vehicles

Article

Modernization of Fire Vehicles with New Technologies and Chemicals

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Abstract: Fire is a stable exothermic chain reaction of flammable materials brought together with oxygen or other oxidizing substances under certain conditions, occurring uncontrollably. Fire vehicles interfere with many types of fire, such as wildfires, factory fires, building fires, etc. During this intervention, fire vehicles generally use water or foam. In this study, new effective fire suppression applications are investigated. Thermal camera applications in fire trucks and also new extinguishing agents—boron-based chemicals—were tested in forest fire simulations. In these experiments, it was observed that the thermal camera detected the fire as soon as it occurred. It seemed appropriate to use thermal cameras for all types of fire vehicles (foam trucks, water tankers, rescue trucks, etc.). It was seen that the thermal camera application could detect and monitor the fire during the fire-extinguishing work of the firefighters. The boron-based fire suppressant had a better extinguishing and cooling effect than water in the experiments. Compared to the water used as a traditional method, the liquid boron-based extinguisher provided 22% faster—while the solid boron-based extinguisher provided 42% faster—suppression and cooling. With three separate experiments, it is predicted that thermal camera applications and the use of boron-based extinguishers in fire vehicles can lead to an effective and positive transformation in the coming years.

Keywords: vehicle technology; energy; fire suppression; boron

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1. Introduction

Fire is a flammable and uncontrolled process in which substances react with oxygen or other oxidizing agents under certain conditions. It is a stable, exothermic chain reaction.

In addition to causing material damage in the geographical area in which they occur, fires also have great negative effects on living creatures and ecological balance.

Concomitant heat generation is also achieved by the fire. This mechanism includes the atoms and molecules reacting with the oxygen in the air. Combustion is the term used to describe the event that starts the fire.

In order to start combustion, the temperature must reach the combustible material's ignition temperature. The ignition temperature that can ignite the fuel in air without a separate ignition source can be defined as the lowest temperature required.

The ignition temperatures of some solid-form combustible materials are shown in Table 1 [1].

Fire vehicles are one of the most important symbols of emergency response. In this respect, the history of fire trucks and how these have evolved from the earliest days of steed-drawn carriages into today's massive vehicles are below.

18th century

In the early 18th century, Englishman Richard Newsham filed two patents for his fire machine design. In 1721, an invention was depicted that could direct a sluice of water toward a fire. The alternate patent, issued in 1725, detailed an outfit operated through a hand pump for which two people worked a large switch while others directed the sock.

Revolutionary in design, these original constructions paved the way for ultramodern firefighting outfits.

Table 1. Ignition temperatures of some solid combustible materials (°C).

Solid Combustible Materials	Ignition Temperature (°C)
Cotton	400 °C
Wool	600 °C
Cotton fabric (Raw cloth)	225 °C
Nylon (6.66)	425 °C
Wood	240–270 °C
Pine tree	260 °C
Polyester	450–485 °C

19th century

Horse-drawn brume pumpers were still the most popular system for putting out fires in the early 19th century. As time passed, nags proved ineffective for larger extremities. After the American Civil War, small levy companies began to combine into larger ones with larger coffers and the power to attack the increasingly frequent and destructive fires sweeping through metropolises. In 1885, the first electric fire machine system patent, designed by Schuyler Wheeler, entered into force in the United States. These great leaps forward from former styles of pumping water allowed firefighters to receive the help they demanded to extinguish fires much more briskly and with added safety.

20th century

Firefighting technology advanced at an inconceivable pace throughout the 20th century. In the early 1900s, motorized pumps replaced gasoline-powered pumps. In the 1960s, water pumps, graduations, and cherry selectors surfaced as commonplace tools for firefighters. This ultramodern equipment allowed firefighters to target areas that were initially inaccessible. The introduction of elevating thunderclaps, enchantresses, and other inventions helped shape the ultramodern firefighting outfit.

21st century

The fire truck of the 21st century is a high-tech, high-powered machine that has been modified over centuries to meet the requirements of the ultramodern firefighting community. In addition to ergonomics, some departments now concentrate on terrain and community configurations when designing their lines. Currently, numerous fire departments focus on the aspects below:

- Safety;
- Optimized storehouses;
- Vehicle-to-vehicle communication;
- Advanced norms [2].

Currently, fire trucks are equipped with motorized machines with sophisticated after-treatment bias and automatic transmissions. Although the changes related to the machine were backed by immigration regulations set forth by the government, the use of motorized technology has brought an edge to the machine and the vehicle. The machine can now tell you when something is wrong with fairly accurate and specific information.

As vehicles become more motorized, the traditional red fire truck may evolve into a red fire truck that can talk to other vehicles, have some automated systems that do not involve human intervention, and have innovative ways to acclimate safety systems ahead of nonsupervisory changes. It will be intriguing to see how these effects manifest themselves to shape the fire truck of the future [3].

Forest fires can develop very quickly and cause great damage in very little time. Special applications should always be considered for forest fires. Thermal camera applications, which are one type of such applications, provide important information about the formation and progression of the fire by detecting temperature increases in places where there is a risk of fire or burning. These efficient and solution-oriented devices can produce results very quickly and can be used in fire-prone areas.

