Risk-Oriented Approach to Industrial Control over Occupational Health & Safety at the Main Gas Pipeline Construction Stage

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Abstract. In the paper, industrial health protection and labor safety inspection certificates have been analyzed. The categories of violations have been composed by the frequency of their occurrence. Based on the General Contractor’s risk assessment method, the severity of potential consequences has been determined and transformed into the ranks. Based on the results obtained, the final rank has been determined for each violation category. It has been proposed to supplement the General Contractor’s Questionnaire with a ranking criterion that will ensure a flexible industrial control system and rational planning of the company’s administrative and material resources.

1. Introduction
Pipeline transportation of hydrocarbons is the most common way to transfer various energy carriers, including natural gas. The construction of pipeline transport infrastructure facilities is associated with a high level of occupational injuries, the reduction of which is the objective of the industrial control procedure in the field of occupational health and safety (IC over OH&S).

2. Relevance and Scientific Significance
Currently, a legislatively approved procedure for IC over OH&S is not available. This is because the control implementation algorithm depends on the enterprise specifics, therefore, each employer independently develops a regulation on this procedure. A similar procedure is provided for by the international standard OHSAS 18001:2007 Occupational Health and Safety Management Systems, for the compliance with which most Russian construction and engineering companies are currently certified. In the works by Balabanova L.A., Kamaev S.K. [1], Baulin A.V., Perunov A.S. [2], Ridel I.A., and Aminova I.A. [3], the mechanism of implementing IC over OH&S at various industrial enterprises has been considered. It is worth noting that construction companies need to allocate significant efforts and resources to implement IC over OH&S, which determines the importance of rational distributing the company’s resources. Introducing a risk-oriented approach may provide significant assistance in solving this issue. The risk-oriented approach specifics are described in the works by Khomenko A.O. [4], Vorobieva O.V., and Gudilin I.E [5].
3. Research Objective
Currently, a risk-oriented approach is being universally implemented in the control and supervision activities of many executive bodies (Rostekhnadzor, Labor Inspectorate, etc.) and has proven itself to be positive. This indicates that the risk-oriented approach is advisable to apply for IC over OH&S at the company level. As a research subject, the activity of the SGM Group of Companies has been considered, which is the leading construction and engineering holding in Russia in the field of oil and gas construction. As part of this study, an approach has been proposed that allows optimizing the costs of material and administrative resources allocated for IC over OH&S.

4. Review of the Current Procedure for IC over OH&S in the Company
As part of the IC activities of contracting organizations, compliance with the industrial safety requirements when performing work (i.e. labor protection, industrial safety, fire safety requirements) according to the RF legislation, the design solutions in industrial safety and the subcontract terms and conditions are monitored.

In the study, the main gas pipeline industrial inspection certificates for 2017-2019 have been analyzed at the Customer and the General Contractor levels. To date, within the General Contractor’s internal documentation system, a Questionnaire for verifying compliance with labor protection requirements in contracting organizations during the construction of facilities (hereinafter - the Questionnaire) has already been developed. Based on the Questionnaire, 11 categories have been determined, which are given in Table 1.

| Table 1. Categories of Potential Violations Detected during IC. |
|---------------------------------------------------------------|
| Category 1. Liability for ensuring safe labor conditions at the construction site |
| Category 2. Arrangement and conduction of training and briefings |
| Category 3. Arrangement and conduction of medical examinations |
| Category 4. Compliance with safety requirements during excavation |
| Category 5. Installation of appropriate safety signs |
| Category 6. Provision of PPE |
| Category 7. Arrangement of the fire prevention regime |
| Category 8. Arrangement and performance of work at heights |
| Category 9. Operation of vehicles |
| Category 10. Operation of electrical installations |
| Category 11. Arrangement of lifting operations |

At the first stage of the study, violations recorded during the main gas pipeline construction have been analyzed. In total, 349 violations have been identified during the period under review. The distribution of the violation categories by frequency is shown in Figure 1. According to the diagram, such a category as the arrangement of lifting operations (including the lack of slinger certificates) most often occurs. The least share of the violations detected comes on those related to the arrangement and performance of work at heights (including the lack of an appropriate safety permit).
5. Assessment of the Existing Level of Injuries in the Company

At the second stage of the study, a relationship has been established between accidents at the SGM GC-controlled facilities during the main gas pipeline construction for 2017-2019 and the IC results. In total, 12 accidents of various severity have occurred at the facilities during the period under review.

When investigating these accidents, the direct causes of injury have been determined and compared with the observation categories within the IC over OH&S. This study has been performed using the Fault Tree Analysis (FTA). As an example, let us consider an accident that occurred with a welder. The accident circumstances were as follows: the welder was near the portable welding machine facing the cabin; nearby a team of workers performed lifting operation; when pipe layers lifted the pipe string, the free end of the string ‘played’ towards the welder and hit him. Figure 2 shows the fault tree for this fatal accident. As a result of building this fault tree, 6 direct causes of the fatal accident have been revealed. Further, these causes have been compared with the observation categories within the IC over OH&S and as a result, violations related to 4 observation categories (1, 2, 5, and 11) have been revealed, which led to employee’s death.
According to the example considered, for each accident, several independent or mutually complementary causes may be simultaneously revealed. An analysis of the remaining accidents allowed establishing that 12 accidents considered were caused by 38 violations distributed according to Figure 3. The predominant causes of the majority of both mild and severe accidents related to the below categories:

- Category 1. Lack of briefings or insufficient briefings on occupational safety for employees
- Category 2. Arrangement and performance of training and briefings
- Category 11. Arrangement of lifting operations

The results confirm those of many other studies [6–8], which emphasize the fact that the most common accident causes are organizational ones, i.e. lack of training and briefings, and low qualification of employees. In turn, pipeline construction activity is primarily associated with lifting operations using hoisting mechanisms, for the safe fulfillment of which employees should not only pass training and briefings prescribed but also have the appropriate qualifications.

