Historical Development of Fire Detection System Technology on Ships

Povijesni razvoj tehnologije vatrodojavnih sustava na brodovima

Miroslav Bistrović
Pula
e-mail: miroslav.bistrovic@uljanik.hr

Danko Kezić
University of Split
Faculty of Maritime Studies
e-mail: danko@pfst.hr

Domagoj Komorčec
Pula

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Summary

Early fire detection has a crucial role in fire spreading and extinguishing. Development of fire detection technology was introduced as a result of series of great fire incidents, which have caused heavy material losses with even greater casualties. Fire is among the major sources of danger to the ship, and therefore special attention must be paid to preventing and extinguishing fires on board. The recent development of fire detection sensors and their integration into the fire alarm system can be traced through the development of four generations of sensors. Integration of fire detection technology with microelectronics and information technologies, a high level of system autonomy is achieved, allowing wireless networking of fire alarm sensor while increasing system reliability and availability.

KEY WORDS
fire
fire detection systems
fire sensors
fiber optic temperature sensor
wireless fire alarm

Sažetak

Rano otkrivanje požara ima presudnu ulogu u njegovu gašenju i sprečavanju širenja. Razvoj vatrodojavne tehnologije potaknut je nizom požarnih incidenata, koji su za posljedicu imali velike materijalne gubitke, uz još veće ljudske žrtve. Vatra je među važnijim izvorima opasnosti na brodovima i zato se mora posvetiti posebna pažnja sprečavanju i gašenju požara na brodu. Dosadašnji razvoj senzora dojave požara i njihova integracija u vatrodojavne sustave može se pratiti kroz razvoj četiri generacije senzora. Integracijom tehnologija dojave požara sa mikroelektroničkim i informacijskim tehnologijama ostvaren je visok stupanj autonomnosti sustava, koji dozvoljava bežično umrežavanje senzora dojave požara uz istodobno povećanje pouzdanosti i raspoloživosti sustava.

KLJUČNE RIJEČI
požar
vatrodojavni sustav
senzori požara
svjetlovodni temperaturni senzor
bežični vatrodojavni sustavi

INTRODUCTION / *Uvod*

Fire protection, through application of science and engineering principles aims to protect people, property and the environment from a devastating fire. From ancient times people have realized that early detection of fire has a positive effect in the fire control. The earliest recorded examples of fire protection can be traced back to the Roman Empire and the catastrophic fires that started in Rome. As a result, Emperor Neron has adopted regulations that required fireproof material for walls and buildings restoration to be used. The second recorded case of adopting fire protection regulations occurred in the year 1666, after the Great fire of London, which destroyed more than 80 percent of the city. The fire of London spurred interest in the development of the first equipment for fire suppression in the form of hand pumps and fire hydrant installation for water supply [1].

From the beginning of the construction of the first simple wooden boats, whose material is very susceptible to fire, until today the sailors' fear of onboard fires was constantly present. Due to these facts fire alarm system played a crucial role in saving ships and people's lives, but are only effective if reliable and fast fire alert with exact location of fire can be provided. There is a direct correlation between the amount of damage caused by fire and interventions time in various marine fire alarm systems. As the time of intervention decreases the ship damage also decreases. Since fire alarm system reaction time (time between fire detection and extinguishing) is its main task, the system needs to detect fire as soon as possible to reduce the fire damages. A lot of attention is devoted to this issue, which requires a professional approach in the ship design and construction, keeping in mind sea conditions during the ship's voyage. "Solas" convention defines a set of rules and requirements for fire alarms and detection systems for various vessel types, and various classification societies apply these rules as a basis for the selection of fire alarm systems on specific ships. Proper selection of a fire alarm system and fire alarm detector for a particular vessel type can significantly prevent the fire spreading, thus allowing the people evacuation from vulnerable parts of the ship. Furthermore, a fire alarm system automatically follows a series of actions such as closing fire doors, turning off ventilation systems, audio and light signaling, starting fire extinguishing systems and so on. Fire alarm system's development led to integration with ships central alarm system, and therefore better performance in monitoring control of a particular system, i.e. an automation system which ultimately aims to decrease work load of the ship's crew.

