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HISTOGRAPHIC ANALYSIS OF INFRARED THERMOGRAMS IN THE FIELD OF THERMAL ENGINEERING

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Abstract

Computerized evaluation of infrared images opens new vistas for infrared thermogrammetry (IR–TGM). While it extends our earlier knowledge regarding temperature field analysis, it requires deeper understanding of relations of thermal phenomena and also more intuitive thermotechnical skills for image processing. Examples from diverse areas, e.g. energy saving, thermal defectometry, electrotechnics are quoted and practical applications of **IR–TGM** in thermal physics of buildings are discussed. The thermal phenomena themselves are illustrated by **IR thermograms**, while temperature distributions are analysed by histograms.

Keywords: infrared thermogrammetry, energy saving, thermal defectometry.

1. Introduction

There are several approaches to and methods for development of digital infrared (IR) images [1],[5],[6]. It can be stated as a rule that evaluation strategy and method are advisably adapted to the examined phenomenòn. This approach generally requires adequate thermal engineering practice and technical intuitiveness [2],[3],[4],[7].

2. Generalities

In analysing and disclosing various types of temperature fields, the following general methods may be attempted, whose applicability and convenience have to be decided for the actual case:

- proper definition of the tested temperature range, and within it, selection of number and width of isobands;
- determination of temperature prevailing in some points of the examined surface at the spiderlines centre (e.g. SPOT = 48.1 °C in *Fig. 1*);

- comparison of temperature distributions along horizontal and vertical lines by means of profile thermograms (see the bottom and the right side of *Fig. 1*);
- determination of the temperature distribution and of the mean temperature in selected minor areas of the surface examined (*Fig. 2* and *Table 1*);
- description of the temperature distribution by methods of mathematical statistics (*Fig. 3* and *Table 1*).

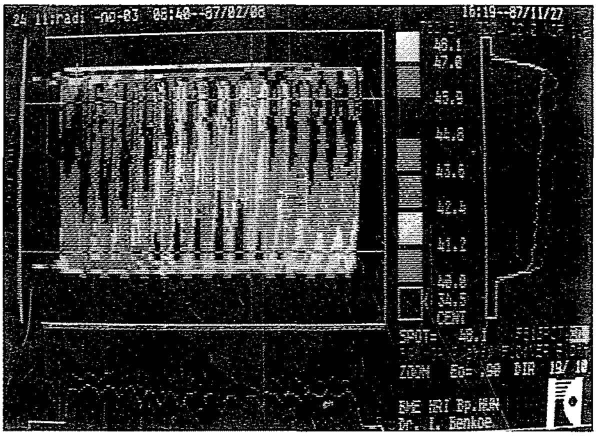

Fig. 1. The two profile thermograms on the bottom and on the right of the IR thermogram show the temperature distribution across the ribs of a radiator

3. Analysis of Temperature Distribution by Histographic Processing

Histographic processing is the usual mode of processing experimentally and otherwise obtained sets of data, but it may be regarded as an efficient way for describing temperature fields, too. Thereby there is still little experience available for such applications and for the proper evaluation of all histogram characteristics.

In histograms which represent temperature fields of digital IR images, pixel numbers with the given temperature are plotted against temperatures occurring within the fields (e.g. *Fig. 3*). Temperatures occurring in the selected area may be displayed both graphically and digitally, and the obtained data lend themselves for further computations. In our practice

