Heat Detectors-Division, Positioning in Object and Simulation

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The main characteristics for early stage of fire are constant increase of temperature and heat releasing. Heat detection presents one of very important factors for fire detection. Heat detectors have a significant place according to other fire detectors. They could be realized as, according to the covered space, point detectors and linear detectors. This paper presents one of the possible ways of heat detectors positioning in object and simulation in PyroSim 2012 software.

Key words: *heat detectors, fire, simulation, object*

1. INTRODUCTION

The base purpose of fire protection systems is to provide information to the user about fire genesis in order to avoid human victims and material damage. For that reason, fire protection system consists of many different parts connected in one unique system. Precision and correct work of every part of fire protection system has crucial importance. Detectors present one of the main elements of all real time systems that collect data measuring material and energetic changes of supervised occurrence. Generally, detector implies three parts:

- Sensor part, which reacts on supervised parameters change,
- Converter part, which converts data from sensor into electrical dimension and
- Part for signal conditioning, which realizes amplification, filtration and normalization of signal gained from sensor.

Within the fire protection systems, the main role of fire detector is to detect fire at the early stage and prevents human victims and material damage.

The projecting of fire protection systems implies cognition of huge numbers of facts according to the object and possible development of fire. The most important results of the fire systems projection process are: the right choice of fire detector and its positioning into an object. For optimal results, it is very important to know the basic facts for fire development in closed space.

The fire, generally, presents uncontrolled and unpredictable process of heat propagation. One of the most important fire parameter is combustion. It presents the series of the chemical reactions between the fire material and oxygen, where the releasing of the heat, smoke and flame are present. To reach the combustion process, the presence of the all components of the fire triangle is required: fire material, heat source and oxygen, which means that the lack of any of noted components stops the combustion process. If the combustion process comes without influence of the external source, it could be defined as self trigger process. The combustion process consequence is the heat transfer. Considering the fire detection, it is very important fact that the heat, as the measure of the warming, presents the only parameter that could produce the signal which is not need to amplify. There were three basic mechanisms of the heat transfer: conduction, convection and radiation. The heat transfer ways are presented on figure 1.

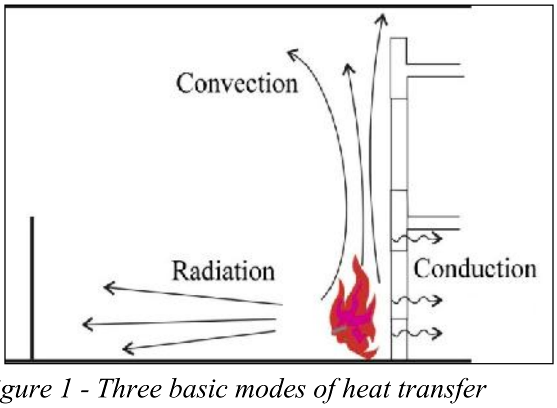

Figure 1 - Three basic modes of heat transfer

The fire is characterized with big number of parameters. These are parameters that characterize burning

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zone, heat effect zone and smoke zone. From detection aspect, material and energetic converts are very important because their products present fire dimensions that could be used for success and precise fire detection. The development time and combustion products that were made in fire present the base for fire detection and information. The combustion products, from detection aspects, could be presented as on figure 2.

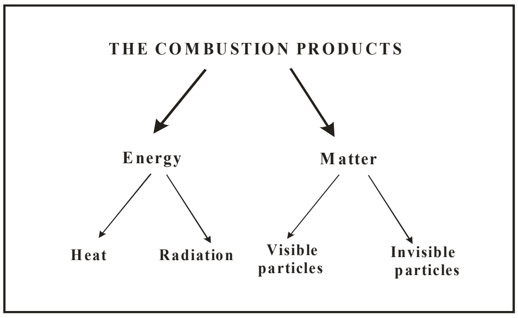

Figure 2 - Combustion products from detection aspect

Depending on the quantity of burning material and ventilation into room, the fire development crosses through several phases after ignition. There are three fire phases that could be noticed:

- Fire development phase,
- Complete developed fire phase,
- Fire pacification phase.

The main role of fire system is to detect fire at the early stage. According to the detection and information aspects, the early stage could be divided on four phases. These phases are presented on figure 3.

