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SELECTED SCIENTIFIC AND ENGINEERING APPLICATIONS OF INFRARED TECHNOLOGY

Abstract

The paper presents applications of infrared measurements. It discusses the use of thermovision in the analysis of heat losses in buildings, environmental monitoring, scientific research in thermal fields on different surfaces and other. Examples of the infrared measurements are given and discussed in the text.

Keywords: heat losses, infrared measurements, visualizations

1. Introduction

Infrared technology used to be an expensive testing method, however, nowadays even small companies can afford to purchase simple thermovision cameras. Their widespread use ranges from heat losses detection in buildings (which is quite common due to the thermal performance analysis) to complex scientific measurements.

The fundamental basis of the infrared testing is the detection of radiation, whose intensity in the simplest form can be calculated according to the Stefan -Bolzmann law. This radiation is emitted by every body of temperature exceeding 0 K and depends on the temperature of the analysed element to the forth order, emissivity (taking values from 0 to 1) and the Stefan-Boltzmann's constant (σ = 5.67x10^{-8} W/(m^2K^4)). In real measurement conditions the detector receives radiation emitted from other sources too and not only from the observed element. As a consequence, correct determination of temperature requires taking into account radiation reflected from the object and coming from sources in the surroundings as well as atmospheric radiation. It is done by the software of an infrared camera when data such as temperature of the surround objects, atmosphere, air humidity and etc. are input to the device.

Literature provides many examples of the application of infrared technology. In [1] the detection of warmer and colder areas of the urban areas is discussed with the view to provide knowledge for proper urban planning. Determination of the temperature of the earth itself is also vital and can be investigated with thermovision [2]. This temperature is a crucial parameter in environmental assessment of e.g. plant vegetation, energy balance, soil humidity and etc. Similarly, measurements of this kind can be performed for the sea surface [3]. In this case the temperature distribution can help to detect anomalies of anthropogenic origin in the analysed areas or obtaining knowledge on climatic conditions. Data collected for many years can enable to create trends of climate changes. Apart from earth, the atmosphere can also monitored with infrared technique. For example water vapour, carbon oxide or ozone particles might be observed with this method [4]. The composition of the atmosphere can be determined with devices located in satellites. In [5] three possible applications have been discussed, namely: local ozone concentration measurements, carbon oxide monitoring and early detection of sulphur dioxide from volcanic emissions.

Thermovision can be applied in the analysis of biochemical activities on landfill sites. In [6] the test results for the landfill located in Ostrowiec Świętokrzyski were presented. Different temperatures were recorded for fresh waste (characterised by higher temperatures due to intense biodegradation processes) and older – of much lower temperature. The speed of the monitoring process and the possibility of analysis large areas were also pointed out.

Chimneys with exhaust products of combustion are the sources of air pollution. Gaseous and particulate contaminants are emitted from them and the knowledge of the spread of air pollution is crucial. In [7] the impact of the technical condition of a cement plant chimney on the spread of air contaminants with regard to its thermal insulation was analised. Thermal imaging of the chimney was used to assess the influence of the reduction of the exhaust gases temperature (caused by improper thermal insulation and elevated heat losses to the surroundings) on the propagation of contaminants in the atmosphere.

Currently, energy saving initiatives are more and more common. On the one hand it is related to environmental protection and emissions of carbon dioxide and other contaminants, while on the other to economics due to reduced costs for heating of well insulated buildings. In this regard infrared technology can help in the assessment of thermal insulation of walls and other elements in buildings. The features of thermovision measurements and their applications for buildings were described in [8]. In [9] and [10] the issue of infrared analysis of buildings was also considered with the focus on heat losses from old multi – flat residential buildings where a thermovision camera can be very efficient in the detection of thermal bridges that usually occur at the junctions of the reinforced-concrete plates.

The use of thermovision is naturally much wider. For example is covers medical applications. With regard to sports medicine and rehabilitation, infrared technique can help to determine the level of exhaustion and assessment of rehabilitation effectiveness. Colder areas due to long – term contraction of the muscle, whose blood vessels are contracted, might be detected with a thermovision camera. The situation is similar in case of spinal curvature, in which colder areas are located opposite the curvature [11]. Infrared imaging can also be applied in knee joints illnesses [12]. While dental use of this technique may cover, among others, analyses of temperature changes at polymerization of composites thorough measuring infrared emissions from surfaces of resin composite restoration during photocuring [13].

