PREGLEDNI RAD-Scientific review

On a flame detectors

O javljačima plamena

dr. sc. Radoje Jevtić

SUMMARY

Fire detectors have a great role in fire protection and present base elements of all systems in real time designed for the measuring of material and energetic occurrences. Fire detectors can be classified according to various factors and different criteria. Fires of some materials produce flames quite quickly. That flame is followed with a very small quantity of smoke, sometimes even none. Because of that, the only practical and effective solution for the detection of such types of fires are flame detectors. Flame detectors can also be used in open spaces and in objects with high ceilings. The main reason for that is the impossibility of smoke detection in given examples (the biggest problems are smoke dilution and convective flow cooling). Such types of fires spread rapidly, so it is important that flame detectors react quickly. For flame detection, infrared and ultraviolet parts of electromagnetic spectrum can be used. This paper was written to present the role of flame detectors in fire protection, and to present the principle of realisation of flame detectors and the rules of the installation of flame detectors arrangement according to valid standards.

Key words: flame, detector, fire, standard.

Sažetak

Detektori požara imaju veliku ulogu u zaštiti od požara i predstavljaju osnovne elemente svih sustava u realnom vremenu namijenjenih za mjerenje materijalnih i energetskih pojava. Detektori požara mogu biti klasificirani prema različitim faktorima i različitim kriterijima. Karakteristično je da požari nekih materijala proizvode

dr. sc. Radoje Jevtić, School for electrical engineering „Nikola Tesla", Aleksandra Medvedeva 18, 18000 Niš, Serbia, milan.jvtc@gmail.com

plamen vrlo brzo. Taj plamen je praćen s veoma malom količinom dima ili potpuno bez dima. Zbog toga, jedino praktično i efikasno rešenje za detekciju takvih požara su detektori plamena. Detektori plamena također mogu biti korišteni na otvorenom prostoru i u objektima s visokim potkrovljem. Glavni razlog je zato što detekcija dima u navedenim primjerima nije moguća (najveći problemi su razrijeđenost dima i hlađenje konvekcijskih strujanja). Navedeni tip požara ima vrlo brz razvoj tako da je važno da detektori plamena reagiraju vrlo brzo. Za detekciju plamena, infracrveni i ultraljubičasti dijelovi spektra mogu biti korišteni. Ovaj rad je napisan da predstavi ulogu detektora plamena u zaštiti od požara, predstavi princip realizacije detektora plamena i da predstavi pravila za postavljanje detektora plamena prema validnim standardima.

Ključne reči: *plamen, detektor, požar, standard.*

INTRODUCTION

Uvod

Fire as occurrence possesses many parameters that could be used for fire detection. Fire detectors present very important parts of fire protection systems. The role of fire detectors is to provide real time, precise and correct, information about fire genesis. Technically, every detector must have three parts: sensor (presents part that reacts on tracked changes), part for conversion (presents part that transforms information from sensor into determined electrical dimension) and part for signal conditioning (presents part that realizes different settings, amplifying, filtering etc.). They can be classified on different ways and related to different criteria (way of activation, work principle, number of states, response mode etc.).

It is known fact that materials that can be found in objects and their fire characteristics directly determinate fire detector`s type. Capability of fire detector on determined fire`s type can be identified by international standard ISO 7240-9: Test fires for fire detectors. This standard defined nine different types of fires with marks from TF1 to TF9. Beside this standard, European regulation classified all fires in six different types of fires with marks from TF1 to TF6 (Jevtić 2015).

Fires of materials such as oil, gasoline or similar materials are characterized with flame development, directly and very fast after their origin. Flame could have different colour and different temperature (as an example, candle flame products temperature of 1300-1400 °C while oxygen with acetylene in burner can product temperature higher than 3300°C). This flame is followed by small quantity of smoke or completely without smoke. Also, smouldering types of fires take a lot of time until the fire is completely developed. In this and similar cases, it is not possible to use fire products for fire detection. Those types of fire can be reliably detected only by flame detectors.

