IDENTIFICATION OF GAS HAZARDS IN A INDUSTRIAL COMPANY WITH USING CHAIN OF EVENTS ANALYZES

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Abstract: The purpose of this article is to present the process of hazard identification as a sequence of events that leads to an accident and / or material loss at the workplace. An event chain can be described as an ordered set of circumstances conducive to the emergence of a threat. The article presents an analysis of the use of elements of the event theory to identify hazards in a chemical plant on the example of a gas explosion event. An analysis of the circumstances surrounding the emergence of a gas explosion hazard by identifying the causes of direct and indirect events and the main conditions leading to the event is also presented. Also identified are events that are responsible for initiating a gas explosion hazard.

Keywords: chain of events, sequences of events, gas hazards, security deficits.

1 Introduction

For risk assessment with work in an industrial plant there is a need to identify all potential hazards. In the analysis of such risks, the most difficult to detect are certain sequences of events or conditions that collectively lead to an increased probability of undesirable results. The cause of this effect is a chain of events leading to loss (loss). In the chain of events, all the parameters of the work environment and the human factor, which are an important factor of potential hazards in the workplace, are taken into account.

The use of events theory elements to identify hazards depends on the analysis of a chain of events culminating in the accident or material damage or occupational disease. Analysis of such a chain of events makes it possible to identify favorable conditions for the creation of hazardous situations. That is why a deep analysis of the circumstances preceding the hazardous event must be made.

2 Environment parameters and gas security

The work environment is defined as a set of objects associated crew organized to produce specific values in the work process. Parameters of the work environment that relates to its objects have the biggest influence work safety. The direct or indirect effects of work environmental parameters on crew and the operations of an industrial plant can be expressed as follows:

- physical parameters associated with a mining environment such as the magnitudes of critical temperatures, pressures, concentration of toxic or explosive gases, velocities of ventilation flows, etc.;
- geometrical parameters including the area of the fire zone, the size of the gas installation, the volume used in the production of gases, the location of the gas tanks,
- pollution of the ventilation air stream by gases and/or dusts [5].

In industrial areas, in particular in the chemical industry where gas hazards are prevalent, the crew may encounter direct or indirect contact with such events as: sudden release of toxic or explosive gas into the environment, explosion or fire [7].

When the parameters of the work environment, where crew is located, are approximately constant or slightly changing, then it may be called normal conditions. Normal working conditions generally entail a relatively constant relationship between the conditions of the work environment and the location. Emergency conditions, on the other hand, usually entail sudden and significant changes in the conditions of the work environment, including such events as a sudden increase in temperature, air pressure, increase of increase in concentration toxic and explosive gases. The intrinsic nature of the chemical plant is such that providing completely comfortable conditions is impossible [7]. Therefore, existing safety standards in the chemical plant represent a compromise between working comfort and production requirements. It is, however, expected that full safety measures be provided for all of the hazards known to be associated with an ongoing chemical plant operation. Security standards for the conditions of the work environment are determined by mandatory safety regulations [12, 13].

3 Elements of technical prevention used in gas safety

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 [8].

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 [2, 8].

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. 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 [8].

Gas sensors according to 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 [7, 8].

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. 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 [7, 8, 9].

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 [12].

4 Events theory elements with relation to the work environment

Events in the work environment can be attributed to the elements of the sequence of events. Events occurring in the work environment are assigned two logical values, 1 or 0. The logical value 1 is assigned to the occurring events (true events), while the logical value 0 is assigned to events that do not occur. The description of events in the work environment uses basic logical functions, such as conjunction, alternative, negation, implication and equivalence. In addition, logical laws are used to describe events according to mathematical logic [1, 11].

The working environment can be considered as a set of elementary events. All events occurring in the environment can be divided into static events, signifying states, and kinetic events, signifying changes in these states. The kinetic events are the cause and static events are results of a sequence of conditions [3]. Besides the elementary events are macro- and micro-complex events, with varying degrees of complexity consisting of environmental subsets. Complex events consist of certain number of static and kinetic events occurring simultaneously and/or one after the other.

