

INTERNATIONAL  
RECOMMENDATION

**OIML R 141**  
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Procedure for calibration and verification of the  
main characteristics of thermographic instruments

Procédure pour l'étalonnage et la vérification des principales  
caractéristiques des instruments thermographiques

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## Foreword

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Bureau International de Métrologie Légale  
11, rue Turgot - 75009 Paris - France  
Telephone: 33 (0)1 48 78 12 82  
Fax: 33 (0)1 42 82 17 27  
E-mail: [biml@oiml.org](mailto:biml@oiml.org)  
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# **Procedure for calibration and verification of the main characteristics of thermographic instruments**

## **1 Scope**

This Recommendation applies to general purpose thermographic instruments and specifies the procedure for their calibration, and also for their initial and subsequent verifications.

## **2 Terminology**

### **2.1 Thermographic instrument**

Optoelectronic instrument designed for non-contact (remote) observation, measurement and registration of the space/space-time distribution of the radiation temperature of objects, in the field of view of the instrument, by forming a time sequence of thermograms and by determining the temperature<sup>1</sup> of the object surface on the basis of the known emittance and influence parameters (ambient temperature, atmospheric transmission, observation distance, etc.).

### **2.2 Thermogram**

Multiple-element, two-dimensional image, each element being attributed a color, or a color gradation, or a screen brightness level, which is determined in correspondence with a conventional radiation scale.

### **2.3 Standard radiator**

Radiator that complies with a black body model (BB).

### **2.4 Standard large aperture radiator**

Standard radiator (i.e. a reference radiator), whose angular dimensions are at least ten times larger than the instantaneous field of view of the thermographic instrument<sup>2</sup>.

### **2.5 Thermal test object**

Device intended to create a plane picture containing a heat-radiating object with a preset spatial frequency, or shape or temperature contrast on a uniform radiating background with a known temperature value and a known emittance value of the object and background.

### **2.6 Number of sensitive elements (detecting elements of the thermogram)**

Number of photosensitive elements which form the thermographic instrument photodetector.

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<sup>1)</sup> According to the International Temperature Scale (ITS-90).

<sup>2)</sup> If the thermographic instrument has a large instantaneous field of view angle, an angular dimension of the standard reference radiator should be wide enough to cover the instantaneous field of view of the thermographic instrument.

## **2.7 Field of view**

Solid angle within which the thermogram is formed.

## **2.8 Instantaneous field of view (IFOV)**

Space angle within which the infrared radiation is detected by one photosensitive element of the photodetector.

## **2.9 Spatial (angular) resolution**

Dimension (angle, or sensitive elements) of a slit on a screen installed in front of a large aperture radiator in the field of view of the thermographic instrument, when the ratio between the peak increment of the slit temperature over the screen temperature to the temperature difference of the radiator and the screen reaches the preset value.

## **2.10 Noise equivalent temperature difference (temperature resolution, $\Delta T_{NETD}$ )**

Temperature increment equal to the root-mean-square value of the noise in a thermogram, when observing a homogeneous background set with a specified temperature and a specified thermogram rate.

## **2.11 Sensitivity to non-uniformity in the field of a thermographic instrument**

Maximum value of the temperature difference of thermogram fragments from a standard large aperture radiator, with a uniform radiation over the surface.

# **3 Characteristics of a thermographic instrument to be verified**

In the process of verification, the following metrological characteristics of a thermographic instrument shall be determined:

- spatial resolution;
- field of view;
- instantaneous field of view;
- accuracy of radiation temperature measurement;
- noise equivalent temperature difference;
- number of damaged sensitive elements;
- sensitivity to non-uniformity in the field;
- influence of environmental conditions on the performance of the instrument; and
- repeatability of the thermographic instrument readings.

## **4 Conditions of verification and calibration**

The process of verification and calibration should be carried out in a stable indoor environment within the temperature range from 20 °C to 25 °C and with a relative humidity in the range from 40 % to 80 %, unless other conditions are specified in the certificate of the thermographic instrument. The thermographic instrument should not be affected by shocks, vibrations, external electromagnetic fields or external radiation sources affecting the readings of measuring instruments.

## **5 Methods for verification and calibration**

### **5.1 Procedures and means of verification**

5.1.1 The procedures and measuring instruments which shall be utilized in the process of verification and calibration are listed in Table 1.

5.1.2 All measuring instruments indicated in Table 1 shall be accompanied by the relevant verification or certification documents.

5.1.3 All measuring instruments and the thermographic instrument to be verified are prepared for operation according to their in-line documentation (ID).