Thermal camera systems can be used to observe heat and how it spreads. These systems work by sensing heat and displaying the data from this heat as a heat map. High-tech thermal camera systems are also preferred for multiple detections of objects.

Many applications have been implemented in fire-extinguishing systems over the years. Fire trucks with water suppressant are considered to be the first generation of firefighter trucks and emerged more than 100 years ago [4].

Second-generation firefighter trucks appeared during the First World War. In these vehicles, there are powder and foam extinguishers. Second-generation firefighter trucks have been successful in fighting fires involving petrochemical-based products in B and C fire classes because these types of fires cannot be extinguished with water.

Increasing industrial developments in recent years have made fires more complex and multifaceted. In this respect, new technologies need to be applied and researched [5].

Foams and synthetic or detergent additives are known as traditional firefighting methods. Such applications may be insufficient against fires reaching or exceeding 700 °C. When fire interventions are examined in general, it is seen that the expectation of firefighters is to control the fire. Compared to traditional fire suppression systems, water mist has shown many benefits for sustainable fire suppression The extinguishing performance of a water mist system under various gas-spray momentum ratios were evaluated, and the effect of fire extinguishing was observed using laser-based measurement [6]. At the same time, Liu et al. [7] showed intervention studies with water mist and demonstrated the possible success of water mist systems in natural gas leakage fires.

Grant et al. [8] stated that water has become the most commonly used fire extinguishing agent. The thermal properties of water make it an ideal extinguishing medium for most types of fires, whether used to extract heat directly from flames, hot combustion products, or fuel surfaces.

Researchers such as Shukhman et al. [5] examined the emission values that occur during fire suppression with different extinguishing products. As a result of the chromatographic analysis of exhaust gases, hazardous formations have been observed for human health and engine inner surfaces. Additionally, early studies showed that Halon 1301 contains the poisonous products of its thermal destruction and chemical responses as HF, HBr, CF_3H, and CF_2O. These species are dangerous to human health and may be anticipated to be present in exhaust fumes while operating in a fire area. These may damage the machine internal shells. It is important to research the extinguishing chemicals that are the least harmful to humans and the environment [5].

Thermal imaging cameras (TIC) are becoming a significant device for many firefighters and other users. Increasing use of these cameras against fires in the future will provide a more effective application against fires. TIC can provide first responders with valuable information to measure track fire growth, a fire incident, allowing them to determine the location of victims [9].

TIC is used extensively in the development of imaging technology for firefighting operations. Firefighters may encounter high temperatures, open flames, sprays of water, etc. Thus, it is important that TIC is capable of seeing in these obstructive conditions with minimal hindrance from the surrounding terrain. Fire service thermal imagers are generally designed to detect radiant thermal energy in the 8 µm–14 µm spectral range. This energy is radiated from solid shells and from certain fumes that radiate.

The traditional method of using water or foam as extinguishing agents is widely used. However, this study investigates new effective fire suppression applications, such as thermal camera applications in fire trucks and the use of boron-based chemicals as extinguishing agents in forest fire simulations. The study found that the thermal camera application in fire trucks can detect fire flames as soon as they occur, making it suitable for all types of fire vehicles. The use of boron-based chemicals had better extinguishing and cooling effects than water in the experiments, indicating their potential to be an effective alternative to traditional extinguishing agents. The study predicts that the combination of thermal camera applications and the use of boron-based extinguishers in fire vehicles can lead to an effective and positive transformation in the coming years. The thermal camera application can detect and monitor the fire at the right time and place during firefighting work, allowing firefighters to take timely and appropriate measures in order to suppress fires. Overall, this highlights the importance of exploring new effective fire suppression applications and methods to improve the safety and effectiveness of firefighting work. The use of boron-based extinguishers and thermal camera applications in fire vehicles can potentially lead to a positive transformation in the firefighting industry, ultimately enhancing public safety.

2. Materials

For this study, water and boron-based solid and liquid fire extinguishers were used for combustion and extinguishing experiments. In addition, a thermal imaging camera (TIC) was used to detect the initial flame. This camera was also used to monitor the extinguishing effects and temperature progressions of the fire extinguishers. The properties of the materials used in the experiments are given below.

2.1. Solid and Liquid Boron-Based Fire Suppressant

In the Exp.SB and Exp.LB experiments, boron-based fire suppressants were used. Boron is used in many different fields. Boron production from boron minerals in the form of ores requires special processes. Boron is generally found in nature as borate salts or boric acid [10].

It is highly resistant to combustion reactions. For this reason, it is used as a fire and flame retardant. Additionally, it can be mixed with other substances with different properties. It prolongs the rate of absorption of the smoke from the fire in the form of embers quickly. Boric acid and borates provide resistance to cellulosic materials and fire. Before reaching the ignition temperature, they remove the water molecules in the cellulose and prevent further combustion by covering the surface of the coal. The use of cellulosic insulating materials such as durable material boric acid for fires, has led to increased demand [11].

Boron-based fire extinguishing chemicals are non-carcinogenic. These also have a long shelf life, superior properties in cooling, and narrow the environment for fire progression and ignition. With these features, they act by suffocating the fire.

