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FIRE EXTINGUISHING INSTALLATION FOR RESIDENTIAL BUILDINGS

BY

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Abstract. The recent development of the concepts of *Internet of Things (IoT)* and *smart home* opens the way to implement the fire detection and extinguishing systems already present in the industrial area, towards the housing construction area. The smart home creates an internet technology home management system through IoT. At present, the fire safety segment, as part of the IoT, aims at monitoring the specific gas, temperature or smoke sensors, without paying attention to the reaction of the smart home in case of a fire. Although on the international level there are intentions to provide residential buildings with sprinklers, in our country there is no concern to equip these constructions with fire extinguishing installations. Considering the fire statistics for this category of objectives, which indicate significant values, there appears the need to offer the owners a solution to protect these constructions by an extinguishing system.

In order to improve the level of fire safety of the constructions, we propose to create an extinguishing system for residential buildings that will use the IoT concept.

Keywords: fire safety; residential buildings fire extinguishing; internet of things; smart home.

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1. Introduction

From the list of fire extinguishing systems with water, the only ones that provide automatic actuation in case of a fire are the sprinkler extinguishing systems. The intention to update sprinkler systems in order increase their efficiency is also facing the rise in the number of possible fault occurrences that may occur, which supports the industry's conservatism regarding the adoption of new solutions for these installations. From the study of the current knowledge, no concerns were identified for the modernization of sprinkler installations in the residential area. So far, in the field of housing construction, there is the NFPA's desire to equip new housing construction with sprinkler installations from 2020, as well as the British standard for designing these installations in this category of construction.

Fig. 1 – Internet of Things (IoT).

The Internet of Things (IoT) is a developing technology that tends to become increasingly part of everyday life (Savu *et al.*, 2017). The multiple aspects of IoT, as well as the increasing number of devices, technologies and platforms in this field, have led to IoT being an extended technology in many fields. The *Internet of Things* is a technology that will enable access to a new economic age for the whole world. IoT is a concept that defines a world in which all objects (cars, appliances, lighting systems, mobile devices, laptops, etc.) are connected to each other through the Internet. IoT is not the result of a single new technology; several complementary technical advances provide capabilities that, taken together, help to bridge the gap between the virtual and the physical world. These capabilities support IoT and its development prospects. In conclusion, economic organizations will have to start

implementing IoT technology if they want to survive in the long run, but they will also need to implement strategies that respond to the many risks associated with the Internet of Things.

The recent development of the concepts of *Internet of Things* (IoT) and *smart home* open the way to study how to implement existing fire detection and extinguishing systems in the industrial area in the housing construction area. According to the data available on the website www.igsu.ro, in 2018 a number of 17,080 fires took place in Romania, of which 9,678 were in households and their annexes. Of the total, 30% were mainly caused by the operation of defective or improvised electrical equipment and 16% were due to defective or unswept chimneys. In the context where 26 households are affected by fires daily, this paper aims to identify the solutions for preventing and extinguishing fires in the industrial area that may be applicable in residential buildings to ensure the prevention and extinguishing of fires in this category of buildings.

The smart home creates a home management system based on Internet technology by IoT. At present, the fire safety segment, as part of the IoT, aims at monitoring the specific gas, temperature or smoke sensors, without paying attention to the reaction of the smart home in case of a fire. Another side of IoT in the case of fire safety is shown by the monitoring of parameters of industrial fire prevention and extinguishing facilities (Zhang *et al*., 2013). However, at the moment, although many constructions in Romania are equipped with fire warning and detection systems as well as with fire extinguishing installations, there is still no centralization of the data provided by them in a single location, through the *Smart City* prism. Thus, a centralization of this information, through the IOT prism, at the level of a fire fighting unit, would allow the real-time monitoring of the operating parameters and, most importantly, would allow a prompt reaction of the fire fighters in case of a fire.

2. Fire Extinguisher Installation in Residential Buildings

In order to achieve fire extinguishing system in houses, a documentation of the studies in this field has been made so far, in order to identify a series of solutions that find themselves in different stages, from laboratory model to the final solution that is already marketed. For the same purpose, the works of modernizing the sprinkler extinguishing systems were analyzed, with a view to their being adapted for use in residential buildings.

Water is used as a fire extinguisher medium in the solutions identified so far, with the tendency to use high working pressure, with the final aim of reducing the amount of water used to reduce the negative side effects of fire.

