TC 85

INTERNATIONAL STANDARD ISO 4071

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Exposure meters and dosimeters — General methods for testing

Exposimètres et dosimètres — Méthodes générales d'essai

First edition — 1978-11-15

UDC 539.1.074 : 620.1 **Ref. No. ISO 4071-1978 (E)**

Descriptors : safety devices, radiation protection, radiation measuring instruments, dosimeters, tests, radiation tests, environmental tests, high-temperature tests, low-temperature tests, mechanical tests, vibration tests, drop tests.

Price based on 29 pages

FOREWORD

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 4071 was developed by technical committee ISO/TC 85, *Nuclear energy*, and was circulated to the member bodies in March 1977.

It has been approved by the member bodies of the following countries :

Australia	France	Spain
Austria	Japan	Sweden
Belgium	Mexico	Switzerland
Brazil	Netherlands	Turkey
Canada	New Zealand	U.S.A.
Czechoslovakia	Poland	U.S.S.R.
Finland	Romania	Yugoslavia

The member bodies of the following countries expressed disapproval of the document on technical grounds :

South Africa, Rep. of
United Kingdom

Printed in Switzerland

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Exposure meters and dosimeters – General methods for testing

0 INTRODUCTION

This International Standard constitutes a guide to defining and carrying out general methods for testing exposure meters and dosimeters[1] used in radiation protection for X-rays and gamma rays with energies below or equal to 3 MeV. It will subsequently be complemented by a second document dealing with rate meters and, in the more distant future, by a third document relating to dosimeters used in the presence of neutrons or gamma rays with energies above 3 MeV. However, study of this latter point necessitates the parallel establishment of definitions of suitable reference radiations.

This International Standard describes a large number of tests from which, in drawing up specifications for a given type of dosimeter or exposure meter, the tests applicable to that type can be selected. The details of the test methods selected, the choice of parameters and the conditions of measurement will be laid down in the particular standards or specifications applying to the dosimeters considered.

To simplify the carrying out of the tests, the methods have been drafted in such a way that each can be read on its own, independently of others.

This International Stnadard merely defines the general test methods and does not deal with the way in which the test results should be interpreted in order to evaluate the qualities of the dosimeter. Such interpretation may be studied in the particular standards applying to the dosimeters considered.

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies general methods of testing dosimeters used in radiation protection for X-rays or gamma radiation of energies below or equal to 3 MeV. It therefore allows a check to be made of whether dosimeters comply with the requirements stated in particular standards or specifications, and allows comparison of various types of dosimeters.

The tests are designed to be carried out on the dosimeter equipped with the operating accessories specified by the manufacturer.

2 REFERENCES

ISO 1757, *Personal photographic dosimeters.*[2]

ISO 4037, *X and γ reference radiations for calibrating dosimeters and dose ratemeters and for determining their response as a function of photon energy.*

ISO 3768, *Metallic coatings – Neutral salt spray test (NSS test).*

IEC Publication 359, *Expression of the functional performance of electronic measuring equipment.*

1) Throughout this text, the generic term "dosimeter" is used to mean both exposure meters and dosimeters.

2) At present at the stage of draft. (Revision of ISO/R 1757-1971.)

3 CLASSIFICATION OF DOSIMETERS

The method adopted for classifying dosimeters, shown in table 1, is based on the effect which reading them has on the information stored, and is intended to enable general test methods to be described.

4 GENERAL REFERENCE CONDITIONS FOR DOSIMETERS TESTS

4.1 Ambient conditions

Except in special cases, most of the tests can be carried out in the following atmospheric conditions[1] :

- temperature between 15 and 35 °C;[2]
- relative humidity between 45 and 75 %;[2]
- atmospheric pressure between 70 and 106 kPa.[2]

The actual atmospheric conditions should be indicated in the test report. They should not undergo large or rapid changes during a series of measurements.

For acceptance tests, it is recommended that the following standard conditions be used :

- temperature : 20 ± 2 °C;
- relative humidity : (65 ± 5) %;
- atmospheric pressure : 90 ± 10 kPa.

When the dosimeters being tested are sensitive to the effects of magnetic or electromagnetic fields, the continuous background of these fields, in the place where the tests are carried out, should not exceed $1/m$ of the threshold sensitivity of the instruments.[3]

4.2 Irradiation conditions

Use, from a qualitative point of view, the reference radiations defined in ISO 4037.

For tests calling for an absolute measurement, these reference radiations must be known quantitatively and in relation to the class of apparatus.

The exposure or exposure rate used for the carrying out of the test must be frequently checked with a reference instrument which has itself been compared with the national standard apparatus.

For tests calling for a comparison of measured values, these must be reproducible within ± 2 %.

Except in the case of special tests, the irradiation should be made perpendicularly to the principal axis or to the sensitive surface of the dosimeter.

The distance "source-dosimeter" is defined as the distance from the centre of the equivalent point source to the geometric centre of the sensitive part of the detecting element of the dosimeter.

The exposure rate due to the natural radiation background, that coming from the container and any possible contamination must not exceed a certain threshold[4] depending on the sensitivity of the apparatus. Whenever, for practical reasons, this threshold is exceeded, that fact must be taken into account.

TABLE 1 — Classification of dosimeters

Class	Effect of reading	Examples of actual dosimeters included in the class
Class A	Reading destroys neither the information nor the dosimeter; resetting to zero is possible	Direct reading dosimeters with electroscope Some capacitor dosimeters with indirect reading Some dosimeters with an electrometer
Class B	Reading destroys neither the information nor the dosimeter; resetting to zero is impossible (except after complicated laboratory processes)	Photoluminescent, semi-conductor and coloured glass dosimeters Exceptionally, some dosimeters with an electrometer Most chemical dosimeters
Class C	Reading destroys the information but not the dosimeter	Most thermoluminescent dosimeters
Class D	Reading does not destroy the information, but renders the dosimeter unusable for further measurements	Photographic emulsion dosimeters Exceptionally, some chemical dosimeters

1) These conditions do not apply to climatic tests (series II).

2) These figures have been selected as best suited to dosimeter tests. They may be adjusted according to particular climatic conditions.

3) The value of m will be fixed according to the particular specifications for each type of apparatus.

4) This threshold will be determined by the particular specifications for each type of dosimeter.

If a radioactive source is used, the duration of irradiation must be much longer (at least 100 times longer) than the times for approaching and withdrawing the source. If this condition cannot be met, the exposure resulting from the times during which the source is being approached and withdrawn must be precisely determined in each case; depending on the test carried out the order of magnitude of the duration of irradiation must be chosen so as to avoid introducing additional errors due, for example, to the effects of :

– the exposure rate;

– leakage.

To facilitate irradiation in the best possible conditions, reproducible within ± 2 %, the dosimetry room should meet the following specifications :

– the irradiation table and supports for the dosimeters should be made of a material of low atomic number (so far as is compatible with the necessary rigidity);

– the dosimeter should be placed so that only the gamma radiation reaches it and so that the scattered radiation has an energy spectrum as constant as possible and does not exceed 5 % of the exposure received directly;

– the distance between dosimeters should be such that no dosimeter affects its neighbours;

– the position of the source (in the irradiation position) and that of the dosimeter should be reproducible within ± 1 mm from one test to another;

– in order to subject several dosimeters of the same batch to the same exposure, their supports should be placed on the dose rate contours (circles). If sufficient homogeneity cannot be achieved, the irradiation table may be made to rotate around the source.

4.3 Reading conditions

In testing dosimeters based on a given principle, whenever possible the same standard reading device of known accuracy should be used.

Before each series of readings, switch on the reference reading device and wait long enough for it to be stabilized.

Before each series of readings, check the zero error of the reference reading device and, if the instrument allows, its correct functioning at some other point.

In addition to photographic dosimeters, any dosimeter which is sensitive shall only be taken out of its case at the time of reading or processing and under conditions prescribed in documents specific to the dosimeters considered.

If the dosimeters have batteries or accumulators, these should be protected during the functioning tests in series II (tests 2.1, 2.2, 2.3 and 2.4) described below. They should be removed for the storage tests of series II (tests 2.5 and 2.6) and series III (test 3.5) described below.

Except for certain special tests, readings should be made after allowing time for the dosimeter response to stabilize.

If a recording system can be connected to the reading device, it is desirable that this adaptation does not affect the reading and that direct readings be supplemented by a recording.

5 TESTS

The tests have been classified in four series :

– **Series I : Tests** with X or gamma radiations for energies below or equal to 3 MeV.

– **Series II :** Climatic tests.

– **Series III :** Mechanical tests.

– **Series IV :** Utilization tests.

5.1 Series I – Tests with X or gamma radiations for energies below or equal to 3 MeV

5.1.1 *Test 1.1 – Zero point stability*

5.1.1.1 PRINCIPLE

To determine the initial indication of the dosimeter before any irradiation takes place and how this indication changes with time.

5.1.1.2 PROCEDURE

Class A :

Before any other test, set n[1)] dosimeters to zero.

Store them under the specified climatic conditions and then read them without resetting them to zero.

The times of storage and or of holding before reading will be laid down by the particular specifications.

Class B :

Store n[1)] dosimeters under the specified climatic conditions, then read them.

The times of storage and of holding before reading will be laid down by the particular specifications.

1) In this test, as in the following ones, the value of n will be laid down in the particular specifications for each type of dosimeter.

Class C :

Set to zero as many times n[1] dosimeters as there are waiting times before reading laid down in the particular specifications. At the end of each of these times, withdraw n dosimeters and read them.

Class D :

Upon receiving them, process and read n[1] dosimeters. After the time laid down in the particular specifications, process and read a further n dosimeters in the same conditions; repeat this test after each of the times laid down in the particular specifications.

5.1.1.3 Results

All classes :

a) For each time, calculate :

– the mean $\overline{I_0}$ of the initial indications of the dosimeters;

– their standard deviation s.

b) Plot the curve showing the change with time of the initial indication of the dosimeter.

5.1.2 *Test 1.2 – Stability of information*

5.1.2.1 Principle

To determine how the information given by the dosimeter varies according to the time which elapses between irradiation and reading, all other conditions remaining unchanged. In particular, the climatic conditions must remain within the reference conditions and the temperature should not vary by more than ± 5 °C from the initial temperature of the test, while remaining within the reference limits.

