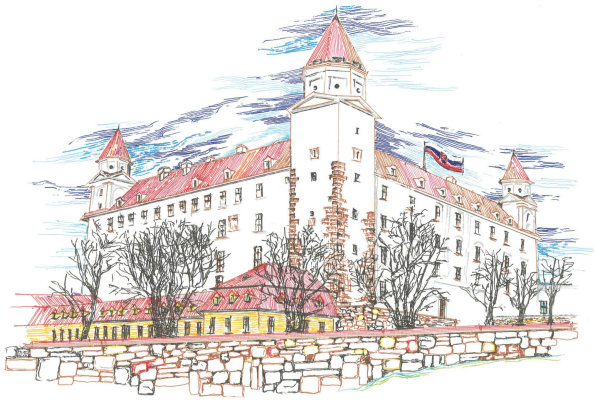
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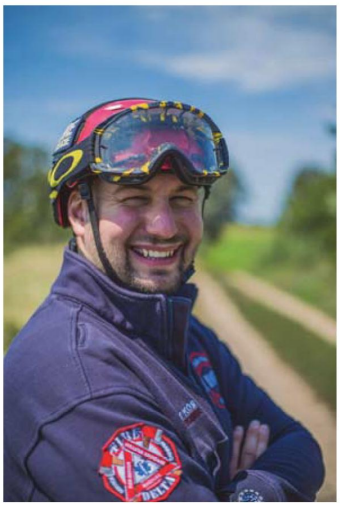
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THERMOGRAPHIC CAMERAS IN THE SERVICE OF FIRE DEPARTMENTS



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Abstract. Even though fire safety and prevention regulations have become significantly stricter in past decades, the rescue role firefighters play in fire safety has not decreased whatsoever. Global warming, terrorism, and industrial development have given fire departments a new set of challenges. Every day they are faced with greater and more destructive vegetation fires caused by climate change. The increase in risk is perhaps less obvious regarding structural and building fires, but we are facing never-before-seen challenges in these areas as well. 35 years ago we would have had an average of 17 minutes to escape an apartment fire before the flashover. Today, this time is only 3-4 minutes. For successfully controlling damage, apart from modernizing operational tactics, it is vital that we implement new and up-to-date self-rescue measures as well as procedures for increasing the odds of survival. One such measure may be the future use of thermographic cameras to search for people in distress. This would allow firefighters to utilize infrared radiation.
Keywords: *infrared radiation, tracking, heat effect, firefighter, safety*

Introduction

The development of infrared cameras dates back to the end of the 1800s. This was when Sir William Herschel discovered rays below red light on the electromagnetic spectrum. [1] This range of the spectrum is named infrared for the English word red and the Latin word for under, infra. There are four basic laws describing infrared radiation. These are the laws of Kirchoff, Stefan-Boltzmann, Planck, and Wien. Research carried out after the discovery initially focused on the development of thermometers and bolometers.

Having built increasingly larger telescopes, he was faced with two problems, on the one hand, the Sun's rays being collected into a too bright bundle and on the other hand, the fact that the rays heated up the apparatus and its environment. This led to his 1800 examination of whether the different colors of the spectrum (rays of different lengths) provided equal heat. With a prism, he separated the sunlight collected with a convex mirror into the different colors and measured each color of the spectrum with a thermometer.

He determined that the thermometer detected the least heat at the violet end of the spectrum and heat increased toward the direction of red. To his great surprise, the heat effect continued to grow beyond the visible color spectrum, that is, from "here to red" which led him to believe that the Sun not only emits light but also heat rays that are invisible to the human eye, and thus, he discovered infrared radiation.[2]

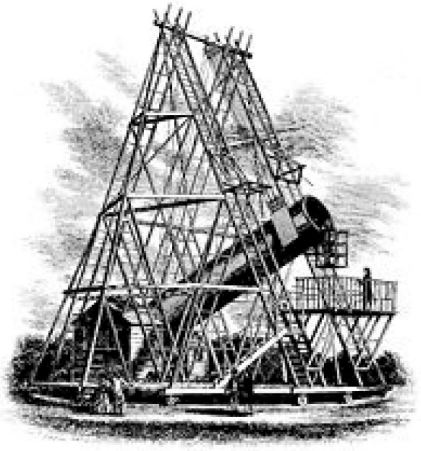


Fig. 1. Herschel's 40 ft long telescope.

