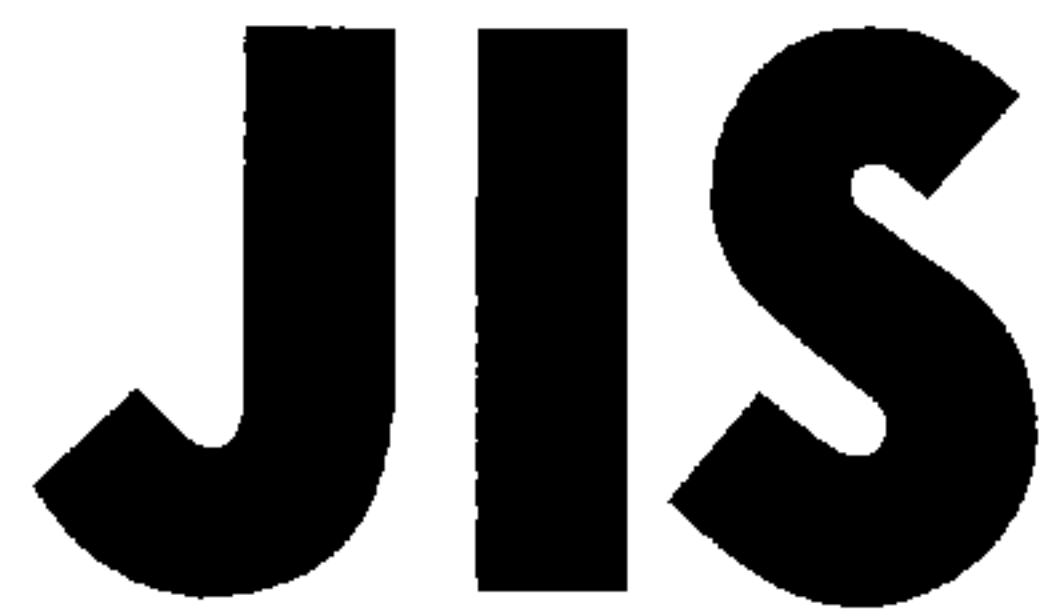




JAPANESE
INDUSTRIAL
STANDARD

Translated and Published by
Japanese Standards Association

JIS Z 4301 : 1997

X-ray film badges

ICS 17.240

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

Reference number : JIS Z 4301 : 1997 (E)

Z 4301 : 1997

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: 1956-10-02

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 4301: 1997, First English edition published in 1998-04

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

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Printed in Japan

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 doseimeters*** published as the first edition in 1980.

1 Scope This Japanese Industrial Standard specifies the X-ray film badges for measuring the 1 cm dose equivalent, 3 mm dose equivalent and 70 μm dose equivalent which a person received from outside of his body by X-ray of 20 keV to 80 keV in effective energy or γ -ray of 20 keV to 80 keV in photo-energy, and the methods for calculating these dose equivalents by using these film badges.

Remarks 1 The method for judging performance in Annex 1, the method for calculating dose equivalent in Annex 2 and the method for practically setting of the effective energy in Annex 3 are specified respectively.

2 The normative references to this Standard are as follows:

JIS K 7557 *Badge films for X-rays*

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 doseimeters*

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

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 doseimeters*

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: Dose equivalent or dose equivalent rate is described as "dose equivalent (rate)" in this Standard.

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

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

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

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

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

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

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

$$RR_x = \frac{R}{R_x}$$

- (8) **badge film** That having packed high, medium and low sensitivity films painted with photographic emulsions having an 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 X-ray out of the different filters set in 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. However, in the case of the film badge not necessary control film, take the dose subtracted with apparent dose of a part corresponding to the 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 decided with the performance of film badge and consideration on the management. This period defined by the period from the day when the film badge is exchanged to the day before the next exchange day, it is not taken into account whether radioactive work is done or not during this period.
- (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 X-ray.
- (19) **relative sensitivity (RS_x)** A value obtained by dividing the ratio of net apparent dose in the case of irradiating X-ray to the exposure (N) by the ratio of net apparent dose in the case of irradiating reference X-ray to the exposure (N_x).

$$RS_x = \frac{N}{N_x}$$

- (20) **film energy characteristic** A relation between energy of X-ray and relative sensitivity.
- (21) **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.
- (22) **energy adjustment filter** In the continuous X-ray, the filter used to adjust the energy.
- (23) **half value layer filter** The filter having the thickness of half value layer.
- (24) **attenuation filter** The filter used to make the attenuation curve.

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) For the high sensitivity film, and to error generated by irradiation of 0.3 mSv, the response corresponding to the error shall be in the range of 1 ± 0.4 with reliability of 95 % and the coefficient of variation shall be 0.1 or under, and to error generated by irradiation of 1.7 mSv, the response corresponding to error shall be in the range of 1 ± 0.2 with reliability of 95 % and the coefficient of variation shall be 0.07 or under.
- (2) For the low sensitivity film, and to error generated by irradiation of 12 mSv, the response corresponding to the error shall be in the range of 1 ± 0.2 with reliability of 95 % and the coefficient of variation shall be 0.07 or under.