DEVELOPMENT CHRONOLOGY OF FIRE ALARM DETECTOR / *Kronologija razvoja detektora dojave vatre*

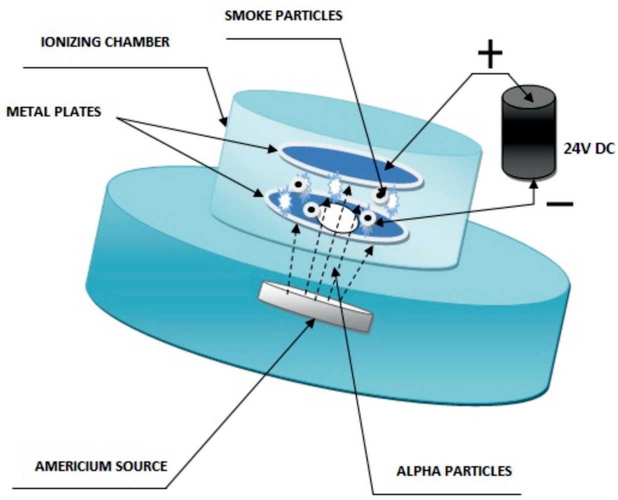
The first generation of fire detection devices (1849-1940) was based on thermal detectors. But the start of fire alarm systems development begins with the invention of the telegraph by Samuel F. B. Morse in 1844. The first practical fire detection systems using telegraph, was developed in U. S. by Dr. William Channing and Moses G. Farmer in 1852. Two years later, he applied for a patent for his electromagnetic telegraph fire protection system intended to be used in cities. In Europe in 1848 the first fire alarm device was developed by C.A. von Steingel, which was operated by the firemen and used button switches and different kinds of bells to give prearranged audio signals. The first telegraph device was created three years later in Berlin and as fire alarm telegraph equipment, used a cable connection, to alert total of 37 fire stations [2].

The development of the first temperature sensors started with the introduction of bimetallic sensors in the 19th century. The working principle of these sensors was based on the unequal expansion between the two metal stripes. Since different metals have different thermal properties, when heated they will bend in one direction, and in the opposite direction when cooled, (hence the term bimetal thermometer or BiMets) [3]. BiMets are reliable and durable, and are considered ideal for many industrial applications, including the first fire alarm sensors used for fire protection systems.

Historical process of smoke detectors evolution can be divided into four generations based on the development of detectors, improvement, and development of the electronic technology industry. The first generation of smoke detectors is considered to be developed until 1960. In1922, Greinacher from Bern ran an experiment to measure the dust content in the air, where he noticed a reduced mobility of ions flow caused by dust. Due to this fact the same year he publishes an article in the Bulletin of the Swiss Association of Electrical Engineering, on the possible use of ionizing chambers for gas detection [4].

The first electronic smoke detector was actually a result of an error. In 1930, a Swiss physicist named Walter Jaeger tried to develop a poison gas detector. He thought that the gas particles would bond with ionized air, thus changing the electrical current flow in the gas detector. But having failed any test, Jaeger lit a cigarette and the smoke detector was activated by reducing electricity flux, leading to the invention of the first electronic device for smoke detection. Swiss scientists ErmstMeil and Jaeger developed the first patented smoke detector in the early 1940s. In1942. begun the commercial use of ionizing smoke detectors, Cerberus. In1960, Canadian researchers conducted a test fire of 342 residential buildings, and have come to the conclusion that smoke detectors reduce the number of deaths by 41%, while heat detectors by only 8 % [5].

In the period from early 1960s until 1975, the second generation of smoke detectors was developed, where americium 24, a radioactive source for ionization, was used for application in the electronics industry. In 1964 an ionization smoke detector with a 24V power supply was developed by Alert [6]. Ionization smoke detectors contain small amounts of radioactive isotopes alpha - particles, which are emitted in the decomposition of americium 241, ionizing air and creating a small electrical charge measured by sensitive devices. When smoke enters the detector, ions are bonded with smoke a particle, which reduces the current flow in the detector. When this occurs, the alarm is turned on. As the path distance of alpha - particles in the air is extremely small, there is no risk of external radiation from these detectors. Still, according to international rules, each ionization detector must have an appropriate radioactivity label. After detectors are used, they must be properly disposed as a radioactive waste.



Source: Authors

Figure 1 Ionizing smoke detector

Slika 1. Ionizirajući detektor dima

Smoke is one of the first signs of a fire in most cases and is therefore an important factor to detect the fire. The biggest advantage of ionizing smoke detectors is that they can detect very small amounts of smoke, which is, from the safety aspect of the ship, very important.