Boron shows oxide properties. The melting temperature of the boron chemical is around 2300 °C. Due to this feature, it is very advantageous to use in combustion applications. Its use as a flame retardant or as an innovative step in fire extinguishing applications is very important. Boron is a chemical in flame retardants; it is used as a component in compounds such as borax, borate, or ammonium fluoroborate. The structure of the boron chemical provides a cooling process and prevents ignition [12].

In these studies, the properties of the liquid boron-based fire extinguisher used in Exp.LB are shown in Table 2. Generally, this product has a melting point above 600 °C. In addition, this product has water-repellent and odorless properties.

Table 2. The properties of boron-based liquid fire suppressant components [13].

Component Name	CAS No	Concentration
$Na_2B_4O_7\ 5H_2O$	12179-04-3	10–20%
SiO_2	112926-00-8	<1%
Sodium bicarbonate	144-55-8	15–30%

For Exp.SB, the solid boron-based fire suppressant was used. In this solid extinguisher, borax pentahydrate is predominantly involved. Borax pentahydrate is obtained from tincal ore in crystal or powder form. The chemical formula of tincal is shown as $Na_2B_4O_7$▪$10H_2O$.

In the production stages of this boron chemical component have melting, filtration, centrifugation, crystallization and drying [12]. The molecular weight of borax pentahydrate is 291.35 g/mol. Regarding physical properties, it can be found in powder, white, crystal, and odorless forms. Boron-based solid fire extinguisher was used in the Exp.SB experiments. This chemical component also has water-repellent properties. Moisture content is 0.25% at maximum, and its bulk density is 1.13 ± 0.007 g/cm^3 at 20 °C. In the tables below, the properties of the boron chemical used in the Exp.SB experiment are indicated. The properties of the liquid boron-based fire extinguisher used in Exp.SB are shown in Tables 3–5.

Table 3. Physical properties of $Na_2B_4O_7$■$5H_2O$ [14].

Features	Value
Bulk Density	0.966 g/cm^3 (granule)
Boiling Point	1575 °C
Heat Capacity	7.6 J/g °C
Thermal Conductivity	0.647 W/mK
Specific Weight	1.815 g/cm^3
Specific Surface Area	<1 m^2/g
Diffusion Coefficient	1.0×10^{-5} cm^2/s
Surface Tension	67.19 mN/m (1.0 wt% aqueous solution)
Melting Point	741 °C
Color Measurement Test	91.92 (avg. L value)
Molecular Weight	291.35 g/mole

Table 4. The properties of boron-based solid fire suppressant component [15].

Component Name	CAS No	Concentration
Boraxpentahydrate ($Na_2B_4O_7$■H_2O)	12179-04-3	10–20%
Silicate (SiO_2)	112926-00-8	<2%

Table 5. Chemical properties of $Na_2B_4O_7$ [14].

Component	Content	
	Granular	Powder
B_2O_3	48.00–49.35%	47.80–49.00%
Na_2O	21.37–21.95%	21.36–21.81%
SO_4	mxm. 135 ppm	mxm. 200 ppm
Cl	mxm. 70 ppm	mxm. 70 ppm
Fe	mxm. 3 ppm	mxm. 3 ppm
Water Insoluble	mxm. 150 ppm	mxm. 150 ppm

Borax pentahydrate transforms into borax dihydrate at 160 °C–170 °C, into borax monohydrate at 290 °C–299 °C, and into anhydrous borax at 400 °C–450 °C. These situations are expressed by the equations below [16].

$$Na_2B_4O_7.5H_2O \rightarrow Na_2B_4O_7.2H_2O \ (160\ ^\circ C\text{–}170\ ^\circ C)$$

$$Na_2B_4O_7.5H_2O \rightarrow Na_2B4O_7.H_2O \ (290\ ^\circ C\text{–}299\ ^\circ C)$$

$$Na_2B_4O_7.5H_2O \rightarrow Na_2B_4O_7 \ (400\ ^\circ C\text{–}450\ ^\circ C)$$

In these studies, an innovative extinguishing technology using boron-based fire extinguishers was tried. Boron chemicals have properties that prevent the progression and re-ignition of the fire. These chemicals form a film layer in the areas to which they are applied and thus provide a suffocating effect in the fire surround. In addition to all these, with their radiation dispersion feature, they provide and facilitate breathing during intervention and ensure the continuity of the intervention. Boron-based suppressants are environmentally friendly in the fire sector. They do not cause a carcinogenic effect on humans and do not cause an explosion. They are safe with fast extinguishing and cooling features [16].

2.2. Thermal Imaging Cameras (TIC)

Thermal imaging cameras (TIC) have become efficient for firefighters in recent years. As this is a new field for firefighters; in order to use TICs correctly and effectively during firefighting applications, performance trials, and standard application, procedures must be put into use [9].

TICs contain many features. They are very successful in detecting and tracking people and objects affected by fire, especially in low-visibility conditions. When the working principles of thermal cameras are examined in the electromagnetic spectrum, special optics and imaging sensors appear to be applied to create a digital image of the infrared range. Such applications are superior in low-visibility conditions, locating heat sources, detecting the possible existence of living things, and temperature measurement [17].

TICs can be used to very quickly detect bad contact of an electrical device and overheated mechanical parts so as to prevent serious fires and short circuits. For those parts that cannot be seen directly due to shielding, the thermal hidden danger can be found according to heat conduction to the external parts.

