Thermal image building inspection for heat loss diagnosis

A. Preda[1] and I. C. Scurtu[2]

1 Constanta Maritime University
2 Mircea cel Batran Naval Academy

andrei.preda@yahoo.com

Abstract. Thermal imaging inspection for building applications it is powerful and non invasive method for monitoring and diagnosing the condition of buildings. With a thermal imaging camera you can identify problems early. This method allows us to check and correct issues before becoming more serious and more costly. By this method, we can exemplify the heat loss through the surface of the building. Thermal imaging consists of scanning the building with infrared, using a special camera. The radiated heat leads to a temperature variation on the surface of the building element in which is embedded. This method, corroborated with the calculation of heat loss, provides a technical and economical solution for the problem of thermal discomfort in the building.

1. Introduction

Usually, thermographic cameras detect radiation in the long-infrared range of the electromagnetic spectrum. They produce images of that radiation, called thermograms. Infrared radiation is emitted by all objects with a temperature above absolute zero according to the black body radiation law. According to this thermography makes it possible to see the environment with or without visible illumination. The amount of radiation emitted by an object increases with temperature; therefore, thermography allows one to see variations in temperature. Thermal images, or thermograms, are actually visual displays of the amount of infrared energy emitted, transmitted, and reflected by an object. Because there are multiple sources of the infrared energy, it is difficult to get an accurate temperature of an object using this method.

2. Principles of infrared thermography

As we already now infrared radiation is the energy radiated by the surface of an object whose temperature is above absolute zero. The emitted radiation is a function of the temperature of the material;

There are three ways by which the radiant energy striking an object may be dissipated: absorption, transmission and reflection.

We generally use three parameters to describe these phenomena: the spectral absorption α_λ, which is the ratio of the spectral radiant power absorbed by the object, the spectral reflectance ρ_λ, which is the ratio of the spectral radiant power reflected by the object, and the spectral transmittance τ_λ, which is the ratio of the spectral radiant power transmitted by the object. These three parameters are wavelength dependent [9]. The sum of these three parameters must be one at any wavelength, as in the following equation:

$$\alpha_\lambda + \rho_\lambda + \tau_\lambda = 1 \quad (1)$$

In the case of opaque materials, the above equation becomes more simple. All of the energy is either absorbed or reflected. $\alpha_\lambda = 1 - \rho_\lambda$ (2)
Materials in which the transmissivity and the reflectivity are null (called blackbodies). In these materials, all of the striking radiant energy is absorbed [9]. In order to calculate the electromagnetic radiation emitted by a blackbody we can use Plank's low as in the following equation:

$$W_{\lambda b} = \frac{C_1 * \lambda^{-5}}{e^{\frac{C_2}{\lambda T}} - 1} \quad (3)$$

Where C_1, C_2 are constants, λ-is the wavelength and T represents temperature.

The energy from a heated object is radiated at different levels across the electromagnetic spectrum. In most of the applications it is the energy radiated at infrared wavelengths which is used to determine the object's temperature. The next figure shows various forms of radiated energy in the electromagnetic spectrum including X-rays, Ultra Violet, Infrared and Radio. They are all emitted in the form of a wave and travel at the speed of light. The only difference between them is their wavelength, which is related to frequency [10].

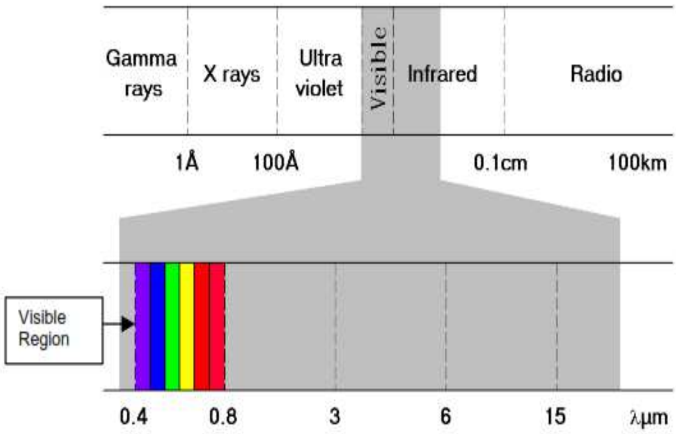

Fig1.Infrared area of electromagnetic spectrum

The human eye responds to visible light in the range 0.4 to 0.75 microns so the vast majority of infrared temperature measurement is made in the range 0.2 to 20 microns.

3. Case study

This article is the result of a thermographic study of an office space in Bucharest. Thermal inspection was made in order to clarify some aspects of comfort and humidity. In this study, we used a thermal image camera from company Testo, called Testo 885-2, which is perfect for industrial, civil and related facilities. The inspection was mad on the 28th of Janury 2019 in the afternoon, outside temperature being +3 °C and humidity 49%.

