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Risk factors and safety at work in potentially explosive environments

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KEYWORDS:

TERM	DEFINITION
accident	Event or series of undesirable events that can lead to fatal injuries, illnesses, losses or material damage to the environment. [risk, danger]
location	Area under the control of the same operator, in one or more facilities, including joint activities and facilities, hazardous substances are present; Initiation of combustion reaction under the action of flame, sparks, inflammatory or kindling. Ignition causes combustion or deflagration of any explosive phenomenon.
ignitiom	Initiation of combustion reaction under the action of flame, sparks, inflammatory or kindling.Ignition causes combustion or deflagration of any explosive phenomenon. [open]
burning	Phenomenon of spreading a exothermic reaction by thermal conductivity, convection and radiation. The term "burning" is sometimes used to describe a particular type of explosive reaction and its effects on the environment. [fuel]
crash	Event that generates major impacts on human health and / or the environment, but has the potential to cause a major accident.
deflagration	Chemical explosion in which the chemical reaction propagates through the media initially subsonic speed, mainly by thermal conductivity. The term "deflagration" is sometimes used to describe a particular explosive reaction and its effects on the environment.
assessment	The whole theoretical analysis and tests set by a recognized authority and intended to verify performance, reliability and safety materials in relation to specified requirements. [approval, characterization, classification].
explosion	A process of nuclear, chemical or physical after which it suddenly releases energy (and often gas), leading to pressure waves or shock. The term "explosion" is sometimes used to describe a specific type of explosive reaction and its effects on the environment. [detonation,

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	deflagration, combustion].
degree of safety	Is a safety measure to a system and expressed as the probability of occurrence of a potentially dangerous event. Depending on system requirements, security measures may be limited in time or may be applied throughout the service.
plant	Technical unit within a site, are produced, used, handled and / or storage of hazardous substances. It shall include all equipment, structures, pipelines, equipment, devices, domestic railways, docks, unloading docks serving the installation, debarcaderele, warehouses or similar structures, floating or otherwise, necessary to operate the facility.
risk	The possibility of occurrence of an accident or specific event, at a time or in specified circumstances, expressed in terms of severity and probability of occurrence of danger. [danger, accident].
security	Acceptable risk level for personnel and material at any time. The term also refers to the need to limit the amount of risk levels in different operational or training situations.

1. GENERAL

Nowadays, when the industrial civilization is facing more and more with the importance of human problems and the human intrinsic value, safety and health is an issue of particular importance.

Every year, a great number of accidental explosions occurred in various industries as a result of accidental initiation of explosion mixtures formed accidentally. Many gaseous materials, with liquid or solid fuel properties may be blended or dispersed into the atmosphere and thus can be easily opened and explode. These phenomena are common in underground mines where methane-air mixtures have as a result several victims or serious injuries.

The existence of aerosol explosions is known since the 19th century, but despite the efforts of the authorities and the companies to avoid such accidents, their high frequency can still be noticed.

Technical and technological progress in the last century prompted the use of increasingly various materials with combustible or explosive properties. Despite the focus on the development and the approval of new technologies, the frequency of the explosive accidents, especially their gravity, show that they are not known completely and that no technical and organizational effective measures are taken.

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Working conditions with solid fuels, liquid or gaseous fuels must be studied carefully in order to outline the environmental conditions under which they work and the conditions under which explosions can occur accidentally.

Safety at work is represented by the absence of conditions that are likely to cause injury or death of persons, property damage or loss of equipment.

Security concerns thus saving people and the facilities, but of course taking into account the incomparable value of human, human caring being the one that must be prevalent, whatever the financial cost.

Integrated occupational safety at work in potentially explosive atmospheres is translated through a knowledge of the properties of raw materials, finished products, processes, facilities and devices used during operations with potentially explosive and dangerous substances: **working with unknown substances is not safe, especially in what concerns their behavior in different environmental conditions in which they can decompose or oxidize, the way in which the oxidation and its explosion effects.** It is therefore necessary for each type of fuel, mixture that is potentially explosive, chemical substances with dangerous properties, to have or to develop the security information statement.