Flame detectors, as a special type of fire detectors, must have some characteristics. At the first place, the flame sensibility must be very high in order to provide detection in supervised area. Flame detectors must be insensitive on radiations that don't belong to fire in order to eliminate false alarms. False alarms could be caused by various sources: arcs welding, jet engine afterburner, flares, different hot objects, lightning etc. Also, flame detectors response speed must be enough to detect fires with fast development at the earliest stage.

The radiation of flame is very complex and it has different spectrum. This spectrum consists of continual radiation, linear spectrum and individual lines. Continual radiation presents spectrum part formed from heating of different solid and liquid particles (steam, dust, soot etc.) during incomplete combustion. This radiation is characterized with two pikes, one on 2.8 μm and other on 4.3 μm. Those pikes originate from steam and carbon dioxide. Linear part of spectrum is formed as result of chemical reactions in flame. Individual lines are formed as result of atomic transitions with outer energy effects (Blagojević 2015).

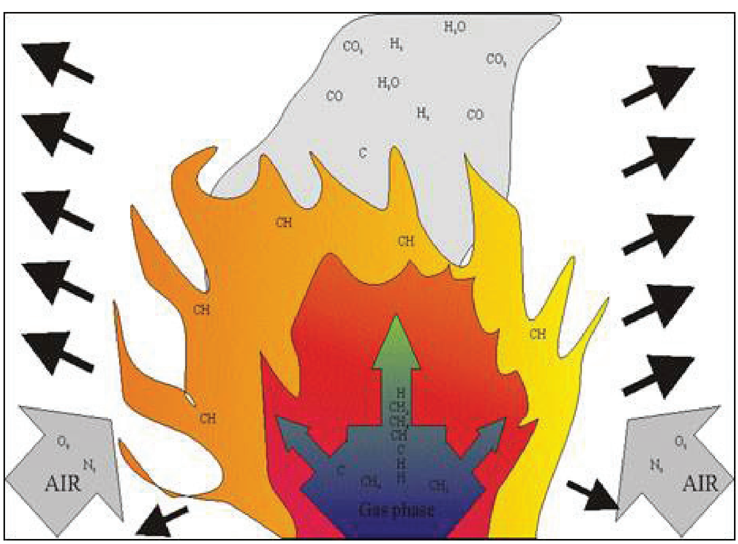

Figure 1. Fire structure

Slika 1. Struktura požara

Flame detectors are very proper for detection of hydrocarbons. This explains fire structure, presented on figure 1 and chemical reactions in fire.

As example, hydroxide (OH*) is formed as it presented on reactions 1 and 2, with emitting of radiation at 308 nm. As M in reaction (1) element that can be used as catalyst is presented.

$$H + O + M \rightarrow M + OH* \quad (1)$$

$$OH* \rightarrow OH + hv \quad (2)$$

Also, (CH*) is formed as it presented in reactions 3, 4 and 5, with emitting of radiation at 431 nm.

$$C_2 + OH \rightarrow CO + CH* \quad (3)$$

$$O + C2H \rightarrow CH* + CO \quad (4)$$

$$O_2 + C_2H \rightarrow CH* + CO_2 \quad (5)$$

The limits of this paper don't allow presentation of every reaction and every radiation spectrum. Of course, it is possible to present adequate spectrum form for some specific fuel. As example, a typical hydrocarbon fire is presented on figure 2.