5.1.2.2 Procedure

The test should be carried out with the shortest possible irradiation time. The time shall be such that the dosimeter reading will not be affected by the dose rate or the accuracy of the chronometer used.

Class A :

Irradiate n dosimeters with an exposure between 50 and 85 % of the calibration or of the scale range normally used and read them as soon as possible after the irradiation (within 15 min) and after each of the times laid down in the particular specifications.

Class B :

As for class A.

Class C :

Irradiate as many times n dosimeters as there are holding times before reading laid down in the particular specifications, with an exposure between 50 and 85 % of the calibration or of the scale range normally used. Withdraw and read n dosimeters as soon as possible after irradiation (within 15 min) and after each of the times laid down.

Class D :

Proceed as appropriate in one of the two following ways :

– Irradiate with the same exposure and in the same conditions as many times n dosimeters as there are holding times before reading laid down in the particular specifications, process them after each of these times and read them.

– Irradiate at staggered intervals (so that the holding times before processing will be those laid down by the particular specifications) with the same exposure and under the conditions laid down by the particular specifications, as many times n dosimeters as there are specified holding times before reading, plus n control dosimeters. Process all these dosimeters simultaneously as soon as possible after the irradiation of the control dosimeters, and read them.

5.1.2.3 Results

All classes :

a) For each time, calculate :

– the mean $\overline{I}$ of the readings;

– their standard deviation s;

– the ratio r of this mean to the exposure read immediately after irradiation.

b) Plot the curve of r as a function of time.

5.1.3 *Test 1.3 – Repeatability*[2]

5.1.3.1 Principle

To determine the repeatability of the measurements made with the same dosimeter subjected to the same exposure in identical conditions.

5.1.3.2 Procedure

Class A :

Set n dosimeters to zero.

1) In this test, as in the following ones, the value of n will be laid down in the particular specifications for each type of dosimeter.

2) **repeatability** : The closeness of agreement between successive results obtained with the same method on identical test material, under the same conditions (same operator, same apparatus, same laboratory and short intervals of time). [ISO 3534.] Repeatability depends upon the dosimeter and the reading device.

Irradiate them with an exposure between 50 and 85 % of the calibration or of the scale range normally used, then read and reset them to zero.

Repeat the test ten times in succession.

If the reading device has several ranges, proceed as described above for each of them.

Class B :

The test cannot be applied to dosimeters of this category, since they cannot be reset to zero.

Class C :

Set n dosimeters to zero.

Irradiate them with an exposure between 50 and 85 % of the calibration or of the scale range normally used, then read them.

Repeat the test ten times.

If the reading device has several ranges, proceed as described above for each of them.

Class D :

This test cannot be applied to dosimeters of this class, since reading renders them unusable.

5.1.3.3 RESULTS

Classes A and C :

For each operation, calculate :

— the mean $\overline{l}$ of the ten readings;

— their standard deviation s.

5.1.4 *Test 1.4 – Batch homogeneity*

5.1.4.1 PRINCIPLE

To investigate the dispersion of the response of the dosimeters submitted to the same exposure under the same conditions (including same laboratory and same operator) and in particular to determine whether this dispersion can be expressed as a normal law (after having taken account of the possible corrections due to the repeatability).

5.1.4.2 PROCEDURE

All classes :

a) *Sampling*

Assuming the distribution to be normal, withdraw at random n_0 dosimeters ($5 < n_0 \leqslant 10$) from the batch to be examined, irradiate them with the same exposure and read them.

Calculate the mean $\overline{l_i}$ of the readings l_i of the dosimeters and the standard deviation s_0 of these readings (s_0 being a first estimate of the standard deviation for the whole batch).

$$\overline{l_i} = \frac{1}{n_0} \sum_{1}^{n_0} l_i$$

$$s_0 = \sqrt{\frac{\sum_{1}^{n_0} (l_i - \overline{l_i})^2}{n_0 - 1}}$$

Choose :

— the percentage error b that can be tolerated on the reading of the exposure l, to determine the margin of error :

$$d \approx \frac{b}{100} \overline{l_i}$$

— the risk α that the estimate is made with an error equal to or greater than d.

Deduce an approximate value n of the number of specimens necessary in order to make an estimate with risk α by means of the formula :

$$n = \left(t_{\alpha, n_0} \frac{s_0}{d}\right)^2$$

t_{α, n_0}, the variable in Student's law, being given by table 2.

TABLE 2 – **Values of t_{α, n_0}**

n_0 \ α	0,1	0,05	0,02	0,01
6	2,015	2,571	3,365	4,032
7	1,943	2,447	3,143	3,707
8	1,895	2,365	2,998	3,499
9	1,860	2,306	2,896	3,355
10	1,833	2,262	2,821	3,250

b) *Selection and test*

Select at random n specimens from the whole batch, and irradiate them with an exposure between 50 and 85 % of the calibration or of the scale range normally used.

Read the dosimeters at equal times after irradiation, since the indication given by the dosimeter varies with time.

5.1.4.3 RESULTS

Plot the frequency diagram for the exposures read (the number of class intervals not being less than 5 in any case).

Calculate the mean value $\bar{l}'$, of the readings of the dosimeters of the sample, and the corresponding standard deviation s'. (Or trace the Henry line and deduce from it another estimate of the mean $\bar{l}''$ and of the standard deviation s''.)

Verify that the hypothesis (of a normal distribution) is correct by a χ^2 test with a risk α.[1)]

5.1.5 *Test 1.5 — Lower limit of reading*

5.1.5.1 PRINCIPLE

To determine :

a) the detection threshold, i.e. the minimum exposure for which the reading obtained is significantly different from the standing indication. The readings corresponding to this value are such that :

$$\bar{l} - \bar{l_0} \geqslant \sqrt{2} \times 1{,}96\, s_{l_0}$$

where

$\bar{l}$ is the mean of the readings for the exposure in question;

$\bar{l_0}$ is the mean of the initial readings either of the batch of dosimeters subjected to test 1.1, "Zero point stability", or of the dosimeters being tested;

s_{l_0} is the standard deviation of the initial readings.

When the initial readings are mostly zero, it is better to simplify the formula to :

$$\bar{l} - l_{0\,\max} \geqslant 1{,}96 s$$

where

$\bar{l}$ is the mean of the readings for the exposure in question;

s is the standard deviation of these readings;

$l_{0\,\max}$ is the maximum value of the initial readings.

b) the lower limit of reading at x %[2)] : i.e. the minimum exposure for which the mean value of the readings having a dispersion ($\bar{l} \pm 2s$) is such that :

$$\left(\frac{100-x}{100}\right) L \leqslant \bar{l} - 2s < \bar{l} + 2s \leqslant \left(\frac{100+x}{100}\right) L$$

where

$\bar{l}$ and s are as defined above :

L is the value read for the test exposure on the linear part of the calibration curve obtained from the graph of the variations of $\bar{l}$ as a function of the exposure during the course of the test. (See figure 1.)

5.1.5.2 PROCEDURE

Class A :

Set n dosimeters to zero.

Irradiate them with an exposure X.

Read them.

Repeat these operations for exposures corresponding to, say :

$2X$, $3X$, $4X$, $5X$, $6X$, $7X$, $8X$, $9X$, $10X$, $15X$, $20X$, $30X$, $40X$, $50X$, $100X$,

X being defined by the absolute value of the error in reading or a multiple of this value, according to the precision expected from the combination of the dosimeter and reading device.

Class B :

Take the initial reading of p batches of n dosimeters.

Irradiate one batch with each of the exposures defined for class A.

Read them.

Class C :

Proceed as for class A.

Class D :

Proceed as for class B.

5.1.5.3 RESULTS

a) For each exposure, calculate :

– the mean $\bar{l}$ of the readings;

– their standard deviation s.

b) Plot the graph of $\bar{l}$ as a function of the exposure.

c) Determine the threshold of detection by means of the inequalities defined in 5.1.5.1.

d) Determine graphically the value of the lower limit of reading at x %.

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1) The same method can be used for the statistical investigation of the variables obtained from other tests.

References for test 1.4 :

– NBS Handbook 91 : *Experimental statistics*, Library of Congress Catalog : 63 60 072.

– *Le contrôle statistique des fabrications*, R. CAVE, Eyrolles.

2) x will be laid down in the particular specifications.

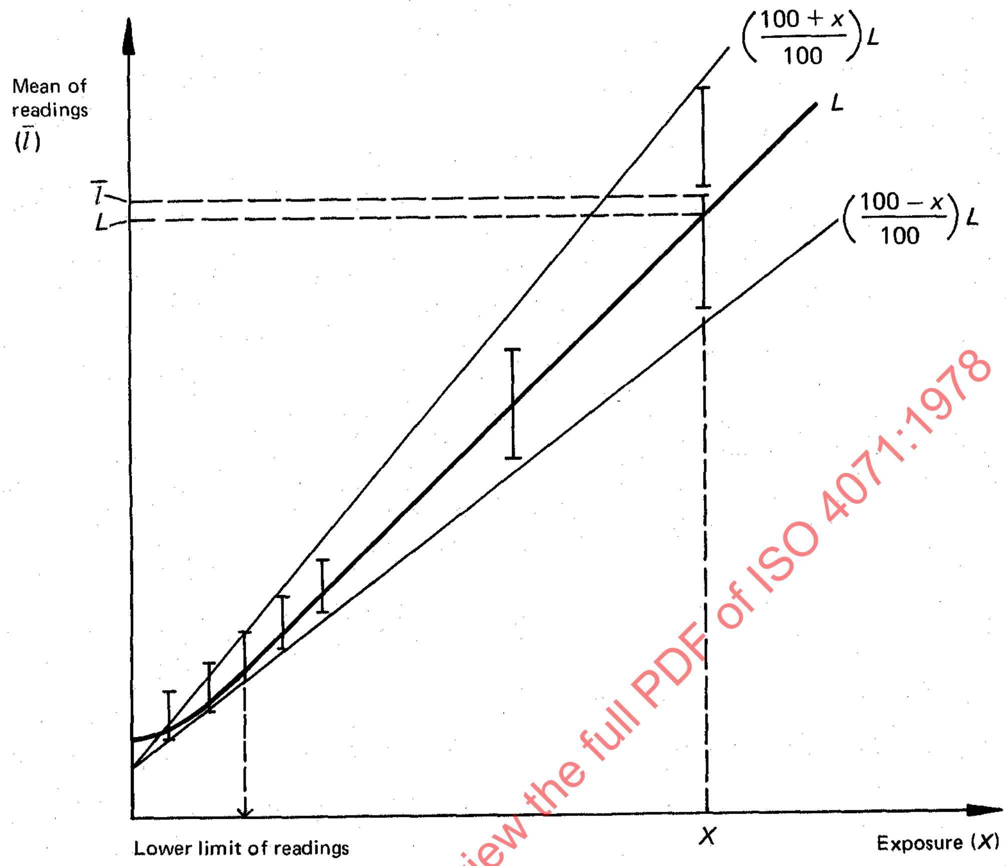


FIGURE 1

5.1.6 *Test 1.6 – Exactness*[1] *and linearity*

5.1.6.1 PRINCIPLE

a) To determine the ratio : $\frac{\text{exposure read}}{\text{exposure received}}$

b) To study the variation over the whole range of measurements.

