Stable Fire Extinguishing Installations with CO₂ Fire Extinguishers

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Stabile systems for fire protection present very important and powerful way for fire protection. The realization of these protection systems can be on different ways and with different fire extinguishers. Fire extinguishers that can be used in these protection systems are water, CO₂, dust, foam, inergen, halon or some „new fire extinguishers“. The biggest meaning of these systems usage is in the fact that they can be used in cases of human or fire fighters absence, in cases when is important to „cover“ large space or volume, in cases where problems and difficulties with fire mobile equipment exist, in cases when fire extinguishers quantity can be small etc. The way of realization of these systems depend from many different factors. This paper was written to present the stabile systems for fire protection with CO₂ extinguishers and FDS computer simulation of extinguishing with this kind of stabile fire protection system.

Key words: fire, extinguishing, CO₂, simulation

1. INTRODUCTION

The main role of stabile systems for fire extinguishing is in the right-timed fire detection and immediate onset of the fire extinguishing. They are very complex, in the sense of design, construction and realisation. They have many different parts-elements on which the functioning the whole system depends from. These include automatic and manual fire detectors, central device for fire detection, different sound and light alarming devices, appropriate electrical installations, appropriate power supply devices and many other additional devices. Examples of the effects of stabile systems are presented on figure 1.

These fire protection systems use different fire extinguishers. In dependence of which fire extinguisher is used, there are fire protection systems that use water as fire extinguisher (sprinkler and drencher types), stabile systems that use foam as fire extinguisher, stabile systems that use CO₂ gas as fire extinguisher, stabile systems that use inergen (the mixture of argon, nitrogen and carbon dioxide) as fire extinguisher, stabile systems that use halons as fire extinguisher, sta-

bile systems that use dust as fire extinguisher, stabile systems that use pyrotechnic generated aerosols etc. The main characteristic of stabile systems is in the fact that they have complete autonomy in work, without human presence, although they can be activated manual.

This way compensates the time that takes for fire-fighters to arrive, because by the time of their arrival, fire extinguishing has already started. An example of stabile system that uses foam as fire extinguisher is presented on figure 1 [1-4].

Figure 1 - Stabile system for fire protection that uses foam as fire extinguisher (image taken from: *Stable extinguishing systems, Tošić A.*)

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2. STABLE SYSTEMS THAT USE CO₂ AS FIRE EXTINGUISHER

Stabile systems that use CO₂ gas as fire extinguishers, generally, can be realised as systems for complete and partial protection and they are intended for volume-three dimensional extinguishing. The complete protection implies extinguishing of completely protected space, while the partial protection implies extinguishing only one part of the protected space, some part of equipment or some part of device in some space, room or object.

Figure 2 - Stable system for fire protection that uses halon as fire extinguisher (slika preuzeta iz: Stalini sistemi za gašenje, Tošić A.)

Stabile systems for complete protection are intended for fire extinguishing in rooms where complete space of gaps that cannot be closed doesn't exceed more than 3% of room's volume. There are systems of pipes and nozzles intended for CO₂ supply. It is very important that every technological production process must be stopped, so as every airflow caused by ventilation, before the activation of stabile system. All doors, windows and other gaps must be automatically closed, what is necessary for generation of enough quantity of CO₂ gas. In the case that some of gaps cannot be closed, then protected screens must be predicted. Stabile systems with CO₂ for partial protection are intended in cases when the complete protection is not justifiable, because of technical or economic reasons. The installation for fire extinguishing with CO₂ gas is presented on figure 3.

Figure 3 - The installation for fire extinguishing with CO₂ gas

It is very important to note that, in the cases when the partial protection is applied, much more quantity of CO₂ gas is needed for generation of enough quantity for extinguishing than in the cases when complete protection is applied.

The activation of these systems is realised by fire signal from the central for fire detection. At this moment, the electromechanical trigger (marked on figure 2 as 5) opens two bottles with CO₂ gas. These bottles present so called „pilot” bottles and they serve to open the other bottles supplied with CO₂ by pneumatic valve. Before the electromechanical trigger activation, the distribution valve opens on pipeline that leads to the volume. The way of storing of bottles with CO₂ gas is presented on figure 4.

Figure 4 - The bottles of CO₂ located in special room for stabile installation (figure source: http://www.spectra.co.rs/images/articles/263_4.JPG)

Related to the activation way, the next systems exist:

- A-manual systems,
- B-mechanical systems,
- C-mechanic-pneumatic systems,
- D-mechanical-electrical systems and
- E-electrical-electrical systems.

System marked as A presents manual system while the rest systems, marked as B, C, D and E present automatic systems. Of course, this division is not general that implies that some systems can be combined. That can be applied in cases when more rooms must be protected from the same group of bottles, but with different fire indication. Related to different conditions, the main elements for fire activation would not be the same.

The main elements of automatic stabile fire protection systems that use CO₂ as fire extinguisher are: the group of bottles with CO₂ or CO₂ tank, different pipes, pneumatic and mechanic valves for bottles, different rubber guts, scales, electro-mechanical trigger, different levers, mechanisms and boxes.