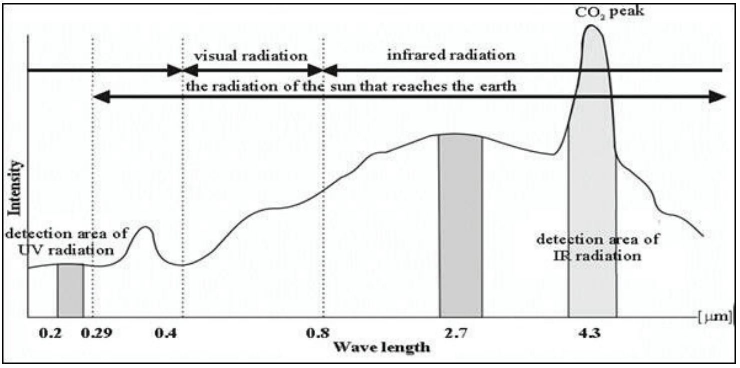

Figure 2. A typical hydrocarbon`s fire

Slika 2. Tipičan požar ugljikovodika

Related to ISO 7240-10, EN 54-10 and in practice, flame detectors can be divided into ultraviolet flame detectors, infrared flame detectors and multiband flame detectors. Related to wave length important for fire detection, ultraviolet flame detectors occupy wave lengths up to 0.38 μm; infrared flame detectors occupy wave lengths from 1.3 μm to 10 μm while multiband flame detectors present combination of noted flame detectors. Multiband flame detectors can be realised in form of UV/IR, IR2 (two infrared sensors), IR3 (three infrared sensors), multi IR (several sensors). In some literature, it is possible to find two groups of flame detectors more, beside noted flame detectors. Those are visible flame detectors, with wave lengths from 0.38 μm to 0.78 μm and approximately infrared flame detectors, with wave lengths from 0.78 μm to 1.3 μm. The most important advantages that IR flame detectors, UV flame detectors, dual flame detectors (IR/IR), dual flame detectors (UV/IR), triple IR flame detectors (IR3) and similar flame detectors on the market have are high speed, moderate or high sensitivity, popular prices, low false alarm rate etc. But, there are also and disadvantages that those flame detectors have. UV flame detectors can be blinded by thick smoke and oil vapours on optics and subjected by false alarms. IR flame detectors are subjected to false alarms from IC sources under the temperature affection. Dual Detector (UV/IR) can also be blinded by thick smoke and oil vapours on optics and subjected by false alarms under affection of UV/IR. Triple IR (IR3) flame detectors mostly have high price. Concerning their application conditions, all of noted can be applied outdoors and indoors except UV flame detectors which are mainly applied indoors.

Today, there are lot of flame detectors on the market with excellent characteristics. As an example, modern flame detectors are capable to detect gasoline fire on area of 30 cm x 30 cm, 60 m away for few seconds (Blagojević, 2015); *(http://www.microtech.co.th/pdf/flam e-detector.pdf)*; (Blagojević, 2015); (Stamatoglou, 2014); *(https://www.ornicom.com/catalogs/ honeywell/Product_catalogue_Morley-IAS.pdf)*.

ULTRAVIOLET FLAME DETECTORS - Ultraljubičasti javljači plamena

UV flame detectors work on principles photons counting or gas filled indicators. Their sensors have a great sensitivity, while the protection from different disturbances was realized by sensitivity changing. It is known fact that UV area purports area of the shortest wave lengths that belong to optic part of electromagnetic spectrum. UV spectrum can be defined related to different criteria. Related to chemical effects, UV radiation can be divided on three parts: radiation that causes ozone origin in stratosphere (175 – 220 nm), UV radiation with germicide effect (220 – 300 nm) and erithemal area of UV spectrum (280 – 320 nm). Related to biological effects, UV radiation can also be divided on three parts-areas: UV-A area (320 to 400 nm), UV-B area (290 to 320 nm) and UV-C area (180 to 290 nm). For fire detection, UV-C area is used because radiation that comes to the earth surface comprehends UV-A and UV-B components. The work principle of this detector is presented on figure 3 (Antonijević 2006).

