



## Effectiveness of gas inflow stimulation works at the final stage of field development

### Eficacia de las obras de estimulación del flujo de entrada de gas en la etapa final del desarrollo del campo

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*(recibido/received: 28-septiembre-2022; aceptado/accepted: 17-noviembre-2022)*

#### ABSTRACT

The focus of the study is the investigation of terminological foundations and the development of practical recommendations for assessing the effectiveness of hydrocarbon inflow stimulation at the final stage of field development. The authors refer to scientific works on the issues of company performance. The paper provides substantiation and improvement of methodological grounds with respect to assessing the effectiveness of gas inflow stimulation works. A classification and analysis of prominent Russian and foreign methods are provided and their issues are identified. As a result, the work refines the methodology for assessing the effectiveness of work at the drilling enterprise. The authors' comprehensive approach to assessing the effectiveness of inflow stimulation works, which allows for obtaining interrelated performance assessments, is proposed.

**Keywords:** hard-to-recover gas reserves; inflow stimulation; reservoir; tectonic elements; arctic regions.

#### RESUMEN

El enfoque del estudio es la investigación de los fundamentos terminológicos y el desarrollo de recomendaciones prácticas para evaluar la efectividad de la estimulación del flujo de hidrocarburos en la etapa final del desarrollo del campo. Los autores hacen referencia a trabajos científicos sobre los temas de desempeño empresarial. El documento proporciona justificación y mejora de los fundamentos metodológicos con respecto a la evaluación de la eficacia de las obras de estimulación del flujo de entrada de gas. Se proporciona una clasificación y un análisis de métodos destacados rusos y extranjeros y se identifican sus problemas. Como resultado, el trabajo refina la metodología para evaluar la efectividad del trabajo en la empresa de perforación. Se propone el enfoque integral de los autores para evaluar la eficacia de las obras de estimulación de caudales, que permite obtener evaluaciones de desempeño interrelacionadas.

**Palabras claves:** reservas de gas de difícil recuperación; estimulación del flujo de entrada; reservorio; elementos tectónicos; regiones árticas.

## 1. INTRODUCTION

The complication of economic relations and the aggravation of competition in current economic conditions of drilling enterprises and assessment of the effectiveness of gas inflow stimulation works are critical problems whose solution is critical both for the existence of these organizations and for the sustainable development of regional economies and Russia's economy overall (Andersen, 2003; Astashova, Demchenko, 2005; Bellman, Zadeh, 2014; Vaganov, Kustyshev, 2016). For this reason, the structuring and further implementation of performance assessment methods for gas inflow stimulation work currently present one of the most topical conditions for the development of drilling enterprises.

Today's economic conditions give rise to the need to create or revise sectoral enterprise management structures, implement new technologies in the drilling process at the final stage of field development, apply modern technical configurations of information systems, increase the role and responsibilities of executives in planning, organization, coordination, managerial decision-making, and control (Vasilev, Dubina, 2011; Galeev et al., 2002). The lack of summarized experience and comprehensive scientific and applied research in the assessment of the effectiveness of drilling works leads to losses and reduced effectiveness of financial and production activities of the sectoral enterprise (Grebnev et al., 2016).

For the above reasons, the development of methodological and organizational foundations for assessing the effectiveness of gas inflow stimulation works with a focus on the successful operation of the enterprise is a priority task in current science and practice.

Thus, methods for assessing the effectiveness of works performed as part of gas inflow stimulation are narrowly focused and address relatively specific issues of improving the organization of drilling operations at the enterprise.

## 2. LITERATURE REVIEW

Assessment of drilling works effectiveness sheds light on the opportunities and directions for the organization's development as a whole. This gives insight into the need to create new demands for equipment and technology, as well as the problems of the participants in the production work performance process as a whole.

Meanwhile, the challenge of assessing the effectiveness of drilling works is in most cases associated with its multifacetedness (Kaplan, Norton, 2003). The established goals of the assessment were addressed with the cascade method applied at the level of divisions and enterprises, as well as all the processes, not excluding the supporting subdivisions – accounting, information support, economic and legal departments, human resources, etc. (Kodrikov, Plotnikova, 2013; Kolocheva, 2013; Krylov, 2015).

