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THE ANALYSIS AND THE SIMULATION OF FIRE RISK IN THE FACILITY FOR FRUIT TREATMENT "POBEDA" IN PROKUPLJE

Abstract: *The technological process of producing sour cherries in alcohol generate flammable and explosive substances that may endanger the health and safety of employees, and even have large-scale consequences. This paper gives the analysis and the calculation of fire risk in buildings where there is a technological process and presents a degree of fire risk within the facility. Following this, the software package ALOHA was used to determine threat zones as a consequence of fire and explosion accidents in overhead tank for ethyl alcohol. In this way, we can obtain an insight into the potential causes of fires and fire hazards. The simulation results obtained via ALOHA programme and the calculations of fire risk can be used to identify specific measures aimed at reducing the risk of fire or explosion.*

Key words: *fire hazard, ALOHA, fire and explosion risk.*

INTRODUCTION

The aim of fruit storage and processing technology is preservation of great amounts and qualitative characteristics of fruit in the longest period possible. In this way, processing technology, together with fruit production, trade and consumption becomes an equal element of organization and management in this type of production.

The improvements in production and the introduction of various technologies and systems demand the appropriate measures for fire and explosion protection in this important industry. Destructive phenomena, whether they are natural or the result of negligence and unprofessional work, leave minor or major damage, whereas fires and explosions that often accompany each other, if allowed to develop, usually leave the most serious consequences. Taking into account that some hazardous and flammable materials are used in manufacturing processes or the sake of maintaining the technological process, it is very important to pay attention to protection against fire and explosion. Therefore, great importance should be given to preventive actions and implemented measures for fire and explosion protection. Fires cannot be completely eliminated, and the most efficient way to protect the resources and reduce material loss is to take the appropriate measures. In order to take adequate fire safety precautions, we must know the cause of fires and fire hazards. The goal of fire protection can be realized if causes of fires are eliminated, fire risks reduced to a minimum, adequate funding and equipment for fire fighting are provided and staff is trained to handle devices and equipment.

The facility for fruit processing "Pobeda" in Prokuplje is taken as the reference system for fire and explosion risk analysis, the visualization of possible accidents and determination of fire risks and threat zones.

LOCATION OF A REFERENCE SYSTEM

Macrolocation

Prokuplje is located in the middle course of the river Toplica, between Jastrebac in the north, the west foot of Kopaonik Mountain in the west, and mountain groups Sokolovica, Arbanaška and Vidojevica in the south. It covers an area of 759 km^2 with the population of 47,995 inhabitants. According to its position, Prokuplje is very transitional. The main road Nis-Pristina, which connects Kosovo and southern Pomoravlje, goes over the Toplica river, and therefore through Prokuplje. Due to the crisis situation in Kosovo, these roads are not sufficiently exploited. In the valley of the Toplica river, the climate is mild continental with pronounced continental features, warm summers and moderately cold winters. Its thermal regime is characterized by negative mean monthly temperature only in the month of January (-0.9 degrees Celsius), whereas the warmest month is July with 22.0 degrees Celsius. The climate is very dry so that the average annual rainfall is only 541mm. In Prokuplje, winds blow usually from the southwest. The processing and manufacturing facility "Pobeda" is located 3.5 km from Prokuplje, along the main road Prokuplje- Niš in the village of Nova Božurna, on the plot no. 392/1 and 393/3.

Microlocation

The processing and manufacturing facility is located on the flat ground, and it does not lean upon the neighboring buildings. The driveway is the main highway. In terms of fire safety, the location of the property is good because the building is located at a proper distance from neighboring buildings. The driveway for fire-fighting vehicle is possible from one direction only.

Figure 1. *Satelite image of the facility and the environment*

TECHNOLOGICAL PROCESS OF PRODUCTION

The processing and manufacturing facility P+1 is intended for fruit processing to the final product, its storage and rapid distribution by various means of transport to distribution trucks. The final product is sour cherry in alcohol kept in barrels, with or without stone seeds, depending on customers' requests.

Freshly picked sour cherries are transported to the handling area in front of the processing hall. After the purchase, sour cherries are primary and secondary washed, cleaned and classified, and afterwards treated by ethyl alcohol. After the purchase, classifying and primary washing, sour cherries are secondarily washed in fruit washing machines, and then transmitted to the treadmill where the workers separate leaves and stems. Sour cherry is transported to the fruit graders, using the elevator, and then graded according to size in the range of 13-35 mm. Such sour cherry is immediately ready for deposition in 80% volume ethyl alcohol, in 160 liter barrels which are closed by the original covers. The ratio of sour cherry and ethyl alcohol in barrels is 50: 50%. After 40-50 days, the concentration of ethyl alcohol in barrels with sour cherry is lowered to 22-25%. Such sour cherry is removed, graded again and sent to pitting, so that the product is ready for distribution to the customer.

