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Measurement of radioactivity - Measurement and evaluation of surface contamination —

Part 2: Test method using wipe-test samples

Mesurage de la radioactivité — Mesurage et évaluation de la contamination de surface —

Partie 2: Méthode d'essai utilisant des échantillons d'essai de frottis

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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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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is 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 7503-2:1988), which has been technically revised.

ISO 7503 consists of the following parts, under the general title *Measurement of radioactivity — Measurement and evaluation of surface contamination*:

- *Part 1: General principles*
- *Part 2: Test method using wipe-test samples*
- *Part 3: Apparatus calibration*

Introduction

ISO 7503 gives guidance on the measurement of surface contamination. This International Standard is applicable to many situations where radioactive contamination can occur. Contamination arises from the release of radioactivity into the local environment. In most circumstances, the release is inadvertent but, on occasion, may be deliberate. Although the purpose and scope of the investigation may differ, the approaches taken to measure the levels and extent of the contamination are essentially similar.

Radioactive contamination can arise from a number of activities or events such as the following:

- routine laboratory use of radiochemicals;
- medical treatments;
- industrial applications;
- transport accidents;
- equipment malfunctions;
- malevolent incidents;
- nuclear accidents.

Without process knowledge or documentation, it is not always possible to identify or distinguish the different radionuclides constituting a surface contamination, and the evaluation of such contamination cannot be made on a quantitative basis. Instead of using instruments with nuclide specific calibrations, it may be necessary to use other instruments which are fit for such a purpose.

However, there may be cases (e.g. a contaminated fuel material transport container) where the radionuclide or the radionuclide mixture can be clearly characterized. A surface contamination evaluation exceeding a pure qualitative assessment of fixed and removable surface contamination may then be needed. Moreover, following requirements laid down in national regulations and in international conventions, a measured surface contamination activity per unit area has to be compared with surface contamination guideline values or surface contamination limits.

Surface contamination guideline values are radionuclide-specific and thus require complex radionuclide-specific calibrations of measurement equipment. Calibration quality assurance is crucial in order to avoid non-detection (i.e. type II decision errors) leading to incorrectly assuming compliance with given surface contamination guideline values or limits. Evaluation of surfaces contaminated by a mixture of radionuclides with known ratios requires respectively proportionated calibration factors.

ISO 7503 is concerned with the measurement and estimation of radioactivity levels. It does not provide advice on decommissioning, planning and surveillance techniques.

Surface contamination is specified in terms of activity per unit area and the limits are based on the recommendations by the International Commission on Radiological Protection (ICRP 103).

This part of ISO 7503 deals with the evaluation of surface contamination by indirect measurement using a wipe test.

Measurement of radioactivity - Measurement and evaluation of surface contamination —

Part 2:
Test method using wipe-test samples

1 Scope

ISO 7503 (all parts) and ISO 8769 are addressed to the people responsible for measuring the radioactivity present on solid surfaces.

This part of ISO 7503 applies to the evaluation of contamination on surfaces in terms of activity per unit area by an indirect method of measurement.

This part of ISO 7503 is applicable to well-defined surfaces, such as those of equipment and facilities, containers of radioactive materials, sealed sources and buildings or land.

This part of ISO 7503 can be used for laboratory and equipment/installation control and for remediation and monitoring activities to comply with release criteria.

This part of ISO 7503 also refers to institutions/authorities controlling nuclear material transports or material/equipment clearance according to national legislation guideline values or international convention limits.

This part of ISO 7503 does not apply to contamination of the skin, clothing or loose material, such as gravel.

NOTE Direct evaluation of surface contamination from alpha-emitters, beta-emitters and photon emitters is dealt with in ISO 7503-1. The calibration of instruments for the evaluation of radioactive surface contaminations is dealt with in ISO 7503-3.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 8769, *Reference sources — Calibration of surface contamination monitors — Alpha-, beta- and photon emitters*

ISO 9698, *Water quality — Determination of tritium activity concentration — Liquid scintillation counting method*

ISO 11929, *Determination of the characteristic limits (decision threshold, detection limit and limits of the confidence interval) for measurements of ionizing radiation — Fundamentals and application*

ISO 18589-2, *Measurement of radioactivity in the environment — Soil — Part 2: Guidance for the selection of the sampling strategy, sampling and pre-treatment of samples*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

IEC 60325, *Radiation protection instrumentation — Alpha, beta and alpha/beta (beta energy >60 keV) contamination meters and monitors*

3 Terms and definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions and those given in ISO 7503-1 apply.

3.1.1

removable surface contamination

radioactive material that can be removed from surfaces by non-destructive means, including casual contact, wiping, or washing

Note 1 to entry: It should be noted that under the influence of moisture, chemicals, etc., or as a result of corrosion or diffusion, fixed contamination may become removable or vice versa without any human action. Furthermore, surface contaminations may decrease due to evaporation and volatilization.