5.1.4 Specialists qualified for performing verification in the field of temperature and radiometric measuring instruments are considered as qualified for verification and calibration.

### **5.2 External examination**

5.2.1 The external examination should demonstrate:

- the correspondence of the complete set and marking of a thermographic instrument to its ID;
- the correspondence of a thermographic instrument to the safety requirements stated in the certificate and/or in the operating manual (OM); and
- the absence of any external damage to the thermographic instrument set to be verified (such damage may have an impact on its metrological characteristics).

A thermographic instrument which does not meet these requirements cannot be considered as verified.

Procedure	Item in the Recommendation	Means of verification and their metrological characteristics	Obligation of procedure	
			Initial verification	Periodical verification /calibration
1. External examination	5.2		Yes	Yes
2. Testing. Functional check of thermographic instruments under various conditions	5.3	Radiator in the form of a BB model.	Yes	Yes
3. Determination of noise equivalent temperature difference	5.4	Standard (reference) large aperture radiator for the temperature range over the ambient temperature by 10 °C with an emissivity not less than 0.96. The temperature instability is not more than $\pm 0.05$ °C/min.	Yes	Yes
4. Determination of the number of defective elements	5.5	Standard (reference) large aperture radiator (See 5.4).	Yes	Yes
5. Determination of field of view and instantaneous field of view	5.6	1. Standard (reference) large aperture radiator (See 5.4). 2. Thermal test objects with an emissivity not less than 0.96. See the sketch of the test objects in Annex A and Annex B. 3. Measuring rule with a length of 500 mm and a scale factor of 1 mm.	Yes	No
6. Determination of spatial (angular) resolution	5.7	1. Standard (reference) large aperture radiator (See 5.4). 2. Thermal test object (See 5.6).	Yes	Yes
7. Checking the range and estimation of accuracy of radiation temperature measurement	5.8	Standard (reference) radiator.	Yes	Yes
8. Determination of sensitivity to non-uniformity in the field	5.9	Standard radiator (See 5.8).	Yes	Yes
9. Check of the influence of environmental conditions on the performance of the instrument	5.10	Standard (reference) radiator (See 5.8). Climatic chamber.	Yes	No
10. Determination of repeatability of thermographic instrument readings	5.11	Standard (reference) large aperture radiator (See 5.4).	Yes	No

Table 1 Procedures and means of verification and calibration of thermographic instruments



### 5.3 Testing and functional check

#### 5.3.1 Testing (performance check)

The thermographic instrument is switched on and its performances are checked in correspondence with the OM.

A thermographic instrument that has malfunctioned during the testing process cannot be considered as verified.

#### 5.3.2 Functional check of a thermographic instrument under various conditions

The thermographic instrument and the radiator (BB model) are set up accordingly to their OM. The thermographic instrument is focused on the emitting surface of the radiation source.

The functioning of the thermographic instrument is checked under all conditions specified in the OM.

If the functions specified in the OM or certificate do not operate under any of the conditions, the thermographic instrument cannot be considered as verified.

### 5.4 Determination of noise equivalent temperature difference

5.4.1 Measurements are taken at a distance that ensures full covering of the field of view of the thermographic instrument by the radiator aperture.

5.4.2 The temperature of the standard (reference) large aperture radiator is set at 30 °C or at the temperature specified in the OM or certificate for determining the relevant characteristics.

5.4.3 The thermographic instrument is focused on the central area of the radiator aperture and is fixed in the chosen position. Two thermograms are recorded in the memory of the thermographic instrument in a short interval of time.

5.4.4 The temperature difference  $\Delta t_{ij}$  (°C) of each sensitive element in the areas of the recorded thermograms, which includes not less than a statistically significant number of sensitive elements, is determined using the software provided with the thermographic instrument, or is calculated by the formula:

$$\Delta t_{ij} = t_{ij}^{(1)} - t_{ij}^{(2)} \quad (1)$$

where:

$t_{ij}^{(1)}$  is the temperature of the sensitive element of the first thermogram with (i;j) coordinates (°C);

$t_{ij}^{(2)}$  is the temperature of the sensitive element of the second thermogram with (i;j) coordinates (°C).

