



JAPANESE
INDUSTRIAL
STANDARD

Translated and Published by
Japanese Standards Association

JIS Z 4302 : 1997

γ -ray and hard X-ray film badges

ICS 17.240

Descriptors : gamma-radiation, X-rays, human body, radiographic film, radiology apparatus (medical), medical radiography, dosimeters, exposure-rate meters, radiography

Reference number : JIS Z 4302 : 1997 (E)

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This translation has been made based on the original Japanese Industrial Standard revised by the Minister of International Trade and Industry through deliberations at Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law:

Date of Establishment: 1957-10-30

Date of Revision: 1997-07-20

Date of Public Notice in Official Gazette: 1997-07-22

**Investigated by: Japanese Industrial Standards Committee
Divisional Council on Medical and Safety**

JIS Z 4302: 1997, First English edition published in 1998-02

**Translated and published by: Japanese Standards Association
4-1-24, Akasaka, Minato-ku, Tokyo, 107-8440 JAPAN**

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Printed in Japan

γ -ray and hard X-ray film badges

Introduction This Standard is a Japanese Industrial Standard which is established without any change of the technical contents of **ISO 1757** *Personal photographic dose-meters* published as the first edition in 1980.

1 Scope This Japanese Industrial Standard specifies, out of the personal dosemeters specified in **JIS Z 4332**, the film badges for measuring the 1 cm dose equivalent, 3 mm dose equivalent and 70 μ m dose equivalent which a person received from outside of his body by hard X-ray of 0.3 MeV to 3 MeV in effective energy and γ -ray of 0.3 MeV to 3 MeV in photon energy, and the methods for calculating those dose equivalents by using these film badges.

Remarks 1 The method for performance judgement in Annex 1 and the method for calculating dose equivalents in Annex 2 are specified respectively.

2 The normative references to this Standard are as follows:

JIS K 7559 *Universal badge films*

JIS K 7652 *Photography—Density measurements—Part 2 : Geometric conditions for transmission density*

JIS K 7653 *Photography—Density measurements—Part 3 : Spectral conditions*

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

JIS Z 4005 *Medical radiology—Terminology*

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

JIS Z 4332 *General requirements for personal X-ray and γ -ray dosemeters*

JIS Z 4511 *Methods of calibration for exposure meters and dose-equivalent meters*

JIS Z 8103 *Glossary of terms used in instrumentation*

JIS Z 8401 *Rules for rounding off of numerical values*

3 The International Standard corresponding to this Standard is as follows:

ISO 1757 *Personal photographic dosemeters*

2 Definitions For the main terms used in this Standard, the definitions in **JIS Z 4001**, **JIS Z 4005**, **JIS Z 4332**, **JIS Z 4511** and **JIS Z 8103** apply, and the rest of the terms are as follows :

Remarks : The dose equivalent or dose equivalent rate is described as “dose equivalent”

lent (rate)" in this Standard.

- (1) **measured value** A dose equivalent calculated from the film badge before rounding off.
- (2) **reference value** The testing dose specified in the testing method as reference.
- (3) **error (ε)** The ratio of the difference between the mean value of measured values ($\bar{X}$) and the reference value (H_0) to the reference value.

$$\varepsilon = \frac{|\bar{X} - H_0|}{H_0}$$

- (4) **coefficient of variation** The ratio of the standard deviation (S) of n measured values (X_i) to the mean value of measured values ($\bar{X}$).

$$C = \frac{S}{\bar{X}} = \frac{1}{\bar{X}} \sqrt{\frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X})^2}$$

- (5) **response (R)** The ratio of mean value of measured values ($\bar{X}$) to the reference value (H_0).

$$R = \frac{\bar{X}}{H_0}$$

- (6) **reference γ -ray** The specific γ -ray to obtain the dose characteristics.
- (7) **relative response (RR_γ)** The ratio of response of γ -ray having optional energy (R) to the response of reference γ -ray (R_γ).

$$RR_\gamma = \frac{R}{R_\gamma}$$

- (8) **badge film** That having packed high, medium and low sensitivity films painted with photographic emulsions having appropriate sensitivity to radiation and different sensitivity in one unit or that having the equivalent performance.
- (9) **control film** The film badge to be used to remove errors caused by foggings of natural radiation and photographic density of film characteristic.
- (10) **filter** A filtering plate having material quality, thickness and size to give photographic density suitable for badge film for calculating dose equivalent.
- (11) **reference filter** A filter specially selected to determine the dose characteristic of γ -ray out of the different filters attached to the badge case.
- (12) **filter position** A position on the badge film capable of observing the effect of filter.
- (13) **apparent dose** A dose corresponding to the photographic density at the filter position on the dose characteristic curve.
- (14) **net apparent dose** A dose obtained from apparent dose at filter position subtracted with apparent dose of control film.

