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Safe transport of radioactive materials — Leakage testing on packages

Sûreté des transports de matières radioactives — Contrôle de l'étanchéité des colis

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

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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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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 that 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 × 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 Pa·m^3·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 × 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 Pa·m^3·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) *Regulations for the Safe Transport of Radioactive Material*	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	Bq·m^{-3}
C_A	Average activity per unit volume of the medium that could escape from the containment system under accident conditions of transport	Bq·m^{-3}
C_N	Average activity per unit volume of the medium that could escape from the containment system under normal conditions of transport	Bq·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 m·s^{-2}
g_0	Constant	g_0 = 1 kg m N^{-1}·s^{-2}
H	Test duration	s
h	Liquid height	m
L	Volumetric leakage rate	m^3·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	m^3·s^{-1}
L_A	Maximum permissible volumetric leakage rate of the medium at pressure p_A, under accident conditions of transport	m^3·s^{-1}
L_N	Maximum permissible volumetric leakage rate of the medium at pressure p_N, under normal conditions of transport	m^3·s^{-1}
M	Relative molecular mass	kg·mol^{-1}
M_i	Relative molecular mass of component *i*	kg·mol^{-1}
M_{mix}	Relative molecular mass of mixture	kg·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 × 10^5 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	Pa·m^3·s^{-1}
Q_{SLR}	Standardized leakage rate; the symbol is used to simplify Figure 1 and represents the use of either $Q_{A(SLR)}$ or $Q_{N(SLR)}$	Pa·m^3·s^{-1}
Q_A	The permissible leakage rate of the medium under accident conditions of transport and is calculated from L_A	Pa·m^3·s^{-1}
$Q_{A(SLR)}$	The permissible standardized leakage rate (SLR) under accident conditions of transport	Pa·m^3·s^{-1}
Q_m	Leakage rate for molecular flow	Pa·m^3·s^{-1}
Q_{mix}	Leakage rate for gas mixture	Pa·m^3·s^{-1}
Q_N	The permissible leakage rate of the medium under normal conditions of transport and is calculated from L_N	Pa·m^3·s^{-1}
$Q_{N(SLR)}$	The permissible standardized leakage rate (SLR) under normal conditions of transport	Pa·m^3·s^{-1}
Q_p	Permeation rate	Pa·m^3·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 $Q_{A(SLR)}$	Pa·m^3·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 $Q_{N(SLR)}$	$Pa{\cdot}m^3{\cdot}s^{-1}$
Q_{TF}	The permissible test leakage rate of the tracer gas at the fabrication verification stage	$Pa{\cdot}m^3{\cdot}s^{-1}$
Q_{TM}	The permissible test leakage rate of the tracer gas at the maintenance verification stage	$Pa{\cdot}m^3{\cdot}s^{-1}$
Q_{TP}	The permissible test leakage rate of the tracer gas at the periodic verification stage	$Pa{\cdot}m^3{\cdot}s^{-1}$
Q_{TS}	The permissible test leakage rate of the tracer gas at the preshipment vérification stage	$Pa{\cdot}m^3{\cdot}s^{-1}$
Q_v	Leakage rate for viscous flow	$Pa{\cdot}m^3{\cdot}s^{-1}$
R	Universal gas constant	R = 8,31 J mol^{-1} 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	$Bq{\cdot}s^{-1}$
R_A	Maximum permissible activity release rate of the contents under accident conditions of transport	$Bq{\cdot}s^{-1}$
R_N	Maximum permissible activity release rate of the contents under normal conditions of transport	$Bq{\cdot}s^{-1}$
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	$Bq{\cdot}s^{-1}$
RG_A	Maximum permissible activity release rate of the gas contents under accident conditions of transport after allowing for permeation	$Bq{\cdot}s^{-1}$
RG_N	Maximum permissible activity release rate of the gas contents under normal conditions of transport after allowing for permeation	$Bq{\cdot}s^{-1}$
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	$Bq{\cdot}s^{-1}$
RP_A	Activity release rate due to permeation under accident conditions of transport	$Bq{\cdot}s^{-1}$
RP_N	Activity release rate due to permeation under normal conditions of transport	$Bq{\cdot}s^{-1}$
S	Leakage rate sensitivity	$Pa{\cdot}m^3{\cdot}s^{-1}$
SHeLR	Standardized helium leakage rate	$Pa{\cdot}m^3{\cdot}s^{-1}$ SHeLR
SLR	Standardized leakage rate	$Pa{\cdot}m^3{\cdot}s^{-1}$ SLR
T	Fluid absolute temperature	K
T_0	Reference temperature	T_0 = 298 K
T_1	Gas temperature at start of test	K
T_2	Gas temperature at end of test	K
u	Velocity	$m{\cdot}s^{-1}$
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	Pa·s

Symbol	Definition	Unit
μ_i	Viscosity of component *i*	Pa·s
μ_{mix}	Viscosity of mixture	Pa·s
ν	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.