The first thermographic camera In 1929 Kálmán Tihanyi [3] built the first night vision television system capable of detecting infrared rays. The invention served the British air defense. In 1947 the US Army collaborated with Texas Instruments to develop the first thermographic camera. These devices were still only infrared scanners and took about an hour to produce a single image. The British Yellow Duckling used in the middle of the 1950s to detect the stream channel of submarines was the first infrared line scanner. Thermographic cameras were first used exclusively for military purposes. The high cost of these devices prevented their use by fire departments. After the sinking of the HMS Sheffield, their regular use was implemented by the firefighters of the British navy. The first documented non-military rescue carried out with the aid of a thermographic camera was in London in 1985 at the time of the Putney gas explosion. The first fire department to purchase a thermographic camera was the Seattle Fire Department in 1997. It had cost 16.000 USD. In 2000 the Los Angeles Times called the thermographic camera the most innovative and also the most expensive fire safety and rescue equipment.

The principle on which thermographic cameras function For the successful and efficient use of thermographic cameras we must first understand their operational principle. Electromagnetic radiation is present everywhere in our environment. *"Electromagnetic radiation is a flow of energy that spreads from a point (source) in any given direction without a medium; it creates oscillating electric and magnetic fields that are perpendicular to each other, it spreads in wave form, in a vacuum it travels at the speed of light carrying energy and impulse."*[4] If we systemize the electromagnetic rays based on their frequency, we get the electromagnetic spectrum. This is the part of the spectrum that falls between 380 nm and 780 nm and is visible to the human eye. Wavelengths higher than this include ultraviolet, x-ray and gamma rays. Infrared, microwaves and radiowaves are in the range lower than visible light. All objects warmer than -273,15 °C, that is, absolute 0 °C emit electromagnetic radiation or reflect it. Using this phenomenon, thermographic cameras detect all infrared radiation between 780 nm and 1 mm and convert this raditaion into an image in which different colors appear.

Glass as a factor hindering infrared detection The structure of glass makes it possible for visible light to pass through it. However, it reflects infrared radiation. Due to this property, glass surfaces can hide people to be rescued or sources of danger. Glass basically acts as a mirror for infrared rays. If, when looking at the image produced by a thermographic camera, we suspect we are seeing ourselves, we must assume that there is a glass surface in front of us and we have to inspect the area more thoroughly with traditional methods.

Near-infrared radiation (NIR, IR-A) with a wavelength of 0,75-1,4 μm is used in optical communication as it only weakens slightly

when passing through glass. The intensity of the image it produces in this range is high, this phenomenon is utilized by night-vision goggles.

Short-wave infrared (SWIR, IR-B) is light with a wavelength of 1,4-3 μm. It weakens at 1450 nm. Light between 1530 to 1560 is used in telecommunication.

Mid-wave infrared radiation (MWIR, IR-C) is between 3-8 μm. It is used in infrared self-guiding missiles. An infra-detector is placed on the head of the rocket, this picks up infrared radiation, e.g. the flames of a jet engine.

Long-wave infrared radiation (LWIR, IR-C) falls in the range between 8-15 μm, it is often referred to as a heat detector as it produces a passive heat image which does not require an external light source or heat. It is sometimes called *far-infrared radiation*.

Far-infrared radiation (FIR) falls in the range between wavelengths of 15-1000 μm

Areas of application:

Extinguishing building fires search,

procedural tactics, increasing procedural safety, determining the source of the fire, searching for persons, rescuing fellow firefighters, inspection of the area after extinguishing the fire

Extinguishing vegetation fires

search, procedural tactics, increasing procedural safety, determining the source of the fire, inspection of the area after extinguishing the fire

Damage control in connection with hazardous materials

search, increasing procedural safety

Outdoor search and rescue operations

searching for persons, water search, injuries caused by freezing temperatures

Vehicular accidents

search, searching for persons, searching vehicles, increasing procedural safety.

