



BSI Standards Publication

Safe transport of radioactive materials — Leakage testing on packages

National foreword

This British Standard is the UK implementation of EN ISO 12807:2021. It is identical to ISO 12807:2018. It supersedes BS ISO 12807:2018, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee NCE/9, Nuclear Installations, Processes & Technologies.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Date	Text affected
28 February 2021	This corrigendum renumbers BS ISO 12807:2018 as BS EN ISO 12807:2021

English Version

Safe transport of radioactive materials - Leakage testing on packages (ISO 12807:2018)

Sûreté des transports de matières radioactives -
Contrôle de l'étanchéité des colis (ISO 12807:2018)

Kernbrennstofftechnologie - Sicherer Transport von
radioaktivem Material - Dichtheitsprüfung der
Verpackung (ISO 12807:2018)

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European foreword

The text of ISO 12807:2018 has been prepared by Technical Committee ISO/TC 85 "Nuclear energy, nuclear technologies, and radiological protection" of the International Organization for Standardization (ISO) and has been taken over as EN ISO 12807:2021 by Technical Committee CEN/TC 430 "Nuclear energy, nuclear technologies, and radiological protection" the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 2021, and conflicting national standards shall be withdrawn at the latest by August 2021.

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Endorsement notice

The text of ISO 12807:2018 has been approved by CEN as EN ISO 12807:2021 without any modification.

Contents

Page

Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Symbols and units	4
5 Regulatory requirements	7
5.1 Relevant regulations	7
5.2 Regulatory containment requirements	7
6 Procedure for meeting the requirements of this document	7
6.1 General	7
6.2 Quality management system	8
6.3 Procedure	8
6.3.1 General	8
6.3.2 Determination of permissible activity release rates	9
6.3.3 Determination of standardized leakage rates	10
6.3.4 Determination of permissible test leakage rates for each verification stage	10
6.3.5 Selection of appropriate test methods	10
6.3.6 Performance of test and record of results	10
7 Determination of permissible activity release rates	10
7.1 Step 1: List the radioactive contents, A_i	10
7.2 Step 2: Determine the total releasable activity, RI_T	10
7.3 Step 3: Determine the maximum permissible activity release rates, R	11
8 Determination of standardized leakage rates	11
8.1 General	11
8.2 Step 4: Determine the activity release rate due to permeation, RP	12
8.3 Step 5: Determine the maximum permissible activity release rate due to leakage, RG	12
8.4 Step 6: Determine the activity per unit volume of the containment system medium, C	12
8.5 Step 7: Determine the maximum permissible volumetric leakage rate of the medium, L	12
8.6 Step 8: Determine the maximum permissible equivalent capillary leak diameter, D	12
8.7 Step 9: Determine the permissible standardized leakage rate, Q_{SLR}	13
9 Containment-system verification requirements	13
9.1 Containment-system verification stages	13
9.1.1 General	13
9.1.2 Design verification	14
9.1.3 Fabrication verification	14
9.1.4 Preshipment verification	14
9.1.5 Periodic verification	15
9.1.6 Maintenance verification	15
9.2 Verification requirements	15
9.2.1 General	15
9.2.2 Step 10: Determine permissible test leakage rate for each verification stage, Q_{TDA} , Q_{TDN} , Q_{TF} , Q_{TS} , Q_{TP} and Q_{TM}	15
9.2.3 Step 11: Select appropriate test methods	15
10 Leakage test procedure requirements	16
10.1 General	16
10.2 Step 12: Perform tests and record results	16
10.3 Test sensitivity	16
10.4 Test procedure requirements	16
10.4.1 General	16

10.4.2 Testing.....	16
Annex A (informative) Preferred leakage test methods	17
Annex B (informative) Methods of calculation.....	31
Annex C (informative) Conversion tables.....	36
Annex D (informative) Worked examples.....	37
Annex E (informative) Rationale	72
Bibliography	85

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 5, *Nuclear installations, processes and technologies*.

This second edition cancels and replaces the first edition (ISO 12807:1996), which has been technically revised.

In this document, the word “shall” denotes a requirement; the word “should” denotes a recommendation; and the word “may” denotes permission, neither a requirement nor a recommendation. Imperative statements also denote requirements. To conform with this document, all operations shall be performed in accordance with its requirements, but not necessarily with its recommendations.

The words “can”, “could” and “might” denote possibility rather than permission.

The word “will” denotes that an event is certain to occur rather than a requirement.

Introduction

The International Atomic Energy Agency (IAEA) *Regulations for the Safe Transport of Radioactive Material* specify permitted release of radioactivity under normal and accident conditions of transport, in terms of activity per unit of time, for Type B(U), Type B(M) and Type C packages used to transport radioactive materials. Generally, it is not practical to measure activity release directly. The usual method used is to relate activity release to non-radioactive fluid leakage, for which several leakages test procedures are available. The appropriate procedure will depend on its sensitivity and its application to a specific package.

The regulations specify permissible activity release for normal and accident conditions of transport. These activity release limits can be expressed in maximum permissible activity release rates for the radioactive material carried within a containment system.

In general, it is not feasible to demonstrate that the activity release limits are not exceeded by direct measurement of activity release. In practice, the most common method to prove that a containment system provides adequate containment is to carry out an equivalent gas leakage rate test.

Safe transport of radioactive materials — Leakage testing on packages

1 Scope

This document specifies gas leakage test criteria and test methods for demonstrating that packages used to transport radioactive materials comply with the package containment requirements defined in the International Atomic Energy Agency (IAEA) *Regulations for the Safe Transport of Radioactive Material* for:

- design verification;
- fabrication verification;
- preshipment verification;
- periodic verification;
- maintenance verification.

This document describes a method for relating permissible activity release of the radioactive contents carried within a containment system to equivalent gas leakage rates under specified test conditions. This approach is called gas leakage test methodology. However, in this document it is recognized that other methodologies might be acceptable, provided that they demonstrate that any release of the radioactive contents will not exceed the regulatory requirements, and subject to agreement with the competent authority.

This document provides both overall and detailed guidance on the complex relationships between an equivalent gas leakage test and a permissible activity release rate. Whereas the overall guidance is universally agreed upon, the use of the detailed guidance shall be agreed upon with the competent authority during the Type B(U), Type B(M) or Type C packages certification process.

It should be noted that, for a given package, demonstration of compliance is not limited to a single methodology.

While this document does not require particular gas leakage test procedures, it does present minimum requirements for any test that is to be used. It is the responsibility of the package designer or consignor to estimate or determine the maximum permissible release rate of radioactivity to the environment and to select appropriate leakage test procedures that have adequate sensitivity.

This document pertains specifically to Type B(U), Type B(M) or Type C packages for which the regulatory containment requirements are specified explicitly.

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.

International Atomic Energy Agency (IAEA). *Regulations for the Safe Transport of Radioactive Material*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in the International Atomic Energy Agency (IAEA), *Regulations for the Safe Transport of Radioactive Material* and the following 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 <https://www.electropedia.org/>

3.1

activity release rate

loss of radioactive contents per unit time through leaks or permeable walls of a containment system

3.2

blockage mechanism

mechanism by which radioactive material might be retained within a containment system due to blockage of potential leakage paths by solid or liquid material

3.3

competent authority

any national or international authority designated or recognized as such for any purpose in connection with the International Atomic Energy Agency (IAEA) *Regulations for the Safe Transport of Radioactive Material* and other applicable regulations

3.4

containment system

assembly of components of the packaging intended to retain the radioactive material during transport

3.5

gas leakage test methodology

method of specifying a gas leakage test which relates permissible activity release rates of the radioactive contents carried within a containment system to equivalent gas leakage rates under specified test conditions

3.6

leak

any unwanted opening or openings through a containment system that could permit the escape of the contents

3.7

leakage

transfer of a material from the containment system to the environment through a leak or leaks

Note 1 to entry: See also *permeation* (3.14).