5.4.5 The temperature resolution  $\Delta t_{\text{NETD}}$ , °C is calculated by the formula:

$$\Delta t_{\text{NETD}} = \frac{\sqrt{2}}{2} \sqrt{\frac{\sum_{i=1}^X \sum_{j=1}^Y (\Delta t_{ij} - \overline{\Delta t})^2}{X \cdot Y}} \quad (2)$$

where:

$\Delta t_{ij}$  is the temperature difference of the sensitive element of the first thermogram with  $(i, j)$  coordinates ( $^{\circ}\text{C}$ );

$\Delta \bar{t}$  is the mean temperature difference ( $^{\circ}\text{C}$ );

$X$  is the number of sensitive elements in the horizontal direction;

$Y$  is the number of sensitive elements in the vertical direction.

5.4.6 If a thermographic instrument has several thermal working ranges, the noise equivalent temperature difference shall be defined for each working range.

5.4.7 The received value of  $\Delta t_{\text{NETD}}$  shall not exceed that specified in the OM or certificate of the thermographic instrument.

## **5.5 Determination of the number of defective sensitive elements of a thermogram**

5.5.1 The procedures described in 5.4.1 and 5.4.2 are carried out.

5.5.2 The thermographic instrument is pointed at the central region of the radiator aperture and is fixed in a chosen position. The thermogram is recorded in the storage device of the thermographic instrument.

5.5.3 With the help of the software provided with the thermographic instrument, the defective sensitive elements are identified. The deviation of the temperatures of each sensitive element  $\delta t$  ( $^{\circ}\text{C}$ ) from the mean value of temperature of thermogram ( $^{\circ}\text{C}$ ) shall not exceed the value of temperature resolution, determined in 5.4, more than 6 times. The sensitive element for which the deviation of the temperature does not meet this requirement is declared defective.

5.5.4 The number of defective sensitive elements shall not exceed 0.3 % of the total number of sensitive elements specified in the OM or shall not exceed the value specified in the OM, or certificate, of the thermographic instrument.

## **5.6 Determination of the field of view and instantaneous field of view**

5.6.1 Selection of the working distance

5.6.1.1 The temperature of the standard (reference) large aperture radiator is set  $10^{\circ}\text{C}$  higher than the ambient temperature. A thermal test object with a variable slit is placed in front of the radiator at a distance of 1–3 cm.

5.6.1.2 The operating mode of a thermographic instrument should be able to attain its maximum sensitivity. The image of the thermal test object shall match the central area of the thermogram.

5.6.1.3 The maximum width of the slit is set and the maximum temperature of the slit in the thermogram is measured.

5.6.1.4 The working distance,  $R$  (mm), is chosen as the maximum distance between the thermographic instrument objective and the thermal test object with a variable slit which provides for the maximum temperature value of the slit in the thermogram, the slit being opened completely.

#### 5.6.2 Determination of the field of view and the instantaneous field of view

5.6.2.1 The temperature of the standard (reference) large aperture radiator is set 10 °C higher than the ambient temperature. A thermal test object with marks is placed in front of the radiator at a distance of 1–3 cm.

5.6.2.2 The operating mode shall enable the thermographic instrument to attain its maximum sensitivity. The image of the thermal test object shall match with the central area of the thermogram. Measurements are carried out at the working distance,  $R$ , specified in 5.6.1.

5.6.2.3 The marginal marks, recorded horizontally or vertically, are noted on the obtained thermogram. The distance between the marginal marks of the test object is measured in millimeters and in sensitive elements.

5.6.2.4 The instantaneous field of view (IFOV)  $\gamma$ (rad) is calculated by the formula:

$$\gamma = \frac{2}{a} \operatorname{arctg} \frac{A}{2R} \quad (3)$$

where:

$a$  is the distance between the marginal marks of the test object (element);

$A$  is the distance between the marginal marks of the test object (mm);

$R$  is working distance determined in 5.4.1 (in mm).

5.6.2.5 The field of view in horizontal  $\varphi_x$  and vertical  $\varphi_y$  directions, degrees, is determined, respectively, by the formulas:

$$\varphi_x = \gamma \cdot X \cdot \frac{180}{\pi} \quad (4)$$

$$\varphi_y = \gamma \cdot Y \cdot \frac{180}{\pi} \quad (5)$$

where:

$\gamma$  is instantaneous field of view (IFOV) (rad);

$X$  is the number of sensitive elements in the horizontal direction;

$Y$  is the number of sensitive elements in the vertical direction.

5.6.2.6 The instantaneous field of view  $\gamma$  and the fields of view  $\varphi_x$  and  $\varphi_y$  should correspond to those indicated in the OM or in the certificate of the thermographic instrument.