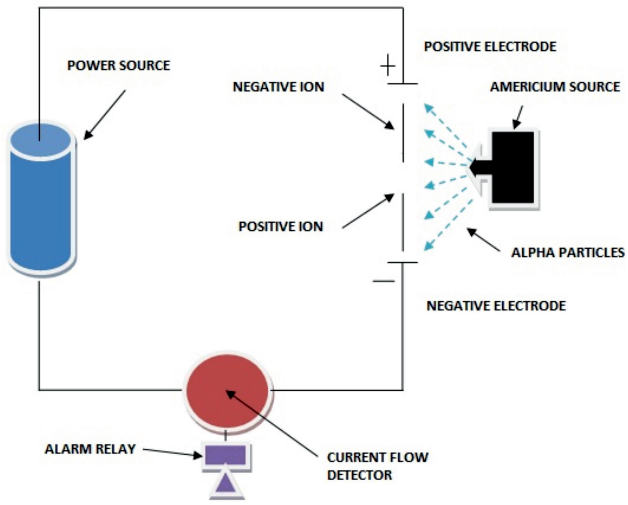


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Figure 2 Ionizing smoke detector working principle

Slika 2. Ionizirajući detektor dima - princip rada

A year after the discovery of ionizing smoke detectors, Duane Pearsall has developed a photoelectric smoke detector [7]. Major changes in smoke detectors technology occurred during the 70s and 80s in last century. Smoke detectors were originally developed to prevent the outbreak of fires in industrial buildings such as factories and warehouses, as well as public buildings, where a large number of persons is exposed to a possible fire. These detectors are today commonly used in fire detection systems for all vessel types.

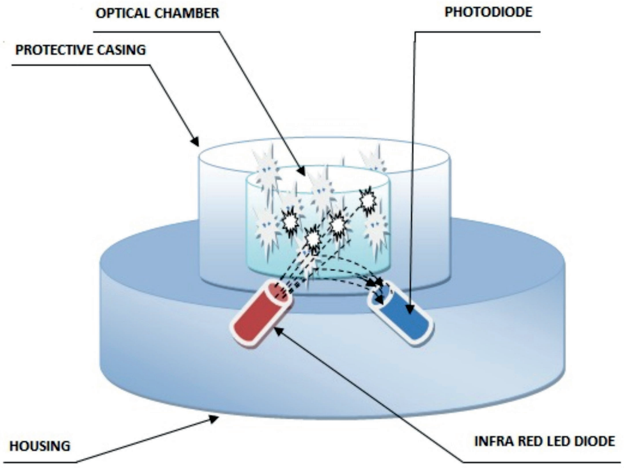

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Figure 3 Optical smoke detector

Slika 3. Optički detektor dima

Common photoelectric smoke detectors operate on the light beam interruption principle. The smoke detector consists of a light source, usually white light or more often low-power laser, and a photoelectric module. A beam of light sent through the detector in normal conditions of cleanliness bypasses photocell usually at approx. 90 degrees. When smoke particles obstruct the light beam, there is a break-ray, which focused on the photo-electric cell changes the physical variables of the set limits thus triggering alarm.

The third generation of smoke detectors (1975-1990) is characterized by an increased interest in smoke detectors. In this period there were a number of key changes in the detectors design, including the replacement of the filament as a light source with a light emitting diode and the use of silicon. With the development of electronics and integrated circuits, there is a decrease in the volume of the detector components, which directly contributes to physical size reduction of the detector and a decrease in energy consumption. In 1982, Pyrotronics XL3 introduced the first analog- addressable detector [8].

The fourth generation of smoke detectors (1990 -present) is characterized by the use of multiple detectors in a loop, and application of algorithms. Development of microelectronics has enabled the application of many different functions. This was particularly important for all types of detectors which, through the utilization of microelectronics, can be produced as intelligent components. In this way, some basic evaluation and decision-making functions can be integrated in the detector. In 1996 a first multi detector (temperature and smoke) was developed as a detector that uses smart "OR" and "AND" logic. Major changes in smoke detectors technology, were introduced by the development of smart detectors. Such smoke detectors provided option to regulate the alarm threshold via a central control panel.