3.8

leakage rate

quantity of solid particles, liquids or gases passing through leaks per unit time

Note 1 to entry: The term leakage rate can refer to the radioactive material (gas, liquid, solid or any mixture of these) or to the test fluid.

Note 2 to entry: The dimensions of the rate of solid leakage are mass divided by time. The dimensions of the rate of liquid leakage can be mass divided by time or volume divided by time. The dimensions of the rate of gas leakage are the product of pressure and volume (this is a mass-like unit) divided by time at a known temperature.

3.9

leaktight

general term indicating that a containment system meets the required level of containment for particular contents

Note 1 to entry: See Clause 8 in [Annex E](#).

3.10**medium**

any fluid, which might or might not be radioactive itself, which could carry radioactive material through a leak or leaks

3.11**molecular flow**

flow of gas through a leak under conditions such that the mean free path is greater than the largest dimension of a transverse section of the leak

Note 1 to entry: The rate of molecular flow depends on the partial pressure gradient.

3.12**package**

packaging together with its radioactive contents as presented for transport

3.13**packaging**

assembly of components necessary to enclose the radioactive contents completely

3.14**permeation**

passage of a fluid through a solid permeable barrier (even if there are no leaks) by adsorption-diffusion-desorption mechanisms

Note 1 to entry: Permeation should not be considered as a release of activity unless the fluid itself is radioactive. In this document, permeation is applied only to gases.

3.15**permeation rate**

quantity of gases passing through permeable walls per unit time

Note 1 to entry: The permeation rate depends on the partial pressure gradient.

3.16**qualitative**

refers to leakage test procedures which detect the presence of a leak but do not measure leakage rate or total leakage

3.17**quantitative**

leakage test procedures which measure total leakage rate(s) from a containment system or from parts of it

3.18 Sensitivity**3.18.1****sensitivity of a leakage detector**

minimum usable response of the detector to tracer fluid leakage, that is, the leakage rate that will produce a repeatable change in the detector reading

3.18.2**sensitivity of a leakage test procedure**

minimum detectable leakage rate that the test procedure is capable of detecting

3.19 standardized leakage rate SLR

leakage rate, evaluated under known conditions, normalized to the flow of dry air at reference conditions of upstream pressure $1,013 \times 10^5$ Pa, downstream pressure 0,0 Pa and temperature of 298 K (25 °C)

Note 1 to entry: The units for standardized leakage rate are written as $\text{Pa} \cdot \text{m}^3 \cdot \text{s}^{-1}$ SLR.

3.20 standardized helium leakage rate SHeLR

helium leakage rate, evaluated under known conditions, normalized to the flow of dry helium at reference conditions of upstream pressure $1,013 \times 10^5$ Pa, downstream pressure 0,0 Pa and temperature of 298 K (25 °C)

Note 1 to entry: The units for standardized helium leakage rate are written as $\text{Pa} \cdot \text{m}^3 \cdot \text{s}^{-1}$ (SHeLR).

3.21 test gas or tracer gas

gas that is used to detect leakage or measure leakage rates

3.22 viscous flow

continuous flow of gas through a leak under conditions such that the mean free path is very small in comparison with the smallest dimension of a transverse section of the leak

Note 1 to entry: This flow may be either laminar or turbulent. Viscous flow depends upon total pressure gradient.

4 Symbols and units

The following symbols and units are used in this document.

Symbol	Definition	Unit
A_i	Activity of radionuclide i	Bq
A_2	Quantity (activity) of radioactive material, other than special-form radioactive material, as defined in the applicable documents listed in the International Atomic Energy Agency (IAEA) <i>Regulations for the Safe Transport of Radioactive Material</i>	Bq
A_{2i}	A_2 value of radionuclide i	Bq
a	Capillary length/leakage hole length	m
C	Average activity per unit volume; the symbol is used to simplify Figure 1 and represents the use of either C_A or C_N	$\text{Bq} \cdot \text{m}^{-3}$
C_A	Average activity per unit volume of the medium that could escape from the containment system under accident conditions of transport	$\text{Bq} \cdot \text{m}^{-3}$
C_N	Average activity per unit volume of the medium that could escape from the containment system under normal conditions of transport	$\text{Bq} \cdot \text{m}^{-3}$
D	Capillary diameter/leakage hole diameter	m
D	Maximum permissible diameter; the symbol is used to simplify Figure 1 and represents the use of either D_A or D_N	m
D_A	Maximum permissible equivalent capillary leak diameter under accident conditions of transport	m
D_B	Bubble diameter	m
D_N	Maximum permissible equivalent capillary leak diameter under normal conditions of transport	m
FC_{iA}	Release fraction of radionuclide i from the radioactive contents into the containment system under accident conditions of transport	—

Symbol	Definition	Unit
FC_{iN}	Release fraction of radionuclide i from the radioactive contents into the containment system under normal conditions of transport	—
FE_{iA}	Fraction of radionuclide i which is available for release from the containment system into the environment under accident conditions of transport	—
FE_{iN}	Fraction of radionuclide i which is available for release from the containment system into the environment under normal conditions of transport	—
g	Acceleration due to gravity	$g = 9,81 \text{ m}\cdot\text{s}^{-2}$
g_0	Constant	$g_0 = 1 \text{ kg m N}^{-1}\cdot\text{s}^{-2}$
H	Test duration	s
h	Liquid height	m
L	Volumetric leakage rate	$\text{m}^3\cdot\text{s}^{-1}$
L	Maximum permissible volumetric leakage rate; the symbol is used to simplify Figure 1 and represents the use of either L_A or L_N	$\text{m}^3\cdot\text{s}^{-1}$
L_A	Maximum permissible volumetric leakage rate of the medium at pressure p_A , under accident conditions of transport	$\text{m}^3\cdot\text{s}^{-1}$
L_N	Maximum permissible volumetric leakage rate of the medium at pressure p_N , under normal conditions of transport	$\text{m}^3\cdot\text{s}^{-1}$
M	Relative molecular mass	$\text{kg}\cdot\text{mol}^{-1}$
M_i	Relative molecular mass of component i	$\text{kg}\cdot\text{mol}^{-1}$
M_{mix}	Relative molecular mass of mixture	$\text{kg}\cdot\text{mol}^{-1}$
p_A	Containment system pressure under accident conditions of transport	Pa
p_N	Containment system pressure under normal conditions of transport	Pa
p_d	Downstream pressure	Pa
p_i	Partial pressure of one component i of gas mixture	Pa
p_{mix}	Total pressure of gas mixture	Pa
p_s	Reference pressure	$p_s = 1,013 \times 10^5 \text{ Pa}$
p_t	Partial pressure of tracer gas	Pa
p_u	Upstream pressure	Pa
p_1	Gas pressure at start of test	Pa
p_2	Gas pressure at end of test	Pa
Q	Leakage rate	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
Q_{SLR}	Standardized leakage rate; the symbol is used to simplify Figure 1 and represents the use of either $Q_{A(\text{SLR})}$ or $Q_{N(\text{SLR})}$	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
Q_A	The permissible leakage rate of the medium under accident conditions of transport and is calculated from L_A	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
$Q_{A(\text{SLR})}$	The permissible standardized leakage rate (SLR) under accident conditions of transport	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
Q_m	Leakage rate for molecular flow	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
Q_{mix}	Leakage rate for gas mixture	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
Q_N	The permissible leakage rate of the medium under normal conditions of transport and is calculated from L_N	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
$Q_{N(\text{SLR})}$	The permissible standardized leakage rate (SLR) under normal conditions of transport	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
Q_p	Permeation rate	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
Q_{TDA}	The permissible test leakage rate of the tracer or test gas that is related to accident conditions of transport at the design verification stage and is determined from $Q_{A(\text{SLR})}$	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$