The designing of these systems must be realised related to appropriate standards and laws. Very important task and problem for these systems is to calculate the complete quantity of CO₂ gas needed for extinguishing. The least quantities of this gas needed for complete protection related to different parameters are defined by technical regulations. The spaces where CO₂ bottles can be located, can be realised by one or two rows of bottles. It is important to note that CO₂ gas stored in bottles cannot be used for any other technical needs, while the CO₂ gas stored in tank can be used for some other technical needs. No matter the CO₂ gas is in the bottles or tanks, they must be subjected to regular and extraordinary inspections and testing. One of the potential thing that can be occurred as a consequence of CO₂ running out in hermetic closed volumes is the pressure increment.

Because of that reason, the safety outlets and gaps must be predicted. It is also important that pipelines and all parts that present elements of pipelines must be made from appropriate material that is protected from corrosion. The calculation of pipeline dimensions is a very difficult task because it depends from many factors (height, pressure decrement etc...). Pipelines must be connected with ground in electrical sense.

The special elements of these systems present nozzles. These elements serve to spray the CO₂ gas and direct it on fire. Related to a proper calculation, the number and arrangement of nozzles are determined. Of course, every nozzle must provide equal flow of CO₂ gas. According to some calculations, one nozzle is enough to cover the space about 30 m². The intersection of nozzle gap depends directly from the quantity of CO₂ gas that needs to flow through it. The smallest intersection of nozzle gap can be 7 mm.

If stabile installation with CO₂ gas must be installed in rooms with big height (more than 5 m), nozzles must be located on height that is equal with one third of room's height. Those nozzles must provide condition that 35 % of complete quantity of CO₂ gas runs out through that nozzles and the reason for that is the fact that this gas must be enough and evenly distributed. Very important factor for stabile systems with CO₂ gas is the correct calculated time of CO₂ leaking.

Those systems must be properly tested, and it is usually realised with ten percentages of complete CO₂ quantity and at least two bottles, one time in one year. If rooms contain explosive atmospheres, then there is no testing in such rooms.

These systems must possess appropriate technical documentation and manuals for correct usage-installation of system, preparing and starting of system, warnings, alarms, failure elimination etc. There also must

exist so called „control book” where every kind of information related to functioning and maintaining must be recorded.

Stabile systems with CO₂ gas that imply huge quantity of CO₂ use big cold tank for CO₂ storing. CO₂ low-pressure tank with scale, for storing of big quantities of CO₂ gas is presented on figure 5 [5-8].

Figure 5 - CO₂ low-pressure tank with scale (figure source: [6], pp. 527).

3. SIMULATION MODEL

Simulation model realized in this paper was realized in FDS software (version 6.6). The purpose of this software is to simulate the fire and smoke propagation in the object and to simulate spreading of CO₂ gas on safety, secure, cheap and correct way. The simulation enables the presentation of temperature decrease with expanding of CO₂ gas.

Simulated object presented room with dimensions 25 m x 25 m x 3 m. Whole simulation object was built from concrete. In the centre of the object was transformer located. Transformer was built from steel and iron, with determinate quantity of oil. The dimensions of the space that transformer occupied were 8 m x 8 m x 1,5 m.

Fire in the object was formed as burner in form of rectangle with dimensions of 1 m x 0.5 m and HRR (Heat release rate per area) of burner 2500 kW/m². The burner's position was in the middle of the room. The CO₂ nozzles were located on the ceiling. According to the noted fact that one nozzle should cover at least 30 m² of space, the number of nozzles in simulation was 25.

Figure 6 - 3 D simulation model of the object in FDS

The activation temperature was set to 68 °C. The ambient conditions in the room were set to be normal (temperature, pressure and humidity). The complete object was pressurized. The 3D simulation model of the object in FDS is presented on figure 6 [9].

4. SIMULATION RESULTS

For realization of simulations was used laptop Lenovo Yoga C930, Intel Core i7-8550U quad-core processor, 12 GB of RAM memory and 256 GB Solid-state drive (SSD).

The duration of the whole simulation was set to 200 seconds. The reason for this was the fact that complete permeation with CO₂ gas should be finished for two minutes. Because of paper limitations in sense of paper pages, only some of simulation results are presented on figures from 7 to 15.

Simulations of fire in some periods are presented on figures from 7 to 10.

Simulations of CO₂ effects, from the start of the CO₂ leakage until the fire suppression are presented on figures from 11 to 16.

Figure 7 - Simulation of the early stage of fire on transformer after 25 seconds from the simulation start

Figure 8 - Simulation of fire on transformer after 50 seconds from the simulation start

Figure 9 - Simulation of fire on transformer after 75 seconds from the simulation start

Figure 10 - Simulation of fire on transformer after 185 seconds from the simulation start

Figure 11 - The start of the CO₂ gas leakage in the room through nozzles

Figure 12 - CO₂ gas leakage in the room through nozzles after 65 seconds from the start of the simulation and fire

Figure 13 - CO₂ gas leakage in the room through nozzles after 89 seconds from the start of the simulation and fire

Figure 14 - CO₂ gas leakage in the room through nozzles after 122 seconds from the start of the simulation and fire

Figure 15 - CO₂ gas leakage in the room through nozzles after 165 seconds from the start of the simulation and fire

Figure 16 - Complete volume of room filled with CO₂ gas after 200 seconds from the start of the simulation and fire

Temperature changes are presented on figure 17 to 20.

