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Test methods for radiation thermometers

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Foreword

This Standard has been prepared by the proposal for revision of Japanese Industrial Standard furnished with the draft of Industrial Standard from Japan Electric Measuring Instruments Manufacturers' Association (JEMIMA)/Japanese Standards Association (JSA) based on Clause 1, Article 12 of the Industrial Standardization Law and revised by the Minister of International Trade and Industry through deliberations at Japanese Industrial Standards Committee. Consequently, **JIS C 1612:1988** is replaced with **JIS C 1612:2000**.

This revision specifies expression of performances and test methods for radiation thermometers.

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Contents

	Page
1 Scope	1
2 Normative references	1
3 Definitions	1
4 Performances	3
4.1 Measuring range	3
4.2 Accuracy rating	3
4.3 Reference operating conditions	4
4.4 Target size	4
4.5 Size-of-source effect	4
4.6 Exponent n	4
4.7 Reproducibility	4
4.8 Resolution	4
4.9 Response time	4
4.10 Temperature drift	4
4.11 Warm-up period	4
4.12 Load resistance of signal convertor/processor	4
4.13 Category temperature range	4
4.14 Category humidity range	4
4.15 Insulation resistance	5
4.16 Dielectric withstand voltage	5
5 Tests	5
5.1 Classification of tests	5
5.2 Test item	5
5.3 Test conditions	5
5.3.1 Installation of radiation thermometer	5
5.3.2 Establishment testing conditions	6
5.4 Testing methods	6
5.4.1 Accuracy rating test	6
5.4.2 Size-of-source effect test	6
5.4.3 Reproducibility test	7
5.4.4 Resolution test	7
5.4.5 Response time test	7
5.4.6 Temperature drift test	8

C 1612 : 2000

5.4.7	Insulation resistance test	8
5.4.8	Dielectric withstand voltage test	8
6	Marking	8
Annex 1 (normative) Calibration method		9
1	Scope	9
2	Calibration of radiation thermometer	9
3	Calibration apparatus	9
3.1	Blackbody furnace	9
3.2	Standard thermometer	11
4	Calibration method	11
4.1	Calibration procedure	11
4.2	Correction by emissivity	12
4.3	Evaluation of cavity emissivity	13
Annex 2 (normative) Standard radiation thermometer		14
1	Scope	14
2	Test	14
3	Characteristics	14
4	Calibration	14
4.1	0.9 μm narrow-band radiation thermometer	14
4.2	0.65 μm narrow-band radiation thermometer	15
5	Fixed-point blackbody furnace	15
6	Maintenance of accuracy	15
7	Exponent n	15
Annex 3 (informative) Characteristics and calibration of radiation thermometers		16
1	Geometric optical system constants	16
1.1	Basic principle of radiation thermometer	16
1.2	Target size	17
1.3	Distance factor and angular field of view	18
1.3.1	Distance factor F	18

1.3.2	Angular field of view 2α	18
1.4	Aiming mechanism	18
1.4.1	View finder system	19
1.4.2	Light beam spotter system	19
1.4.3	Other systems	20
2	Output characteristics and accuracy verification method of radiation thermometers	21
2.1	Characteristic formula of radiation thermometer	21
2.2	Method for calculation of constant	23
2.3	Error in temperature scale	23
2.4	Maximum error in temperature scale	24
2.5	Verification of accuracy rating	25
2.6	Verification for accuracy rating of linearizer output	26
3	Exponent n of radiation thermometer	28
3.1	Utilization of exponent n	28
3.2	Calculation method of constants in exponent n	29
3.3	Values of constants	30
3.4	Correction of emissivity by constants in exponent n	30
4	Examples of classification and structure of blackbody furnaces	31
5	Cavity emissivity, cavity reflectivity and cavity effective temperature	35
5.1	Effective temperature	36
5.2	Measurement of cavity reflectivity	39
5.3	Evaluation of cavity emissivity	40
6	Calibration of 0.65 μm narrow-band radiation thermometer in temperature area of 2 000 °C to 3 000 °C	40
6.1	Calibration by means of beam attenuator	40
6.2	Calibration by non-linearity measurement	41
7	Examples of structure and characteristics of narrow-band radiation thermometer	43
8	Method for determination of constants in characteristic formulae of narrow-band radiation thermometer	44
9	Examples of types and structure of fixed-point blackbody furnace	45
10	Expression of structure	46
10.1	Structure	46