This overview of the uses of thermovision is naturally not complete since many more applications are possible. In the following chapter of this paper selected uses of this technique will be discussed and examples of the authors' research will be given.

2. Examples of the measurements

2.1. Thermal losses analysis in buildings

At the beginning of an overview of the example applications of infrared measurements it is worth noting that practical experience of the user of a thermovision system and knowledge of the measurement errors are crucial to properly conclude about the obtained results. Producing an infrared image itself is easy, however, its interpretation might be challenging, at times. For instance, the radiation can be reflected from surrounding sources and influence the temperature reading of the analysed surface, as presented in Figure 1. Here, the surface on the left hand side "seems" to have warmer areas, while it is just a reflection phenomena of radiation coming from the radiator. This reflective surface is a door covered with white metal layer.

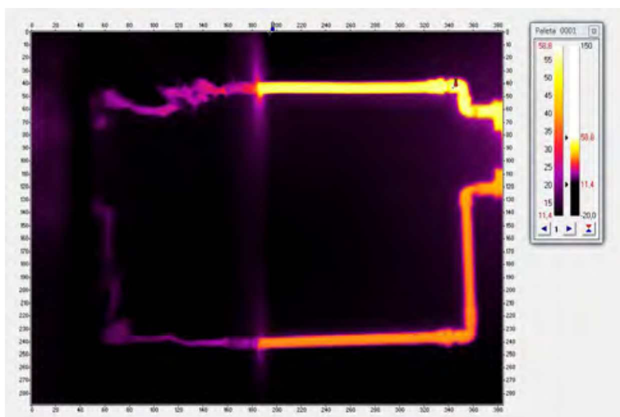


Fig. 1. Reflection phenomenon on the reflective surface

Buildings themselves consume significant amounts of energy – both in the winter when heating is needed and in the summer if they are air conditioned. This consumption can be reduced, for example through better insulation. As a result, maintenance costs might be lower, which has both environmental and ecological benefits.

Thermal imaging can be used in this case to analyse areas of increased heat losses during the winter time. Figure 2 presents the thermal map of a modern multi-flat building where areas of elevated heat losses are presented in red, pink and yellow colours.

Fig. 2. Thermograph of the multi-flat building

Particularly hot might be chimneys (Fig. 3). Their improper thermal insulation results in the reduction in temperature of the exhaust gases due to heat losses, which might effect the special propagation of air pollutants in the atmosphere, as discussed in [7].

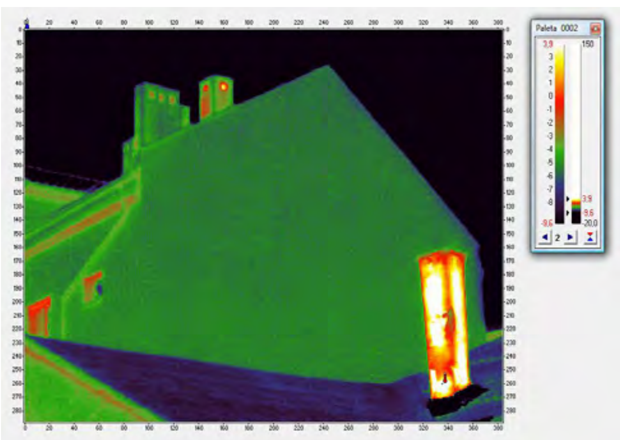


Fig. 3. Thermograph of the modern multi-flat building with the chimney

Within the building structure some elements are more prone to heat losses for example balconies. They might act as fins of a heat exchanger and promote heat losses. In this case a temperature gradient occurs along their length as presented in Figures 4a and 4b, which shows temperature changes along line L1 on the analysed element in the analysed multi-flat building. It is worth noting that proper construction of balconies can help to avoid the occurrence of this unfavourable phenomenon.