Symbol	Definition	Unit
Q_{TDN}	The permissible test leakage rate of the tracer or test gas that is related to normal conditions of transport at the design verification stage and is determined from $Q_{\text{N(SLR)}}$	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
Q_{TF}	The permissible test leakage rate of the tracer gas at the fabrication verification stage	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
Q_{TM}	The permissible test leakage rate of the tracer gas at the maintenance verification stage	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
Q_{TP}	The permissible test leakage rate of the tracer gas at the periodic verification stage	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
Q_{TS}	The permissible test leakage rate of the tracer gas at the preshipment verification stage	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
Q_{v}	Leakage rate for viscous flow	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
R	Universal gas constant	$R = 8,31 \text{ J mol}^{-1} \text{ K}^{-1}$
R	Maximum permissible activity release rate; the symbol is used to simplify Figure 1 and represents the use of either R_{A} or R_{N}	$\text{Bq}\cdot\text{s}^{-1}$
R_{A}	Maximum permissible activity release rate of the contents under accident conditions of transport	$\text{Bq}\cdot\text{s}^{-1}$
R_{N}	Maximum permissible activity release rate of the contents under normal conditions of transport	$\text{Bq}\cdot\text{s}^{-1}$
RG	Maximum permissible activity release rate of the gas contents; the symbol is used to simplify Figure 1 and represents the use of either RG_{A} or RG_{N}	$\text{Bq}\cdot\text{s}^{-1}$
RG_{A}	Maximum permissible activity release rate of the gas contents under accident conditions of transport after allowing for permeation	$\text{Bq}\cdot\text{s}^{-1}$
RG_{N}	Maximum permissible activity release rate of the gas contents under normal conditions of transport after allowing for permeation	$\text{Bq}\cdot\text{s}^{-1}$
RI_{iA}	Releasable activity of radionuclide i under accident conditions of transport	Bq
RI_{iN}	Releasable activity of radionuclide i under normal conditions of transport	Bq
RI_{T}	Total releasable activity for all radionuclides; the symbol is used to simplify Figure 1 and represents the use of either RI_{TA} or RI_{TN}	Bq
RI_{TA}	Total releasable activity for all radionuclides under accident conditions of transport	Bq
RI_{TN}	Total releasable activity for all radionuclides under normal conditions of transport	Bq
RP	Activity release rate due to permeation; the symbol is used to simplify Figure 1 and represents the use of either RP_{A} or RP_{N}	$\text{Bq}\cdot\text{s}^{-1}$
RP_{A}	Activity release rate due to permeation under accident conditions of transport	$\text{Bq}\cdot\text{s}^{-1}$
RP_{N}	Activity release rate due to permeation under normal conditions of transport	$\text{Bq}\cdot\text{s}^{-1}$
S	Leakage rate sensitivity	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$
SHeLR	Standardized helium leakage rate	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ SHeLR
SLR	Standardized leakage rate	$\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ SLR
T	Fluid absolute temperature	K
T_0	Reference temperature	$T_0 = 298 \text{ K}$
T_1	Gas temperature at start of test	K
T_2	Gas temperature at end of test	K
u	Velocity	$\text{m}\cdot\text{s}^{-1}$
V	Gas volume	m^3
V_{A}	Volume of medium under accident conditions of transport	m^3
V_{N}	Volume of medium under normal conditions of transport	m^3
μ	Dynamic viscosity of fluid	$\text{Pa}\cdot\text{s}$

Symbol	Definition	Unit
μ_i	Viscosity of component <i>i</i>	Pa·s
μ_{mix}	Viscosity of mixture	Pa·s
v	Bubble-generation rate	s ⁻¹
ρ	Density	kg m ⁻³
ρ_g	Gas density	kg m ⁻³
ρ_l	Liquid density	kg m ⁻³
σ	Liquid surface tension	N m ⁻¹

5 Regulatory requirements

5.1 Relevant regulations

See 5.1 in [Annex E](#) for further information on relevant regulations.

5.2 Regulatory containment requirements

See 5.2 in [Annex E](#) for further information on the Type B(U), Type B(M) or Type C packages containment requirements.

6 Procedure for meeting the requirements of this document

6.1 General

Compliance with package containment requirements may be demonstrated either by measurement of the radioactive-contents release rate or by other methods. This document shows how the package containment requirements can be demonstrated by an equivalent gas leakage test. All measured test leakage rates shall be correlated to the potential release of the contained material by performance of tests on prototypes or models, reference to previous demonstrations, calculations or reasoned arguments.

This document is based on the following premises.

- a) The radioactive material which could be released from the package could be in any one or any combination of the following forms:
 - liquid;
 - gas;
 - solid;
 - liquids with solids in suspension;
 - particulate solids in a gas (aerosols).

The maximum permissible activity release rate can be expressed in terms of a maximum permissible leak diameter when the physical form and properties of the radioactive contents are taken into account.

- b) The assumption of steady-state condition is an appropriate approximation.
- c) Gas leakage test procedure can be used to measure gas flow rates. These rates can be related mathematically to the diameter of a single straight capillary which in most cases is considered to conservatively represent a leak or leaks.

- d) Gas leakage test procedures can be used to demonstrate compliance with regulatory containment requirements when the diameter of the single straight capillary associated with the leakage test from 6.1 c) is equal to or smaller than the maximum permissible leak diameter from 6.1 a).

For activity release, or retention considerations, according to this document, the phenomena of viscous flow, molecular flow, permeation and blockage should be considered.

6.2 Quality management system

A management system, based on international, national or other standards, shall be established and implemented. To ensure the consistent quality of the activities described in this document, the implementation of ISO 9001:2015 is advised.

See 6.2 in [Annex E](#) for further information on the regulatory requirements on the management system.

6.3 Procedure

6.3.1 General

Using the flow chart in [Figure 1](#) as a guide, the procedure below shall be used. The text within each box in the flow chart indicates the result of the particular step.

Steps 1 to 8 in [Figure 1](#) pertain to containment of the radioactive contents, while Steps 10 to 12 pertain to leakage of a test gas. Step 9 is a reference step which links containment of the radioactive contents to the leakage of a test gas.

Because the releasable radioactive material might be in the form of gas, liquid or solid, or a combination of these, it is necessary to follow the appropriate part of the procedure below, as applicable to the form of the radioactive material, to obtain the permissible standardized leakage rates.

[Figure 1](#) has been prepared for the general case. In some cases, it is not necessary to complete all the steps, for example, in the case of a single radionuclide in liquid form. In other cases, such as a mixture of radioactive materials that are in different forms, it might be necessary to repeat some steps in a reiterative fashion. However, for any of these cases it will be necessary to complete the appropriate steps in [Figure 1](#) for both normal and accident conditions of transport.

