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A rational–targeted model for the development of an integrated safety and security system at oil and gas enterprises in Russia

The article presents an analysis of existing approaches to ensuring integrated security at industrial enterprises. This research is focused on the use of an interdisciplinary approach in its provision at the enterprises of oil and gas sector (OGS) in Russia. In the article, the author presents a methodology developed for Russian oil and gas enterprises in the form of a comparative model and a flexible approach in the form of an existing and developing integrated security system to reduce various types of damage. The aim of the study is to solve the scientific problem of developing an integrated security system at the enterprises of the Russian oil and gas sector. The presented results of the study prove the feasibility of using the results of the assessment of the state of integrated security for the enterprises. Thus, the important problem in terms of rationally-targeted allocation of resources that can be used to eliminate exactly those procedures that have high impact of damage from accidents and fires, is solved. The monitoring results are presented in the form of using a new rational-target model for the development of Russian oil and gas companies. This model allows in practice solving the problem of reducing damage from accidents and fires in the integrated safety system of these enterprises.

Keywords: *oil and gas sector, integrated safety and security system, interdisciplinary approach, rational and targeted development, effective functioning*

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INTRODUCTION

Today, an important place in the system of safe and reliable development in Russia is occupied by enterprises that are part of the oil and gas sector (OGS), the scale and importance of the sectoral functioning of which are simply undeniable not only in Russia, but also in any other country in the world. Russian oil and gas companies are actively involved in international trade, as in regard to 60 % of Russian oil and 90 % of gas are supplied to the countries of European Union (EU). In fact, the biggest oil and gas companies with large production volumes such as Rosneft, Gazprom and Zarubezhneft are owned by the Russian government [1].

The effective functioning of the considered enterprises of the oil and gas sector plays an exceptional role in creating conditions for the development and sustainable growth of the national economy. Currently, oil and gas companies belong to the main strategic potential for the development of the world economic system, their condition, security, and sustainable operation determine the prospects for the country's economic and social development, the performance of such essential functions as protecting the national sovereignty and security of the country and the livelihood of its population.

Reduction of accidents and fires damage in departmental (sectoral) subsystems of industrial safety (IndS), fire safety (FS), labour protection (LP) at the Russian OGS enterprises can occur in the case when, in general for integrated security (IS) of the enterprises in question will be selected for its targeted and comprehensive development. The development of the security of any enterprise is the change of the old, formed by years long approach to its management and the introduction of such a new approach, which would be based on the results of the introduction of innovation, advanced knowledge in science, application of new technologies, etc. The introduction of a new approach to safety management in the enterprise requires the development of an appropriate scientific and methodical apparatus (models, methods, etc.) to manage this condition [2].

The stable functioning of the safety of Russian OGS enterprises (as opposed to its development) is its ability not only to preserve its properties against accidents and fires, but also to return to equilibrium in the event of deviations. The article presents the system of IS, created at the Russian OGS enterprises, consisting of subsystems (IndS, FS, LP), designed to neutralize instability in the management of the enterprise security under the conditions of its resource limitations. The key idea in solving the problem of ensuring a high-quality level of safety at the Russian OGS enterprises is directly related to the development of a comprehensive interdisciplinary approach [3] based not only on the use of scientific and technical advances in the field of reliability of physical objects, but also in the development of new scientific results for the implementation of organizational and technical measures in the transition to a new qualitative level of development [4].

The above circumstances are characterized by a high degree of relevance, the author of the article offers to substantiate the use of a rational-target model of development of the IS system at the Russian OGS enterprises.

METHODS

In terms of integrated safety, multidisciplinary research aimed at improving the safety of industrial enterprises has been applied in various schools dealing with the improvement of safety at various sites. The main schools in this scientific direction are:

- Mechanical Engineering Research Institute of the Russian Academy of Sciences (IMASH RAN);
- All-Russian Research Institute for Civil Defense and Emergency Situations of the Ministry of Emergencies of Russia (Federal Center for Science and High Technologies).

Interdisciplinarity refers to the unification of two or more scientific fields or to the development of subject areas or the unification of two or more professions, technologies, and the same method can be created for any strategic goal [5]. Under interdisciplinary approach the "principle of organization of new scientific knowledge" opens wide possibilities of interaction of many disciplines in solution of nature and society complex problems. Since the results obtained in them, it allows researchers to go beyond their discipline, to use known advances in a new production and to obtain new scientific results [6–8].

