

USE OF THERMAL IMAGING IN CONSTRUCTION

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Abstract. Thermovision is a research method based on non-invasive and non-contact evaluation of temperature distribution on the surface of the examined body. These methods are based on observation and recording of the distribution of infrared radiation, sent by each body whose temperature is higher than absolute zero (-273°C) and visualization of the temperature field by thermal imaging equipment. In construction, thermovision is used to assess the quality of materials used in construction, structural solutions and the quality of construction work. With its help we can locate, for example, thermal bridges, which are the result of improperly made or damaged during the operation or installation of thermal insulation. Detection of thermal bridges helps to reduce the amount of fuel used and thus save on the costs of heat energy. Using thermal imaging it is also possible to assess the condition of heating pipelines (damage to insulation, corrosion, location of leaks), control heating devices such as: heat substations, radiators. The subject of the study is to show examples of how thermal imaging is used and useful in construction.

Keywords: thermal imaging, infrared radiation, heat loss, thermal imaging camera

ZASTOSOWANIE TERMOWIZJI W BUDOWNICTWIE

Streszczenie. Termowizja to metoda badawcza polegająca na bezinwazyjnej i bezdotykowej ocenie rozkładu temperatury na powierzchni badanego ciała. Metoda ta opiera się na obserwacji i zapisie rozkładu promieniowania podczerwonego, wysyłanego przez każde ciało, którego temperatura jest wyższa od zera bezwzględnego (-273°C). Wizualizacji pola temperaturowego wykonywana jest przez aparaturę termowizyjną. Zaletą pomiarów termowizyjnych jest ich mobilność, fakt że wyniki pomiarów otrzymujemy w tej samej chwili i możemy je rejestrować w formie zdjęć lub filmów w zależności od typu kamery. W budownictwie termowizja wykorzystywana jest do oceny jakości zastosowanych do budowy materiałów, rozwiązań konstrukcyjnych oraz jakości wykonania prac budowlanych. Przy użyciu termowizji można również dokonać oceny stanu rurociągów grzewczych (uszkodzenia izolacji, korozję, z lokalizować nieszczelności), dokonywać kontroli urządzeń grzewczych, takich jak: węzły cieplne, grzejniki. Przedmiotem opracowania jest pokazanie w jaki sposób termowizja jest wykorzystywana i przydatna w budownictwie. na przykładzie wykonanych badań i przy użyciu profesjonalnego oprogramowania do obróbki termogramów.

Słowa kluczowe: termowizja, promieniowanie podczerwone, straty ciepła, kamera termowizyjna

Introduction

Thermovision is a research method based on non-invasive and non-contact evaluation of temperature distribution on the surface of the examined body. This method is based on the observation and recording of the distribution of infrared radiation, sent by each body whose temperature is higher than absolute zero (-273°C). The visualization of the temperature field is performed by thermal imaging equipment. The advantage of thermographic measurements is their mobility, the fact that the results of measurements are obtained at the same time and we can record them in the form of photos or films depending on the type of camera. In construction, thermal imaging is used to assess the quality of materials used in construction, structural solutions and the quality of construction work. With its help we can locate, for example, thermal bridges, which are the result of improperly made or damaged during the operation or installation of thermal insulation. Detection of thermal bridges can reduce the amount of fuel used and thus save on the cost of heat energy. Using thermal imaging it is also possible to assess the condition of heating pipelines (damage to insulation, corrosion, location of leaks), control heating equipment such as: heat exchangers, radiators and detect irregularities in the operation of equipment such as: pumps and electric motors, allowing early removal of damage and prevent the occurrence of more serious failures. The subject of the study is to show how thermal imaging is used and useful in the construction industry. On the example of research and using professional software to process thermograms [5].

1. Thermography and thermovision

Thermography is the conversion of an infrared image into a radiometric image, which allows to read temperatures. Because infrared radiation has more energy than visible radiation, it can be detected from a greater distance than visible radiation. This is done by means of an installed infrared radiation detector matrix and a cooperating image search system. The micro-bolometer detector used, which is designed to detect the temperature reaching the camera's thermal radiation, produces a type of electrical signal based on the reading from the pixel sensor matrix,

which in the next stage is converted to a digital form, which is displayed on the camera's display. The obtained image is called a thermogram or thermal image. The temperature distribution in the studied objects is presented in the form of coloured isotherms, where one color corresponds to points of the same temperature.