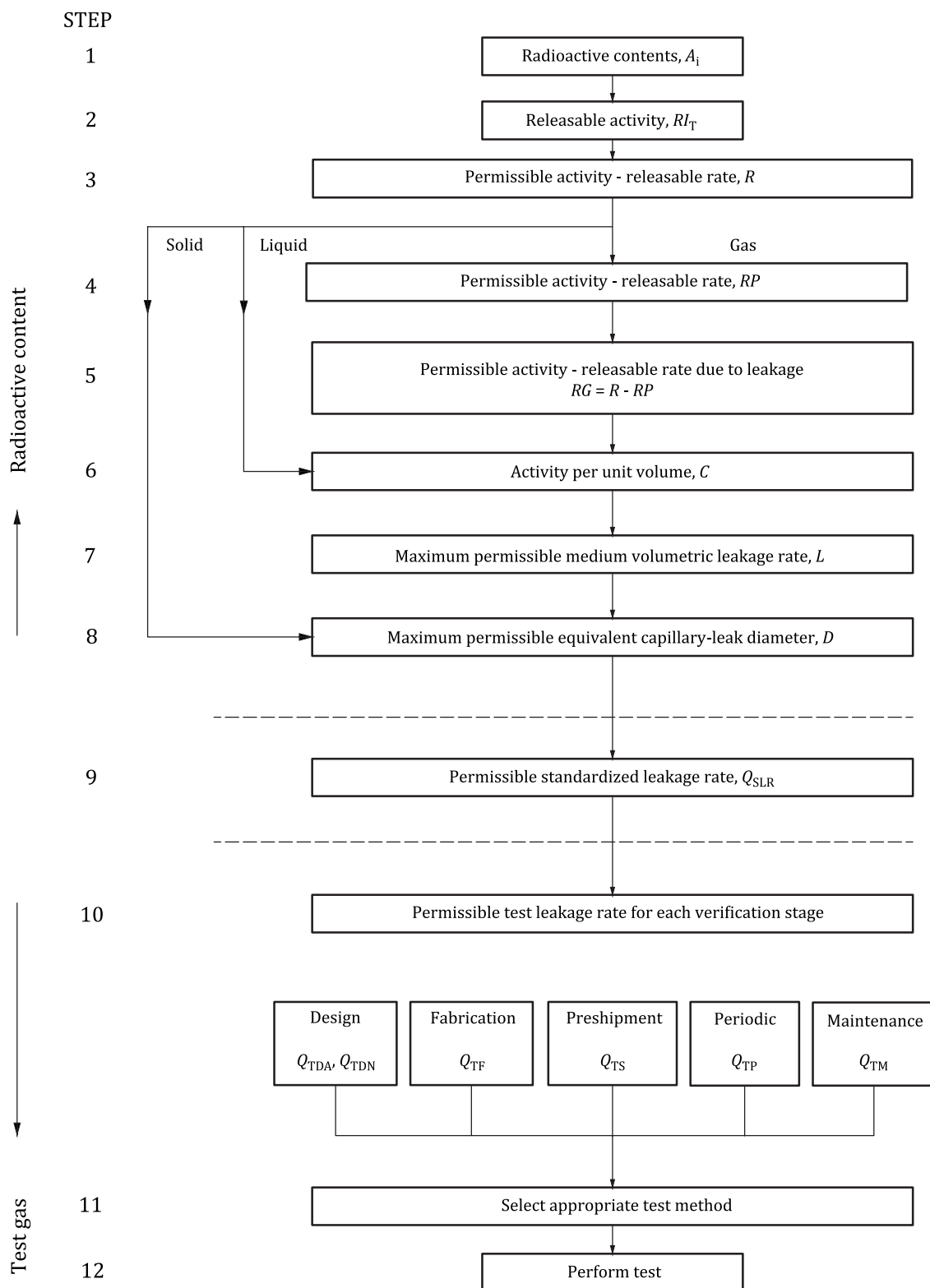


Figure 1 — Flow chart for gas leakage test methodology

6.3.2 Determination of permissible activity release rates

The inventory of the releasable radioactive contents shall be identified and the releasable contents shall be compared to the regulatory containment requirements. See Steps 1 to 3 in [Figure 1](#) and [Clause 7](#).

6.3.3 Determination of standardized leakage rates

The permissible activity release rates shall be converted to equivalent standardized leakage rates. See Steps 4 to 9 in [Figure 1](#) and [Clause 8](#).

6.3.4 Determination of permissible test leakage rates for each verification stage

The appropriate gas leakage rates shall be determined for the design, fabrication, preshipment, periodic and maintenance verification stages. See Step 10 in [Figure 1](#) and [9.2](#).

6.3.5 Selection of appropriate test methods

The appropriate gas leakage test methods shall be selected for the design, fabrication, preshipment, periodic and maintenance verification stages. See Step 11 in [Figure 1](#) and [9.2](#).

6.3.6 Performance of test and record of results

The required tests shall be performed and the results shall be recorded. See Step 12 in [Figure 1](#) and [Clause 10](#).

7 Determination of permissible activity release rates

Permissible activity release rates shall be determined by following Steps 1 to 3 for both normal and accident conditions of transport.

7.1 Step 1: List the radioactive contents, A_i

This gives an inventory of the radioactive contents and includes the activity and physical characteristics for each radionuclide. It could be necessary to consider the contents as separate phases, i.e. liquids, gases and solids. Aerosols can be considered as gases. Fine particles in solution can be considered as a liquid.

When it is impractical to determine actual radioactive contents, the bounding radioactive contents shall be estimated by the user and shall be acceptable to the competent authority.

7.2 Step 2: Determine the total releasable activity, RI_T

In some cases, the radioactive contents might be contained by more than one container in the containment system. An irradiated fuel rod assembly in a transport packaging is an example of this situation. Then, for either normal or accident conditions of transport, only a fraction of the radioactive contents might be released from the innermost container into the containment system FC_{iN} , FC_{iA} and, of this fraction, only another fraction may be available for release from the containment system to the environment, FE_{iN} , FE_{iA} . The numerical value of any release fraction will depend on the specific radionuclide and, if the radioactive contents consist of a mixture of radionuclides, many release fraction values could result. Also, release fraction values for normal conditions of transport might differ from those for accident conditions of transport, even for the same radionuclide.

The releasable fractions depend upon such factors as:

- a) the chemical and physical forms of the materials within the containment system, for normal and accident conditions of transport;
- b) the possible release modes, such as permeation of gases, mobility of aerosols or particulates, reactions with water or other materials present in the system, and solubility;
- c) the maximum temperature, pressure, vibration, mechanical strains or distortions, and the like, to which the contained material would be subjected for normal and accident conditions of transport. These shall be determined by the performance of tests on prototypes or models, by reference to previous demonstrations, calculations, or a reasoned argument.

Where a release fraction cannot be quantified, a value of 1,0 shall be assumed. The values of the release fractions normally require agreement with the competent authority.