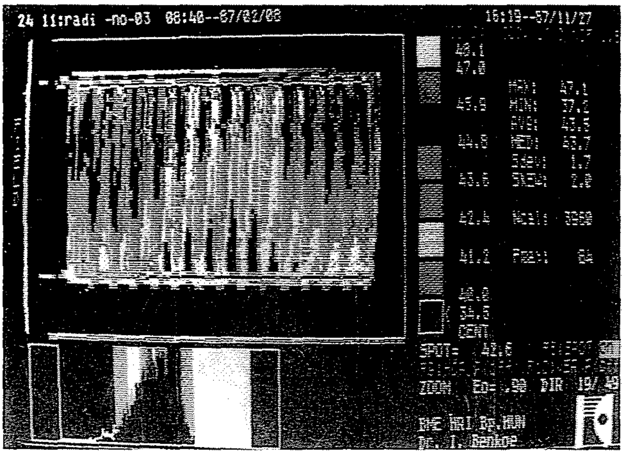

Fig. 2. Histographic representation of *Fig. 1*

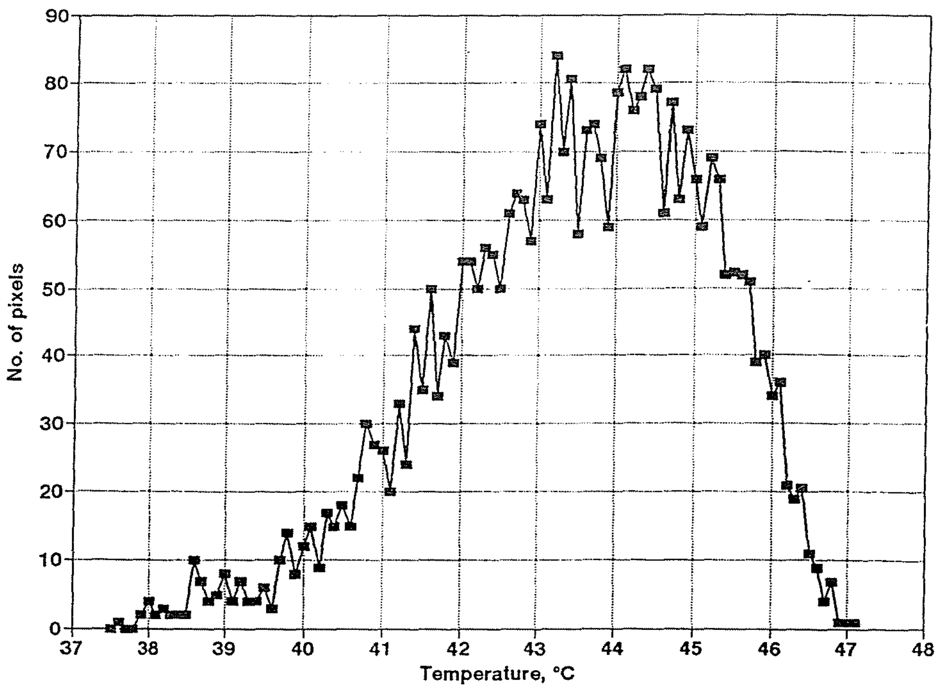

Fig. 3. Histogram of a radiator (See *Fig. 2*)

satisfactory results were obtained when the temperature varied by tenths of degrees within the range.

Among essential values characteristic of the histograms, the following are pointed out: the highest (MAX), the lowest (MIN) and the average (AVG) temperature in the defined area; median (MED), standard deviation (Sdev) and skewness (SKEW) (see *Table 1*); number of pixels in the examined area (Ncal) and the maximum value on the ordinate of the histogram (Fmax) (e.g. *Fig. 2*). This paper presents several practical applications of IR image analysis in the field of thermal engineering.

4. Thermal Engineering Applications

For the calculation of heat loss of a surface, in steady-state conditions we have to know the wall temperature with appropriate accuracy. Connection between the average wall temperature (t_{avg}) and heat loss ($\dot{Q}$) is given by the following equation:

$$\dot{Q} = \sum_{i=1}^{n} A_i \alpha_i (t_{avg} - t_{env}). \tag{1}$$

Here A_i is a selected minor area ($i = 1 \dots n$) of the measured surface where α_i, the coefficient of heat transfer and emissivities are constant, t_{env} is the temperature of environment. So the values of temperature distribution in the selected area (*Table 1*) are very important for the determination of heat loss and other practical calculations.

4.1 Checking Radiator Operation

Operation of an aluminium radiator may be checked by means of infrared images (*Fig. 1*). Here isotherms and temperature distribution diagrams below and right of the image show that hot water supply of about six radiator ribs in the middle is less sufficient than that of the others, due to the poor internal flow conditions. Consequently, lower heat output occurs. The histographic representation of *Fig. 1* can be seen in *Figs. 2* and *3*. Data of histogram in *Fig. 3* obtained by computerized analysis are presented in *Table 1*.

4.2 Wall and Floor Heating

Determination of heat transfer by panels with internal heating (*Figs. 4* and *5*) at a due accuracy requires the knowledge of the mean wall temper-

Table 1
Collected data of histograms referred to

	Topic	No. of histogram	No. of ref.fig.	Values of temperature distribution, °C Characteristics of the histogram				
				MAX/MIN	AVG	MED	Sdev	SKEW
1.	Radiator	24–11	3.	47.1/37.2	43.5	43.7	1.7	2.0
2.	Wall heating coil	33–21	7.	53.1/23.5	38.2	38.5	4.8	5.5
3.	Insulation	PR–19	10.	21.3/ 7.3	9.9	9.8	1.1	1.8
4.1	Below the windows	46–26	12.	16.1/12.7	13.8	13.7	0.5	0.6
4.2	Between the windows	46–28	16.	14.8/12.2	13.3	13.2	0.4	0.4
4.3	Around a window	46–28	16.	15.2/12.4	13.8	13.8	0.5	0.6
5.1	Turbine insulation	33–13	22.	157 /11.7	56.0	49.7	23.4	29.6
5.2	Turbine piping	33–13	22.	222 /35.5	76.7	75.2	22.0	34.4