Note 2 to entry: It should be emphasized that the ratio between fixed and removable contamination can vary over time, and that some decisions, such as those related to clearance, should be based on total activity with the potential to become removable over time, not just the amount that is removable at the time of a survey.

3.1.2

wipe test

test to determine if removable contamination is present through wiping the surface with a dry or wet material, followed by evaluation of the wipe material for removable contamination

Note 1 to entry: The type of wipe test, wet or dry, needs to be assessed by a competent person. In some instances (e.g. tritium contamination) a wet wipe may be preferred. In others, it may be more practical or advisable to use a dry wipe.

3.1.3

wiping efficiency

ratio of the activity of the radionuclides removed from the surface by one wipe sample to the activity of the radionuclides of the removable surface contamination prior to this sampling

Note 1 to entry: The wiping efficiency is defined by the following relationship:

$$\varepsilon_{\mathrm{w}} = \frac{a_{\mathrm{R}}}{a_{\mathrm{T}}}$$

where

a_{R} is the activity of the radionuclides removed by wipe test;

a_{T} is the total removable activity of the radionuclides present on the wiped area.

Note 2 to entry: In practice, it is almost impossible to measure the total amount of removable activity on the surface; and in most cases, a value for “wiping efficiency” cannot be assessed but can only be estimated.

Note 3 to entry: For important combinations of contaminant and surface material, the wiping efficiency can be determined experimentally using the method of “exhaustive removal by repetitive wipe tests”. The step-by-step addition of the removed activities results in an approximation of the total removable activity (a_{T}), to which the activity removed by the first wipe test (a_{R}) can then be related to yield the wiping efficiency.

Note 4 to entry: The method of “exhaustive removal by repetitive wipe tests” is only applicable if it can be guaranteed that exactly the same area is wiped on each occasion and exactly the same pressure is maintained uniformly over the area wiped. Moreover, results of this method are only valid for a specific nature and structure of a surface and are not transferable to other surface structures.

3.1.4

tritium surface contamination

total activity of tritium adsorbed upon and absorbed into the surface

3.1.5

removable tritium surface contamination

fraction of surface contamination which is removable or transferable under normal working conditions

Note 1 to entry: It should be noted that

a) under external influences of a chemical nature (e.g. moisture, corrosion) or of a physical nature (e.g. ambient pressure or temperature changes, vibration, impact, expansion and contraction), and also as a result of diffusion, the total tritium activity may be transformed into removable contamination or non-removable. The state is reversible multiple times,

b) tritium surface contamination may be volatile or contain volatile fractions which may volatilize under normal working conditions - this also contributes to the removable contamination and should be evaluated appropriately (see also Clause 7), and

c) as a result of diffusion of tritium into the surface structure, removal of the tritium surface contamination by exhaustive wipes may be without effect as the removed tritium contamination may be replaced in short time (see also Clause 7).

3.1.6

indirect evaluation of removable tritium surface contamination

evaluation of the removable tritium activity by means of a wipe test

Note 1 to entry: Any wipe used for tritium can only be analysed reliably using liquid scintillation counting. Direct measurements of tritium contaminated wipes may have large uncertainties or are not possible.

3.2 Symbols and abbreviated terms

For the purposes of this part of ISO 7503, the following symbols and those given in ISO 7503-1 apply:

ε_W	wiping efficiency
a_R	activity of the radionuclides removed by wipe test in Bq
a_T	total removable activity of the radionuclides present on the wiped area in Bq
a_r	activity per unit area of the removable contamination of the wiped surface in Bq·cm^{-2}
a_W	activity of the wipe sample in Bq
S_W	wiped surface area in cm^2
$C(A)^{ind}$	activity calibration factor for wipe sample in (Bq·cm^{-2})/s^{-1}

4 Sources of surface contamination

A surface can be contaminated with naturally occurring or man-made radionuclides.

The main natural radionuclides are ^{40}K and radionuclides originating from ^{238}U and ^{232}Th decay series. Natural radioactivity may vary considerably from one type of natural material to another (e.g. building materials).

Laboratories that intentionally handle naturally occurring radioactive material, such as radium or thorium, should anticipate surface contamination from these radionuclides.

The sources of surface contamination by man-made radionuclides can arise from a number of activities such as the following:

- routine laboratory use of radio chemicals;
- medical treatments;

- industrial applications;
- transport accidents;
- equipment malfunctions;
- malevolent incidents;
- nuclear accidents.

5 Objectives of the surface contamination evaluation

The ultimate goal is to protect the worker and the general population from direct and indirect radiation exposures, such as inhalation, ingestion, skin contact, and skin absorption pathways. This is done by measuring surface contamination to assess the impact of release and to prevent resuspension and remobilization of radioactive materials.

Radiation protection depends on knowledge of the surface activity and of the removable fraction of activity.

