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Determining the explosion risk level and the explosion hazard area for a group of natural gas wells

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Abstract. Starting from the fact that the natural gas engineering profession is generally associated with a high occupational risk, the current paper aims to help increase the safety of natural gas wells and reduce the risk of work-related accidents, as well as the occurrence of professional illnesses, by applying an assessment method that has proven its efficiency in other industrial areas in combination with a computer-aided design software. More specifically, the paper focuses on two main research directions: assessing the explosion risk for employees working at natural gas wells and indicating areas with a higher explosion hazard by using a modern software that allows their presentation in 3D. The appropriate zoning of industrial areas allows to group the various functional areas function of the probability of the occurrence of a dangerous element, such as an explosive atmosphere and subsequently it allows also to correctly select the electrical and mechanical equipment that will be used in that area, since electrical apparatuses that are otherwise found in normal work environments cannot generally be used in areas with explosion hazard, because of the risk that an electric spark, an electrostatic discharge etc. ignites the explosive atmosphere.

1. Introduction

The natural gas producing and distributing industry is characterised by a high level of occupational risk. Therefore, the assessment of the explosion and fire hazard has to play an important role when selecting the type of equipments that can be used in specific areas of natural gas engineering facilities. [1]

For example, the considerations regarding the usage of electrical equipments in areas with explosion hazard are significantly different from those employed in the case of normal-risk areas.

In order to ensure the explosion safety of the operating personnel and of the installations that function in such industrial environments, it is necessary, even before implementing any technical solutions, to analyse thoroughly whether it would be possible for flammable substances to accumulate and generate an explosive atmosphere.

Also, it is necessary to determine the probability of an explosive atmosphere to occur within the considered industrial space and to identify all types of employed flammable substances so as to facilitate the grouping of that area within one of the standardised types of explosion hazard areas.

Whereas the possibility to assess the explosion risks in various other parts of a natural gas extraction, storage and transportation system has been discussed by various authors ([2, 3, 4]), in the current paper, the authors use a consecrated method to determine the explosion risk for the specific case of a group of natural gas wells; furthermore, they also used a specialised 3D computer-aided design software to indicate the main problem areas within this facility.

2. The analysed facility

For an optimal exploitation and monitoring of the surface installations corresponding to natural gas extraction wells, these are usually grouped spatially, forming so-called groups of wells.

The spatial grouping of the wells also allows a better possibility for the operating personnel to intervene in the extraction process.

The technological installations of the considered group of natural gas wells has been modelled by the authors using the software package AutoCAD Plant 3D and consist of following component elements: measurement polygons for each well (isolation faucets for instruments, measurement diaphragm, pressure regulator, pressure valves, horizontal subterraneous separators), wastewater storage tank, pumping station, natural gas metering and regulating station etc.

Figure 1 presents a general overview of the analysed group of natural gas wells, while figure 2 presents some individual equipments from the group of natural gas wells.