For normal conditions of transport, the releasable activity of radionuclide i , RI_{iN} , in becquerels, is:

$$RI_{iN} = FC_{iN} \times FE_{iN} \times A_i$$

and for the total inventory

$$RI_{TN} = \sum_i RI_{iN}$$

Similarly, for accident conditions of transport, the releasable activity of radionuclide i , RI_{iA} , in becquerels is:

$$RI_{iA} = FC_{iA} \times FE_{iA} \times A_i$$

and for the total inventory

$$RI_{TA} = \sum_i RI_{iA}$$

7.3 Step 3: Determine the maximum permissible activity release rates, R

The data from Steps 1 and 2 identify the radionuclides that could be released from the package and their physical form. Then, for any radionuclide, the A_2 value shall be established or, in the case of mixtures, an equivalent A_2 value shall be used (see paragraph 405 in the 2012 Edition of the International Atomic Energy Agency (IAEA) *Regulations for the Safe Transport of Radioactive Material*). Next, the regulatory containment requirements shall be calculated as indicated in E.5.2. At this stage, the containment requirements will be given in units of activity per hour or activity in a period of one week. Because gas leakage test rates are normally given in units of flow per second, it is necessary to convert the time units of the regulatory containment requirements to seconds for compatibility reasons. In this document it is assumed that leakage occurs at a uniform rate over the regulatory time period (1 h for normal conditions of transport/1 week for accident conditions of transport). Other time-averaging methods may be used, provided they are accepted by the competent authority. When all the above factors have been taken into account, the permissible activity release rates will have been determined.

8 Determination of standardized leakage rates

8.1 General

Standardized leakage rates shall be determined by following Steps 4 to 9 for both normal and accident conditions of transport.

In some cases, where the standardized leakage rates are relatively low, the relevant competent authority may permit the use of a specified rather than a calculated value for the standardized leakage rate. Also, where the standardized leakage rates are relatively high, the relevant competent authority may agree that leakage tests are inappropriate and unnecessary or may permit the use of a specified rather than a calculated value for the standardized leakage rate. See Clause 8 in [Annex E](#).

In this clause, the method for determining the standardized leakage rate (from which the test leakage rate can be determined) is detailed for all the leakage mechanisms. The procedure followed in Steps 4 to 9 shall establish maximum permissible standardized leakage rates which are numerically equivalent to the appropriate regulatory containment requirements.

A knowledge of the radioactive contents, their properties and of the containment system of the packaging is essential in order to carry out the requirements of Steps 4 to 9.

8.2 Step 4: Determine the activity release rate due to permeation, RP

For a radioactive gas, determine the release rate of activity due to permeation. See [B.13](#).

8.3 Step 5: Determine the maximum permissible activity release rate due to leakage, RG

When the contents include a radioactive gas, deduct the release rate due to permeation, as determined in Step 4, from the regulatory containment requirement which was determined in Step 3.

If $RG < 0$, the package does not meet the regulatory requirement.

If the pressure inside the containment system remains lower than the external one during the whole transport, activity can only be released by permeation and molecular flow (if predominant compared to laminar flow) driven by the partial pressures of radioactive substances.

8.4 Step 6: Determine the activity per unit volume of the containment system medium, C

The activity per unit volume in the medium that could escape from the containment system to the environment shall be designated as C_N and C_A for normal and accident conditions of transport respectively. Values of C_N and C_A depend upon the activity of each radionuclide and the fraction of inventory that is available for release to the containment cavity and then available for release to the environment.

For a medium volume of V_N , C_N , in becquerels per cubic metre ($Bq \cdot m^{-3}$), is determined as follows:

$$C_N = \frac{RI_{TN}}{V_N}$$

For a medium volume of V_A , C_A , in becquerels per cubic metre ($Bq \cdot m^{-3}$), is determined as follows:

$$C_A = \frac{RI_{TA}}{V_A}$$

8.5 Step 7: Determine the maximum permissible volumetric leakage rate of the medium, L

When the data from Step 3, or Step 5 if permeation shall be taken into account, are divided by the data from Step 6, the data for Step 7 results. This gives the maximum permissible volumetric flow rate of the medium that could escape from the package due to a leak. At this stage, the medium will be at its operating pressure and temperature conditions.

For normal conditions of transport, the maximum permissible volumetric leakage rate for the medium, L_N , in cubic metres per second ($m^3 \cdot s^{-1}$), shall be determined from the following equation:

$$L_N = \frac{R_N}{C_N}$$

For accident conditions of transport, the maximum permissible volumetric leakage rate for the medium, L_A , in cubic metres per second ($m^3 \cdot s^{-1}$), shall be determined from the following equation:

$$L_A = \frac{R_A}{C_A}$$

8.6 Step 8: Determine the maximum permissible equivalent capillary leak diameter, D

For liquids, the volumetric flow rate from Step 7 can be converted to a diameter for a single leak using the Poiseuille's law [[Formula \(B.7\)](#)].

For gases and aerosols, the volumetric leakage rates, L_N and L_A , from Step 7 shall be converted to permissible leakage rates, Q_N and Q_A , in pascals cubic metres per second ($\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$), by using the following equations:

$$Q_N = L_N \times p_N$$

$$Q_A = L_A \times p_A$$

For gas and aerosol leakage rates, a diameter for a single leak may be calculated using the Knudsen's law [Formula (B.1)].

For solids, including particulates, and some liquids, it might be possible, by assessing the characteristics of the radioactive material, such as particle size or fluid viscosity, to establish a limiting diameter through which the radioactive material will not flow and hence, by this blockage mechanism [see 6.1 C b) in Annex E], there will be no activity release. The use of this blockage mechanism shall be accepted by the competent authority.

8.7 Step 9: Determine the permissible standardized leakage rate, Q_{SLR}

Where the maximum permissible equivalent capillary leak diameter has been determined in Step 8, the value of this diameter may be used in Formula (B.1) to determine the permissible standardized leakage rate (see examples in D.3, D.10, D.11 and D.13).

If the total pressure in the containment system is lower than the external one (for instance, if the initial pressure in the containment system is lower than the external one, and if Q_{SLR} is such that the internal pressure remains lower than the external one during the whole transport (see example in D.15) and if molecular flow is the predominant mode, only molecular flow driven by the partial pressures of radioactive substances needs to be regarded. For this, the first summand of Formula (B.1) should be set to zero. In the second summand, the properties of the radioactive substances (molecular mass, partial pressure) shall be used. This assessment shall be performed for each relevant radioactive substance and the results shall be combined.

Standardized leakage rates shall be determined for both normal and accident conditions of transport, D_A shall be used to determine $Q_{A(SLR)}$ and D_N shall be used to determine $Q_{N(SLR)}$. Where the radioactive material is in more than one form, values of D_A , $Q_{A(SLR)}$, D_N and $Q_{N(SLR)}$ shall be determined for each form.

The most restrictive value of $Q_{A(SLR)}$ shall be assessed to determine if this value needs to be made more restrictive to account for the activity releases in the other forms.

Similarly, the most restrictive value of $Q_{N(SLR)}$ shall be assessed to determine if this value needs to be made more restrictive to account for the activity releases in the other forms.

The above determinations and assessments will result in the values of $Q_{A(SLR)}$ and $Q_{N(SLR)}$ that shall be used in Step 10.

9 Containment-system verification requirements

9.1 Containment-system verification stages

9.1.1 General

Compliance with package containment requirements shall be demonstrated by verification procedures at the design, fabrication, preshipment, periodic and maintenance stages. It is necessary to establish a set of test requirements for each test stage.

Verification procedures shall demonstrate that all the regulatory containment requirements will be satisfied for both normal and accident conditions of transport. Therefore, leakage tests are only part

of the verification procedures. It will be necessary to establish a set of procedures acceptable to the competent authority for the different verification stages.