Using an interdisciplinary approach in the Russian oil and gas companies, it became necessary to find a method used for the rational-targeted development of the IS system at Russian oil and gas companies. The formed conviction as a non-standard approach allows to combine scientific achievements obtained in the different fields, the author of this article considered it necessary to use the mass center as a geometric point, the position of which is determined by the distribution of mass in the body, and the movement characterizes the movement of the body or mechanical system as a whole, in this regard oil and gas companies must use a flexible approach [9, 10].

If the entire volumetric resource of an enterprise, designed to ensure the stable functioning of subsystems (IndS, FS, LP) of Russian oil and gas companies, is considered as a content consisting of smaller volumes (masses), each of which in its own way affects the general condition of the IS at the enterprises under consideration, then the task of finding a rational target point for the development of an enterprise is reduced to the task of finding an existing

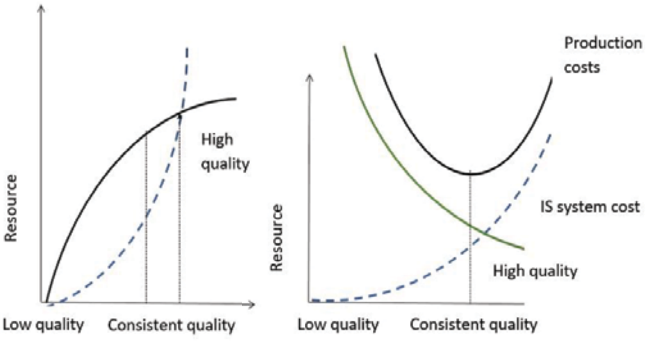

Fig. 1. Function to improve the performance of the IS system at the Russian Oil and Gas Sector enterprises

starting point, which is located in the coordinates of a stable functioning of the enterprise. The presence of two points allows to build a directional vector from the starting point towards the point indicating the direction to achieve a research purpose.

Between the quality of the functioning of the IS system and the resource of the enterprise in the Russian OGS, intended to ensure it, there is a relationship of the form in Fig. 1. The most rational will be the qualitative level at which a slight increase in efficiency will require a sharp increase in costs, which will provide a rational function between the resource volume invested in subsystems (IndS, FS, LP) and the indicator of damage reduction from accidents and fires. The option of the IS qualify level which is more to the right of the stable quality line adjacent to the resulting curve will be rational [11, 12].

The rational-target model for the development of the IS system at the enterprises of the oil and gas sector in Russia is considered on Fig. 2, which shows points with an integral indicator of the impact on reducing damage from accidents and fires, where the left side shows resources, each of which is characterized by an individual volume allocated to the safety subsystem (IndS, FS, LP),