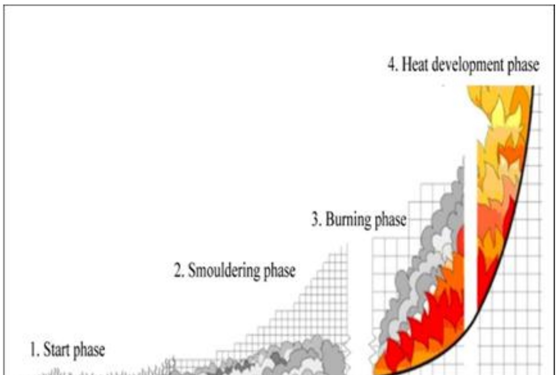

Figure 3 - Fire phases after ignition from detection aspect

One of the most important parameters that becomes as the combustion process is smoke. The smoke presents the suspension of the liquid, solid and gas particles. According to the fire material and combustion conditions, every fire was followed by the releasing of some combustion products, which had a great appliance in the fire detection. The smoke is one of the most used fire dimensions for fire detection because it develops at the early stage of fire.

The flame also presents very important factor for fire detection. It implies gas environment where the physical and chemical reactions of the reactants participator are happening. Every flame, no mater of fire type, is characterized by two characteristics: the presence of the high temperature area (the combustion zone) and adequate gas current that realizes the transfer of mass and heat.

According to all noted, it could be concluded that the fire is characterized with the large number of parameters as the uncontrolled combustion process, which properties and specifications could be used for success detection and neutralization, but also it could be out of control and it could start to propagate unexpectedly. Noted fire parameters and combustion products have direct affect on fire classification. Fire detectors are projected to react on smoke, heat, flame or some combination of these parameters. Irrespective from the detectors type, the most important parameter which determinates efficiency of detection is complete response time of detector. This time is determined by methods based on mathematics fire models.

The fire detectors could be classified on different ways and according to different criteria (for example, according to the combustion product types, according to the detector effective zone, according to the detector activation mode etc.). One of those classifications is presented on figure 4.

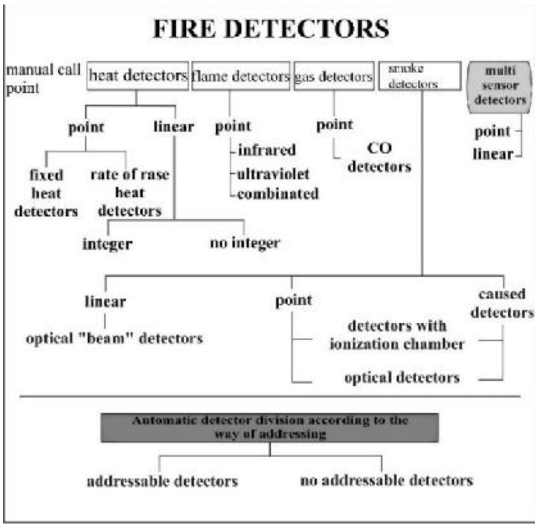

Figure 4 - Fire detectors division

One of the most frequently used detectors in fire protection systems are heat detectors [1, 4].

2. HEAT DETECTORS

Continuous heat release characterizes fire at early stage. This is, at the same time, followed by increase of temperature. Heat detection could be realized as, according to the covered area, point or linear heat detectors. No matter of realization ways, there are two conditions for alarm reaction: increase of temperature or increase of temperature change speed.

According to their construction, there was no unique principle of realization because the heat release could be detected on different ways. It implies that, as sensor element in heat detector circuit, could be used: sensor with two metals with different coefficient of dilatation, sensor with electric resistance temperature dependence, sensor of metal fusible pinchbeck, sensor with dispersal fluids, sensor as coaxial heat sensitive cable, sensor with magnetic induction temperature dependence, composite sensor element etc.

It is very important to note that heat detectors are less sensitive than other detectors, so they wouldn't be used for supervision of high rooms, workshops etc.

Point heat detectors could be divided on two groups: fixed heat detectors and rate of rise detectors. These detectors present the oldest type of automatic fire detectors. The best appliance of these detectors is in the small rooms and in the rooms where ambient conditions don't allow usage of other types of fire detectors.

The fixed heat detectors could be realized as thermo statically and thermo maximal. Rate of rise heat detectors could be realized as thermo differential.

Linear heat detectors could be applied in the tunnels, storages, hangars and other objects where one dimension is much higher then the other (for example, length is much higher than width).

They could be realized by using of electrical lines-typical and no typical, optical cables or net of capillary pipes. Earlier, it was possible only to determinate the fire disturbance by linear heat detectors in form of coaxial cables. Today, there are several ways to determinate the fire disturbance location. Also, the latest solutions based on optical cables give very good results for detection and determination of fire disturbance. Some applications of linear heat detectors dated since 1970 [5, 7].

3. HEAT DETECTORS POSITIONING

The selection of the right detector, their number and position in the object, are one of the most important and always open problems in fire protection.

The reduction of the range between detectors leads that the system sensibility becomes higher. It is important to note that increment of fire detector numbers over the optimal limit brings small gain according to the price of the system. Because of that, it is important to find an optimal relation between performance increment and price.