Figure 17 - Temperature around the transformer in the moment of maximal burning

Figure 18 - Temperature around the transformer after 20 seconds from maximal burning

Figure 19 - Temperature around the transformer after 42 seconds from maximal burning

Figure 20 - Temperature around the transformer after 80 seconds from maximal burning

5. ANALYSIS OF THE RESULTS

Figures from 7 to 10 present fire spreading with smoke and flame, from the beginning of the simulation to the end of the simulation. CO₂ nozzles will start leaking after temperature on detector of 68 °C.

Figures from 11 to 16 present CO₂ leaking, from the moment of detectors reaction to the end. According to the rules, the permeation of fire sector must be realized for the time of two minutes. The quantities of CO₂ gas needed for fire protection were calculated and presented on tables from 1 to 3.

In the cases when the room's noted in table 1 serve to store special materials, such as materials noted in table 2, then needed quantities of CO₂ gas noted in

table 1 are not enough and must be multiplied by the factor presented in the second column of table 2.

Table 1. Needed quantity of CO₂ gas related to room's volume (table source: [8])

Room's volume [m ³]	CO ₂ quantity [kg/m ³]
From 1 to 100	1.00
From 100 to 300	0.95
From 300 to 500	0.90
From 500 to 1000	0.85
From 1000 to 1050	0.80
From 1500 to 2000	0.75
Over 200	0.7

Table 2. Correction factors for needed quantities of CO₂ gas for special materials (table source: [8])

Material	Factor
C ₂ H ₅ OH	1.30
C ₄ H ₁₀ O	1.45
C ₂ H ₄	1.55
C ₂ H ₄ O	1.75
C ₂ H ₂	2.4
CO	2.5
CS ₂	2.5
H ₂	3.15

The quantities of CO₂ gas for some special plants are presented in table 3.

Table 3. Correction factors for needed quantities of CO₂ gas for special materials (table source: [8])

Type of plant	CO ₂ quantity [kg/m ³]
Transformer stations	2
Switching relays and devices	1.0
Lacquer plants	1.5
Drying furnaces with open aisles	1.5

Noted figures also show the right and gradual distribution of the CO₂ gas. Figures from 17 to 20 show the gradual decrease of room's temperature as a consequence of CO₂ gas influence. Already after 20 seconds from the time of maximum fire development (about 78 seconds from the simulation start), the temperature decreases because of the action of CO₂ gas. Simulation results related to temperature showed that fire was completely extinguished to the end of the total time set by the simulation.

6. CONCLUSION

Stable fire extinguishing installations with CO₂ fire extinguishers present very important and effective installations in fire protection. CO₂ gas eliminates fire in such a way that increases the concentration of CO₂ gas in the room and, at the same time, decreases the

concentration of oxygen. The efficiency of these systems depends from correct installation, what implies, at the first place, the right-time alarm, automatic closing of all openings, doors etc. and automatic stopping of all processes.

The usage of simulation software can be very useful in the sense of safety and cheapness. By the simulation usage, the determine fire can be simulated so as influence of fire extinguishers on fire, such as water and CO₂. It is possible to calculate needed quantities of fire extinguishers (water and CO₂) for fire extinguishing in some predicted time. Very important thing that can be predicted by simulation is fire and fire products spreading, what can be very dangerous in real [10-13].

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REZIME

STABILNE INSTALACIJE ZA GAŠENJE POŽARA POMOĆU CO₂

Stabilni sistemi za gašenje požara predstavljaju veoma važan i moćan način zaštite od požara. Realizacija ovih sistema zaštite može biti na različite načine i sa različitim sredstvima za gašenje. Sredstva za gašenje koja mogu biti korišćena u ovim sistemima zaštite su voda, CO₂, prah, pena, inergen, halon ili neka „nova sredstva za gašenje”. Najveći značaj upotrebe ovih sistema je u činjenici da ona mogu biti korišćena u prisustvu ljudi ili vatrogasaca, u slučajevima kada je važno „pokriti” veliki prostor ili zapreminu, u slučajevima gde postoje problem i poteškoće sa mobilnom opremom za gašenje požara, u slučajevima kada količina sredstava za gašenje može biti mala itd. Način realizacije ovih sistema zavisi od mnogo različitih faktora. Ovaj rad je napisan da prikaže stabilne sisteme za gašenje požara sa CO₂ sredstvima za gašenje i FDS kompjutersku simulaciju gašenja sa ovom vrstom sredstava za gašenje.

Ključne reči: požar, gašenje, CO₂, simulacija