5.1.6.2 PROCEDURE

Class A (Dosimeters having generally only one effective range) :

Take the *n* dosimeters subjected to test 1.5, "Lower limit of reading", and set them to zero.

Irradiate them successively with the exposure X_0 corresponding to the lower limit of reading, with at least two exposures equally spaced between X_0 and the exposure corresponding to 85 % of the calibration or the effective range of the scale normally used, and with the exposure corresponding to 85 % of the calibration.

Read them and reset them to zero after each irradiation.

Class B (Test of linearity and additivity) :

Take dosimeters not previously exposed and observe their initial reading (I_0).

Irradiate them successively with exposures such that the cumulative total of the exposures is equal to the values shown in table 3 for a dosimeter with three effective ranges. When the dosimeter has *n* effective ranges ($n > 3$), proceed for intermediate ranges as for the second effective range.

Read the dosimeters after the reading has become stabilized (see test 1.2, "Stability of information").

Class C :

Take the *n* dosimeters having been subjected to test 1.5, "Lower limit of reading". If these dosimeters have received high exposures, an additional operation to erase them may be necessary.

Irradiate them successively with exposures equal to the values in table 3.

Read them.

1) **exactness** : The quality which characterizes the capability of a measuring instrument to give indications equal to the conventionally true value of the measured quantity.

Class D :

Take p lots each of n dosimeters.

Irradiate them respectively with exposures equal to the values in table 3.

Process and read them.

5.1.6.3 Results

Class A :

Calculate :

- the mean $\overline{l}$ of the readings of the n dosimeters;
- the ratio of this mean to the exposure received;
- the standard deviation s of the readings and of the ratio; plot the curve as a function of the exposure received.

Class B :

For each cumulative exposure X_i, calculate :

- the mean $\overline{l_{(X_i)}}$ of the readings of the n dosimeters;
- the ratio ϱ of this mean to the cumulative exposure received X_i :

$$\varrho = \frac{\overline{l_{(X_i)}} - \overline{l_0}}{X_i}$$

- the standard deviation s of the readings and of the ratio ϱ; plot the curve giving ϱ as a function of the cumulative exposure received.

Class C :

Proceed as for class A.

Class D :

For each batch (corresponding to a given exposure) calculate :

- the mean $\overline{l}$ of the readings of the n dosimeters;
- the ratio ϱ of this mean to the exposure received;
- the standard deviation s of the readings and of the ratio ϱ; plot the curve giving ϱ as a function of the exposure received.

5.1.7 *Test 1.7 — Memory effect (Remanence)*

5.1.7.1 Principle

To determine the effect of the past history of the dosimeters on :

- the lower limit of reading;
- the response.

5.1.7.2 Procedure

a) *Memory effect produced by irradiations corresponding to normal use of dosimeters :*

Class A :

Take a number of dosimeters equal to the number used for tests 1.5, "Lower limit of reading", and 1.6, "Exactness and linearity", and irradiate them k times at one of the exposures used in test 1.6 between the lower limit of reading X_0 and 85 % of the calibration or of the effective range on the scale normally used.

The number k shall correspond to an economical use of the dosimeter by the user.

TABLE 3 — **Cumulative exposure**

	Cumulative exposure		Reading
First effective range			l_0 (initial reading)
	X_0	lower limit of reading	$l_{(X_0)}$
	X_1, X_2	points equally spaced between X_0 and X_3	$l_{(X_1)}$, $l_{(X_2)}$
	X_3	= 85 % of $C1$, where $C1$ is the value of the first effective range	$l_{(X_3)}$
	X_4	= $C1$	$l_{(X_4)}$
Second effective range	X_5, X_6	points equally spaced between X_4 and X_7	$l_{(X_5)}$, $l_{(X_6)}$
	X_7	= 85 % of $C2$, where $C2$ is the value of the second effective range	$l_{(X_7)}$
	X_8	= $C2$	$l_{(X_8)}$
Third effective range	X_9, X_{10}	points equally spaced between X_8 and X_{11}	$l_{(X_9)}$, $l_{(X_{10})}$
	X_{11}	= 85 % $C3$	$l_{(X_{11})}$

After each irradiation, read the n dosimeters and reset them to zero if this is necessary in order to continue the test satisfactorily.

At the end of the k irradiations, determine the lower limit of reading X'_0 as described in test 1.5, then irradiate them with the previous exposure of test 1.6, and read them.

Class B :

Since dosimeters of this class cannot be reset to zero, this test does not apply to them.

Class C :

Proceed as for class A.

Class D :

Since reading renders dosimeters of this class unusable, this test does not apply to them.

b) *Memory effect produced by one or more strong accidental irradiations :*

Class A :

1) Take the n dosimeters used for tests 1.5, "Lower limit of reading", and 1.6, "Exactness and linearity", and irradiate them k times, each irradiation lasting between 8 and 12 h :

– for scale ranges or calibrations not exceeding 500 R[1)], at one of the exposures corresponding to 50 times the rating or the effective range on the scale normally used, without exceeding 1 000 R;

– for scale ranges or calibrations greater than 500 R, at an exposure fixed by the manufacturer.

After each irradiation, read the n dosimeters and reset them to zero.

After the k irradiations, determine the lower limit X'_0 of the n dosimeters in accordance with the method of test 1.5, then irradiate the dosimeters at one of the exposures of test 1.6 between X_0 and 85 % of the calibration or the effective limit of the scale range normally used, and read them.

2) Repeat the same test with n dosimeters irradiated but each irradiation lasting between 1 and 5 min.

Class B :

Since dosimeters of this class cannot be reset to zero, this test does not apply to them.

Class C :

Proceed as for class A.

Class D :

Since reading renders dosimeters of this class unusable, this test does not apply to them.

1) 1 R = 2,58 × 10^{-4} C/kg

2) Mainly γ + neutrons.

5.1.7.3 RESULTS

Classes A and C :

Normal use [5.1.7.2 a)] or accidental irradiation [5.1.7.2 b)] :

a) *Change in the lower limit of reading :*

Check by what percentage the new lower limit of reading X'_0 differs from the original lower limit of reading X_0.

b) *Change in the response of the dosimeter :*

Calculate the mean $\overline{l}$ of the readings of the n dosimeters at the kth irradiation and the standard deviations s of these readings.

Check by what percentage this mean and standard deviation differ from the mean and standard deviation found for the same irradiation during test 1.6, "Exactness and linearity".

5.1.8 *Test 1.8 – Relative spectral sensitivity*

5.1.8.1 PRINCIPLE

To determine, as a function of the radiation energy, the response of the dosimeter (intended for use in a field of either gamma or mixed radiation)[2)] subjected to radiation (X or gamma) at a constant exposure rate.

5.1.8.2 DEFINITION OF TEST CONDITIONS

The test is valid only for dosimeters having a linear dose response and those whose standardization curves for different doses show affinity one with another.

The radiations to be used are those defined in ISO 4037.

The standards peculiar to each type of instrument will enable the base radiation and other radiations to be used to be selected from among these radiations and will determine the operating conditions (in particular the geometrical conditions, exposure rate, etc.).

5.1.8.3 PROCEDURE

The investigation should be made with the exposure giving the best compromise between :

– the available means of testing with X-rays and radioactive sources;

– the exposure times having regard to the effect of the exposure rate and its drift during the exposure;

– the degree of precision of the reading.

Class A :

Take n dosimeters and set them to zero.

Subject them to an exposure X of the base radiation.

Read them and reset them to zero.

Subject them to the same exposure X of the other standard radiations chosen.

Read them and reset them to zero.

Class B :

Proceed as indicated for class A :

– either subjecting the same batch of n dosimeters to all the different energies, if the additivity (determined from test 1.6) is satisfactory;

– or, if this is not so, using for each energy a new batch of n dosimeters which have not previously undergone any radiation.

Class C :

Proceed as for class A.

Class D :

Proceed as for class A, but using for each energy a new batch of n dosimeters since reading them renders dosimeters of this class unusable.

5.1.8.4 Results

All classes :

a) For the base radiation and for the radiations of energies E_1, E_2, etc., calculate :

– the mean $\overline{l}$ of the readings of the n dosimeters :

$\overline{l_B}$; $\overline{l_{E_1}}$; $\overline{l_{E_2}}$; etc.

– the standard deviation s of these readings :

$s(\overline{l_B})$; $s(\overline{l_{E_1}})$; $s(\overline{l_{E_2}})$; etc.

b) Find the ratios :

$\dfrac{\overline{l_{E_1}}}{\overline{l_B}}$; $\dfrac{\overline{l_{E_2}}}{\overline{l_B}}$; etc.

c) Plot the curve giving the variation of these ratios as a function of the energy.

The limit of error on the curve will be equal to

$$s\left\{\frac{\overline{l_{E_i}}}{\overline{l_B}}\right\}$$

which is given by Taylor's formula :

$$\left[\frac{s\left\{\dfrac{\overline{l_{E_i}}}{\overline{l_B}}\right\}}{\dfrac{\overline{l_{E_i}}}{\overline{l_B}}}\right]^2 = \left[\frac{s\left\{\overline{l_{E_i}}\right\}}{\overline{l_{E_i}}}\right]^2 + \left[\frac{s\left\{\overline{l_B}\right\}}{\overline{l_B}}\right]^2$$

5.1.9 *Test 1.9 – Isotropy*

5.1.9.1 Principle

To investigate the effect on the indication shown by the dosimeter of its orientation in relation to the direction of the beam of radiation.