They represent a specific process taking place in the work environment. In certain circumstances, crew activities can directly or indirectly cause of an activation of a specified hazard [6, 10].

The sequence of events determines the principle: every effect is clearly and sufficiently appointed by the general causes and conditions in which it occurs. A sequence of events illustrates causes and effects in the work process. A set of events immediately preceding the change (qualitative and quantitative) presents a sufficient conditional sequence of events. A sufficient condition-specific effect consists of:

- principal cause and conditions (fixed);
- side conditions (random).

Principal conditions occur whenever they are a necessary condition for a result representing a qualitative change [1, 3, 10]. For example, spark or high temperature and explosive gas cloud are the cause and the main condition which are necessary to initiate a gas explosion. Side conditions in a sequence of conditions are random variables that can make the accident more or less likely or affect the size, the course and range of the event. For example, when gas explodes, side conditions determining its strength and range are: the size of the room that determines the growth of the dangerous concentration, the proportion of other volatile components, etc.

Phenomena occurring in the work environment can be described by using the chain events model. A model of such an events chain is well illustrated by dominoes blocks, standing side by side. Knocking over all of the dominoes requires the toppling of the first block, which knocks over the second domino, and so on, until the last. In order for the dominoes to fall, the toppling of the first domino must appear as a factor initiating the entire sequence of events [4, 6].

Relevant combinations of necessary event sequences in the work environment of the chemical plant can be events both in terms of work environment parameters (materials factors) and the human factors (actions and decisions). The scope of activity of the chemical plant is the cause of the hazards of the specified work environment parameters, their change, the processes that affect them and finally, the activities and states on the side of the crew, are the effects of their action. For example, the effect of an action might be: crew members present in a particular place, use ordered technologies under specified conditions. Uncontrolled event sequences occurring in the workplace, on the side of the work environment parameters and the human factors side, can lead to the initiation of the full hazard, that is to say, to undesired processes immediately preceding the harmfulness . The necessary events chain preceding the accident shows the arrangement of subsequent indirect effects and necessary reasons for remaining in the causal relationship [4].

These processes, in which events are considered due to their arrangement, can be assigned to an image geometry, called a graph. A graph is a topological mapping of an events sequence, defining unequivocally the relationships between the individual events. In the graph, nodes represent the necessary conditions of the events sequence, and the branches oriented towards the implication represent indirect results, that can turn into causes in in the nodes and/or principal conditions of the event sequence [1].

5 The results of the analysis of the chain of events for the gas explosion

In order to identify the cause of an explosive gas event with the effect of an accident and material failure SM, an undesired sequel of events prior to a gas explosion should be analyzed. As mentioned above, there is a risk of material damage associated with accidental hazards, which may accompany some accidents. Accident at work WY or / and material injury SM implies trauma UR and a chain of conditions necessary of sequence of events in the full-risk phase. The essential components of the conditions necessary for the initiation of the full-risk phase are:

- uncontrolled processes, uncontrolled parameter changes or uncontrolled crew operations,
- activities currently performed by the crew,
- technical condition of the gas installation,
- the influence of the crew on the course of technological processes,
- the influence of the management on the maintenance of the chemical plant [14, 15].

To determine whether a particular event is an essential component of the chain of necessary conditions, it should be considered whether without this event it would be possible to consider the consequence of events.

For the analyzed hazard: gas explosion EG, essential chain components of the conditions necessary in the full hazard phase are:

- gas leaks on the valve - WGz,
- unsealing of the tank - RZ,
- leakage of other components of the gas installation – NI.