2.PROVISIONS AND REGULATIONS REGARDING THE CONTROL OF MAJOR ACCIDENT RISKS

On February 3, 1999, was implemented by the EU countries the European directive 96/82/CE from December 9, 1996., regarding the major risk management that involve dangerous materials. This directive, called Seveso II requires that the institutions that are responsible for presenting such risks to demonstrate:

- That they have identified the risks regarding their own facilities, on the one hand;
- And secondly, that they control these risks through technical measures or through organizational measures, in a major accident prevention policy or safety management system;

In Romania, the directive 96/82/EC was implemented by:

- Government Decision no. 804 from August 8, 2007 on the control of major accident hazards that involve dangerous substances;
- OM no. 142 from February 25, 2004, for the approval of the procedure for the assessment of the security on the activities which involve the production of major accident hazards that involve dangerous substances;
- OM no. 251 from March 26, 2005 for the organization and the functioning of the secretariats of risk control activities that present hazards of accidents that involve dangerous substances;

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- OM no. 647 from May 16, 2005 for the approval of the Detailed Rules on making contingency plans in case of accidents that involve dangerous substances;
- OM no. 1299 from December 23, 2005 regarding the approval of the inspection procedure for presenting the objectives of producing major accident hazards that involve dangerous substances;
- OM no. 1084 from December 22, 2003 regarding the approval of the procedures for the notification of the activities which are producing major accident hazards that involve dangerous substances and accidents;
- OM no. 520 from May 29, 2006, regarding the approval of the procedure for investigating the major accidents that involve dangerous substances

There are several notable provisions of Resolution No. 804 from 25.07.2007, regarding the control of major accident hazards that involve dangerous substances.

This document covers steps for the prevention of major accidents that involve dangerous substances, and limiting their consequences for the health of people and for the environment, to ensure a high level of protection, in a coherent and effective way. [2]

The operator (an individual or a juridical person) must take all the necessary measures in order to prevent major accidents and limit their consequences on the health of people and on the environment. Also, the operator is required to prove the authorities, anytime and especially during the inspection and control activities, that he has taken all the necessary measures, under the provisions of the decision. Also, he has to develop a document setting out its policy of preventing major accidents and to ensure that it is properly implemented to protect, at a high level, the health of the persons and the environment by means, appropriate systems and structures of management.

Safety report is elaborated in order to:

a) Demonstrate that it has implemented the prevention policy of major accidents, but also the security management plan in order to implement this policy;
b) Demonstrate that it has identified the potential hazards of major accidents and that measures have been taken to prevent such accidents and limiting their consequences for the health of the persons and for the environment;
c) Demonstrate that it has included adequate safety measures in the design, the construction, the operation and the maintenance, the storage units, the equipment and the infrastructure within the site, that present risks of major accidents;
d) Demonstrate that the internal emergency plan has been developed and the information needed to prepare the external emergency plan was provided for the ISU, for taking the appropriate action in case of a major accident;

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The safety report must include:

Present the environment of the location: the description of the site and its environment, identify the installations and other activities within the location that could present a major accident hazard, describe areas in which this may cause a major accident.

The description of the facilities: describing the activities and of the main products, of the sources of major accident hazards and of the conditions that can cause a major accident, the description of the proposed preventive measures, the description of the processes, the methods of operation in particular.

The description of dangerous substances: the inventory of dangerous substances, the physical, chemical, toxicological characteristics and the indication of the hazards, both immediate and long-term, for the human and for the environment, the physical and the chemical behavior in normal use or/and in predictable cases of accident, identifying and analyzing the accident risks and prevention methods.

The description of the technical parameters and of the equipment used for the security of the installations.

Protection and intervention measures in order to limit the consequences of an accident.

3.GENERAL PRINCIPLES IN EVALUATING THE RISKS OF THE ACCIDENTS WITH ACCIDENTAL AND OCCASIONAL EXPLOSIVES

3.1. Introduction

Making the operations and the activities with explosive mixtures in terms of accidental occurrence (gaseous, liquid or aerosol) is always associated with the risk of occurrence of accidents and hazards, generically known as explosive accidents.

In order to reduce the consequences of accidents on people, goods, materials associated with risks and the dangers, it is necessary that each workstation for each activity or operation, with some potentially explosive material or substance, to be developed explosive safety studies.

The risk is the result from the consequence/gravity of the accident and its probability of its occurrence. It represents an assessment (qualitative or quantitative) when an accident or incident occurs or may occur and assumes all actual or potential circumstances that may cause injury, the death of the employees or to bring damage to the equipment and the supplies or even their loss. [1]

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The level of the risk is the measure of the risk. Explosive risks may be expressed quantitatively just by physical quantities, characteristic for the consequences of the explosive accidents, such as: the value of pressure in front air shock wave generated, the kinetic energy of the fragments, the bubble radius of fire etc.

The risk can be assessed by measuring the consequence of the accident or incident likely to occur, without specifying the probability of occurrence. In other words, when there is no history of events and the likelihood of the accidents on that event cannot be assessed, it can be worst if the probability of the occurrence of the accident is 1. Meaning that the event can occur at any time.

