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ANALYSIS OF FACTORS AFFECTING GAS HAZARDS IN INDUSTRIAL PLANTS

12.1 INTRODUCTION

In today's business environment, occupational safety, property protection and environmental protection requirements continue to increase. The aim should be to analyze all the hazards that occur in an industrial plant. Identification and control of hazards and the assessment of occupational risk resulting from the law are the responsibility of the employer. For this reason, facilities for early detection of hazards and their analysis are commonly used in workplaces to take appropriate preventive measures. One of the greatest hazards is the possibility of leakage of dangerous substance into the atmosphere, which can cause catastrophic consequences for people, property and the environment. Gas hazards in the enterprise include many factors, including external factors (environmental), technical faults in gas installations and human errors (human factor). For each group of factors, appropriate methods of hazard identification and control should be selected.

Identification of factors affecting gaseous hazards was carried out on the example of analysis of the operation of the gas system in a selected chemical company. The technical and personal factors were analyzed, with particular emphasis on the specificity of the human factor.

12.2 CHARACTERISTICS OF INDUSTRIAL GAS INSTALLATION

In enterprises where gas appliances are used, a gas hazard signaling system is required. The principle of operation and elements that create the gas signaling system at the workplace are consistent with the fire alarm system. The purpose of such a system is primarily to detect and signal dangerous concentrations of monitored gas. The remaining tasks of the system are to alert employees of potentially explosive and fire hazards (fire protection devices) and to initiate countermeasures to reduce the risk [1]. One of the most important features of gas detection systems is the ability to easily adapt to the requirements of a particular industrial plant. The variable number of gas sensors, the type of substance to be detected, the number of alarm zones, the required control algorithms, and the output type parameters require a special gas protection design.

12.2.1 Construction of the gas signaling system

The gas signaling system consists of the following elements: signaling panel, gas sensors (in the form of electrochemical sensors), alarms, manual fire alarm and guard lines. All elements forming the signaling system are subject to mandatory certification.

The gas fire alarm control panel is a decision-making device that coordinates the operation of the entire signaling system. The main tasks of modern signaling panels are:

- receiving signals from attached detectors and manual fire alarm detectors,
- determining which of the received signals meet the criteria of the alarm and informing people in an optical and acoustic manner of danger,
- transmission by the transmission equipment of the alarm signal to the monitoring station or to the fire brigade,
- indication of the location of the hazard,
- depending on the functionality, the commissioning of neutralizing devices,
- supervision of the functioning of the whole plant, including control of cooperating fire protection devices and signaling of damage,
- logging events occurring in the system [1].

Activation of the alarm signaling should be initiated within a maximum of 10 seconds after starting the manual fire alarm or after the detector has started. This time is necessary for the exchange of information between the control panel and the fire detectors on the surveillance line [6]. The function of the control panel is also the activation of external alarms. Other common functions of the control panel are: detection and indication of the danger area and control of the system reliability (detection and reporting of defects). Alarm control panel may have a two-stage alarms – alarm cycle and secondary alarm, if the installation relates to a highly toxic gas or explosive.

Chemical sensors according to IUPAC (International Union of Pure and Applied Chemistry) are devices that process chemical information (concentration of a particular component of a sample) into an analytically useful signal. The chemical sensor contains two basic elements: a chemically selective detector layer and a transducer element. The transmitter's main task is to convert the measured parameter into an electrical, optical or acoustic signal. The increasing popularity of chemical sensors is mainly due to the choice of the optimum method of measurement and the optimum solution for the technological process [2, 4].

Alarm devices are an important element of the signaling system – allow for quick notification of people in danger. They contribute to speeding up the intervention to neutralize the hazard or to minimize the loss of people and property. Most commonly used alarm devices are acoustic signaling devices or acoustic signaling devices. Sound emitted from the acoustic signal should stand out in the environment. It is recommended that the alarm be continuous or variable frequency and amplitude [3, 6].

All components of the gas signaling system in an industrial plant are operated as intrinsically safe. For the safe operation of the gas system and monitoring system, there is a requirement for periodic calibration of sensors every 6 months. This control guarantees reliable operation of the gas monitoring system and the life of electrochemical sensors from 3 to 5 years [1].

12.2.2 Other security systems and devices used

In order to ensure gas safety and avoid major industrial accidents or reduce the impact of an accident, the following technical security systems are most commonly used:

- sprinkler system in production halls,
- water supply network with water hydrants – terrestrial,
- fire alarm system, lightning protection and static electricity,
- safety valves on technical gas installations,
- emergency stop buttons for technological processes and fire extinguishers,
- double supply of particularly important components of the production plant,
- installations (nitrogen or other) for safety and firefighting purposes,
- pressure switches for pumps and handheld gas analyzers for staff equipment.