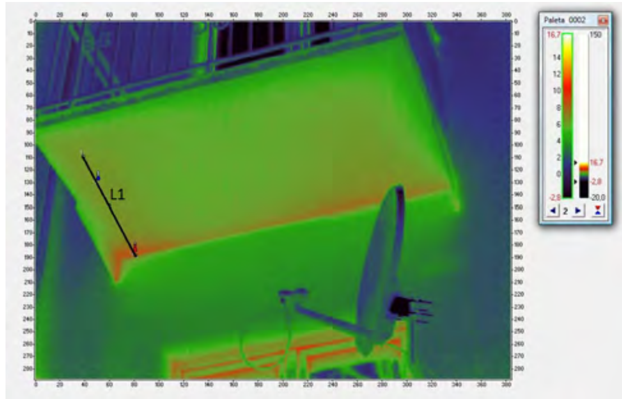


Fig. 4a. Thermograph of the balcony

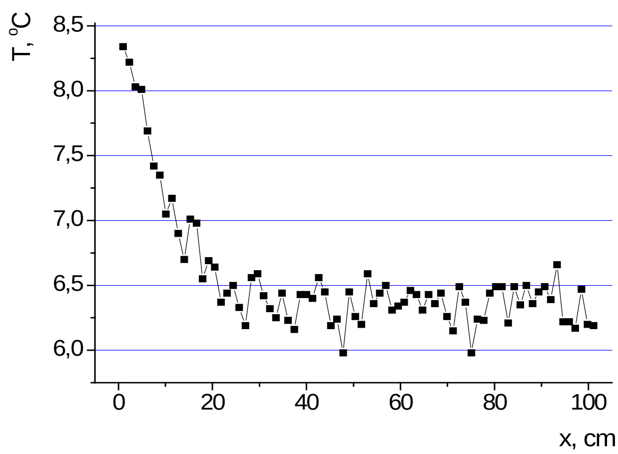


Fig. 4b. Temperature changes along line L1

Heat losses can occur at different locations within the building. Figure 5a presents a thermograph of the old multi-flat building. In this case elevated losses can be observed along line L2. Here pipes of the central heating system might run within the building and this area proves to have higher surface temperatures. Figure 5b presents the temperature changes for the analyses line.