Extinguishing building fires Thermographic cameras can be best utilized by firefighters in cases of building fires. During the 360-degree search that takes place directly after firefighters arrive on the scene, the commanding officer can get a more complex image of the location of the fire, its extent, state and intensity using the thermographic camera. Having gathered this information they are able to make a more responsible decision about the most appropriate place(s) of action and the best methods. Apart from taking the most appropriate and efficient measures for the event, operational safety can also be increased. By using a thermographic camera, the rescue team entering the building can carry out rescue efforts more quickly and efficiently despite poor visibility conditions. During an interior attack (initiating extinguishment of the fire from the inside of the building) firefighters are at greater risk. Those between the current point of the fire and the direction it is spreading in are the most at-risk. With a thermographic camera, potential sources of danger such as flashover, backdraft, rollover or flowpath would be detectable thereby increasing operational safety for the rescue team members.[5] Apart from sources of danger, the detection of the hot points and the fire sources as early as possible enabling extinguishment with as little delay as possible allows for quicker and more efficient extinguishment. Furthermore, thermographic cameras can be used effectively during the post-extinguishment inspection process for finding smoldering after the flames have been put out.

Extinguishing vegetation fires Simil early to the case of building fires, thermographic cameras can be used successfully during search efforts after firefighters arrive on the scene of a vegetation fire. Fire sources can thus be determined effectively and much quicker even in low visibility situations when there is a significant amount of smoke.

Damage control in connection with hazardous materials As hazardous materials stored in different containers are generally of different temperatures than the containers themselves and thermographic cameras can ascertain the amount of the material present. If hazardous liquids are released out into the open, a thermographic camera can be used to determine the physical extent of the pollution.

Outdoor search and rescue operations Similarly to outdoor rescue efforts, when rescuing persons in an enclosed space, the differing temperature between the human body and its environment can be utilized for successful search procedures. Foremost in situations where search with the naked eye is limited (eg.: darkness, fog, areas covered with thick vegetation, etc)

Vehicular accidents Foremost suitable for increasing operational safety. Leakage of fuel or other hazardous materials can be

ascertained with thermographic cameras. In the case of accidents where the presence of more than one person in the vehicle cannot be excluded, the device can be used to search for other victims.

Tactical application of thermographic cameras The spread of thermographic cameras has been one of the greatest development in firefighters' equipment in recent decades. When used properly thermographic cameras can greatly assist the work of those carrying out the operation during damage control efforts. However, for their efficient use, it is necessary that we understand their limitations and know how to interpret the images they produce. Thermographic cameras used by firefighters can be divided into two basic categories. Personal thermographic cameras and collectively applied ones. The former mainly aid firefighters in orientation. These are not suitable for full-spectrum search efforts or making decisions. The reason for this is their smaller screens, lower image resolution and weaker processor performance which all mean it takes longer to refresh the image.



Fig. 2. BULLARD T3 max+camera

Image interpretation Thermographic cameras depict hotter points as light grey to white. Colder objects are darker grey to black. Because the image appearing on the screen is always relative to the examined area it is capable of highlighting warm-blooded living things such as humans, pets, etc. The most modern cameras like the BULLARD T3 max+ have a so-called Super Red Hot function with which they indicate the points of differing temperature as yellow beginning at 500 °F (260℃) and as the temperature rises, they change to orange and red. Thus, thermographic cameras do not detect temperature but temperature differences. This is why they are able to indicate heat imprints as well.

Heat inversion The heat of the average human body is approximately 37 ℃ which means that in a room-temperature space a thermographic camera would depict it as a white or light grey shape. A firefighter in a burning building would be indicated as a darker shape on the screen as they are likely to be among the coldest objects in the space.

Heat contrast This means that objects can be separated from one another. Whether the heat contrast is sharp or blurred depends on the sensitivity of the infrared detector and the difference in temperature between the objects on the image.

Heat saturation This can happen if the objects absorb a large amount of energy and radiated it back with uniform temperatures. This will result in a nearly uniformly white image and hinder the efficient use of the device. This characteristically occurs during the fire and afterward.

Conclusions

Thermographic cameras can be successfully used to search for persons in low visibility conditions (e.g. smoke-filled spaces). When approaching the space to be inspected from six directions (ceiling, the four walls, floor) we must continuously inspect and evaluate. It may occur that not every victim is indicated with an easy to recognize shape or color. This may be due to clothing, bedding or debris hindering infrared radiation from reaching the camera. We must search for the obvious and unrecognizable shapes alike. With the help of the thermographic camera, we inspect areas where a victim could potentially be present (eg. bed, closet, a pile of debris, etc.)

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