3.2 Variation characteristic 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 1.7 mSv.
- (2) 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 12 mSv.

3.4 Energy characteristic When the film is tested according to 6.2.5, the relative response at each energy of X-ray for high 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 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 badge The film badge 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 characteristics for calculating X-ray of 20 keV to 80 keV in effective energy and γ -ray of 20 keV to 80 keV in photon energy.

5 Badge film The badge film shall be that complied with the specification of JIS K 7557 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
Atmospheric pressure	hPa	1 013±50
1 cm dose equivalent rate of test environment	μSv/h	≤0.2

6.1.2 Calibration apparatus The X-ray calibration apparatus shall be the X-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**.

X-ray energy shall be effective energy and the practical setting method shall be in accordance with the technique in Annex 3.

6.1.3 1 cm dose equivalent The 1 cm dose equivalent shall be determined by multiplying the exposure with conversion factor corresponding to energies of 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 are in the range given in Table 1.
- (2) The test dose shall be 1 cm dose equivalent and shall be set in the range of 80 % to 120 % of the dose equivalent specified in each item, and the same quantity shall be set for each set.
- (3) The X-ray energy shall be set in the range of 90 % to 110 % of energy specified by each item and the same energy shall be set for each set.
- (4) 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** shall be arranged in rear of the film badge.
- (5) In the case where the film badge is arranged in the front of phantom, it is to be set in the range shown in Fig. 1.

Further, the distance between surface of phantom and the calibration point of film badge is optionally selected in the range of 1 cm to 3 cm and the setting error shall be ±2 mm, and the same condition shall be kept through each test.

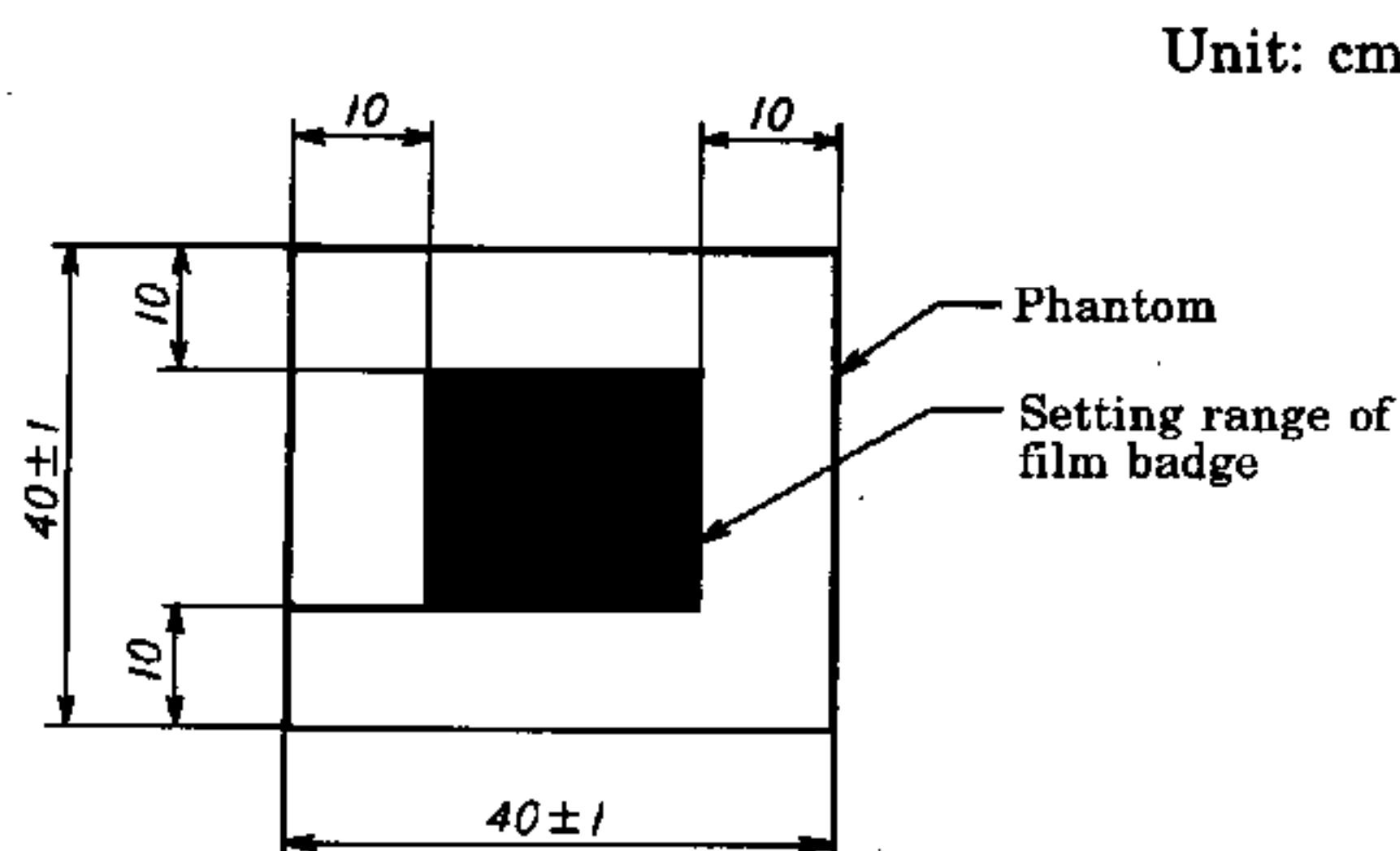


Fig. 1 Setting range of film badge on phantom

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

- (8) The calculating formula of dose equivalent relating to X-ray shall be in accordance with 2 (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.
- (9) The judgement method of performance shall be in accordance with Annex 1.
- (10) The calculating method of measured values shall be in accordance with Annex 2.