Along with optical smoke detector, a flame detector was developed. Flame detectors are solutions for almost all applications where fire may occur due to large losses of complex equipment such as oil and gas pipelines, offshore platforms, automotive manufacturing facilities, aircrafts, ships, ammunition factories, nuclear plants, and where the risk of staff injury is high. These systems use devices that match the radiation energy visible to the human eye (about 4000-7000 Angstroms) or radiation energy outside the range of human vision usually IR (Infra - red), ultraviolet (UV Ultra-violet), or both. [9] Flame detectors are sensitive to ember, charcoal, or actual fire of sufficient intensity to activate the detector and trigger the alarm. In order to reduce false alarms due to a possible misidentification of real alarms caused by lightning strikes sparks during welding, sunlight or cigarette use, a 2-3 seconds delay is often included in the design of UV Flame Detector. Ultraviolet (UV) detectors work with wavelengths shorter than 300 nm. These detectors detect fire and explosion within 3-4 milliseconds due to UV radiation emitted at the time of their activation[10].

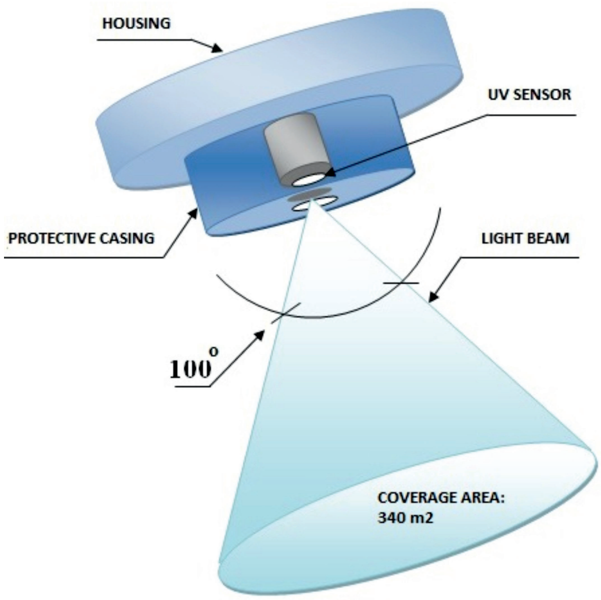

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Figure 4 UV flame detector

Slika 4. UV detektor plamena

Data in Table 2 shows the type of fire, whether smoldering fire or open fire, properties and phenomenon of fire, combustion process, smoke types, optical properties of smoke, air volume, UV / IR radiation, temperature intensity, combustion gas type, volume intensity and pressure rise due fire.

Table 1 Fire properties by type

Tablica 1. Značajke vatre prema tipu

Fire type / Fire properties and phenomenon	Smoldering fire		Open fires		
	Carbonization process	Glimmer fire	Solids	Liquids	Gases
Combustion process	Demands constant energy supply	Independent after start of fire	Independent after start of fire	Independent after start of fire	Independent after start of fire
Smoke type	Very bright smoke	Bright smoke	Dark smoke	Very dark smoke	Oxygen mixing, carbon content and chemical structure dependent
Optical properties of smoke	Fast spreading	Fast spreading	Strong absorption Slow spreading	Strong absorption Slow spreading	
Air volume	High	High	High	High (except for pure ethanol)	
UV/IR radiation	Low	Low to medium	High	High	Increases with carbon content
Temperature intensity	Low	Low to medium	High	High	High
Combustion gases	High CO, low CO2	High CO, low CO2	Medium CO, high CO2	High CO, low CO2	High CO, low CO2
Fire sound intensity	No	No	Medium	Medium	Medium
Pressure increment	No	No	Low to medium, depending on the pressure	Low to medium, depending on fire phenomenon	Low

Source: www.cfaa.ca/Files/flash/EDUC/TECHNICAL

SMOKE ALARMS DEVELOPMENT OFFICE / *Ured za razvoj dojavljivača dima*

Technological development of fire detection systems is closely linked to technological developments of fire detectors. Today's fire alarm technology does not exclude men, but it is still based on the premise that the fire is always a result of causes and effects. This means that early automatic fire detection is possible by one's knowledge and definition of fire causes and the course of fire. Development of microelectronics has enabled the integration of a growing number of functions in one device at the same time decreasing its physical size. For detectors development this is important, because thanks to the microelectronics technology, they can be produced as intelligent components. In this way, some of the functions of assessment and decision-making can be exported to the detector.

A chronological development of fire detection systems can be traced through the history of each equipment manufacturer. One of the largest manufacturers of fire alarm detection control systems and fire alarm detectors on the market, with a long tradition and history, is the Consilium company.