## 5.7 Determination of the spatial (angular) resolution

### 5.7.1 Determination of the scale parameter

5.7.1.1 The sequence of operations is carried out in accordance with 5.6.2.2 and 5.6.2.3.

5.7.1.2 The distances between the holes of the thermal test object are measured in sensitive elements, using the obtained thermogram of the thermal test object with marks.

5.7.1.3 The scale parameter  $k$  is determined as a ratio of the distance between the corresponding holes on the thermogram (element) and those on the thermal test object (mm).

### 5.7.2 Determination of the resolution in the horizontal direction

5.7.2.1 The temperature of the large aperture radiator is set 10 °C higher than the ambient temperature. A thermal test object with a variable slit is placed in front of the radiator at the distance of 1–3 cm in the vertical direction (the slit axis is orientated vertically along the height of the thermogram).

5.7.2.2 The sequence of operations is carried out in accordance with 5.6.2.2.

5.7.2.3 The maximum width of the slit is set and then measured. The maximum temperature of the slit  $t'_{max}$  (°C) is determined on the basis of the thermogram. On the basis of the temperature measurement results the contrast of the slit  $K_s$  on the thermograms is calculated by the formula:

$$K_s = \frac{t'_{max} - t'_0}{t_s - t'_0} \quad (6)$$

where:

$t'_{max}$  is the maximum temperature value of the slit with the width  $A$  determined by the thermogram (°C);

$t'_0$  is the mean temperature value of the shutters determined by the thermogram (°C);

$t_s$  is the maximum temperature value of the slit at the maximum width determined by the thermogram (°C).

5.7.2.4 On the basis of the recorded values of the slit width  $A$ , mm, the slit width  $a$  on the image plane (thermogram) is calculated by the formula:

$$a = A \cdot k \quad (7)$$

where:

$a$  is the slit size (element);

$A$  is the slit width (mm);

$k$  is the scale parameter determined by 5.7.1 (elements/mm).

5.7.2.5 The slit width  $A$  (mm) is reduced and measurements are taken according to 5.7.2.3 and 5.7.2.4.

5.7.2.6 The procedures from 5.7.2.5 are performed at least five times.

5.7.2.7 On the basis of the obtained measurement results, the dependence of slit contrast on thermograms  $K_s$  upon slit width  $a$  (element) – the slit response function ( $SRF$ ) is set:

$$SRF = K_s(a) \quad (8)$$

5.7.2.8 An example for calculating the spatial resolution in the horizontal direction  $F_X$  is given in Annex C.

5.7.2.9 The resolution in the horizontal direction  $F_X$ , equal to the resolution in the angular direction or, in terms of sensitive elements, to the slit size, should correspond to the value specified in the OM or in the certificate of the thermographic instrument, for a specified value of the slit contrast.

### 5.7.3 Determination of resolution in the vertical direction

5.7.3.1 The vertical resolution is determined in a similar way to that described in 5.7.2. The thermal test object with variable slit is set flat (the slit axis being orientated along the thermogram row). To calculate the angular dimension of the slit, the angle of the field of view of the thermographic instrument  $\varphi_y$ , determined in 5.7 and the number of the vertical sensitive elements of the thermogram  $Y$  are used.

5.7.3.2 The resolution in the vertical direction  $F_Y$  equal to the angular one or to the slit size in sensitive elements should correspond to the value specified in the OM or certificate of the thermographic instrument, the slit contrast value also being fixed.

## 5.8 Checking the range and estimating the accuracy of the radiation temperature measurement

5.8.1 Measurements are taken at a distance from the reference radiator and the thermographic instrument that ensures coverage, by the aperture of the radiator, greater than 20 % of the field of view of the thermographic instrument. The emitting surface of the standard radiator is matched with the central area of the thermogram.

5.8.2 The accuracy of a thermographic instrument is determined for at least five points of the working temperature range (the lower, the upper and three points within the range) for each operation mode (temperature range). When the steady-state conditions of a radiator are set, a minimum of five measurements is taken by the thermographic instrument for each temperature.

The mean value of the radiation temperature of the standard radiator is determined using the thermogram  $t_{mean}^t$  (°C) taking into account its emissivity and the temperature of the background radiation.

5.8.6.3 The accuracy  $\Delta t$  (°C) for each temperature of a thermographic instrument is calculated by the formula:

$$\Delta t = t_{90} - t_{mean}^t \quad (9)$$

where:

$t_{mean}^t$  is the mean temperature value in the area confining the image of the radiator aperture on the thermogram, which is determined by the thermographic instrument (°C);

$t_{90}$  is the temperature of the standard radiator (°C).