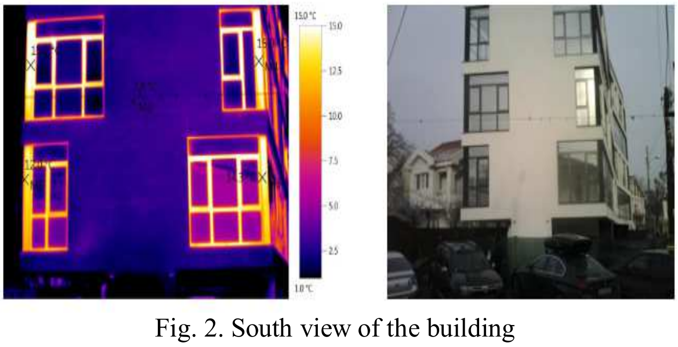

Fig. 2. South view of the building

In figure 2 we can see a thermal image of the south façade of the building where the average temperature on the wall is +24 °C. There are some small places where the heat signature is increased due to outside factors not internal ones.

Fig. 3. East facade and south-east corner of the building

As we know a thermal imaging camera is capable of performing algorithms to interpret that data and build an image. Although the image shows the viewer an approximation of the temperature at which the object is operating, the camera is actually using multiple sources of data based on the areas surrounding the object to determine that value rather than detecting the actual temperature. [8]

This method also helps in discovering hidden flaws that create an increased discomfort within the premises.

Fig. 4. Open air garage – ground floor and inside curtain wall

This thermography was done both externally and internally as a result of the owner's notification to determine the places with the greatest heat loss. As you can see, the plate above the ground floor has not been properly insulated and there is a heat loss that can become significant over time. The temperature indicates 3,4°C on the exterior joint comparing with the next one of 0.3 °C. It is clearly that the insulation in that part is poor or does not exist. Taking a few inside pictures we realised the interior works were done properly only a few small things are due to be redone ore replaced.

Because the owner had a cold sensation while living in the building we had to take more picture and to reveal that the problem comes from the disposal of the air-heating elements. The air from the convectors does not cover all the aria of the windows, leaving some of them totally uncovered which produce this cold sensation even when the temperature reaches 20-21 °C.

Fig. 5. Inside- 3rd floor south window

The top floor of the building show as a very good insulation of the rooftop but a poor quality of the frames and glass. We recommend the owner to change them with other with a better quality. At least 5 rooms for the frame and three layers of glass.

During the summer, to minimize heat inputs, has two corroborating ways. First is to apply a transparent film that resumes some of the ultraviolet but lets the light penetrate into the room and the second one, which leads to installation of curtains in most of the rooms.

4. Thermography conclusions

Remark the influence of solar radiation, which leads to the heating of the exterior carpentry, the carpentry being dark; high temperature value that does not represent a large heat loss of carpentry (but only the influence of solar radiation).

The temperature on the opaque surface (wall) is homogeneous, which means good thermal insulation;

We observe small temperature variations on the ceiling to the floor (outward) with variations of 3 ° C, which leads to a possible variation of the thermal insulation thickness in that area (IR 1865, 1866, 1868, 1869);

The minimum temperature recorded on the carpentry is 12 °C in restricted areas, there is no risk of condensation;

Low temperature on carpentry can occur from external air infiltrations, which are normal or moderate. Moderate outdoor air infiltrations are useful for refreshing indoor air;

No problems related to exterior carpentry can be noticed, in most thermograms the surface temperature is between 15-20 °C. Since the thermal resistance is half that of the outside wall, it is normal for the temperature to be lower than the wall.

To determine the average interior temperature of an arbitrary window, a window has been averaged; the one in the bottom figure (the median was made in the rectangle that defines the window being analysed). The average value of camera software is 19.3 °C, value on the inside. The inside temperature considered was 22 °C.

IOP Conf. Series: Journal of Physics: Conf. Series **1297** (2019) 012004 doi:10.1088/1742-6596/1297/1/012004

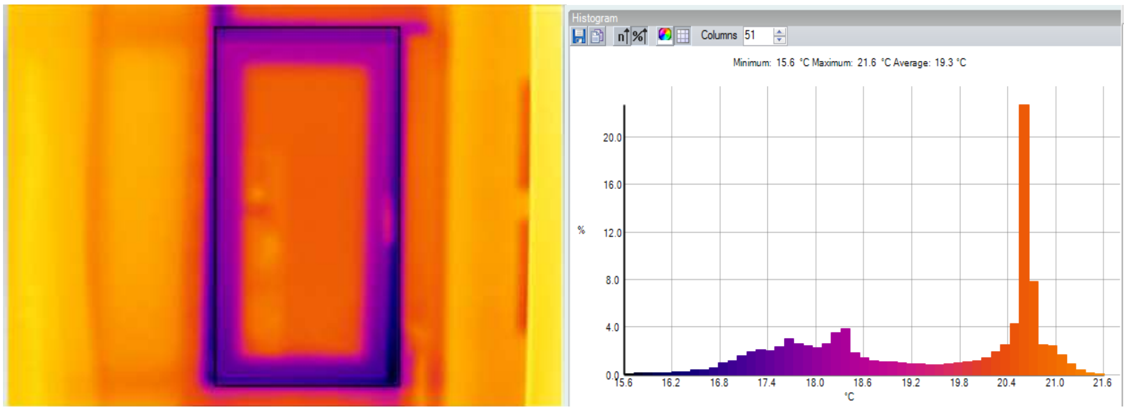

Fig. 6. Determining the average temperature of a window on the inner face (inside the rectangle defining the window) in the left figure