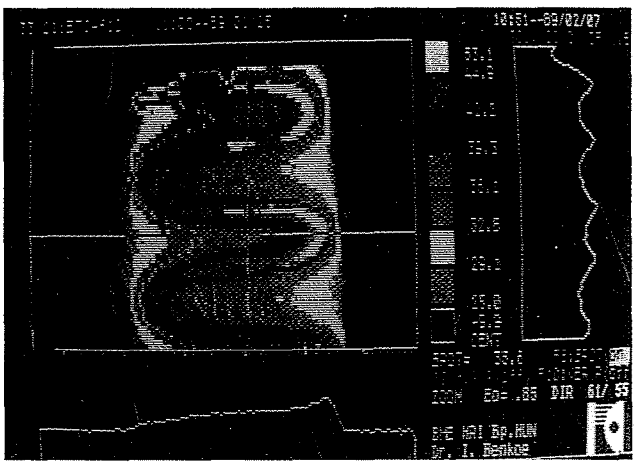

Fig. 4. IR thermogram and profile thermograms of a wall section heated by an internal pipe coil

ature (*Eq.* 1). The obtained thermogram and histograms (*Figs. 6* and *7*) assist reliable thermal sizing. One horizontal (a) and vertical (b) profile thermogram set across the wall section, which is heated by an internal pipe coil, are shown in *Fig. 5*, according to *Fig. 4*. The data of histogram: MAX: 53.1, MIN: 23.5, AVG: 38.2 (See *Table 1*).

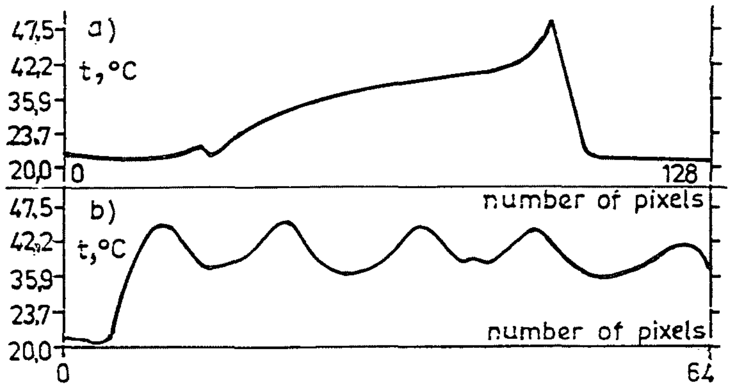

Fig. 5. Horizontal (a) and vertical (b) profile thermograms across a wall section heated by an internal pipe coil (See *Fig. 4*)

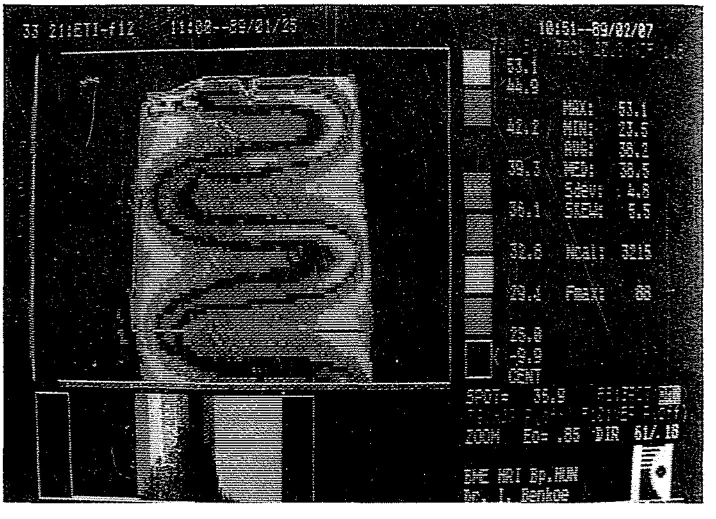

Fig. 6. Histogram of *Fig. 4* in a selected minor area

4.3 Insulation Defects of a District Heating Line

Infrared pictures (*Fig. 8*) taken from heating pipelines hint at possible causes of heat losses. Typical insulation defects of heating pipelines are presented (*Fig. 9*). Histogram data: MAX: 21.3, MIN: 7.3, AVG: 9.9 at -1°C environmental temperature (*Fig. 10* and *Table 1*).