The effectiveness of drilling works is evidenced by the results of the gas inflow stimulation task and the ultimate performance of the drilling organization. These results may be indicated by a significant rise in the number of new commissions for work, which, in turn, affects the enterprise's profit. Other major criteria are the rise in employees' labor productivity, the increase in production scale, and the growth of the overall profitability of the drilling enterprise.

Assessment of work performance is conducted in the following order:

- 1) definition of the goals of drilling works;
- 2) identification of effectiveness indicators for drilling works;

- 3) monitoring of the performance indicators of drilling;
- 4) comparison of the obtained indicator values with the planned ones;
- 5) development of corrective measures;
- 6) adjustment of target values of indicators of the drilling process in view of the stimulation.

The choice of criteria for the assessment of drilling works needs to account for:

- the goals of the process;
- requirements of customers and other stakeholders (the state, the region);
- the results of performance analysis for previous years.

Performance assessment criteria are chosen individually for each enterprise depending on the specifics and configuration of the drilling organization. In this context, an assessment of the effectiveness of drilling works is conducted by different methods, which can be grouped into two blocks.

The first block includes the methods of analysis. The analysis starts from dividing the studied object into parts, elements, and components inherent in this object. Each constituent element is then examined separately, the significant elements are identified, and then combined into a single whole (Peaceman, 1978).

The primary methods of analysis and the field in general can be represented by the following:

- the comparison method requires the comparability of the compared indicators, which account for all stages of drilling operations (unity of evaluation, elimination of the influence of differences in volume and assortment, etc.);
- the balance method involves comparing the interrelated indicators of the drilling process in order to identify and measure their mutual influence, as well as to calculate the possible reserves to improve the effectiveness of the drilling process and increase the intensification of hydrocarbon inflow;
- the elimination method identifies the influence of a specific factor on the summary indicators of drilling work performance while eliminating the effects of other factors;
- the graphic method serves as a tool to illustrate drilling processes and report the results of analysis;
- functional cost analysis is applied according to the purpose of the object (work, process, drilling characteristics) in order to increase the useful effect per unit of total costs per drilling cycle.

The second block covers the methods of assessing the effectiveness of drilling works, which is calculated by determining the performance of the objects singled out in the organization as a mean value of all the received assessment scores.

The methods of drilling work effectiveness assessment can be differentiated on the following grounds:

- analysis of the degree of attainment of target indicators that are reflected in the goals and achieved in the drilling works;

- assessment of the effectiveness of drilling processes and hydrocarbon inflow stimulation;
- assessment of the functioning of selected objects which the organization considers important in the process of drilling and hydrocarbon inflow stimulation;
- analysis of the work of the structural division that performs the drilling;
- analysis of compliance with the items of the standard containing requirements for drilling works at the enterprise;
- information about the results of the internal audit of drilling works.

The general approach to developing a methodology for quantifying the effectiveness of drilling operations can be presented as follows:

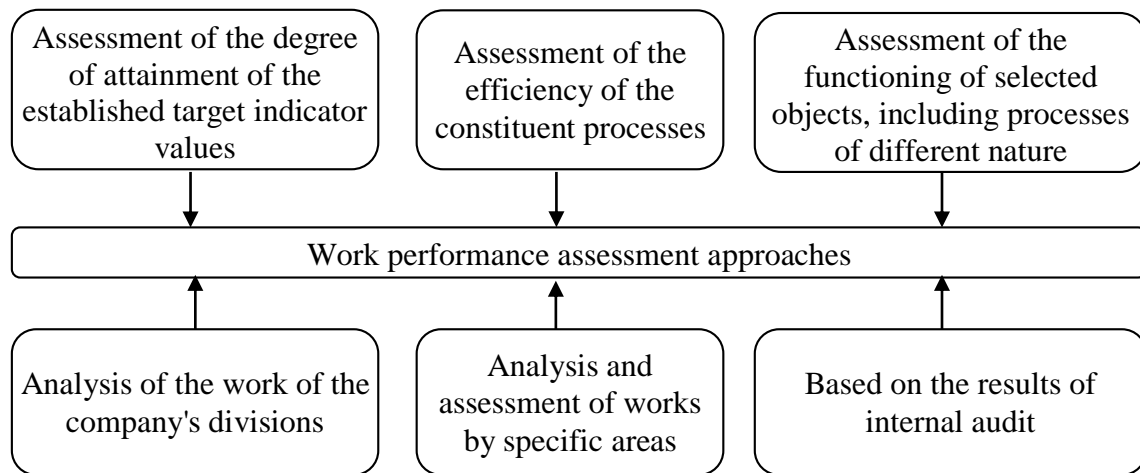
- the assessment of drilling effectiveness is expressed by a coefficient (from 1 to 100 or from 0 to 1);
- the coefficient is comprised of the sum of criterion scores, which are ranked and have a weighting factor;
- the criteria are decided by a group of experts from among the drilling enterprise's employees and external experts relying on their knowledge of drilling operations and hydrocarbon inflow stimulation;
- the assessment is presented both as an absolute value and in relation to the ideal values of the coefficients (criteria) or the base value (for some period).

