INTERNATIONAL
RECOMMENDATION

OIML R 48

Edition 2004 (E)

Tungsten ribbon lamps for the calibration of radiation thermometers

Lampes à ruban de tungstène pour l'étalonnage des thermomètres à radiation

OIML R 48 Edition 2004 (E)

ORGANISATION INTERNATIONALE
DE MÉTROLOGIE LÉGALE

INTERNATIONAL ORGANIZATION
OF LEGAL METROLOGY

Contents

Foreword

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This publication - reference OIML R 48 (E) Edition 2004 - was developed by the OIML Subcommittee TC 11/SC 3 *Radiation thermometers*. It was approved for final publication by the International Committee of Legal Metrology in 2003 and will be submitted to the International Conference of Legal Metrology in 2004 for formal sanction. It supersedes the first edition dated 1980.

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Tungsten ribbon lamps for the calibration of radiation thermometers

1 Scope

The present Recommendation applies to tungsten ribbon lamps used for the calibration of radiation thermometers (including visual or photoelectric tungsten ribbon lamps) and specifies the requirements for tungsten ribbon lamps subject to legal metrological control.

The purpose of this Recommendation is to ensure that uniform calibration of these lamps can be carried out in all countries in a homogeneous manner with the accuracy specified hereinafter.

The present Recommendation also specifies for these lamps:

- Temperature measurement units;
- Main technical characteristics;
- Main parameters characterizing their metrological quality and the values of these parameters;
- Main methods to ensure the uniformity of calibrations.

2 Terminology

2.1 Radiance temperature

Temperature of a black body which has a radiance equal to the radiance of the object at a particular wavelength or narrow wavelength band.

2.2 Time necessary to reach thermal equilibrium

Minimum time period ranging from the moment of switching on a lamp to the moment at which thermal equilibrium is reached, expressed in temperature stability of the tungsten ribbon of a lamp.

2.3 Calibration temperature characteristic of the lamp

Relationship between the values of the radiance temperature of the tungsten ribbon and the values of the current in its circuit.

2.4 Slope of the calibration characteristic

Ratio of a small change in the current in the lamp circuit to the corresponding change in its radiance temperature.

2.5 Temperature inhomogeneity of the target area

Difference between the radiance temperature values obtained across the surface of the tungsten ribbon in the field of view. The temperature inhomogeneity is characterized by a maximum variation in temperature values obtained as a result of measurements when observing along and across the ribbon within the marked area relative to the position determined by the index and the center of the ribbon after the field of view has been displaced within the specified limits.

2.6 Instability of the calibration characteristic

Variation in the temperature of a tungsten ribbon. The temperature instability is characterized by a temperature equivalent to the current change in the lamp circuit per 1 hour.

2.7 Temperature coefficient of the lamp

Dimensionless quantity numerically equal to a change in the radiance temperature of the ribbon (in °C) under changes of the ambient temperature by 1 °C at a constant lamp current.

2.8 Nominal base temperature

Temperature at which the socket (and terminals) of the lamp shall be thermostated.

2.9 Base temperature coefficient of the lamp

Dimensionless quantity numerically equal to a change in the radiance temperature of the tungsten ribbon (in °C) under changes in the base temperature by 1 °C at a constant lamp current.

2.10 Temperature equivalent of a change in the current within the lamp circuit

Change in a value of radiance temperature (in °C) of the tungsten ribbon caused by a given change in the current within its circuit.

3 Units of measurement

3.1 Tungsten ribbon lamps have to be calibrated in accordance with the International Temperature Scale of 1990 (ITS-90). The temperature shall be expressed in degrees Celsius, °C or in kelvin, K.

3.2 Tungsten ribbon lamps reproduce the radiance temperature scale at the given wavelength.

3.3 Lamps can be calibrated for radiance temperature at different wavelengths provided that the glass window of the bulb is transparent enough for these wavelengths. In all cases the wavelength values must be specified in the certificate issued for the lamp.

4 Metrological requirements

4.1 Tungsten ribbon lamps are subdivided into ordinary accuracy lamps and high accuracy lamps. The former shall be used for the calibration of ordinary accuracy radiation thermometers, and the latter for the calibration of high accuracy radiation thermometers.

4.2 Ordinary and high accuracy lamps differ by the values of the lamp parameters:

- Temperature inhomogeneity;
- Instability;
- Calibration uncertainty;
- Base temperature (thermostated).

4.3 The temperature inhomogeneity is characterized by a maximum variation in temperature observed after a displacement of the field of view within ± 0.5 mm along and across the ribbon with respect to the marked area. Both the height and the width of the field of view should not exceed 1/2 of the ribbon width.

Table 1

Accuracy	Temperature °C	Permissible characteristics		
		Temperature inhomogeneity °C	Instability °C/h	Calibration uncertainty(*) °C
Ordinary	800	1.5	0.01	0.9
	1100	1.0	0.01	0.7
	1300	1.2	0.03	1.0
	1700	2.0	0.05	1.3
	2000	2.5	0.10	1.7
	2300	3.0	0.15	2.2
High	800	1.0	0.005	0.6
	1100	0.8	0.005	0.5
	1300	1.0	0.01	0.7
	1700	1.5	0.03	1.0
	2000	2.0	0.05	1.2
	2300	2.5	0.08	1.7

(*) $k = 2$. A confidence probability of 0.95 is ascribed to all uncertainty values.