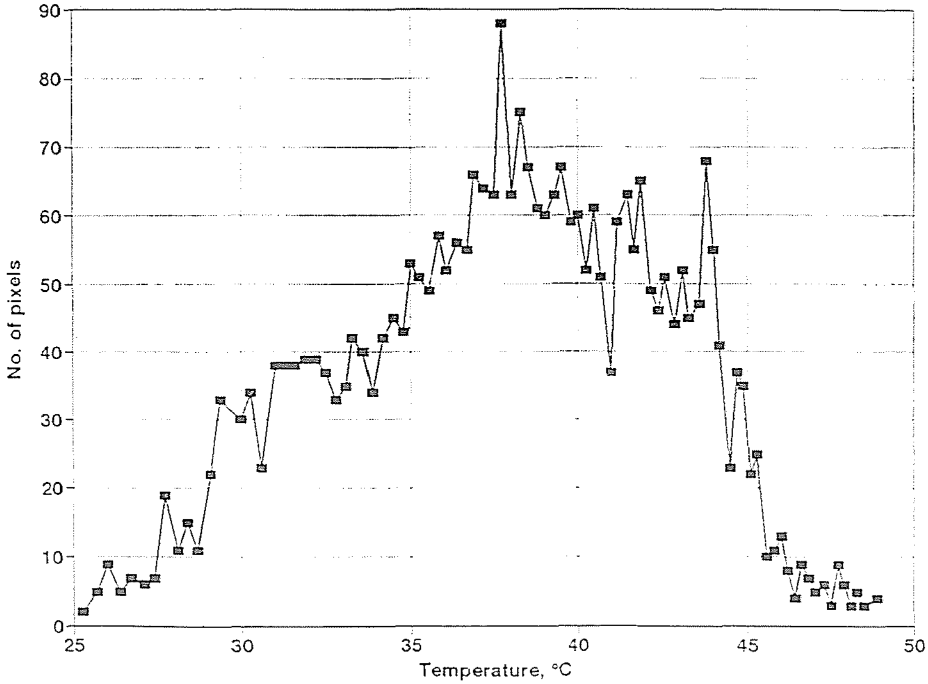

Fig. 7. Histogram of a wall heating coil (See *Fig. 6*)