Fig. 5a. Thermograph of the multi-flat building

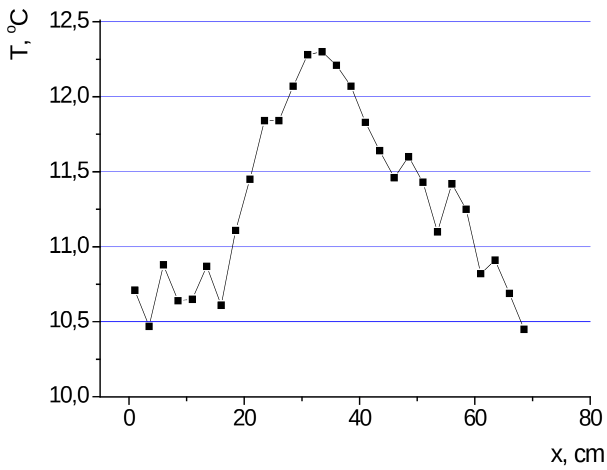


Fig. 5b. Temperature changes along line L2

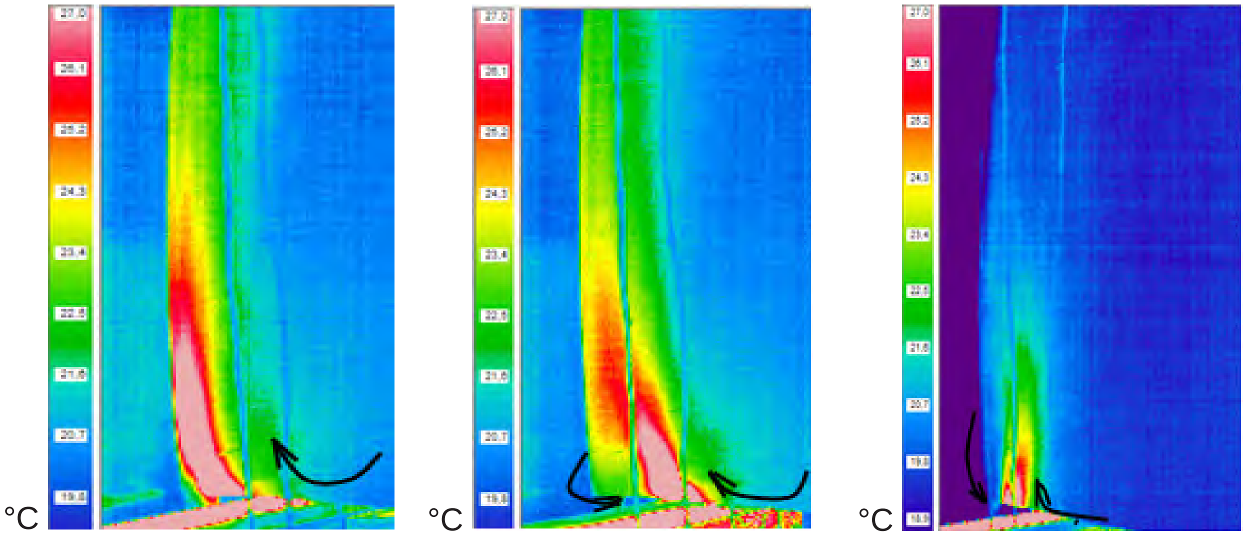
Apart from thermal bridges the infrared technique can be useful in the detection of humid areas in the building as well as determination of leakage spots in pipes transporting warm liquids.

2.2. An analysis and visualization of heating systems streaming by the help of thermovision

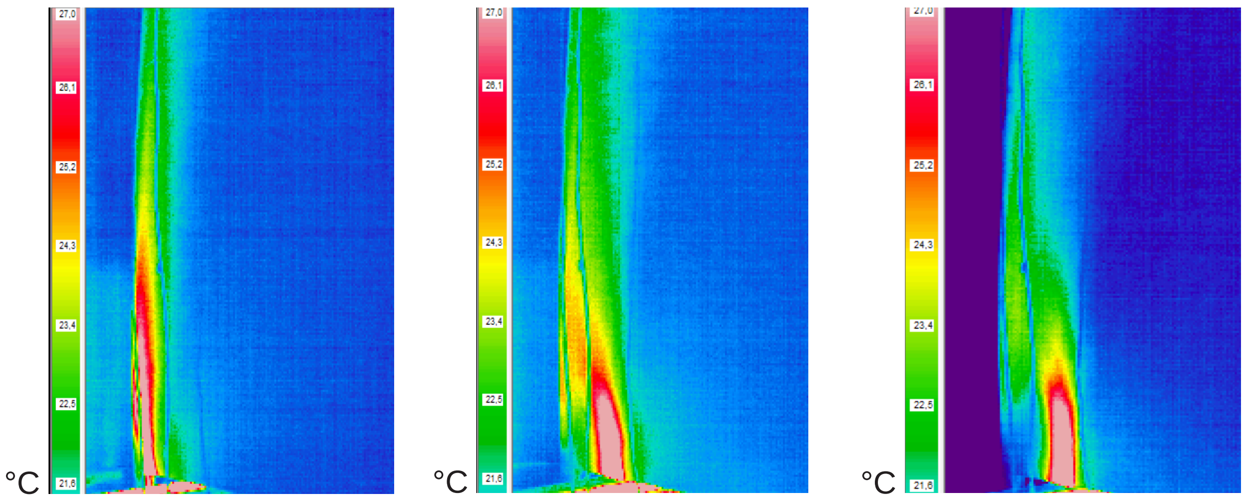
To know the mechanism of the heat transfer from the floor convector to the surrounding atmosphere through the natural convection, it is necessary to know the shape of the streaming and the temperature distribution in the direct closeness to the surface. Many visualization methods exist to visualize density changes close to the surface of the body with the heat transfer, starting from the shadow method, orifice method to interferometric or holographic methods. To visualize natural air streaming it is also possible to use the methods with marking the streaming for example by helium bubbles or by temperature marks. But this method is not suitable to visualize the streaming from the floor convector as the measurements were made in the thermostatic chamber where it is not suitable to install other necessary devices (a lamp, a compressor) with high heat output.

