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JIS Z 4511 : 2005
(JEMIMA/JSA)

**Methods of calibration for exposure
meters, air kerma meters, air absorbed
dose meters and dose-equivalent
meters**

ICS 17.240

Reference number : JIS Z 4511 : 2005 (E)

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Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by Japan Electric Measuring Instruments Manufacturers' Association (JEMIMA)/Japanese Standards Association (JSA) with the draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law applicable to the case of revision by the provision of Article 14.

Consequently JIS Z 4511 : 1999 and JIS Z 4511 : 2001 (Amendment 1) are replaced with this Standard.

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Methods of calibration for exposure meters, air kerma meters, air absorbed dose meters and dose-equivalent meters

Introduction This Japanese Industrial Standard revises JIS Z 4511:1999 completely including the amendment added in the fiscal year of 2000. The revision responds to enforcement of the new radiation hazard prevention related statute which incorporates the new Measurement Law effective as of April, 2001 and ICRP-1990 recommendation. The revision introduces an air kerma standard and concerns the fundamental matters of the system of calibration.

1 Scope This Standard specifies the calibration method (however, excluding the calibration based on the Measurement Law by a specified standard instrument or a specified secondary standard instrument, etc.) of an exposure meter, an air kerma meter, an air absorbed dose meter, and a dose-equivalent meter of photon energy 10 keV to 3 MeV (hereafter referred to as “meters”).

2 Normative references The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. If the indication of the year of publication is given to these referred standards, only the edition of the indicated year constitutes the provision of this Standard but the revision and supplement made thereafter do not apply. The normative references without the indication of the year of coming into effect apply only to the most recent editions (including amendments).

JIS Z 4001 *Glossary of terms used in nuclear energy*

JIS Z 4331 *Calibration phantom for X-, γ - and β -ray personal dosimeters*

JIS Z 8103 *Glossary of terms used in measurement*

JIS Z 8401 *Guide to the rounding of numbers*

ISO 4037-1:1996 *X and gamma reference radiation for calibrating dosimeters and doserate meters and for determining their response as a function of photon energy—
Part 1: Radiation characteristics and production methods*

ISO 4037-3:1999 *X and gamma reference radiation for calibrating dosimeters and doserate meters and for determining their response as a function of photon energy—
Part 3: Calibration of area and personal dosimeters and the measurement
of their response as a function of energy and angle of incidence*

3 Terms and definitions For the purposes of this Standard, the definitions given in JIS Z 4001 and JIS Z 8103 and the following definitions apply.

Remarks 1 The dose equivalent per unit time is called “dose equivalent rate”, and the dose equivalent (or dose equivalent rate) is expressed with “the dose equivalent (rate)” in this Standard.

- 2 The exposure per unit time is called “exposure rate”, and an exposure (or exposure rate) is expressed with “an exposure (rate)” in this Standard. Similarly, an air kerma and air absorbed dose per unit time are called “the rate of an air kerma”, and “rate of an air absorbed dose”, respectively. In this Standard, an air kerma (or rate of an air kerma) is expressed with an air kerma (rate), and an air absorbed dose (or rate of an air absorbed dose) is expressed with an air absorbed dose (rate).

a) **Dose-equivalent-related terms and definitions**

- 1) **ICRU sphere** a sphere where mass percentage is elemental composition of oxygen 76.2 %, carbon 11.1 %, hydrogen 10.1 %, and nitrogen 2.6 %, the density is 1 g/cm³ and the diameter is 30 cm
- 2) **ICRU slab** a rectangular parallelepiped where mass percentage is elemental composition of oxygen 76.2 %, carbon 11.1 %, hydrogen 10.1 %, and nitrogen 2.6 %, the density is 1 g/cm³ and the dimension is 30 cm × 30 cm × 15 cm
- 3) **1 cm dose equivalent** generic name of 1 cm dose equivalent in connection with a place, and 1 cm dose equivalent in connection with an individual

1 cm dose equivalent in connection with a place is the dose equivalent at the depth of 1 cm from an entrance plane on the principal-axis along the direction of incidence, when an ICRU sphere is irradiated with the photon of the plane parallel beam of the single direction. Moreover, 1 cm dose equivalent in connection with an individual is the dose equivalent at the depth of 1 cm from an entrance plane on the principal axis, when ICRU slab is irradiated at right angles to a principal plane with the photon of the plane parallel beam of the single direction. 1 cm dose equivalent is indicated by $H_{1\text{cm}}$.

