_p^a = \frac{\sum_i^n |d_i|}{n}. \quad (2)$$

b) in relative terms

$$K_p^{rel} = \frac{\sum_i^n |d_i|}{\sum_i^n Q_p}, \quad d_i = Q_{ai} - Q_{pi}, \quad (3)$$

where Q_{ai} и Q_{pi} are actual and plan values of the production volume in the i-th interval, m; n is the number of intervals.

Let us calculate the absolute indicator of plan implementation by formula (2):

$$K_p^a = \frac{3228}{12} = 269\ .$$

It shows that the monthly variance between the actual and pal indicators is 269 m, i.e. monthly over-fulfillment of the plan is 269 m.

The relative fluctuation index is calculated by formula (3):

$$K_p^{rel} = \frac{3228}{210395} = 0.02.$$

The actual monthly plan overfulfilment is 2%.

The fluctuation indices of actual values around relative to the average ones can be estimated in various ways. The can be calculated using the Fisher's rhythm coefficient:

$$K_p^a = \left[1 - \frac{\sum d_i}{2Q_a(1-\frac{1}{m})}\right]100, \quad (4)$$

where Q_a is the total actual volume of products produced for the period under study.

$$K_p^a = \left[1 - \frac{3228}{2 \cdot 213623(1-\frac{1}{12})}\right]100 = 99.2\ \%.$$

Let us calculate positive and negative variances between plan and actual values using the Adamov's rhythm coefficient:

(5)

$$K_p^{A-} = \sum_1^n (1 - \frac{Q_{ai}}{Q_{pi}}), \quad \text{at} \quad Q_{ai} < Q_{pI}. \quad (6)$$

The coefficient of positive variance is calculated by formula (5):

$$K_p^{A+} = 0.301.$$

The coefficient of negative variance is calculated by formula (6):

$$K_p^{A-} = 0.126.$$

Total variance is calculated by formulas:

$$K_p^{AO} = K_p^{A+} + K_p^{A-}\ , \quad (7)$$

$$K_p^{A} = K_p^{A+} / K_p^{A-}\ . \quad (8)$$

The coefficient of absolute total variance calculated by formula (7):

$$K_p^{AO} = 0.301 + 0.126 = 0.427.$$

The coefficient of relative total variance calculated by formula (8):

$$K_p^{A} = 0.301 / 0.126 = 2.4.$$

The calculated indicators show that the conditional enterprise achieved the plan rhythm of the drilling work and overfulfilled the plan by 3228 m. The failure to fulfill the plan was observed in the autumn-winter period due to the climatic conditions (off-road, snowstorm, etc.).

To calculate the proportionality of production, the initial data are quarterly performance indicators of the main workshops (Table 7).

TABLE VII. DATA ON THE WORK OF DEPARTMENTS OF THE CONDITIONL ENTERPRISE

Indicator	Quarter				Year
	I	*II*	*III*	*IV*	
The assembly crew finishes drilling	28	26	34	29	117
Drilling crews start drilling	23	31	36	31	121
Drilling crews finish drilling	25	29	35	33	122
Well commissioning	21	30	32	41	124

The proportions of production capacity for each phase are determined in relation to the power of the leading unit (the leading phase) [9]:

$$C_1/C_0 : C_2/C_0 : C_i/C_0 : \ldots : C_n/C_0 = \\ = P_1 : P_2 : P_i : \ldots : P_n, \quad (9)$$

where M_i is production capacity of the i-th phase, well; M_0 is the capacity of the leading unit, well.

The unit of the main production is a leading unit.

Using formula (9), we can find the proportion of production capacities taking the commissioning as a leading unit.

1) The proportions of production capacities for each phase is presented in Table 8.