Chronological development of Consilium company [11]:

1935	The company was founded in Norway named Radiodoktor (Servotekknik);
1959	First generation of Salwico gas detectors, KVC-1, was developed by Salen&Wicander AB.;
1967	Salen&Wicander developed the first generation of automatic fire detection system Salwico SGC-8;
1971	In cooperation with the Stromberg (ABB), a second-generation of fire detection system, SPSP, is designed;
1973	In collaboration with Nittan Japan begins the production of NID-38 smoke detectors;
1980	Delivery of fire alarm system to at the time the world's largest cruiser, S / S "Norway" - SFDU-77 with 4,500 conventional detectors;
1982	The first conventional fire alarm system, Salwico C-300; Regardless of the technology used, fire alarm system is monitoring lines which have a large number of conventional fire alarm detectors interconnected. Detectors are powered from the same line. In case of detector activation, there is an alarm signal in the central fire alarm station, indicating appropriate supervisory line (zone). It is not possible to identify which detector is activated.
1983	The first addressable fire alarm system, MBSA-802;
1989	Fourth generation of the first analog - addressable system CS3000 fire alarm is launched; SalwicoCS3000 fire alarm system is an analog addressable type system, which was developed directly for the marine market. The system combines reliable fire detection with proven protection against false alarms. Due to the high demands that the system provided it is very well suited for any environment with high and rigorous regulations. Salwico CS3000 is designed to meet the requirements of ISO, EN54 and CE standards, SOLAS requirements and all major marine classification societies' requirements. Across the use of display fire alarm system offers almost endless possibilities for monitoring and controlling system and associated loops.
2000	The first analogue addressable system Nittan;
2004	The fifth generation of fire alarm CS4000; Key benefits and features of this analogue addressable system is in the central unit intelligence that can start a fire alarm as a pre - alarm function, the system provides the ability to connect up to 254 units of address (detectors) in the loop, and the loop length can be up to 2000 meters. It is suitable for all types of vessels. It also meets the requirements of ISO, EN54 and CE standards, SOLAS requirements and all major marine classification societies' requirements. Sensors that fire alarm system uses are intelligent sensors with built-in logic.
2009	Integration of fire alarm system with integrated navigation systems;
2010	Delivery of the fire detection system for ship EPICP with most addressable detectors (9000), for Norwegian Cruise Line company.

Source: www.consilium.se

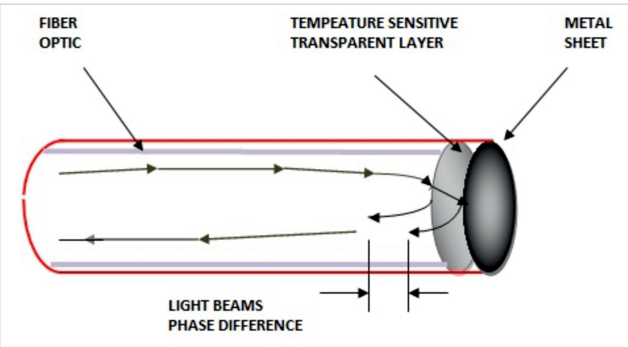
USE OF FIBER OPTIC CABLE IN THE FIRE ALARM SYSTEM / *Korištenje vlaknastog optičkog kabela u sustavu dojave vatre*

Optical fibers are widely used for data transfer and physical research. In terms of physical applications, optical fiber can be used to detect variations in temperature using the light beam refraction index and the modified geometric properties. Fiber optic cable as the temperature detector was first used in the fire alarm systems in the late 1980s. Unlike conventional fire detectors, the fiber optic temperature sensor uses the optical fiber as a medium for reading. Fiber optic temperature sensor measures the temperature in range from -160 to 600 degrees Celsius, and sometimes more [12].

One of the most modern fire detection systems, based on the use of fiber optic cables as a detector, is a system that uses a laser beam as a light source. The operation principle of this system is based on the change in the laser beam parameters inside the fiber optic cable caused by its deformation. The deformation is caused by the expansion of tubes filled with wax due to the temperature rise. The process is reversible - when the temperature starts to decrease, the tube with the wax and the fiber optic returns to the previous form and dimensions. A tube with wax and an optical guide shielded with metal pipe makes the whole cable very robust. Before using as a fire detection system, the cable is divided into logical sectors, by using accompanying software, which allows the location of the fire to be known with great accuracy, also defining the area of affected zone, the dominant direction and speed of fire progression. Such systems are now mostly used in road tunnels, airports, various utilities, oil refineries etc. [13].