2.1 Water Mist Extinguishing System

One of the patents that may be applicable for the development of a fire extinguisher in residential buildings is US Patent 4,079,786 of March 21, 1978 (Moling, 1978), by which LeRoy I. Moling proposes a fire extinguishing system with water mist. This patent involves the installation of a perimeter system at the ceiling level, that allows water to flow through it and has a series of holes that allow it to flow in the form of water mist. The entire system is composed of a pressure water source, a valve that controls the water to the perimeter system, sensors that open the valve when the presence of fire is indicated and close it when the fire has been extinguished. The inventor was concerned about the integration of the extinguishing system into the room decoration, which is also noticeable in the case of water discharge nozzles. The inventor's recommendation is that all pipes and the associated connectors be made of plastic. Considering that the patent was obtained in 1978, the valve is actuated by smoke and temperature sensors in the range 60÷105°F. We noticed the author's concern for the amount of water discharged over the fire, as large quantities of water are specific to sprinkler systems, his introducing of a minimum temperature leads the interruption of the water discharge. This patent represents the beginning of the studies for the prevention and extinguishing of fires in residential buildings with the use of reduced amounts of water for fire extinguishing in comparison with the sprinkler installations.

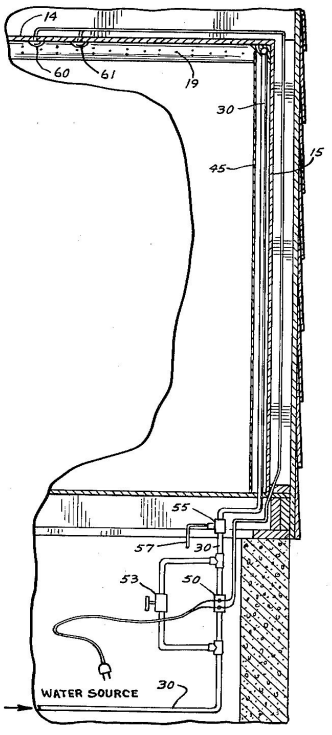

Fig. 2 – Extinguishing system according to the patent US Patent 4,079,786 / 1978.

2.2. The AUTOMIST Fire Extinguishing System

The attention given to the quantity of water used to extinguish house fires has resulted in the development of solutions using water mist. One such

example is the solution developed by PLUMIS and known as AUTOMIST (Dyson, 2017). It includes a small high-pressure pump, connecting pipes and a mist discharge pivoting head fitted with an automatic infrared sensor that locks into the fire location when activated by a heat detector. Unlike the conventional sprinkler system, the nozzle is mounted on the wall, allowing it to remove the water mist from the side and avoid the super-hot evaporative layers above the fire. Classified as an active fire extinguishing system, this facility uses water mist technology to extinguish or suppress fires long enough to allow people to escape safely and enable fire fighters to intervene.

Its main advantages over sprinklers or other conventional water mist systems are that it uses less water: less water means less damage, it needs minimal installation requirements and is therefore a major attraction for owners, occupants, architects, fire engineers and insurers.

The manufacturers of this system are going to develop another installation in the sense that, if the pump, the nozzle design and the operating principle are the same, the novelty is connecting several heads to the same pump. The most interesting thing is the way the system chooses which of the many nozzles to use in case of fire. When a smoke detector is activated, all discharge heads are activated, their infrared heat sensors are scanning the rooms to detect rising heat. Together, they send data to a central unit. After a fire has been confirmed, an algorithm determines which nozzle is best suited to intervene. The central unit closes the nozzles that are not required for the discharge and starts the pump sending the water from the mains to the remaining functional nozzle, which discharge the water mist over the fire.

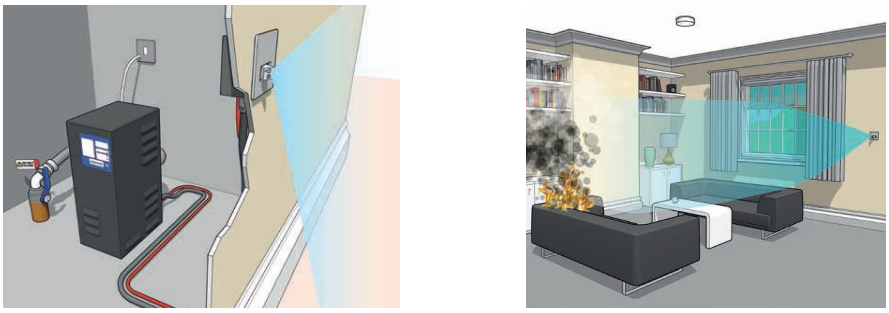

Fig. 3 – AUTOMIST type extinguishing system.