6.2.2 Test of error in measured values and coefficient of variation Prepare 40 film badges consisting of badge film of the same lot. Take 10 pieces as one group, make 4 groups, and take as H₁ group, H₂ group, L group and C group. Irradiate X-ray of 45 keV to each group as given in Table 2. However, take C group as control films and do not irradiate X-ray.

Store the exposed badge films together with the control films for 3 days and then develop them. Calculate the measured values from the high sensitivity film for H₁ and H₂ groups 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 according to error
 ε : error

Table 2 Dose equivalent for error test

Unit: mSv

Group	H ₁	H ₂	L
1 cm dose equivalent	0.3	1.7	12

6.2.3 Test of characteristic variation by time of measured values Prepare 40 film badges consisting of badge film of the same lot. Take 5 pieces as one set, make 8 sets and take 4 sets in each to make H 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 X-ray of 45 keV in accordance with Table 3. However, take the badge films of residual each set as control films and do not irradiate X-ray.

Store the exposed badge films together with control films at ambient temperature of 20±5°C in accordance with Table 3. Furthermore, prepare 40 film badges consisting of badge films of the same lot mentioned above and after treating them with the same manner mentioned above, store these exposed film badges at ambient temperature of 40⁺⁵₀ °C in accordance with Table 3.

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

For respective film badges stored at ambient temperature of 20±5 °C and 40⁺⁵₀ °C, obtain the variation rate by time (R_f) with the following formula:

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

where, R_f : variation rate by time
 $\bar{X}_0$: mean value of measured values corresponding to storing day of 3 days

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

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

Group		H		L	
		1st	2nd	1st	2nd
1 cm dose equivalent	mSv	1.7	1.7	12	12
Number of storing days	d	3	33	3	33

6.2.4 Test of proportionality of measured values Prepare 65 film badges consisting of badge films of the same lot. Take 5 pieces as 1 set, make 13 sets and take 6 sets as H group and 7 sets as L group. Irradiate X-ray of 45 keV 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 X-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 and from low sensitivity film for L group, obtain the ratio of the response of 1.7 mSv for high sensitivity film, 12 mSv for low sensitivity film to the response of each dose equivalent.

Table 4 Dose equivalent of proportionality test

Unit: mSv

Group	H	L
1 cm dose equivalent	0.3	4.0
	1.0	8.0
	1.7	12
	2.5	16
	3.4	20
		24

Remarks: The same value of 1 cm dose equivalent shall be applied for each set.

6.2.5 Energy characteristic test Prepare 60 film badges consisting of badge films of the same lot. Take 5 pieces as one set, prepare 12 sets and take 6 sets in each as H group and L group. Irradiate X-ray to each set of each group in accordance with Table 5. However, take one set of each group as control films and do not irradiate X-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 and from low sensitivity film for L group, obtain the relative response for each energy.

Table 5 Dose equivalent for energy characteristic test

Energy of X-ray keV	1 cm dose equivalent mSv	
	H group	L group
20	3.4	24
30	2.1	15
45	1.7	12
60	1.9	13
80	2.8	20

Remarks: The same value of energy of X-ray and 1 cm dose equivalent shall be applied for each set.

6.2.6 Directional characteristic test Prepare 50 film badges consisting of badge film of the same lot. Take 5 pieces as 1 group and make 10 groups. Take 1 group out of them as control films and do not irradiate X-ray. Take the normal direction to the front of film badge as 0° in incident angle of X-ray, and irradiate X-ray of 45 keV given in Table 6 from total 9 directions of 0°, 30° top, bottom and left, right and 60° top, bottom, and left, right. For film badges, use each one group in each direction and irradiate to each group successively.

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, obtain the ratio of response in the case of irradiating from each direction to the response of 0° direction.

Table 6 Dose equivalent for directional test

X-ray energy keV	1 cm dose equivalent mSv
45	2.0

Remarks: The same value of dose equivalent shall be applied for each set.

6.2.7 Stability test for humidity Prepare 40 film badges consisting of badge film of the same lot. Take 5 pieces as one set, prepare 8 sets and take 4 sets in each as H group and L group. Take 2 sets in each from each group and irradiate X-ray of 45 keV in accordance with Table 7. However, take 2 sets from each group as control films and do not irradiate X-ray.

Store the exposed badge films together with control films for 3 days at the environmental conditions as given in Table 8 and then develop them. After the measured values were calculated from the high sensitivity film for H group and from low sensitivity film for L group, obtain the ratio of response of 90 % in relative humidity or over to the response of 50 % or under.