A gas explosion may occur when two conditions are present: the occurrence of a spike ZI or a high temperature ZT with the simultaneous leakage of gas from the gas system. Event string Π (EG) accompanying the hazard of gas explosion EG is the following set of events Zz:

$$EG \Rightarrow WY \wedge SM \Rightarrow UR \Rightarrow \Pi(EG) \equiv Zz \equiv \{[ZI \quad \vee ZT] \wedge [WGz \ \vee RZ \vee NI \quad]\}$$

The expanded chain of events is as follows:

$$\begin{aligned} EG \Rightarrow WY \wedge SM \Rightarrow UR \Rightarrow \Pi(EG) \equiv \{Zz \\ \equiv \{[ZI \quad \vee ZT] \wedge [WGz \quad \equiv \{Ae \vee Uz \vee Bs \equiv \{no\}\}] \vee [RZ \\ \equiv \{Pp \wedge Bsy \equiv \{ac \vee no\} \wedge Wc \equiv \{np \vee ns\}] \vee [NI \equiv \{Og \wedge Bsy\}]\} \Rightarrow \\ no \wedge ac \wedge np \wedge ns, \end{aligned}$$

where
Ae - electrovalve failure
Uz - external damage
Bs - control error
no - operator inattention
Wc - increase in pressure or temperature in the tank
Bsy - no pressure sensor signal
Pp - production process
eg - abnormal chemical process
ns - incorrect control
ac - sensor failure
Og - the presence of gas in the installation.

The analysis of the event chain for the incident and material loss in the form of gas explosion EG has identified three direct causes: WGz, RZ, NI and five indirect causes: Uz, Bs, Wc, Bsy, Ae. In the event chain, three main conditions were also identified for the analyzed event: Pp, Og, WG, and four first cause: ac, np, ns no. The above analysis points to human errors committed in the control and control process of the production process and minor faults, such as the failure of the gas concentration signaling sensor, which are the first cause of the analyzed event and can lead to serious consequences.

Conclusion

Building a security system aimed at eliminating harmfulness and identifying a relative hazard requires that all components of the essential necessary sequences of events preceding the effects (losses) in the chemical plant be identified. For this purpose, an analysis of the chain of preconditions preceding the damage is carried out. The use of elements of event theory to identify hazards very clearly shows the complexity of the causes of the damage (loss). Such analysis gives a broad understanding of the factors (indirect and direct) influencing such events as: accident, material loss at the workplace. When analyzing the chain of events, the threats that cause the intermediate and final effects and the causal link between the causes of the losses in the chemical plant are identified.

The unwanted sequel of the events preceding the gas explosion at the chemical plant is the essence of the gas hazard present, posing a certain risk to the production process. The risk consists of 8 causes (indirect causes and principal conditions) which may be determined by the 15 possible security deficits (deviations from the prescribed safety levels on the parameters of the work environment) and 5 possible deviations on the human side.

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IDENTYFIKACJA ZAGROŻEŃ GAZOWYCH W PRZEDSIĘBIORSTWIE PRZEMYSŁOWYM Z WYKORZYSTANIEM ANALIZY ŁAŃCUCHA ZDARZEŃ

Abstrakt (Streszczenie): Celem artykułu jest przedstawienie procesu identyfikacji zagrożeń jako łańcucha następstwa zdarzeń, które prowadzi do wypadku i/lub straty materialnej na stanowisku pracy. Łańcuch zdarzeń może być opisany jako uporządkowany zbiór okoliczności sprzyjających pojawieniu się zagrożenia. W artykule przedstawiono analizę zastosowania elementów teorii zdarzeń do identyfikacji zagrożeń w zakładzie chemicznym na przykładzie zdarzenia wybuchu gazu. Zaprezentowano również analizę okoliczności sprzyjających powstaniu zagrożenia wybuchem gazu poprzez wyznaczenia przyczyn bezpośrednich i pośrednich zdarzenia oraz warunków głównych prowadzących do zdarzenia. Wskazano również praprzyczyny zdarzenia, które stanowią czynnik inicjujący zagrożenie wybuchem gazu.

Klíčová slova (Słowa kluczowe): łańcuch zdarzeń, następstwo zdarzeń, zagrożenia gazowe, deficyty bezpieczeństwa.