Note: *The concentration of 22-25% ethyl alcohol which is to be found in barrel with sour cherries, is not considered a hazardous substance for fire occurrence.*

Figure2. *Transporter -treadmill*

Admission and intake of alcohol

Rectified ethyl alcohol of 96% VOL is transported by a closed cistern weighing up to 30t. After being admitted, the tanks are dispensed (total amount of alcohol) using mono pumps (closed system). Alcohol is dispensed through a hose pump into a 40,000 liters tank, which is set on a concrete base (static). Static tank is plastic and made of strong material, resistant to high and low temperatures and impact. After alcohol is dispensed from the moving truck tank (made of stainless steel) in a static cistern, the valves on the tanks are closed, and pumps are removed

- Alcohol is stored in the static tank where absolute ethanol is stirred by adding water in order to reduce the concentration of alcohol from 80 to 82% vol. The stirring process with two stitching poles creates a blend of alcohol and water and the concentration is reduced to 80% vol.
- After blending, alcohol is poured into 2,500 gallon tanks using mono pumps, and unloaded into 160 liter barrels using a valve.
- The balanced amount of alcohol in 160 liter barrels is brought to production, where sour cherries are being sunk (washed and graded). After sinking, sour cherries are stirred 2-3 times within 45-50 days where the alcohol concentration drops to 23-25% VOL. After osmosis is completed and alcohol concentration is reduced, sour cherries are re-graded, and then, if necessary, plucked and welled for delivery as stoneless sour cherries in alcohol.

Table 1. *Physical-chemical characteristics of ethyl alcohol*

Ethyl alcohol – absolute (C_2H_5OH)	
The molar mass	46 g/mol
Appearance	Colorless clear liquid
Solubility in water	Complete
Density	0,789 g/cm^3
Boiling point	78,4 ºC
Dynamic viscosity	1,2 mPas
Acidity (Pka)	15,9
EU Classification	Flammable (F)
Flash point	13 ºC
Combustion heat	31,1 MJ/kg (23,5MJ/lit)
Vapour pressure	5,866 kPa
Vapour density	1,59
Limits of explosive mixtures	3,3-1,9 % vol
Autoignition temperature	425 ºC

THE ANALYSIS OF FIRE RISK AND FIRE LOAD

The measure of fire risk in a given building is most commonly fire load density.

Fire load (SRPS U.J1.030) is the value of total heat energy that can be released during the burning of combustible material present in the room (the production hall, warehouse, fire sector or entire building) or outdoors. Fire load also covers combustible structural elements of the building.

The specific fire load of the building is calculated according to the following formula

$$P_i = \frac{\sum \rho_i \cdot V \cdot H_i}{S}$$

Where:

$P_i\ [\frac{kJ}{m^2}]$ - specific fire load,

$\rho_i \left[\frac{kg}{m^3}\right]$ - bulk density of material,,

$V_i \left[m^3\right]$ - volume of material,

$S\left[m^2\right]$ - base surface

$H_i \left[\frac{kJ}{kg}\right]$ - heating value of combustible materials.

The calculation includes all combustible materials in terms of SRPS U.J1.020 standard.

The calculation of the fire load is done by the following formula:

$$Po = \frac{G1 \cdot K1 + G2 \cdot K2 + \ldots Gn \cdot Kn}{F}$$

Where:

P_0 - fire load (GJ/m^2)

G1, G2, Gn - total weight of some combustible materials (kg)

K1, K2, Kn - heating value of combustible material (J/kg)

F - building area (m^2)

- This standard defines three groups of specific fire load:
- **low** fire load - up to 1GJ/m^2,
- **moderate** fire load - up to 2 GJ/m^2 i
- **high** fire load over 2 GJ/m^2.

Fire load density

Ground floor

Number of barrels - 300 pieces

Quantity of alcohol - 35 kg/ vessels

Plastic vessel - G1=5x300=1500 kg K1=42 MJ/kg

Alcohol - 35x300=10500 kg K2=25 MJ/kg

Surface of the premise - 504,99 m^2

P_0=(1500x42+10500x25)/504,99=644,567 MJ/m^2

Floor

Fire load on the floor is calculated according to Annex 2 (Amendments 1/88). Collection of Federal Regulations in the field of fire and explosion with explanations for practical application.

Restaurant - 251MJ/m^2

From the above examples and the use of the facility, it can be concluded that fire load in the processing and manufacturing facility P + 1 is **LOW.**

Based on the already completed classification of technological processes in the 5th group of the Collections of fire safety regulations, page 47, the amount of fire load in technological process of sour cherries in alcohol is 504 MJ/m^2, Class 2 Hazard.