5.8.4 The results of verification or calibration are considered to be favorable if the accuracy calculated by Eq. (9) does not exceed the values specified in the OM for all points.

## **5.9 Determination of the sensitivity to non-uniformity in the field**

5.9.1 The procedures in 5.8.1 are carried out.

5.9.2 The sensitivity to non-uniformity in the field of a thermographic instrument is determined at five points of the working temperature range (the lower, the upper and three points within the range). When the steady-state conditions of the radiator are set, a minimum of five measurements is taken at each temperature.

5.9.3 The emitting surface of the standard radiator is positioned successively within at least five different areas of the thermogram (e.g. with the center and four corners of the thermogram).

5.9.4 The mean temperature of the radiation source corresponding to the source aperture is measured in various positions on the thermogram.

5.9.5 The sensitivity to non-uniformity in the field of a thermographic instrument  $\delta t$  (°C) is calculated by the formula:

$$\delta t = \bar{t}_{\max} - \bar{t}_{\min} \quad (10)$$

where:

$\bar{t}_{\max}$  is the maximum temperature value among the mean obtained temperatures;

$\bar{t}_{\min}$  is the minimum temperature value in the area of the thermogram.

5.9.6 The received value of  $\delta t$  should not exceed that specified in the OM or certificate of the thermographic instrument.

## **5.10 Check of the influence of environmental conditions on the performance of the instrument**

5.10.1 The check of the influence of environmental conditions on the performance of the instrument shall be carried out in a climatic chamber at the upper and lower limits of operating temperature and humidity values.

5.10.2 Measurements are taken according to 5.8.1.

5.10.3 The check of the influence of environmental conditions on the performance of the thermographic instrument is determined for three points of the working temperature range (the lower, the upper and one point within the range) for each operation mode (temperature range). When the steady-state conditions of the radiator are set, a minimum of five measurements using the thermographic instrument is taken for each temperature. The average (mean) value of the standard radiator radiation temperature is determined using the thermogram  $t_{mean}^t$  (°C) taking into account its emissivity and the background radiation temperature.

5.10.4 The accuracy of the thermographic instrument  $\Delta t_{EC}$  (°C) for each its temperature is calculated by the formula:

$$\Delta t_{EC} = t_{90} - t_{mean}^t \quad (11)$$

where:

$t_{mean}^t$  is the mean temperature value in the region confining the image of the radiator aperture on the thermogram, which is determined by the thermographic instrument (°C);

$t_{90}$  is the value of the standard radiator (°C).

5.10.4 The accuracy of the thermographic instrument (5.8) must be valid over the complete operating ambient temperature and air humidity range specified in the operating manual for the instrument, if not stated otherwise. If the accuracy does comply with the complete ambient conditions operating range, the manufacturer must state a temperature and humidity coefficients which give the additional measurement uncertainty when the instrument temperature deviates from a given reference temperature.

## 5.11 Determination of the repeatability of thermographic instrument readings

5.11.1 The temperature of the standard (reference) large aperture radiator is set 10 °C higher than the ambient temperature.

5.11.2 The image of the center of the standard extended radiator matches with the central region of the thermogram; measurements are taken every 10–15 seconds during 15 minutes, if no other minimum time interval is specified in the OM.

5.11.3 The mean temperature values are determined on the basis of the measurement results during three time intervals, five minutes each. The difference between the minimum and maximum values of the mean temperature values should not exceed the temperature repeatability specified in the OM or certificate of the thermographic instrument.

## 5.12 Drawing up verification and calibration results

5.12.1 Verification and calibration results are recorded in reports, the forms for which are given in Annex D.

5.12.2 A verification or calibration certificate is issued if the verification or calibration results are favorable. If the verification or calibration results are unfavorable, a notice of non-serviceability of the thermographic instrument is issued and the reasons are identified.

5.12.3 The verification or calibration certificate shall contain the following data and parameters:

- spatial (angular) resolution;
- field of view;
- instantaneous field of view (IFOV);
- accuracy of the radiation temperature measurement;
- noise equivalent temperature difference (temperature resolution,  $\Delta T_{\text{NETD}}$ );
- number of defective sensitive elements;
- sensitivity to non-uniformity in the field;
- influence of environmental conditions on the performance of the instrument; and
- repeatability.