Assembly shall be performed in accordance with a written quality assurance procedure that includes a checklist for verifying that all parts of the containment system comply with the applicable requirements, are in place, and are properly secured.

9.1.2 Design verification

Design verification procedures shall demonstrate that the package design meets all the regulatory containment requirements for both normal and accident conditions of transport.

The packaging shall be tested to show that it has a leakage rate less than or equal to the maximum permissible test leakage rates Q_{TDN} and Q_{TDA} .

The maximum permissible test leakage rates shall be Q_{TDN} and Q_{TDA} for tests relating to normal and accident conditions, respectively. When tests are carried out at conditions (such as temperature and pressure) which are different from the normal and accident conditions, it will be necessary to show that the measured leakage rates are relevant and representative.

See 9.1.2 in [Annex E](#) for further information on regulatory references.

9.1.3 Fabrication verification

Fabrication verification procedures shall demonstrate that each packaging of a given design is fabricated in such a way that the regulatory containment requirements will be satisfied for both normal and accident conditions of transport, assuming the package is correctly assembled before shipment and the packaging is correctly maintained.

The packaging shall be tested to show that it has a leakage rate less than or equal to the maximum permissible test leakage rate Q_{TF} . The entire containment boundary, including base material, welds, seals, closures, valves, rupture disks, or other boundary elements shall be tested, except those for which evidence can be given that the leakage rate is negligible.

The maximum permissible test leakage rate, Q_{TF} , shall be the more restrictive of Q_{TDN} and Q_{TDA} . Where the test conditions differ from the worst case conditions for normal and accident conditions as appropriate, test leakage rates shall be chosen such that the tests demonstrate that the package would not leak more than the maximum permissible leakage rates for normal and accident conditions of transport.

See 9.1.3 in [Annex E](#) for further information on regulatory references.

9.1.4 Preshipment verification

Preshipment verification procedures shall demonstrate that, before each shipment, and after the contents are loaded, the package is assembled and the packaging is maintained so that, during transport and in any conditions (normal and accident), regulatory containment requirements will be fulfilled. For this purpose, the procedures shall verify that the package has been properly assembled and the packaging is correctly maintained, and that the containment function has been established.

Preshipment verification shall show that the packaging has a leakage rate less than or equal to the maximum permissible test leakage rate, Q_{TS} .

The maximum permissible test leakage rate, Q_{TS} , shall be the more restrictive of Q_{TDN} and Q_{TDA} . Where the test conditions differ from the worst case conditions for normal and accident conditions as appropriate, test leakage rates shall be chosen such that the tests demonstrate that the package would not leak more than the maximum permissible leakage rates for normal and accident conditions of transport.

See Clause 8 in [Annex E](#) for further information on exception.

See 9.1.4 in [Annex E](#) for further information on regulatory references.

9.1.5 Periodic verification

Periodic verification procedures shall demonstrate that all packaging built to an approved design shall continue to comply with the regulatory containment requirement, even after repeated use.

The packaging shall be tested to show that it has a leakage rate less than or equal to the maximum permissible test leakage rate, Q_{TP} . Because of the possible difficulties with disassembly of component parts, the extent of the containment and the number of seals to be tested, the numerical value for Q_{TP} shall be accepted by the competent authority.

The time between periodic tests shall be acceptable to the competent authority.

See 9.1.5 in [Annex E](#) for further information on regulatory references.

9.1.6 Maintenance verification

Maintenance verification procedures shall demonstrate that any maintenance, repair, or replacement of components has not degraded the containment system.

Maintenance verification shall be performed prior to returning a package to service to show that it has a leakage rate less than or equal to the maximum permissible rate Q_{TM} .

Maintenance verification tests need only to be performed for the affected area or joint, and can be combined with the preshipment verification.

See 9.1.6 in [Annex E](#) for further information on regulatory references.

9.2 Verification requirements

9.2.1 General

The appropriate permissible test leakage rate for each verification stage, as described in [9.1](#), shall be determined in order to demonstrate that the containment system satisfies the regulatory containment requirements and appropriate test methods shall be selected.

9.2.2 Step 10: Determine permissible test leakage rate for each verification stage, Q_{TDA} , Q_{TDN} , Q_{TF} , Q_{TS} , Q_{TP} and Q_{TM}

The results from Step 9, as appropriate, shall be taken into account in specifying the permissible test leakage rates.

$Q_{A(SLR)}$ should be considered to determine Q_{TDA} and $Q_{N(SLR)}$ should be considered to determine Q_{TDN} . For Q_{TF} , Q_{TS} , Q_{TP} and Q_{TM} , the more restrictive value of $Q_{A(SLR)}$ and $Q_{N(SLR)}$ should be considered.

Similarly, the more restrictive value of the permissible standardized leakage rates, calculated for both normal and accident conditions of transport, shall be established for determining the appropriate permissible test leakage rate in Step 10.

See [B.2](#) and Clause 8 in [Annex E](#) for further information on the determination of standardized leakage rates and on the consideration of various test conditions (i.e. different tracer gases, operating temperatures and pressures during measurement).

9.2.3 Step 11: Select appropriate test methods

For each permissible test leakage rate established in Step 10 (design, fabrication, preshipment, periodic or maintenance), select an appropriate test method and specify suitable test procedures.

[Table A.1](#) lists some suitable test procedures.

10 Leakage test procedure requirements

10.1 General

All leakage tests shall be performed in accordance with a written quality-assurance program. Tests shall be performed in order to ensure that the leakage test requirements are met. If, during any fabrication, preshipment or verification test, it is found that the actual leakage rate is greater than the maximum permissible, actions shall be taken to reduce the leakage rate to the acceptable level.

10.2 Step 12: Perform tests and record results

The successful completion of this step will demonstrate compliance with the regulatory containment requirements. Minimum requirements for any gas leakage test procedure that is to be used are specified in [10.3](#) and [10.4](#).

10.3 Test sensitivity

The sensitivity of each leakage test procedure, as determined by reference to applicable literature or performance of tests, shall be considered adequate when it is less than or equal to one-half of the permissible test leakage rate for the tracer gas, as determined in Step 10 in [9.2.2](#).

Consideration shall be given to the leakage test procedures as they are applied to the test item. For example, the gas pressure drop test (test [A.3.1](#), [Table A.2](#)) and gas pressure rise test (test [A.3.2](#), [Table A.2](#)) are dependent on the gas volume under test, and therefore the sensitivity of these tests shall be adjusted (for volume as well as time). In many cases, the sensitivity of a leakage test procedure can be varied extensively by changing volume, pressure, temperature, mixture composition, or time. Leakage test procedures performed under well-controlled, laboratory conditions will normally be more sensitive than the same procedures under field conditions.

10.4 Test procedure requirements

10.4.1 General

Leakage test procedures shall be compatible with the test item, and, when applied to the containment system, shall have sufficient sensitivity to demonstrate compliance with test requirements for containment-system verification.

Allowable test leakage rates and test sensitivities shall be determined from activity release rates to satisfy the requirements for containment-system verification.

The tests shall be designed to preclude false acceptance. This might include assuring the presence of a tracer gas and a driving force (pressure difference).

Any necessary safety precautions shall be implemented.

Leakage test procedures shall be established and reviewed by personnel qualified according to ISO 9712 or equivalent standard. All leakage tests shall be performed by qualified operators. Operators should be qualified according to ISO 9712 or equivalent standard.