In this case the thermovision was used to visualize the heat output from the convector. It is known that by the help of the thermovision it is possible to visualize also small temperature differences. But the object must not be diathermal and the emission coefficient of its surface should be close to 0.9 because the air close to the surface of the floor convector heated through the natural convection is also diathermal and so it is invisible on the infra screenshots. From this reason the method of the heating of a thin, most often paper, foil was used for the visualization. The foil was placed at the surface so that the orientation of its surface was along the air streaming and so that it does not influence the natural convection. The foil is heated by the streaming warm air on temperatures close to the streaming air and the temperature profile in the closeness of the object is properly visible as well as quantifiable. The way of placing the foil for the visualization in the thermostatic chamber is shown at Figure 6. On various screenshots the visualized area of natural convection is shown. The infracam MIDAS 320L was used and the pictures were evaluated by the help of the Pyrosoft software.

Fig. 6. Floor convector in the thermostaic chamber

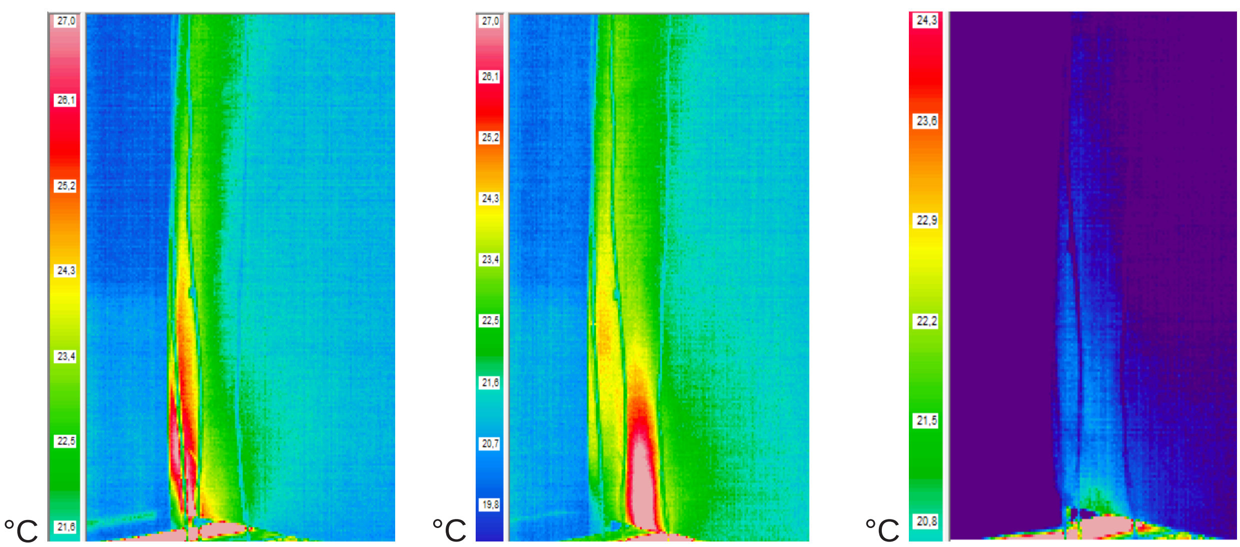


Measurement 1

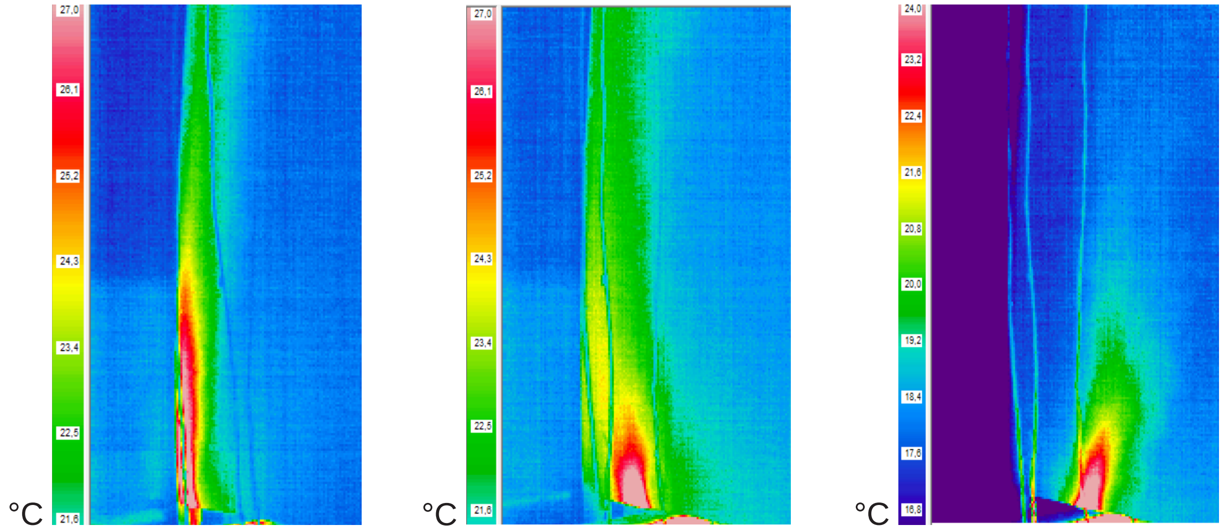


Measurement 2

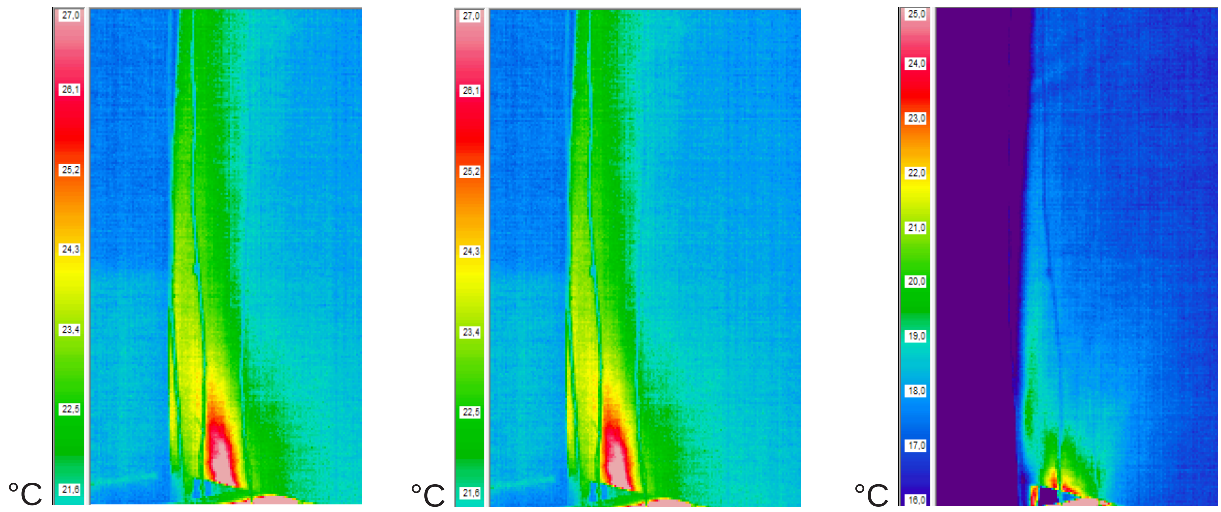
Fig. 7. Visualization of temperature fields: measurement 1 and 2



