

SCIENTIFIC AND METHODOLOGICAL FOUNDATIONS FOR ASSESSING AND MANAGING FIRE AND EXPLOSION HAZARDS OF PETROLEUM PRODUCT STORAGE TANKS

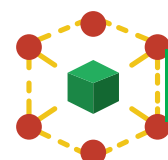
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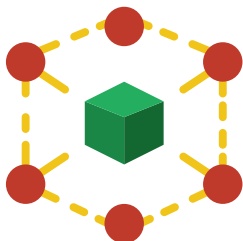
Abstract. The article examines issues related to ensuring fire and explosion safety of tanks used for the storage of petroleum products. Based on an analysis of the main hazardous factors arising during the storage and technological operations involving petroleum products, the sources contributing to fire and explosion hazards are systematized. Particular attention is paid to the formation of vapor-air mixtures, the presence of ignition sources, increases in pressure and temperature, loss of tightness of tank equipment, and the development of emergency scenarios. A scientific and methodological approach is proposed for the comprehensive assessment of the fire and explosion hazard level of storage tanks, taking into account the relationship between the probability of an emergency event and the severity of its potential consequences. The scientific novelty lies in substantiating an integral assessment of the fire and explosion hazard of storage tanks based on the combined consideration of technological, operational, and organizational risk factors. The results obtained can be used to improve industrial and fire safety systems at petroleum product storage facilities.

Keywords: petroleum products, storage tank, fire safety, explosion hazard, fire and explosion risk, hydrocarbon vapors, ignition source, emergency scenario, risk assessment, risk management.

1. Introduction. The storage of crude oil and petroleum products is among the technological processes characterized by an increased level of fire and explosion hazard. Tank farms at oil depots, petroleum refining enterprises, and industrial facilities contain significant volumes of combustible liquids. During evaporation, explosive vapor-air mixtures may form in the vapor space of storage tanks and in adjacent areas [1, 4].

The relevance of this study is determined by the need to improve the effectiveness of existing systems for preventing fires and explosions at petroleum product storage facilities. The traditional approach to safety assurance is mainly based on compliance with regulatory separation distances, technical requirements for storage tanks, the availability of fire protection equipment, and the implementation of organizational measures [4, 6]. However, the development of an accident is generally caused not by a single factor but by a combination of interrelated technological, operational, and organizational causes.





Particular hazards are associated with tank filling and emptying operations, during which the concentration of petroleum product vapors, pressure, and temperature in the vapor space may change. Additional risk factors include malfunction of breathing equipment, loss of tightness, static electricity, atmospheric electrical discharges, hot work, and failure of automatic monitoring systems [5, 6].

Therefore, there is a need to develop a scientifically grounded approach that makes it possible to move from the assessment of individual hazardous factors toward a comprehensive assessment of the fire and explosion hazard of storage tanks [10, 11]. The aim of the study is to develop a scientific and methodological approach to the comprehensive assessment and reduction of fire and explosion hazards of petroleum product storage tanks, taking into account the interrelationship between technological, operational, and organizational risk factors.

2. Research Methods.

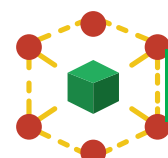
The study employs methods of system analysis, hazard identification, analysis of cause-and-effect relationships, emergency scenario analysis, expert assessment, and a risk-oriented approach.

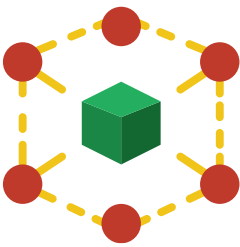
The following factors are proposed as the main determinants of the fire and explosion hazard level of a storage tank:

- physicochemical properties of the stored petroleum product;
- flash point and autoignition temperature;
- evaporation intensity;
- concentration of hydrocarbon vapors;
- tank volume and structural characteristics;
- equipment tightness;
- effectiveness of breathing equipment;
- presence of potential ignition sources;
- technical condition of equipment;
- effectiveness of fire detection and extinguishing systems;
- compliance with technological regulations;
- level of organizational fire safety management [6, 12].

3. Results of the Study.

The analysis conducted shows that the development of accidents involving petroleum product storage tanks should be considered as a sequence of interrelated stages:





Escalation of a Hazardous Situation

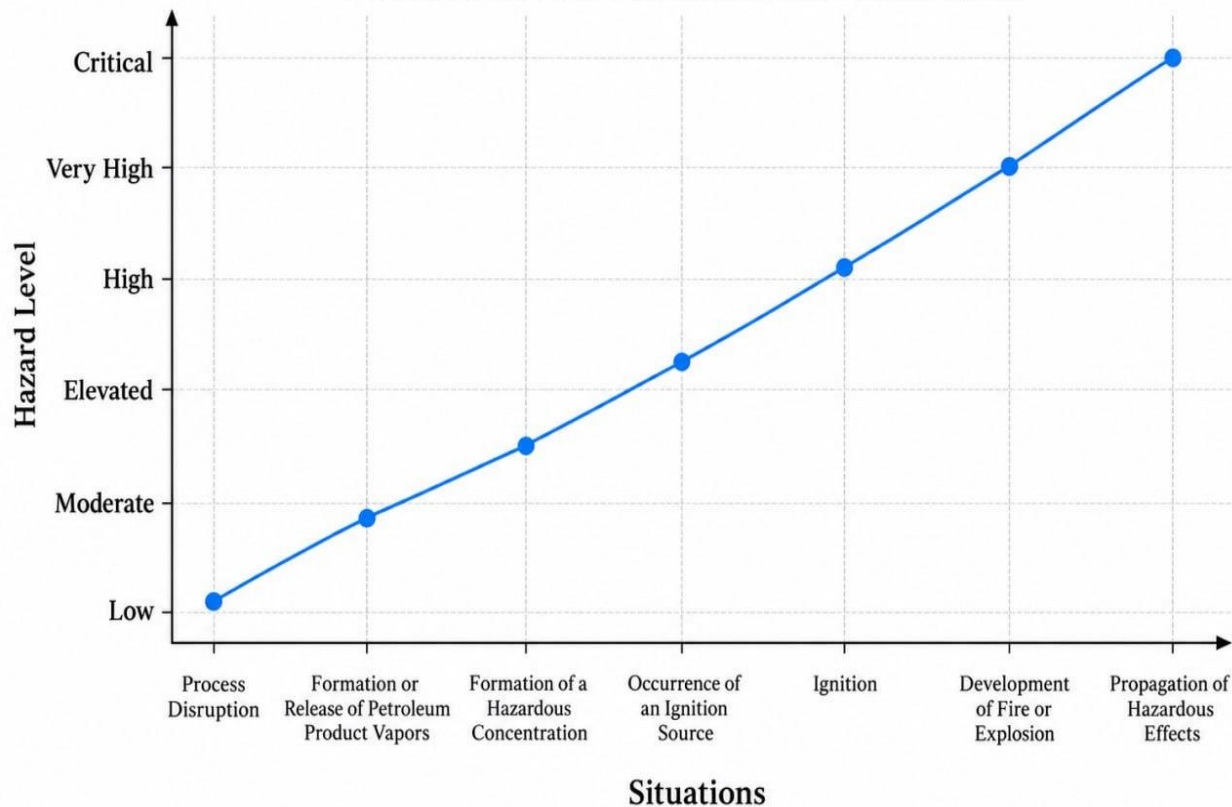


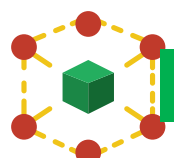
Figure 1 — Escalation of a hazardous situation in storage tanks.

This representation makes it possible to identify critical points at which the emergency chain can be interrupted.

As the principal scientific result, the risk factors affecting storage tanks are proposed to be classified into three interrelated groups:

- 1. Technological factors** — properties of petroleum products, temperature, pressure, filling and emptying rates, filling level, and evaporation conditions.
 - 2. Technical factors** — condition of the tank, pipelines, breathing equipment, shut-off valves, monitoring and alarm systems, and automatic fire extinguishing systems.
 - 3. Organizational factors** — compliance with technological regulations, frequency of technical maintenance, personnel training, control of hot work, and organization of emergency response.
- Based on this classification, a priority matrix of risk factors can be developed. The most critical factors are those characterized simultaneously by a high probability of occurrence and significant severity of consequences.

The proposed scientific and methodological approach involves the following sequential stages:



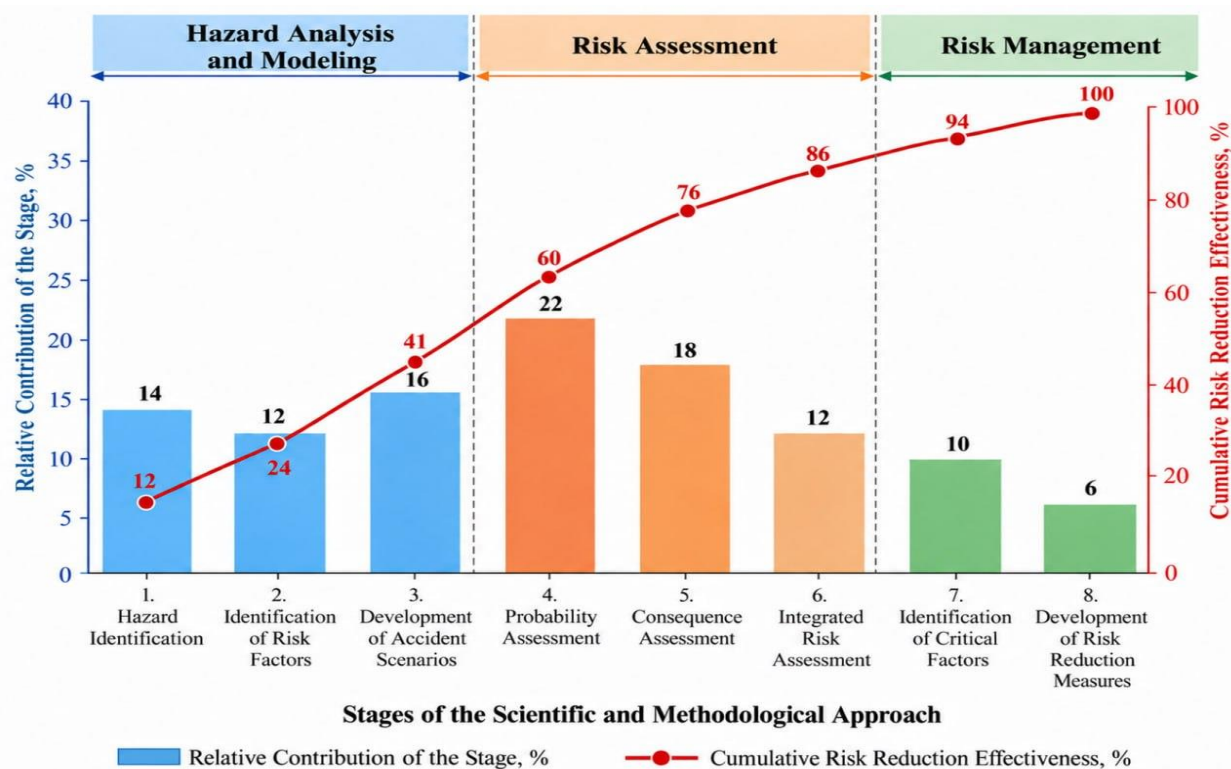
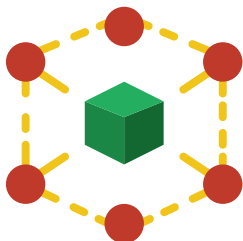
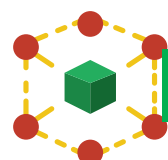
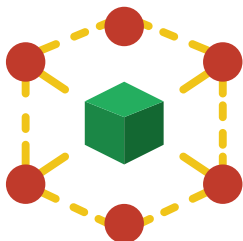


Figure 2 — Scientific and methodological approach to assessing and reducing the fire and explosion hazard of petroleum product storage tanks.

This sequence provides a basis for identifying critical stages in the development of an accident and determining priority areas for preventive intervention. The results of the functioning of the prevention system should be taken into account during subsequent assessments of the condition of the storage tank and the effectiveness of the implemented protective measures. This makes it possible to establish a feedback mechanism within the safety management system and to adjust preventive measures based on the results obtained. In general, the proposed approach is aimed at ensuring continuous monitoring of the main parameters determining the fire and explosion hazard of storage tanks. These include the tightness of equipment, temperature and pressure, concentration of hydrocarbon vapors, technical condition of protective systems, and the operational status of fire detection and extinguishing equipment.

The implementation of preventive measures at the stages preceding ignition makes it possible to interrupt the development of an emergency before the transition to a fire or explosion. Thus, the





assessment of fire and explosion hazards should be considered not as a one-time procedure but as a continuous process integrated into the overall safety management system.

4. Conclusion. The study made it possible to formulate a scientific and methodological approach to the assessment and management of fire and explosion hazards of petroleum product storage tanks based on the comprehensive consideration of technological, technical, and organizational factors.

A cause-and-effect relationship in the development of emergency processes has been established, ranging from disruption of the technological regime and loss of tightness to the formation of a combustible vapor-air mixture, its ignition, and the subsequent development of a fire or explosion with propagation of damaging factors.

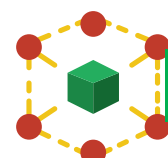
It has been demonstrated that reducing fire and explosion hazards should involve not only the improvement of fire protection systems but also continuous monitoring of equipment tightness, technological parameters, and combustible vapor concentrations, as well as early detection of hazardous deviations [10, 12].

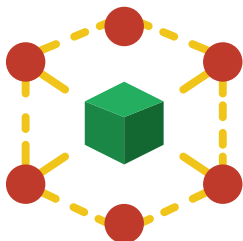
The proposed approach provides a scientific and methodological basis for the subsequent development of a quantitative model for the integral assessment of risk, taking into account the properties of petroleum products, structural characteristics of storage tanks, operating conditions, and the effectiveness of protective systems.

The practical implementation of this approach is aimed at transitioning from response to the consequences of accidents toward preventive risk management, reducing the probability of fires and explosions, and limiting the potential scale of their consequences.

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