- (15) **dose equivalent calculating formula** The calculating formula to calculate the dose equivalent from net apparent dose at each filter position of the badge film.
- (16) **proportionality test** The test to confirm that the response corresponding to 1 cm dose equivalent is constant.
- (17) **using period** In the case of continuously managing the personal dose, the period is decided with the performance of film badge and consideration on the management. This period is defined by the period from the day when the film badge is exchanged to the day before its exchange day. The radiation work in this period is regardless.
- (18) **dose characteristic** A relationship between photographic density at the filter position of reference filter (hereafter, called reference filter position) and the exposure of reference γ -ray.
- (19) **fading** The phenomenon that photographic density after development is less than the photographic density immediately after irradiation because of variation by time of latent image made in the film emulsion.

3 Performance

3.1 Error and coefficient of variation of measured values When the film is tested according to 6.2.2, its error and coefficient of variation of the measured values shall be as follows:

- (1) About the high sensitivity film, as for an error generated by irradiation of 0.4 mSv, the response corresponding to the error shall be in the range of 1 ± 0.3 at reliability of 95 % and the coefficient of variation shall be 0.07 or under, and as for an error generated by irradiation of 4.0 mSv, the response corresponding to the error shall be in the range of 1 ± 0.1 with reliability of 95 % and the coefficient of variation shall be 0.05 or under.
- (2) About the medium sensitivity film, as for an error generated by irradiation of 30 mSv, the response corresponding to the error shall be in the range of 1 ± 0.1 with reliability of 95 % and the coefficient of variation shall be 0.07 or under.
- (3) About the low sensitivity film, as for an error generated by irradiation of 200 mSv, the response corresponding to the error shall be in the range of 1 ± 0.1 with reliability of 95 % and the coefficient of variation shall be 0.07 or under.

3.2 Variation by time of measured values When the film is tested according to 6.2.3, the variation rate by time for 30 days of measured values shall be 0.15 or under with reliability of 95 % for that stored at 20 ± 5 °C, and 0.25 or under for that stored at 40^{+5}_0 °C.

3.3 Proportionality of measured values When the film is tested according to 6.2.4,

the proportionality of measured values shall be as follows:

- (1) For high sensitivity films, the response to every dose equivalent is in the range of 1 ± 0.15 with reliability of 95 % to the response of 4.0 mSv.
- (2) For medium sensitivity films, the response to every dose equivalent is in the range of 1 ± 0.15 with reliability of 95 % to the response of 30 mSv.
- (3) For low sensitivity films, the response to every dose equivalent is in the range of 1 ± 0.15 with reliability of 95 % to the response of 200 mSv.

3.4 Energy characteristic When the film is tested according to 6.2.5, the relative response at each energy for high, medium and low sensitivity films shall be in the range of 1 ± 0.3 with reliability of 95 %.

3.5 Directional characteristic When the film is tested according to 6.2.6, the response in every angle for high sensitivity film shall be in the range of 1 ± 0.2 with reliability of 95 % to the response in 0° direction.

3.6 Stability for humidity When the film is tested according to 6.2.7, the response of relative humidity of 90 % or over for high, medium and low sensitivity films shall be in the range of 1 ± 0.15 with reliability of 95 % to the response of relative humidity of 50 % or under.

3.7 Stability for light When the film is tested according to 6.2.8, the difference between photographic density of the film irradiated by light and that of the film not irradiated by light shall be 0.02 or under with reliability of 95 %.

4 Structure

4.1 Film badges The film badges shall consist of a badge case and badge films.

4.2 Badge case The badge case shall consist of a part containing badge film and filter.

Further, the badge case may be attached with jig for equipment such as clip and the like.

4.3 Filter The filter shall be possessed of an appropriate characteristic for calculating hard X-ray or γ -ray of 0.3 MeV to 3 MeV in effective energy or in photon energy.

5 Badge film The badge film shall be that complied with the specification of JIS K 7559 or that equivalent in performance thereto.

6 Tests

6.1 Test conditions

6.1.1 Common test conditions The common test conditions shall be in accordance with Table 1 unless specially specified in test methods of 6.2.

Table 1 Common test conditions

Item		Conditions
Ambient temperature	°C	20 ± 5
Relative humidity	%	60 ± 15
Atomospheric pressure	hPa	$1\,013 \pm 50$
1 cm dose equivalent rate of test emvironment	$\mu\text{Sv/h}$	0.2 or under

6.1.2 Calibrating apparatus The γ -ray calibrating apparatus to be used for testing shall be ^{137}Cs or ^{60}Co γ -ray irradiation apparatus of which exposure (rate) has been measured by the exposure (rate) measuring instrument having traceability to the exposure standard specified in JIS Z 4511, or ^{137}Cs or ^{60}Co reference γ -ray sources.