For fire trucks, the vehicle rescue equipment is the necessary equipment to ensure operational safety.

Compared to the main firefighting vehicle used in fire detection vehicle infrared cameras, the vehicle-mounted thermal camera is safe, simple, easy to operate, and easy to use. The entire vehicle thermal imaging camera system is based on an advanced, excellent vehicle thermal camera with a simple control system and a control terminal set in the cab. The vehicle-mounted thermal camera is controlled by the system motor and can have a remote connection through a tablet computer from the cab remote control.

It is suitable for all kinds of fire trucks (command vehicle, city main fighting vehicle, water tanker, foam truck, rescue truck, etc.). With large petrochemical fires; tire factories, paper mills, and other large factory fires; large residential fires; vehicle accident rescue and relief, etc., it can be a great help.

Thermal camera systems are a technology that makes it possible to see thermal radiation from objects that cannot be seen with the human eye (Figure 1). Thermal radiation is the energy transmitted by an object through its temperature and the wavelengths emitted by the electromagnetic spectrum. This technique is the result of accelerated charges emitting radiation in accordance with the laws of electrodynamics. Thermal cameras generally show heat density information in the range specified on the color scale (red = warm, blue = cold) [18].

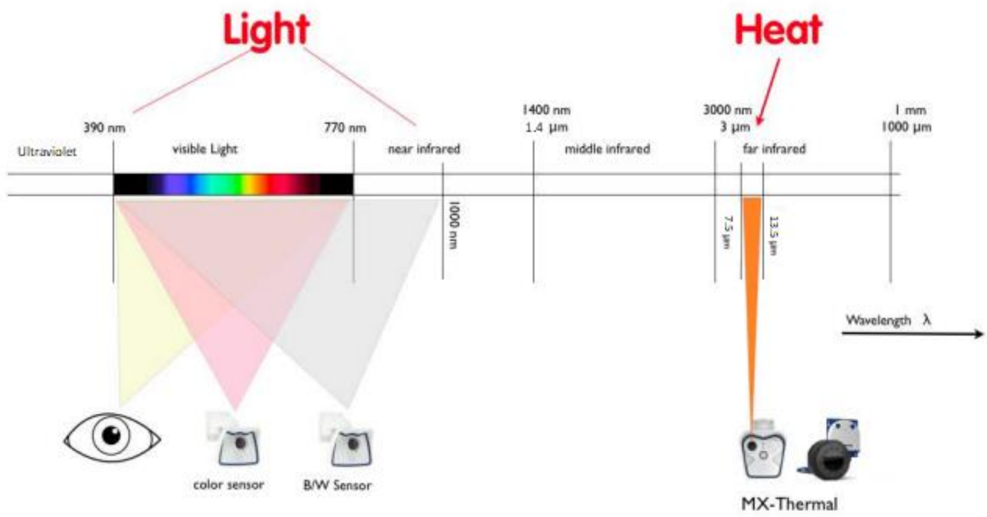

Figure 1. Spectral visible range [18].

Thermal cameras offer a distinctive feature compared to cameras with optical image sensors: the ability to show the slightest temperature differences with different colors. Thermal cameras can show upward temperature changes from a very low temperature value, such as 0.05 °C. In addition, it can indicate and signal the slightest temperature and heat change thanks to its features, such as the time of fire and set value. Thermal cameras have been used in many places where there is a risk of fire. In recent years, they have also been located in observation towers, especially during forest fires. The use of thermal cameras in fire trucks is also important in terms of responding to fires very quickly and efficiently.

The main characteristics of the thermal camera which was used in the experiments are given below and shown in Figures 2 and 3.

✓ Integrated speaker and microphone;
✓ Mx6 system platform (2nd generation) compatible with MxBus, H.264 and ONVIF;
✓ Thermal field of view; 45°, 25°, or 17°;
✓ Possibility of recording to an internal MicroSD card (4 GB as standard);
✓ Can be used in total darkness with MxActivitySensor feature;
✓ TR: calibrated thermal image sensor for measurable added value;
✓ Thermal camera POE with power consumption < 10 W;
✓ Fixed premium thermal image sensor with 50 mK.

The advantages of TIC are given below:

✓ High sensitivity and resolution in temperature and heat measurements;
✓ High temperature alarm detector feature;
✓ Provides image sharpening with auto focus feature;
✓ High temperature digital alarm, special alarm algorithm against forest fires is available;
✓ False alarm reduction can be achieved thanks to the monitoring protection area feature;
✓ Enlarged and finalized range of information for fire occurrence confirmation;
✓ 3D positioning function;
✓ This type of camera searches for fire and flame at a wide range. In fire formations, they can be observed even from a short distance.

Figure 2. Thermal imaging camera which was used in the experiment.