The radiation energy chosen for each type of dosimeter shall be the lowest energy at which the dosimeter will be used.

5.1.9.2 Procedure[1)]

Class A :

Set n dosimeters to zero.

Irradiate them with an exposure between 50 and 85 % of the calibration or the scale range normally used, the dosimeters being placed in the position recommended by the manufacturer in relation to the direction of the radiation beam.

Read them (l_R).

Reset the dosimeters to zero.

Make at least five irradiations with the same exposure, followed by reading l_{α_i} and resetting to zero, in the following positions :

– three irradiations, rotating the dosimeter about the geometrical centre of the sensitive part by 90°, 180°, and 270° in relation to the initial position in the plane defined by the vertical and the direction of the radiation beam;

– two irradiations, rotating the dosimeter about the centre of the sensitive part by 90° and then 270° in relation to the initial position in the plane perpendicular to the direction of the radiation beam.

Other directions can be chosen depending on the user's needs or the manufacturer's specifications.

Class B :

Proceed as for class A, irradiating each time a new batch of n dosimeters.

Class C :

Proceed as for class A but without resetting to zero.

Class D :

It is possible to proceed as for class B.

Since making this test would use up a considerable quantity of dosimeters of this class, a simplified test valid for a certain number of dosimeters has been described in ISO 1757.

1) For certain dosimeters which are particularly sensitive to the direction of the radiation, a more detailed test can be worked out.

5.1.9.3 RESULTS

All classes :

For each dosimeter (n) and each direction (α_i); calculate the deviation of the readings, d :

$$d = \frac{l_{(n,\alpha_i)} - l_R}{l_R} \times 100$$

5.1.10 *Test 1.10 – Geotropism*

5.1.10.1 PRINCIPLE

To investigate the influence on the indication given by the dosimeter of the reading position of the combination "dosimeter/reading device" relative to the vertical. This test applies only to assemblies which are easily orientated.

5.1.10.2 PROCEDURE

Class A :

Set n dosimeters to zero.

Irradiate them with an exposure between 50 and 85 % of the calibration or the effective range on the reading scale normally used.

Read them in the usual position defined by the manufacturer (l_R).

Read them after rotating the combination through 90° in four perpendicular directions (if this is possible) (l_{α_i}).

Class B :

Proceed as for class A.

Class C :

Proceed as for class A, but irradiating the n dosimeters for each reading position.

Class D :

Since reading dosimeters of this class renders them unusable, this test does not apply to them.

5.1.10.3 RESULTS

Classes A, B and C :

For each dosimeter (n) and each position (α_i), calculate the deviation in the readings, d :

$$d = \frac{l_{(n,\alpha_i)} - l_R}{l_R} \times 100$$

5.2 Series II – Climatic tests

5.2.1 *Test 2.1 – Change in performance in an atmosphere of "dry heat" or "cold"*

5.2.1.1 PRINCIPLE

To determine the change in performance as a function of the temperature during irradiation.

5.2.1.2 TEST RIG CHARACTERISTICS AND TEST CONDITIONS

a) The test shall be carried out in one or more climatic chambers which allow a temperature θ, laid down in the particular specifications and lying between -40 °C and $+70$ °C, to be attained and held constant within ± 2 °C everywhere within the enclosed volume. The relative humidity shall be less than 65 %. The rate of rise (or fall) of temperature shall not be less than 0,4 °C/min.

b) The radiations to be used are laid down in sub-clause 3.3, "Gamma radiations emitted by radionuclides", of ISO 4037.[1] The particular specifications for each type of dosimeter will determine which of these radionuclides is to be used.

The radioactive sources may be situated inside or outside the climatic chamber but in such a way that they produce during the test an exposure rate constant within $\pm\delta$, δ being laid down in the particular specifications.

The exposure rate shall be such that the exposure read lies between 50 and 85 % of the calibration or of the effective range on the scale normally used, the duration of exposure being compatible with the results of test 1.2, "Stability of information".

1) In any case, X-rays are not to be used.

c) The dosimeters shall be subjected to a temperature cycle as follows (for a given temperature θ). The irradiation shall be carried out starting at a time t_2 after each temperature level is reached and shall be completed by the time t_3. (See figure 2.) The determination of the irradiation period in the interval t_2 to t_3 is influenced by the fading characteristics.

The cycle shall be performed for $\theta = 20$ °C, and then for increasing temperatures θ_1, spread between 20 °C and θ_{sup}.

A fresh cycle shall be performed for $\theta = 20$ °C, and then a series of cycles for decreasing temperatures θ_2, spread between 20 °C and θ_{inf}.

θ_{sup} is the upper limit of the temperature range laid down in the particular specifications;

θ_1 is a temperature between 20 °C and θ_{sup};

θ_{inf} is the lower limit of the temperature range laid down in the particular specifications;

θ_2 is a temperature between 20 °C and θ_{inf}.

5.2.1.3 PROCEDURE

Class A :

Set n dosimeters to zero.

Put them inside the climatic chamber maintained at 20 °C.

After conditioning them at 20 °C in the chamber until time t_1, bring the temperature to θ.

Irradiate from time t_2 to t_3 under the conditions laid down in 5.2.1.2 c).

At time t_3, rapidly remove the dosimeters from the chamber and read them. The temperature of the dosimeters at the moment of reading should be as close as possible to that of the test.

Replace the dosimeters in the chamber and bring its temperature back to 20 °C.

At time t_4, remove the dosimeters and re-read them.

When θ equals 20 °C, the readings at times t_3 and t_4 serve as reference data.

Class B :

Put a batch of n dosimeters inside the climatic chamber maintained at 20 °C.

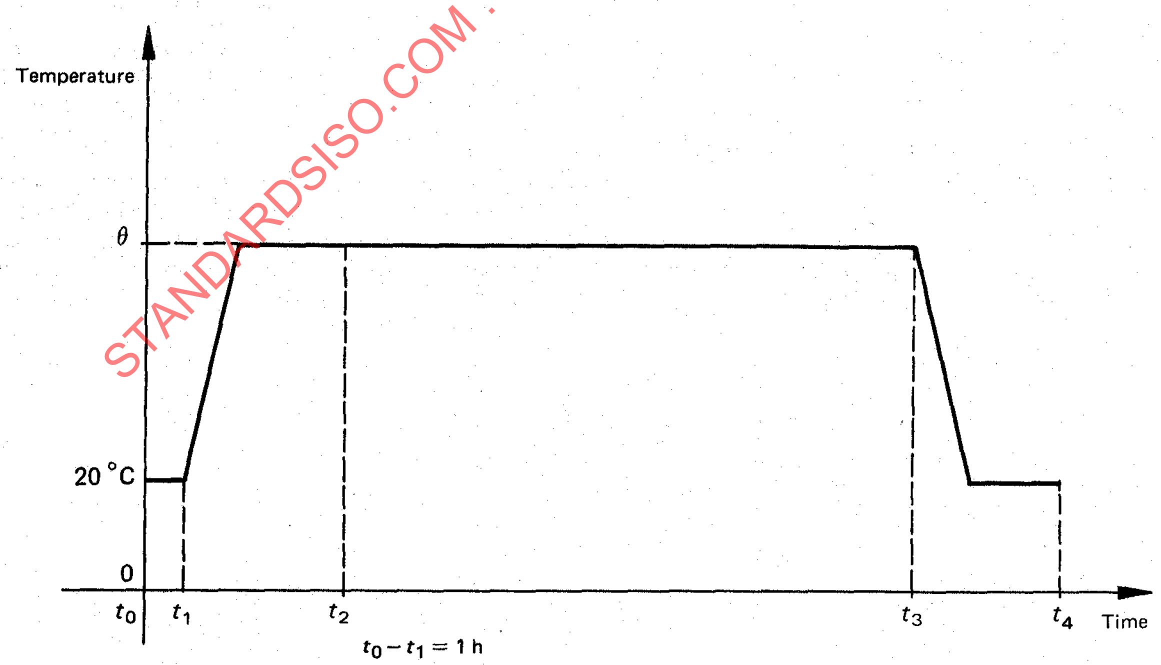
After conditioning them at 20 °C in the chamber until time t_1, bring the temperature to θ.

Irradiate from time t_2 to t_3 under the conditions laid down in 5.2.1.2 c).

At time t_3, bring the temperature of the chamber back to 20 °C.

At time t_4, remove the dosimeters and read them.

Use different batches for each temperature θ.



$t_0 - t_1 = 1$ h

$t_1 - t_2 = 4$ h

$t_2 - t_3 = 15$ h

$t_3 - t_4 = 4$ h

FIGURE 2

Class C :

Set n dosimeters to zero.

Proceed as for class B, using different batches of dosimeters for all the temperatures θ.

Class D :

Proceed as described for class B, using different batches for each temperature θ.

5.2.1.4 RESULTS

For each dosimeter and each temperature of irradiation, calculate :

Class A :

The percentage deviation d_1 at the temperature θ :

$$d_1 = \frac{l_{(\theta, t_3)} - l_{(20\,^\circ\mathrm{C}, t_3)}}{l_{(20\,^\circ\mathrm{C}, t_3)}} \times 100$$

All classes :

The percentage deviation d_2 at the end of the period of stabilization at + 20 °C :

$$d_2 = \frac{l_{(\theta, t_4)} - l_{(20\,^\circ\mathrm{C}, t_4)}}{l_{(20\,^\circ\mathrm{C}, t_4)}} \times 100$$

where

$l_{(20\,^\circ\mathrm{C},\, t_3)}$ is the reading of the dosimeter irradiated at 20 °C and read at time t_3;

$l_{(20\,^\circ\mathrm{C},\, t_4)}$ is the reading of the dosimeter irradiated at 20 °C and read at time t_4;

$l_{(\theta,\, t_3)}$ is the reading of the dosimeter irradiated at temperature θ and read at time t_3;

$l_{(\theta,\, t_4)}$ is the reading of the dosimeter irradiated at temperature θ and read at time t_4.

5.2.2 *Test 2.2 — Change in performance in an atmosphere of humid heat*

5.2.2.1 PRINCIPLE

To determine the change in performance and investigate the behaviour of dosimeters subjected to irradiation in an atmosphere of high relative humidity.