3.2. General principles of explosive security

The objective of any health and safety activities at work is to limit the risks to acceptable limits. [5] In the field of explosive risk activities 4 basic principles of security have been formulated, the last three being set since 1925 by Varin-Bohan.

A Principle 1: knowing the risks

Like the explosive materials, explosive mixtures are accidental hazardous materials. These can be characterized by physical, chemical, thermodynamic, sensitivity and stability, behaving in different ways under certain conditions of climatic, mechanical and electrical environment.

How to take action against hazards if the properties of the substances are not known, and can accidentally combine and become substances with explosive properties, also the behavior in different situations, so of the risks associated with their use?

A precise knowledge of the risks is the best guarantee of a better explosive security.

B Principle II: separating the risks

In accordance with this principle there can be accepted at a workplace only jobs that imply similar risks and different risks.

In fact, to prevent or combat a given risk, safety devices are adopted ; if it comes to different risks in the same place, it could be possible that different devices to be incompatible with each other.

C Principle III: limiting the risks

Performing tasks in potentially explosive atmospheres requires the existence of combustible substances and air or other oxidizing. Since the likelihood of explosive mixtures and explosive events can never be zero risk, it can never be eliminated. Therefore, risks should be limited.

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Under this principle, in a given building or location or of a particular workstation it will be limited the size and its potential exposure is possible.

Applying this principle implies that it was accepted before the highest risk of occurring, but that will take care to minimize possible effects of any accidental explosions.

D Principle IV: overlapping safety devices

When installing the work points, equipment layout and work organization should overlap safety devices. This principle was set out early in 1920 and was well applied from Chatelier before being set out.

To reduce the probability of occurrence of the accident, there must be made within certain safety devices certain equipment, installation of protection systems in buildings and requiring the staff to obey the work dispositions.

The probability that the standard thing to be violated, as also the failure of safety devices at the same time, able to lead to accidents, will be the product of probabilities for each of the deficiencies that occur in the independently, except that they are independent events.

4. THE PROCEDURE FOR ASSESSING THE RISKS OF EXPLOSIVE ACCIDENTS

The overall purpose of a safety study in potentially explosive atmospheres is to identify risks, assess the likely consequences of accidents and frequency and finally to establish technical and organizational measures that lead to the cancellation of the business risks.

However, activities with potentially explosive materials or explosive systems makes this impossible. In this case, the main purpose is to reduce, mitigate risks to an acceptable level. For this, after risk analysis, risks will be identified in order to find a solution in order to limit and protection measures will be taken, or measures in order to limit them.

4.1. The definition of Risk

Risk is the product of the severity of an accident and the probability of occurrence of the accident.

The seriousness or the severity of the accident

To provide a qualitative assessment of the effects of personnel error, environmental conditions, inadequate design, procedural deficiencies, the fall of the system

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components or of the subsystem, or a system malfunction that resulted in an explosive accident, the concept of seriousness (severity) of the accident is introduced. The descriptions of the categories are shown in the table below.

Table 1 The categories of the gravity of the accident

DESCRIPTION	CATHEGORY	DEFINITION
DISASTER	I	*Death or loss of the system.*
CRITICAL	II	*Serious injury, severe professional illness or major damage of the system.*
MEDIUM	III	*Injury and medium damage, with consequences between major and marginal.*
MARGINAL	IV	*Minor injury, minor professional illness or minor damage of the system.*
NEGLIGIBLE	V	*Injury, professional illness or less minor damage of the system.*

The probability of occurrence of the accident

The likelihood of an explosive accident can be described as the possibility of occurrence of an event per unit time, the events, the people, issues or activities. The combination of quantitative magnitudes of the possibility of occurrence of the accident, before the event to occur is generally impossible. It is possible to give values of probability of occurrence of events by statistical means, which interprets and processes data from the history or events over time, appeared similar to systems analysis. Rational support for assigning a probability of occurrence of risks should be documented in reports of risk analysis. An example of classification of the likelihood of accidents is presented below in Table 2.

Table 2 The probability of occurrence of accidents

DESCRIPTION *	LEVEL	DEFINITION	FOR A RANGE OF MATERIALS **
FREQUENTLY	A	Likely to occur in a frequent way	Experimented in a continuous way
PROBABLY	B	It will happen a few times in life	It will frequently occur
OCCASIONAL	C	It will probably occur sometimes during life	It will occur a few times
ISOLATED	D	Unlikely, but likely to occurrence in life	Unlikely, but may occur
UNLIKELY	E	It can happen so rarely that it cannot be experienced	Unlikely, but possible to occur

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* The definitions of descriptive words may need to be adjusted, based on the quantities involved.