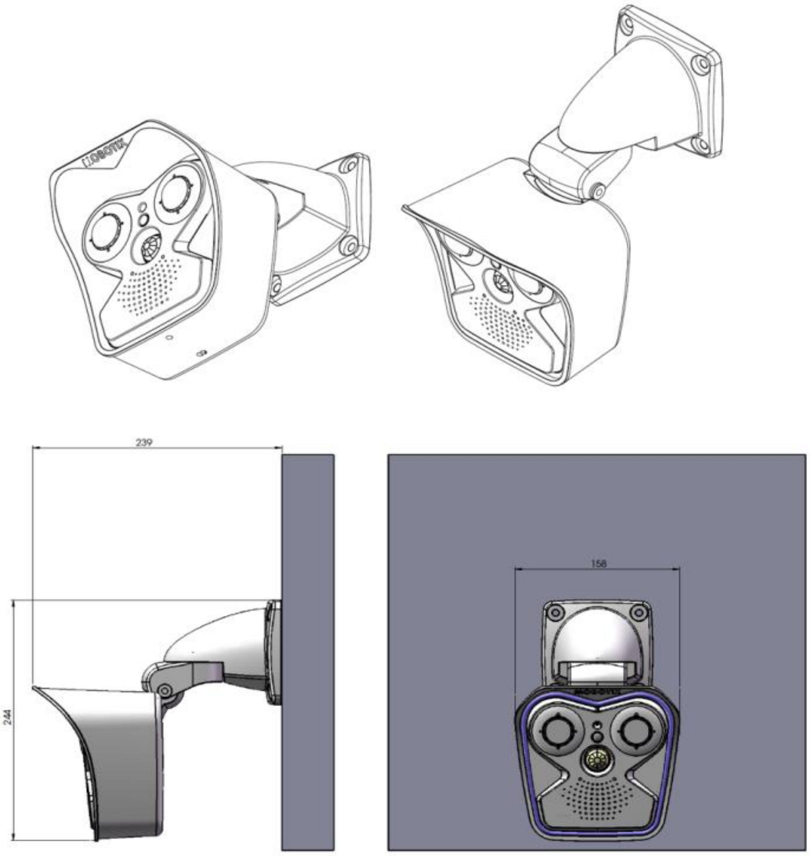

Figure 3. TICs technical drawings.

3. Experimental Setup

To observe the benefits of using thermal cameras and boron-based fire suppressants for fire trucks, a well-designed experimental setup is required. First, a fleet of fire trucks should be selected as participants in the experiment. These fire trucks should be equipped with thermal cameras and boron-based fire suppressants, respectively. Next, a controlled fire should be set up to simulate a real-world fire scenario. This could involve creating a fire in a controlled environment, such as a large field or empty lot. The fire should be allowed to grow and spread naturally, giving the fire trucks ample opportunity to respond and test the effectiveness of their equipment.

During the fire, data should be collected on several key metrics. First, thermal imaging footage should be captured to analyze the effectiveness of the thermal cameras in detecting hotspots and tracking the spread of the fire. Secondly, visual observations should be made to assess the effectiveness of the boron-based fire suppressants in extinguishing the flames. Additional data should also be gathered on factors such as response time, water usage, and the overall efficiency of the fire trucks equipped with thermal cameras and boron-based fire suppressants. This data can then be analyzed to determine the effectiveness of these technologies in real world fire scenarios. Overall, a well-designed experimental setup that carefully measures key metrics is essential to accurately assessing the benefits of thermal cameras and boron-based fire suppressants for fire trucks. By conducting such an experiment, researchers can better understand the potential of these technologies to improve the safety and effectiveness of firefighting efforts.

In the experimental setup, which was prepared by utilizing the steps made by Li et al. [19]. In the prepared experimental setup for this study, examinations of the first flame formation in the fire, the follow-up of the fire, and its extinction at every stage were carried out with a thermal camera.

For this research, three experimental setups were prepared and classified as Exp.W, Exp.SB, and Exp.LB. For the fire suppression operations, water was used in Exp.W, boron-based solid fire suppressant was used in Exp.SB, and boron-based liquid fire suppressant was used in Exp.LB. In all three experiments, the fire studies appeared to be similar to forest fires. For this, pinecones and branches were prepared in equal amounts and placed in the burning pan. Red pine, which is frequently found in the Mediterranean region, was used. Additionally, in this study, thermal imaging cameras (TIC) were used to detect the initial exacerbation of the generated fire pattern and to monitor the extinguishing effect and temperature progression of the fire extinguishers. All of the experiments were conducted with Çukurova University and Adana Metropolitan Municipality Department of Fire and Rescue officers.

As can be seen in Figure 4, the distance between the fire environment and the thermal camera is 15 m. The thermal camera is located at a height of 3 m. The experiment was carried out at ambient temperatures. Different extinguishing agents were manufactured by firefighters.

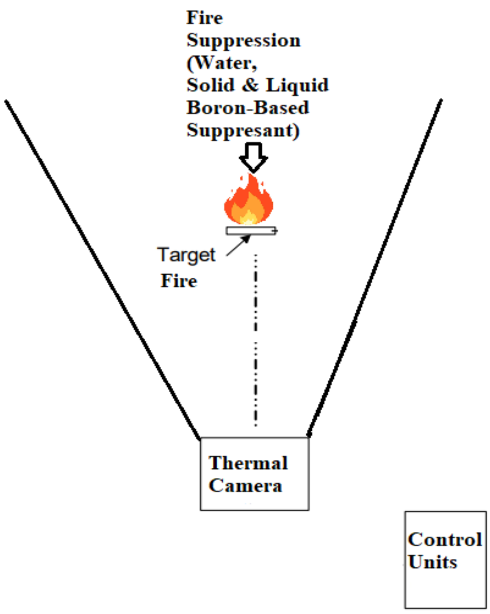

Figure 4. Experimental setup.