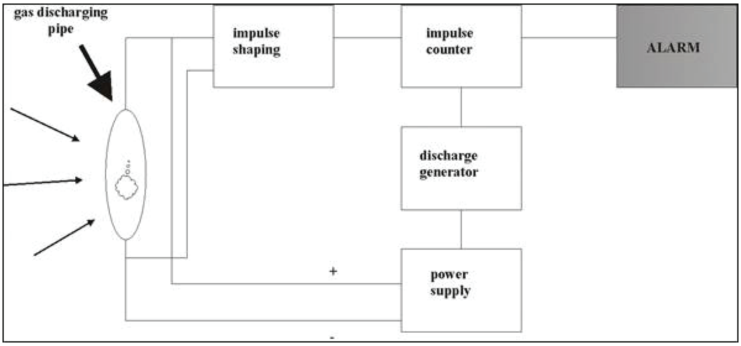

Figure 3. Work principle scheme of UV flame detector

Slika 3. Shema principa rada UV detektora plamena

Ultraviolet radiation is registered in detector`s photo-tube with cold cathode. Tube is filled with ionized gas. Electrons abstracted from cathode accelerate to anode and collide with molecules of this gas, what causes an „avalanche" effect. This part of flame detector presents measuring part. Next part (impulse shaping, impulse counter, discharge generator and power supply) prepares signal, while alarm is activated. This kind of detectors detects fire on range from 10 to 12 meters, with response of few seconds, even much faster, with response of few milliseconds. This characteristic of these detectors is very appropriate for explosions detections. Also, these detectors are appropriate for liquid fires (alcohols), gasses (ammonia, sulphur etc.) fires and fires of metals without smoke development.

The main advantages are solar insensitivity, responds to different causes (metal fires, hydrocarbon fires, hydrogen fires etc.) and very fast response. The main disadvantages are false alarms caused by welding, photo devices and gamma radiation; sensitivity on some vapours, gasses, oils and fats that can cause completely disability of detector. It was noticed that ultraviolet radiation is absorbed on organic liquid, gaseous and solid materials and that can cause problems for detection *(https://firesafety.tips/fire-detectors-uv-flame-detectors/)*; (Blagojević, 2018); *(https://www.det-tronics.com/Content/Documents/Det-Tronics-Ultra-High-Speed-Releasing-Tech -Paper-(86-1000-1)*.

INFRARED FLAME DETECTORS - Infracrveni javljači plamena

This flame detectors works only in infrared part of spectrum. These detectors are embedded with sensors appropriate to detect thermal radiation and the variation of light signals. Photo cell with filter installed in detector detects infrared radiation and by optoelectronic transformer, this signal is transformed into electrical signal. This part of detector presents measuring part. In the signal detection and preparation, important role has flame flickering. Signals are carefully analysed with different techniques (correlation to memorized spectral analysis, comparatives techniques, mathematical ration and correlation between different signals etc.). Spectrum area that is used by IR flame detectors is from 4.15 μm to 4.55 μm. The evaluation of flame flickering is performed for frequencies from 5 Hz to 30 Hz. These detectors are designed that installed active filter and counter filtering flickering frequency and memorize input impulses. For alarm generation, two conditions must be done: wave length must be appropriate with infrared area that should be detected and flickering frequency must be appropriate to flame frequency. The work principle of this detector is presented on figure 4.

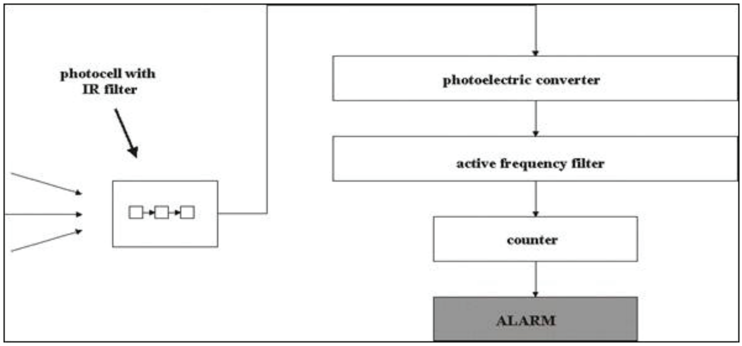

Figure 4. Work principle scheme of IC flame detector

Slika 4. Shema principa rada IC detektora plamena

The field of appliance for these detectors are fires without smoke development what purports use with easy flammable materials. These detectors are very appropriate for cold and rude environment. Special designed heat optical window allow them to work in snow and ice conditions. Related to the fact that they are weather resistible, these detectors can be easily programmed for different environments and requirements. False alarms can be caused by radiation of different heat bodies. Standard range for most of these devices is from 4.1 μm to 4.7 μm. Increase of resistance to false alarms was realized by using of as much as possible higher wave lengths in infrared area. A very good way for prevention of these detectors from false alarms is to embed them in multiple high tech detectors.

