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Radiation protection — Sealed sources — Leakage test methods

Radioprotection — Sources scellées — Méthodes d'essai d'étanchéité

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

This second edition cancels and replaces the first edition (ISO 9978:1992), which has been technically revised. The main changes compared to the previous edition are as follows:

— Clause 4: Revised to add text specifying factors to be considered in designing an effective leak testing regime for a particular type of sealed source;

— Clause 4: Requirement added that personnel performing leak tests be appropriately trained and qualified, informative reference to ISO 9712 added;

— Clause 4: Requirement added that measurement uncertainty shall be considered in sentencing non-binary test results;

— Table 1 — "Threshold detection values and limiting values for different test methods" has been revised for clarity;

— 5.1: Informative reference to suitable assay techniques for immersion test liquid samples added: ISO 19361 and ISO 19581;

— 5.1.1, 5.1.2, 5.1.4: Composition of suitable immersion test liquids clarified;

— 5.3: Informative reference to suitable wipe testing techniques (ISO 7503-2) added and clarification that acceptance criteria is absolute without correction for wiping efficiency required;

— 6.1: Normative reference to ISO 20485 added for methods of helium leak testing and calculation of acceptance limits;

— 6.2: Cautionary text added to state that efficacy of tests assume ideal conditions for vision of bubbles;

— 6.2.1: Cautionary text added regarding bubble testing of self-heated sources;

— A.1: Text expanded to clarify which tests to use under given circumstances.

Introduction

The use of sealed sources has become so widespread that standards to guide the user, manufacturer and regulatory agencies are necessary. When establishing these standards, radiation protection is the prime consideration.

The purpose of this document, in conjunction with ISO 2919, is to minimise the risk to the public caused by leakage of radioactive material into the general environment.

Leakage test methods for sealed sources were standardised in the first edition of this document. The experience acquired since this date has necessitated the revision of this document.

Radiation protection — Sealed sources — Leakage test methods

1 Scope

This document specifies the different leakage test methods for sealed sources. It gives a comprehensive set of procedures using radioactive and non-radioactive means.

This document applies to the following situations:

— leakage testing of test sources following design classification testing in accordance with ISO 2919[1];

— production quality control testing of sealed sources;

— periodic inspections of the sealed sources performed at regular intervals, during the working life.

Annex A of this document gives guidance to the user in the choice of the most suitable method(s) according to situation and source type.

It is recognized that there can be circumstances where special tests, not described in this document, are required.

It is emphasized, however, that insofar as production, use, storage and transport of sealed radioactive sources are concerned, compliance with this document is no substitute for complying with the requirements of the relevant IAEA regulations[17] and other relevant national regulations. It is also recognized that countries can enact statutory regulations which specify exemptions for tests, according to sealed source type, design, working environment, and activity (e.g. for very low activity reference sources where the total activity is less than the leakage test limit).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20485:2017, *Non-destructive testing — Leak testing — Tracer gas method*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
capsule
protective envelope, used to prevent leakage of radioactive material

3.2
dummy sealed source
facsimile of a sealed source, the capsule of which has the same construction and is made with exactly the same materials as those of the sealed source that it represents, but containing, in place of the radioactive material, a substance resembling it as closely as is practical in physical and chemical properties

3.3
leachable
soluble in water, yielding quantities greater than 0,1 mg/g in 100 ml of still water maintained at 50 °C for 4 h

3.4
leakage
transfer of contained radioactive material from the sealed source to the environment

3.5
leaktight
term applied to sealed sources which, after undergoing leakage testing, meet the acceptance criteria

Note 1 to entry: The acceptance criteria are given in Table 1.

3.6
model designation
manufacturer's unique term (number, code or a combination of these) which is used to identify a specific design of sealed source

3.7
non-destructive test
test used to detect internal, surface and concealed defects or imperfections in materials, using techniques that do not damage or destroy the items being tested

3.8
non-leachable
insoluble in water, yielding quantities less than 0,1 mg/g in 100 ml of still water maintained at 50 °C for 4 h

3.9
sealed source
radioactive material sealed in a capsule or associated with a material to which it is closely bonded, this capsule or bonding material being strong enough to maintain leaktightness of the sealed source under the conditions of use and wear for which it was designed

3.10
simulated sealed source
facsimile of a sealed source, the capsule of which has the same construction and is made with exactly the same materials as those of the sealed source that it represents but it contains, in place of the radioactive material, a substance resembling it as closely as possible in physical and chemical properties and trace quantities of radioactive material

Note 1 to entry: The tracer is in a form soluble in a solvent which does not attack the capsule and has the maximum activity compatible with its use in a containment enclosure.

3.11
standard helium leakage rate
helium leakage rate at an upstream pressure of 10^5 Pa ± 5 × 10^3 Pa and a downstream pressure of 10^3 Pa or less at a temperature of 296 K ± 7 K (23 °C ± 7 °C)

Note 1 to entry: In this document, the unit Pascal cubic meter per second is used[1)].