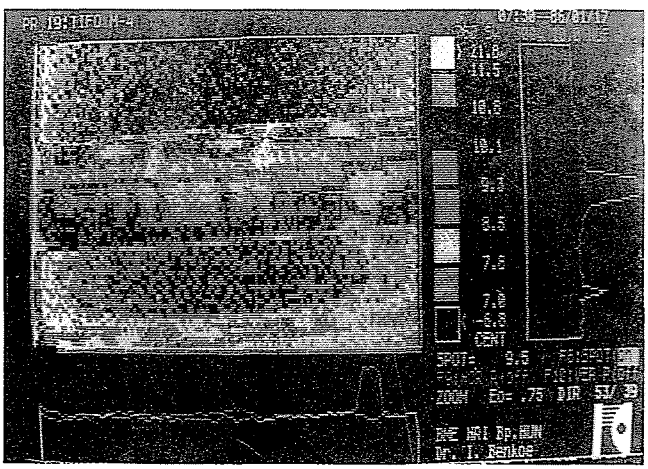

Fig. 8. IR thermogram of insulation defects of a district heating line

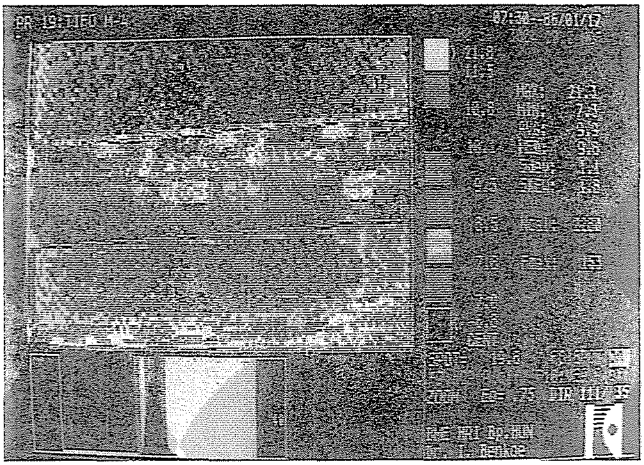

Fig. 9. Histogram of *Fig. 8* in the area of insulation defects

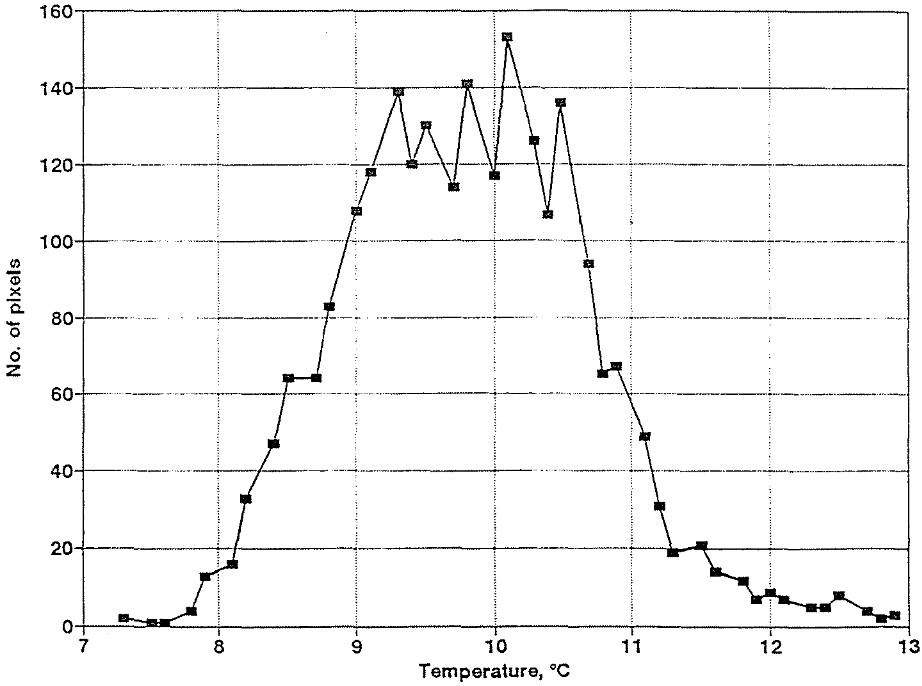

Fig. 10. Histogram of a district heating line (See *Fig. 9*)

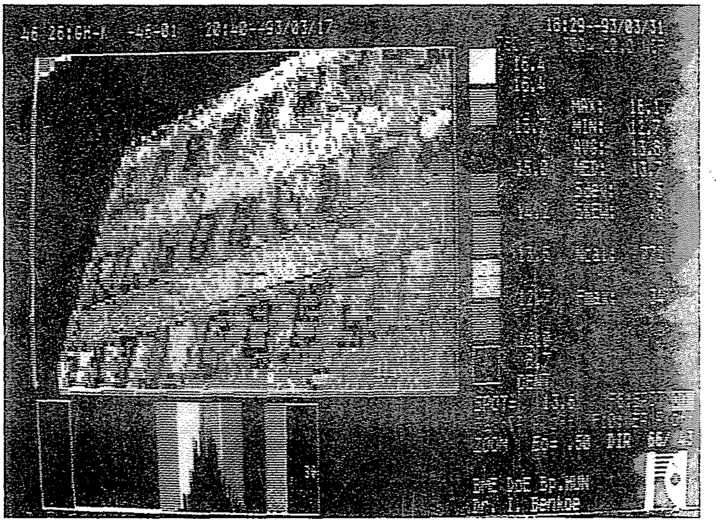

Fig. 11. Histogram of a selected minor area below the windows of a prefabricated panel building

4.4 Checking a Building Envelope

Insulation quality control of the prefabricated panel buildings is an important practical task. The spots of thermal bridges may be pointed out in IR-images (*Figs. 11* and *13*). For calculating the local heat losses the different areas of the building envelope can be analysed. IR thermogram and histogram below the windows are presented in *Figs. 11* and *12*.

Histograms of a selected area between the windows in *Fig. 11* can be seen in *Figs. 13* and *15*. A special relief thermogram of the same area *Fig. 13* is presented in *Fig. 14*. This shows the spots of the thermal bridges. For the comparison of different areas of the building envelope in *Fig. 15* the histogram around a window is presented and in *Fig. 16* as comparative results. The data of the referred IR histograms are collected in *Table 1*.

4.5 Halogen Lamp

Internal and superficial temperature distribution of a TCF 250 6A-type high pressure sodium-vapour lamp manufactured by Tungsram has been tested (*Figs. 17* and *19*), helping to determine thermal fatigue versus frequency, hence expected service life of the sodium vapour lamp. One horizontal (a) and one vertical (b) temperature curve across the sodium vapour

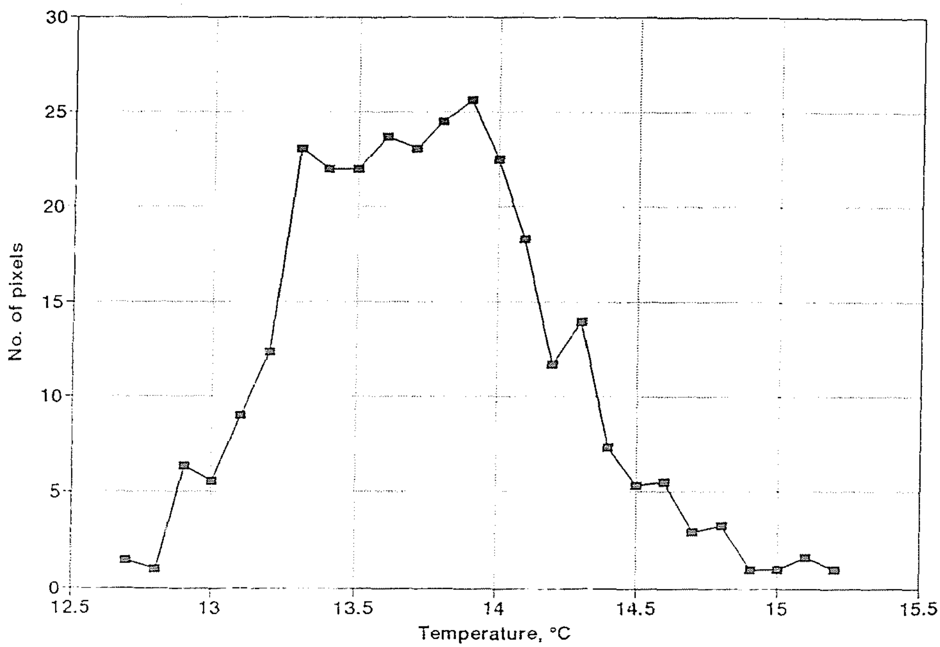

Fig. 12. Histogram of a building envelope (below the windows) (See *Fig. 11*)

tube in the lamp can be seen in *Fig. 18* in the period of maximum thermal wave (*Fig. 17*).