A point fire detector supervises circuit area with determinate diameter, where the maximal range between two detectors wouldn't be the same according to the direction.

An example of supervised area of point fire detector is presented on figure 5, where surface A presents the rectangle surface.

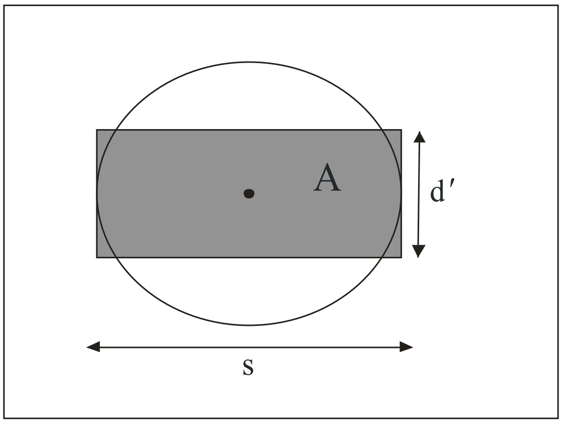

Figure 5 - Supervised area of the point fire detector

The supervised area of heat detectors, in the most of the western standards, was declared on 50 m^2. The general rule for needed number of heat detectors and their positioning is to divide the supervised area with detector supervised area. Of course, there are lots of other factors that should be considered, such as shape and slope of the roof, barriers, girt, walls positioning, installation positioning, positions of holes into the walls, room height etc.

The position of the detectors should be easy accessible, because of its testing and repairing. For example, British standard classifies supervised area into two categories, according to the room width with plane roof, for rooms with width up to 5 m and for rooms with width over 5 m.

Room height could be very important factor in heat detector determination. With height increase, the temperature falls down, the flame intensity decreases, the smoke density decreases. According to that factor, heat detectors could be divided into three classes:

- The first class-up to 7.5 m of room height,
- The second class-up to 6 m of room height,
- The third class-up to 4.5 m of room height.

In the passages or corridors, heat detectors should be positioned on that way that theirs between ranges could be 10 m. Also, at the place of corridors or passages crossing, the detector could be positioned without chance to overreach the maximal allowed supervised areas. According to British standard, the range between heat detectors in the corridors or passages is presented in table 1.

Table 1. Maximal range between heat detectors in the corridors according to the British standard

Corridor width [m]	Maximal range between heat detectors [m]
1.2	14.4
1.6	14.0
2.0	13.5
2.4	13.0
2.8	12.5
3.2	12.0
3.6	11.5
4.0	10.9
4.4	10.3
4.8	9.7

American standard NFPA is one of the standards which on the most comprehensive and the most detail way regulates problem of fire detection. Regardless to noted fact, this standard also has a lot of regulates that are significantly different from other regulates from similar standards. The projecting regulates of fire detection systems are located in one unique document together with rules according to the fire extinguished systems, NPB 88-2001 (Нормы пожарной безопасност НПБ 88-2001). For example, according to this document, rules for point heat detectors are presented in table 2.

Table 2. Rules for point heat detectors positioning

Room height [m]	Detector supervised area [m^2]	Maximal range [m]	
		between detectors	detector from wall
up to 3.5	up to 25	5.0	2.5
3.5-6.0	up to 20	4.5	2.0
6.0-9.0	up to 15	4.0	2.0

Based of all noted facts, the problem of detectors selection and its positioning depends of many different factors that could appear for some specific object [8, 10].

4. SIMULATION

The fire simulation was realized within large project of fire simulation and evacuation simulation in Electro technical school "Nikola Tesla" in Niš. The simulation was realized in PyroSim software. The large results of this project were published in some earlier papers [11, 14]. Inventary at the simulation model was presented according to its real materials. The complete simulation model with all inventary is presented on figure 6.

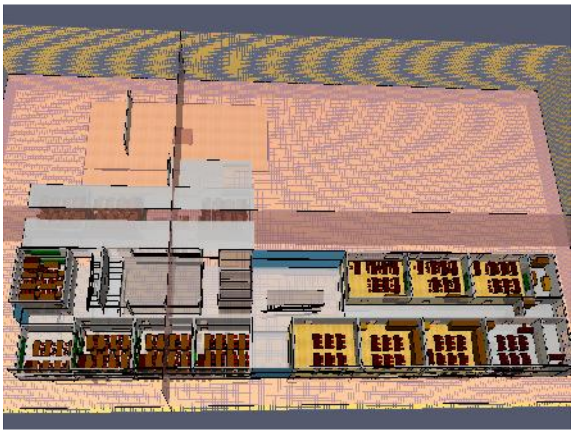

Figure 6 - Simulation model of the Electro technical school "Nikola Tesla" in Niš, in PyroSim 2012 software