C 1612 : 2000

10.2	Optical system	47
10.3	Aiming	47
10.4	Filter	47
10.5	Detecting element	47
10.6	Signal processing system	47
10.7	Input-output system	47
10.8	Accessory	47

Test methods for radiation thermometers

1 Scope This Japanese Industrial Standard specifies expression of performances and test methods for radiation thermometers which measure the radiance of the target, convert the measured quantity to a temperature and indicate the temperature. However, spectral sensitivity is excluded from this Standard because expression of the characteristics by parameters is not yet established.

2 Normative references The following standards contain provisions which, through reference in this Standard, constitute provisions of this Standard. The most recent editions of the standards indicated below shall be applied.

JIS Z 8750 *Methods of calibration for vacuum gauges*

JIS Z 8710 *Temperature measurement — General requirement*

3 Definitions For the purpose of this Standard, the following principal definitions apply:

a) Classification

- 1) **narrow-band radiation thermometer** A type of radiation thermometer by which only the radiant energy in a narrow wavelength band is measured.
- 2) **partial radiation thermometer** A type of radiation thermometer by which the radiant energy in a comparatively wide wavelength band is measured.
- 3) **total radiation thermometer** A type of radiation thermometer by which the radiant energy in a wide wavelength band is measured.
- 4) **multi-wavelength radiation thermometer** A type of radiation thermometer in which the relationship between the radiant energies in plural different wavelength bands is utilized.
- 5) **scanning radiation thermometer** A type of radiation thermometer in which the object is measured by a sequential scanning, and the wavelength band for measurement belongs one of those given in 1) to 4).

b) Terms relating with radiation thermometers

- 1) **detecting element** An element which senses radiation and produces an electric signal corresponding the radiant energy.
- 2) **optical system** A mechanism which condenses or focuses the radiation from the target.
- 3) **lens type** An optical system in which lenses are used.
- 4) **mirror type** An optical system in which mirrors are used.
- 5) **light guide type** An optical system in which light guides are used.
- 6) **fiber type** An optical system in which optical fibers are used.
- 7) **object distance** The distance from the tip end or the reference point of a radiation thermometer to the target.

- 8) **target size** The size (expressed in diameter and so on) of the target specified as the object of a radiation thermometer at a given object distance.
- 9) **distance factor** The ratio of the object distance to the target size.
- 10) **size-of-source effect** Such a behavior that the output of a radiation thermometer changes when the area of object differs.
- 11) **field of view** The extent which can be measured by a radiation thermometer.
- 12) **angular field of view** The magnitude of field of view expressed in the angle based on the principal point of an optical system.
- 13) **viewing** To look at a target or the like.
- 14) **aiming** A mechanism to view the target correctly.
- 15) **wavelength** The wavelength to which a radiation thermometer responses.
- 16) **effective wavelength** The effective wavelength which is measured by a radiation thermometer.
- 17) **exponent n** The exponent which expresses the relationship between the temperature of a target and the output signal of detector/sensing head of a radiation thermometer.
- 18) **half-width** The difference between two wavelengths which are corresponding to 1/2 of the maximum transmittance in a band-pass optical filter.
- 19) **detector/sensing head** A device which detects the radiance of a target and convert it into an electric signal, and which is composed of an optical system, detecting element and electrical system.
- 20) **signal convertor/processor** A device which converts the output signal of a detector into the electrical signal for use in instrumentation and control.
- 21) **allowable load resistance** The load resistance which can be connected with a system, within which the performances of the system are guaranteed.
- 22) **reference operating conditions** The extent of operating conditions within which the influence of change in the ambient conditions on the equipment is negligible.
- 23) **normal operating conditions** The extent of operating conditions within which normal measured values can be obtained by correcting the influences of ambient conditions.
- 24) **accuracy rating** The limit of the maximum error permissible for a radiation thermometer under the reference operating conditions.
- 25) **reproducibility** Such a nature that the individual measured values coincide to each other when a measuring object is measured repeatedly by the same method under the same conditions.
- 26) **resolution** The distinguishable temperature difference.
- 27) **response time** The time until the output reaches a prescribed ratio of the final value in a step response. It is generally expressed by the time to 63.2 %, 90 %, 95 %, or 98 % of the final value.
- 28) **warm-up period** The period of required time for an apparatus to operate normally from the start of the apparatus.