** The size range of materials must be specified.

Risk assessment

Risk assessment requires making the product of the magnitude of the accident or undesired event and its likelihood of occurrence. Subsequently, the question arises as to limit those risks to acceptable levels. If there is no solution to reduce or to limit their risk to acceptable levels, then other activities that do not impose these risks are recommended. Risk assessment can be made using a risk matrix as the one presented in Table 3.

Table 3 Risk assessment matrix

	ACCIDENT SEVERITY				
FREQUENCY	I CATASTROFIC	II CRITICAL	III MEDIUM	III MARGINAL	IV NEGLIGIBLE
(A) FREQUENTLY	1A	2A	3A	4A	5A
(B) PROBABLY	1B	2B	3B	4B	5B
(C) OCCASIONALLY	1C	2C	3C	4C	5C
(D) IZOLATED	1D	2D	3D	4D	5D
(E) UNLIKELY	1E	2E	3E	4E	5E

The suggested risk acceptance criteria

1A,1B, 1C, 2A, 2B, 3A unacceptable

1D, 2C, 2D, 3B, 3C, 4A, unwanted (SSM responsible decision is required)

1E, 2E, 3D, 3E, 4B, 4C acceptable, with the observations of the SSM responsible

4D, 4E, 5A, 5B, 5C, 5D, 5E acceptable without any comment

4.2. The classification of the operations with potentially explosive materials

Operations with combustible materials or potentially explosive mixtures involve the exercise of their external applications or the application of external stimuli (mechanical action, thermal action, electric discharge or electrostatic, etc.).

These applications can be characterized by an amplitude (size) and a duration of the action. To characterize the overall concept of these applications, the term aggression is used.

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The likelihood of an accident while carrying out an operation in potentially explosive atmospheres can be measured from the reference level (level 1 or aggression of gravity 1) and taking into account the following:

- the aggressions which aerosol explosive material may be exposed, both in terms of frequency and in terms of amplitude or intensity;
- the sensitivity of the product or of the explosive mixture on aggression actions:
  - Assessing the sensitivity resulting from the experimental results of flammability tests, whose values appear in files with data security, the information presented in documents with the outcome of product development research;

It can be inferred from theoretical studies or comparisons made with the results obtained for similar products.

Table 4. A The degrees of probability

The level of aggression:						
6 : An operation or a phase of an operation involving a mechanical action, heat or electricity that is aggressive near flammable materials and substances						
5 : leading or involving the use of tools or mechanical or electrical processing equipment or part of the operation, involves a mechanical or electrical action less aggressive on the materials and on the flammable substances						
4 : The operations or parts of operations that require or involve external energy input, other than the mechanical energy of materials and of flammable substances						
3 : The transport, the handling and the manipulation of materials and flammable substances in packages which are not approved or unpackaged						
2 : The transport and the handling of materials and of flammable substances in containers approved for transport						
1: The storage of materials and of flammable substances under appropriate conditions for these materials						
Material or explosive device						
Material 1 : Substance or mixture of fuel substances / extremely sensitive oxidant / flammable	P2	P2	P3	P4	P4	P5
Material 2 : Substance or mixture of fuel substances / very sensitive oxidant / flammable	P1	P1	P2	P3	P3	P4
Material 3 : Substance or mixture of fuel substances / sensitive oxidant / flammable	P1	P1	P2	P2	P2	P3

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4.3. The probability of occurrence of an incident or the degree of probability

Next, the likelihood of accidents or degrees of probability will be presented, depending on the levels of aggression faced by materials or the explosive devices, according to their sensitivity or flammability.

B The probability of occurrence of an explosive accident

For each workstation and each individual plant, depending on the nature of flammable materials or hazardous substances that can be found at work, and the type of operation to be carried out, the likelihood of an explosive accident must be assessed and approved as P1, P2, P3, P4, P5 depending on how it may occur: extremely rare, very rare, rare, quite often or frequently.

The likelihood of an explosive accident must be estimated in a sufficiently realistic way for each of the elementary facilities and private materials used in the process.

To allow a certain diversification of opportunities to place the installations in the dangerous locations, there have been designed that there are 5 degrees of probability of occurrence of accidents that can be achieved: P1, P2, P3, P4, P5. Their characteristics are shown in the table below.