4.6 Efficiency of Thermal Insulation of Steam Turbines

Comparative analysis has been performed between thermal insulations of two turbines of the same type and service condition (*Fig. 20*). The results may also help in repairing thermal insulation. Data of histogram of LIMPET (British made) insulation: MAX: 197, MIN: 30.5, AVG: 75.4, and those of the Hungarian insulation: MAX: 157, MIN: 11.7, AVG: 56. The selected areas of the examined two parts of the turbines (insulation and piping) can be seen in *Fig. 21*. For comparison the histograms of areas on the insulation ($\varepsilon = 0.9$) and piping ($\varepsilon = 0.4$) are presented in *Fig. 22*.

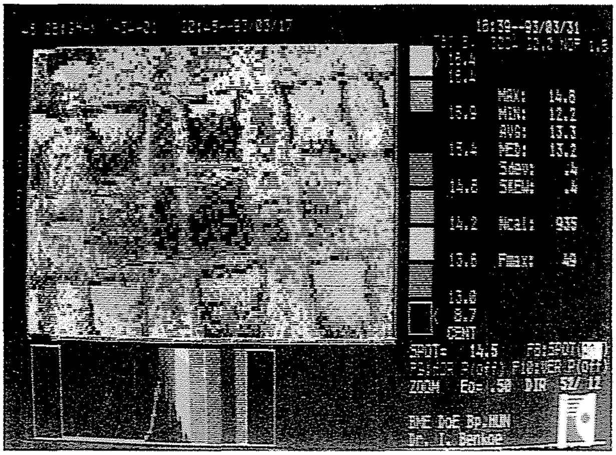

Fig. 13. Histogram of a selected area between the windows of a panel building

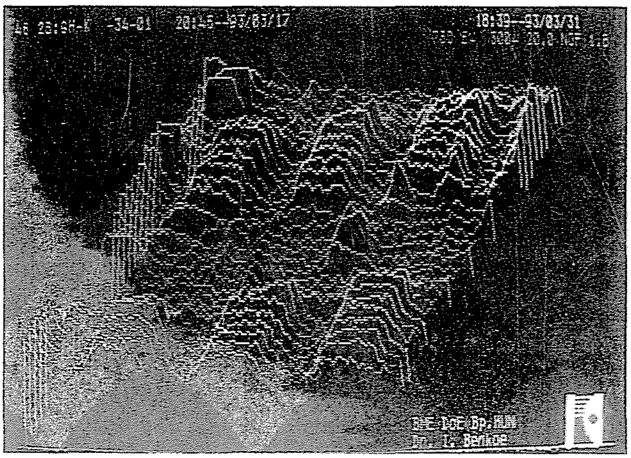

Fig. 14. Relief thermogram of *Fig. 13* shows the temperature distribution on the wall

