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SRĐAN STANKOVIĆ[1]
IVAN KRSTIĆ[2]
EMINA MIHAJLOVIĆ[3]

[1]Opštinska uprava opštine Doljevac
[2,3]University of Nis
Faculty of Occupational Safety

[1]*stankovicsrdjan67@gmail.com*
[2]*ivan.krstic@znrfak.ni.ac.rs*
[3]*emina.mihajlovic@znrfak.ni.ac.rs*

IDENTIFYING HAZARD ZONES AT LPG STATION "DAKI PETROL"

Abstract: *Technological processes, either in regular operation or in case of an accident, may produce flammable and explosive gases and vapours which can be the cause of fire and explosion. In case of major accidents involving the vessels with flammable gases, those gases leak and evaporate rapidly thus creating the cloud of mixtures (fireballs). Ignition of such mixture is initiated by ignition sources, and it may be the cause of explosion and detonation. The consequences of the combustion of flammable gases and vapours in unlimited atmosphere go beyond the limits of typical fires. These activities are the origins of environmental hazards in facilities endangered by flammable and explosive gases and vapours, or toxic products of combustion, heat radiation and shock wave. There is a need to develop the methods for identifying threat zones which would serve to reduce the risk of vulnerability to the acceptable level. Therefore, the subject of the research is the development of methodologies for estimating threat zones and application of ALOHA software package that can be used to determine the threat zones which are the consequence of gases and vapours clouds, as well as thermal radiation of shock wave and toxic products of combustion.*

Key words: *hazard zones, fire, explosion.*

INTRODUCTION

The paper describes the identification of threat zones in a reference system - the LPG tank at a petrol station "Daki Petrol" doo, according to the national standards SRPS N.S8.003 and SRPS N.S8.007 and ALOHA (*Areal Locations of Hazardous Atmospheres*) software package. Hazard zone, according to the above mentioned national standards, is the area in which energy, material or information flows develop hazard. By defining hazardous areas, we can identify the limits of impacts and activities of hazards with certain intensity.

The first step in identifying hazardous areas is the identification and grading the sources of hazard.

Hazard sources are the spots that contain and discharge a flammable substance into the surrounding area, or the atmosphere, thus creating explosive mixtures.

There are three basic degrees of hazard sources, listed according to the possibility of discharge of gases and vapors, and they are the following:

- permanent source of hazard- a source with a permanent discharge, or a source that is expected to discharge a flammable substance in the atmosphere, either for a longer period of time or very often in a short time,
- the primary source of hazard- the source which causes flammable atmospheres that are part of the normal running of the plant
- the secondary source of hazard - the source which is not expected to discharge any flammable substance during the normal running of the plant, and if discharge happens, it will last for a short period of time.

According to legislative acts, classification of hazardous areas is threefold:

• **Zone 0 Hazardous Area** - the area in which an explosive atmosphere is present continuously or for a longer period of time;

• **Zone 1 Hazardous Area** - the area in which an explosive atmosphere may occur as a part of the normal running of the plant;

• **Zone 2 Hazardous Area** - the area in which it is unlikely that an explosive atmosphere will occur as a part of the normal running of the plant, but if it happens it will last for a short period of time.

According to the recommendations of IEC, hazardous areas are graphically displayed as follows:

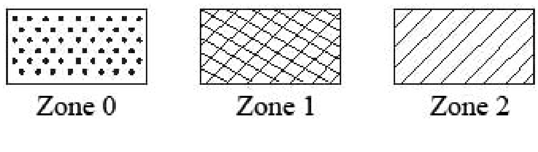

Figure 1. *Hazardous areas according to IEC recommendation*

ALOHA is a model for displaying dispersion (spread) of emissions. It is used to estimate wind-direction-oriented contamination cloud dispersion. The estimation is based on physical and chemical properties of substances that cause the accidents, weather conditions at the moment of accident and the circumstances under which the uncontrolled emissions occurred.