Currently on the market, this type of fiber optic is very expensive, which is the reason why it is not yet used broadly in the shipbuilding industry, although it would be ideal for car carriers with multiple decks. It is possible that in the near future this type of optical detectors for fire detection systems gets much cheaper, and will be used on ships. Fiber optical sensors are measures of temperature gradient and the maximum set temperature.

Another approach is the principle of optical detectors where the sensor is mounted at the end of the cable, and works on the principle of phase difference between two light beams [14]

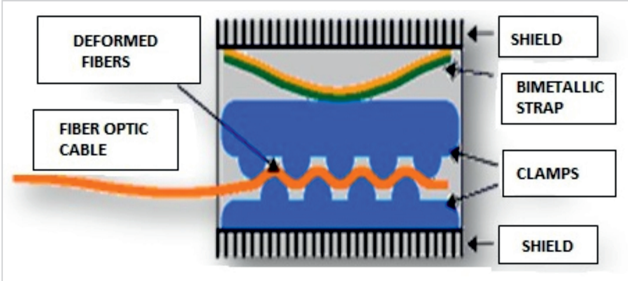


Source: Authors

Figure 5 Fiber optic temperature detector based on light beams phase difference measurement

Slika 5. Vlaknasti detektor temperature temeljen na izmjeni razlika faze svjetlosnih zraka

The third approach in using fiber optic cables as the temperature sensors is the method of bimetallic strips, where the ambient temperature changes are bending metal stripe, which in turn is pressing the fiber optic cable enough to generate a measurable physical change [15].



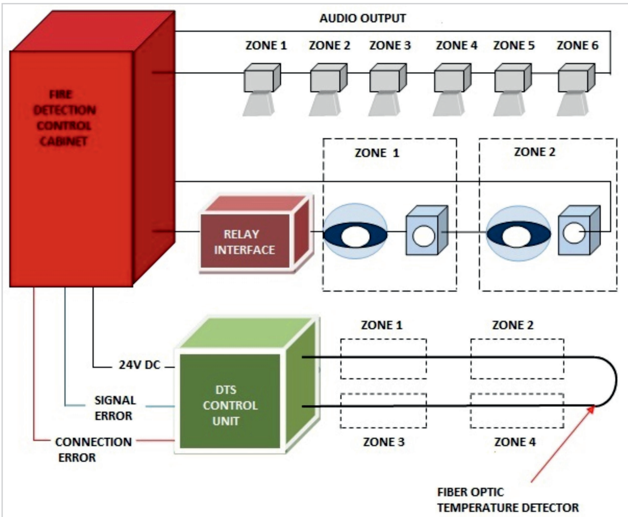
Source: http://www.capgo.com/Resources/Temperature/FibreOptic/Fibre.html

Figure 6 Fiber optic detector based on fiber optic cable deformation measurement

Slika 6. Vlaknasti optički detektor temeljen na izmjeni deformacije optičkog kabela

Characteristics of the fiber-optic cable are:

- Simple installation;
- Reliable quick temperature LHD (Linear Heat Detection) detection technology;
- Complete immunity to electromagnetic influences, pressure shocks, humidity, vibration,
- temperature changes due to weather conditions;
- High resistance to aggressive chemicals, mechanical effects, dust and dirt accumulation, splash;
- Fiber is completely passive sensor and has a very long life;
- There are no electronics or moving parts;
- Temperature measurements are provided over a total length of fiber optic cable



Source: Authors

Figure 7 Communication channels between fire detection system control cabinet and fiber optic sensor loop via DTS

Slika 7. Komunikacijski kanali između kabineta sustava dojave vatre i spirale putem DTS vlaknastog optičkog senzora

Aforementioned chart shows the fiber optic linear temperature detector that operates through temperature sensor (DTS) distributor, which uses fiber optics as a detector. This system is called fire laser and can examine the temperature at every interval of 1 meter along the installed fiber optic cable up to 4 km along the loop with a temperature resolution of better than1°C. The system provides a number of alarm conditions such as the maximum temperature threshold, the growth rate of the threshold temperature and temperature variations [16].