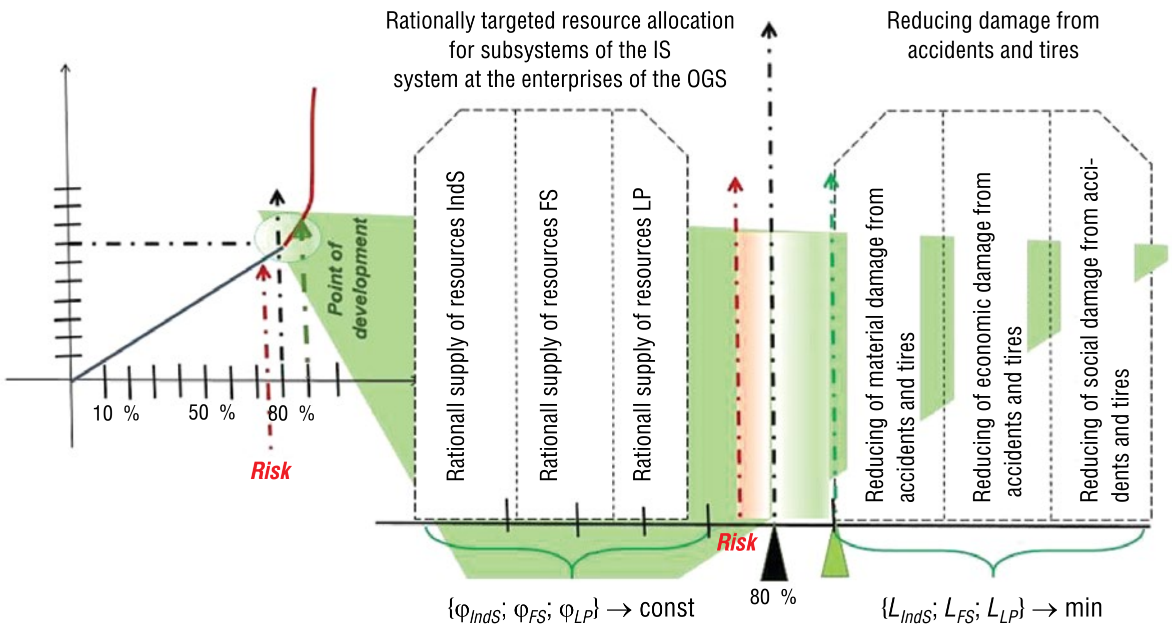

Fig. 2. The rational-target model for the development of the IS system at the Russian Oil and Gas Sector enterprises

formed from the summed volumes of its private indicators, corresponding to the property of proportionality of damage.

The presence of two points on the horizontal scale for the stable and developing states of the functioning of the enterprise makes it possible to determine such a rational amount of resource for each of the subsystems (IndS, FS, LP), so that the point moves to the right, tends to reach a level approximately equal to 90 %.

For instance, the scientific problem for the development IS system, created at the enterprises of the oil and gas sector in Russia was solved. To demonstrate it, the management of oil and gas companies in Russia make a decision to develop the IS system created at these enterprises, thus, in a certain period of time, transfer it from a state of stable (sustainable) functioning to a new qualitative state of development. The management of Russian oil and gas companies determined a dedicated time period for the transition, considered as the initial time reference point — t_0 and the goal achievement point — t_1, presented in a model of the form:

$$\sum_{i=1}^{N} P_{\varphi_{n1}}(t_0) \to \sum_{i=1}^{N} P^{*}_{\varphi_{n2}}(t_1), \tag{1}$$

where $P_{\varphi_{n1}}(t_0)$, $P^{*}_{\varphi_{n2}}(t_1)$ — values of indicators of the subsystem state (IndS, FS, LP) at the beginning and at the end of the transition period;

n_1, n_2 — values of resource volume indicators calculated for the initial time reference point t_0 and goal achievement point t_1.

If in the subsequent period t_1 the values of the indicators have changed and become equal $P^{*}_{\varphi_{n2}}(t_1)$, then the sum of all changes will be as follows:

$$\sum_{i=1}^{N} \left| P^{*}_{\varphi_{n2}}(t_1) - P_{\varphi_{n1}}(t_0) \right| = \Delta(t_1), \tag{2}$$

where $\Delta(t_1)$ — the total difference in changes for all indicators in the period t_1;

$|\ldots|$ — sign indicating that the number is taken modulo.

In this task, it is required to present a calculation of the effective impact on the SC subsystem, which would allow to testify to the fact of positive dynamics in reducing the damage caused to the considered subsystems. The solution of the problem is as follows: if the total difference $\Delta(t_1)$ in changes in all indicators in the period is known t_1, then the indicator of change in the level of development $L(t_1)$ in the goal achievement point — t_1 can be calculated using the formula:

$$L(t_1) = \frac{\Delta(t_1)}{E_n}, \tag{3}$$

where E_n — is the efficiency of the volumetric contribution of the resource to (1 – N) departmental (sectoral) subsystems (IndS, FS, LP, etc.). It is a value for the calculation that involves hundreds of indication.

To obtain adequate calculations in order to determine the effective volumetric contribution of the resource to (1 – N) departmental (sectoral) subsystems (IndS, FS, LP, etc.) is required to carry out the following calculations.

Assuming that the actual – $P^{risk}_{\varphi_{n1}}(t_0)$ – limit and $P^{Av}_{\varphi_{n1}}(t_0)$ – the average value of indicators of damage to subsystems (IndS, FS, LP) for the previous period. Next, the target for damage reduction considered for the forecast period is determined ($t_0 - t_1$) taking into account the deviation of actual damage indicators from average indicators:

$$\sum_{i=1}^{n} \left| P^{Av}_{\varphi_{n1}}(t_0) - P^{risk}_{\varphi_{n1}}(t_0) \right|. \tag{4}$$

Next, a rational-target indicator is determined $P^{prog}_{\varphi_{n1}}(t_1)$ reduction of damage to subsystems (IndS, FS, LP), compared as a ratio of the indicators of the current and forecast periods ($t_0 - t_1$), taking into account the deviation of the average damage indicators from the planned indicators:

$$\sum_{i=1}^{n} \left| P^{prog}_{\varphi_{n1}}(t_1) - P^{Av}_{\varphi_{n1}}(t_0) \right|, \tag{5}$$

where n — the total number of indicators taken into account in the calculations.