- 29) **temperature drift** The output variation of a radiation thermometer caused by change of the ambient temperature.

c) **Terms relating with measurement**

- 1) **object** A substance which is a subject of measurements.
- 2) **target** The area in an object on which measurements are carried out.
- 3) **radiant energy** The energy which is emitted, transmitted or received in a form of radiation.
- 4) **radiance** The radiant energy from a radiation source per unit time and per unit solid angle in a given direction divided by the orthogonal projection area of the radiation source in that direction.
- 5) **blackbody** An ideal heat radiant body which absorbs all the incoming radiation irrespective of the wavelength, direction of incidence and polarized state. It has the maximum spectral radiance at any direction and any wavelength among heat radiant bodies of the same temperature. It is also referred to as a perfect radiant body.
- 6) **blackbody cavity** A cavity which is formed by opaque walls to approximately realize a blackbody, and has an aperture for measurement.
- 7) **blackbody furnace** A device which has a blackbody cavity and a heating or cooling mechanism.
- 8) **radiance temperature** The temperature of a blackbody which has a radiance equal to the radiance of the object at a specific wavelength or wavelength band.
- 9) **spectral radiance** The spectral density of a radiance.
- 10) **emissivity** The ratio of the radiance of a substance to the radiance of a blackbody at the same temperature as that of the substance.
- 11) **cavity emissivity** The emissivity of the aperture of a blackbody cavity in a specific direction when the blackbody cavity wall is at a uniform temperature.
- 12) **cavity reflectivity** The rate of radiation which is reflected in a blackbody cavity and comes out again from the aperture, to the radiation which is introduced into the blackbody cavity in a specific direction through the aperture.

4 Performances

4.1 Measuring range The lower limit value and the upper limit value of the temperature to be measured shall be expressed. If a function to change over the range is provided, the extent in each range shall be expressed.

4.2 Accuracy rating The guaranteed accuracy rating shall be expressed in $\pm [\quad]$ °C or in $\pm [\quad]$ % of the marked temperature. If the expression method is different from that given above, and if the accuracy rating differs according to the measuring range or measuring temperature, such facts shall be clearly stated. In a thermometer which has the temperature indication and temperature output, or which has plural temperature outputs, it shall be clearly stated that the accuracy rating relates to which one.

4.3 Reference operating conditions This conditions shall be an ambient temperature $23\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ and a relative humidity 35 % to 75 %. If the conditions differ from the above, the conditions shall be clearly stated.

4.4 Target size The dimensions of target shall be given which is expressed by the object distance which realizes the said size. The relationship between the target size and the object distance may be shown by an equation or a figure. If necessary, the angular field of view, distance factor, effective diameter of objective lens or mirror, etc. should be additionally stated.

4.5 Size-of-source effect The difference between the indications obtained by carrying out the test at the target size and 1.4 times the size (area is twice) and the test temperature shall be given to express. When the value at other size is described side by side, the magnification of the test size to the target size shall be clearly stated.

4.6 Exponent n The exponent n which can be obtained from the output characteristics of the detector shall be expressed in an equation or the effective wavelength which can be obtained from the optical characteristics shall be expressed. If necessary, the wavelength range should be appended.