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1) $[1 \times 10^{-6}\ \text{Pa}\cdot\text{m}^3 \cdot \text{s}^{-1} = 1\ \mu\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1} \approx 10^{-5}\ \text{atm}\cdot\text{cm}^3\cdot\text{s}^{-1} \approx 1 \times 10^{-5}\ \text{mbar}\cdot\text{l}\cdot\text{s}^{-1} \approx 7,5 \times 10^{-3}\ \text{lusec.}]$

3.12
test source
sample used in the performance tests, having the same material and construction as sealed sources of the model for which classification is being established

Note 1 to entry: A test source may be a simulated sealed source, a dummy sealed source or production source.

Note 2 to entry: The performance tests are described in ISO 2919.

4 Requirements

The tests described in this document are all designed to test and verify that the sealed source is leaktight. However not all tests are applicable in all circumstances. Correct application and choice of test method and testing media is critically important in designing an effective leak test programme. Factors to be considered include:

— the chemical form of the active material if leak test is by radioactive means;

— the type of test liquid used in immersion tests;

— the number of encapsulations;

— the internal void volume when tests are carried out by volumetric means;

— the temperature of the sealed source;

— the suitability of the test method for the environment in which it is being performed;

— the reason for performing the test (integrity testing of a test source, production leakage tests, routine in service testing);

— the required sensitivity and acceptance criteria.

The test programme for test and production sealed sources should be considered as part of the design process and validated or justified as appropriate to demonstrate its effectiveness and sensitivity. This process may include the analysis of historic data.

The tests described in this document shall be designed, validated and carried out by competent and qualified persons who have demonstrable appropriate training in the applied test methods. For test methods by radioactive means, the persons shall also have appropriate training in radiation protection and measurement.

NOTE 1 Qualification and certification methods for non-destructive testing personnel can be found in ISO 9712[2].

An evaluation should be made of uncertainty in the case of non-binary test results (e.g. radiation measurements on immersion test samples) and taken account of in sentencing the result.

Guidance for choosing suitable tests are specified in Annex A.

According to the test type and the sealed source type, at least one of each of the tests described in Clauses 5 and 6 should be carried out [see Annex A for the choice of the test(s)].

It should be noted that it is best practice to carry out more than one type of leakage test and also to perform a final wipe as a contamination check.

The tests described in this document do not form an exhaustive list, and other test methods may be developed. However, in the case where a special test, which is not described in this document, is carried out (see Clause 1), the organisation shall validate that the applied method is at least as effective as the corresponding method(s) given in this document in order to be able to claim compliance with this document.

At the conclusion of the performed test(s), the sealed source shall be considered to be leaktight if it complies with the acceptance criteria specified in Table 1.

It has been asserted that there is correspondence between the acceptance criteria for volumetric and radioactive leak tests. Whilst there is no universally accepted basis for this assertion, experience has shown that sources meeting the acceptance criteria shown in Table 1 have not subsequently been found to leak.

NOTE 2 A leakage rate of 10 µPa · m^3 · s^{-1} for non-leachable solid contents and a rate of 0,1 µPa · m^3 · s^{-1} for leachable solids and liquids was historically considered to be equivalent to the activity release limit of 2 000 Bq (≈50 nCi)[18].

NOTE 3 A further confirmation of the volumetric acceptance threshold is given by Reference [8]. A leakage rate of 10^{-7} atm · cm^3 · s^{-1} or more based on dry air at 298 K (25 °C) and for a pressure difference of 1 atm against a vacuum of 10^{-2} atm (equivalent to or less) is considered to represent a loss of leaktightness, irrespective of the physical nature of the content.

Table 1 — Threshold detection values and limiting values for different test methods