The observed temperature variations shall not exceed the maximum permissible inhomogeneity limits specified in Column 3 of Table 1.

Note: In the case of applying the lamps only for the calibration of visual optical pyrometers of low accuracy, the usage of lamps having an instability greater than that indicated in Table 1 is permitted. In doing this the time necessary to reach thermal equilibrium can be reduced (see Table 2).

4.4 The instability of the calibration characteristic is defined by variations in the radiance temperature of a tungsten ribbon after a period of 25 hours' operation at the maximum operating temperature. The instability of all types of lamps shall be measured at the temperatures given in Column 2 of Table 1. Instability values shall not exceed those indicated in Column 4 of Table 1.

4.5 The calibration uncertainty is the difference between the radiance temperature value indicated in the lamp certificate and the corresponding value of the radiance temperature represented by the reference meter (see 6.1). This uncertainty results mainly from three quantities:

- Calibration uncertainty stated in the lamp certificate;
- Instability of calibration characteristic;
- Temperature inhomogeneity of the target area.

These quantities shall be within the limits specified in Table 1.

4.6 The time necessary to reach thermal equilibrium after switching on the lamp should not exceed the values indicated in Table 2. Thermal equilibrium is the state at which the change in temperature is less than 0.01 °C/min for ordinary accuracy lamps and less than 0.008 °C/min for high accuracy lamps.

In the case of changing the temperature by 100 °C, a time interval of 10 to 15 min (for gas-filled lamps) or 15 to 20 min (for vacuum lamps) is necessary.

Table 2

Temperature range (°C)	Time necessary to reach thermal equilibrium (min)	
	Ordinary accuracy lamp	High accuracy lamp
800–1200	45	60
1300–1700	35	40
1800–2300	40	45

4.7 Normal operation conditions for tungsten ribbon lamps are as follows:

- Correctly aligned working position as indicated in the calibration certificate;
- The lamp should be maintained in still air;
- The ambient air temperature is 23 °C ± 5 °C;
- The nominal base temperature (for high accuracy lamps only);
- The lamps should be operated with direct current, with the direction as indicated in the certificate.

4.8 The temperature coefficient of vacuum lamps near to the freezing point of gold shall not exceed 0.2 (for ordinary accuracy lamps) and 0.1 (for high accuracy lamps).

5 Technical characteristics

5.1 Tungsten ribbon lamps can be of two types: vacuum and gas-filled.

5.2 Bulbs of tungsten ribbon lamps must be fabricated from colorless transparent glass and must have no defects in the field of view.

5.2.1 High accuracy lamps must have flat windows forming a specified angle with the ribbon avoiding interreflexions which can affect the readings of the radiation thermometer. This angle shall not exceed 10°. The useful window aperture (i.e. the ratio of the window diameter to the distance between the window and the ribbon) shall be not less than 1/4.

5.3 Tungsten used for the fabrication of the incandescent lamp ribbon must enable a high mechanical and dimensional stability at radiance temperatures of up to 2300 °C.

5.4 The total length of the ribbon must be such that the temperature inhomogeneity meets the condition of 4.3 and the temperature coefficient meets the condition of 4.8.

5.4.1 The following parameters are recommended for the ribbon:

- Width: 1.2–3.0 mm;
- Thickness: 20–70 μm;
- Total length: At least 30 mm for ordinary accuracy and 50 mm for high accuracy.

5.4.2 Irrespective of the ribbon position inside the bulb, both ends of the ribbon must be held mechanically in a way to minimize displacements of the target area caused by changes in temperature. To avoid bending, flexure sections close to the ends of the ribbon are recommended.

5.5 The target area of the ribbon to be used during calibrations shall be close to the area of the highest temperature and must be indicated by a marker. The marker must ensure the determination of the target area centre within ± 0.2 mm for ordinary accuracy lamps and ± 0.1 mm for high accuracy lamps. When vertical adjustment is finished, the lamp is to be displaced in the direction of the optical axis of the radiation thermometers in order to refocus the ribbon.

In the case of high accuracy lamps, if the marker is a notch, its depth shall preferably not exceed 0.1 mm.

5.6 The bulb of the tungsten ribbon lamp must have an alignment marking (or indices) for fixing the ribbon at a point at which the angle between the optical axis of the radiation thermometers and the normal to the ribbon takes the correct value within ± 5° for ordinary accuracy lamps and ± 2° for high accuracy lamps.

5.7 In the case of high accuracy lamps the socket/base of the lamp shall be thermostated and measured. When the temperature is maintained within ± 0.1 °C of the nominal base temperature, no base temperature correction is necessary. Otherwise, the base temperature coefficient has to be measured and the deviation of the nominal temperature shall be corrected.

