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STUDY FOR EXPLOSION RISK ASSESSMENT IN CHEMICAL INDUSTRY

ROBBANÁSVÉDELMI ESETTANULMÁNY A VEGYIPARBAN

Abstract

To work safely in the chemical industry, it is necessary to ensure an appropriate work environment (including a fire protection system) that complies with the requirements for the used hazardous substances and also, to make the internal regulations and work instructions ready. This is especially applicable in case of operations performed with explosive materials - creating a safe work environment with potentially explosive substances. To determine a potentially explosive work environment, there is a calculation method fixed in the standards, which is partly passed on the objective judgment of the expert, a professional. Once the potentially explosive work environment is determined, the requirements for used equipment, machines and the conditions of working - depending on the zone classification - are clearly defined in standards and legal regulations. It also shows the importance of the topic, that the cost of work (including the cost of certified machines and equipment) in a potentially explosive work environment is multiple if we compare it with working in normal and standard work conditions.

Keywords: *potentially explosive environment, risk, ATEX,*

Absztrakt

Vegyipari környezetben történő biztonságos munkavégzés alapfeltétele (a tűzvédelmi előírások betartása mellett), hogy a felhasznált veszélyes anyagoknak megfelelő, vonatkozó előírások és munkautasítások betartásra kerüljenek. Különösen fontos az előzőek betartása robbanásveszélyes anyagok felhasználása esetén, valamint biztonságos munkakörnyezet kialakítása. Potenciálisan robbanásveszélyes területek lehatárolása és kialakítása a vonatkozó szabványokban található előírások alapján történik, melynek kialaktása és tervezése a szakértő feladata. Mind a berendezések, gépek és a munkakörnyezet – a zónabesorolás függyvényében – kialakítása és követelményei a vonatkozó szabvámnyokban megtalálhatóak. Az alábbiakban bemutatásra kerül, kiemelve annak fontosságát, hogy a bekerülési költsége (a minősített berendezések és eszközök mellett) egy potencialisan robbanásveszélyes munkahely és egy nem robbanásveszélyes munkahely kialakításának költsége a többszöröse lehet.

Kulcsszavak: *potenciálisan robbanásveszélyes munkakörnyezet, kockázat, ATEX,*

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1. INTRODUCTION

The engineering experience shows that the explosion safety, as one of the key parameters at the design, is an area which has not been adequately treated and understood in the industrial practice. The primary problem is that that the students of Bachelor engineering courses, do not get in touch, not even tangentially with subjects dealing with explosion protection. This is moderately true for the training of firefighters also [1], who are supposed to prevent an explosion which has not occurred yet, or who arrive to the scene after an explosion arrive to mitigate the damages. The firefighters' wide range educational material contains only a tangential knowledge related to explosions [2] [3], and also, the training of fire prevention specialists might be expanded by some areas of knowledge [4] [5]. That is why, in many cases, the professionals working in executive positions do not take into account – the parameters connected with risk of explosion, while having regard to the danger and harms of the hazardous substances in the working area [6] [7]. The aim of this article is to give a short and comprehensive picture of the perspectives of professional challenges.

2. RELEVANT LEGAL REGULATIONS

In order to prevent an explosion, very strict rules of technical requirements apply to equipment used in areas with explosion hazard. The Act XCIII of 1993 on Labour Safety – in agreement with the Minister for Social and Family Affairs and the Minister for Health – determines the rules for work equipment, and the minimum level work safety requirements for workplaces, including rules for the construction works with temporary or changing workplace. [8]

Based on the above authorization, the Minister for Agriculture together with the Minister for Social and Family Affairs and the Minister for Health constituted the joint regulation about the minimum work safety requirements for workplaces with potential risk of explosion, No. 3/2003. (III.11.).

The regulation defines the concept of an explosive atmosphere and an environment with potential risk of explosion, according to which:

- explosive atmosphere: is such mixture of flammable gases, vapour, mists (aerosols) or dusts and air, that in case of fire – under normal circumstances – the flame spreads to the entire mixture;
- environment with potential risk of explosion: is that part of the workplace where explosive atmosphere might occur. [9]

According to the Section 9 of the regulation, the employer has to prepare a documentation of explosion protection, including the risk assessment and evaluation and also the classification of workplaces into zones.