ALOHA models cover three categories of risks: the dispersion of toxic gas, thermal radiance in fires and explosions, as well as the level vapour cloud pressure formed during the explosion.

ALOHA helps modeling of accidents from four types of emission sources: direct source, puddle formed by disharge, the tank and the pipeline.

After all the parameters for the accident scenario are obtained, the stage that follows is the processing of a simulation model. This involves the implementation of pollutant dispersion models in which numerical algorithms are used to calculate the desired dynamic variables in the space-time continuum. Post processing phase in this software package is the visualization of simulation results in textual description of an accident and graphical display.

Graphic display shows the diagram of threat zones. It displays the so-called Levels of Concern (LOC) which represent the level of risk to humans and the environment.

Fire and explosion scenario include the level of concern due to thermal radiance and detonation pressure.
To determine a thermal radiation level of concern, ALOHA uses three threshold values to define the vulnerability zones:

- red: 10 kW/m^2 (potentially lethal within 60 seconds);
- orange: 5 kW/m^2 (2nd degree burns within 60 seconds);
- yellow: 2 kW/m^2 (pain within 60 seconds).

The effects of thermal radiation depend on exposure to certain level of thermal radiation. Prolonged exposure to even lower levels of thermal radiation can produce serious physiological effects.

To determine the level of concern due to detonation pressure, ALOHA uses three threshold values:

- red: 8,0 psi (destruction of buildings);
- orange: 3,5 psi (occurrence of serious injuries);
- yellow: 1,0 psi (glass breaking).

DESCRIPTION OF THE REFERENCE SYSTEM

The reference system is a LPG tank for fuelling motor vehicles, owned by the company "Daki petrol" doo, located in the Cara Konstantina 82 St, with coordinates 43°18'25.1"N 21°57'18.0"E, as shown in the following figure.

Figure 2. *Location of the LPG tank at the petrol station "Daki Petrol" doo*

The reference system is an business center facility made of solid building material with the external facade of brick wall, and with the underground LPG tank at 15.3 m distance. The distance of the tanks from the neighboring parcel is 12.1 m. At the aforementioned location (plot), there is a building (cage) for storing LPG cylinders for retail. The LPG station has the following equipment and the facilities.

The storage tank

A cylindrical lying underground tank with 30 m3 volume is intended for storing liquefied petroleum gas. It is built according to the Serbian standard SRPS M.Z2.600. The tank is equipped with all necessary connectors, metal frameworks and measuring equipment as required by the regulations. The distance of the tank from the public road is 29.8 m, the distance from the paths inside the plant is 6m and the facilities to accommodate employees 15,25 m, which is more than the prescribed distance of 10 m, which is recommended by the Regulations on the construction of the facility for liquefied petroleum gas and storing and transferring liquefied petroleum gas.

Filling the storage tank from the truck tank

The storage tank and the pump are enclosed by a 2m high protective m with a canopy made form light material, placed over the pumping area.

Fuel transfer area

The storage tank is filled with LPG from truck tanker that is connected to the storage using flexible hoses. Fuel transfer area is located at 2.3 m distance from the access road and 26.5 meters from a public road which complies with the requirements by the Regulations on the construction of LPG facilities and storing and transferring liquefied petroleum gas. Fuel transfer area is above the ground and it is equipped with all necessary reinforcements, connections and metering equipment according to the rules. The pipeline from the fuel transfer area to the storage tank will be placed under the ground. Pipes are fixed using L-shaped reinforcement which is immersed in concrete in its underground part. Fuel transfer area is protected by a 2m high wire fence, with door that opens outwards.