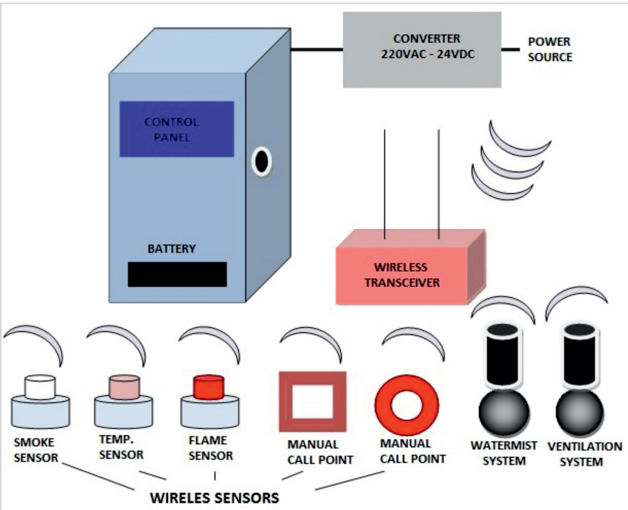
WIRELESS FIRE ALARM / *Bežični vatrodojavni sustav*

Traditionally, fire alarm systems are designed in a way that fire alarm detectors are connected via cable to the central unit.

Possible communication standard is NMEA 2000, [17]. Combining different detectors and indicator modules we can monitor e.g. temperature, smokiness, the presence of carbon monoxide, explosive gases, etc. Problem of collision of parameters in huge networks exist so the signal priority can be introduced [18].

Using cables is an expensive option, and implies that the whole system (the installation of cables, different connectors' types, power supplies and transformers, energy consumption) is expensive. Wireless alarm system is an alternative to classical systems. The system provides reliable wireless control unit with fully supervised wireless signals instead of wires.

Also, devices that require power, such as smoke detectors, temperature detectors, flame detectors, and all other peripherals in the fire detection system require costly power supply as a result of the cable length causing a voltage drop. Because wireless fire detection system does not require a cable for connection between the central unit and peripheral equipment, wireless systems can eliminate the costs associated with the cables. Central wireless transmitter fully supervises peripheral equipment. Wireless central device regularly sends a message over the transmitter to the equipment in the system, i.e. detectors, and the system is constantly aware of the status of each detector through this two-way communication. Transmitters are used to transmit any change in status [19].



Source: Authors

Figure 8 Wireless fire detection system
Slika 8. Bežični vatrodojavni sustav

Today's modern technology allows the production of very stable, addressable fire detection system, using wireless technology. Wireless fire alarm detection systems are safe as the systems using conventional cables for connection, because it is a two-way communication between the detector and the central unit over the transmitter, and is thus provided with continuous readiness of the system and valid errors reporting when occurred, such as low voltage fault, the fault of electronics, communication error, contaminated detectors or any other alarm condition.

CONCLUSION / *Zaključak*

Effective object and facilities fire protection today is unthinkable without the fire detection system. Fire alarm systems are used for early fire detection, which protect lives and property from damage caused by fires. There is a direct correlation between the amount of damage caused by fire and fire alarm system interventions time in fire fighting situations. Fire detection and sensor technologies development trends are constantly evolving with new sensing principles, the integration of different types of sensors in a single detector and implementation of software solutions, all with the goal of faster, more efficient and more reliable fire detection. Thanks to new technologies, intelligent sensors and dedicated software interfaces make automatic fire alarm detectors and systems achieve a high level of intelligence. By adding intelligent properties to fire alarm sensors a new capabilities are been developed, so we can for example, track the spreading of a fire in a specific area. Such features are especially useful for military applications or for monitoring forest fires. Technologies for early fire detection are very reliable today, while the false fire alarm rates are kept to minimum, and the integration of fire extinguishing systems with fire alarm systems further contributes to better fire protection.

But even today's fire detection technology does not exclude men, meaning that the human factor still has a great influence in fire protection. Complexity of the fire detection technology also requires an understanding of the system by the end-user, which can sometimes be a problem if the user is not sufficiently trained and qualified to work with the system. Also, the adoption of new technologies by designers, commissioning engineers and users and the introduction to the widespread use requires a certain adjustment period. With full integration of information and communication technologies along with intelligent sensor technology in fire alarm and detection systems, a maximum possible degree of fire protection will be achieved providing better and simpler utilization to users.

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