

Abstract

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The topic of the dissertation research: «Methods for reducing the risk of fire and explosion hazardous industrial facilities based on the probabilistic-economic safety indicator of protective barriers».

The relevance of the research topic is determined by the fact that safety in production remains a declared priority, yet in practice, it is implemented through formal, rigidly defined standards that do not provide flexibility for making reasoned decisions. In such conditions, it is important to develop approaches based on quantitative risk assessment, so that effective protection measures can be chosen with an understanding of their impact on safety and costs. This is especially relevant for enterprises striving to comply with requirements while remaining competitive. A key state task is ensuring fire and explosion safety at oil, gas, and energy facilities, which are the backbone of the country's economy. The analysis of accidents at oil, gas, and energy facilities shows an increase in emergency situations, leading to fires with significant material damage. This emphasizes the relevance of developing new methods and approaches to reduce fire risks.

The goal of the research: ensuring fire, industrial, and economic safety of hazardous industrial facilities (HIFs) with consideration of the cost-effectiveness of protective measures corresponding to the expected level of risk at petrochemical and chemical production facilities.

Research tasks:

To achieve the goal set in the dissertation, the following tasks are solved:

1. Analyze the normative and methodological base and existing approaches to the risk-oriented approach to fire and industrial safety of HIFs, identify problematic aspects of applying probabilistic risk analysis when selecting protection measures.
2. Develop methodological approaches to setting risk acceptability criteria and decision-making when choosing protection measures for HIFs, considering the ALARP principle and practical application limitations.
3. Develop an approach for quantitative risk assessment at HIFs, ensuring the comparison of protection measure options in conditions of limited input data and analysis resources.
4. Develop an approach for the technical and economic justification of protection measures, allowing the consideration of the cost-effectiveness of risk reduction under given constraints.
5. Justify the procedure for applying and combining hazard identification methods and subsequent quantitative risk assessment at various stages of the HIF life cycle.
6. Develop an approach for selecting optimal protection measure sets for HIFs under given risk level and resource constraints and conduct testing of the proposed solutions using HIF examples.

Scientific novelty of the work:

A risk-oriented approach to selecting protection measures for HIFs is proposed, which links the effectiveness of protective functions with economic feasibility and allows substantiating the adequacy of the security system configuration under individual and economic risk constraints.

An economic efficiency index (EEI) is introduced for comparing protection measures based on the «risk reduction/costs» criterion and assessing the contribution of individual barriers to residual risk; based on this, an iterative procedure for selecting a set of measures with recalculating risk and EEI at each step in the ALARP logic is developed.

Risk acceptability criteria are developed based on background risks, taking into account the uncertainty of probabilistic estimates, and the integration of HAZOP FTA for quantitative risk assessment and selecting protective functions under limited data and analysis resources is substantiated.

Practical significance of the work:

The proposed approach enables enterprises to select the most effective configurations of protection systems that correspond to the acceptable level of risk without additional investments. This is especially relevant under strict regulatory control, when production organizations are forced to find a balance between safety and economy.

The method, tested at oil, gas, and energy facilities, has proven its effectiveness: costs for protection systems in implemented projects were reduced during the development, implementation, and trial operation period while maintaining an acceptable level of safety, demonstrating its universality in application by both design organizations and industrial safety services.

The developed methodology can be integrated into existing risk analysis procedures at HIFs without violating existing regulations, significantly simplifying its implementation and providing mechanisms for rational management of protection measures. The examples of applying the methodology to real production conditions presented in the work underline its practical significance.

Positions to be defended:

1. Methodological foundations of risk-oriented fire and industrial safety at HIFs have been developed: elements of the conceptual apparatus and decision-making criteria (acceptable risk, background risk, ALARP principle application procedure) have been clarified and agreed upon, ensuring uniform criteria setting and comparability of probabilistic risk analysis results when selecting protection measures.
2. A methodology for quantitative risk assessment and the economic feasibility of protection measures has been developed, including an economic efficiency index that allows calculating the

«costs-effect» ratio as a function of risk reduction and using this indicator to justify the feasibility of implementing/upgrading protection systems under given constraints.

3. A procedure for differentiated and integrated application of hazard identification methods at HIFs under given constraints (data, resources, analysis stages) has been developed: the selection of method combinations and their integration scheme, implemented through HAZOP analysis and fault tree construction for subsequent quantitative risk calculation and justification of protection measures, has been substantiated.

4. A method (algorithm) for determining optimal combinations of protection systems and rational configurations of protection measures for HIFs has been developed, based on risk reduction under constraints on acceptable levels of individual, environmental, economic (and other) risks, and considering the ALARP principle; the selection criterion includes economic efficiency assessment (including the economic efficiency index), which allows obtaining optimal sets of protection measures that provide the required risk reduction at justified costs.

The reliability of the research is confirmed by the adequacy of the use of systems analysis methods, mathematical statistics processing, and hazard analysis, as well as its testing within the framework of scientific research. Limitations are associated with the quality of initial data and failure statistics, the dependence of HAZOP on the composition of the working group, and the uncertainty of probabilistic estimates.