TABLE VIII. PROPORTIONS OF PRODUCTION CAPACITIES

Indicator	Кп1	Кп2	Кп3
Quarter 1	28/21=1.3	23/21=1.1	25/21=1.2
Quarter 2	26/30=0.9	31/30=1.0	29/30=1.0
Quarter 3	34/32=1.1	36/32=1.1	35/32=1.1
Quarter 4	29/41=0.7	31/41=0.8	33/41=0.8
year	117/124=0.9	121/124=1.0	122/124=1.0

2) The proportionality rate is calculated by formula:

$$K_{PR} = 1 - \sum_1^n \left| \frac{K_{ni}^0 - K_{ni}^a}{aK_{ni}^0} \right|,$$

$$a = \begin{cases} 1, if & K_{ni}^a \le K_{ni}^0 \\ K_{ni}^o, if & K_{ni}^a > K_{ni}^0 \end{cases} \quad (10)$$

where K_{ni}^a *and* K_{ni}^0 are calculated (optimal) and actual coefficients of proportionality of the i-th phase; *a* is the correction coefficient accounting for variances between actual and optimal coefficients.

The proportionality level for each quarter and year is calculated by formula (10):

K_{pl1}=1-(|(1.1-1.3)/1.1×1.1|+(|(1.1-1.1)/1.1×1.1|+(|(1.1--1.2)/1.1×1.1|)=0.75;

K_{pl2}=1-(|(1.1-0.9)/1.1×1.0|+(|(1.1-1.0)/1.1×1.0|+(|(1.1--1.0)/1.1×1.0|)=0.64;

K_{pl4}=1-(|(1.1-0.7)/1.1×1.0|+(|(1.1-0.8)/1.1×1.0|+(|(1.1--0.8)/1.1×1.0|)=0.1;
K_{plyear}=1-(|(1.1-0.9)/1.1×1.0|+(|(1.1-1.0)/1.1×1.0|+(|(1.1--1.0)/1.1×1.0|)=0.64.

K_{pl1} = 1 means that in the first quarter, the production was proportional. K_{plyear}=0.64 means that the production was not proportional during the year.

3) The probability indicator for program implementation is calculated by formula

$$K_{ni} = 1 - \sum_{1}^{n} \left| \frac{K_{ni}^{0} - K_{ni}^{a}}{K_{ni}^{0}} \right|,$$
$$K_{ni}^{a} = \begin{cases} K_{ni}^{a}, if & K_{ni}^{a} \le K_{ni}^{0} \\ K_{ni}^{o}, if & K_{ni}^{a} > K_{ni}^{0} \end{cases}. \quad (11)$$

For each quarter, the performance indicator for the production program is
K_{pi1}=1-(|(1.1-1.1)/1.1|+|(1.1-1.1)/1.1|+|(1.1--1.1)/1.1|)=1;
K_{pi2}=1-(|(1.1-0.9)/1.1|+|(1.1-1.0)/1.1|+|(1.1--1.0)/1.1|)=0.64;
K_{pi4}=1-(|(1.1-0.7)/1.1|+|(1.1-0.8)/1.1|+|(1.1--0.8)/1.1|)=0.1;
K_{piyear}=1-(|(1.1-0.9)/1.1|+|(1.1-1.0)/1.1|+|(1.1--1.0)/1.1|)=0.64.

K_{pi1} > K_{pi2} > K_{pi4}, the program implementation probability rate is higher on the first quarter than in the second and fourth ones since the program implementation coefficient in the first quarter is 1. The rate of production program implementation in the fourth quarter is 0.1. For the whole year, there is a probability of failure to implement the production program as K_{piyear}=0.64.

TABLE IX. ACTUAL AND PLANNED INDICATORS OF THE PRODUCTION PROGRAM

Indicator	Actual	Plan	Variance, +, -
Production continuity	0.71	0.85	0.12
including			
construction works	0.68	0.72	0.04
drilling	0.94	0.98	0.04
development	0.54	0.68	0.32
Relative rhythm	0.02	0.00	0.02
Fisher rhythm coefficient, %	99.2	100	-0.8
Proportionality level	0.64	1.0	-0.36
Probability of program implementation	0.64	1.0	-0.36

III. CONCLUSION

The strategy of production program implementation should be aimed at closing the gap between actual and plan values [10] (Table 9).

Low values of the coefficients of continuity and proportionality indicate that there are failures when implementing the production program due to poor managemement of well construction works. The value of these coefficients was influenced by an increase in the well construction cycle, waiting for drilling crews and the downtime of wells waiting for development crews.

In order to comply with the basic principles of production management, it is necessary to evaluate the production program of a drilling enterprise in terms of continuity, rhythm and proportionality of production at the stage of approval of the production program for the next financial year.

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