Test method	Subclause	Threshold of detection[a]	Acceptance criteria	
			Non-leachable content	**Leachable or gaseous content**
Radioactive methods				
Immersion test (hot liquid)	5.1.1	(10 to 1) Bq	<200 Bq	<200 Bq
Immersion test (boiling liquid)	5.1.2	(10 to 1) Bq	<200 Bq	<200 Bq
Immersion test with a liquid scintillator	5.1.3	(10 to 1) Bq	<200 Bq	<200 Bq
Immersion test at room temperature	5.1.4	(10 to 1) Bq	<200 Bq	<200 Bq
Gaseous emanation test	5.2.1	(4 à 0,4) Bq	*Unsuitable*	<200 Bq (^{222}Rn/12 h)
Emanation test with a liquid scintillator	5.2.2	(0,4 to 0,004) Bq	*Unsuitable*	<200 Bq (^{222}Rn/12 h)
Gaseous emanation test (for krypton-85 sealed sources)	5.2.3	(10 to 1) Bq	*Unsuitable*	<4 000 Bq (^{85}Kr/24 h)
Wet wipe test	5.3.1	(10 to 1) Bq	<200 Bq	<200 Bq
Dry wipe test	5.3.2	(10 to 1) Bq	<200 Bq	<200 Bq
Non-radioactive methods – Helium tests		Standard helium leakage rate		
Helium test *(He filling before sealing)*	6.1.1	(10^{-2} to 10^{-4}) µPa · m^3 · s^{-1}	<1 µPa · m^3 · s^{-1}	<0,01 µPa · m^3 · s^{-1}
Helium pressurisation test *(He bombing after sealing)*	6.1.2	(1 to 10^{-2}) µPa · m^3 · s^{-1}	<1 µPa · m^3 · s^{-1}	<0,01 µPa · m^3 · s^{-1}
Non-radioactive methods – Bubble tests		Corresponding standard helium leakage rate		
Vacuum bubble test	6.2.1	(10 to 1) µPa · m^3 · s^{-1}[b]	No bubbles observed	*Not sensitive enough*
Hot-liquid bubble test	6.2.2	(50 to 5) µPa · m^3 · s^{-1}[b]	*Not sensitive enough*	*Not sensitive enough*

[a] The threshold of detection is expressed as a range; its upper end defines the smallest detectable leak under typical, well controlled industrial leak testing conditions and its lower end indicates the smallest detectable leak under excellent (ideal) industrial leak testing conditions. Smaller leaks than those indicated can be detected under laboratory conditions.

[b] Threshold values shown for bubble tests are rough approximations of the corresponding standard helium leakage rates and are applicable only to single leaks under favourable visual conditions.

Table 1 *(continued)*

Test method	Subclause	Threshold of detection[a]	Acceptance criteria	
			Non-leachable content	Leachable or gaseous content
Gas pressurisation bubble test	6.2.3	(10 to 1) µPa · m^3 · s^{-1}[b]	No bubbles observed	*Not sensitive enough*
Liquid nitrogen bubble test	6.2.4	(10^{-1} to 10^{-2}) µPa · m^3 · s^{-1}[b]	No bubbles observed	No bubbles observed
Non-radioactive methods – Mass gain		Mass gain of water [µg]		
Water pressurisation test	6.3	10	Mass gain < 50	*Not sensitive enough*

[a] The threshold of detection is expressed as a range; its upper end defines the smallest detectable leak under typical, well controlled industrial leak testing conditions and its lower end indicates the smallest detectable leak under excellent (ideal) industrial leak testing conditions. Smaller leaks than those indicated can be detected under laboratory conditions.

[b] Threshold values shown for bubble tests are rough approximations of the corresponding standard helium leakage rates and are applicable only to single leaks under favourable visual conditions.

Prior to undergoing the following leakage tests the source shall be subject to a thorough visual examination. The source may have to be cleaned to facilitate this. Any cleaning method should avoid the blocking of any potential leakage path for subsequent tests.

All equipment used for tests shall be suitably maintained and calibrated.

The wipe test should only be considered as a leakage test for some specific types of sources (e.g. sources with very thin windows such as foils for smoke detectors), for periodic inspections and in cases where no other test is more suitable.

Wipe tests or liquid immersion test samples should, wherever possible, be checked immediately on basic contamination measuring equipment; for example, a Geiger counter to establish whether there is any gross contamination prior to final measurement on more sophisticated calibrated equipment.

5 Test methods by radioactive means

5.1 Immersion tests

NOTE Suitable assay techniques for evaluation of the activity in the test liquids for all of these immersion tests may be found in ISO 19361[3] and ISO 19581[4].

5.1.1 Immersion test (hot liquid)

Immerse the sealed source in a liquid which does not attack the material of the outer surfaces of the source and which, under the conditions of this test, is considered effective for detection of a leak. Examples of such liquids include distilled water, weak detergent solutions or chelation agents and also slightly alkaline or acid solutions with concentrations of about 5 %. Heat the liquid to 323 K ± 5 K (50 °C ± 5 °C) and maintain it at that temperature for at least 4 h. Remove the sealed source and measure the activity of the liquid. If a group of more than one source is tested at the same time in the liquid sample, the acceptance criteria for a single source shall be used for the group as all the activity in the liquid sample could be originating from a single leaking source. Further testing shall be performed in such cases on smaller groups, or individual sources, in order to identify the leaking source and positively confirm leak tightness of other sources in the group.

An ultrasonic cleaning method can also be used. In this case, the immersion time in the liquid at 343 K ± 5 K (70 °C ± 5 °C) can be reduced to approximately 30 min.

5.1.2 Immersion test (boiling liquid)

Immerse the sealed source in a liquid which does not attack the material of the outer surfaces of the source and which, under the conditions of this test, is considered effective for detection of a leak.