In addition to technical security systems, the company also has a number of warning signs and signals, the main task of which is to inform employees of the hazards present in the workplace. All premises where gaseous hazards are present should be marked with special safety markings or colors in accordance with the general health and safety at work regulations. Additional security is the use of sound and light signals located inside and outside the objects [2].

12.3 METHODS OF HAZARD IDENTIFICATION

There are many methods for identifying hazards in the subject matter literature. Most often, these are retrospective methods such as document analysis, checklists, or accident card analysis. For identifying dynamic dangers (eg. gas hazards), prospective methods of hazard identification are most commonly used. They involve identifying threats and anticipating possible threats. These include: change analysis, failure mode and effect analysis (FMEA), gross hazard analysis (GHA), hazard and operability analysis (HAZOP), job safety analysis (JSA), technique of operations review (TOR), total job analysis (TJA). Fractional tree analysis (FTA) and event tree analysis are often used [5].

The error tree method is used to determine the sequence or combination of factors that are causing the hazard. The method is based on the establishment of a peak event for which causes need to be determined. The error tree is a graphical representation of logical event combinations that can lead to a peak event. A tree of errors indicates the cause of the threat. The method can be used when events can be predicted, and the relationships between them are simple.

In the event tree method, the analysis begins with determining the causes (hazard factors) and then identifies the hazards that result from them. The event tree schema defines the areas of the event header (description of the initiation event) and the event tree (sequence of possible events). This method allows for the analysis of complex safety systems and emergency procedures involving human – operator [5].

12.4 ANALYSIS OF TECHNICAL HAZARDS IN OPERATION OF GAS INSTALLATION

In enterprises that use gas installations, hazardous agents in the workplace occur mainly in the presence of: compressed gases, combustible gases in the form of gases or liquids, hot air and toxic gases and vapors. In areas where it is produced, used or stored flammable or toxic gases, it is possible to penetrate these gases into the air and create air mixtures. When a sufficient amount of flammable gas above the lower explosion limit or below the upper explosion limit is formed, an explosive mixture rapidly ignites.

Under such conditions, any leaks in the gas system or its components, such as gas tanks, valves, regulators, manometers and others, threaten to explode or poison the workers. Other hazards may be associated with external factors such as: high temperature effects on gas system components (eg during fire), improper maintenance of equipment in the installation and other.

In the analysis of technical hazards arising from the operation of the gas installation and auxiliary equipment, identification methods such as: fault tree analysis, gross hazard analysis, failure mode and effect analysis and hazard and operability analysis are best used.

The Fault Tree Method (FTA) leads to identifying the causes of hazards – threatening factors, showing their logical connections that could lead to a hazard. Use this method to identify events whose combinations lead to a peak event. The failure mode and effect analysis method (FMEA) make it possible to identify defects in particular components (eg gas installations) that can cause hazards. Hazard identification is based on analysis of elements or modules of a technical object. The Hazard and operability analysis method (HAZOP) allows to identify deviations from the intended function that could lead to hazards. The analysis is based on the physical properties of the analyzed elements.

12.5 HAZARD ANALYSIS WITH THE PARTICIPATION OF HUMAN FACTORS

The level of human safety depends on their knowledge, experience, attitudes towards risk, motivation for safe behavior, and the current psychophysical fitness of the day. Efficacy of a person changes with age as a result of fatigue, stress and health. The cause of the mistakes is also the maladjustment of the work to the ability of employees, the bad conditions of the physical work environment, and poorly organized tasks, such as creating situations of time pressure or generating states of physical or mental overload. The main causes of accidents caused by dangerous human errors are: loss of control over threats or self-control. In particular, they may be: human factors malfunction, difficult and dangerous tasks, social patterns of conduct, negligence, and breaking rules.

Factors that can cause permanent disability to work safely include: lack of training, insufficient knowledge, lack of practice and experience, insufficient motivation for safe behavior, insufficient physical fitness. Factors causing temporary disability to work safely include: Routine, illness or bad body condition, stress, anger, fear and fatigue. These elements can lead to situations such as accident, almost an accident or unplanned situation [5].

Hazardous event sequence studies show that the use of appropriate hazard identification methods can be used to design effective safe work procedures. An example of a fragmented hazard analysis for gas operation using the event tree is shown in Figure 12.1. The event tree method allows to indicate the event that initiated the threat, the consequences of the sequence of events, and the decisions made by the operator. In this case, the degree of hazard depends on the employee's behavior.