*Fire load density of 504 MJ/m^2 for the production of sour cherries in alcohol classifies this facility as having a **low fire load**.*

Fire danger in the facility

According to the Requirements for the hydrant network, Official Gazette, No.30/91, alcohol treatment facilities belong to K2 category of technological process in terms of fire risk.

In this case, the processing-plant for production of alcoholized sour cherries is classified Fire hazard, Class 2.

The degree of fire resistance

These data and the assessments are precauations for protection during the design of the architectural construction of the project. Therefore, this facility is considered as having level 4 of resistance (SRPS.U.J1.240), which necessitate the following features of the facility:

Table 2. *The degree of fire resistance*

Type of building structure	Fire resistance (h)
Bearing walls	2,0
The supporting pillars	2,0
Shoring beams	1,5
The roof covering	3/4
Non-bearing walls	1/2
Openings	1,0

Calculation of fire risk in the building

Fire risk depends on the potential fire intensity and fire duration, as well as on the structural characteristics of the building, and is calculated according to the formula:

$$Ro = \frac{Po \cdot C + Pk \cdot B \cdot L \cdot S}{W \cdot Ri} = \frac{1{,}4 \cdot 1{,}4 + 0{,}2 \cdot 1 \cdot 1 \cdot 1}{1{,}8 \cdot 1{,}3} = 0{,}923$$

Where:

R_0 - fire risk index within the building,
P_0 – fire risk index of building contents,
C - burnability index of building contents,
P_k - the index of fire load of the material embedded in the building structure,
B - the index of the size and the position of the fire sector,
L - extinguishment delay index,
S - fire sector width index,
W - fire resistance index of the bearing structure of the building, and
R_i - risk reduction index.

Fire risk of the building content is as follows

$$R_s = H \cdot D \cdot F = 2 \cdot 2 \cdot 1{,}5 = 6$$

Where:

H - human risk index
D - asset risk index and
F - fume index.

To obtain the value of fire risks for the facility "Ro" and fire risk of the building content of the facility "Rs", we have determined the design point using the included diagram and the known abscissa (fire risk of the content of the building) and the ordinate (fire risk for buidlings). When a point is in E and F parts of the diagram, it is justified to set up stable fire-extinguishing system based on the building fire risk. If by calculation we have obtained the point in A, B, C or D parts of the diagram, it is necessary to take measures such as, for example, replacement of the basic structural elements, reducing the fire load in the building, establishing the appropriate fire units or others.

A - The risk is very small, preventive measures for fire protection are sufficient.

B - Automatic fire extinguishing systems and alarm system is not required.

C - The system for automatic shutdown is required, the system does not alarm.

D - Requires a fire alarm system, stable extinguishing systems do not.

E - It is recommended to double protection (installation of fire detection and extinguishing system stable) in the E1 system is required for fire, E2 is required for installation of fire alarm systems.

F - Obligatory double protection.

R_o=0,923 i R_s=6 , **field D → Fire alarm system is required, stable extinguishing systems are not required.**

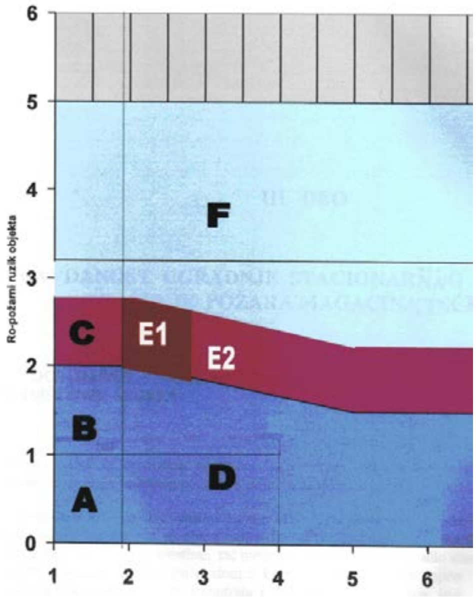

Figure 3. *Fire risk of the building*

THE SIMULATION IN THE SOFTWARE PACKAGE ALOHA

ALOHA (Areal Locations of Hazardous Atmospheres) is a modeling program that estimates threat zones, including the clouds of toxic gas, fire and explosions. The threat zone is an area where a hazard i.e. a risk (such as toxicity, flammability, thermal radiation or damaging overpressure) has exceeded a user-specified *Level of Interest*, the *Level of Risk* or the *Level of Concern* - LOC.

The main features of the programme are:

- The programme generates a variety of scenario-specific outputs scenarios, including threat threats at specific locations, and source strength graphs
- It calculates how quickly chemical are escaping (release) from tanks, puddles (on both land and water) and gas pipelines, and predicts how the release rate changes over time.
- It models many release scenarios: toxic gas clouds, BLEVE's (Boiling Liquid Expanding Vapor Explosions), jet fires, vapour cloud explosions, and pool fires
- It estimates various types of hazards (depending on the release scenario): toxicity, flammability, thermal radiation, and overpressure.