In addition, this dose equivalent rate is indicated by $\dot{H}_{1\text{cm}}$.

- 4) **70 μm dose equivalent** generic name of 70 μm dose equivalent in connection with a place, and 70 μm dose equivalent in connection with an individual

70 μm dose equivalent in connection with a place is the dose equivalent in the depth of 70 μm from an entrance plane on the principal-axis along the direction of incidence, when an ICRU sphere is irradiated with the photon of the plane parallel beam of the single direction. Moreover, 70 μm dose equivalent in connection with an individual is the dose equivalent in the depth of 70 μm from an entrance plane on the principal axis, when ICRU slab is irradiated at right angles to a principal plane with the photon of the plane parallel beam of the single direction. The 70 μm dose equivalent is indicated by $H_{70\mu\text{m}}$.

In addition, this dose equivalent rate is indicated by $\dot{H}_{70\mu\text{m}}$.

- 5) **ICRU-sphere dose equivalent (rate)** generic name of 1 cm dose equivalent (rate) and 70 μm dose equivalent (rate) in connection with a place
- 6) **ICRU slab dose equivalent (rate)** generic name of 1 cm dose equivalent (rate) and 70 μm dose equivalent (rate) in connection with an individual

- 7) **dose-equivalent conversion factor** conversion factor used when computing the ICRU-sphere dose equivalent (rate) or the ICRU slab dose equivalent (rate) from an air kerma (rate) in the free space
- 8) **air absorbed dose conversion factor** conversion factor used when computing an air absorbed dose (rate) from an exposure (rate) ($= 33.97 \text{ Gy} \times \text{kg/C}$)
- 9) **air kerma conversion factor** conversion factor used when computing an air kerma (rate) from an exposure (rate) ($= 33.97 \times (1 - g)^{-1} \text{ Gy} \times \text{kg/C}$). Here, g shows the loss rate by bremsstrahlung

b) **Calibration-related terms and definitions**

- 1) **exposure meter** meter for measuring an exposure (rate)
- 2) **air kerma meter** meter for measuring an air kerma (rate)
- 3) **air absorbed dose meter** meter for measuring an air absorbed dose (rate)
Hereafter, in this Standard, for the photon not exceeding 1.5 MeV, an air absorbed dose meter is included in an air kerma meter.
- 4) **dose-equivalent meter** meter for performing measurement of an ICRU-sphere or the ICRU slab dose equivalent (rate)
- 5) **exposure (rate) standard** exposure (rate) used as the standard which is set up by the calibrating apparatus
- 6) **air kerma (rate) standard** air kerma (rate) used as the standard which is obtained by multiplying an exposure (rate) standard by an air kerma conversion factor
- 7) **air absorbed dose (rate) standard** air absorbed dose (rate) standard used as the standard which is obtained by multiplying an exposure (rate) standard by an air absorbed dose conversion factor
Hereafter, in this Standard, an air absorbed dose (rate) standard is included in an air kerma (rate) standard.
- 8) **dose-equivalent (rate) standard** the ICRU-sphere dose equivalent (rate) or the ICRU slab dose equivalent (rate) used as the standard which is obtained by multiplying an air kerma (rate) standard by a dose-equivalent conversion factor
- 9) **dose (rate) standard** generic name of an exposure (rate) standard, an air kerma (rate) standard, an air absorbed dose (rate) standard, and a dose-equivalent (rate) standard
- 10) **calibration** to find a relation between a dose (rate) standard and a value indicated by a meter
- 11) **calibrating apparatus** a reference instrument, irradiation equipment, or γ -ray source used as a standard for setting up an exposure (rate) or an air kerma (rate) standard

12) **specified standard instrument** standard meter which the Minister of Economy, Trade and Industry specified based on the Measurement Law

13) **specified secondary standard instrument** standard instrument which are calibrated by using a specified standard instrument based on the Measurement Law

Moreover, in this Standard, this category includes the standard instrument (working standard) which is deemed to be equivalent to a specified secondary standard instrument based on the Measurement Law.