6.1.3 1 cm dose equivalent The 1 cm dose equivalent shall be determined by multiplying the exposure by conversion factor corresponding to energies of γ -ray and hard X-ray given in Attached Table 1.

6.2 Test methods

6.2.1 Test methods general The test methods general shall be as follows:

- (1) In case where the test is performed with a certain item out of test conditions changed, the other conditions shall be in the range given in Table 1.
- (2) The test dose shall be 1 cm dose equivalent and set in the range of 80 % to 120 % in the energy specified in every item, and the same quantity shall be set for each set.
- (3) The tests of 6.2.2, 6.2.5 and 6.2.6 shall be performed under the condition where the phantom specified in JIS Z 4331 is arranged in rear of film badge.
- (4) In the case where the film badge is arranged in the front of phantom, it shall be set in the range shown in Fig. 1.

Further, the distance between surface of phantom and the calibrating point of film badge can be optionally selected in the range of 1 cm to 3 cm and the setting error is ± 2 mm, and it is kept constantly through every test.

Unit : cm

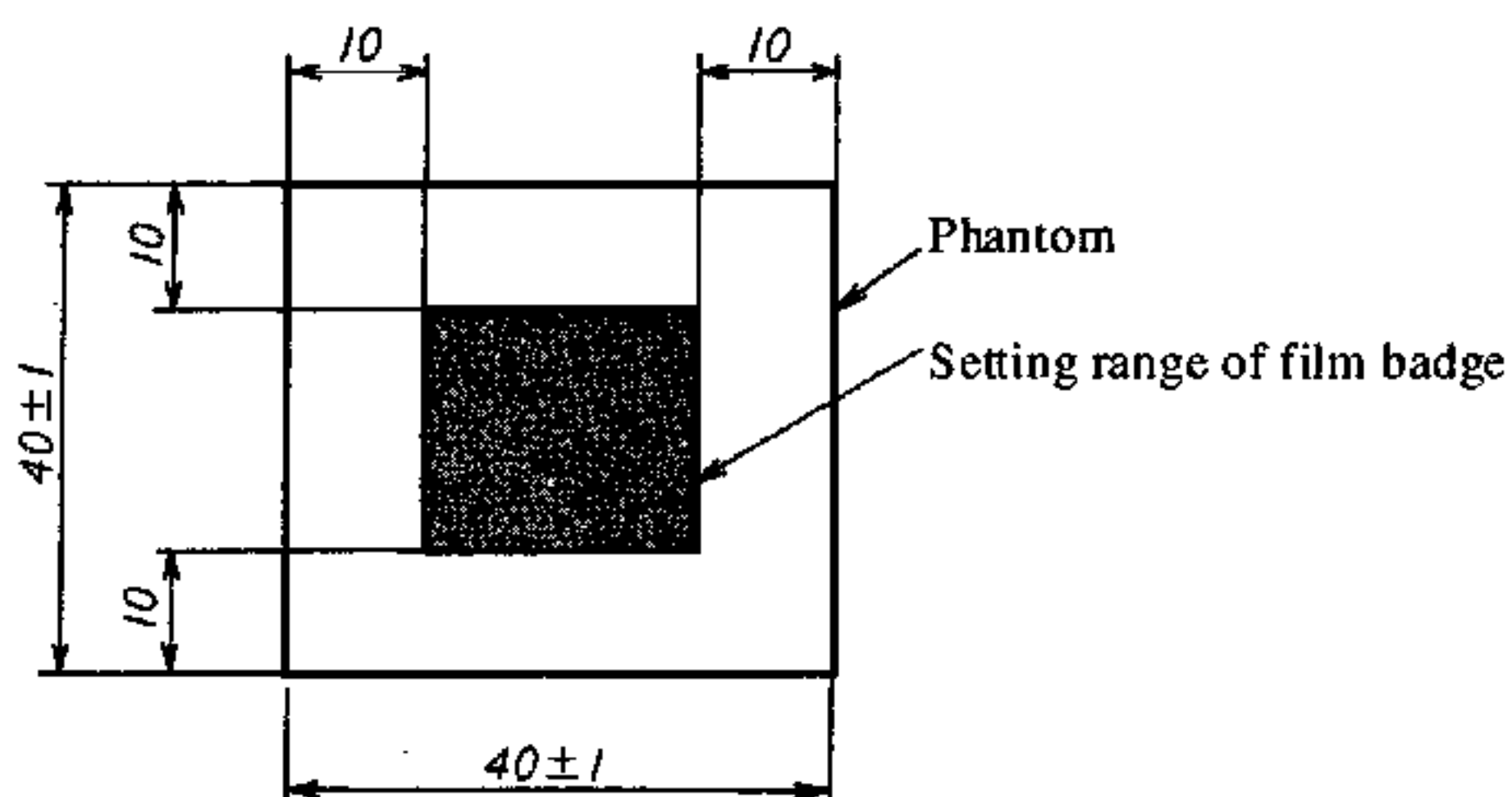


Fig.1 Setting range of film badge on phantom

- (5) The test specified in 6.2.2 is performed, whenever the lot of badge film is varied.
- (6) In each test method, the mean value, standard deviation and the standard deviation relating to the mean value of measured values shall be obtained with the following formulae, excepting 6.2.8.