2.3. Extinguishing Fires with Fire Robots

The fixed fire extinguishing systems have the disadvantage of not being able to discharge the extinguishing agent directly over the fire in the first moments after the fire started. In order to compensate for this disadvantage,

research has been developed that will materialize by making robots that will ensure the extinguishing of fires. The concern for such solutions was found in the sense of manufacturing and testing small robots that have fire detection and extinguishing functions. Thus, we find a mobile platform equipped with an early fire detection unit (Sucuoglu, 2018). This robot has obstacle avoidance functions having to follow prescribed routes, scanning the environment to detect the source of fire. Smoke, flame and temperature sensors were used in the system to detect fire. Another concept of robot (Rehman, 2015) has in the foreground the objective of bypassing the obstacles as well as of the use of fire detection sensors.

A result of another research (Aliff, 2019) is the development of a robot called QRob that can extinguish the fire without the need for fire fighters to be exposed to unnecessary danger. QRob is designed to be more compact in size than other conventional fire fighting robots, to make it easier to enter small locations to put out fires in confined spaces. QRob is also equipped with an ultrasound sensor to prevent it from hitting any obstacles and surrounding objects, while a flame sensor is attached for fire detection. QRob is programmed to find the location of the fire and stop at a maximum distance of 40 cm from the fire. A human operator can monitor the robot using a camera that connects to a smart phone or remote devices.

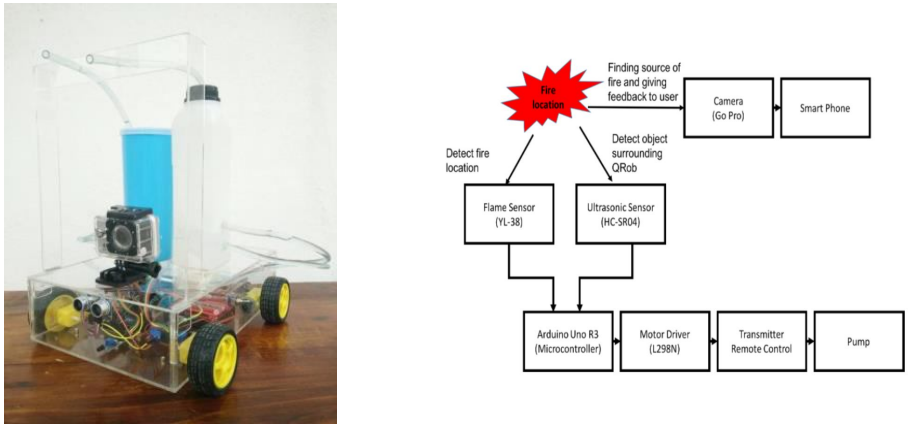

Fig. 4 – The Qrob fire extinguisher and its logical operating scheme.

2.4. Extinguishing Fires with Sprinklers

The sprinkler installations have not undergone significant upgrading in their 129 years of existence. The first part of the chapter presents the existing international standards, as well as the norms in our country, that regulate the

design of these installations; mention must be made that there is only one standard relating to the design of these installations in residential buildings, *i.e.*, the British standard BS 9251:2005. The greatest evolution in the design and execution of sprinkler installations is represented by computer-aided design. The software products approach the design of sprinkler installations with emphasis on the way the installation sizing calculations of are made, while their graphic representation is less represented. Further on, this chapter presents two proposals for the upgrading of sprinkler installations. The first one was developed by Gefest Enterprise Group and concerns the electric activation of sprinklers and the second one was proposed by FM Global Research, which also designed a system called SMART (Simultaneous Monitoring, Assessment and Response Technology) and is composed of two sensors, a relay, an emission/reception system, electric conductors, a solenoid valve and an open sprinkler. The current state of research in this area highlights the lack of concern for the modernization of sprinkler installations for their use in residential buildings.

2.4.1. *International Regulations*

At the EU level, the standard *EN 12845 Fixed firefighting systems - Automatic sprinkler systems - Design, installation and maintenance* is used. This standard sets the requirements and directions for the design, installation, and maintenance of fixed sprinkler extinguishing systems in industrial buildings and installations and sets the specific requirements for these systems that are an integral part of life protection systems. The requirements and directions in this standard also apply to any additions, extensions, repairs or any other modification of the sprinkler type extinguishing systems. They do not apply to sprayers and flood systems.