The pump

LPG dispensers (for fueling vehicles) are supplied with gas from one pump with an electric motor which is designed for operation in explosion endangered areas. The pump is automatically controlled from the electrical cabinets in the house station. The pump is mounted on a concrete base elevated 10 cm from ground level, at 1.7 m distance from the storage tank and 6.4 m distance from the access road, in accordance with the Regulations on the construction of LPG facilities and storing and transferring liquefied petroleum gas. The pump produces the necessary pressure in the system for fueling vehicles, while pressure regulation is done using the pressure relief valve. In addition, the pump can be used for transferring LPG from tank trucks to storage tank, using the pipe system and the locking valves. Explosion protection equipment is installed in the pump.

Installation (the pipeline)

The pipeline, made of certified steel seamless tubes, is used to transport LPG from the fuel transfer area to the storage tank, and from the pump to the LPG dispensers. The pipeline is installed underground, in the channels 80 cm below ground level. The pipes under the main road are placed inside the reinforced concrete channels, also 80 cm below the road. Before being installed, the pipes are insulated. In the part of the pipeline around the pump and the tank, as well as in the fuel transfer area around the terminal, the pipeline is built above ground, and the pipes are protected by an anti-corrosive coating and finishing. The pipes are welded, and connected to the reinforcements using threaded parts and flanges.

LPG dispenser

Two LPG dispensers, type "Duplex" with 2 nozzles designed for operation in explosion endangered areas, are used for filling up motor vehicle tanks. The capacity of these instruments is 50 l/ min. The dispensers are placed on a safety island which is 14 cm above the road. Vehicle access is provided on both sides of the dispenser island. The size of the island is 6x1,5 m. There is a canopy above the LPG dispensers. Flexible hoses are used to connect the dispensers to the pipeline.

Access roads and fire roads

The access road is design to enable the access of motor vehicles to LPG dispensers. This road has the radii of curves in its beginning and in the end, so that it does not jeopardize road safety. The access to the dispenser island is enabled from both sides. Truck tanks and fire engines can approach the fuel transfer area through the 5.5 m wide road, with the possibility to get closed during gas refilling.

Fire safety system

Fire safety system comprises of:

- hydrant network;
- fire extinguishers;
- warning signs.

Hydrant network consists of two ground hydrants as recommended by the regulations, at distances greater than 25 m and less than 35 m from the storage tank.

The station is equipped with the following fire extinguishers:

• Tank	S-50	1 pc
• Fuel transfer area	S-50	1 pc
• Pump	S-9	1 pc
• Storage	S-9	3 pc
• LPG dispenser	S-9	1 pc

Apart from this, in addition to LPG dispensers, there is a 0.3 m^3 fire sand box.

Warnings signs are placed according to regulations.

IDENTIFYING HAZARD ZONES

Fire hazardous areas

Hazardous areas of a reference system were defined on the basis of national standards SRPS N.S8.003 and SRPS N.S8.007.

Underground storage tank

- Zone 1 covers the inside of the tank and concrete bed, or chambers if there are any, and the shaft above the entrance to the tank
- Zone 2 involves the area around the entrance to the underground tank, shafts with charging ports, piping and pressure relief valve; the radius is 3 m measured horizontally and the height is 1m measured from the ground, above the shaft, piping and pressure relief valve.
- Zone 3 involves the area above the surrounding area, 5 m wide if measured horizontally from the edge of the zone 2, and 0.5 m high if measured from the ground.

Fue transfer area

Safety zone around fuel transfer area is 7.5 m from the tanks.

LPG dispensers

- Zone 1 includes the interior of dispenser, reinforcements and other equipment which are part of the measuring instrument.
- Zone 2 covers the area around the fuel dispensers, the radius of 2.5 m if measured horizontally and 1m above the dispenser (if measured from the ground), and the area around the hole for refueling of motor vehicles, the radius of 1 m if measured horizontally and 1m above the holes if measured from the ground.

- Zone 3 includes the area above the surrounding terrain, 5m wide if measured horizontally from the edge of the zone 2 and 0.5 m high if measured from the ground.