3. CRITERIA OF THE RISK ASSESSMENT

It is the duty of the Employer to identify – within the risk assessment procedure – the anticipated risks as far as the work safety and health at work is concerned. The risk and its range shall be determined by taking into account the followings:

- the probability of development and subsistence of an explosive atmosphere, and its duration;
- probability of incendiary effect in the explosive atmosphere, including electrostatic discharge;
- equipment, used materials, procedures and their possible interaction;
- the range of anticipated impact in case an explosion occurs.

Closed spaces, where explosive atmosphere might occur and which are connected with spaces with potential risk of explosion by windows and doors, must be also considered in term of risk assessment. [9]

If an explosion occurs, the injury can be defined in different ways. By the assessment of the individual injury, we suggest to take into account the overpressure rate at which the tympanic membrane breaks. In case of explosion, the approach of probit function cannot be used to determine the individual risk. [10]

4. CRITERIA OF ZONING

Earlier the Hungarian Standard, called MSz 1600/8:1977, dealt with the electrical danger of spaces with risk of explosion. The Hungarian Standard (MSz) No 15633-1:926 was the first, which formulated the potentially explosive space based on the EN standards, and this standard was fully included in the Regulation No 2/2002 (I.23.) Appendix 4, Chapter IX of the Ministry for Internal Affairs. The classification of areas with the hazard of explosion was the part of fire safety regulation until 2004. [11]

After joining the European Union, the international regulations – Directive 94/9/EC of the European Parliament and the Council of 23 March 1994 on the approximation of the laws of the Member States concerning equipment and protective systems intended for use in potentially explosive atmospheres – were built into the Hungarian system of laws and the requirement of zoning was included in the joint regulation No. 3/of 2003. (III.11.).

The Employer shall classify its working spaces, where explosive atmosphere might develop into one of the following zones:

Zone 0: A working space in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist (aerosols) is present continuously or for long periods or frequently.

Zone 1: A working space in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist (aerosols) is likely to occur in normal operation occasionally.

Zone 2: A working space in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist (aerosols) is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Zone 20: A working space in which an explosive atmosphere in the form of a cloud of combustible dust in air is present continuously, or for long periods or frequently.

Zone 21: A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally.

Zone 22: A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only. [9]

The zoning of working areas is the analysis and classification method of such circumstances, where explosive gases may occur. Its target is to facilitate the selection and installation of electrical apparatus operating safely in such areas. The classification takes into account the ignition characteristics, the ignition energy (gas group) and the ignition temperature (temperature class) of the gas or vapour. [12]

Besides the classification of the area and the danger zones, it is necessary to mention the education or training required for the classification:

- specialized engineering degree (chemical, mechanical, electrical, mechatronics),
- degree of higher education specialized in fire protection,
- degree of higher education in work safety,
- authorization to act as a regional work safety expert.

5. RECOMMMENDED PROCESS OF RISK ANALYSIS

Several methods can be used when conducting a risk analysis. The risk assessment methods used in safety documentations are the followings:

1. Facility selection method (according to CPR 18E – Purple Book – so called „Dutch filter")
2. Dow Fire and Explosion Index (TRI)
3. Checklists [9]
4. Preliminary hazard analysis [10]
5. Hazard and operability study (HAZOP)
6. Failure mode and effect analysis (FMEA)
7. Failure mode analysis, effects and criticality analysis (FMECA) / Risk matrix [11]
8. Fault tree analysis
9. Event tree analysis
10. Probability analysis by Monte Carlo simulation
11. Analysis of domino effect with DominoXL code
12. Models of spreading impacts (consequence analysis) [13]

Regardless of the methods, the general principle of the process to be followed is:

1. During the analysis of the technology and workflow, the possibility of developing an explosive area shall be determined
2. The presence of ignition sources in the area have to be assessed
3. The circumstances where an explosion evolves have to be determined
4. The risks must be assessed based on the consequences of an explosion. [14]