Table 5 The probability of occurrence of explosive accidents

The degree of probability	Observations
P1	P1 should normally correspond to an annual probability of less than 10.4 pyrotechnic accident.
P2	P2 should normally correspond to an annual probability of fireworks accident at least 10.4 but less than 10-3.
P3	P3 should normally correspond to an annual probability of fireworks accident at least 10.3 but less than 10.2.
P4	P4 should normally correspond to an annual probability of fireworks accident at least 10.2 but less than 10.1.
P5	P5 should normally correspond to an annual probability of fireworks accident at least 10.1.

4.4. Risks to be prevented and dangerous areas

A Classification of hazardous areas

Within each workstation or job located outdoors or in a building, isolated or part of a local warehouse, warehouse containing materials or mixtures that may form potentially explosive mixtures, hazards occur as a result of the presence of these types of materials.

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Depending on the total quantity of material that can create explosive mixtures or potentially explosive aerosols, it is possible to classify the areas of danger in 5 categories, according to the seriousness of the consequences of the accidents for the persons or for the material goods.

Table 6

Categories of dangerous areas	Z1	Z2	Z3	Z4	Z5
Injuries on people	Fatal injuries in more than 50% of the cases	Serious injuries that can even lead to the loss of life	Injuries	The possibility of injury	Reduced possibilities of mild injury
Degradation of material goods	Extremely serious damages	Important damages	Medium and light damages	Light damages	Very light damages

B The dimensions of dangerous areas

The dimensions dangerous areas depend in an essential way on the configuration of the land, on the means of protection used, the nature and the type of explosive materials and the mixtures that can generate explosive accidents.

The dimensions of the dangerous areas are characterized by distance R (in meters), indicated in this document, are the limit distances for obtaining the accident caused by the gravity loads Q total weight (in kilograms), of the explosive materials or mixtures, placed at the ground level , under temperature and pressure conditions of 15 ° C and 1013 mbar, placed above a flat ground which doesn't have a special protection.

The dimensions of dangerous areas can be calculated according to the type of aerosols or explosive mixtures formed and according to the way in which they react (combustion, deflagration or detonation). They determine the mechanical and thermal effects.

5. CONCLUSIONS

In the economy of each country, for industrial, agricultural, transport, storage activities and even for domestic activities, many combustible solid, liquid, gas or combinations of materials are used. Many of them are raw materials for manufacturing and some are finished products for consumption. Whatever the type

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or the chemical composition of these materials, fuel / petrol is designed to provide, in combination with oxygen in the air or other oxidizing, thermal effects, strong heated reaction products, at temperatures and pressures that allow them to later perform different actions: propulsion, thermal etc.

Accidental explosive mixtures cover all states of aggregation of the material. They can be aerated and generally consist of mixtures of fuel gas with air, without excluding the combination with other gases. They can be mixtures of volatile liquids, flammable with the air and not least, they can be made of solid fuel, more or less divided in powder form, in mixtures with the air - creating aerosols or in warehouses, the air broadcasting among solid particles.

In all the situations and the types of chemical combinations, accidental explosive mixtures have demonstrated the full virulence explosion effects by the severity of the accidents, measured by property damage, personal injury and even death of hundreds or even thousands of people. An accidental explosion proved to be more dangerous than the accidental explosion of explosive material for several reasons:

- in what concerns the accidental explosive mixtures, it may not be aware the fact that the mixtures of explosive materials have properties or the circumstances in which they may become dangerous, e.g. in a store of grain, starch dust suspended in air can be ignited by a short electrical circuit;
- changing the process parameters can lead to the increased likelihood of developing accidentally mixtures, for example the increase the speed of conveyer belts can cause the necessary turbulence for the potentially explosive aerosol ;
- the ignorance of the conditions in which accidental explosions appear results in the number of persons on the workstation an not being limited;

The accident occurs in a technological operation, transport, storage or preserving, preparation, processing, loading, contrary to our will or what we expect, of accidental explosive mixtures, and the explosion that can occur may have adverse consequences (property or physical damage , up to the death of people).

The purpose of this paper is to present the first major elements of health and safety at work, imposed by the various national and international resolutions to several industrial operators and to define the exact scientific principles of safety and explosive safety in this area.

The risk assessment procedure is based on the classification of the materials that can generate accidental explosion and then to determine the probability of occurrence depending on the flammability and the aggression. Dangerous areas are classified according to the severity of the consequence of the accident.

After highlighting the technological activities or operations involving casual or accidental explosives, the risk factors are presented in the specific area of work in

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potentially explosive atmospheres, offering methods and techniques for limiting the risk of an explosive nature.

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