**Annex A**  
**Sketch of the thermal test object with a variable slit**  
**(Informative)**

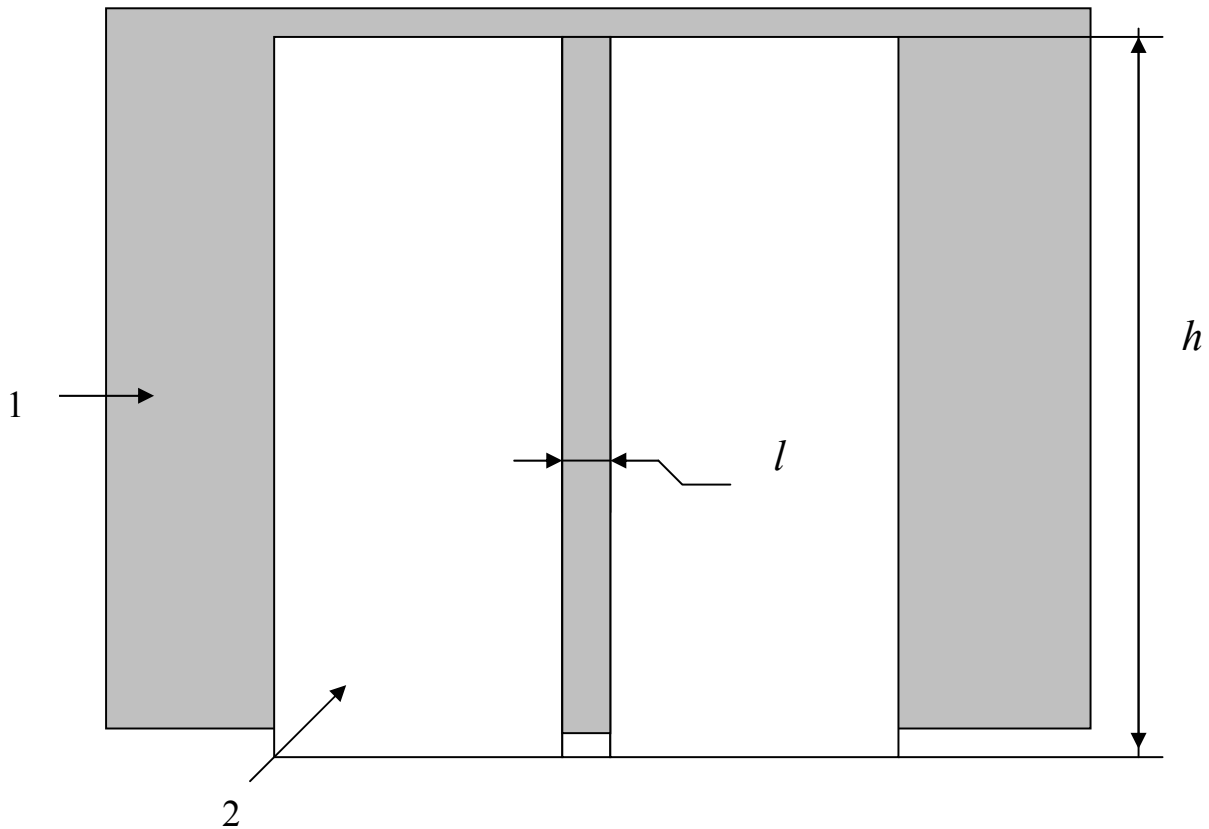


Figure A1 Sketch of the thermal test object with a variable slit

The shutters of the thermal test object are made of copper, 1 mm thick, and are blackened on the outer side.

<sup>1)</sup> standard large aperture radiator;

<sup>2)</sup> thermal test object with a variable slit (shutter height  $h = \text{const}$ , distance between the shutters  $l$  changes from 0 to 50 mm, the pitch being 1 mm, the uncertainty of setting the slit width is  $\pm 0.1$  mm).