5.2.2.2 TEST RIG CHARACTERISTICS AND TEST CONDITIONS

a) The test shall be carried out in a climatic chamber which allows a temperature θ and a relative humidity U, laid down in the particular specifications and exceeding the following minimum limits, to be attained and held constant within ± 2 °C and ± 5 % respectively everywhere within the enclosed volume :

- temperature 40 °C;
- relative humidity 90 %.

The rate of rise (or fall) of temperature shall not be less than 0,4 °C/min.

b) The radiations to be used are laid down in sub-clause 3.3, "Gamma radiations emitted by radionuclides", of ISO 4037.[1)]

The particular specifications for each type of dosimeter will determine which of these radionuclides is to be used.

The radioactive sources may be situated inside or outside the climatic chamber but in such a way that, during the test, they produce an exposure rate constant within ± δ, δ being laid down in the particular specifications.

The exposure rate shall be such that the exposure read lies between 50 and 85 % of the calibration or of the effective range on the scale normally used, the duration of exposure being compatible with the results of test 1.2, "Stability of information".

1) In any case, X-rays are not to be used.

c) The dosimeters shall be subjected to the following cycle. The irradiation shall be carried out at a time t_2 after each temperature level is reached, and shall be completed by the time t_3. (See figure 3.) The determination of the irradiation period in the interval t_2 to t_3 is influenced by the fading characteristics.

5.2.2.3 Procedure

Class A :

Set n dosimeters to zero.

Put them inside the climatic chamber maintained at 20 °C and at $U_0 \leqslant 65$ %.

After conditioning them at 20 °C and at $U_0 \leqslant 65$ % in the chamber until time t_1, bring the temperature to θ and the relative humidity to U.

Irradiate from time t_2 to t_3 under the conditions laid down in 5.2.2.2 c).

At time t_3, rapidly remove the dosimeters from the chamber. Inspect them visually and read them. The temperature of the dosimeters at the moment of reading should be as close as possible to that of the test.

Replace the dosimeters in the chamber and bring the temperature back to 20 °C and the relative humidity back to $U_0 \leqslant 65$ %.

At time t_4, remove the dosimeters, re-inspect them visually and re-read them.

When θ equals 20 °C, the readings at times t_3 and t_4 serve as reference data.

Class B :

Put a batch of n dosimeters inside the climatic chamber maintained at 20 °C and at $U_0 \leqslant 65$ %.

After conditioning them at 20 °C and at $U_0 \leqslant 65$ % in the chamber until time t_1, bring the temperature to θ and the relative humidity to U.

Irradiate from time t_2 to t_3 under the conditions laid down in 5.2.2.2 c).

At time t_3, bring the temperature back to 20 °C and the relative humidity to $U_0 \leqslant 65$ %.

At time t_4, remove the dosimeters, inspect them visually and read them.

Use different batches for each temperature θ.

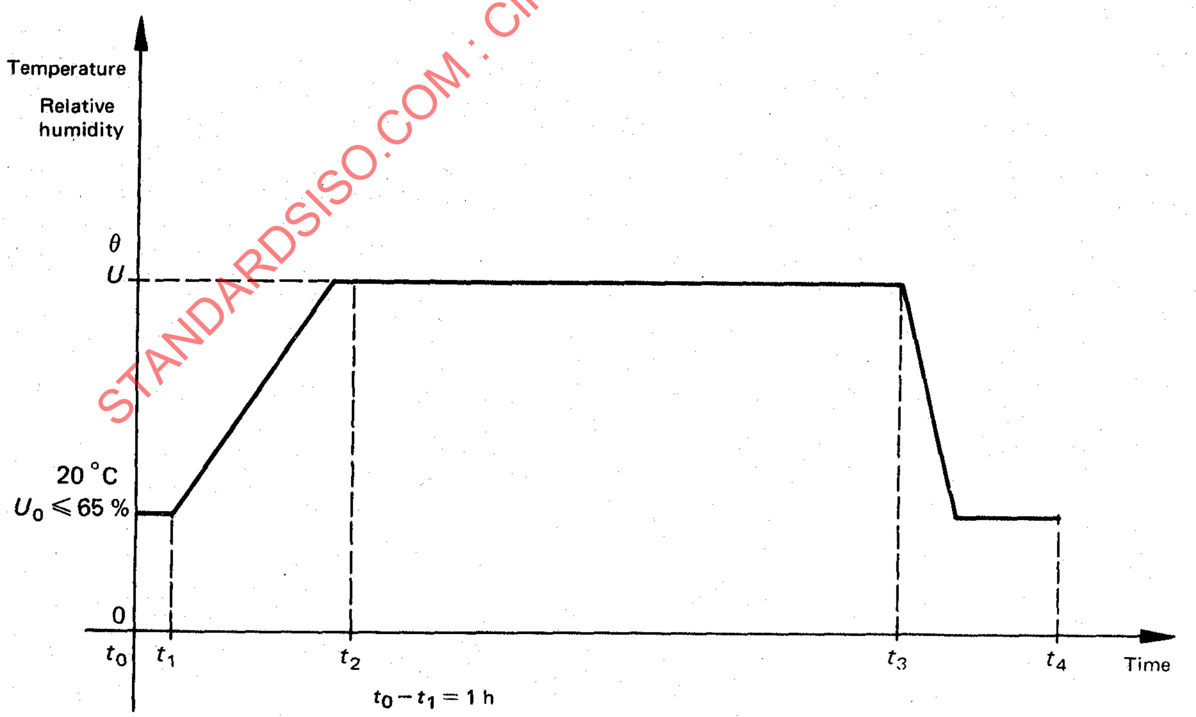
Class C :

Set n dosimeters to zero.

Proceed as for class B, using the same batch of dosimeters for all the temperatures θ.

Class D :

Proceed as for class B, using different batches for each temperature θ.



$t_0 - t_1 = 1$ h
$t_1 - t_2 = 4$ h
$t_2 - t_3 = 15$ h
$t_3 - t_4 = 4$ h

FIGURE 3

5.2.2.4 Results

a) The visual inspection before each reading is to detect the possible presence of moisture within the case.

b) Calculate the percentage deviation, d :

Class A :

$$d_1 = \frac{l_{(\theta,t_3)} - l_{(20\,°\mathrm{C},t_3)}}{l_{(20\,°\mathrm{C},t_3)}} \times 100$$

All classes :

$$d_2 = \frac{l_{(\theta,t_4)} - l_{(20\,°\mathrm{C},t_4)}}{l_{(20\,°\mathrm{C},t_4)}} \times 100$$

where

$l_{(\theta,t_3)}$ is the reading of the dosimeter irradiated at θ and read at time t_3;

$l_{(20\,°\mathrm{C},t_3)}$ is the reading of the dosimeter irradiated at 20 °C and read at time t_3;

$l_{(\theta,t_4)}$ is the reading of the dosimeter irradiated at θ and read at time t_4;

$l_{(20\,°\mathrm{C},t_4)}$ is the reading of the dosimeter irradiated at 20 °C and read at time t_4.

5.2.3 *Test 2.3 – Effect of high and low temperatures on dosimeter indication*

5.2.3.1 Principle

To investigate the variation in dosimeter response after storage at cycled temperatures in the irradiated state.

5.2.3.2 Test rig characteristics and test conditions

a) The test shall be carried out in one or more climatic chambers which allow temperatures θ_1 and θ_2, laid down in the particular specifications and lying between − 40 °C and + 70 °C, to be attained and held constant within ± 2 °C everywhere within the enclosed volume (the relative humidity being less than or equal to 65 %).

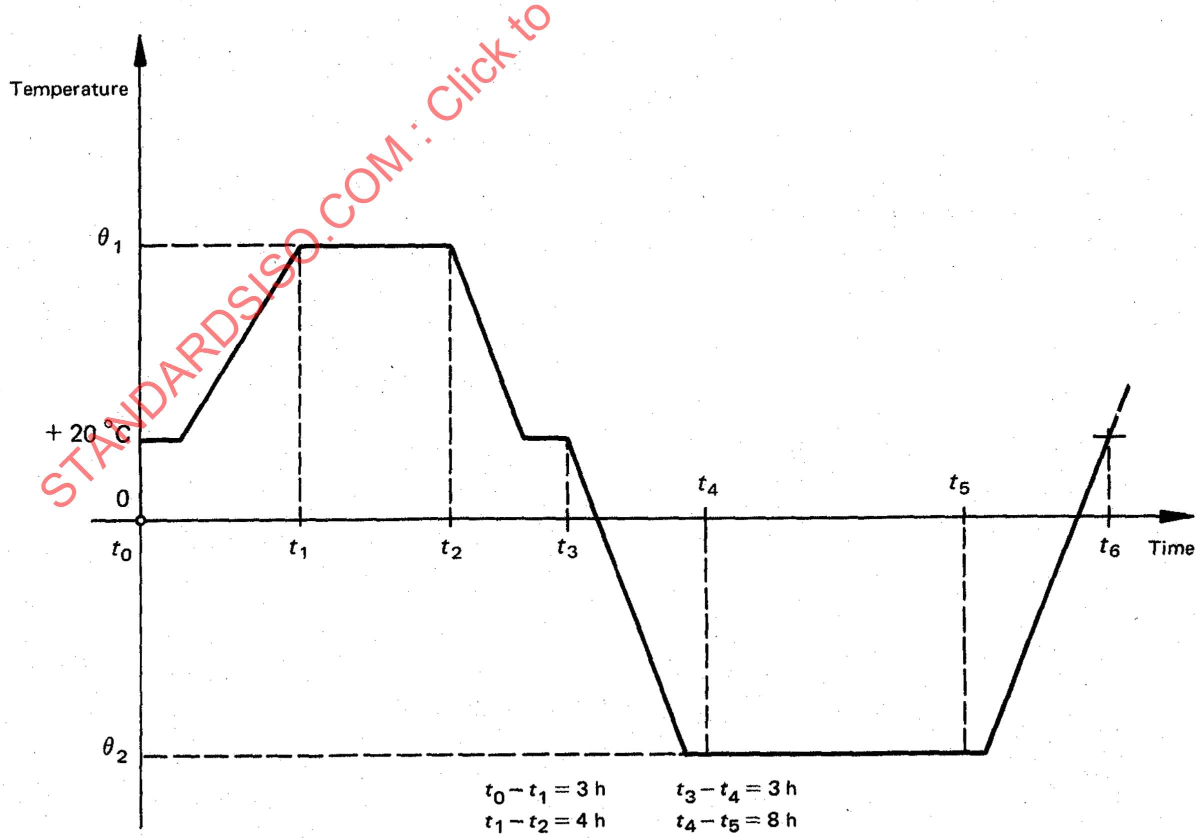
The rate of rise or fall of temperature shall not be less than 0,4 °C/min.

b) The dosimeters shall be subjected to the temperature cycle shown in figure 4.