It is important to note that no matter on flame detectors type, with increase of fire distance, fire must occupy bigger surface to be detected *(https://firesafety.tips/fire-detectors-infrared-flame-detectors /)*; (Blagojević 2018).

RULES FOR INSTALATION OF FLAME DETECTOR- Pravila za postavljanje detektora plamena

There are lot of different types of flame detectors on the market. Their spatial angles are mostly from 90° to 120°. But, flame area is the most important factor for detection and response time. It is known fact that electromagnetic radiation decreases related to law of 1/r2 (r presents distance). This fact purports if the flame detector`s range increased for two times, flame area must be four times bigger, for the same response time. This dependence from distance for the same response time is presented on figure 2 (S signifies area while r signifies distance from flame detector) and it is presented on figure 5.

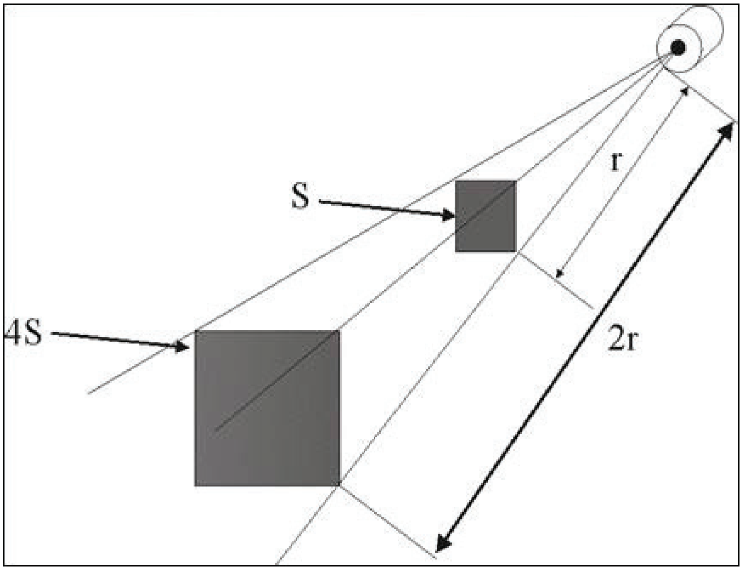

Figure 5. Dependance of flame detector from distance for the same response time

Slika 5. Ovisnost detektora plamena od udaljenosti za isto vrijeme odziva

It is very important to note that so called „field of view" of flame detector can be valid only for space angle of 60°, no matter on the fact that manufacturers note significantly larger angles, as it is presented on figure 6.

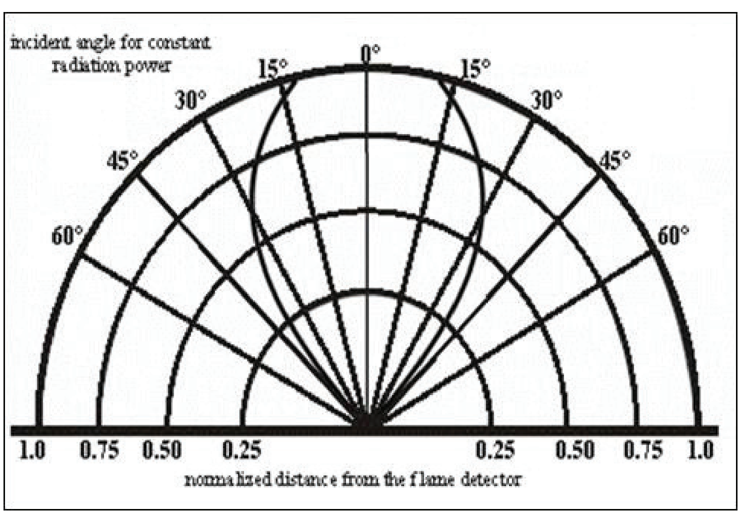

Figure 6. „Field of view" of flame detector

Slika 6. „Polje pogleda detektora" plamena

Flame detectors are suitable for areas with high ceiling, areas without ceiling and indoors and have the fastest response related to other fire detectors. It is very important for installation that flame detector supervises all areas where fires can occur. Also, the existence of obstacles can lead to shadows and unsupervised areas appearances. Rules for flame detectors installations were defined by standards.