Hazardous areas where explosive atmospheres may occur

LPG cylinder retail store

On the basis of the available data for retail store intended for selling LPG gas bottles - Methodology for identifying hazard zones - flammable liquids and gases – hazard zones of explosive atmospheres are as follows:

- Hazard zone zero "0" is the inside of the gas bottle;
- Hazard zone two "2" is the area around the valve on the cylinder, 1 m radius down to the ground.

Characteristics of flammable substances

The gas station is intended for storage and retail sales of liquefied petroleum gas.

Liquefied petroleum gas is a mixture of propane and butane with the following characteristics, as given in Table 1.

Table 1. *Characteristics of the mixture of propane and butane*

Density of gas in the liquid state	0,515	kg/l
Density of gas in the gaseous state	2,21	kg/m^3
The specific volume of gas in gaseous state	0,46	Nm^3/kg
Calorific value	119,2	MJ/m^3
Ignition temperature of the mixture with air	430-465	° C
Lower explosive limit	propane 2,1% butane 1,6%	
Upper explosive limit	propane 9,5% butane 8,5%	
Group and temperature class	AT2	

Figures 1 and 2 show the layout plan with defined hazard zones for LPG fueling station, "Daki petrol" doo, Figure 3 displays hazard zones for tank manhole, and in Figures 4 and 5 show hazard zones for LPG dispenser of the danger zone for LPG dispensers and safety valve tubes.