It should be remembered, however, that the stream reaching the lens of the thermal camera is the sum of the streams: the proper one (sent by the examined object), scattered and reflected from the surface of the examined body. Each thermal radiation is also to some extent attenuated by the atmosphere between the camera and the examined body. The measurement results are also influenced by: sun rays absorbed and reflected by the observed surface, interfering factors coming from the environment (clouds, sky, high air humidity) and other objects of elevated temperature that are in the environment (furnaces, heaters, etc.).

Therefore, in order for the thermal imaging device to correctly determine the object temperature, the camera operator must enter the following data

- emission factor, which determines the amount of energy emitted by a given body to the energy that should be emitted by the so-called black body (which is the emission standard).
- the distance of the object-camera in order to determine the transmission of the atmosphere,
- the temperature of the atmosphere,
- humidity of the air,
- the temperature of the ambient radiation reflected from the object (in most cases it is assumed to be equal to the temperature of the atmosphere).

The main reason for measurement errors is incorrect camera setting and the introduction of false ambient and measurement parameters. [2, 3]

2. Use of thermal imaging in construction

The range of tests performed with thermal imaging cameras in the building industry is wide, but most often it is used for:

- to detect heat losses in the building by checking:
 - thermal insulation of buildings,
 - location of thermal bridges,
 - cracks in the structure of buildings,

- the work of ventilation, air conditioning and heating systems,
- the state of thermal insulation of boilers, pipelines,
- leaks in windows and doors,
- to search for leaks and leaks in pipes,
- for the detection of moisture in walls and structural elements (roof leaks),
- to monitor the drying of bulkheads,
- to locate the wires in the bulkheads,
- to evaluate the electrical installation [6].

3. Conditions under which photographs are taken

When detecting anomalies in the building industry, it is important to observe a few rules when taking pictures. They will depend on the location of the measurement. If the tests are carried out outside the building, they are carried out under certain atmospheric conditions, i.e. under certain conditions:

- if there is no sunlight, it is best to choose a cloudy day,
 - at a wind speed not exceeding 1 m/s (windless day),
 - with no precipitation (walls should be dry),
 - the difference in temperature between the room temperature and the outside temperature should not be less than 15 K
- in addition:
- the building should be stable and heated (select a period of stabilized outside temperature),
 - we don't open windows,
 - we avoid sharp angles of "looking at the object",
 - we don't consider windows [7].

4. Examples of thermal imaging applications in construction

Below are some examples of the use of thermal imaging in construction. The results of the research were presented in the form of thermograms. Colour thermograms present quantitative distributions of temperatures in the form of colourful isotherms, each of which represents a certain range of temperatures. The temperature ranges together with the colour scale are given on the right side of each thermogram. For better orientation, linear profiles have been added to the thermograms, they represent the temperature variation along the determined profile. Most of the thermograms also include video photographs of the object being tested. The thermographs also show the maximum and minimum temperatures for the examined areas. The study was performed with IR 928+ camera. Detailed analysis of thermal images was performed with the use of Guide IR Analyser software [1, 4].

4.1. Checking the effect of thermal upgrading of the building

Measurements were made for the thermomodernized facility of the Rzeszów University of Technology. The measurements were carried out on 31 January after sunset (after midnight - the previous cloudy day) and a year later on 14 February, in similar weather conditions. The photos (Fig. 1–2) show a selected fragment of the building K, Rzeszów University of Technology at Powstańców Warszawy Street. The measurements were taken before and after the thermal modernization of the building. The obtained thermograms were corrected due to the emission of windows and the surface of external walls. The correct ambient temperature has also been taken into account. Thermograms were performed (depending on the terrain possibilities) from a distance of 10 m.