Assessment of the effectiveness of drilling operations requires the following conditions to be met:

- executive discipline of evaluators;
- involvement of the highest possible number of employees in the assessment of drilling effectiveness;
- detailization of the goals of the drilling organization up to the level of technological processes and performers;
- clear criteria for the assessment of drilling effectiveness shared by all performers;
- an established understandable algorithm for self-assessment;
- standard forms and templates for reporting on the results of drilling operations.

### **3. METHODS**

The performed analysis of the existing scientific research in the sphere of the effectiveness of any type of work allows us to summarize and group them into the following blocks (Figure 1).



\*created by the authors

Figure 1. Approaches to performance assessment\*

First block: assessment of the degree of attainment of the established target indicator values in the sphere of drilling operations and stimulating the inflow of hydrocarbon raw materials.

Second block: assessment of the effectiveness of the constituent components, which requires identification of the processes included in drilling operations considering the stimulation of hydrocarbon inflow (including their weight).

Third block: performed based on performance assessment of the identified objects that perform drilling operations.

Fourth block: performed based on the analysis of work of all structural divisions of the enterprise that perform drilling services by the following elements:

- attainment of the goals of drilling operations considering the stimulation of hydrocarbon raw materials inflow;
- compliance with the standards for drilling operations;
- effectiveness of the processes of drilling operations;
- satisfaction of the customer of drilling operations, taking into account the uniform weighting coefficients.

Fifth block: determined based on the analysis of drilling operations in particular directions, for example considering the stimulation of hydrocarbon inflow followed by additive convolution of the obtained data.

Sixth block: assessment of the effectiveness of drilling works may be conducted based on the results of the internal audit. This assumes the acquisition of the following assessments:

- compliance of operations with the requirements of the normative documentation on drilling operations;
- the processes of drilling and inflow stimulation;
- the divisions performing drilling works;

- the work of the drilling organization in relation to the number and significance of detected inconsistencies.

According to the presented method, the performed drilling works may be considered effective with scores ranging from 0.7 to 1.0 (with the overall range of possible scores from 0 to 1.0).

The above shows that there is a wide range of approaches to performance assessment, which demonstrates a recognition of its importance for the successful operation of the drilling organization and the identification of its future development prospects.

At present, there is no single universally recognized method for assessing the effectiveness of works developed based on international standards.

The performance evaluation algorithm for inflow stimulation works is based on the implementation of the “Continuous Improvement” principle.

At the first stage of the algorithm, assessment criteria are determined based on the requirements of the system standards, and their target values are established.

At the second stage, indicators for each parameter are identified. Ratios between the planned and actual values are calculated for each criterion to be used to determine the effectiveness of stimulation works’ performance.

The third stage involves the identification of target values for each criterion.

At the fourth stage, the importance of indicators is determined using T. Saati’s hierarchy analysis method.

At the fifth stage, the effectiveness of work is calculated using the formula (1):

$$E_{QMS} = \sum_{j=1}^n E_{pri} \times m_j \quad (1)$$

where  $E_{pri}$  – effectiveness of the j-th process;

$m_j$  – weight coefficient of the j-th process;

j – the number of processes.

At the sixth stage, after the effectiveness is determined, it is evaluated by the Harrington Desirability Scale with respect to the following conditions provided in Table 1.