Simulation implied fire simulation at the second floor of the laboratory part of Electro technical school "Nikola Tesla" in Niš. The fire source was positioned at laboratories 112, 113 and 101 at different places and on different heights, and it was simulated as burner with dimensions 1 m x 0.5 m and the heat release rate per area of the fire source was set to 500 kW/m^2. The simulation time was set to 240 seconds. Every laboratory had its own inventory, such as desks, chairs, tables, cupboards etc. The heat detectors were positioned according to the objects dimensions and it is presented on figure 7. For cleaner and better view of the second floor of the laboratory part of the Electro technical school "Nikola Tesla", the HIDE function in simulation software was used [15, 16].

Figure 7 - Simulation model of the second floor of the Electro technical school "Nikola Tesla" laboratory part, with positioned heat detectors (above view)

5. SIMULATION RESULTS

Simulation results for the first case, where the fire source was at cupboard in laboratory 112, at the height of 1.1 m were presented on figures from 8 to 15. The heat detectors were placed at every laboratory ceiling, on the height of 3 m. The reaction temperature for heat detectors was 74 ° C, while the response time index (RTI) was 100 $m^{½}s^{½}$. For example, EN 54 regulates reaction temperature for alarm of 57 ° C, but, in order to avoid false alarms, in practice, reaction temperature is relatively high (more than 70 ° C).