European standard EN 54-14 determinates several factors for flame detectors installation. At the first place, flame detector must have direct sight line to any point in supervised area. The existence of obstacles must be eliminated because flame detectors will not be able to „see" every point of supervised area. The existence of other sources of radiation also must be eliminated because false alarms can be generated. The references about volume of supervised area were not presented. Also, maximal distances for detections were noted (25 m, 17 m, and 12 m for classes 1, 2 and 3).

German standard VDE 0833-2 determinates similar references for flame detectors sensitivity decreasing with distance increasing. Standard accents that vibrations could have influence on flame detectors functioning. Humidity can also have influence on flame detectors functioning, so it was referenced that these fire detectors should be used in areas where humidity doesn't exceed 95 %. The number of flame detectors depends from volume and ambient conditions and they must be installed on that way that complete supervised area must be covered. In the case that flame detector must be installed in the corner of the room or on the wall, optical axis of the detector must have an angle of 45° related to the floor or wall. This provides symmetric circle angle of 90° for supervision of room. It is obvious that there is a difference between European standard and German standard. That difference is in the fact that European standard defines maximal distance for detection no matter on angle related to optical axis of detector, while German standard defines maximal distance in the detector`s axis, also and dimensions of supervised volume. With deeper analyse, it can be noticed that flame detector covering bigger area then European standard EN 54-10 defined, but with condition that flame must occupy bigger area. Related to noted fact, German standard allows installation of flame detectors at higher altitude. Of course, the area of effective supervision must be calculated. Also, German standard recommends that for rooms with heights above 26 m supervised areas must be defined for any particular case.

British standard BS 5839-1 notes basic facts about flame detectors like other standards and that maximal distance should be determined related to manufacturer`s manuals.

Russian standard НПБ 88-2001 insists that every point in supervised area must be treated with at least two flame detectors. These detectors must be installed opposite each other. Supervised area should be estimated related to angle of installed detector and its classification. This classification was noted in standard НПБ 72-98. It is important to note that НПБ 72-98 standard is not valid anymore and it has replaced with Свод правил СП 5.13130 (2009), but substantial changes for flame detectors haven't been done. Of course, manufacturer's manuals must be consulted. For detection of test fires TF-5 and TF-6, with maximal response time of 30 seconds, standard НПБ 72-98 defines four classes of flame detectors: class 1 with maximal distance detection of 25 m; class 2 with maximal distance detection of 17 m; class 3 with maximal distance detection of 12 m and class 4 with maximal distance detection of 8 m. Test fire TF-5 presents fast burning fire of chemical materials (liquid fire without smoke). This fire purports fast increase of temperature and presence of invisible smoke particles. It can be simulated with burning of n-heptane and toluene with flame or spark. It also has a small quantity of carbon monoxide and the mostly invisible aerosol spectrum. Test fire TF-6 presents fire of methyl alcohol (liquid fire with smoke). This fire purports fast development with presence of small quantity of visible smoke and high quantity of invisible smoke. It doesn't have carbon monoxide and aerosol spectrum.

American standard NFPA 72 similarly defines sensitivity of flame detectors along optical axis. This standard requires analysing of several important factors in the case of detectors installation. These factors are: fire dimension that should be covered, sensitivity of flame detector, combustible material type, flame detector`s field of view, response time, attendance of other radiation sources, distance from fire etc. (Blagojević, 2018); (ISO /TS 7240-9, 2006); (*https://www.det-tronics.com/content/documents/Meeting_NFPA_Standards-Fire_Safety_AR-1123.pdf.*).