Table 1. Scale of criterion property intensity\*

Name of gradation	Numeric intervals	Actions with respect to the system
Very high	1.0-0.8	The works are performed effectively, but preventive measures need to be developed; if P = 100%, then the system does not require the development of any measures.
High	0.8-0.63	The works are performed effectively, but minor preventive measures need to be developed.

Medium	0.63-0.37	The works are performed effectively, but preventive measures need to be developed.
Low	0.37-0.2	The works are performed ineffectively, major preventive measures need to be developed.
Very low	0.2-0.0	The works are performed ineffectively and require senior management intervention if P = 0%.

\*created by the authors

At the seventh stage, decisions are made on the further conduct of flow stimulation works. Once the level of effectiveness is determined according to the desirability scale, based on the derived conclusions, a management representative together with the process owners proceeds to develop corrective and/or preventive actions and measures to improve the processes with further control and analysis of their execution.

Thus, the information obtained about the effectiveness of gas inflow stimulation works serves as a basis for analysis of the system by executives and is used for prompt process control, revision of documents and procedures, periodic reconsideration of policies and objectives, and analysis and improvement

#### **4. RESULTS AND DISCUSSION**

An important indicator of drilling operations for gas inflow stimulation is their effectiveness, which is a multifaceted indicator representing an integral assessment that includes: resultativeness, cost-effectiveness, efficiency, quality (of management, the technical and technological process of work performance, working conditions, etc.), productivity, innovativeness, balance of the interests of key groups interested in drilling operations for gas inflow stimulation, etc. (Barbe, 1983; Emmanuel, Ranney, 1981; Ertekin, Adewumi, 1995).

There are several primary approaches to the definition of work performance effectiveness:

- as the degree of attainment of the purpose of these works, in which it is vital to recognize their dynamism and a clear distinction between the official goals of the organization and the operational goals of drilling operations themselves. This approach is advisable when the established goals are specific and measurable and cover a wide range of the company's operations;
- as the ability to use all the internal and external environments to find rare resources used in the operations. One of the main aspects of this approach is interdependence between the drilling enterprise and its external environment in the form of the exchange of certain resources, goods, and products. In contrast to the requirement of maximization posed by other approaches, this method suggests optimization of the use of the environment;
- as the ability to achieve maximum results in drilling operations with fixed costs or the ability to reduce costs while obtaining the required results;
- as the ability to achieve the goals based on reasonable internal characteristics because the correctly chosen gas inflow stimulation drilling technology and technique increase satisfaction and a sense of security and control;
- as the level of satisfaction of the customers of drilling services, i.e. the gas producer. This approach is applied in cases when there are certain groups of stakeholders outside of the drilling organization who are, nevertheless, able to exert significant influence on its functioning.

According to a prominent researcher in the field of management, P. Drucker, “effectiveness results from doing the right things”. Essentially, effectiveness applies primarily to attaining the goals of the organization, it reflects the quality of the drilling works, and major importance is attributed to proper goal-setting.

A. Feigenbaum believes that the formation of the category of effectiveness is associated with the logic of the conceptual sequence: need – goal – end result. In this case, the goal as an element of management reality is determined by the needs of stakeholders. The end result takes the form of satisfaction of a certain need on which the system is focused.

F. M. Rusinov associates effectiveness with the implementation of management objectives and the performance of the managed object for a certain period. Thus, the goal to implementation of which is assessed can be compared with the end result – the product and the degree to which it satisfies the social needs of society. End results as an economic category have to be expressed in a system of indicators that reflect their quantity and quality.

N.V. Tereshchenko and N.S Iashin (2016) argue that effectiveness characterizes the level of goal achievement, as a condition for the organization to achieve the necessary results.

Based on the proposed provisions, we can formulate the following definition: effectiveness is assessed as the degree of attainment of the results of drilling operations adequate to the established and intended goals (gas inflow stimulation) that meet the needs of stakeholders (customers and the drilling enterprise) and creates conditions for the constant development of the drilling organization.