Measurement 3

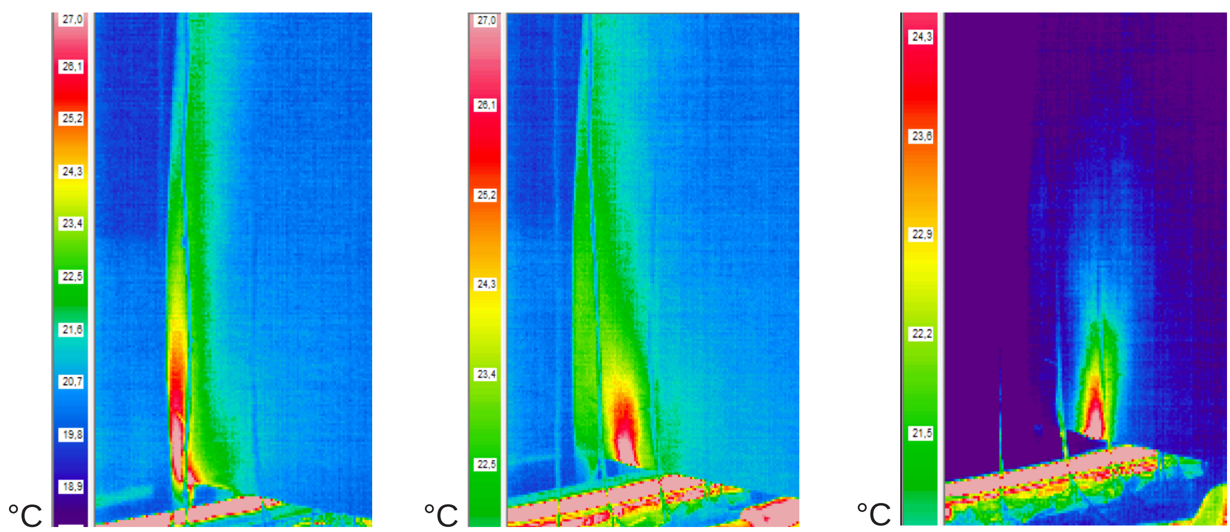


Measurement 4



Measurement 5

Fig. 8. Visualization of temperature fields measurement 3, 4 and 5



Measurement 6

Fig. 9. Visualization of temperature fields measurement 1 and 6

environment

From the visualization of temperature fields from the measurement 1–6 in the thermostatic chamber, temperature fields at three different measured states are visible (a – convector at the wall, b – convector from the wall, c – cold front wall). From following pictures it is evident, that with the increasing output also the stream reach increases. From the pictures of temperature fields it is possible to define also the picture and a direction of the air streaming in the thermostatic chamber. When the floor convector is placed close to the wall, the colder air is being sucked from the area of the chamber and the warmed air streams along the front wall. When the floor convector in the tube was placed farther from the wall (Figures 7b–9b) it is visible that the air stream from the convector sucks cold air from the wall which causes its mild shift. Finally, it sticks to the wall with smaller distance. At experimental measurements of floor convectors in the thermostatic chamber there was also visualized a state where the front wall of the convector was cooled by the maximum output of the cooler and the other walls were switched off, Figure 7c – 9c. From these visualizations it is evident that cold air falls along the front wall and it presses warmed air from the convector in the direction into the room. Furthermore, it is evident that the higher the convector output is, the smaller is the shift. At the measurement 2 Figure 7c, where the floor convector with the highest output was measured, it is visible that even when the front wall is undercooled the air stream from the floor convector mildly sticks to the wall and warms it.

3. Conclusions

Infrared measurements are more and more common in the industry and science. The availability of thermovision systems due to their lower prices has enabled broader use of this technology. Possible applications range from heat losses analysis in buildings, heating systems, medical testing, environmental monitoring and many other. Because of such widespread scope of uses the infrared technology will undoubtedly be even more commonly used in the future.

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Wybrane naukowe i inżynierskie zastosowania techniki termowizyjnej

1. Wstęp

Technika termowizyjna do niedawna była jeszcze bardzo kosztowna, jednak dziś nawet niewielkie firmy mogą pozwolić sobie na zakup systemów termowizyjnych. Ich zastosowanie jest szerokie – od dość prostej detekcji mostków cieplnych w budynkach po skomplikowane badania naukowe. Pomiary opierają się o detekcję promieniowania, które jest emitowane przez obserwowane ciało. Na podstawie prawa Stefana-Bolzmanna możliwe jest wyznaczenie temperatury analizowanego elementu. Istotnym czynnikiem jest właściwe określenie współczynnika emisji – przyjmującego wartości od 0 do 1 – i wprowadzanego do oprogramowania kamery.

Literatura zawiera szereg przykładów wykorzystania pomiarów w podczerwieni. W [1] analizowano detekcję obszarów w wyższej i niższej temperaturze do celów urbanistycznych, a w [2] w pomiarach temperatury powierzchni ziemi w zagadnieniach środowiskowych. Podobnie w [3] rozpatrywano pomiary temperatury powierzchni morskich. Innym zastosowaniem jest monitoring stężenia pary wodnej, tlenku węgla czy ozonu w atmosferze [4]. Podobnie w [5] rozpatrywano wykorzystanie techniki termowizyjnej do pomiarów lokalnego stężenia ozonu, monitoringu tlenku węgla czy wczesnego wykrywania emisji dwutlenku węgla ze źródeł wulkanicznych.