Coefficient influencing the reduction of damage from accidents and fires at Russian oil and gas companies λ_n, calculated for effective values, will be presented in the form:

$$\lambda_n(t_0) = \frac{\sum_{i=1}^{n} \left| P^{Av}_{\varphi_{n1}}(t_0) - P^{risk}_{\varphi_{n1}}(t_0) \right|}{\sum_{i=1}^{n} \left| P^{Av}_{\varphi_{n1}}(t_0) \right|}. \tag{6}$$

Coefficient influencing the reduction of damage from accidents and fires at oil and gas companies of Russia — λ_n, calculated for the period of development of the enterprise IS system, will be presented in the form:

$$\lambda_n(t_1) = \frac{\sum_{i=1}^{n} \left| P^{Prog}_{\varphi_{n1}}(t_1) - P^{Av}_{\varphi_{n1}}(t_0) \right|}{\sum_{i=1}^{n} \left| P^{Av}_{\varphi_{n1}}(t_0) \right|}. \tag{7}$$

Achieved system development target IS $L(t_1)$ can be calculated based on the difference in ratios of the coefficients λ_n, affecting the reduction of damage from accidents and fires at Russian oil and gas companies:

$$L(t_1) = \lambda_n(t_1) - \lambda_n(t_0). \tag{8}$$

RESULTS

The article considers an example using the results of assessing the state of IS at the Russian Oil and Gas Sector enterprises. In the current conditions of the functioning of the IS system at the Russian Oil and Gas Sector enterprises, without having the results of calculating the indicators of impact from an unfulfilled activity, distributes the resource allocated for subsystems (IndS, FS, LP) based on intuitive considerations. Under such conditions, errors may occur in the formation of priorities for activities included in the general list, for which priority allocation of resources is required.

During the experiments, a set of indicators included in the sample was carried out from the limiting minimum (from 0.003) to the maximum (0.201) values. During the experiments, an arbitrary exclusion of indicators was carried out (about 40 units in total) with a fixed variable step (from 3 to 5 units). Then the results obtained during the experiments were calculated for the average value. As for the calculation of the overall indicator for the sample of results obtained using the scientific and methodological apparatus for the rational and targeted development of the IS system at the Russian Oil and Gas Sector enterprises, the content of the sample included all activities from position 1 to 159 (volume 80 %) of all activities presented in the list (Fig. 3).

The ratio of the influence indicator $L(t_0)$ is shown on the Fig. 4 for the conditions of stable functioning of the IS system to the influence indicator $L(t_1)$, allowing to develop the IS system of Russian oil and gas companies. Positive dynamics in reducing damage from accidents and fires at Russian oil and gas companies will directly depend on an increase in the overall indicator of impact on