The National Fire Protection Association, the non-profit organization established in 1896, has as its sole purpose the limitation of the number of casualties (dead and injured persons) as well as the limitation of the material losses caused by fires. For this purpose, the standard for the *Installation of Sprinkler Systems*, *NFPA 13*, has been developed; this is used in the United States of America. The 2019 edition of this standard is undergoing an organizational re-structuring, following the over 60 revisions and over 120 years of experience, which supports the efficiency of designers' and executors' activity of sprinkler extinguishing installations.

BS 9251:2005 is the British standard that regulates the design, installation, components, water supply, maintenance, and testing of sprinkler

systems in individual homes. For sprinkler installations in the industrial areas in the United Kingdom, the international standard BS EN 12845 has been adopted.

Beyond the area of technical regulation, we can also identify a concern of the insurance system relative to the design correctness of these installations, as a guarantor of a good functioning in case of fire. In this respect, the regulation issued by the European Insurance Commission, *Sprinkler Systems: Planning and Installation (CEA 4001:2006)* was identified.

2.4.2. *Regulations at National Level*

In Romania, the national standardization body ASRO has approved the European standard, with its latest update in 2016, under the indicative *SR EN 12845:2015/AC:2016: Fixed firefighting installations. Automatic sprinkler extinguishing systems. Sizing, installation and maintenance*, English version.

In 2013, the Ministry of Regional Development and Public Administration issued the *Fire Safety Regulations for Buildings, Part II: Extinguishing Facilities, indicative P118/2-2013*. The provisions of this norm represent the minimum conditions applying to the design, execution and operation of new fire extinguishing systems for fires in buildings and installations, regardless of their specificity, type of property and their destination, as well as the extension, change of destination, upgrading or restoration of the existing ones. The norm is complementary to the reference standard and establishes the categories of constructions where sprinkler installations are necessary.

The activation time of sprinklers depends on the size and location of the fire, on the obstacles between the fire and the sprinkler head and, last but not least, on the vertical air circulation in the respective enclosure. The activation time of the classic sprinklers increases in proportion to the height of their placement and is a disadvantage for protected areas with very high ceilings. In order to overcome this limitation of traditional sprinklers, Gefest Enterprise Group has designed and developed an electric sprinkler activation system in collaboration with the Russian Fire Prevention Research Institute, supported by the St. Petersburg State Polytechnic University (Kopylov, 2012).

The system is connected to a fire alarm system, which can use various ways of detecting fires, including optical, temperature or smoke sensors; this allows a very rapid identification of the occurrence of fire. After having identified the location of the fire, the system operates the sprinkler heating element above the fire outbreak until the trigger temperature is reached. Another improvement to the classic sprinkler extinguishing system is the possibility of simultaneous operation, from the initial phase, of several sprinkler heads, which leads to an improvement of the extinguishing efficiency.

The electric actuation of the sprinklers can be achieved: (1) automatically, by means of the electrical signal sent by the detection installation; (2) automatically by the electrical signal sent by the activated sprinklers or by the water drain sensor; (3) manually by an electrical signal transmitted by an operator.

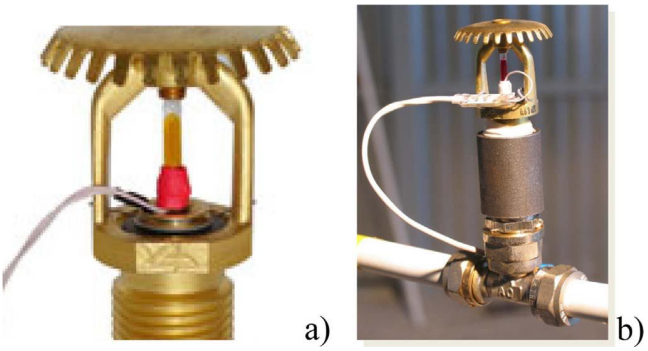

Fig. 5 – Electrically controlled sprinkler:
a) heating element on the glass bulb; b) installed sprinkler.

The system thus developed is designed to ensure the protection of the spaces intended for trade, production or storage with ceiling heights up to 20 meters.