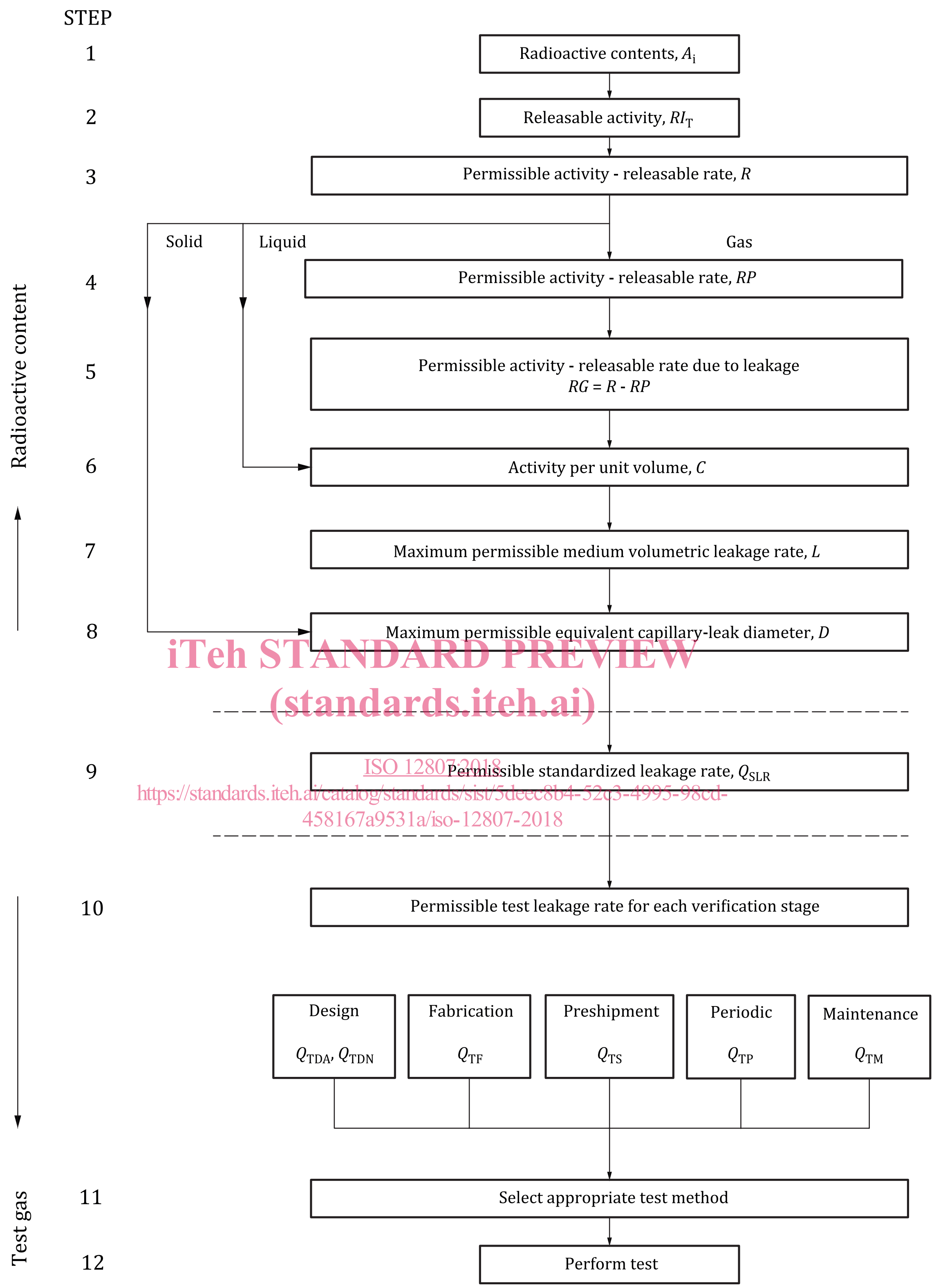

Figure 1 — Flow chart for gas leakage test methodology

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.