For this study, a forest fire model was prepared. For this model, pine tree branches and cones were prepared as flammable materials in three different experiments. (Exp.W, Exp.SB, Exp.LB).

The extinguishing and cooling times of these three extinguishers were tested by using water, boron-based liquids, and solid fire suppressants. The weight of the burning brushwood in each trial was 15 kg. Totals of 50 L of water, 5 L of boron-based liquid suppressant, and 5 kg of boron-based solid suppressant were used in the experiments (Table 6, Figures 5 and 6). In addition, a thermal camera system was used in all three trials, and thermal analysis was investigated for all three trials with a thermal camera. All trials were conducted outdoors and under the supervision of the firefighters. The fire start temperature was assumed to be ambient. The fire environment did not intervene until the temperature reached 700 °C. After reaching 700 °C, the fire extinguishing process started. The fire temperature was allowed to drop to 80 °C, and it was determined how long the extinguishers took to bring the fire under control and extinguish it.

Table 6. The experimental setups.

Experiment Name	Combustible Materials	Extinguishing Agent
Exp.W	pine cones and branches (15 kg.)	water (50 lt.)
Exp.SB	pine cones and branches (15 kg.)	boron-based solid fire suppressants (5 kg.)
Exp.LB	pine cones and branches (15 kg.)	boron-based liquid fire suppressants (5 lt.)

Figure 5. Brushwood fire setup.

Figure 6. Brushwood fire suppressions with water and solid boron-based fire suppressant.

4. Results and Discussion

The thermal energy that radiates onto the TIC lens is concentrated on the detector. The signals generated by the detector are also manipulated into a video signal that is transferred to the display. Some TICs also have a video camera that can be used to record the signal via a hardwired connection or wireless transmitter. The signal that goes to the video display is not generally exactly the same as the signal that goes to the TIC display. The overall mileage of the TIC is therefore truly dependent on the capability of the observer to interpret the image displayed on the screen well enough to perform a task or operation successfully.

The thermal imaging camera is located in a place that sees the fire point from above for testing. In all three trials, it started to signal immediately after manual exacerbation. Afterwards, the thermal camera recorded the temperature and heat conditions. With these images, the heat dissipation and extinction conditions between the three experiments were observed (Figure 7). Experimental changes for the experiments, according to the types of chemical used in Exp.W, Exp.SB, and Exp.LB, are shown in the figures (Figures 8–10) and tables (Tables 7–9) below.

Figure 7. Thermal imaging camera images.

Table 7. Exp.W results.

Steps	Temperature and Time
Starting the fire	33 °C, 14:12:38
Start of suppression with water	700 °C, 14:16:20
End of the fire	80 °C, 14:23:34

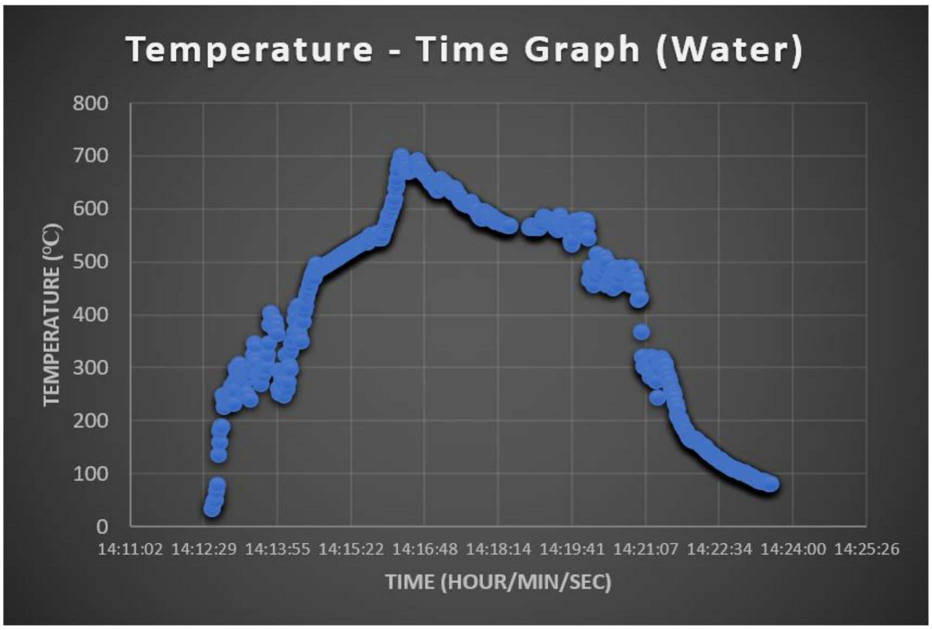

Figure 8. Exp.W results (temperature/time).