14) **reference instrument** meter which serves as a standard when calibration is carried out

In the class of reference instrument, there are a reference meter and a practical reference meter. Moreover, in the class of practical reference meter, there are an exposure or an air kerma practical reference meter, and a dose-equivalent practical reference meter.

15) **irradiation equipment** generic name of the γ -ray irradiation equipment or X-ray irradiation equipment which are used for calibration

16) **reference γ -ray source** a γ -ray source used as the standard for setting up a dose (rate) standard, whose value is decided by a specified secondary standard instrument

17) **practical γ -ray source** a γ -ray source used only in order to calibrate a practical meter

There are a practical standard γ -ray source whose dose rate was decided by the reference meter, and a γ -ray source without a dose-rate standard for calibration for confirmation.

18) **practical irradiation equipment** simple irradiation equipment for setting up a dose (rate) standard

19) **practical meter** meter which is in practical use

There are an exposure practical meter, an air kerma practical meter, an air absorbed dose practical meter, and a dose-equivalent practical meter. In this Standard, an air absorbed dose practical meter is included in an air kerma practical meter.

20) **reference calibration** calibration of a specified secondary reference instrument, a reference meter, or a practical reference meter

21) **practical calibration** calibration of a practical meter

22) **confirmation calibration** simple calibration performed about the practical meter which is in practical use, without using a dose (rate) standard and with paying attention to whether the calibration constant varies or not due to a practical radiation source, whose purpose is to confirm periodical performance maintenance

- 23) **substitution method** method to calibrate by placing alternately a reference instrument and a meter to be calibrated in the irradiation field of the same condition

Here, the substitution method includes the two methods. One is that a meter to be calibrated and a reference instrument specified in ISO 4037-3 are simultaneously irradiated. The other is that the beam monitor which monitors the output change of irradiation equipment is concurrently used.

- 24) **radiation-source method** method to calibrate a meter to be calibrated by using a reference γ -ray source or a practical reference γ -ray source
- 25) **inverse square law** method to calculate the exposure, the air kerma, or the dose equivalent (rate) at an arbitrary distance based on a dose (rate) standard, and to calibrate a meter to be calibrated
- 26) **calibration constant** value obtained by dividing the exposure (rate), the air kerma (rate), or the dose equivalent (rate) specified as a standard by the indicated value of a meter to be calibrated

4 System of calibration The system of calibration which is traceable from a national standard to primary, secondary and a practical exposure (rate), or an air kerma (rate) standard is specified in figure 1 and the following:

- a) Calibration is classified into the reference calibration for a specified secondary standard instrument, a reference meter, or a practical reference meter, and the practical calibration for a practical meter.
- b) Reference calibration consists of calibration by the primary exposure (rate) or the primary air kerma (rate) standard of a specified secondary standard instrument, calibration by the secondary exposure (rate) or the secondary air kerma (rate) standard of a reference meter, and calibration by the practical exposure (rate), the practical air kerma (rate) or the practical dose-equivalent (rate) standard of a practical reference meter.
- c) Practical calibration consists of the calibration of an exposure practical meter and an air kerma practical meter by the practical exposure (rate) standard and the practical air kerma (rate) standard, respectively, as well as the calibration for confirmation. Calibration of a dose-equivalent practical meter shall be based on the dose-equivalent (rate) standard which is obtained by multiplying the practical air kerma (rate) standard by the dose-equivalent conversion factor. It shall also be based on the practical dose-equivalent (rate) standard whose value is decided by the practical dose-equivalent (rate) standard, as well as the calibration for confirmation.
- d) A specified standard instrument is a national standard instrument of the highest class in the Measurement Law. A specified secondary standard instrument is a standard meter which is calibrated by the primary exposure (rate) standard or the primary air kerma (rate) standard.