**Annex B**  
**Sketch of the thermal test object with marks**  
**(Informative)**

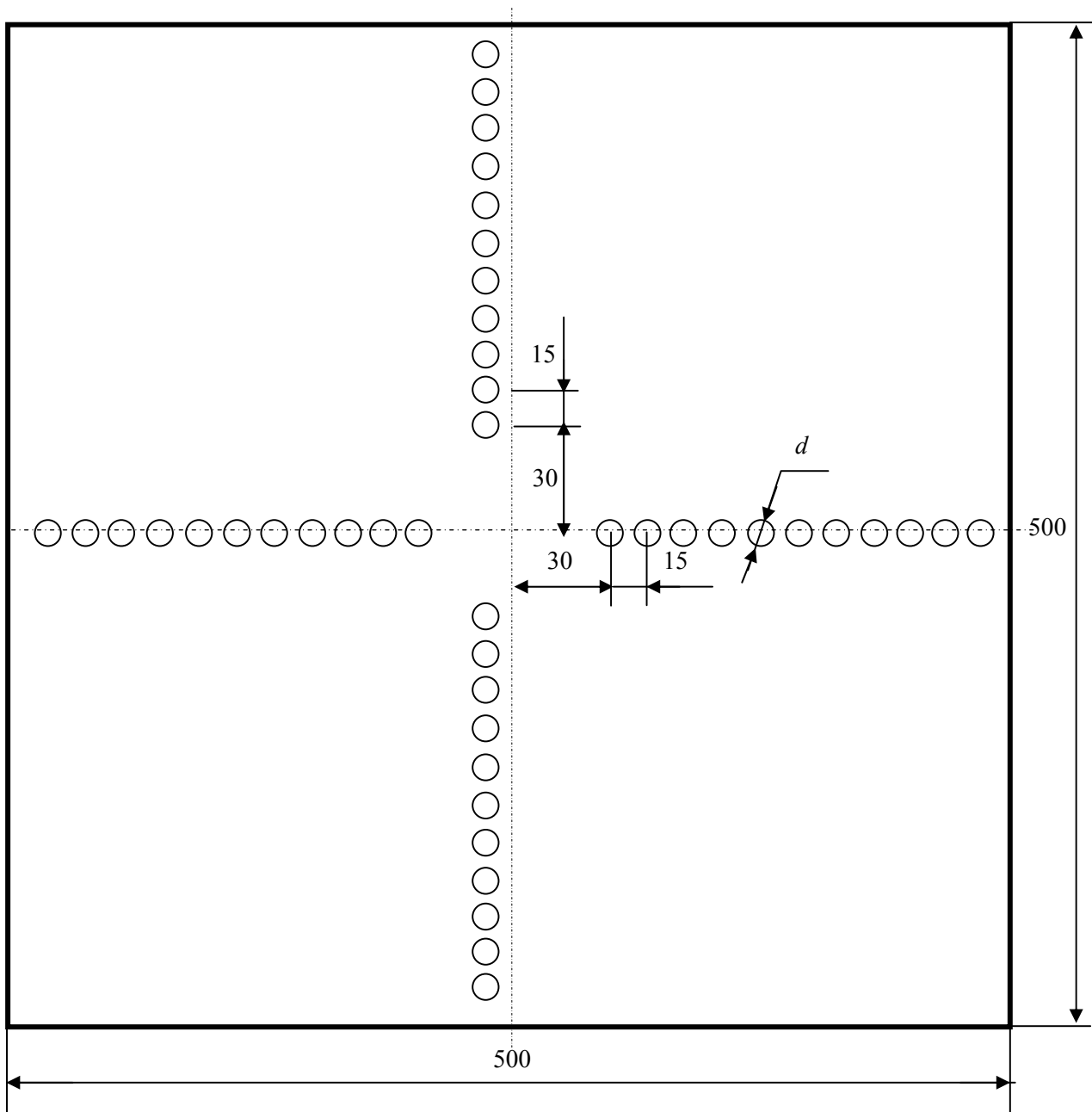


Figure B1 Sketch of the thermal test object with marks

Material – copper, 1 mm thick.

The outer side is blackened.

$d$  – diameter of the hole (10 mm).

## Annex C

### Calculation of the spatial resolution in the horizontal direction (Informative)

With the Gaussian approximation of the line spread function, the function of the slit response is determined by the ratio transformed to the table function  $erf(x)$ :

$$SRF(a) = erf\left(\frac{a}{2\sigma}\right) \quad (C.1)$$

where:

$a$  is the slit width (element);

$\sigma$  is a parameter determining the width of the spread function line (element).

An approximation of the experimental data array ( $K_{si}, a_i$ ) using equation C.1 is made when choosing the value of the parameter  $\sigma$  that will ensure the minimum value of the standard deviation of the experimental data from the specified function:

$$S = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (K_{si} - erf\left(\frac{a_i}{2\sigma}\right))^2} \quad (C.2)$$

where:

$N$  is the number of measurement results.

The spatial resolution in the horizontal direction is determined as the slit width, for which the contrast on the thermogram is equal to 99 % of the maximum value:

$$F_x = \sigma_x \cdot 3.64 \quad (C3)$$

where:

$\sigma_x$  is the value of the parameter  $\sigma$  (element) in the sensitive elements, chosen as a result of the approximation.