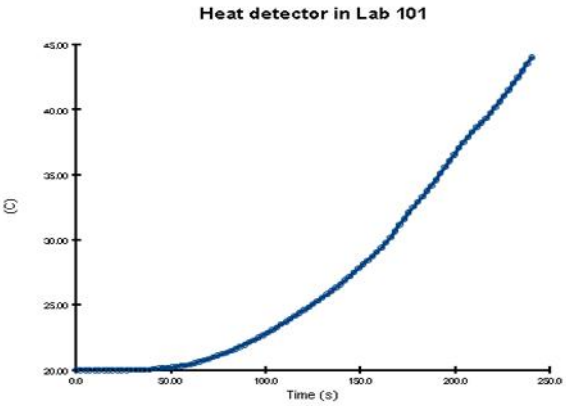

Figure 8 - Temperature results in the laboratory 101

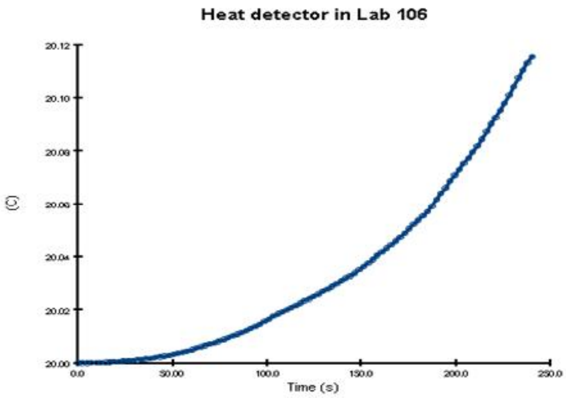

Figure 9 - Temperature results in the laboratory 106

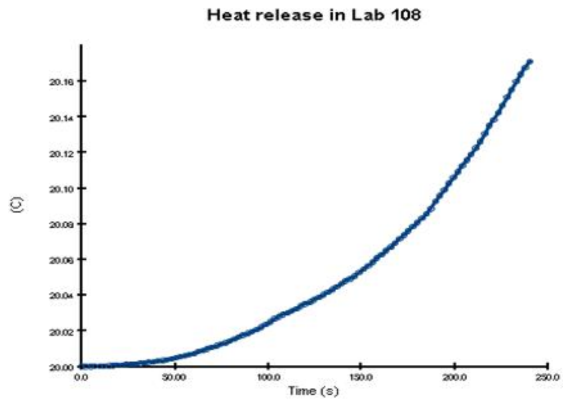

Figure 10 - Temperature results in the laboratory 108

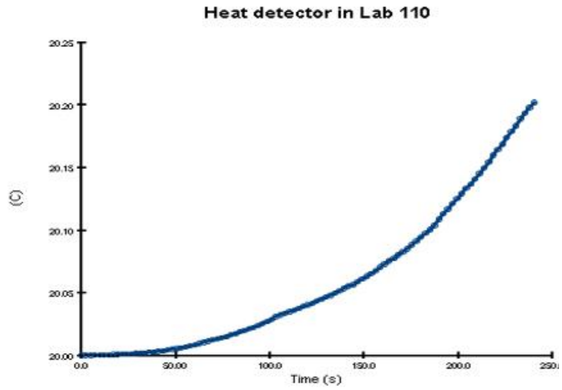

Figure 11 - Temperature results in the laboratory 110

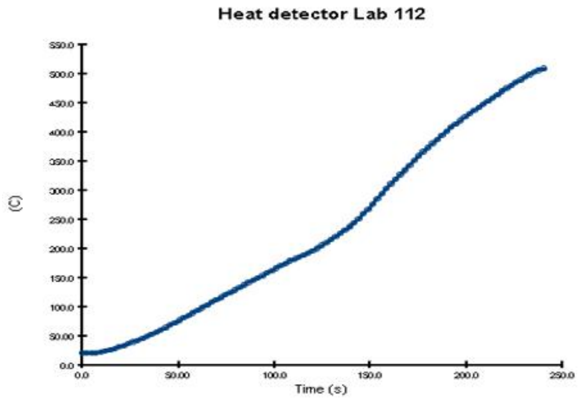

Figure 12 - Temperature results in the laboratory 112

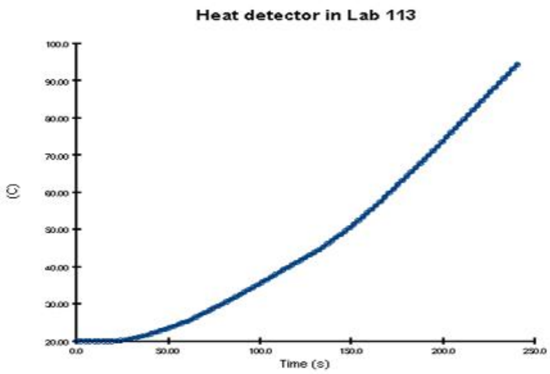

Figure 13 - Temperature results in the laboratory 113

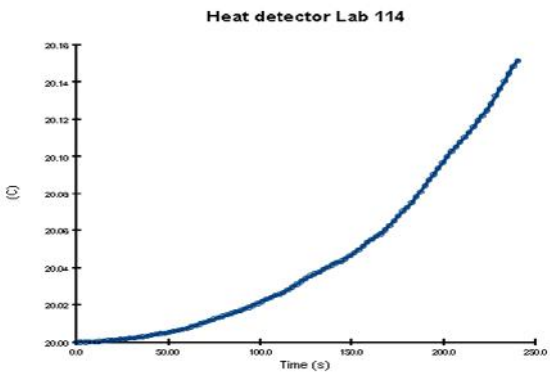

Figure 14 - Temperature results in the laboratory 114

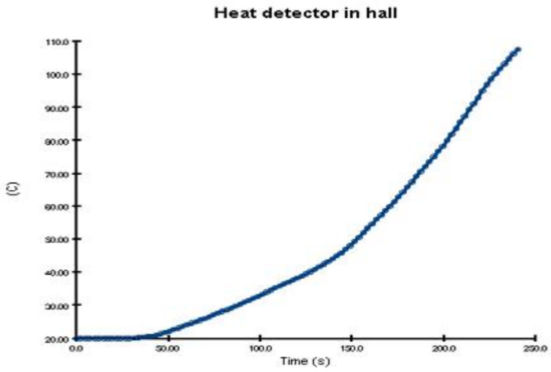

Figure 15 - Temperature results in the hall

Simulation results for the second case, where the fire source was at the floor in laboratory 113, near the wall with the entrance door, were presented on figures from 16 to 23. In this case, beside the fire flame, a lot of smoke was presented. The reason for that was the material that the floor was made of. As it was expected, the simulation results showed the biggest temperature increase and the biggest temperature value at the laboratory 113. Also, it could be noted that laboratory 113 was the only place where heat detector reacted (the temperature value reached over 74 ° C).

According to the prior case, it took more time for alarm temperature to react.