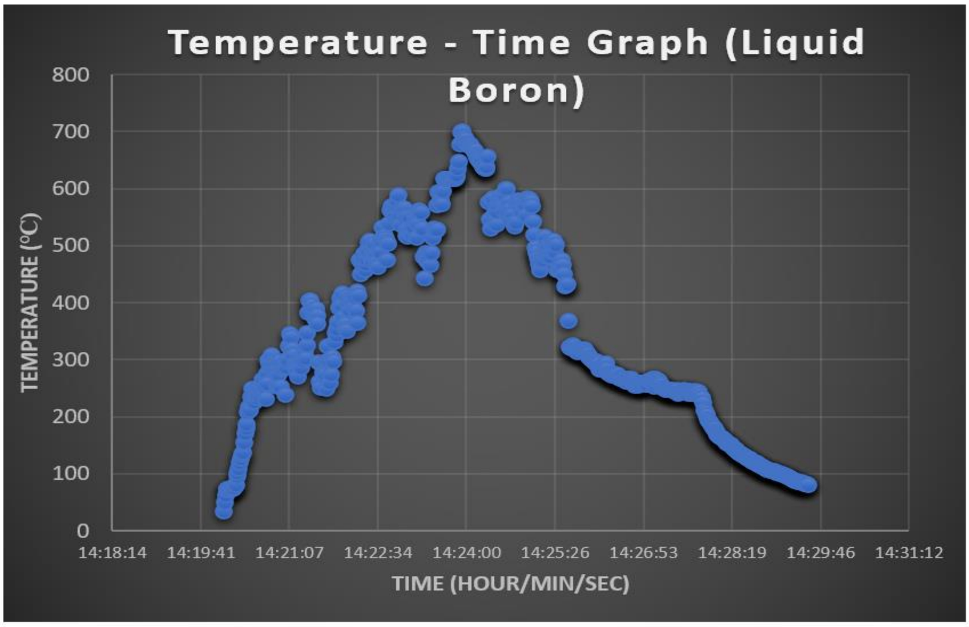

Figure 9. Exp.LB results (temperature/time).

Table 8. Exp.LB results.

Steps	Temperature and Time
Starting the fire	33 °C, 14:20:03
Start of suppression with liquid boron suppressant	700 °C, 14:23:56
End of the fire	80 °C 14:29:34

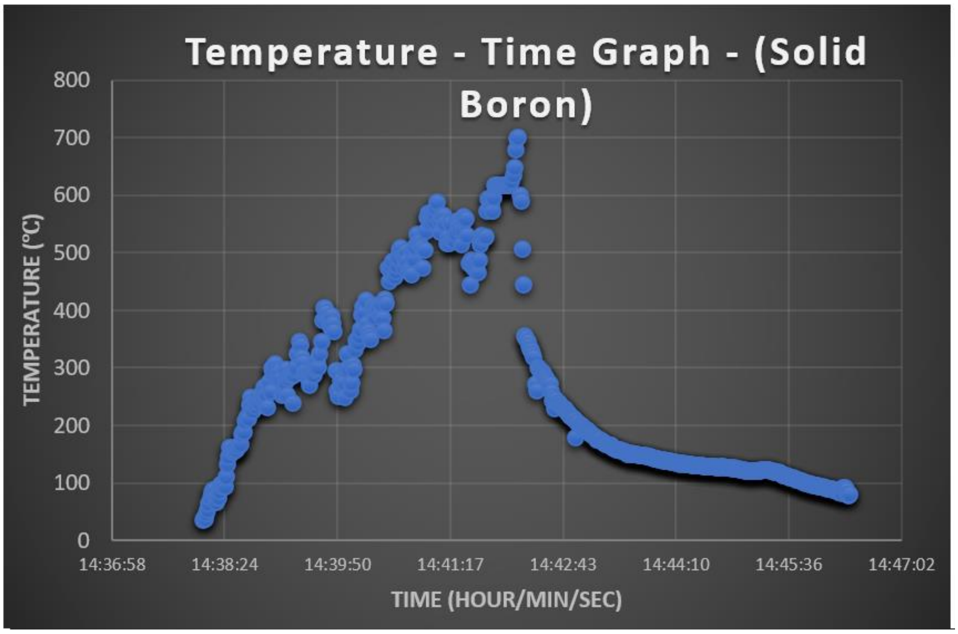

Figure 10. Exp.SB results (temperature/time graph).

Table 9. Exp.SB results.

Steps	Temperature and Time
Starting the fire	35 °C, 14:38:07
Start of suppression with solid boron suppressant	700 °C, 14:42:09
End of the fire	80 °C, 14:46:23

In the experiments, it has been determined that the solid boron-based fire extinguisher is more successful than the liquid boron-based fire extinguisher and the water extinguisher. It has been observed that the solid boron-based extinguisher provides a faster temperature drop and controls heat dissipation better. It is important to use different extinguishers instead of water in fires belonging to different types of fire classes.

It has been observed that, instead of water, boron-based extinguishers extinguish the fire much faster and provide cooling.

A boron report specifies that boron-based fire suppressants work by forming an insulating layer of borate glass. Boron, which the mineral contains in its makeup, reacts with oxygen and moisture to produce this fire-fighting protective barrier when heated up or contacted with water vapor or misty air. Its composition includes four elements: sodium, oxygen, hydrogen, and boric oxide, which we call "borate," as it provides protection against wildfires through the chemical reactions described above during exposure to heat or fire conditions. Boron is a chemical element that does not leave harmful residues, and its high cost makes it less desirable for widespread use in consumer products. Still, this property has made it the most effective material to utilize when combating large-scale fires from petroleum or coal processing facilities. Working with boron-based fire suppressants allows firefighters time to reach locations where they are needed before there is any risk from flames. After this compound starts burning, the smoke released is white and non-toxic [20].