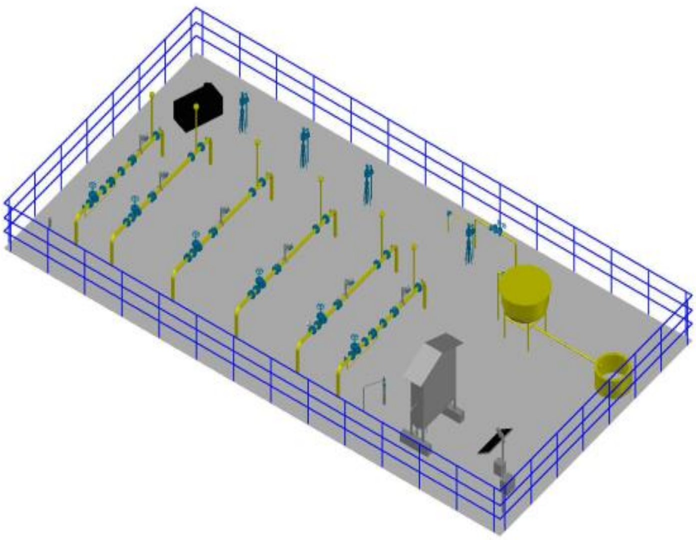

Figure 1. Overview of the analysed group of natural gas wells

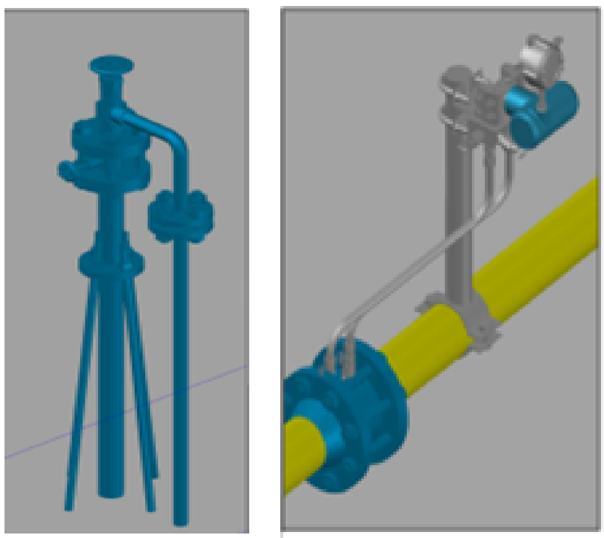

Figure 2. Individual equipments from the analysed group of wells

3. The general risk assessment methodology

In the following, the authors used for determining the explosion risk level within the analysed group of natural gas wells, a method based on the one elaborated by the National Institute for Research and Development for Environmental Protection Bucharest, Romania (I.N.C.D.P.M.). This method targets the quantitative determination of the risk/security level for a workplace, sector, section or plant, based on the systemic analysis and the assessment of the risks for accidents and professional illnesses.

The method implies identifying all explosion risk factors within the analysed system (or workplace) based on predetermined checklists and then quantifying the magnitude of the risk based on a combination of the gravity and frequency of the maximal predictable consequence. It is then possible to assess the security level for a workplace as being inversely proportional to the risk level.

In order to apply the method, several mandatory steps have to be followed:

- defining the analysed system (workplace);
- identifying the risk factors in the system;
- assessing the explosion risks;
- ranking the risks and determining the prevention priorities;
- proposing prevention measures.

In turn, these steps require the preparation of several important work instruments:

- a list for the identification of risk factors;
- a list of possible consequences of the action of risk factors on the human body;
- a scale for ranking the gravity and probability of consequences;
- a risk assessment grid;
- a risk level scale and a safety level scale, respectively;
- a workplace assessment form (centralising document);
- a list of proposed measures.

Based on the individual risk factors identified during these steps, there can be defined a global risk level for a workplace (N_r), as a weighted average of the risk levels determined for the risk factors. The rank of each risk factor has been used as weighing element (it being equal to the risk level), so as to make sure that the obtained result reflects reality as closely as possible.

The formula for calculating the global risk level is given in equation 1:

$$N_r = \frac{\sum_{i=1}^{n} r_i \cdot R_i}{\sum_{i=1}^{n} r_i} \tag{1}$$

where:

N_r is the global risk level for a workplace;

r_i - the rank of the risk factor „i";

R_i - the risk level for the risk factor „i";

n - the number of risk factors identified for the considered workplace.

4. Assessing the explosion risk in the analysed for the group of natural gas wells

In order to identify the explosion risk factors for the natural gas wells, the authors analysed the tasks indicated in the job description files for the personnel unfolding its activity within this system, as well as the corresponding technological processes. The risk factors were identified and grouped by the generating element within the work system (operator, work task, production means and work environment - figure 4). In all, there were identified 58 risk factors. Based on this, the authors then determined the partial risk level for each risk factor. Taking these into account, there was then determined the global risk level, using the formula:

$$N_r = \frac{\sum_{i=1}^{58} r_i R_i}{\sum_{i=1}^{58} r_i}, \qquad (2)$$

that, when using the corresponding numerical values, leads to:

$$= \frac{0\cdot(7\cdot7)+0\cdot(6\cdot6)+3\cdot(5\cdot5)+6\cdot(4\cdot4)+25\cdot(3\cdot3)+16\cdot(2\cdot2)+8\cdot(1\cdot1)}{(0\cdot7)+(0\cdot6)+(3\cdot5)+(6\cdot4)+(25\cdot3)+(16\cdot2)+(8\cdot1)} = \frac{468}{154} = 3.03$$

Thus, the global risk level calculated for the workplace "Group of natural gas wells operator" is 3.03, a value that places it among the workplaces with small to medium risk levels.

From figure 3, showing the partial risk levels for the risk factors at the considered group of natural gas wells, it can be noticed that of the total of 58 identified risk factors, 9 surpass, as partial risk level, the value of 3, thus being considered medium to high risk factors.