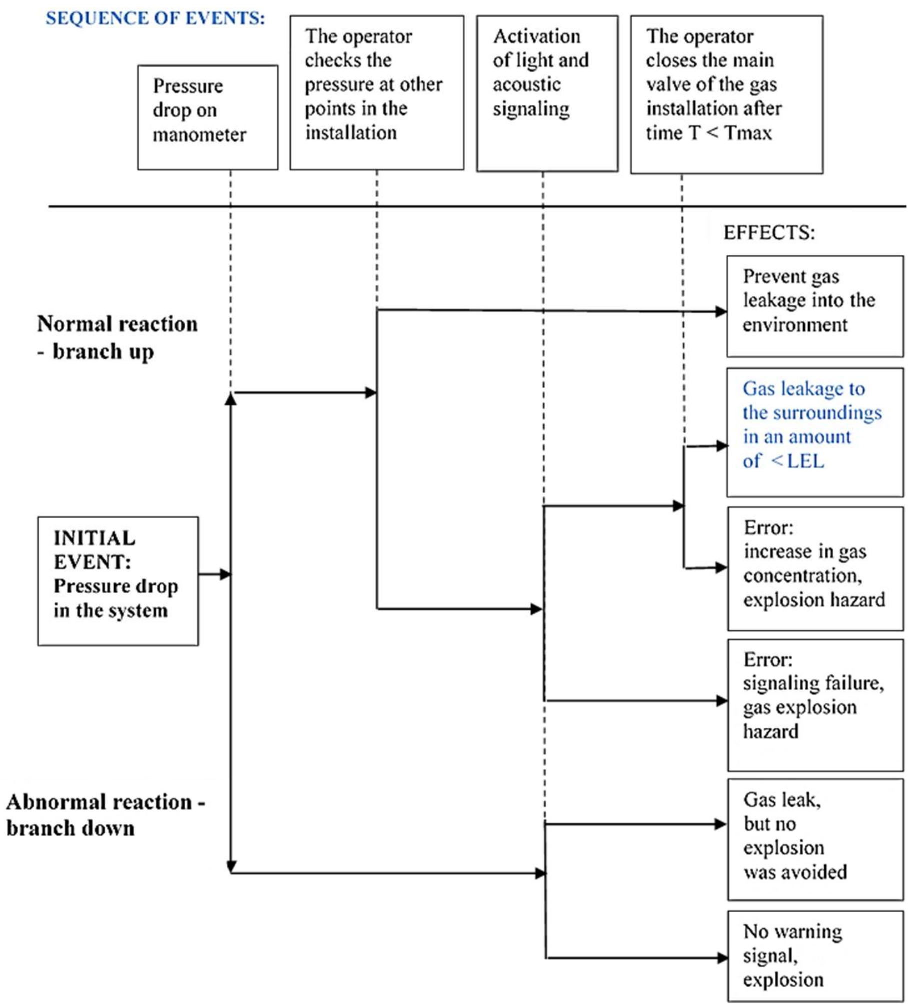

Fig. 12.1 Scheme of the fragment of the event tree for gas safety procedure (explosion hazard)
Source: own study

12.6 CONCLUSION

Event tree methods and error trees seem to be the most transparent methods for identifying hazards in the case of dangers combining technical elements with human action. The Event Tree method allows you to track, as shown in Figure 12.1, the entire sequence of events from the initiating event to the effects.

The event tree method presented here can be used to assess the risk of explosion or crew poisoning by gases in industrial enterprises such as chemical, machine and repair plants (mainly in welding processes), mining and heating plants and steel and non-ferrous metal works where the hazard Toxic and explosive gases are large.

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Abstract: *The article presents characteristics of industrial gas installations and hazards associated with their operation. The methods of hazard identification used in industrial processes have been analyzed. An explosion hazard analysis was performed using the event tree method, taking into account the factors influencing employee error (human factor).*

Key words: *hazard identification methods, gas installations, gas signaling system, human factor*

ANALIZA CZYNNIKÓW WPŁYWAJĄCYCH NA ZAGROŻENIA GAZOWE W ZAKŁADZIE PRZEMYSŁOWYM

Streszczenie: *W artykule przedstawiono charakterystykę przemysłowych instalacji gazowych oraz zagrożeń związanych z ich eksploatacją. Przeanalizowano metody identyfikacji zagrożeń stosowane w procesach przemysłowych. Przedstawiono analizę zagrożenia wybuchem metodą drzewa zdarzeń z uwzględnieniem czynników wpływających na błędy pracownika (czynnik ludzki).*

Słowa kluczowe: *metody identyfikacji zagrożeń, instalacje gazowe, system sygnalizacji gazowej, czynnik ludzki*