Figure 2. Fault Tree for Fatal Accident.
6. Development of Risk-Oriented Approach to IC over OH&S

Based on the results of the analysis of violations and accidents occurred, a risk-oriented approach to IC over OH&S has been proposed. To do this, it is proposed to introduce the ranking of the violation categories in the General Contractor’s Questionnaire.

The ranking proposed is based on the below formula:

\[ B = 10q \cdot F, \]  

where \( B \) is the total violation category rank rounded to the nearest whole number,

\( q \) is the specific weight of the violation category (defined as the frequency of violations detected within a specific category and adopted according to Table 3),

\( F \) is the consequence severity rank determined according to Table 2.

The procedure for ‘Planning in the OH&S Management System’ has been developed within the General Contractor’s internal documentation system, the objective of which is preventing occupational injuries, accidents, incidents, and diseases, identification and control of hazards, effective risk management, and elaboration of justified recommendations to reduce risk. Within this method, a three-point scale (1, 3, and 5) has been developed to assess the severity of potential consequences.

This scale has been proposed as a basis for assessing the severity of the violation consequences (\( F \)) (table 2) and adjusted. To increase the sensitivity, the scale was detailed within the medium-high interval; the medium level could be thereby divided into two independent positions, i.e. moderate and essential signs (numerical values of 3 and 4, respectively). A four-point scale was obtained with a missing numerical value of 2. It seems rational not to add a rank with a numerical value of 2 since in this case, the scale is detailed within the ‘minor-medium’ interval, which is not required, unlike the ‘medium-high’ one. For the \( F = 1 \) rank, fatal accidents do not occur. For the \( F = 3 \) and \( F = 5 \) ranks, on the contrary, both severe and fatal accidents can be observed, which causes the need to differentiate such an array of conditions. That is why an intermediate rank was introduced with a numerical value of 4 [3, 5].

![Distribution of the Accident Causes by Categories for the Reporting Period](image)

**Figure 3.** Analysis of the Accident Causes.
Table 2. The Consequences Severity Ranking.

| Rank (F) | The Factor Sign | Characterization of Consequences |
|----------|------------------|----------------------------------|
| 1        | Minor            | The violation category studied has caused: ≥1 minor accident, or a single severe accident over the last 3 years, or no accidents. |
| 3        | Moderate         | The violation category studied has caused: ≥2 severe accidents over the last 3 years, or ≥1 fatal accident over the last 3 years. |
| 4        | Essential        | The violation category studied has caused: ≥2 severe accidents over the last 2 years, or a single fatal accident over the last 2 years, or a single severe accident over the last year. |
| 5        | High             | The violation category studied has caused: ≥2 fatal accidents over the last 2 years, or ≥2 severe accidents, or single fatal accident over the last year. |

In Table 3, the q and F parameter values, as well as the final rank for the violation category (B) are given.

Table 3. The Final Violation Category Rank.

| Violation Type | Violation Category Share, q | Consequence Severity Rank, F | Final Rank for Category B |
|---------------|----------------------------|-----------------------------|---------------------------|
| Category 1.   | 0.054                      | 5                           | 3                         |
| Category 2.   | 0.126                      | 5                           | 6                         |
| Category 3.   | 0.077                      | 5                           | 4                         |
| Category 4.   | 0.115                      | 4                           | 5                         |
| Category 5.   | 0.097                      | 5                           | 5                         |
| Category 6.   | 0.074                      | 4                           | 3                         |
| Category 7.   | 0.069                      | 1                           | 1                         |
| Category 8.   | 0.040                      | 3                           | 1                         |
| Category 9.   | 0.100                      | 5                           | 5                         |
| Category 10.  | 0.072                      | 1                           | 1                         |
| Category 11.  | 0.175                      | 5                           | 9                         |

It is proposed to determine the final rank according to Table 4. Thus, the violation categories with a rank of B≥5 require the most attention since the correlation between the prevailing violations in terms of frequency and severity of consequences is obvious (see Table 3). For these categories, effective preventive measures aimed at improving the safety level should be taken first.

For the violation categories with a rank of B<3, high efficiency and sufficiency of the measures taken are noted, therefore, efforts should be directed to maintain the current safety level.

As for categories with a rank of 1, 3, and 6 (3≤B<5), the low industrial control efficiency should be noted. Such violations are relatively rarely detected, but a majority of severe and fatal accidents occur just for the reasons associated with these violation categories.
### Table 4. Violation Category Ranking.

| Final B Rank | Description of the Violation Category Level |
|--------------|--------------------------------------------|
| B < 3        | Low significance                           |
| 3 ≤ B < 5    | Medium significance                        |
| B ≥ 5        | High significance                          |

7. Conclusion
Introducing a risk-oriented approach to industrial control over occupational health and safety, on the one hand, will allow the auditor to determine the sequence, priority, and frequency of inspections for the compliance with the labor protection requirements, and on the other hand, effectively spend the construction company resources.

8. References
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