4.7 Reproducibility The value obtained by the test and the test temperature shall be given to express.

4.8 Resolution The value obtained by the test and the test temperature shall be given to express.

4.9 Response time The 95 % response time under such a state that a thermal radiation which varies from 0 % to 50 % of the measuring range is applied to the field of view stepwise, shall be given to express. However, a value different from the above may be given if the conditions are clearly stated.

4.10 Temperature drift The temperature coefficient or variation range and the test temperature (radiance temperature) under normal operating conditions shall be given to express.

4.11 Warm-up period If a warm-up period of 1 min or more is necessary, the warm-up period shall be expressed by the required time.

4.12 Load resistance of signal convertor/processor The load resistance of signal convertor/processor of analog output shall be expressed.

4.13 Category temperature range The range from the lower limit value to the upper limit value of the ambient temperature under which use of the thermometer is possible, shall be given to express.

4.14 Category humidity range The range from the lower limit value to the upper limit value of the ambient humidity under which use of the thermometer is possible, shall be given to express.

4.15 Insulation resistance The tested portion, the value obtained by the test, and the test voltage shall be given to express.

4.16 Dielectric withstand voltage When an external power supply is used, the tested portions and the test voltage shall be given to express. In the case where external power supply is not used, the expression is not made.

5 Tests

5.1 Classification of tests The tests shall be classified as follows:

- a) **Type test** The test carried out on a type of radiation thermometer at the stage of trial manufacture or early production, mainly to verify attainment of intended performances. Based on the results of this test, general specification of the product is determined and the performances are expressed.
- b) **Individual test** The test carried out on individual product before its shipment to verify whether the product is good or not.

In witnessed test, this individual test shall apply, unless otherwise specified.

5.2 Test item The tests shall be carried out on the items marked with ○ in Table 1.

Table 1 Classification and items of test

Test item	Classification of test			
	Thermometer employing external power supply		Thermometer not employing external power supply	
	Type	Individual	Type	Individual
Accuracy rating	○	○	○	○
Size-of-source effect ⁽¹⁾	○	—	○	—
Reproducibility	○	—	○	—
Resolution	○	—	○	—
Response time	○	—	○	—
Temperature drift	○	—	○	—
Insulation resistance ⁽²⁾	○	○	○	○
Dielectric withstand voltage	○	—	—	—

Notes ⁽¹⁾ Not applicable to scanning radiation thermometers.

⁽²⁾ Not applicable to thermometers which do not use external power supply and have no output terminals.

5.3 Test conditions

5.3.1 Installation of radiation thermometer In general, the radiation thermometer shall be installed as in the relationship illustrated in Fig. 1 to receive the radiant energy of the blackbody furnace adequately (see Annexes 1 and 2).

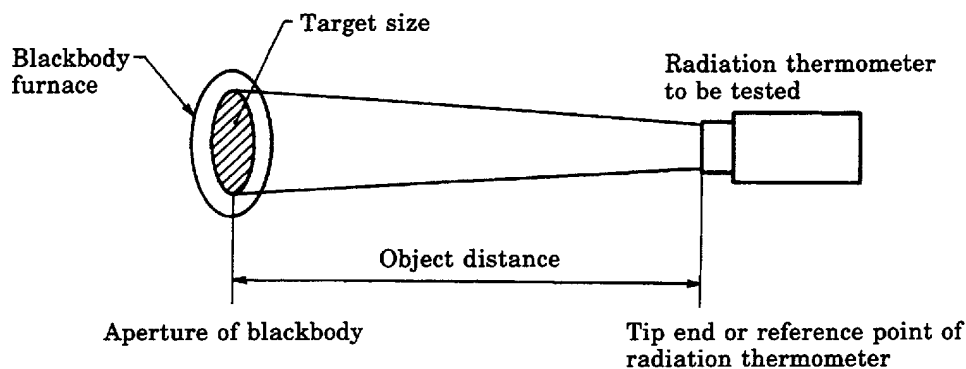


Fig. 1 Installation of radiation thermometer

5.3.2 Establishment of testing conditions

- The tests shall be carried out under the reference operating conditions specified in 4.3.
- The object distance shall be set to a prescribed value.
- A prescribed size shall be ensured for the target size.
- The focus adjustment shall be done adequately.
- The blackbody furnace specified in Annex 1 shall be used.
- The standard thermometer specified in Annex 2 shall be used.