FLAME DETECTORS APPLIANCE - Primjena javljača plamena

Related to the facts that flame detectors have fast response and that their distance from fire doesn't have affection on their work, flame detectors have a large application. Areas of applications are aircraft hangars, office areas, power industry, chemical plants, warehouses, atrium areas, fuel transport load facilities, heavy duty vehicles, huge fuel and oil tanks etc.

Aircraft hangars are protected by flame detectors very often. Especially critical places can be areas under aircraft`s wings. Of course, other fire detectors are also present as fire protection. An example of aircraft hangar fire protection by flame detectors is presented on figure 7 (Hosch 2016).

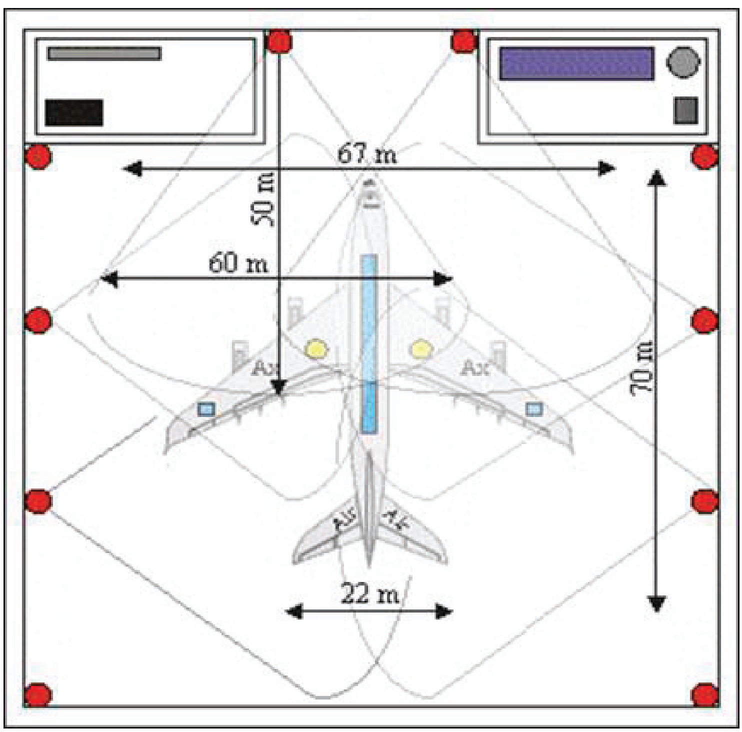

Figure 7. Flame detectors installed in aircraft hangar

Slika 7. Detektori plamena instalirani u zrakoplovnom hangaru

Fuel transfer trucks present very distinct example for flame detectors usage. Flame detectors on loading facility must be installed from both sides of vehicle to enable any flame that can be occurred, as it presented on figure 8 (*https://www.johnsoncontrols.com/-/media/jci/be/united-kingdom/oil-and-gas/pdfs/flame_detection_application_manual.pdf.*).

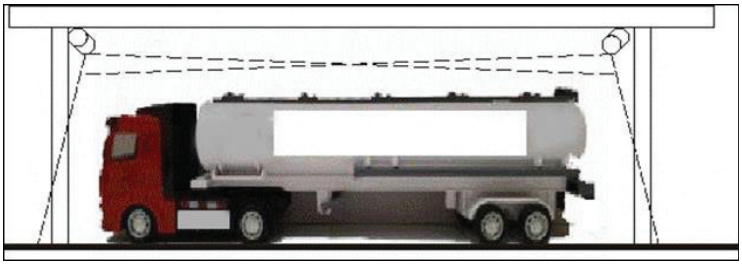

Figure 8. Flame detectors installed on fuel loading facility

Slika 8. Detektori plamena instalirani na pogonu za dopunu goriva

CONCLUSION

Zaključak

Flame detectors have great role in fire protection. This role is reflected in the possibility that they can be applied on places where fire products cannot be used for fire detection. Their characteristics, at the first place response speed, make them irreplaceable in certain situations. Of course, it is very important to respect standards rules and install them on the most suitable places for fire detection.

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