5.2.3.3 Procedure

All classes :

Irradiate 2 n dosimeters with an exposure lying between 50 and 85 % of the calibration or of the effective range on the scale normally used.



$t_0 - t_1 = 3$ h
$t_1 - t_2 = 4$ h
$t_2 - t_3 = 3$ h
$t_3 - t_4 = 3$ h
$t_4 - t_5 = 8$ h
$t_5 - t_6 = 3$ h

FIGURE 4

Keep n of these dosimeters at ambient temperature.

Subject the other n dosimeters six times to the cycle laid down in 5.2.3.2 b).[1)]

24 h after the end of the test, read the 2 n dosimeters.

5.2.3.4 Results

All classes :

Calculate the percentage deviation d after subjecting to high and low temperatures :

$$d = \frac{\overline{l} - \overline{l_A}}{\overline{l_A}} \times 100$$

where

$\overline{l_A}$ is the mean of the readings of the n dosimeters kept at ambient temperature;

$\overline{l}$ is the mean of the readings of the dosimeters subjected to the cycles of high and low temperatures.

5.2.4 *Test 2.4 — Effect of moist heat on dosimeter indication*

5.2.4.1 Principle

To investigate the variation in dosimeter response, after storage in moist heat, in the irradiated state.

5.2.4.2 Test rig characteristics and test conditions

a) The test shall be carried out in a climatic chamber which allows a temperature θ and a relative humidity U, laid down in the particular specifications and exceeding the following minimum limits, to be attained and held constant everywhere within the enclosed volume :

- temperature 40 °C;
- relative humidity 90 %.

The rate of rise (or fall) of temperature shall be not less than 0,4 °C/min.

b) The dosimeters shall be subjected to the cycle shown in figure 5.

5.2.4.3 Procedure

All classes :

Irradiate $2n$ dosimeters with an exposure lying between 50 and 85 % of the calibration or of the effective range on the scale normally used.

Keep n of these dosimeters at ambient temperature. Subject the other n dosimeters six times to the cycle laid down in 5.2.4.2 b).[1)]

24 h after the end of the test, read the 2 n dosimeters.

5.2.4.4 Results

All classes :

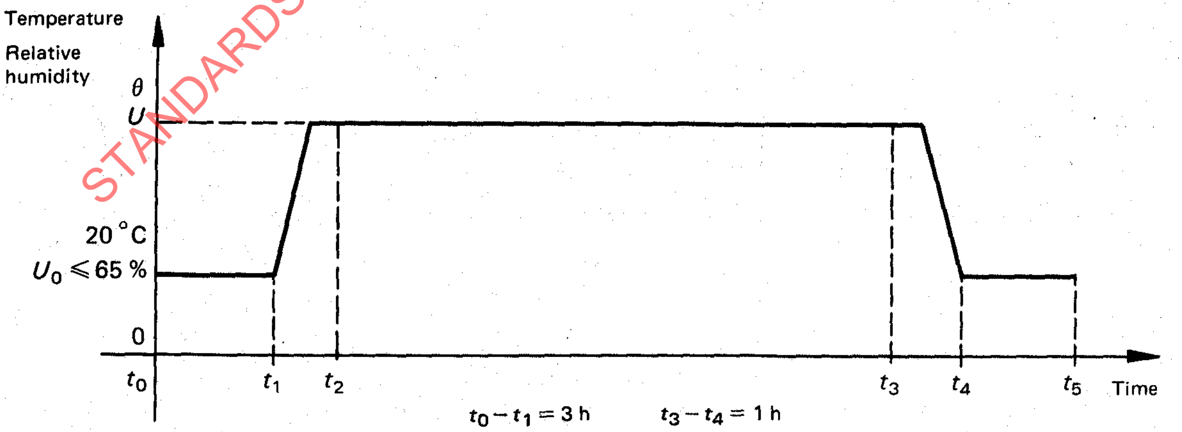
Calculate the percentage deviation d after being kept in moist heat :

$$d = \frac{\overline{l} - \overline{l_A}}{\overline{l_A}} \times 100$$

where

$\overline{l_A}$ is the mean of the readings of the n dosimeters kept at ambient temperature;

$\overline{l}$ is the mean of the readings of the dosimeters subjected to the cycles in moist heat.



$t_0 - t_1 = 3$ h $\quad t_3 - t_4 = 1$ h

$t_1 - t_2 = 1$ h $\quad t_4 - t_5 = 3$ h

$t_2 - t_3 = 6$ h

FIGURE 5

1) The succession of cycles may be interrupted by a rest period.

5.2.5 *Test 2.5 – Effect of storage at high and low temperatures on dosimeter response*

5.2.5.1 PRINCIPLE

To investigate the variation in dosimeter response after storage at high and low temperatures in the unirradiated state.

5.2.5.2 TEST RIG CHARACTERISTICS AND TEST CONDITIONS

a) The test shall be carried out in one or more climatic chambers which allow temperatures θ_1 and θ_2, laid down in the particular specifications and lying between − 40 °C and + 70 °C, to be attained and held constant within ± 2 °C everywhere within the enclosed volume (the relative humidity being less than or equal to 65 %).

The rate of rise (or fall) of temperature shall be not less than 0,4 °C/min.

b) The dosimeters shall be subjected to the temperature cycle shown in figure 6.

5.2.5.3 PROCEDURE

Classes A and C :

Set n dosimeters to zero.

All classes :

Subject n dosimeters ten times to the cycle laid down in 5.2.5.2 b).[1)]

24 h after the end of the test, carry out the tests

1.1, "Zero point stability"

1.2, "Stability of information"

1.3, "Repeatability"

1.5, "Lower limit of reading"

1.6, "Exactness and linearity"

on these n dosimeters at the same time as on the dosimeters subjected to the tests in series I.

5.2.5.4 RESULTS

Interpret the results at the same time and in the same way as for the dosimeters subjected to the tests in series I.

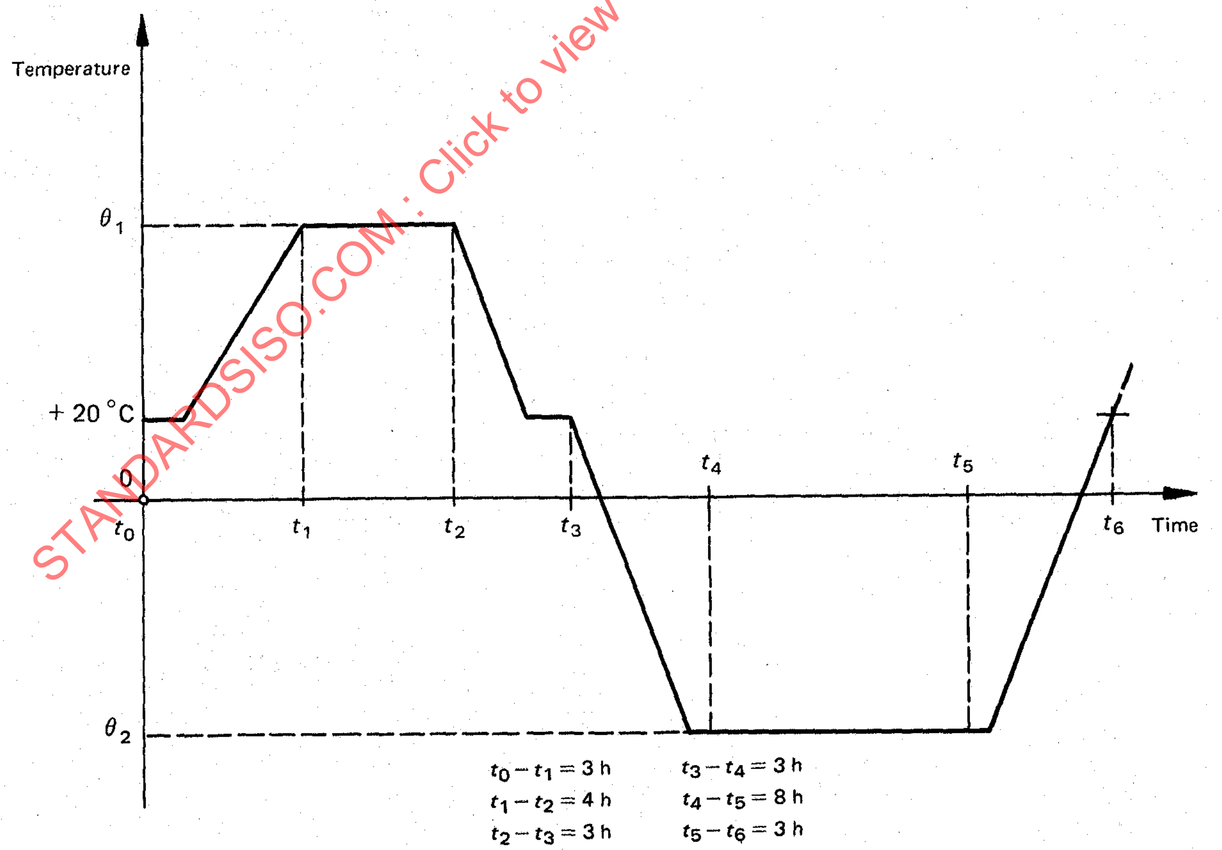


FIGURE 6

1) The succession of cycles may be interrupted by a rest period.

5.2.6 *Test 2.6 — Effect of storage in moist heat on dosimeter response*

5.2.6.1 Principle

To investigate the variation in dosimeter response after storage in moist heat in the unirradiated state.

5.2.6.2 Test rig characteristics and test conditions

a) The test shall be carried out in one or more climatic chambers which allow a temperature θ and a relative humidity U, laid down in the particular specifications and exceeding at least the following minimum limits, to be attained and held constant within ± 2 °C and ± 5 % respectively everywhere within the enclosed volume :

- temperature 40 °C;
- relative humidity 90 %.

The rate of rise (or fall) of temperature shall not be less than 0,4 °C/min.

b) The dosimeters shall be subjected to the cycle shown in figure 7.