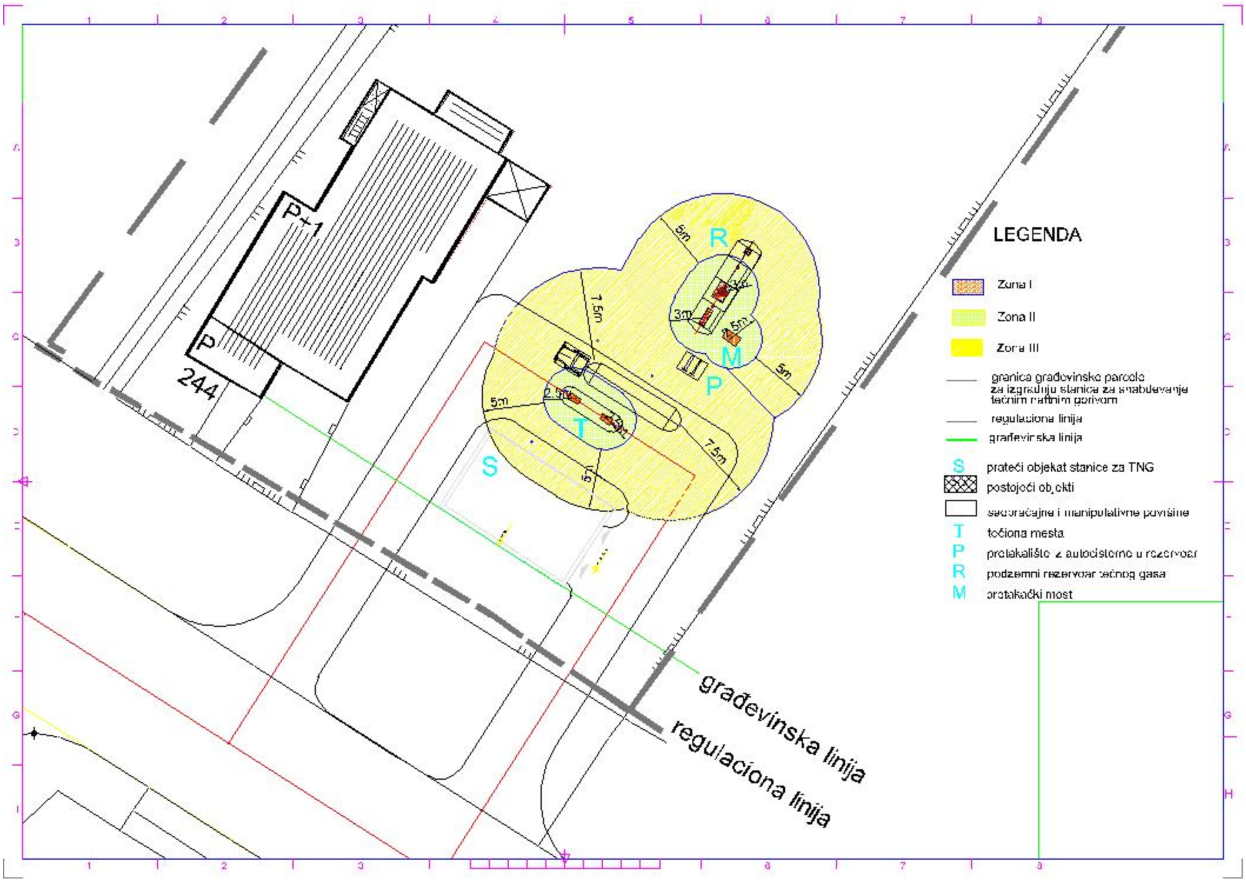

Figure 1. *Layout plan with hazard zones*

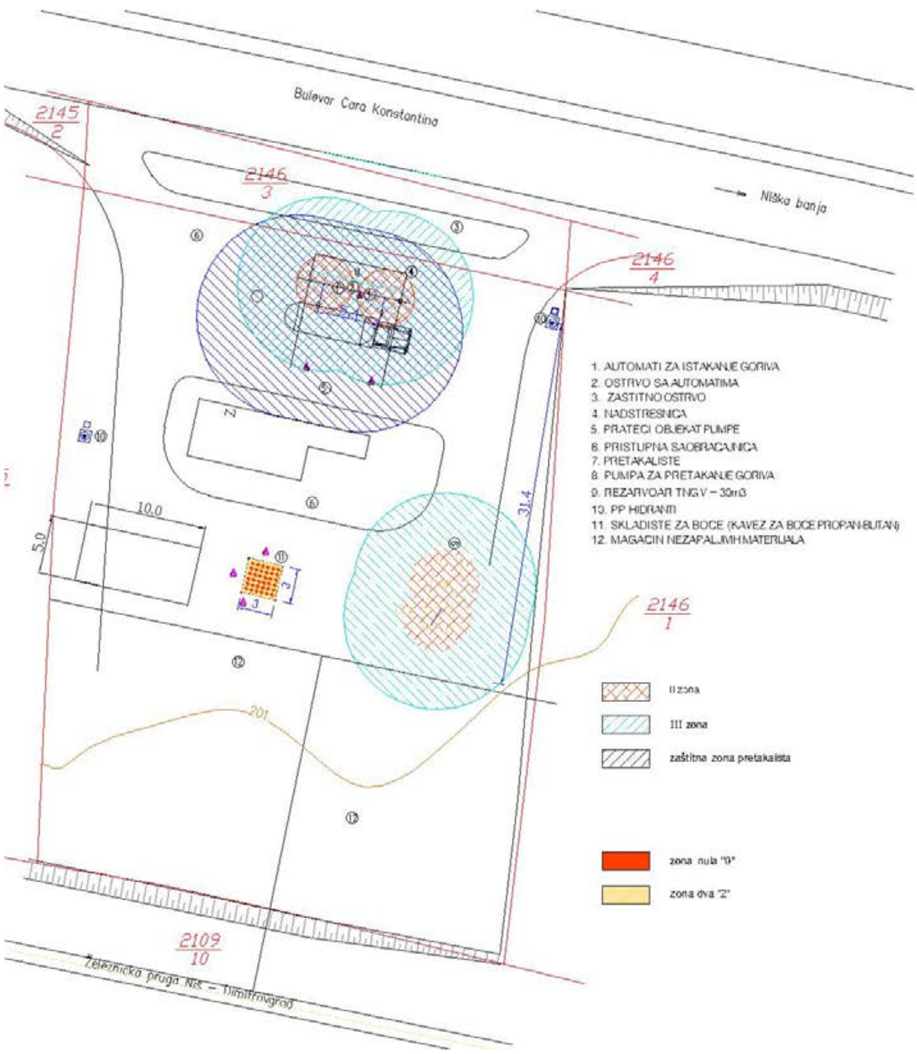

Figure 2. *Layout plan with hazard zones*

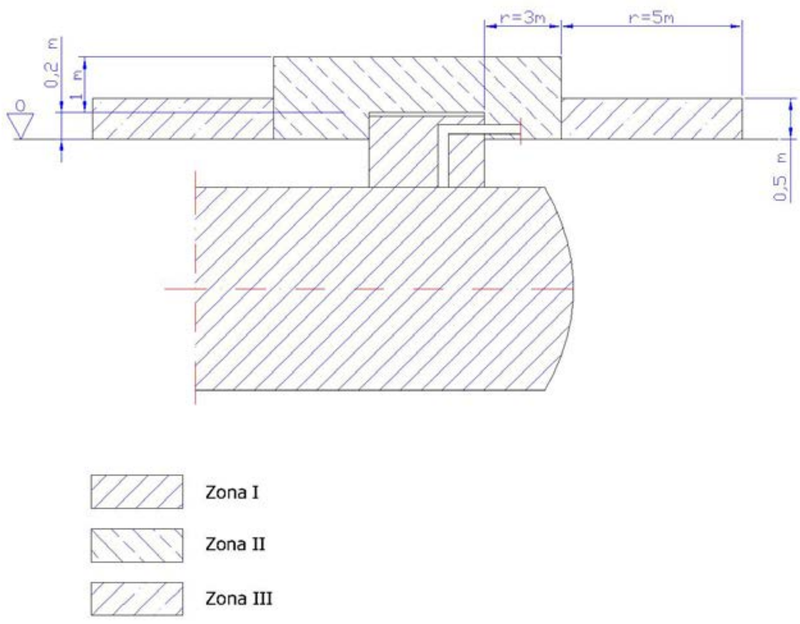