The task of this simulation is, by using software package ALOHA, to estimate the impact of fire and explosion of overhead tank for ethyl alcohol on personnel and property in the area, which would at the same time involve assessing the risk of fire or explosions.

Parameter simulation involved visualization which displayed the threat zones due to thermal radiation, the diagram of the thermal radiation at a given point in relation to the place of accident and the diagram of source strength.

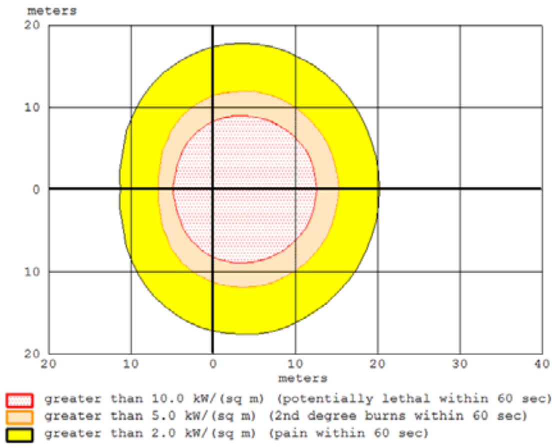

Figure 4. *Threat zones due to thermal radiation*

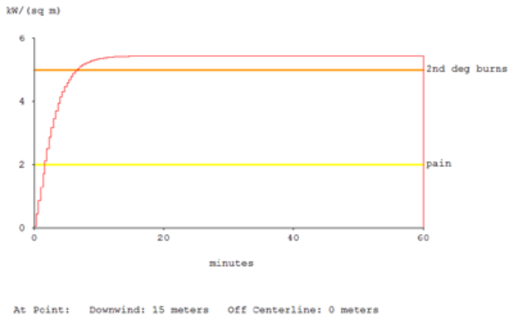

Figure 5. *Diagram of thermal radiation at a given point in relation to the place of accident*

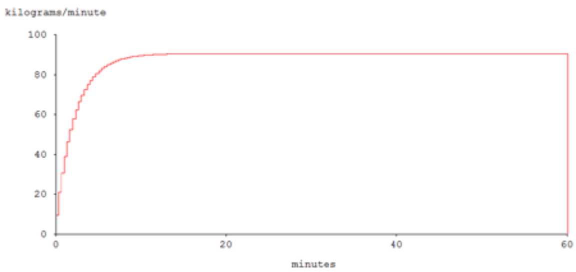

Figure 6. *Diagram of the source strength (release rate)*

CONCLUSION

Facilities for technological processes have an increased risk of fire and explosion if they happen to be the locations for handling combustible materials. These substances are the triggers of fire hazards and they can cause rapidly spreading fires with catastrophic consequences. In practice, there are different approaches and methodologies of fire risk assessment which depends on the objective and the purpose of risk assessment. In addition to the standard fire risk assessment within technological facilities, due to the development of information technologies, risk assessment and analysis are carried out with the aid of special programmes and models for making simulations. This enables a new and more significant approach to risk management which reducs the number of fires, human casualties, property damage and makes a cost-effective safety system.

A new approach to fire and explosion risk assessment within technological facilities enables successful predicting, assessment and making optimal decisions in fire protection.

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BIOGRAPHY

Tanja Jovanović was born in Prokuplje, Serbia, in 1982. She graduated from the Faculty of Occupational Safety in Nis, Department of Fire Safety. She is currently attending PhD studies at the Faculty of Occupational Safety. Her field of interest and research include risk management, fire and explosion risk assessment, fire safety systems. She has participated in the organization of a number of forums and conferences in this field.

ANALIZA I SIMULACIJA POŽARNOG RIZIKA OBJEKTA ZA PRERADU VOĆA „POBEDA“ U PROKUPLJU

Tanja Jovanović

Rezime: *U tehnološkom procesu proizvodnje višnje u alkoholu pojavljaju se zapaljive i eksplozivne materije koje mogu ugroziti zdravlje i bezbednost zaposlenih, čak i imati posledice širih razmera. U tom smislu, u radu je najpre data analiza i proračun požarne ugroženosti objekta u kome se odvija tehnološki proces i određen stepen požarne ugroženosti objekta, a zatim je softverskim paketom ALOHA izvršeno određivanje zona opasnosti usled akcidentne situacije požara i eksplozije nadzemnog rezervoara za etil alkohol. Na ovaj način se dobija uvid u potencijalne uzroke požara i požarne opasnosti. Zahvaljujući rezultatima koji se dobijaju iz simulacije preko programa ALOHA i proračuna požarne ugroženosti mogu se utvrditi konkretnije mere u cilju smanjenja rizika od požara i eksplozija.*

Ključne reči: požarna ugroženost, ALOHA, rizik od požara i eksplozija.