5.8 Tungsten ribbon lamps must be supplied with DC power, and polarity must be observed during setup. The direction of the current must be indicated on the socket or on the lamp terminals as well as in the certificate.

5.9 Lamps presented for calibration (initial or first) should first be subjected to stabilizing annealing (ageing). Ageing should be performed using direct current. After the ageing the lamp stability is checked (see 4.4). If the lamp complies with the criteria, then it can be calibrated; if not, the ageing and the stabilization shall be repeated. If the lamp does not comply with the criteria the second time then the lamp shall be rejected.

5.9.1 The ageing of ordinary accuracy lamps shall take 70 hours. The ageing temperature should exceed the highest operating temperature by at least 100 °C. However, for vacuum lamps it should not be lower than 1200 °C or higher than 1900 °C, and for gas-filled lamps it shall not be lower than 1700 °C or higher than 2400 °C.

5.9.2 The ageing of high accuracy lamps shall take 200 hours. The ageing temperature should exceed the highest operating temperature by at least 100 °C. However, for vacuum lamps it shall not be lower than 1200 °C or higher than 1800 °C, and for gas-filled lamps it shall not be lower than 1700 °C or higher than 2300 °C.

5.10 Each tungsten ribbon lamp shall bear the following marking:

- Type (see 4.1);
- The highest operating temperature;
- Manufacturer's trade mark;
- Date of manufacture;
- Serial no.;
- Marker for the direction of the current;
- The maximum value of current of the lamp.

6 Calibration of lamps

6.1 In order to comply with the maximum permissible calibration uncertainty[1], it is recommended to follow the requirements listed below. The maximum permissible calibration uncertainties are specified in Table 1, Column 5.

The uncertainties of monochromatic radiation thermometers, photoelectric spectropyrometers and spectral comparators shall be at least 3 times less than the uncertainty as specified in Table 1, Column 5.

6.2 The calibration is carried out at the wavelength whose value is indicated in the certificate.

6.3 The stability and temperature inhomogeneity are defined at the operating wavelength using a monochromatic radiation thermometer, a photoelectric spectropyrometer or a spectral comparator. The temperature resolution of these instruments shall be at least 10 times better than the uncertainty specified in Table 1, Column 5.

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[1] See Note #) to Table 1

7 Metrological control

If tungsten ribbon lamps are subject to metrological control, this control must include, in accordance with national regulations, all types of the controls listed below.

7.1 Pattern approval

7.1.1 Each instrument pattern of any manufacturer is subject to approval.

7.1.2 If changes have been introduced into a pattern which has already been approved, this pattern must be submitted for a new approval.

7.2 The primary ageing shall be specified either in the certificate, or by applying a special mark onto the base of the lamp.

7.3 Calibration of the lamps shall be realized in accordance with the detailed instructions consistent with the present Recommendation.

7.4 All lamps shall be calibrated at least every 2–4 years[#] or after every 100 hours of use at the maximum temperature.

7.4.1 It is important to check the stability of the lamps after every 100 hours of use.

8 Presentation of results

8.1 For each lamp, the results of metrological control shall be presented in the certificate issued by the calibration service.

[#] This depends on the type of lamp and on the frequency of its usage (number of cycles, operating at very high temperatures, presence of emergencies in work, etc.)

Page 1 of 3

Annex A
Test Report Format

Note: This Annex is informative with regard to implementation of this Recommendation in national regulations; however, use of the Test Report Format is mandatory for the application of the Recommendation within the *OIML Certificate System for Measuring Instruments*.

Report on testing a tungsten ribbon lamp

Reference: OIML R 48 (2004) ..... Report number: .....

Type of lamp: .....

Trade mark of the lamp: .....

Manufacturer: .....

Address: .....

.....

.....

Customer: .....

Address: .....

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Temperature range: .....

Accuracy class: .....

Wavelength: .....

Measurement conditions: .....

Procedure for alignment of the lamp: .....

Base (nominal) temperature (only for high accuracy lamps): .....

Base temperature coefficients (only for high accuracy lamps and if not controlled within ± 0.1 °C): .....

Additional parameters (if specified by the manufacturer): .....

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Page 2 of 3

Table 1 Results of calibration

Radiance temperature °C	Current A	Slope A/°C	Uncertainty °C	Temperature of the base °C

Conclusion: Pass ☐ Fail ☐

Comments: .....

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Table 2 Auxiliary metrological characteristics

Metrological characteristics **1**	**Requirements of this Recommendation** **2**	**Data obtained** **3**
1. Stability		
2. Temperature inhomogeneity: • along the ribbon length • along the ribbon width		
3. Time necessary to reach thermal equilibrium: • For vacuum lamps over the temperature ranges: • 800–1000 °C • 1000–1700 °C		
• For gas-filled lamps over the temperature ranges: • 1300–2000 °C • 2000–2300 °C		

Conclusion: Pass ☐ Fail ☐

Comments: .....
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.....
.....

Person(s) responsible for the testing:

Name: ..... Title: .....

Signature: ..... Date: .....

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