5.2.6.3 Procedure

Classes A and C :

Set n dosimeters to zero.

All classes :

Subject n dosimeters 14 times to the cycle laid down in 5.2.6.2 b).[1]

24 h after the end of the test, carry out the tests :

1.1, "Zero point stability"

1.2, "Stability of information"

1.3, "Repeatability"

1.5, "Lower limit of reading"

1.6, "Exactness and linearity"

on the n dosimeters at the same time as on the dosimeters subjected to the tests in series I.

5.2.6.4 Results

Interpret the results at the same time and in the same way as those for the dosimeters subjected to the tests in series I.

5.3 Series III — Mechanical tests

The tests shall always be carried out with dosimeters in the condition in which they are used.

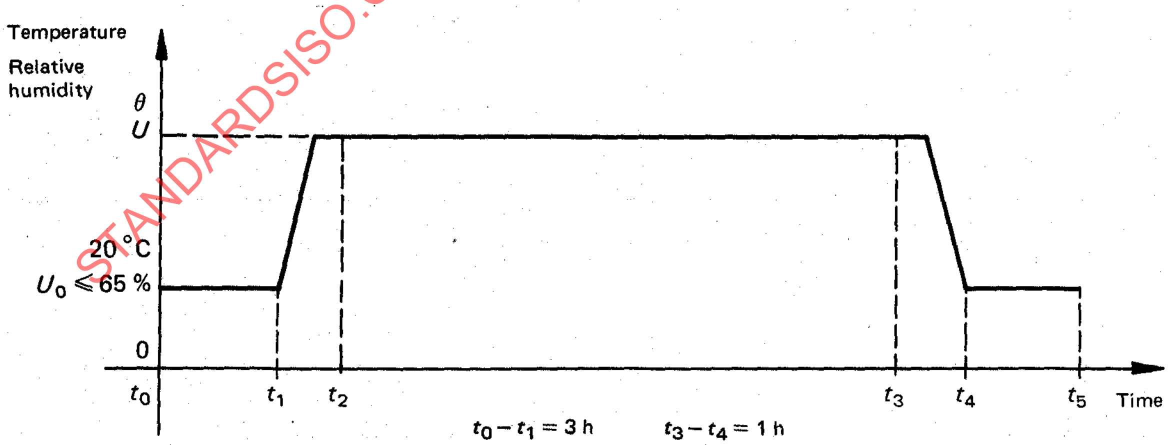
Each mechanical test shall be carried out on n dosimeters.

After each test, two checks shall be made :

- a check of the retention of information (on n' dosimeters irradiated before the test):
- a check of working condition (on n'' dosimeters in the irradiated state).

The different irradiations shall be made with the same reference radiation.

The n dosimeters shall be irradiated with an exposure X between 50 and 85 % of the calibration or of the effective range on the scale normally used.



$t_0 - t_1 = 3$ h $\quad t_3 - t_4 = 1$ h

$t_1 - t_2 = 1$ h $\quad t_4 - t_5 = 3$ h

$t_2 - t_3 = 6$ h

FIGURE 7

1) The succession of cycles may be interrupted by a rest period.

5.3.1 *Test 3.1 – Dropping*

5.3.1.1 Principle

To judge the resistance of dosimeters to shocks which they may suffer when dropped while being handled.

5.3.1.2 Test rig characteristics and test conditions

The dosimeter shall be supported by a device which can release it suddenly, reproducibly and without initial velocity, above an oak board, in a single piece 5 cm thick, resting directly on a concrete base.

The height of the drop shall be measured between the upper surface of the board and the lowest point of the dosimeter.

Drop heights : 0,25 m, 0,5 m, 1 m, 1,5 m and 2 m.

The dosimeters shall be dropped p times from each height. The position of the dosimeter before each drop as well as the desired point and angle of impact shall be determined in relation to its shape.

5.3.1.3 Procedure

a) *Retention of information*

Class A :

Irradiate the n' dosimeters with an exposure X.

Read them (l_1); do not reset them to zero.

Submit them to p drops of 0,25 m, p being fixed by the particular specifications.

Examine them. Read them (l_2).

Repeat for the next drop height. The different heights at which the test will be carried out, chosen from among those given in 5.3.1.2, will be fixed by the particular specifications.

Class B :

Proceed as for class A.

Class C :

Irradiate the n' dosimeters with exposure X.

Read them (l_1). Check that they have properly returned to zero; if not, reset them to zero.

Irradiate them again with exposure X, then proceed as described for class A (l_2).

Class D :

Irradiate 2 n' dosimeters with exposure X. Read a first batch of n' dosimeters (l_1). Proceed as described for class A with the second batch of n' dosimeters (l_2).

b) *Working test*

All classes :

Submit n'' non-irradiated dosimeters to p drops of 0,25 m, p being fixed by the particular specifications.

Examine them.

Irradiate them with exposure X.

Read them (l_3).

Note any apparent damage.

Repeat for the next drop height. The different heights at which the test will be carried out, chosen from among those given in 5.3.1.2, will be fixed by the particular specifications.

5.3.1.4 Results

All classes :

For each drop height :

a) *Retention of information*

Specify any damage revealed by visual inspection.

Calculate the deviation of the readings, d_1 :

$$d_1 = \frac{l_2 - l_1}{l_1} \times 100$$

b) *Working test*

Specify any damage revealed by visual inspection.

Calculate the deviation of the readings, d_2 :

$$d_2 = \frac{l_3 - l_1}{l_1} \times 100$$

5.3.2 *Test 3.2 – Vibrations*

5.3.2.1 Principle

To evaluate the resistance of equipment submitted to vibrations of variable frequency.

5.3.2.2 Test rig characteristics and test conditions

The dosimeters, attached firmly to a vibrating table, shall be submitted successively in three mutually perpendicular directions to a movement defined as follows :

– rectilinear sinusoidal movement;

– amplitude : 1 mm;

– frequency cyclically variable between 10 and 55 Hz;

– duration of the complete sweep through the frequency range from the lower limit to the higher and back to the lower, the ascending and descending times being approximately equal : 1 min;

– duration of the test : 30 min to 2 h, fixed by the particular specifications;

– number of cycles per direction : 10 to 40, fixed by the particular specifications.

5.3.2.3 PROCEDURE

a) *Retention of information*

Class A :

Irradiate n' dosimeters with exposure X.

Read them (l_1); do not reset them to zero.

Submit them to the test described in 5.3.2.2.

Inspect them.

Read them at the end of the test (l_2).

Class B :

Proceed as for class A.

Class C :

Irradiate n' dosimeters with exposure X.

Read them (l_1).

Irradiate them again with exposure X.

Submit them to the test described in 5.3.2.2.

Inspect them.

Read them at the end of the test (l_2).

Class D :

Irradiate $2\,n'$ dosimeters with exposure X.

Read a first batch of n' dosimeters (l_1).

Submit the second batch of n' dosimeters to the test described in 5.3.2.2.

Inspect them.

Read them at the end of the test (l_2).

b) *Working test*

All classes :

Submit n'' non-irradiated dosimeters to the test described in 5.3.2.2.

Inspect them.

At the end of the test, irradiate them with exposure X and read them (l_3).

5.3.2.4 RESULTS

All classes :

a) *Retention of information*

Specify any damage revealed by visual inspection.

Calculate the deviation of the readings, d_1 :

$$d_1 = \frac{l_2 - l_1}{l_1} \times 100$$

b) *Working test*

Specify any damage revealed by visual inspection.

Calculate the deviation of the readings, d_2 :

$$d_2 = \frac{l_3 - l_1}{l_1} \times 100$$

5.3.3 *Test 3.3 – Shocks*

5.3.3.1 PRINCIPLE

To determine the behaviour of dosimeters under repeated shocks.

5.3.3.2 TEST RIG CHARACTERISTICS AND TEST CONDITIONS

The dosimeters, firmly attached to a shock table, shall be submitted to shocks defined as follows (see figure 8) :

– maximum nominal deceleration, D : 40 g (g = 9,81 m·s^{-2});

– duration, T, measured at 10 % of the nominal maximum deceleration : 6 ± 1 ms;

– maximum deviation between the real instantaneous deceleration and the theoretical instantaneous deceleration : 10 % of the nominal maximum deceleration;

– rebounds : less than ± 10 % of the nominal maximum deceleration.

The dosimeters shall be subjected to 1 000 shocks at the rate of one every 2 s.

5.3.3.3 PROCEDURE

a) *Retention of information*

Class A :

Irradiate n' dosimeters with exposure X.

Read them (l_1); do not reset them to zero.

Submit them to the test described in 5.3.3.2.

Inspect them.

Read them at the end of the test (l_2).

Class B :

Proceed as for class A.

Class C :

Irradiate n' dosimeters with exposure X.

Read them (l_1).

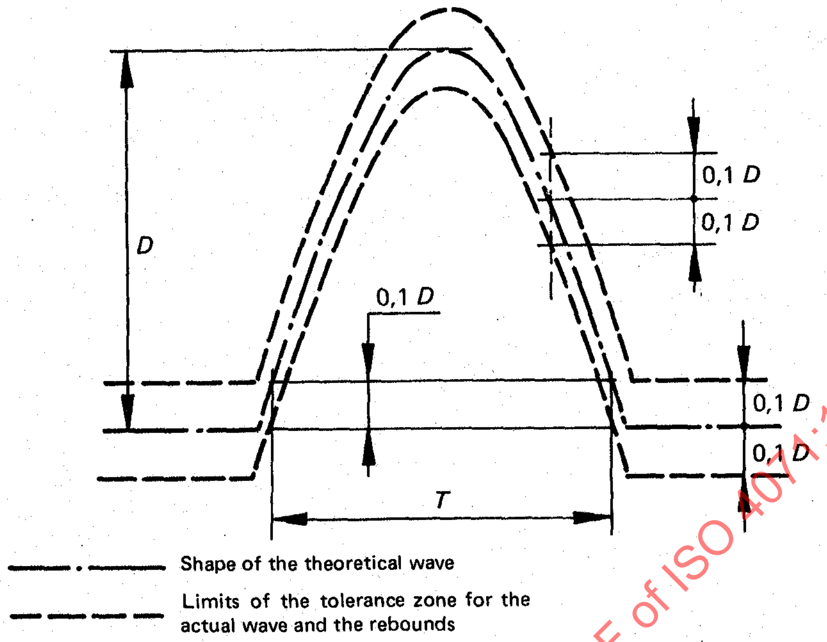


FIGURE 8

Irradiate them again with exposure X.