Proceeding from the above provisions as initial data, we can conclude that the performance of operations can be effective if the following conditions are satisfied:

- the goals are viewed as temporary, derived from the requirements imposed by both the drilling customer and the drilling organization;
- the content of the goals corresponds to the characteristics of the drilling organization and reflects the internal and external conditions of its functioning;
- the set goals are successfully achieved and justify the resources spent; the required cost-benefit ratio is met;
- the goals are attained by the accepted and universally approved means of the enterprise; the need for this condition is determined by the socio-economic environment of the drilling organization, and its satisfaction prevents additional costs brought by social conflicts that may arise at the enterprise (Koontz, O’Donnell, 2014; Merkushova, 2011; Sazhin, Pletneva, 2014).

There are three blocks of factors that affect the effectiveness of work performance. The first block consists of systemwide factors that determine the prerequisites for the efficient operation of the drilling enterprise:

- the degree of implementation of the principles of work of drilling organizations;
- organizational culture formed and developing at the drilling enterprise;
- the system of selection and evaluation of managerial decisions made by the organization’s executives with respect to the execution of drilling operations and the choice of the gas inflow stimulation method;



- the organizational mechanism that provides coordination and interconnection of technical and technological processes as part of gas inflow stimulation.

The second block covers external factors that limit the activities of the drilling organization and are caused by communication patterns, the key among which are the requirements of the external environment (the state and the region) and the constraints of investment resources;

The third block includes the factors of development management of the drilling organization, the presence of prospective programs of drilling operations, and provision with resources.

In terms of the significance and impact of particular factors, it is necessary to distinguish those that exert the strongest influence on the effectiveness of gas inflow stimulation drilling (Skripko, 2013; Stepanov, 2012).

For an organization providing drilling services to be successful for a long period of time and successfully achieve its goals, the organization needs to be both efficient and effective (Shvets, 2014).

According to P. Drucker, effectiveness is the result of “doing the right things”, while efficiency comes from “these things being done right”.

Efficiency in general should be presented through relation and comparison. Efficiency is the relation of some effect (result) to the costs of its attainment. For example, the value of an indicator has to be compared to either some ideal value or to the level achieved by organizations previously (Vaganov et al., 2017). Here it is crucial to distinguish between cost-effectiveness and efficiency. The fact that the amount of resources spent was less or more than planned does not indicate effectiveness.

The present study investigated the terminological foundations for the assessment of the effectiveness of gas inflow stimulation drilling operations and considered the main approaches to effectiveness assessment. Analysis of the approach showed that the most acceptable and appropriate for today's practice and for successful work are the system and process approaches, which allow organizing the work as a continuous chain of structural and logical stages affecting the processes of substantiating the feasibility of inflow stimulation by implementing sequential, logically interrelated stages.

The paper provides a classification and analysis of the most prominent Russian and foreign methods and identifies the problems that arise in assessing the effectiveness of gas inflow stimulation operations at the final stage of field development. The existing definitions of effectiveness give reason to conclude that the effectiveness assessment method allows for a broader consideration of the entire variety of factors, goals, and economic results, which demonstrates the particular importance of effectiveness assessment.

The conducted analysis of the current state of scientific and methodological support for the functioning of an organization reveals the lack of an accessible scientifically grounded method for assessing the effectiveness of performed works that would be adapted to the real conditions of scientific organizations and rely on the fundamental principles of classic management on the one hand and modern information technology on the other.

We propose a comprehensive approach to the assessment of gas inflow stimulation operations that delivers interrelated effectiveness assessments. The described effectiveness assessment method assumes the following sequence of key stages: classification and ranking of processes; formation of the set of performance indicators and their ranking by significance; comparison of the current value of indicators with their normative values; point scoring of each indicator; calculation of the effectiveness of processes and group of processes; and calculation of the integral indicator of the organization's effectiveness.

## 5. CONCLUSION

As a result of the effectiveness assessment of gas inflow stimulation works, we arrive at the following conclusions:

- a system is developed for monitoring the compliance and assessing the effectiveness of work performance processes, as well as other activities of the organization to meet the standard and its own requirements concerning the development, maintenance, and improvement of the organization;
- by means of audit programs, systematic, consistent, timely, and qualified assessment of the compliance and performance of works is ensured;
- data are identified to determine the root causes of discrepancies, and corrective and preventive actions are developed to improve effectiveness;
- increasingly high goals for gas inflow stimulation works are set and the conditions necessary to achieve them are created.

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