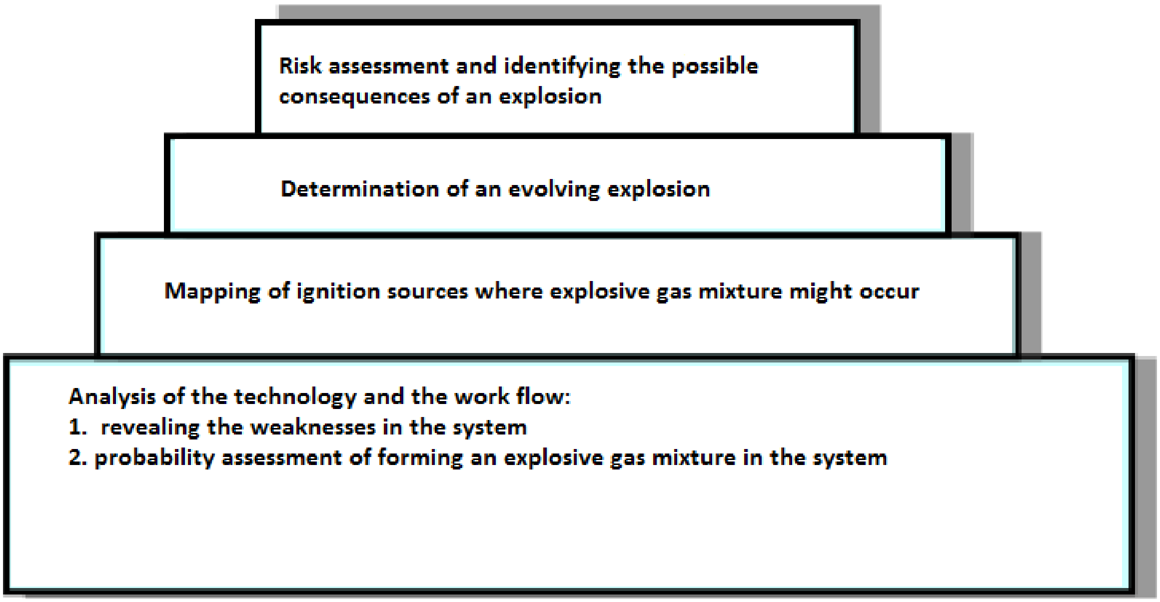

Fig 1: General process of risk analysis [14]

The work process proposed five interrelated steps:

1. The first step of the process is the technology and workflow analysis with the internationally recognized and used Failure Mode and Effects Analysis method. The aim of the method is to determine the possibility and probability of forming an explosive atmosphere, thereby narrowing and focusing the analysis from the whole company to the critical areas. The method must be adapted to the analysed system. [15]
2. The second step of the process is to survey and assess the present and potential sources of ignition in the area of the potential "scenarios" revealed in the first step.
3. Then the weaknesses revealed during the technology and workflow analysis shall be ranked.
4. Analysis of the impact of the explosion on the workers (overpressure) with explosive blast pattern calculation and explosion simulation software.
5. The results of the risk analysis, and the suggestions to suppress or decrease the risks based on the FMEA analysis data sheet.

5.1 Failure Mode and Effects Analysis

The Failure Mode and Effect Analysis is a preliminary and inductive procedure, suitable to analyse the failure types of the system units, and to determine the effect of failures on the whole system. The aim of this analysis – during the preparation of the explosion protection documentation – is to identify those parts of the system (subsystems), those technological processes and their possible failures – the so called weak points – where explosive atmosphere or explosion might occur.