5.4 Testing methods

5.4.1 Accuracy rating test Give a prescribed test temperature to the specimen, and examine the indication at that time.

- For the measurement of indication, read the attached indicator for integrated type, and measure the output value with a digital voltmeter for separated type without indicator. When a digital voltmeter is used, prepare a voltmeter with enough accuracy as compared with the accuracy rating of the radiation thermometer to be tested (specimen).
- In the type test, examine the error in the indication by comparing with the indication of standard thermometer, while realizing a temperature within each of temperature zones equal to about 0 %, 0 to 20 %, 20 to 40 %, 40 to 60 %, 60 to 80 %, 80 to 100 % and about 100 % of the measuring range of the specimen, in the blackbody furnace.
- In the individual test, examine the error in the indication by comparing with the indication of standard thermometer, while realizing a temperature within each of temperature zones equal to 0 to 30 %, 30 to 70 % and 70 to 100 % of the measuring range of the specimen, or the temperature at which the maximum error occurs if it is known, in the blackbody furnace. However, the test temperature may be altered, according to the purpose of use and the test requirements.

5.4.2 Size-of-source effect test Carry out the test as follows:

- a) Prepare a blackbody furnace or a heat source which has an aperture with a diameter not less than 1.5 times the target size specified for the specimen and which can be set to a temperature in almost middle of the measuring range (30 % to 70 %) of the specimen.
- b) To change the target size, prepare an aperture diaphragm corresponding to the specified target size (hereafter referred to as "standard diaphragm"), and a diaphragm having an aperture diameter not less than 1.4 times the target size.
- c) Set the specimen in accordance with the requirements given in 5.3, and place the said two diaphragms, one on the other, in front of the target. Set the blackbody furnace or heat source to a temperature in almost middle of the measuring range of the specimen, and examine the indication of the specimen after the temperature is completely stabilized. Successively withdraw the standard diaphragm and examine the indication at that time, then obtain the difference between both indications.
- d) Carry out the measurement of indication similarly to 5.4.1 a).

5.4.3 Reproducibility test Examine the change of indication by inserting and withdrawing a radiation screen which interrupts the radiant energy of blackbody furnace into and from the field of view of the specimen.

- a) Set the blackbody furnace to a temperature almost equal to 50 % of the measuring range of the specimen.
- b) The radiation screen shall have enough size to completely cover the field of view. Insert the radiation screen into the field of view after the indication of the specimen has stabilized, and allow it to remain there until the indication becomes in stabilized state. Repeat this operation 10 times.
- c) Examine the indication of the specimen corresponding to the blackbody furnace temperature at every measurement, obtain standard deviation σ of indication and express the amount of change by 2σ .

5.4.4 Resolution test Set the furnace as specified in 5.4.3 a), examine the indication of specimen, and obtain the resolution from the noise included in the output. Take $N = \frac{N_{PP}}{2\sqrt{2}}$ as the resolution (N), where N_{PP} is the width of change in the indication.

When the indication is in digital and the noise is negligible, the marked resolution may be indicated.

5.4.5 Response time test Carry out the test in accordance with the following method:

- a) Set the blackbody furnace as specified in 5.4.3 a) and install the specimen so that the temperature of blackbody furnace can be correctly measured.
- b) Obstruct a part of the field of view of the specimen with a radiation screen and adjust the position of the screen so that the indication is almost zero %.
- c) Obtain the response time from the output change of the specimen. Carry out the operation of radiation screen at a speed which will not cause any trouble for obtaining the response time.