Figure 3. *Hazard zones for tank manhole*

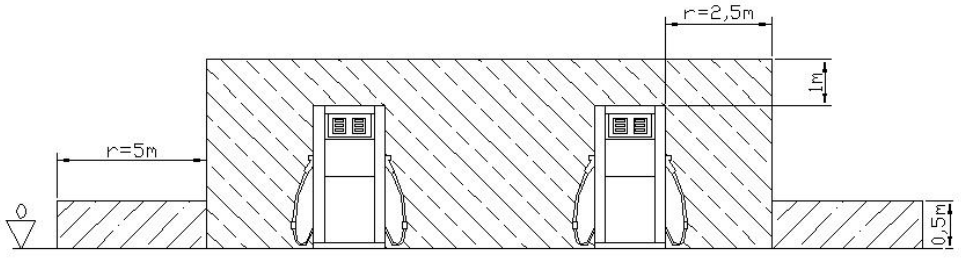

Figure 4. *Hazard zones for LPG dispenser*

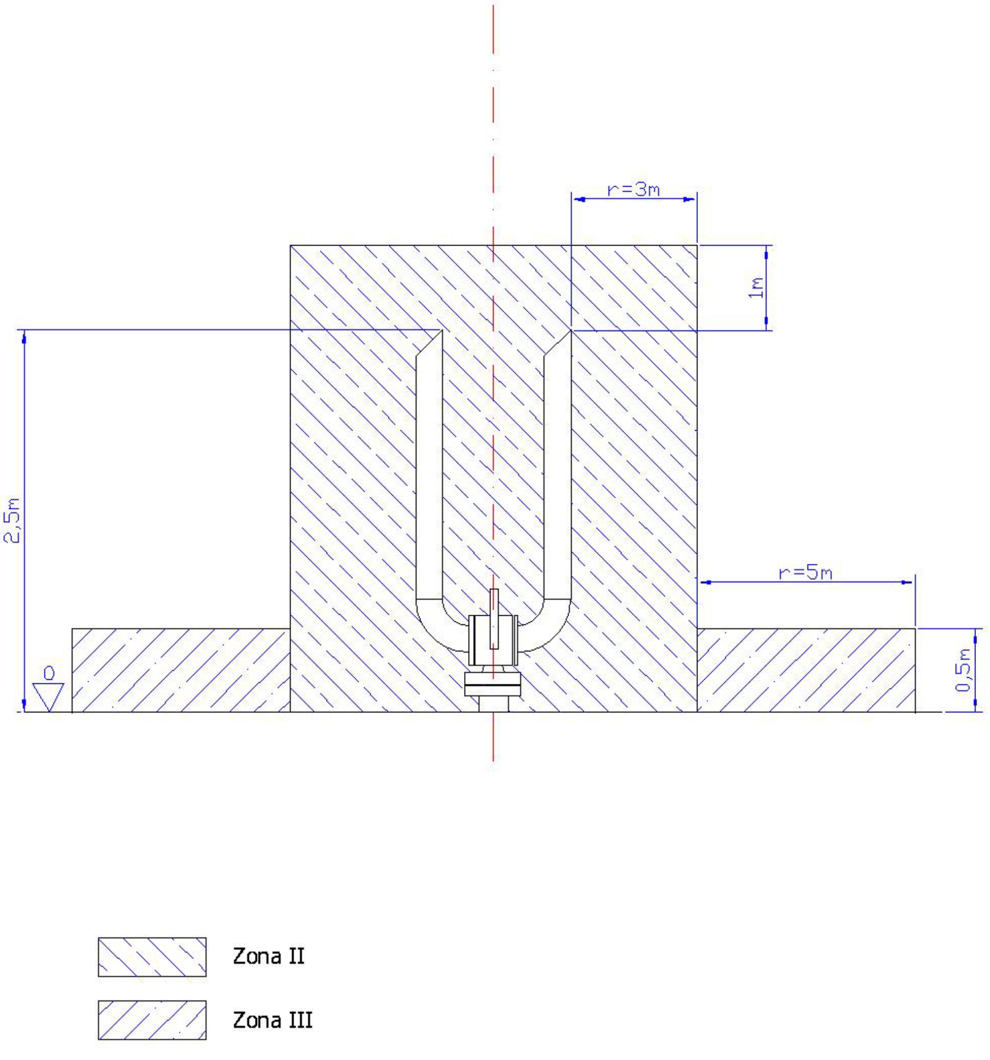

Figure 5. *Hazard zones for safety valve tubes*

Graphic displays of fire and/or explosion scenario in the post processing phase are hown in Figures 6 and 7.

Sa slike se vidi da je zona opasnosti usmerenog oblika dimenzija reda veličine stotine metara.