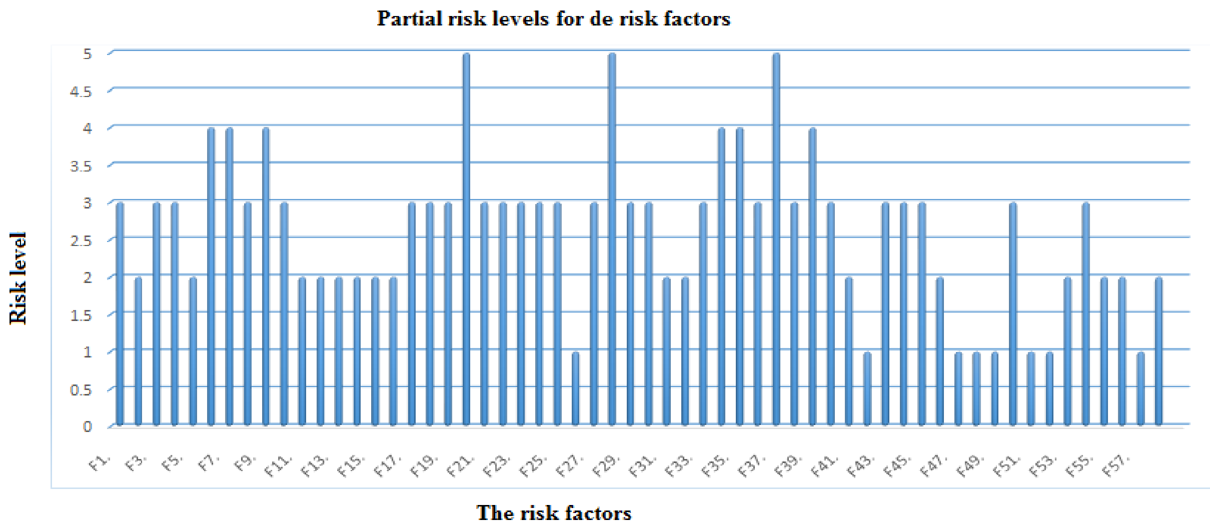

Figure 3. Partial risk levels for the risk factors at the group of natural gas wells

Figure 4 presents a distribution of the identified risk factors for the group of natural gas wells, by generating sources. Of the 58 risk factors:

- 25 factors are related to the operator (43%);
- 17 factors are related to the production means (29%);
- 8 factors are related to the work task (14%);
- 8 factors are related to the work environment (14%).

By determining the explosion risk level, it is possible to determine the priorities in prevention measures for the workplace, but also to optimise the usage of resources allocated for this purpose.

An advantage of the method elaborated at the I.N.C.D.P.M. Bucharest, Romania is the fact that its application is not limited by the condition of the physical existence of the system that needs to be assessed. It can be used in all stages related to the lifecycle of a work system or of an element of this work system: conceiving and design, physical creation, putting into production, unfolding of the work processes.

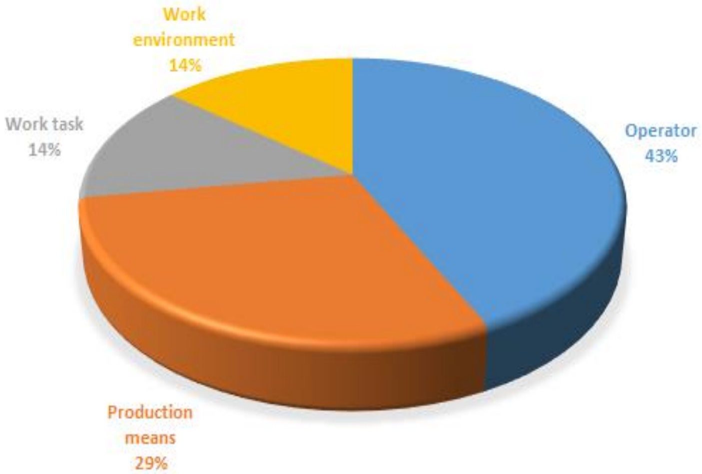

Figure 4. Distribution of the risk factors by generating sources

5. Indication of the explosion risk areas

An explosion risk area represents an industrial space in which, under normal functioning conditions, there can accumulate, permanently or accidentally, gases, vapours of flammable liquids, dusts or powders in sufficient amounts to give birth to an explosive atmosphere. Explosion hazard areas can be classified into several types, function of the length of the periods during which the explosive atmosphere is present. [5]

- area 0 - is the area in which the explosive atmosphere is present during the normal functioning of the technological installations, permanently or for a period of more than 1000 hours per year.
- area 1 - is the area in which the explosive atmosphere can occur during the normal functioning of the technological installations for intermittent periods with durations comprised between 10 and 1000 hours per year.
- area 2 - comprises the industrial areas within which an explosive atmosphere cannot occur during the normal functioning, but only in cases of predictable defects or for periods between 0.1 and 10 hours per year.