5.4.6 Temperature drift test Carry out the test in accordance with the following method:

- a) Set the blackbody furnace or a heat source with stable radiance temperature to the middle (30 % to 70 %) of the measuring range of the specimen.
- b) Change the ambient temperature of the specimen in the normal operating conditions, and examine the change of indication at intervals of about 10 °C.

5.4.7 Insulation resistance test Measure the insulation resistance between the power supply circuits and input output terminals, and the enclosure at 500 V d.c. However, the test may be carried out at a voltage specified by the manufacturer, if a part of the power supply circuits is earthed through an earthing element such as a capacitor.

5.4.8 Dielectric withstand voltage test Carry out this test by applying a substantially sinusoidal a.c. voltage of 1 000 V at a frequency of 50 Hz or 60 Hz, across the power supply terminals and the enclosure for 1 min. However, if power supply voltage (E) exceeds 150 V, test the specimen at $(2E + 1\,000)$ V.

The test may be carried out at a voltage specified by the manufacturer, if a part of the power supply circuits is earthed through an earthing element such as a capacitor.

6 Marking The following items shall be marked at an adequate position of each radiation thermometer:

- a) Type assigned by manufacturer
- b) Manufacturer's name or abbreviation
- c) Serial number or year and month of manufacture

Related standards:

- JIS B 0155 *Industrial-process measurement and control — Terms and definitions*
JIS T 1141 *Medical infrared thermographs*
JIS Z 8103 *Glossary of terms used in instrumentation*
JIS Z 8113 *Lighting vocabulary*
JIS Z 8120 *Glossary of optical terms*
JIS Z 8706 *Methods of temperature measurement by optical pyrometers*

Annex 1 (normative) Calibration method

1 Scope This Annex specifies calibration method for radiation thermometers.

2 Calibration of radiation thermometer The temperature of the blackbody cavity shall be measured by the radiation thermometer to be calibrated (specimen) and a thermometer used as the standard (hereafter referred to as "standard thermometer") and both indications so obtained shall be compared.

3 Calibration apparatus Radiation thermometers, platinum resistance thermometers or glass thermometers shall be used as standard thermometers. The blackbody furnace shall be classified into two types i.e. standard blackbody furnace and comparison blackbody furnace according to the type of the standard thermometer to be used.

- a) **Standard blackbody furnace** The blackbody furnace when a glass thermometer or platinum resistance thermometer is used as the standard thermometer.
- b) **Comparison blackbody furnace** The blackbody furnace when a radiation thermometer is used as the standard thermometer.

The types of blackbody furnace, the temperature ranges over which the calibration is possible and the standard thermometers to be used are shown in Annex 1 Table 1.

Annex 1 Table 1 Types of blackbody furnace, temperature range and standard thermometer

Type of blackbody furnace		Temperature range of blackbody furnace	Type of standard thermometer
Standard blackbody furnace	Low temperature area	-50 to 300 °C	Glass thermometer Platinum resistance thermometer
	Intermediate temperature area	50 to 500 °C	Platinum resistance thermometer
Comparison blackbody furnace	Intermediate temperature area	400 to 1 100 °C	0.9 µm narrow-band radiation thermometer
	High temperature area	800 to 1 500 °C	0.9 µm narrow-band radiation thermometer 0.65 µm narrow-band radiation thermometer
	Extra-high temperature area	1 000 to 3 000 °C	0.9 µm narrow-band radiation thermometer (2 000 °C max.) 0.65 µm narrow-band radiation thermometer

3.1 Blackbody furnace The construction and performances of blackbody furnace shall be as follows:

- a) The aperture diameter of blackbody cavity shall be at least 1.5 times the target size obtained from the distance factor of the radiation thermometer to be calibrated (see Annex 3).
- b) The blackbody cavity shall have a depth of at least twice the aperture diameter, and the inside wall shall be made of a material having a surface emissivity of 0.7 or more and small change of emissivity due to wavelength. It shall be verified that the cavity reflectivity is not more than 0.02. However, when radiation thermometers of the same wavelength area are compared, or required calibration accuracy is low, the above conditions are alleviated (see Annex 3).
- c) The blackbody furnace shall be such that the temperature of its cavity can be maintained at a prescribed temperature by means of a hot bath or electric furnace, and the stability under steady state shall fall within a range of ± 0.5 °C/min.
- d) During steady state of a blackbody furnace, the temperature distribution (difference from the temperature at the center of bottom) on the bottom face of blackbody cavity, and the ratio of the temperature fall or rise at the apparent aperture to the bottom face temperature shall be within the value given in Annex 1 Table 2 according to the type of blackbody furnace. However, when required calibration accuracy is low, the above conditions are alleviated (see Annex 3).