10.4.2 Testing

The user shall be responsible for verifying that the selected procedure is relevant to particular situations and that the test is applied correctly.

Testing shall be performed in accordance with [10.4.1](#), as applicable, and shall be documented.

Annex A (informative)

Preferred leakage test methods

A.1 General

There are numerous text books and submitted papers related to the complex subject of leakage testing methods. Some of these are listed in the Bibliography. The purpose of this annex is to assist the user in the selection of appropriate test procedures. Consequently, this annex gives a concise description of suitable leakage test methods, their range of sensitivity, their advantages and limitations and information about safety-related considerations.

It is the user's responsibility to specify a detailed test procedure that is appropriate to the particular situation. Often, this annex will not provide enough detail and therefore the user should obtain additional information from other sources. It is also the user's responsibility to ensure that the test procedure is applied correctly.

Leakage test procedures that are not listed in this document may be used if they meet the minimum requirements of this document and are acceptable to the competent authority.

Practical leakage testing techniques for measuring the leaktightness of packages have been reviewed, and tests appropriate to packages for radioactive materials identified and recommended for use.

Detailed procedures have been developed for the recommended methods, with emphasis on the factors relevant to particular types of container.

These methods and their nominal sensitivity are listed in [Table A.1](#). For most, the actual sensitivity shall be calculated for each application since it is a function of pressure, time, volume, temperature: and gas properties. The methods have been classified in [Table A.1](#) and in the text under quantitative and qualitative methods. The quantitative methods provide measurements of total leakage. The qualitative methods locate discrete leaks. If possible, the qualitative methods should be checked using calibrated leaks.

The recommended methods of leakage testing are listed, with diagrammatic representation, in [Table A.2](#). The table summarizes the test method, nominal sensitivity and applicability of each method, it is intended to be used as a guide when choosing a test method for a particular container.

A.2 Comments and precautions

A.2.1 Risks of explosion

For test items with high design pressure or large gas volumes, or both, take precautions against risks of explosion. For large gas volumes, even modest gas pressures can be hazardous. Either reduce the pressure to a known safe value or fill the test item with a liquid or solid, so that only a small gas volume remains for testing. It might be better to hydrostatically proof-test the item to help ensure safety. When a liquid is used, be certain that it cannot interfere with the leakage test.

Tests may be conducted at pressures and temperatures other than those used during operation, if the effects of the difference on containment system geometry and performance are negligible, or if operating conditions do not give sufficient pressure difference for meaningful results. Leakage flow direction during testing should be the same as during operation; flow in the reverse direction shall be justified.

Table A.1 — Leakage test sensitivities

Subclause	Test method	Nominal test sensitivity $\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ SLR
	Quantitative methods	
A.3.1	Gas pressure drop	10^{-2} to 10^{-6} a
A.3.2	Gas pressure rise	10^{-2} to 10^{-6} a
A.3.3	Gas filled envelope (gas detector)	10^{-4} to 10^{-10}
A.3.4	Evacuated envelope (gas detector)	10^{-4} to 10^{-9}
A.3.5	Evacuated envelope (with back pressurization)	10^{-4} to 10^{-9}
	Qualitative methods	
A.4.1	Gas bubble techniques	10^{-4} b,c
A.4.2	Bubble test	10^{-4} b
A.4.3	Tracer gas (sniffer technique)	10^{-4} to 10^{-7}
A.4.4	Tracer gas (spray method)	10^{-4} to 10^{-7}

a Sensitivity depends upon volume, pressure, time, gas properties and temperature stability.

b Higher reliable sensitivities can be achieved by the use of calibrated leaks to check the test equipment and the technique used.

c Gas bubble techniques include hot water bubble, vacuum bubble and pressurized cavity bubble methods.

Table A.2 — Summary of leakage tests

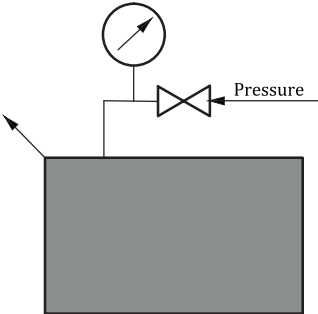
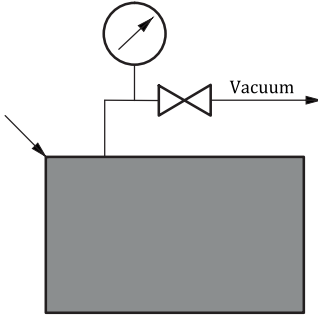
Corresponding subclause	Illustration
A.3 Quantitative methods	
A.3.1 Gas pressure drop The method involves pressurizing the test item, or interspace, and measuring the pressure drop. The sensitivity of the method is inversely proportional to the test volume. The method is particularly useful for testing double O-ring seals, where the small interspace volume makes the method most sensitive and the primary seal of the cavity shall not be broken. Nominal test sensitivity: 10^{-2} $\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ to 10^{-6} $\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ SLR.	
A.3.2 Gas pressure rise The method involves evacuating the test cavity to 10^3 Pa, or less, and measuring a pressure rise during a specified test period. The method applies to test items with pressure tap connections, but can also be used for testing double O-ring seals. Test sensitivity is inversely proportional to the test volume. Nominal test sensitivity: 10^{-2} $\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ to 10^{-6} $\text{Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ SLR.	

Table A.2 (continued)