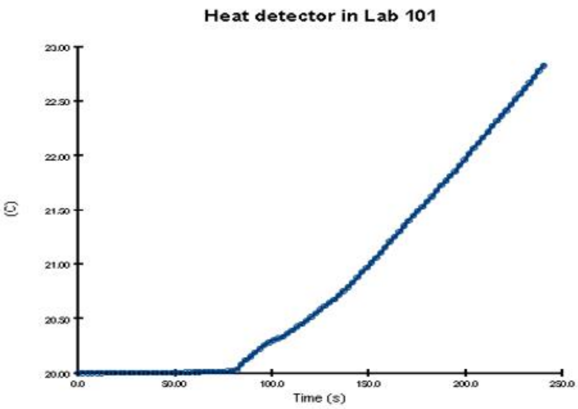

Figure 16 - Temperature results in the laboratory 101

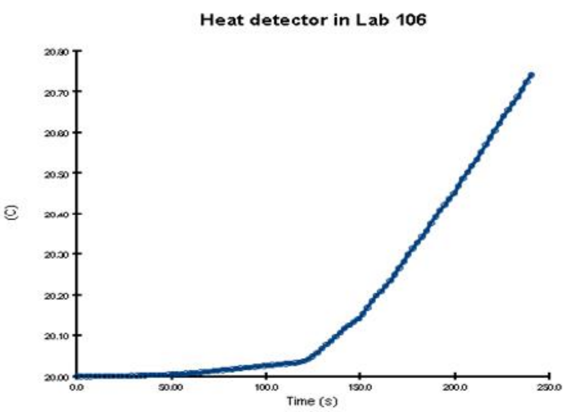

Figure 17 - Temperature results in the laboratory 106

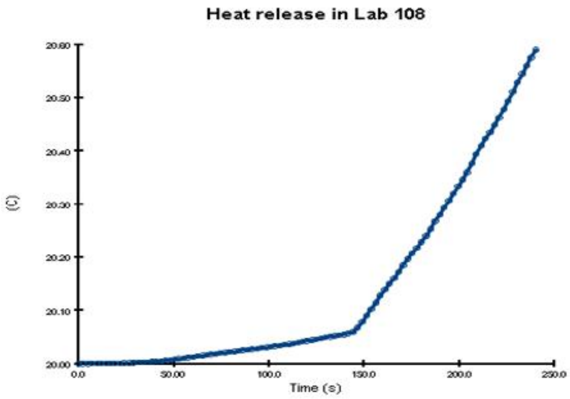

Figure 18 - Temperature results in the laboratory 108

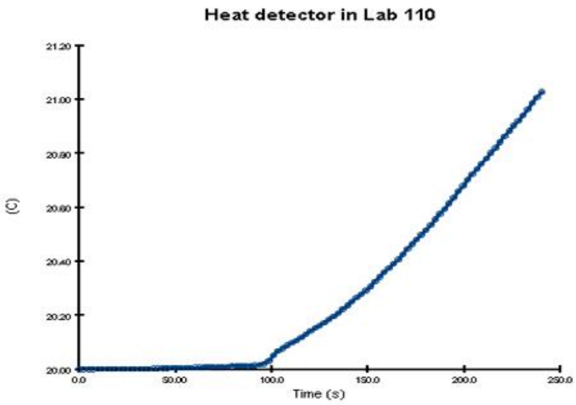

Figure 19 - Temperature results in the laboratory 110

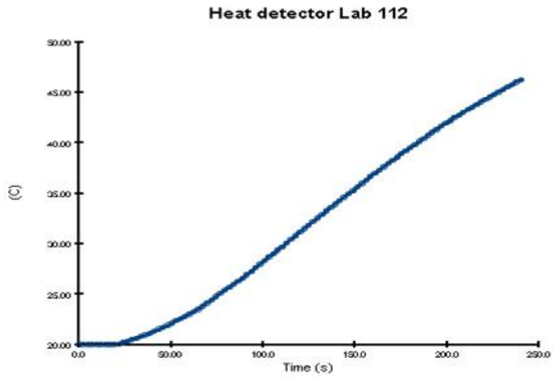

Figure 20 - Temperature results in the laboratory 112

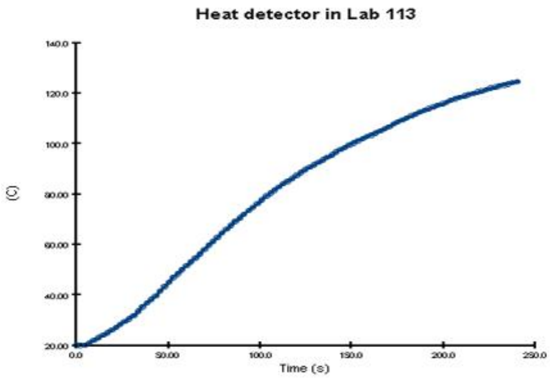

Figure 21 - Temperature results in the laboratory 113

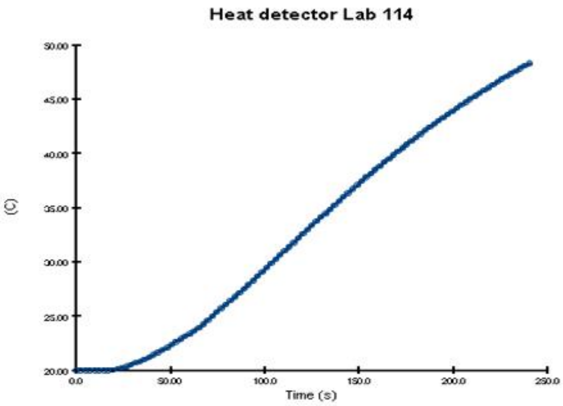

Figure 22 - Temperature results in the laboratory 114

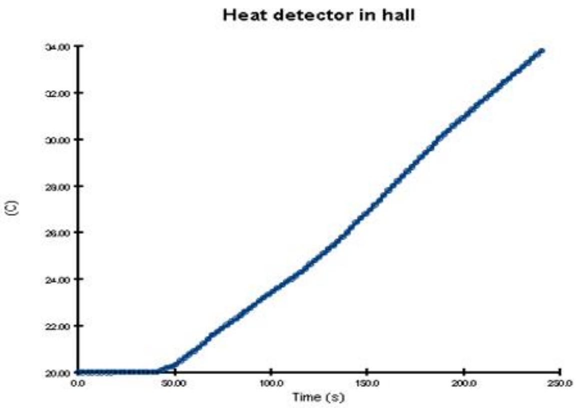

Figure 23 - Temperature results in the hall

Simulation results for the third case, where the fire source was at the floor in laboratory 101, near the wall with the outer windows, were presented on figures from 24 to 31. In this case, the fire source was the uttermost from the nearest detector. In this case, also, beside the fire flame, a lot of smoke was presented. As it was expected, the simulation results showed the biggest temperature increase and the biggest temperature value at the laboratory 101. Also, it could be noted that laboratory 101 was the only place where heat detector reacted (the temperature value reached over 74 ° C).