As a result of the experiments, it was seen as an appropriate step to install the TIC systems on the stairs of the fire vehicles. Observations can be made from high points with the activation of the ladder and the gain of height. Additionally, the rotary head feature can provide even better observation capabilities. The figure below provides a visual of where to install TICs on a fire truck (Figure 11).

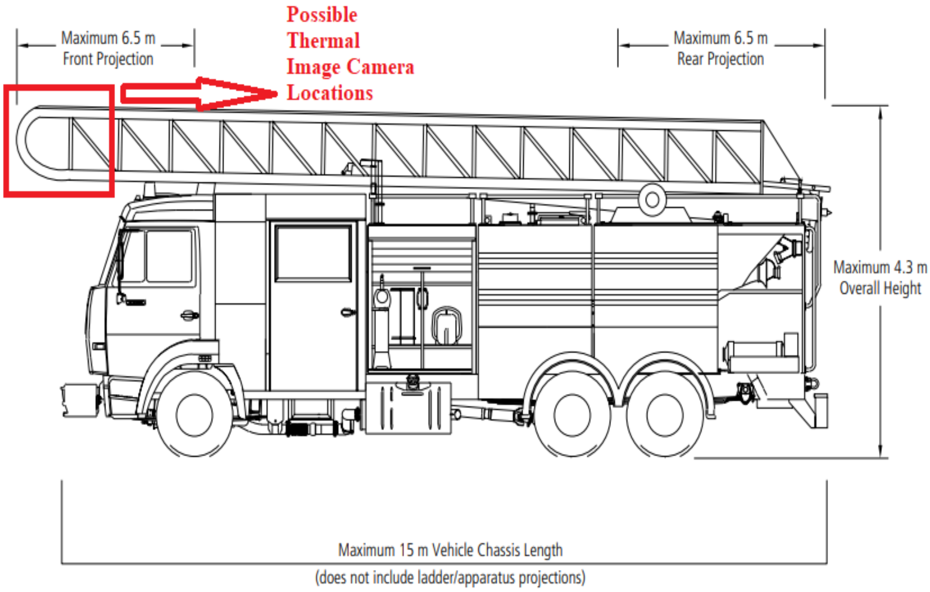

Figure 11. Possible TIC location for fire trucks.

5. Conclusions

For this study, three experiments were carried out with fire extinguishers with boron properties and with water. Suppression experiments were investigated with water and liquid and solid boron-based suppressants.

In each of these trials, plus the initial stage of flare-ups with a thermal camera, the heat dissipation view of the fires formed was given an overview.

In all trials, the extinguishing process was carried out by burning combustible material (pine tree twigs) under the same conditions. In this study, it was seen that boron-based suppressants displayed better performance for restraining the heat release rate than water. If water is used in fire suppression applications, a large amount of water should be used in general.

Boron-based fire extinguishers are very effective for extinguishing and cooling high-temperature fires. In the future, the usage of boron-based fire extinguishers should be further increased. Boron based extinguishers to be used during fire extinguishing works should be applied especially in forest fires. Boron-based extinguishers do not harm either nature or firefighters while extinguishing and cooling fires. With this feature, this type of extinguisher can be considered an environmentally friendly product and can also contribute to the rehabilitation of forests. The existence of boron-based extinguishers in the air and long-term performance effects on the engines of fire trucks must be investigated in the future. The boron-based fire suppressant had better extinguishing and cooling effects than water in the experiments. Compared to the water used as a traditional method, the liquid boron-based extinguisher provided 22% faster—and the solid boron-based extinguisher provided 42% faster—suppression and cooling.

Heat release rate (HRR) is considered the single most important fire response feature, as the heat released by a burning material can contribute to the growth and spread of fire.

At this point, the fight against HRR in large-scale fires includes a difficult process. These studies should be carried out in the future.

Thermal cameras, which have been applied in areas with fire risk in recent years, have the ability to quickly catch the onset of flare-ups. With laser illumination, infrared thermal imaging, night vision, image acquisition, and network transmission, thermal cameras can quickly detect fires from their onset.

Thermal cameras generally detect abnormal flame, smoke, and fire in the fire monitoring area in the desired time interval. They analyze the fire and make a quick comment about the characteristic situation of the fire. With these features, they help firefighters to deal with fires. They can greatly reduce the occurrence of false alarm situations. One of the most important features of these cameras is direct command and dispatch fire extinguishing according to the intuitive picture based on a real-time view of the scene. These cameras can be installed in places where there is a fire risk as well as by attaching them to the rising stairs of fire trucks. In the event of a fire, they can quickly analyze the fire area. Thus, they can give information to firefighters about the existence of living things in the area, the progress of the fire, and its extinguishing properties.

In addition, thermal cameras also assist firefighters in navigating in low-visibility conditions to find heat sources and to measure the temperature. These cameras are suitable for use in observation towers in forests where there is a risk of fire, in areas such as factories and landfills, as well as on the head of the rotating and rising ladder parts of fire trucks.

Firefighters can benefit from the use of thermal imaging cameras. The cameras have sensors and lenses that provide them with access to the IR spectrum. A firefighter can conduct successful search and rescues thanks to these features.

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