The process starts at the subsystem level and the effects of a failure are tracked on system level and also the whole operation level, as it is required by the analysis. The analysis is the series of the following logical steps:

1. Collecting all the important design information regarding the analysed or considered system: e.g. technological documentation, flow chart, list of machinery and equipment;

2. Collecting the possible operation failures of each component and their possible causes, using the worksheet form;
3. Determining the impact of failures on the related subsystem levels;
4. Overview of monitoring and diagnostic activities preventing or avoiding the failure modes. [16] [17]

Photochemical ignition. If the radiant energy of quantum energy is big enough, it is able to the initiation of throttle response. Example: at the illumination of hydrogen and chlorine, convert for hydrochloride (explosively).
Blue or violet and ultraviolet light causes the formation of explosion (more than 243 kJ energy), the less wavelength not. There are known many photochemical reactions, But the photochemical ignition in the practices of safety and fire prevention is subordinate

Auto-ignition, pyrophoric. The auto-ignition temperature is the lowest temperature at which ignites and burns a self-sustaining manner, without an external ignition source of the material.

Electrostatic ignition source. The materials electrically are neutral in original condition. The material is made up of positively and negatively charged particles. These are the charge carriers which are located inside both materials and on surface equal number and uniformly distributed.

5.2 Weak point analysis

The scope of critical risk assessment is the followings:

- Failure specifying: cause of system failures- accident.
- Quantitative analysis: explosion risk investigation – by on effect, risk, countermeasure, reduce amount of risk.

5.3 Modelling

Explosion pressure: increasing pressure against atmospheric pressure (normal) cause by weapons and explosives (Compression of the explosion wave heats the molecules of air). [22]

Calculation methods defined by MSZ EN 60079-10-1:2009, effective areas could be defined with using of software (note: another article have to defined because of the effect of calculation and modelling by using of software tools, important because of installing/construction costs and operating costs).

Defining of Zone areas: using software modelling tools to define lower and higher burning/explosion levels. For countermeasures have to define the pressure levels and effects.

5.4 Risk assessment, reduce the amount of risks

Scope: explosion effects against human body and calculating relevant chance of explosion (against operating, engineering failures, etc.).

Have to install hardware tools against explosion risk areas (explosion proof equipment) - responsibility of the employer. [23]

5.5 Criterions of working environment and the minimum levels of working conditions:

The explosion-proof of technology processes has to be granted by explosion prevention, explosion protection, organizational and technical measures. The presence of ignition source has to be excluded in order to prevent explosions and generating of explosive aerospace.
The general requirements of electrical equipment using in explosive aerospace are the followings:

The electrical equipment on the main components has to be marked with the following information in clearly visible and corrosion-resistant manner:

- Manufacturer name and address,
- Type ID,
- “Ex” mark,
- Used protection method,
- II. Group sign, sign of temperature class, “G” mark (explosive aerospace caused by gases, vapours or fog),
- Serial number,
- name and sign of the certificate issuer, certification ID,
- the CE mark.

Operating manual has to be enclosed to the equipment that has to be includes the following written instructions:

- information about the equipment mark,
- safe conditions of using for the commissioning, usage, assembly and disassembly, maintenance, installation and setup,
- rules for operator trainings,
- detailed information in order to decide that the usage of equipment is safe or not in the specified area with expected operating conditions,
- the maximum surface temperature and other limits,
- the special conditions of use,
- the relevant characteristics of tools used for equipment,
- the list of the standards which prove the product satisfying

6. CONCLUSIONS

It is important to treat the above described area of expertise as a matter of high priority, because the inherent risks in the individual substances (chemicals) are not always known. Likewise, we do not have the necessary knowledge about the mixtures and powders/hybrid powders used in the chemical industry. The approach in each case is based on in-depth planning. The revision of the planned process (P&I and HAZOP), taking into account the properties of the materials to be used there (risks of fire and explosion) is of high importance. In the planning phase, there is a possibility to reduce the dangerousness of the materials (by using additives – inhibition), this way the technological processes may be improved and rationalized. In case the realization of the previously described is not possible, getting to know the explosive parameters of each substances and further tests (measurements) – in case of mixtures – become important. Otherwise, the engineering estimation may be used, which is conservative in every case, and it certainly increases the cost.

Since the explosion safety is the crucial point in fire protection, therefore it is absolutely necessary to have the area in question reviewed (see the recent industrial even in China) and authorized by the Fire Authorities (disaster management). The author believes that the area is not treated properly (work safety authority and legal system), so further investigation is needed.

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