As can be seen in Fig. 3-4, the average temperature of the wall between windows at the temperature outside -6°C is 17.7°C , max. temp. 19°C and min. 15.8°C . After insulating the wall with 8 cm layer of polystyrene foam, the partition temperatures decreased in the same place during similar weather conditions (Fig. 5-6). The average temperature was 10.6°C , maximum 11.2°C and minimum 10.5°C . The heat losses through the walls decreased. The partition image became almost homogeneous. The assumed effect was obtained.



Fig. 1. A fragment of a wall of a thermal upgrading building (before thermal upgrading)



Fig. 2. A fragment of a wall of a thermal upgrading building (after thermal upgrading)

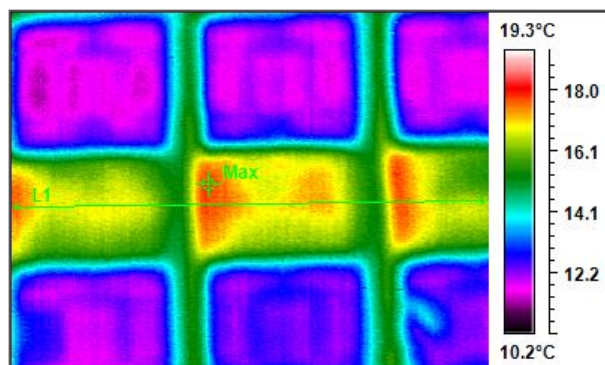


Fig. 3. Thermographic image of a selected fragment of the partition before thermal upgrading

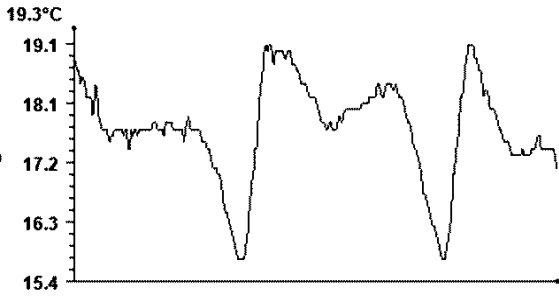


Fig. 4. Temperature linear profile

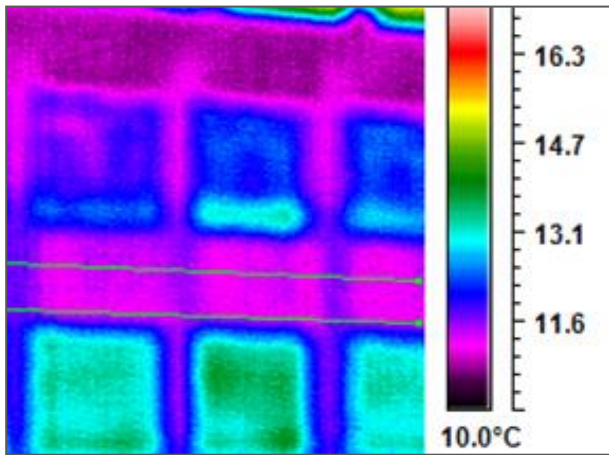


Fig. 5. Thermographic image of a selected fragment of the partition after thermal upgrading

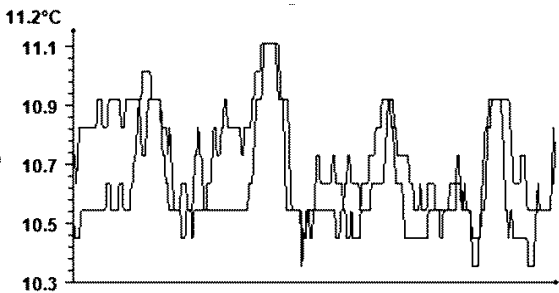


Fig. 6. Temperature linear profile

4.2. Temperature distribution on the building

The thermally inspected building is a single-family detached building that has been inhabited for a year. It is realized in the SUNDAY System technology. It is a steel skeleton made of thin-walled galvanized cold-formed sections. The heat transfer coefficient of walls is $u = 0.28 \text{ W/m}^2\text{K}$, while the heat transfer coefficient of windows is $u = 1.1 \text{ W/m}^2\text{K}$.