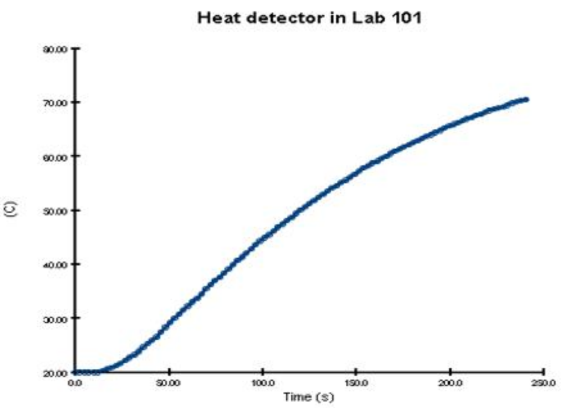

Figure 24 - Temperature results in the laboratory 101

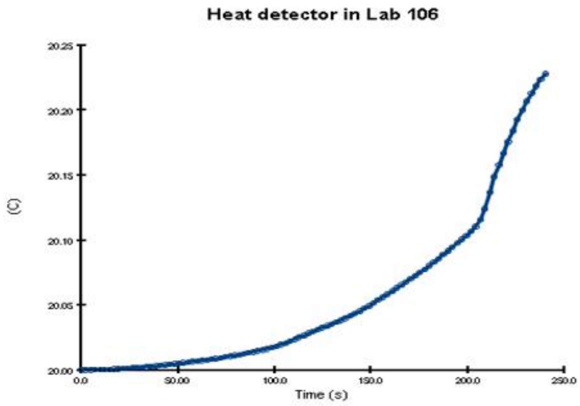

Figure 25 - Temperature results in the laboratory 106

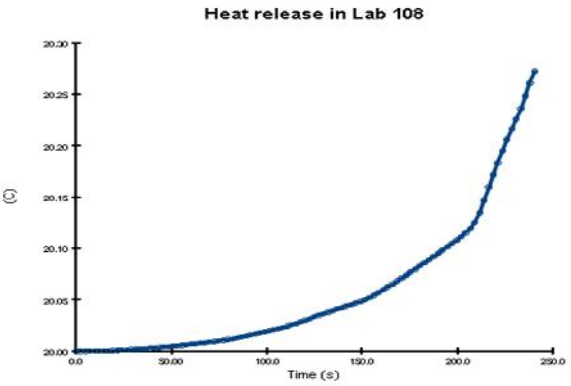

Figure 26 - Temperature results in the laboratory 108

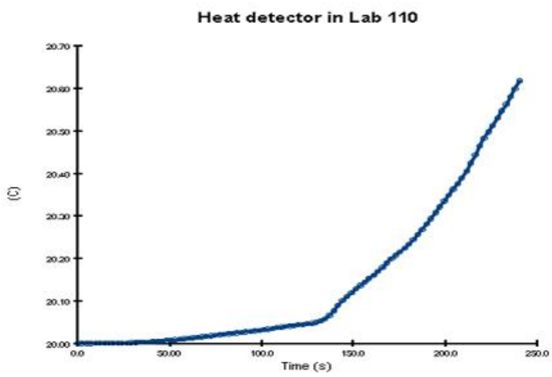

Figure 27 - Temperature results in the laboratory 110

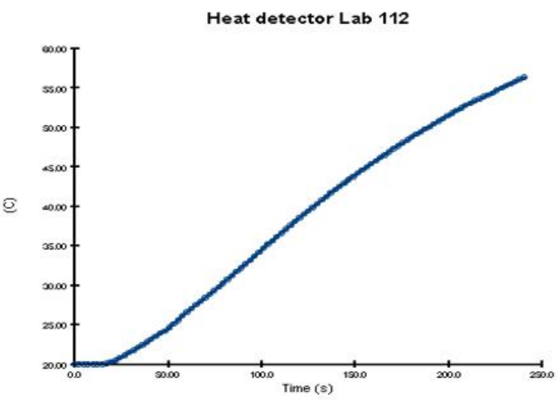

Figure 28 - Temperature results in the laboratory 112

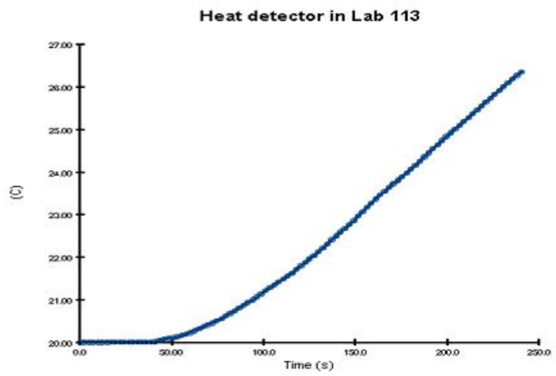

Figure 29 - Temperature results in the laboratory 113

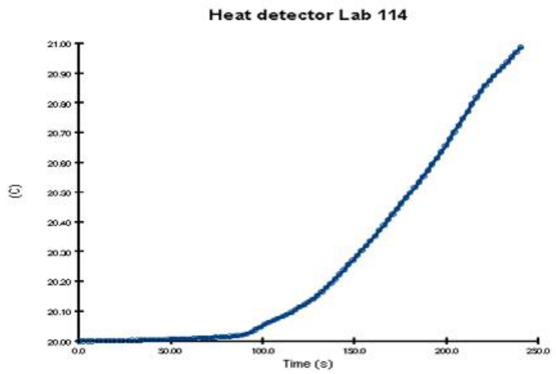

Figure 30 - Temperature results in the laboratory 114

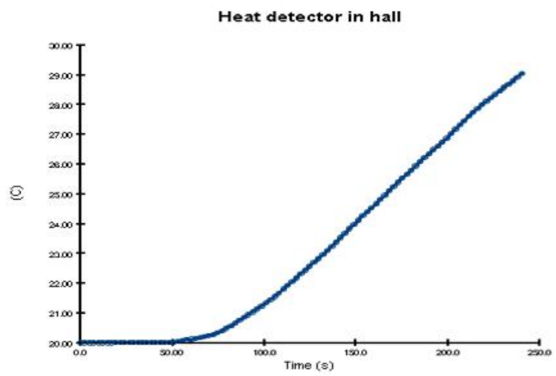

Figure 31 - Temperature results in the hall

6. DISCUSSION AND CONCLUSION

Simulation results showed that in all three cases, alarm reaction was achieved, for noted detectors locations. The biggest temperature was achieved in the first case, and the lowest in the third case. Simulation results clearly showed the other detectors states, in other laboratories and hall, when the fire in the particular laboratory was presented. Although this paper considered the usage of heat detectors, it is very important to note that different types of detectors could be used in combination for some cases. The main important case of everything is the fire detection at early stage. The different object could be very complex for adequate fire protection in sense of their geometry or some other parameter. It could includes the usage of bigger number of detectors, which often isn't optimal, because bigger number of detector doesn't have to mean better fire system sensibility, but does mean bigger price.

According to the position of detectors in object, there are several ways of detector's dispositions, such as triangle, hexagonal etc. But, in every case, it is not an easy task to provide optimal protection in sense security-price. Because of that, it is necessary to know the great number of different parameters and understand the ways of fire spreading and detectors work principles [17, 19].

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REZIME

JAVLJAČI TOPLOTE - PODELA, POSTAVLJANJE U OBJEKTU I SIMULACIJA

Glavne karakteristike požara u ranoj fazi su konstantno povećanje temperature i oslobađanje toplote. Detekcija toplote predstavlja jedan od veoma važnih faktora za dojavu požara. Detektori toplote zauzimaju značajno mesto u odnosu na ostale detektore požara. Mogu se realizovati kao, u zavisnosti od prostora koji se pokriva, tačkast detektori i linijski detektori. Ovaj rad predstavlja jedan od mogućih načina postavljanja detektore toplote u objektu i simulaciju u PyroSim 2012 programu.

Ključne reči: *detektori toplote, požar, simulacija, objekt*