FM Global Research has also designed a system called SMART (Simultaneous Monitoring, Assessment and Response Technology) designed to extinguish fires in storage spaces with heights over 12 meters (Xin *et al*., 2016a; Xin *et al*., 2016b). A SMART sprinkler is composed of: two sensors, a relay, a reception/emission system, electric conductors, a solenoid valve and an open sprinkler. In the event of fire, the two sensors from each SMART sprinkler communicate the event to a central unit and then the fire pump starts, in order to provide the necessary amount of water and pressure for extinguishing the fire; the solenoid valve is also actuated to allows the water to flow through the sprinkler located in fire outbreak area.

The new protection system includes several key functions such as: multi-sensor detection, real-time calculation of fire location, dynamic sprinkler activation, and wireless communication enabling the coordination of system components. A series of fire detection, sprinkler activation, and fire extinguishing tests were performed in order to evaluate these system functions. The results show that a combination of smoke and temperature sensors can detect the fire at a very early stage, providing sufficient data for the location of the outbreak.

In order to demonstrate the efficiency of SMART sprinklers, a detailed study was performed and it was followed by real fire extinguishing tests at shelf deposits. The tests were performed on shelves with heights of maximum 12 meters and the system triggered a group of six sprinklers following the signal transmitted by a smoke detector. The guarantee of the safe triggering of a sprinkler group allowed the extinction intensity to be 50% of the level used in the case of classic sprinklers.

3. Conclusions

The object of increasing the efficiency of sprinkler systems by upgrading them is also facing an increase in the number of possible faults that may occur, which is an aspect that comes to support the industry's conservatism regarding the adoption of new solutions for these installations. From the study of the current state of knowledge, no interests were identified for the modernization of sprinkler installations in residential areas. So far, in the field of housing construction, there is the NFPA's desire to equip new housing constructions with sprinkler installations from 2020 onwards, as well as the British standard for designing these installations in this category of construction.

The development of the *Internet of Things (IoT)* and *smart home* concepts, in conjunction with the sprinkler modernization initiatives described above, open the way to studying the modalities of implementing modern sprinkler installations in residential buildings. We consider, on the one hand, the adoption of measures to be taken in the domain of national regulation of this type of installations and, on the other hand, the development of these installations, in relation to the destination of the spaces to be protected.

From the analysis of the current state of knowledge, we conclude that there is no concern in our country to provide residential buildings with fire extinguishing systems. The development of IoT technology makes it possible to analyze the results obtained from the home sensors in the online environment and, subsequently, it becomes possible to make a decision relative to the use of the extinguishing system. So far, IoT is focused on connecting all equipments to the Internet and, in the field of fire safety, it only deals with fire detection.

In this context, a fire extinguisher can be designed for residential buildings and can be subsequently extended to spaces with other destinations and relatively small areas of the rooms. The fire extinguishing system to be developed should have the following characteristics:

– the installation must be connected to the IoT to obtain information about the outbreak of a fire;

– the heads discharging the extinguishing agent can be controlled by IoT;

– as an extinguishing agent, the water mist will be used and a powder extinguishing system will remain under consideration;

The main feature of this installation will have to be the prompt action over/on the fire outbreak.

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INSTALAȚIE DE STINGERE A INCENDIILOR ÎN CLĂDIRI REZIDENȚIALE

(Rezumat)

Dezvoltarea în ultima perioadă a conceptelor *Internet of Things (IoT)* şi *smart home*, deschide calea către studierea modalității de implementare a unor instalații de

detectare şi stingere a incendiilor deja existente în zona industrială, către zona construcțiilor de locuințe. Casa inteligentă creează un sistem de management al locuinței prin tehnologia internetului prin intermediul IoT. În prezent segmentul de securitate la incendiu, ca parte a IoT, vizează monitorizarea senzorilor specifici: de gaz, de temperatură sau de fum, fără a acorda o atenție pentru reacția casei inteligente în cazul manifestării unui incendiu. Deşi pe plan internațional există intenții de echipare cu instalații de sprinklere a clădirilor rezidențiale, la nivelul țării noastre nu există o preocupare de a echipa aceste construcții cu instalații de stingere a incendiilor. Având în vedere statistica incendiilor la această categorie de obiective, care indică valori semnificative, apare necesitatea de a oferi proprietarilor o soluție de protejare a acestor construcții, prin intermediul unei instalații de stingere.

Pentru a îmbunătăți nivelul de securitate la incendiu al construcțiilor, se propune realizarea unei unei instalații de stingere destinată clădirilor rezidențiale, care să valorifice conceptul IoT.