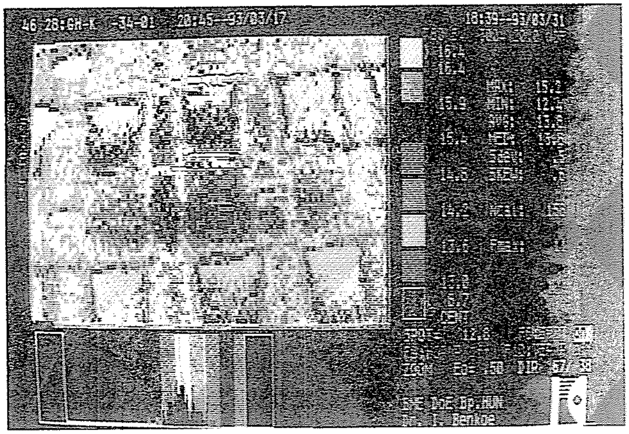

Fig. 15. Histogram of an area around the window in *Fig. 13*

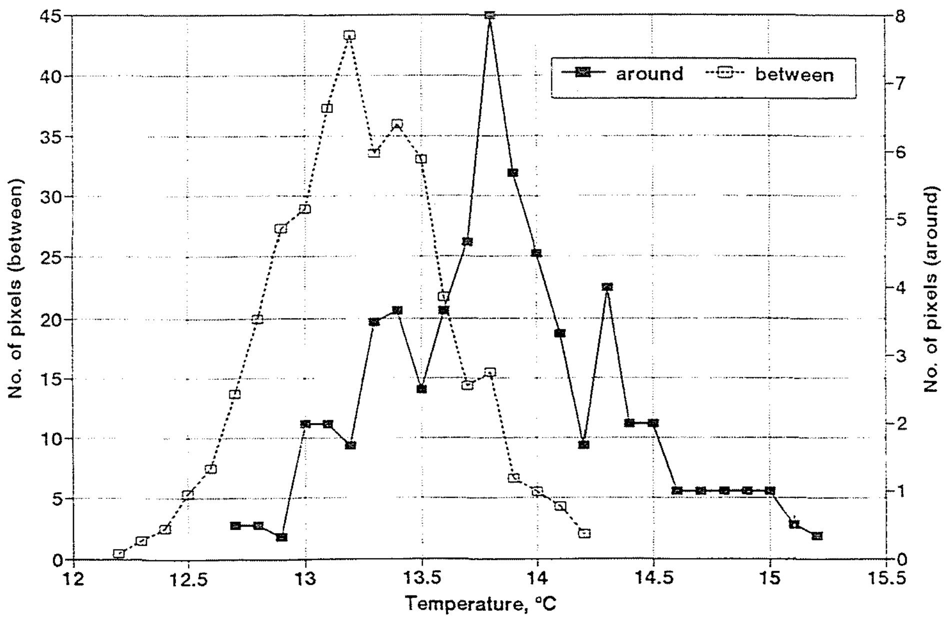

Fig. 16. Comparison of the histograms of a building envelope between and around the windows (See *Fig. 13* and *15*)

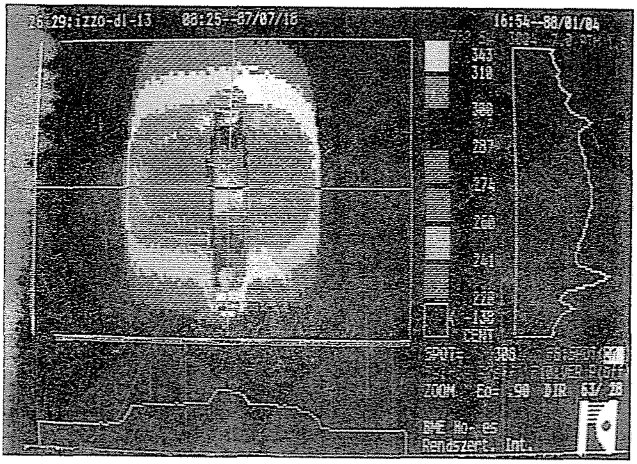

Fig. 17. IR thermogram of a sodium vapour tube in the lamp and profilethermograms across the tube in the period of maximum thermal wave

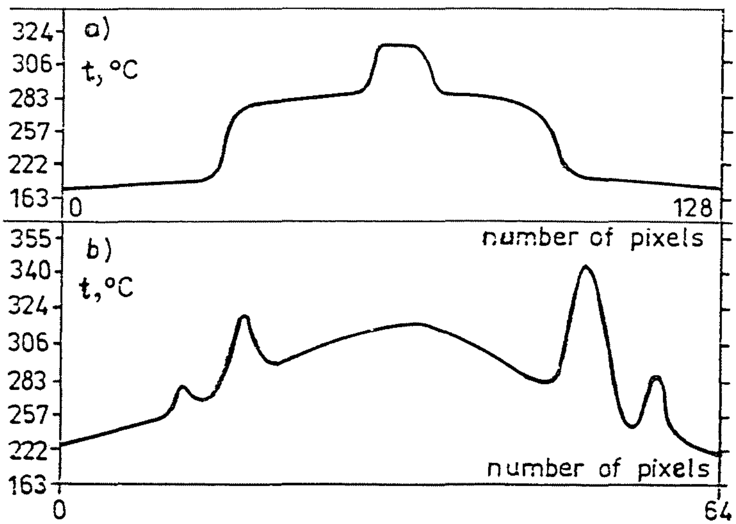

Fig. 18. Horizontal (a) and vertical (b) profile thermograms of *Fig. 17* across a sodium vapour tube in the lamp