Annex 1 Table 2 Types of blackbody furnace and temperature distribution of blackbody cavity

Type of blackbody furnace	Temperature distribution on bottom face	Rate of aperture temperature to bottom face temperature
Standard blackbody furnace	± 1 °C	-2 % to +0.4 %
Intermediate temperature area comparison blackbody furnace	± 2.5 °C	-10 % to +2 %
High temperature area comparison blackbody furnace	± 5 °C	-10% to +2 %
Extra-high temperature area comparison blackbody furnace	± 10 °C	-20 % to +4 %

Remarks 1 Temperature distribution on bottom face is expressed by the temperature difference from the center.

2 The ratio of aperture temperature to bottom temperature (%) shows the ratio of the temperatures expressed in Kelvin.

3 In the case of a cylindrical blackbody cavity without aperture diaphragm, the position on cavity wall at which the temperature fall reaches that of Annex 1 Table 2 shall be considered as the apparent aperture.

4 In a blackbody cavity having an aperture diaphragm of large throttling ratio and a spherical blackbody cavity, the ratio of the aperture temperature to the bottom temperature shall be 1/2 of that given in the table.

- e) In a blackbody furnace, the position of aperture or bottom face of blackbody cavity in the hot bath or electric furnace shall be indicated.

- f) The standard blackbody furnace shall be so constructed that a standard thermometer can be attached and detached, the position for installation is reproducible, the indication of standard thermometer and the bottom temperature of blackbody cavity shall coincide within ± 0.2 °C in hot bath, or ± 0.5 °C in electric furnace, and the coincidence shall be ensured.
- g) In a comparison blackbody furnace, such a method that the temperature is measured by a thermoelectric thermometer and calibrated by a standard thermometer complying with Annex 2 periodically may be used, if the temperature of blackbody cavity is not more than 1 500 °C.

3.2 Standard thermometer The following thermometers shall be used as the standard thermometer according to the type of blackbody furnace.

- a) **Standard blackbody furnace** In the case of a blackbody furnace which employs a hot bath, a standard thermometer calibrated to an accuracy better than ± 0.5 °C shall be used, and in the case of the one which employs an electric furnace, a standard thermometer calibrated to an accuracy better than ± 0.2 °C shall be used. The standard thermometer shall be calibrated as specified in **JIS Z 8705** and **JIS Z 8710** as practicable.
- b) **Comparison blackbody furnace** The standard radiation thermometer based on Annex 2 shall be used.

4 Calibration method

4.1 Calibration procedure

- a) The method for installation and viewing of radiation thermometer shall be as given below according to the type of blackbody furnace. In any case, there shall be no eclipse.
 - 1) For a standard blackbody furnace, view the apparent aperture or the furnace bottom in the same optical axis.
 - 2) For an intermediate or high temperature area comparison blackbody furnace, view the apparent aperture or the furnace bottom with the standard thermometer and the specimen installed in the same or different optical axis as shown in Annex 1 Fig. 1 a) or b).
 - 3) For a high or extra-high temperature area comparison blackbody furnace, carry out the viewing as specified in above 2). However, in the case of such a comparison blackbody furnace that the construction is symmetric in its front and rear and it is verified that the difference in temperature between the front and the rear is within the specified tolerances, it is permitted to employ such a method that the standard thermometer and the specimen are installed in opposite direction as shown in Annex 1 Fig. 1 c), and each furnace bottom is viewed.