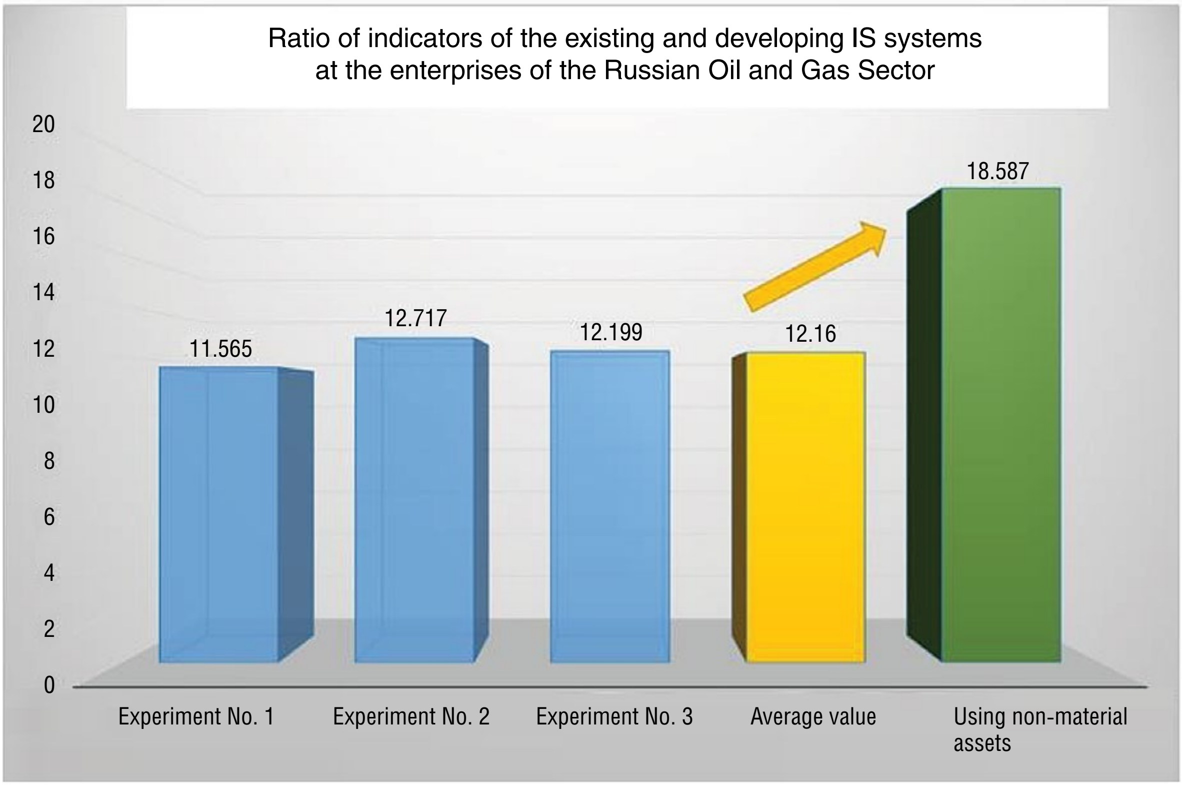

Fig. 3. Graph of the ratio of indicators of the existing and developing IS systems at the Russian Oil and Gas Sector enterprises

reducing damage from accidents and fires $L(t_1)$ (represented by formula (8)), which allows us to consider in the form of an expression:

$$m\lambda_n = \sum_{i=1}^{n}\left[Q_j^{\min} + \cdots + Q_j^{\max}\right] \approx 19, \quad (9)$$

where $m\lambda_n$ — the mathematical expectation of a general indicator that affects the reduction of damage from accidents and fires, calculated using numerical values taken from the sample (footnote (1));

$Q_j^{\min} + \cdots + Q_j^{\max}$ — numerical values with minimum and maximum values, taken from the sample (footnote (1)).

Expression (9) presents a general calculated indicator that affects the reduction of damage from accidents and fires and is directly related to the damage indicated in the reports on accidents and fires for the period of 2014–2020 for Russian oil and gas companies (Table).

Damage indicators (see Table) are directly related to the coefficient λ_n, which has an impact on reducing damage from accidents and fires at Russian oil and gas companies. When carrying out a simple calculation procedure, a result was obtained that makes it possible to tie social and economic damages to a conditional unit of the coefficient — λ_n, which has a direct impact on reducing damage from accidents and fires at Russian oil and gas companies (Fig. 4).

The presence of different planning periods for the development of the IS system at the Russian Oil and Gas Sector enterprises makes it possible to form a unified approach to the distribution of resources, as well as to carry out all approvals at the very beginning of this long process. Over the last 20 years, Russian companies have become the larger Liquefied Natural Gas (LNG) producers of global relevance [13]. So, according to statistic data,

Total damage caused by accidents and fires at Russian oil and gas companies in the period of 2014–2020

Category	Damage from accidents in the reports of the Federal Service for Environmental, Technological and Nuclear Supervision (Rostechnadzor)	Damage from fires in the reports of the EMERCOM of Russia	Total damage
Deceased, people	42	23	65
Victims, people	122	111	233
Economy damage, million rubles	19,756	16,710.1	36,466.1

Moscow is considered as an LNG “global force”, being the 4th largest exporter in the world [14].

The plans define the time horizon for achieving the strategic goal, which sets the time period for achieving sub-goals of the tactical and operational levels [15, 16]. Management sets a long-term strategic target, but the path to its achievement should be systematic (monthly, quarterly).