The temperature linear profile (Fig. 9) shows that there is an increase in temperature at the connection of the roof with the external wall, and at the connection of the external wall with the foundation (red line), at the corner (green line), losses at windows and balcony (blue line).

Fig. 10 shows intensive thermal bridges at window and door lintels and thermal bridges at the connection of the wall with the foundation and the roof. A higher temperature at the roof (about 2°C higher than the elevation temperature) is also a result of warm shade (surfaces shielded from the radiation influence of the cold sky). The setting of the balcony is not very effective in terms of thermal insulation.

Higher temperature of the upper part of window openings (at lintels) is also influenced by two phenomena: the phenomenon

of warm shade and the accumulation of warmer air (which is why the upper edges of window openings are warmer, first of all). The windows themselves, on the basis of thermograms analysis, perform relatively well.



Fig. 7. View of the building under investigation

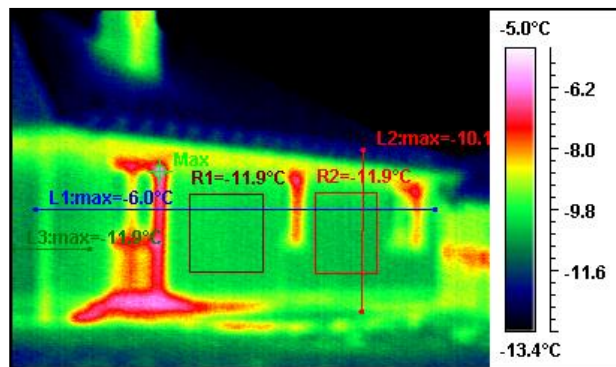


Fig. 8. Thermal imaging

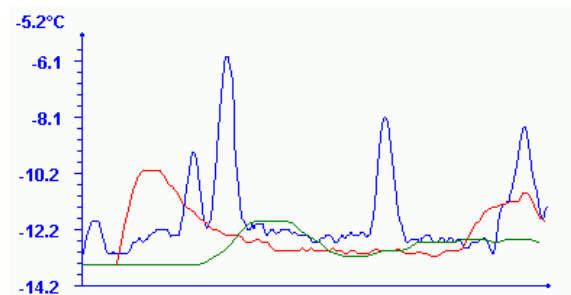


Fig. 9. Temperature linear profile

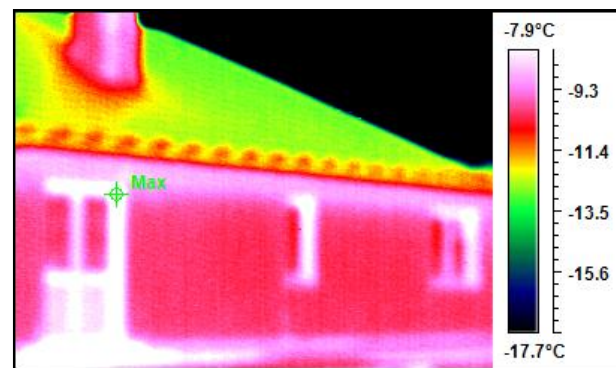


Fig. 10. Thermal imaging

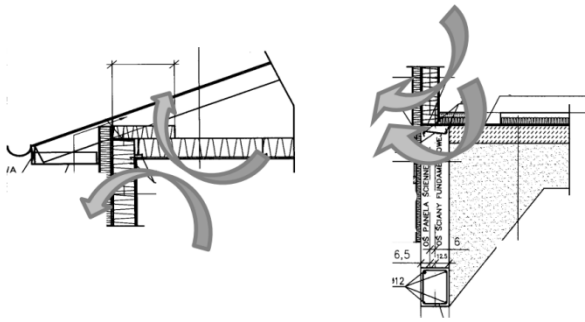


Fig. 11. Details of the connection: a) walls with a roof b) walls, foundations and floors

4.3. Control of the wall heating system implementation

Thanks to thermal imaging we can easily check and locate wires and pipes under the surface. On the photo (Fig. 12) there is a preview of the wall in which heat pipes are installed. Heat pipes are filled with low boiling liquid, which heats up from the heating medium flowing in the lower part of the pipes and changes its state of concentration to steam. The steam rises upwards and releases heat to the environment and cools and condenses, flowing down the tube and the cycle repeats itself. As you can see (Fig. 12), the middle tube was damaged during assembly, it is not filled with low boiling liquid, so it does not heat up. The linear section (Fig. 13, 14) confirms this.