To calculate the indoor and outdoor climatic conditions in which the thermal resistance of the window was measured, the following relationship is used:

$$R = 0.125\frac{22-0}{22-19.3} = 1.01 \text{ m}^2 \text{ K/W}$$

The convective thermal resistance on the inside is 0.125 m2 K / W, the internal temperature 22 °C, the outside temperature 0 °C and the average surface temperature 19.3 °C, determined previously. Typically, three layers of windows have around 1.2 m2 K / W, thermal resistance, the determined value being close to value. This value is indicative of the measurement errors of the used method, so it is only advisory and does not take into account a measurement in the laboratory, in the climatic cell in which the internal conditions are stable and constant, according to the norms and standards under which it is measured of carpentry.

Interpretation af observed temperature differences from the anticipated values

	Walls			**Windows**			**Doors**		
Anticipated values	21.8	22	22.5	10	10.5	10.5	19	19.2	19.5
Observed values	18	21	21.5	11	13.2	14.3	17.8	18	18.5

Table 1. Values of temperatures

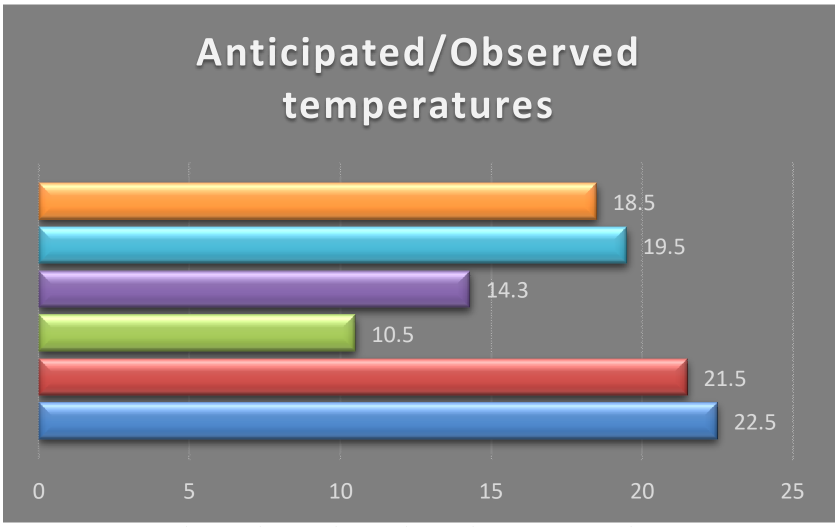

Fig 7. Observed & estimated temperature chart

If ΔT is between 1-10 – It is a minor problem . It is recommended to be solved within the next regular maintenance . This difference can be coused by moisture in 90 % of the cases.

If ΔT is between 10-15 – It is a average problem and a physical inspection it is needed. Must be fixed in the next maintenace.

If ΔT is between 15-20 or above - the problem becomes critical and needs intervation as soon as possible to fix it.

In our case, whole differences are less than 10 degrees Celsius. There are no major problems and most of all can be solved very rapidly.

References

[1] Giuliano Dall'O' , Luca Sarto, Angela Panza., "Infrared Screening of Residential Buildings for Energy Audit Purposes: Results of a Field Test," Energies 2013, 6, 3859-3878; doi:10.3390/en6083859 F. De Lillo, F. Cecconi, G. Lacorata, A. Vulpiani, EPL, 84 (2008).

[2] Commission of the European Communities. Green Paper: A European Strategy for Sustainable, Competitive and Secure Energy; COM (2006) 105 Final; European Commission: Brussels, Belgium, 2006.

Barreira ,E; De Freitas V. P.; Thermography Applications in the Study of Buildings Hygrothermal Behaviour, www.intechopen.com March 2014.

[3] Palyvos, J.A. A survey of wind convection coefficient correlations for building envelope energy systems' modeling. Appl. Therm. Eng. 2008, 28, 801–808).

[4] Barreira ,E; Almeida ,R; "Infrared Thermography for Building Moisture Inspection", 2018.

[5] http://certificat-energetic24h.eu/termografia-in-constructii-termoviziune-sau-termografie-cladiri.html.

[6] Flir., "Thermal Imaging guidebook for buildings and renewable energy applications " www.flir.com M. Ben Rabha, M.F. Boujmil, M. Saadoun, B. Bessaïs, Eur. Phys. J. Appl. Phys. (to be published).

[7] https://en.wikipedia.org/wiki/Thermography

[8] Usamentiaga, R; Molleda, J; Bulnes,G,F;"Infrared thermography for temperature mesuremnts and non-destructive testing" , Sensors 2014 14, 12305-12348; doi:10.3390/s140712305

[9] Land instruments international – "A basic guide to thermography", 2004, No:Training Thermography V1/1104.