- e) A reference γ -ray source is a γ -ray source where a specified secondary standard instrument determines the value of the exposure rate, the rate of an air kerma, or the dose equivalent rate of a radiation source. When γ -ray irradiation equipment with the similar value setting is used independently, it shall be included in this category.
- f) A practical reference γ -ray source is a γ -ray source where a reference meter determines the value of the exposure rate, the rate of an air kerma, or the dose equivalent rate of a radiation source. When γ -ray irradiation equipment with the similar value setting is used independently, it shall be included in this category.

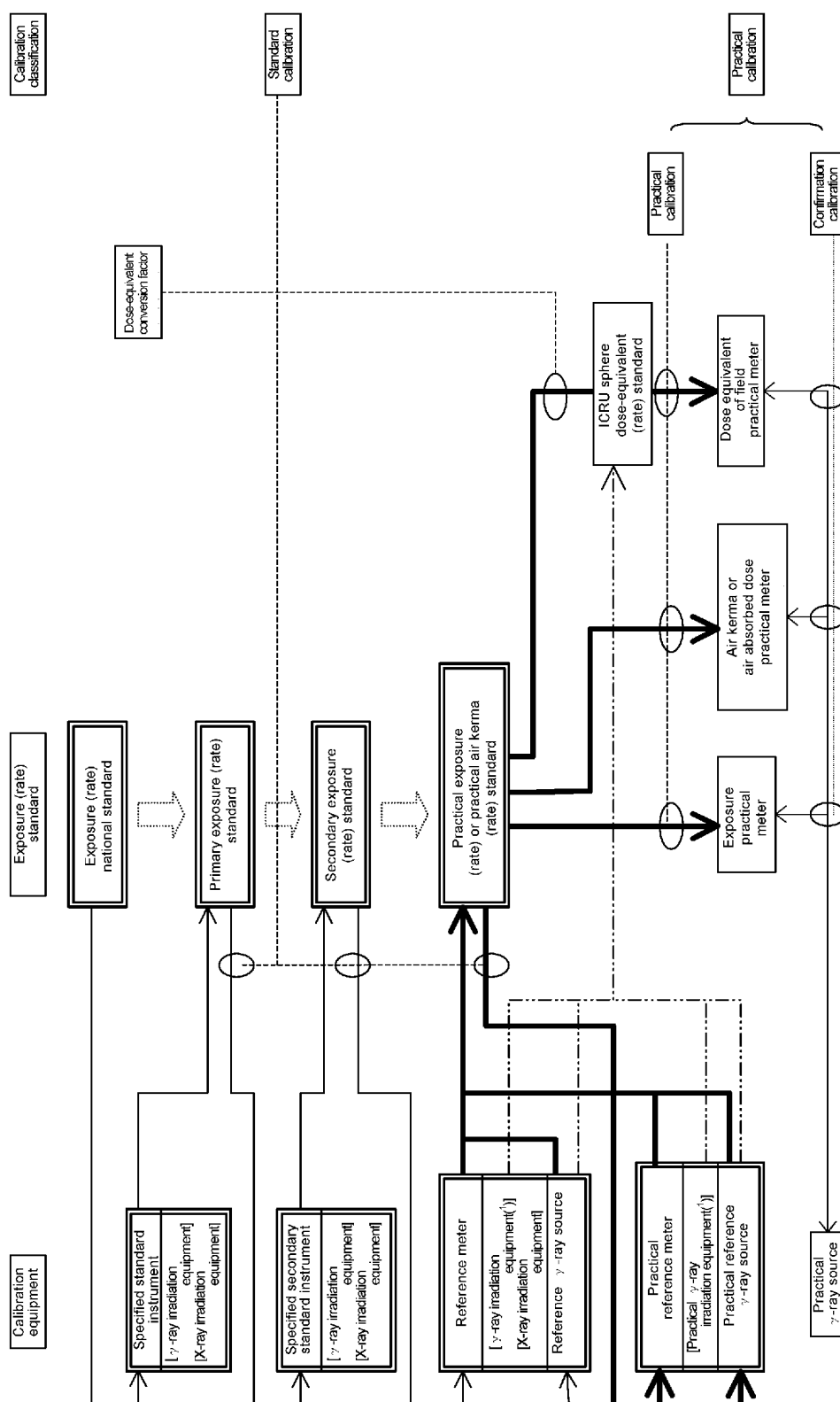


Figure 1 System of calibration

Note (1) The air kerma (rate) of a collimate type γ -ray irradiation equipment or a reference γ -ray source is multiplied by a dose-equivalent conversion factor, and it can be used as the irradiation equipment or the reference γ -ray source of the ICRU-sphere dose equivalent (rate). Practical γ -ray irradiation equipment is assigned a value by the ICRU-sphere dose equivalent (rate), and it can set a practical ICRU-sphere dose-equivalent (rate) standard.

Remarks 1 Calibration of a specified secondary standard instrument and a reference meter (including a working reference standard) is outside the scope of this Standard. Moreover, the method of confirmation calibration is shown in Annex 2.

- 2 A solid line shows actual relation and the arrow of a dotted line shows relation of between a national standard and reference standard. A long dashed double-short dashed line shows the relation to a practical ICRU-sphere dose-equivalent (rate) standard.
- 3 The system of the calibration by an ICRU slab dose-equivalent (rate) standard is shown in Annex 1 attached figure 1.

Reference : An exposure (rate) standard is multiplied by an air kerma conversion factor, and it can be used as an air kerma (rate) standard. Moreover, the practical exposure (rate) standard is multiplied by the air absorbed dose conversion factor in order to set up the filed of the practical air absorbed dose (rate) standard. In such a field, an air absorbed dose practical meter can be calibrated.

Figure 1 (concluded)