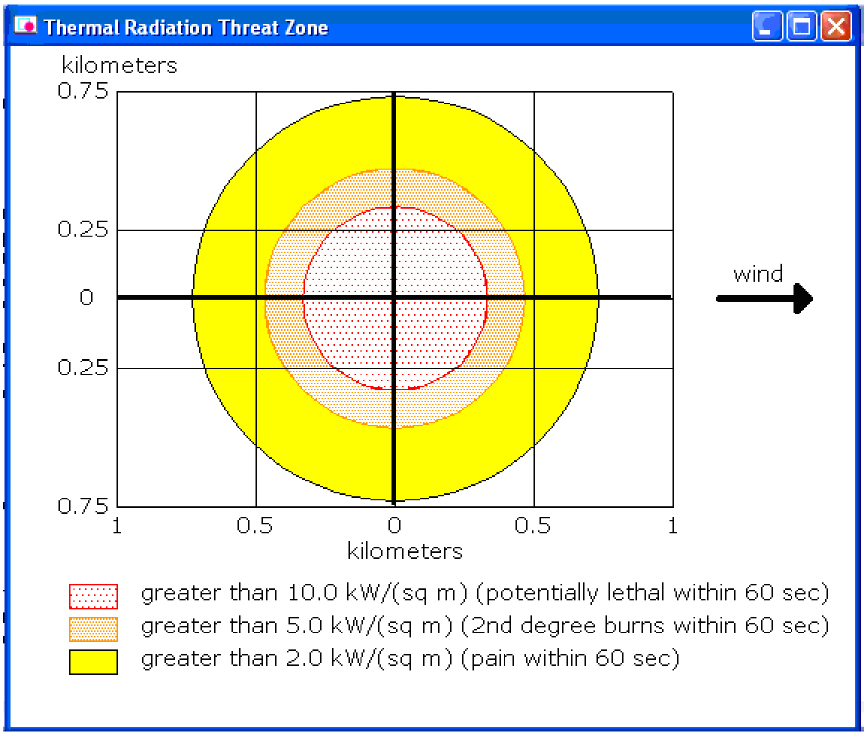

Figure 6. *Display of threat zones*

Figure 7. *Display of threat zones of the reference system in line with the chosen scenario*

CONCLUSION

One of the key tasks in preventing accidents is the development of models which simulate the accidents and thus allow timely response. The results obtained from modelling could be used in accident prevention, fire and explosion protection, developing standards for environmental quality, as well as structural standards that refer to the location of facilities and safety zones, residential zones, the height of the chimney, choice of equipment, the type of fuel, etc. Methodology for accident management and software package ALOHA were used to simulate the outdoor discharge of flammable and explosive gases, which was again used to determine threat zones.

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BIOGRAPHY

Srđan Stanković was born in Nis in 1967. He obtained Master's degree from the Faculty of Occupational Safety in Nis, in the area systems safety and risks- fire safety. He is employed at the Municipal Administration of Doljevac Municipality, where he is in charge of fire protection, environmental safety inspections, municipal inspection, waste management, environmental impact assessment and occupational health and safety. He has the Certificate for Safety and Health at Work, the Certificate for fire safety expertise for workers with a university degree, a License for fire protection grand projects and he is also appointed to be an a permanent court expert for fire, explosion and accident protection and occupational safety.

ODREĐIVANJE ZONA OPASNOSTI NA TNG STANICI „DAKI PETROL“

Srđan Stanković, Ivan Krstić, Emina Mihajlović

Rezime: *Pri odvijanju tehnoloških procesa može, u redovnom radu ili u slučaju udesa, doći do izdvajanja zapaljivih i eksplozivnih gasova i para i stvaranja uslova za nastanak požara i eksplozija. Pri potpunoj havariji sudova sa zapaljivim gasovima dolazi do njihovog isticanja i brzog isparavanja i obrazovanja oblaka smeše (vatrene lopte). Paljenje ovakve smeše nastaje iniciranjem izvora paljenja pri čemu može doći do eksplozije i detonacije. Posledice sagorevanja zapaljivih gasova i para u neograničenom prostoru atmosfere prevazilaze granice delovanja klasičnih požara. Sve to izaziva ekološku opasnost objekata ugroženih zapaljivim i eksplozivnim gasovima i parama, odnosno toksičnih produkata sagorevanja, toplotne radijacije i udarnog talasa.*
Sve to nameće potrebu za razvojem metoda za određivanje zona opasnosti kojima bi se nivo rizika ugrženosti sveo na prihvatljiv nivo. U tom smislu, predmet istraživanja je razvoj metodologija za proračun zona opasnosti i primena programskog paketa ALOHA kojima se može odrediti zona uticaja efekata sagorevanja oblaka gasova i para, kao i toplotno zračenje udarnog talasa i toksičnih produkata sagorevanja.

Ključne reči: zone opasnosti, požar, eksplozija.