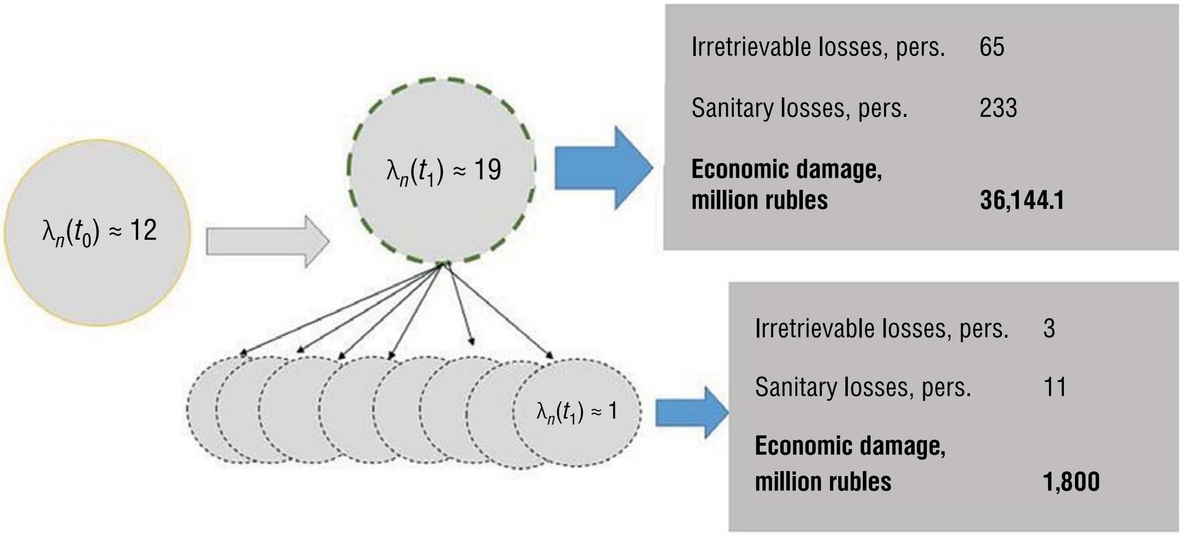

Fig. 4. The ratio of socio-economic damage to the indicator λ_n, equal to one conventional unit

At the tactical level, the horizon for determining future activities is limited to one year. As for the distribution of resources for subsystems (IndS, FS, LP) included in the enterprise IS system, then at this time interval coordination is carried out with all structural divisions authorized in the distribution of the enterprise resource. Moreover, at the operational level, all actions implemented during the month (quarter) are worked out, which is displayed in the target operational planning documents.

The plans developed on the basis of time horizons display: a list of ongoing activities; responsible executors; deadlines; officials exercising control, in a separate column of the planning document being developed, the approved amount of resource support allocated to a specific subsystem (IndS, FS, LP) included in the enterprise IS system is demonstrated.

CONCLUSIONS

The article substantiates and demonstrates the use of a new rational-target model for the development of the IS system at the enterprises of the Russian oil and gas sector, and shows an example proving the feasibility of its use. To achieve the predictive goals of the strategic level, which requires a significant reduction in damage from accidents and fires at the enterprises of the Russian Oil and Gas Sector, it is required to use a modern scientific and methodological base (models, methods, techniques, etc.).

The use of a new rational-target model for the development of oil and gas companies in Russia makes it possible in practice to solve the problem of reducing damage from accidents and fires in the integrated security system of these enterprises, solving a problem of great social and economic importance for Russia.

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Рационально-целевая модель развития системы комплексной безопасности на предприятиях нефтегазового комплекса России

В статье представлен анализ существующих подходов к обеспечению комплексной безопасности на промышленных предприятиях. Данное исследование ориентировано на использование междисциплинарного подхода при его обеспечении на предприятиях нефтегазового комплекса (НГК) России. Представлена методология, разработанная для российских нефтегазовых предприятий, в виде сравнительной модели и гибкого подхода подобно существующей и развивающейся комплексной системы безопасности для снижения различных видов ущерба. Цель исследования — решить научную задачу разработки комплексной системы безопасности на предприятиях НГК России. Представленные результаты исследования доказывают целесообразность использования результатов оценки состояния комплексной безопасности предприятий нефтегазового комплекса России. Таким образом, решается важная задача по рационально-целевому распределению ресурсов, которые могут быть использованы для устранения именно тех мероприятий, которые имеют высокие показатели воздействия ущерба от аварий и пожаров. Результаты мониторинга представлены в виде использования новой рационально-целевой модели развития нефтегазовых компаний России. Данная модель позволяет на практике решить задачу снижения ущерба от аварий и пожаров в системе комплексной безопасности этих предприятий.

Ключевые слова: *нефтегазовый комплекс, система комплексной безопасности, междисциплинарный подход, рационально-целевое развитие, эффективное функционирование*

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