Submit them to the test described in 5.3.3.2.

Inspect them.

Read them at the end of the test (l_2).

Class D :

Irradiate 2 n' dosimeters with exposure X.

Read a first batch of n' dosimeters (l_1).

Submit the second batch of n' dosimeters to the test described in 5.3.3.2.

Inspect them.

Read them at the end of the test (l_2).

b) *Working test*

All classes :

Submitt the n'' non-irradiated dosimeters to the test described in 5.3.3.2.

Inspect them.

At the end of the test, irradiate them with exposure X and read them (l_3).

5.3.3.4 RESULTS

All classes :

a) *Retention of information*

Specify any damage revealed by visual inspection.

Calculate the deviation of the readings, d_1 :

$$d_1 = \frac{l_2 - l_1}{l_1} \times 100$$

b) *Working test*

Specify any damage revealed by visual inspection.

Calculate the deviation of the readings, d_2 :

$$d_2 = \frac{l_3 - l_1}{l_1} \times 100$$

5.3.4 *Test 3.4 – Immersion*

5.3.4.1 PRINCIPLE

To test the water-tightness of dosimeters by prolonged immersion in water.

5.3.4.2 TEST RIG CHARACTERISTICS AND TEST CONDITIONS

The maximum difference between the temperature of the dosimeters before the test and that of the testing water shall be + 20 °C.

The temperature of the water shall be the same as the ambient temperature.

The dosimeters shall be immersed to a depth of at least 30 cm, measured from their highest part.

The immersion shall last 2 h.

Only the test of retention of information shall be carried out (testing of n' irradiated dosimeters).

5.3.4.3 PROCEDURE

Class A :

Irradiate n' dosimeters with exposure X.

Read them (l_1); do not reset them to zero.

Submit them to the test described in 5.3.4.2.

Inspect them.

Read them at the end of the test (l_2).

Class B :

Proceed as for class A.

Class C :

Irradiate n' dosimeters with exposure X.

Read them (l_1).

Irradiate them again with exposure X.

Submit them to the test described in 5.3.4.2.

Inspect them.

Read them at the end of the test (l_2).

Class D :

Irradiate 2 n' dosimeters with exposure X.

Read a first batch of n' dosimeters (l_1).

Submit the second batch of n' dosimeters to the test described in 5.3.4.2.

Inspect them.

Read them at the end of the test (l_2).

5.3.4.4 RESULTS

All classes :

Ascertain by visual observation whether the case (if any) is watertight or not.

Calculate the deviation in the readings, d :

$$d = \frac{l_2 - l_1}{l_1} \times 100$$

5.3.5 *Test 3.5 – Abnormal atmospheric conditions*

5.3.5.1 PRINCIPLE

To determine the behaviour of dosimeters after being stored in a place where the atmospheric conditions are unusual (as, for example, when transported by air).

5.3.5.2 TEST RIG CHARACTERISTICS AND TEST CONDITIONS

a) Carry out the test in a climatic chamber where it is possible to obtain and maintain constant the minimum temperature θ and pressure p, θ and p being fixed by the particular specifications, by the statement of requirements or by the manufacturer.

The rate of lowering of the temperature shall not be less than 0,4 °C/min. The time required to lower the temperature shall not exceed 5 min.

b) The dosimeters shall be subjected to a period of 16 h at temperature θ under pressure p.

Only the working test shall be carried out (test of n'' non-irradiated dosimeters).

In simulating transport by air, the temperature θ and the pressure p can be chosen from among the values given, as examples, in table 4.

5.3.5.3 PROCEDURE

Class A :

Irradiate n'' dosimeters with exposure X under normal atmospheric pressure.

Read them (l_1) and reset them to zero.

Store them under low atmospheric pressure.

TABLE 4 – **Examples of simulated air transport conditions**

Flight altitude h m	Baggage compartment	Pressure p mbar[1)]	Temperature θ °C
$h \leqslant 5\,000$	unpressurized not climatized	500	– 50
$5\,000 < h \leqslant 10\,000$		250	– 55
$10\,000 < h \leqslant 15\,000$		115	– 55
$15\,000 < h \leqslant 21\,000$		45	– 55
$21\,000 < h \leqslant 30\,000$		24	– 55

1) 1 mbar = 100 Pa

Irradiate them with exposure X under normal atmospheric pressure.

Read them (l_2).

Class B :

Irradiate a first batch of n' dosimeters with exposure X under normal atmospheric pressure.

Read them (l_1).

Store a second batch of n' dosimeters under low atmospheric pressure.

Irradiate them with exposure X under normal atmospheric pressure.

Read them (l_2).

Class C :

Proceed as for class A.

Class D :

Proceed as for class B.

5.3.5.4 RESULTS

All classes :

Calculate the deviation of the readings, d :

$$d = \frac{l_2 - l_1}{l_1} \times 100$$

5.4 Series IV — Utilization tests

5.4.1 *Test 4.1 — Resistance to moulds*

This test is composed of two parts :

- susceptibility to degradation by moulds (5.4.1.1);
- resistance to invasion (5.4.1.2).

5.4.1.1 SUSCEPTIBILITY TO DEGRADATION BY MOULDS

5.4.1.1.1 PRINCIPLE

To evaluate to what extent the dosimeters or certain of their parts (particularly plastic materials) can be a nutritive medium for moulds.

5.4.1.1.2 TEST RIG CHARACTERISTICS AND TEST CONDITIONS

Prepare a mixed inoculum from the following strains :

- *Sterigmatocystis nigra*;
- *Aspergillus amstelodami*;
- *Aspergillus flavus*;
- *Penicillium brevi compactum*;
- *Penicillium cyclopium*;
- *Peacilomyces varioti*;
- *Trichoderma*;
- *Chaetomium globosum*;
- *Myrothecium verrucaria*;
- *Stachybotris atra*;
- *Memnoviella echinata*;
- *Penicillium funicolosum*.

Prepare an incomplete medium (without nutritive substances) with the components listed in table 5.

TABLE 5 — **Incomplete medium**

Component	Chemical formula	Quantity
Ammonium nitrate	NH_4NO_3	3 g
Magnesium sulphate	$MgSO_4$	0,5 g
Potassium chloride	KCl	0,25 g
Potassium dihydrogen phosphate	KH_2PO_4	1 g
Agar-agar		20 g
Distilled water		1 000 ml

A dark tank is needed, in which the following conditions can be obtained :

- temperature : 30 ± 1 °C;
- relative humidity : (95 ± 5) %.

5.4.1.1.3 PROCEDURE

Class A :

Irradiate n dosimeters with an exposure X lying between 50 and 85 % of the calibration or of the effective reading range normally used.

Read them (l_1) and reset them to zero.

Clean them according to the manufacturer's directions and dry them in the air. If need be, clean and dry their cases.

Place the dosimeter and case together in an airtight container containing the inoculated agar medium. A control on which the culture can develop normally shall be inoculated at the same time.

Put the containers with the dosimeters and the control in the tank and leave them for 4 weeks.

Determine the susceptibility of the components of the dosimeter to degradation by moulds, by inspecting them each week with the naked eye or with a magnifying glass.

After 4 weeks, clean and dry the dosimeters, irradiate them with exposure X and read them (l_2).

Class B :

Irradiate a first batch of n dosimeters with an exposure X lying between 50 and 85 % of the calibration or of the effective range of the scale normally used.

Read them (l_1).

Subject a second batch of n dosimeters to mould as described for class A.

After 4 weeks, clean and dry these dosimeters, irradiate them with exposure X and read them (l_2).

Class C :

Proceed as for class A.

Class D :

Proceed as for class B.

5.4.1.1.4 RESULTS

All classes :

a) Evaluate the susceptibility of the dosimeters and their cases to degradation by moulds by the following codes :

- **0** – No development of fungus visible with magnifying glass.
- **1** – No development visible to the naked eye, but visible with the magnifying glass : germination of spores not exceeding a limited and sterile mycelium.
- **2** – Development visible to the naked eye, in the form of scattered spots or a moderate uniform development.
- **3** – Considerable development (not extending over the whole dosimeter).
- **4** – Very considerable development (extending over the whole dosimeter).

If appropriate, specify the part affected.

b) For each dosimeter, calculate the deviation of the readings, d :

$$d = \frac{l_2 - l_1}{l_1} \times 100$$

Evaluate the significance of the deviation by comparison with the standard deviation given by the homogeneity test (test 1.4).

5.4.1.2 RESISTANCE TO INVASION

5.4.1.2.1 PRINCIPLE

To evaluate the resistance of dosimeters to invasion by mould in the presence of a nutritive medium.

5.4.1.2.2 TEST RIG CHARACTERISTICS AND TEST CONDITIONS

Use the inoculum specified in 5.4.1.1.2.

Add glucose to the development medium to make it nutritive.

A dark tank is needed in which the following conditions can be obtained :

- temperature : 30 ± 1 °C;
- relative humidity : (95 ± 5) %.

5.4.1.2.3 PROCEDURE

Class A :

Proceed in the same way as for the test of susceptibility to degradation by moulds (5.4.1.1.3).

Place the mycelium in the tank for 3 days in the presence of the nutritive medium. The mycelium should cover the whole surface of the medium. After 3 days, put the n dosimeters in the tank and leave them there for 4 weeks.

Class B :

Proceed in the same way as for the test of susceptibility to degradation by moulds (5.4.1.1.3).

Treat the mycelium as described for class A.

After 3 days, put the second lot of n dosimeters in the tank and leave them for 4 weeks.

Class C :

Proceed as for class A.

Class D :

Proceed as for class B.

5.4.1.2.4 RESULTS

All classes :

a) The degree of resistance to invasion is given by the following codes :

- **0** – No development visible on the dosimeter with a magnifying glass.
- **1** – No development visible to the naked eye. With the magnifying glass, visible invasion of the edges by a fructified mycelium and/or of the surface by a sterile mycelium.
- **2** – Development visible to the naked eye, in the form of a considerable invasion of the edges of the dosimeter or a moderate invasion of the surface.
- **3** – Invasion of at least half of the dosimeter by a fructified mycelium (note the area affected).
- **4** – Invasion of the whole dosimeter by a fructified mycelium.