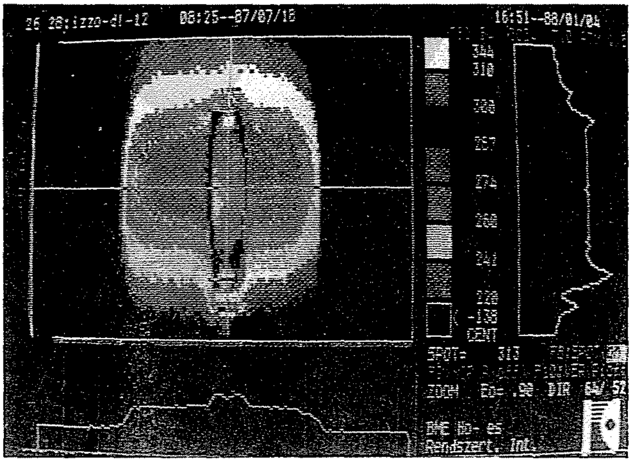

Fig. 19. Profile thermograms of *Fig. 17* in the period of minimum thermal wave

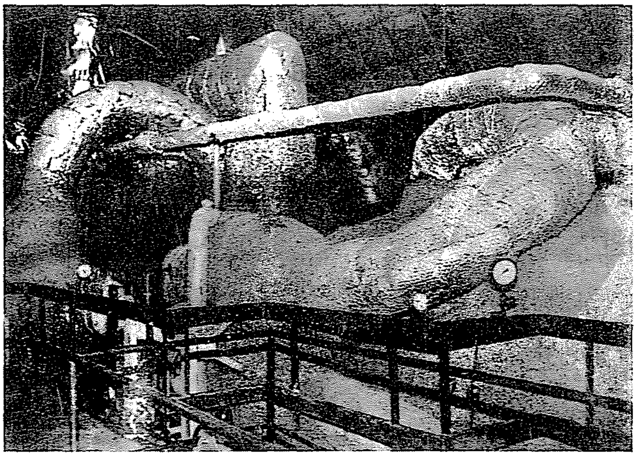

Fig. 20. The examined section of the thermal insulation and piping of a steam turbine

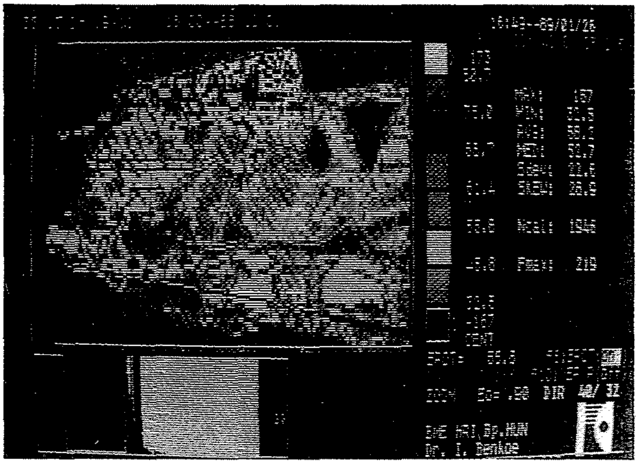

Fig. 21. IR thermogram of *Fig. 20* shows the selected areas for presentation of histograms on the piping and insulation of the turbine

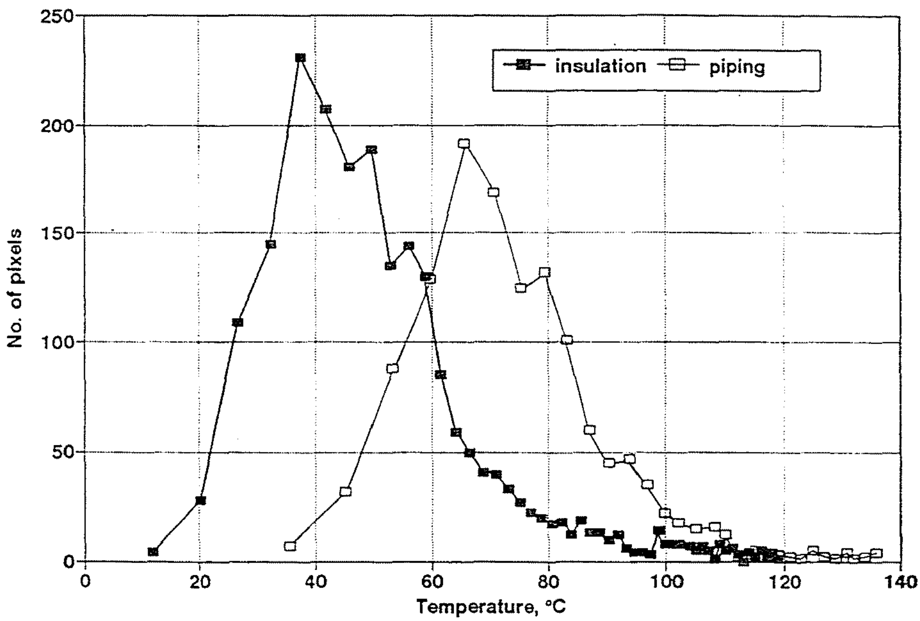

Fig. 22. Comparison of the histograms of turbine insulation and piping (see *Fig. 21*)

5. Conclusion

Applications of quantitative IR–TGM by histograms in the representation of temperature fields give direct results in heat loss calculations, checking thermal insulation efficiency and defects as well as in observing thermal fatigue in electrical lamps.

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