5 Method to obtain the uncertainty of the calibration constant The reliability in the uncertainty of the calibration constant shall be 95 %. Synthesis of uncertainty shall be the square root of the sum of square of the uncertainty related to each event. The uncertainty in calibration shall be found the square root of the sum of the square of uncertainty of the field where a standard was set (uncertainty of the calibration including the performance of a reference meter, or uncertainty of calibration of a reference γ -ray source) and the sum of the square of uncertainty of a meter to be calibrated (including uncertainty of calibration).

6 Uncertainty of calibration

6.1 Uncertainty of reference calibration The uncertainty of reference calibration shall be specified as follows:

- a) In the field where the γ -ray energy of ^{137}Cs or ^{60}Co was used to set the practical exposure (rate) standard or the practical air kerma (rate) standard, when an exposure or an air kerma practical reference meter is to be calibrated, its uncertainty shall be 6 % or under.
- b) In the field where the γ -ray energy of ^{137}Cs or ^{60}Co was used to set the dose-equivalent (rate) standard, when a dose-equivalent practical reference meter is to be calibrated, its uncertainty shall be 6 % or under.

Information : In the field where the secondary exposure (rate) standard or the secondary air kerma (rate) standard was set, when a reference meter is to be calibrated, its uncertainty shall be 5 % or under.

6.2 Uncertainty of practical calibration The uncertainty of practical calibration shall be specified as follows:

- a) In the field where the practical exposure (rate) standard or the practical air kerma (rate) standard was set, when an exposure or an air kerma practical meter is to be calibrated, its uncertainty shall be 20 % or under.
- b) In the field where the practical air kerma (rate) standard was multiplied by the dose-equivalent conversion factor, and the dose-equivalent (rate) standard was set, when a dose-equivalent practical meter is to be calibrated, its uncertainty shall be 20 % or under.

In addition, the error of the dose-equivalent conversion factor for finding a dose-equivalent (rate) standard shall not be considered.

7 Reference instrument and irradiation equipment

7.1 Reference meter The detector of a reference meter shall be an ionization-chamber type. The ionization chamber shall have the wall thickness or entrance window thickness and meet the performance indicated in table 1, depending on each energy range used.