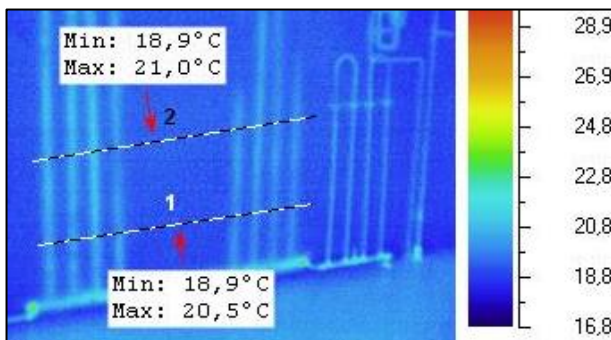


Fig. 12. Thermal imaging of heat pipes

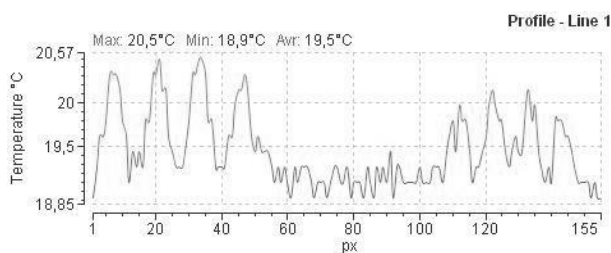


Fig. 13a. Temperature linear profile – profile-line 1

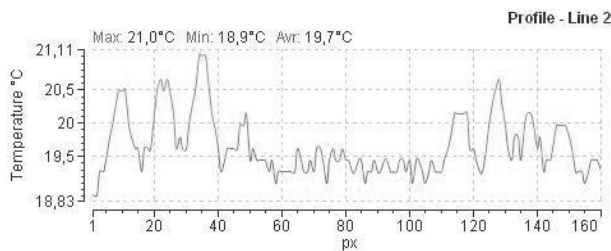


Fig. 13b. Temperature linear profile – profile-line 2

4.4. Detection of heat leakage

Another example shows how thermal imaging can be used to locate heat losses on a corroded heat pipe (Fig. 14, 15). As you can see in the visible picture, the heat pipe is strongly corroded. But only the thermovision photo indicated exactly where the largest heat losses are.

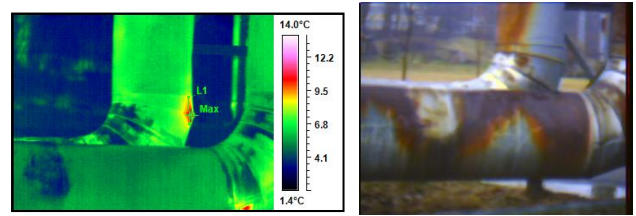


Fig. 14. Temperature distribution on the corroded heat pipe

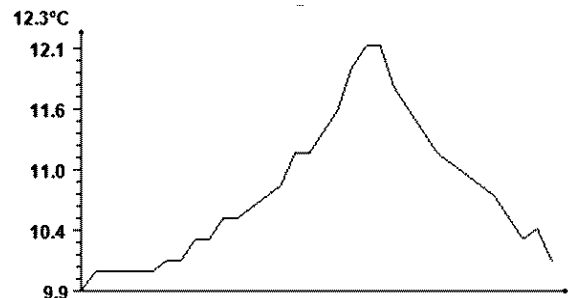


Fig. 15. Temperature linear profile

5. Conclusions

Thermography (thermal imaging) is a very useful tool for the qualitative assessment of thermal protection of buildings. It enables the detection of places with the greatest heat losses and possible defects or deviations from the design conditions, but in order to obtain high quality results it is necessary to meet a number of measurement requirements. It allows to check the effect of thermal modernization of buildings. Thermography can also be used to search for hidden installations in bulkheads as well as to locate leakages, as shown in the examples.

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