Termowizję można też wykorzystywać w pomiarach aktywności biochemicznej składowisk odpadów [6] czy w analizie wpływu stanu technicznego kominów na rozprzestrzenianie się zanieczyszczeń [7]. Szerokie jej zastosowanie wiąże się z detekcją obszarów o podwyższonych stratach ciepła w budynkach, co opisano w [8–10]. Pomiary w podczerwieni można również wykorzystywać w medycynie. Temu zagadnieniu poświęcono np. następujące publikacje [11–13].

Powyższy przegląd nie wyczerpuje szerokiego spektrum zastosowania pomiarów w podczerwieni. W kolejnym rozdziale autorzy opiszą własne przykłady wykorzystania termowizji.

2. Przykłady pomiarów

2.1. Analiza strat ciepła w budynkach

Przed przystąpieniem do analizy przykładów zastosowania termowizji warto zwrócić uwagę na konieczność posiadania odpowiedniej wiedzy i doświadczenia przez osoby obsługujące kamery. Jest to związane z możliwymi trudnościami, związanymi z analizą obrazu. Na przykład powierzchnia na rysunku 1 wydaje się być cieplejsza, natomiast jest to związane jedynie ze zjawiskiem odbicia promieniowania od drzwi pokrytych blachą.

Budynki konsumują znaczną ilość energii – w zimie na cele grzewcze, a w lecie, jeśli występuje chłodzenie powietrza. Ograniczenie strat ciepła może wpłynąć na znaczne zmniejszenie ilości pobieranej energii. W tym zagadnieniu może być przydatna technika termowizyjna.

Rysunek 2 przedstawia termogram nowoczesnego budynku wielorodzinnego z obszarami o podwyższonej temperaturze uwidocznionych w kolorze czerwonym, różowym i żółtym. Kominy mogą mieć znaczną temperaturę (rys. 3), a spadek temperatury spalin może wpływać na rozprzestrzenianie się zanieczyszczeń, co poddano dyskusji w [7].

Niektóre elementy budynku mogą stanowić źródło zwiększonych strat ciepła. Są to na przykład balkony. W tym przypadku mogą one działać jak żebra czyli wymienniki ciepła. Wówczas na długości pojawia się gradient temperatury, co zilustrowano na rysunku 4a i 4b. Rysunek 5 przedstawia termogram innego budynku. W tym przypadku obszar o podwyższonej temperaturze może odnosić się do niezaizolowanego termicznie pionu instalacji c.o. Termowizja może także służyć do detekcji obszarów zawilgoconych czy wykrywania nieszczelności w przewodach transportujących czynnik o podwyższonej temperaturze.

2.2. Analiza i wizualizacja efektu działania elementu grzewczego przy pomocy termowizji

Wiedza na temat mechanizmu wymiany ciepła z konwektora podłogowego do powietrza w po-

environment

mieszczeniu poprzez konwekcję swobodną wymaga znajomości kształtu strugi i rozkładu temperatury w bezpośredniej bliskości powierzchni. W warunkach prac prowadzonych w komorze termostatycznej do badań wymiany ciepła z konwektora wykorzystano pomiary termowizyjne. Obserwowano powierzchnię umiejscowioną wzdłuż strumienia powietrza tak, aby nie zaburzała ona konwekcji naturalnej (rys. 6). Ciepłe powietrze ogrzewało obserwowany element, a rozkład temperatury mierzono kamerą termowizyjną MIDAS 320L. Uzyskane obrazy analizowano oprogramowaniem Pyrosoft. Na podstawie uzyskanych rozkładów temperatury dla różnych lokalizacji konwektora można było wnioskować o przepływie strumienia ciepłego powietrza z badanego elementu grzejnego.

3. Wnioski

Pomiary termowizyjne stają się coraz powszechniejsze zarówno w przemyśle jak i nauce. Dostępność systemów do badań w podczerwieni związana z niższymi cenami umożliwia ich szerokie zastosowanie w wielu dziedzinach np. do analizy strat ciepła w budynkach, pomiarów elementów systemów grzewczych, monitoringu środowiska i innych. W związku z tak szerokim spektrum aplikacji termowizji metoda ta będzie bez wątpienia stawać się coraz powszechniejsza.