The angular dimension of the space resolution in the horizontal direction is determined in rad:

$$\Sigma_x = 2 \arctg \left( \frac{F_x}{X} \operatorname{tg} \frac{\varphi_x}{2} \right) \quad (C4)$$

where:

$X$  is the number of sensitive elements in a row of the thermogram;

$\varphi_x$  is the angle of field of view of the thermographic instrument along a row (grad).

## Annex D

### Thermographic instrument verification report (Informative)

#### D.1 Verification conditions

D.1.1 Humidity

D.1.2 Ambient temperature

#### D.2 Results obtained in determining the instantaneous field of view and the angle of field of view in the horizontal and vertical directions

D.2.1 The angle of field of view of the thermographic instrument was measured against a thermal test object with marks.

- Temperature of the standard large aperture radiator,  $t_{90}$ , \_\_\_\_ °C.
- Working distance from the radiator,  $R$ , \_\_\_\_ mm.
- Instantaneous field of view,  $\gamma$ , \_\_\_\_ rad.
- The thermographic instrument angle of field of view is equal to, in the horizontal direction,  $\varphi_x$ , \_\_\_\_ degrees, in the vertical direction,  $\varphi_y$ , \_\_\_\_ degrees.
- Measurement uncertainty is \_\_\_\_\_.

#### D.3 Results of determining the noise equivalent temperature difference

- Temperature of the standard large aperture radiator,  $t_{90}$ : \_\_\_\_ °C.
- Noise equivalent temperature difference,  $\Delta t_{NETD}$ : \_\_\_\_ °C.
- Number of defective sensitive elements, \_\_\_\_ elements.

#### D.4 Determining the spatial (angular) resolution of the thermographic instrument having the horizontal field of view of \_\_\_\_ degrees, and vertical field of view \_\_\_\_ degrees.

The spatial resolution of the thermographic instrument is determined by the slit response function (*SRF*) in the horizontal and vertical directions, and is measured against a thermal test object having a variable slit.

Temperature of the standard (reference) large aperture radiator,  $t_{90}$ , \_\_\_\_ °C.

D.4.1 Results obtained in determining the spatial resolution of the thermographic instrument:

Spatial resolution in the horizontal direction $F_x$		Spatial resolution in the vertical direction $F_y$	
In sensitive elements	In millirad	In sensitive elements	In millirad

**D.5 Results of checking the temperature range and determining the accuracy**

Temperature of the standard radiator, $t_{mean}$ (°C)	Reading of the thermographic instrument, $t'_{mean}$ (°C)	Accuracy, $\Delta t$ (°C)	Permissible error of the thermographic instrument (°C)	Measurement uncertainty (°C)

**D.6 Results of determining the sensitivity to non-uniformity in the field**

Mean measured temperature of the standard radiator for different positions of the standard radiator in the field of the thermogram:

Temperature of the standard radiator, $t_{90}$ (°C)						
Mean measured temperature, $t'_{mean}$ (°C)	In the upper left region of the thermogram					
	In the upper right region of the thermogram					
	In the central region of the thermogram					
	In the lower left region of the thermogram					
	In the lower right region of the thermogram					
Maximum value of the mean temperatures obtained, $\bar{t}_{max}$ (°C)						
Minimum value of the mean temperatures obtained, $\bar{t}_{min}$ (°C)						
Sensitivity to non-uniformity over the field, $\delta t$ (°C)						
Measurement uncertainty (°C)						

**D.7 Results of checking the influence of environmental conditions on the performance of the instrument**

Condition in the climatic chamber		Temperature of the standard radiator, $t_{90}$ (°C)	Reading of the thermographic instrument, $t'_{mean}$ (°C)	Error in readings, $\Delta t$ (°C)	Permissible error of the thermographic instrument (°C)	Measurement uncertainty (°C)
Temperature (°C)	Humidity (%)					

**D.8 Results of checking the repeatability of the thermographic instrument readings**

Temperature of the standard radiator, $t_{90}$ (°C)	Mean measured temperature for the 1st time interval, $t'_{mean1}$ (°C)	Mean measured temperature for the 2nd time interval, $t'_{mean2}$ (°C)	Mean measured temperature for the 3rd time interval, $t'_{mean3}$ (°C)	Difference between maximum and minimum values of the mean temperature values, $\Delta t'_{mean}$ (°C)	Temperature repeatability of thermographic instrument (°C)	Measurement uncertainty (°C)