For the case of the analysed system (a group of natural gas wells), no area was identified that would be consistent with the requirements for inclusion in area 0.

The zoning of industrial spaces represents the process of classification of spaces within an industrial installation function of the probability of occurrence of an explosive atmosphere and is important for the subsequent correct selection of the electrical and mechanical equipment that will be used in that area. The electrical apparatuses for normal environments cannot be used, in general, in areas with explosion hazard due to the risk of the explosive atmosphere igniting due to electric sparks or arcs, hot surfaces of equipment, electrostatic discharges etc. [3, 4]

Therefore, at the execution of the electrical apparatuses and equipment for potentially explosive areas, there have to be applied certain supplemental constructive measures that would offer them safety during functioning and in the presence of the explosive atmosphere.

For the zoning of the group of natural gas wells, the authors have used the software package AutoCAD Plant 3D, that allowed to clearly emphasise the areas with explosion hazard, as shown in figure 5 and figure 6.

6. Conclusions

The current paper has presented the results of applying a tested, general assessment method to the specific work area of a group of natural gas wells.

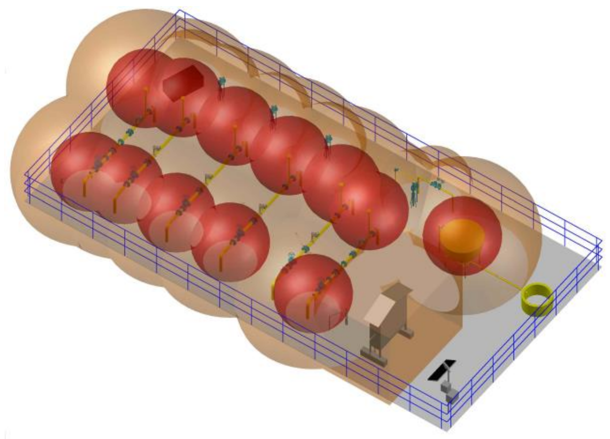

Figure 5. Zoning plan showing the physical location of areas with explosion hazard

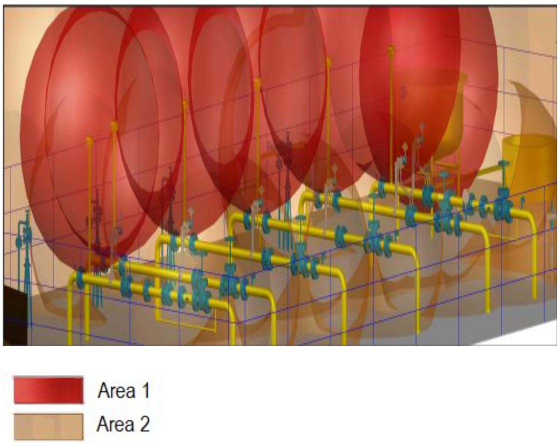

Figure 6. Detail of the zoning plan for the analysed group of natural gas wells

One of the main advantages of the method presented in this paper is that its application is not limited by the condition of a physical existence of the system to be assessed. It can be used in all stages related to the lifecycle of a work system or of an element of such a system: conceiving and design, physical creation, putting into production, unfolding of the work processes.

The application of the gravity/probability method for the analysed workplace has allowed the identification of explosion risk factors and to determine the dimension of risks for the occurrence of an explosion at this workplace. For this, for each identified risk factor there will be indicated technical and organisational measures that need to be taken in order to keep the risk level in the "area of acceptable risks".

After the division of the space into specific hazard areas, the electrical installations can be conceived either through the usage of electrical equipment certified for such areas, or, if no such equipment is available, through conceiving new equipment and then certifying it.

In future, the authors intend on the one hand to try to refine the method so as to better take into account all intervening factors and on the other hand to apply it to further similar systems.

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