(a) The mean value of measured values shall be obtained with the following formula:

$$\bar{X} = \frac{\sum_{i=1}^n X_i}{n}$$

where, $\bar{X}$: mean value of measured values (mSv)

X_i : i -th measured value (mSv)

n : number of measured values

(b) The standard deviation of measured values shall be obtained with the following formula:

$$S = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X})^2}$$

where, S : standard deviation of measured values (mSv)

X_i : i -th measured value (mSv)

$\bar{X}$: mean value of measured values (mSv)

n : number of measured values

(c) The standard deviation relating to mean value of measured values shall be obtained with the following formula:

$$S_m = \frac{S}{\sqrt{n}}$$

where, S_m : standard deviation relating to mean value of measured values (mSv)

S : standard deviation of measured values (mSv)

n : number of measured values

- (7) The calculating formula of dose equivalent is in accordance with 5.3 of Annex 2 and the same formula shall be applied through all tests necessary for obtaining the measured values for each type of film badge.
- (8) The judgement method of performance shall be in accordance with Annex 1.
- (9) The calculating method of measured values shall be in accordance with Annex 2.

6.2.2 Error test for measured values and variation test Prepare 50 film badges consisting of badge film of the same lot. Take 10 pieces as one group, prepare 5 groups, and make H_1 group, H_2 group, M group, L group and C group. Irradiate γ -ray of ^{137}Cs or ^{60}Co to each group as given in Table 2. However, take C group as control films and do not irradiate γ -ray.

Store the exposed badge films together with control films for 3 days and then develop them. Calculate the measured values from the high sensitivity film for H_1 and H_2 groups, from medium sensitivity film for M group and from low sensitivity film for L group and obtain the response corresponding to error according to the following formula:

$$R_e = \varepsilon + 1$$

where, R_e : response corresponding to error

ε : error

Table 2 Dose equivalent for error test

Unit : mSv

Group	H_1	H_2	M	L
1 cm dose equivalent	0.4	4.0	30	200

6.2.3 Test of characteristic variation by time of measured values Prepare 60 film badges consisting of badge film of the same lot. Take 5 pieces as one set, make 12 sets and take 4 sets in each to make H group, M group and L group. Take 2 sets from each group to make as the 1st set and the 2nd set. Take up each 1 set from 1st set and 2nd set and irradiate γ -ray of ^{137}Cs or ^{60}Co given in Table 3. However, take the badge films of residual each set as control films and do not irradiate γ -ray.

Store the exposed badge films together with control films at ambient temperature of $20 \pm 5^\circ\text{C}$ in accordance with Table 3.

Furthermore, prepare 60 film badges consisting of badge films of the same lot mentioned above and after treating them with the same manner mentioned above, store these film badges at ambient temperature of $40^{+5}_0^\circ\text{C}$ in accordance with Table 3.

After development, calculate measured values from high sensitivity film for H group, from medium sensitivity film for M group and from low sensitivity film for L

group.

For respective film badges stored at ambient temperature of $20 \pm 5^\circ \text{C}$ and $40^{+5}_0^\circ \text{C}$, obtain the change rate by time (R_f) with the following formula:

$$R_f = \frac{|\bar{X} - \bar{X}_0|}{\bar{X}_0}$$

where, R_f : change rate by time

$\bar{X}_0$: mean value of measured values of the sets corresponding to storing days of 3 days

$\bar{X}$: mean value of measured values of the sets corresponding to storing days of 33 days

Table 3 Irradiation dose and storing days for test of characteristic variation by time

Group	H		M		L	
	1st	2nd	1st	2nd	1st	2nd
1 cm dose equivalent mSv	4.0	4.0	30	30	200	200
Number of storing days d	3	33	3	33	3	33

6.2.4 Proportionality test of measured values Prepare 100 film badges consisting of badge film of the same lot. Take 5 pieces as one set, prepare 20 sets and take 6 sets as H group, and 7 sets as M group and L group. Irradiate γ -ray of ^{137}Cs or ^{60}Co to each set of each group in accordance with Table 4. However, take each 1 set of each group as control films and do not irradiate γ -ray.

Store the exposed badge films together with control films for 3 days and then develop them. After the measured values were calculated from the high sensitivity film for H group, from medium sensitivity film for M group and from low sensitivity film for L group, obtain the ratio of the response of 4.0 mSv for high sensitivity film, 30 mSv for medium sensitivity film and 200 mSv for low sensitivity film to the response of each dose equivalent.