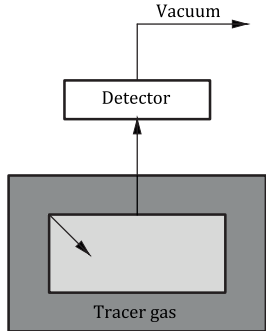
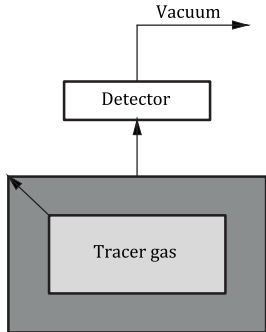
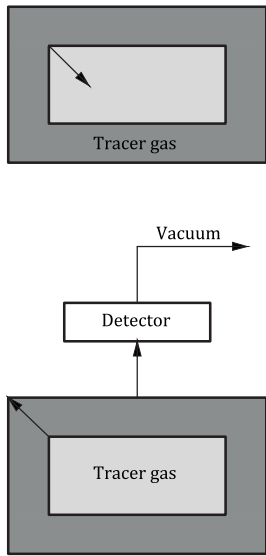
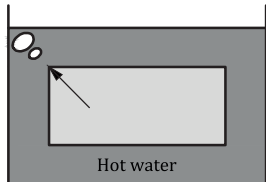
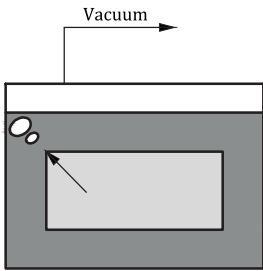
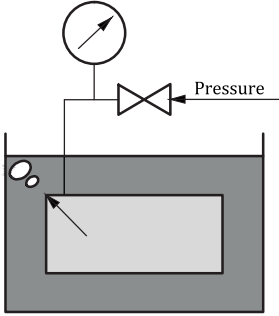
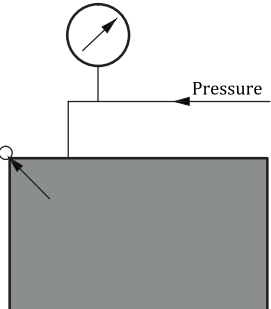
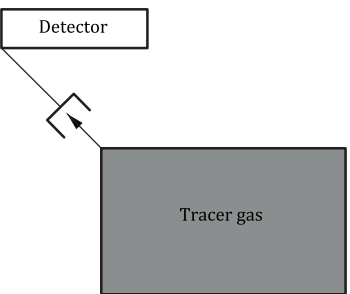
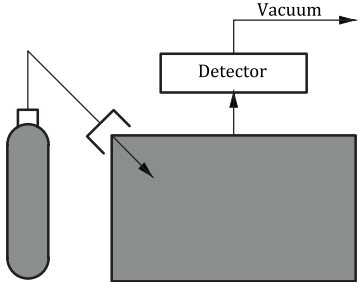
Corresponding subclause	Illustration
A.3.3 Gas filled envelope (gas detector) The method involves evacuating the test item connected to a gas detector and placing the item in an envelope filled with a test gas (usually helium or halogen compound). The method is suitable for large test items which have a replaceable seal. Where several seals are used (e.g. a double O-ring closure), the procedure can be applied to each seal in turn. Nominal test sensitivity: $10^{-4} \text{ Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ to $10^{-10} \text{ Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ SLR.	
A.3.4 Evacuated envelope (gas detector) The method involves pressurizing the test item with test gas (usually helium or halogen) while placed in a vacuum chamber connected to a gas detector. The method is ideal for small test items which have a replaceable seal. Where several seals are used (e.g. a double O-ring closure), the procedure can be applied to each seal in turn. Nominal test sensitivity: $10^{-4} \text{ Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ to $10^{-9} \text{ Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ SLR.	
A.3.5 Evacuated envelope (with back pressurization) The method involves externally pressurizing the test item in an envelope of the test gas (usually helium) for a certain time, and subsequently transferring the test item to an evacuated envelope connected to a gas detector. The method is ideal for welded capsules from the very small up to the limit of the pressurizing chamber. The internal void volume of the test item should be at least 10 mm^3. This method can be used in laboratory or in manufacturing. The procedure should be carefully validated and carried out. Nominal test sensitivity: $10^{-4} \text{ Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ to $10^{-9} \text{ Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ SLR.	
A.4 Qualitative methods	
A.4.1.4.1 Hot water bubble The method involves submerging the test item in hot water, which raises the internal pressure. A leak is indicated by a stream of bubbles. This method applies to welded capsules and small test items, usually without pressure tap connections. It can be used in the field without sophisticated equipment. Nominal maximum test sensitivity: $10^{-4} \text{ Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ SLR. NOTE This method is also a quantitative method but should not be used as such.	

Table A.2 (continued)

Corresponding subclause	Illustration
A.4.1.4.2 Vacuum bubble The method involves producing a vacuum above the liquid in which the test item is submerged. A leak is indicated by a stream of bubbles. The method is suitable for welded capsules and small resealable items. The method can be used for sources or containers with void volumes greater than 10 mm³. The size of the test item is limited only by the size of vacuum vessel. Nominal test sensitivity: 10⁻⁴ Pa·m³·s⁻¹ SLR.	
A.4.1.4.3 Pressurized cavity bubble The method involves pressurizing the test item, and immersing it in water, glycol or isopropyl alcohol. A leak is indicated by a stream of bubbles. This method applies to welded capsules, containers with pressure tap connections, or where the pressure required within the cavity can be obtained by the vaporization of solid carbon dioxide. Nominal test sensitivity: 10⁻⁴ Pa·m³·s⁻¹ SLR. NOTE This method is also a quantitative method but should not be used as such.	
A.4.2 Bubble test The method involves pressurizing the test item, and coating the surface with a leak detection liquid film. A leak is indicated by a bubble on the surface. This method applies to containers with pressure tap connections. The required pressure within the cavity can be obtained by the vaporization of solid carbon dioxide crystals. Nominal test sensitivity: 10⁻⁴ Pa·m³·s⁻¹ SLR.	
A.4.3 Tracer gas (sniffer technique) The method involves pressurizing the test item with the test gas (usually helium or halogen compound). A leak is detected by moving a probe (connected to gas detector) across areas that are likely to leak. The method is best used on large test items where the area of potential leak (e.g. a weld or seal is clearly visible. Some facility shall be available for pressurizing (with gas) the inside of the weld or seal. Nominal test sensitivity: 10⁻⁴ Pa·m³·s⁻¹ to 10⁻⁷ Pa·m³·s⁻¹ SLR.	
A.4.4 Tracer gas (spray method) The method involves evacuating a test item connected to a gas detector and spraying the test gas (usually helium or halogen compound) over the surface. The method can be used for testing partially finished vessels provided that one side of a potential leak can be evacuated and the other side is easily accessible with a supply of test gas. Nominal test sensitivity: 10⁻⁴ Pa·m³·s⁻¹ to 10⁻⁷ Pa·m³·s⁻¹ SLR.	

A.2.2 Tracer materials

Tracer materials shall be clean and free of contaminants that might affect test results. Care shall be taken to ensure that a known representative tracer mixture reaches the boundary being tested. Ensure

that there are no adverse reactions that would affect either the containment system contents or the leakage testing properties of the tracer.

A.2.3 Leakage rates

For some of the bubble tests, individual leakage rates as small as $10^{-7} \text{ Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ SLR can be detected under favourable laboratory conditions at a pressure difference of 10^5 Pa . However, test capabilities are reduced by problems such as poor visibility due to inadequate lighting, test object configuration, bath turbulence, gas solubility, operator inattention, leak clogging by liquids, limited time of application, and the possibility that there could be a multitude of leaks too small to be detected that collectively exceed the maximum allowable leakage rate. Tracer gas pressure shall overcome the hydrostatic head of the liquid bath and surface tension effects.

The bubble test has additional problems, such as ensuring simultaneous coverage over the complete area to be tested and recognizing the effects of ambient relative humidity and temperature. Bubble tests should not be used for quantitative measurements.

For these reasons, the total leakage rate is considered to be $10^{-4} \text{ Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ SLR when no bubbles are observed, unless the particular situation can be verified to have a higher sensitivity.

A.2.4 Avoid wetting the test item

For leaks expected to be smaller than $10^{-7} \text{ Pa}\cdot\text{m}^3\cdot\text{s}^{-1}$ SLR, wetting of the test item before the leakage test should be avoided whenever possible. When wetting cannot be avoided, the test item shall be dried thoroughly before the test.

A.2.5 Partial pressure

The partial pressure of tracer gas in the test mixture should be at least 10 % of the total pressure and shall be known. A correction factor for the partial pressure percentage shall be used. See [Formula \(B.13\)](#).

A.2.6 Vacuum conditions

When normal operations are with positive pressure, consideration shall be given to the behaviour of the containment boundary, closure, and seal while testing under vacuum conditions.

A.2.7 Performing leakage test

All leakage tests shall be performed by qualified operators.

A.3 Quantitative methods

A.3.1 Gas pressure drop

A.3.1.1 Applicability of the method

This procedure is used with items having pressure tap connections. The test volume can be the container volume or the small interspace volume associated with a double O-ring seal.

A.3.1.2 Leakage rate indication

The total leakage rate is indicated by a pressure drop from a known initial pressure, over a given period of time. If the test duration is long, corrections may be required to take into account changes in ambient temperature and pressure.