The removable fraction may vary over time (see Clause 7) and should be conservatively applied, depending on the intent of the surface contamination characterization.

Prior to any measurements, qualified and experienced radiation professionals should develop the required program of work to ensure that the best possible information is gathered to characterize the type and spread of contamination.

6 Strategy

A strategy for the determination of surface contamination is normally established by qualified individuals that have appropriate experience and expertise in the measurement and assessment of surface contamination. The strategy should be based on

- random and/or systematic screening[1][2][7],
- check of critical positions (e.g. storage areas of radioactive sources, door handles, or the surfaces of any container or building in which radioactive materials are stored), and
- complete monitoring of the surface.

A remediation monitoring process (e.g. Reference [7]) or a systematic monitoring strategy as outlined in ISO 18589-2 may be the basis for the specification of surface contamination measuring points in a laboratory, on an extended container or on a site. Such strategies, however, do not replace a complete monitoring of surfaces, on which radioactive contaminations are assumed.

A strategy for surface contamination control at an operating facility may also be the analysis and identification of critical operational sequences potentially leading to surface contamination.

7 Methods for evaluating surface contamination

The applicability and the reliability of direct measurement or indirect evaluation of surface contamination are strongly dependent on the particular circumstances [e.g. the physical and chemical form of the contamination, the adherence of contamination on the surface (fixed or removable), the accessibility of the surface for measurement or the presence of interfering radiation fields].

Direct measurement as dealt with in ISO 7503-1 is used when the surface is readily accessible, reasonably clean and when no interfering radiation, such as a high background, is present. Direct measurement is used to establish the presence of both fixed and removable contamination.

Indirect evaluation of surface contamination is more generally applicable when the surfaces are not readily accessible because of difficult location or configuration, where interfering radiation fields adversely affect contamination monitors or when methods of direct measurement with standard instrumentation are not available (e.g. tritium). Also, the indirect method cannot assess fixed contamination, and, due to the uncertainty associated to the wiping efficiency, application of this method results in conservative estimations.

Due to the inherent shortcomings of both the direct measurement and the indirect evaluation of surface contamination, in many cases, the use of both methods in tandem ensures results which best meet the aims of the evaluation.

Tritium and its compounds are special case. As a nuclide of hydrogen, tritium has great mobility and may penetrate into a surface (e.g. along grain or crystal boundaries) to a depth that makes the indirect evaluation of the tritium surface contamination very difficult. This holds also for other mobile radionuclides.

In many cases, tritium contamination is present in the form of contaminated water, which can evaporate, making the tritium airborne. Because of the ability of tritium (as HT, T_2 or HTO) to diffuse and substitute hydrogen against tritium in hydrogen containing compounds, tritium contaminations are found on and in the surface. Therefore, special care shall be taken when evaluating tritium surface contamination. The total surface contamination cannot be accurately evaluated in any cases. Indirect measurements performed by dry or wet wipe tests generally provide only a “best guess” of the removable surface contamination at the time of collection. Because of diffusion (e.g. as HTO) into the surface, absorbed tritium contamination tends to replace the removable surface contamination that was partially or totally removed by a decontamination process or by wet wipe tests. Therefore, a radiological hazard from volatile tritium may still remain.

8 Wipe test material

The wipe material should be chosen to suit the purpose of the wipe test and surface to be checked (for example, filter paper for smooth surfaces, cotton textile for rough surfaces). Circular filter papers or circular cotton textile should preferably be used as the wipe material. Expanded polystyrene [Polystyrene (PS) foam][4] and cotton-tipped swabs can also be used as wipe material when appropriate.

If a wetting agent is used, it shall be compatible with the nature of the contamination to be sampled, and in case of liquid scintillation counting, the scintillation cocktail should be adapted to the applied wetting agent.

9 Instrumentation

9.1 General

Measurements of wipe samples are often carried out using well shielded, pulse-counting, installed laboratory instruments.

Portable surface contamination meters or monitors can also be used, but not in preference to well shielded installed laboratory instruments.

Characteristics and performance of the portable measuring instruments shall comply with IEC 60325 and be adapted to the measurement objectives.

Both instrument types shall be capable of measuring activities below the levels of the nuclide specific surface contamination guideline values or limits set by national legislations or international conventions, to which the results of the contamination measurements are to be compared.

If a portable instrument is calibrated for the direct method of surface contamination evaluation, it is of value to calibrate it also for the indirect method (see ISO 7503-3). In the absence of interfering radiation fields, portable instruments may be used to evaluate surface contamination when preferred laboratory instruments are not available.

If wipe tests with high activities are expected, a pre-measurement using an adequate portable measuring instrument is recommended to avoid contamination of installed instruments.

9.2 Liquid scintillation counters

Liquid scintillation counting is primarily used to count low energy betas particles and to a lesser extent alpha particles. Counting efficiencies range from 30 % up to 100 %. The liquid scintillation method is most often used to measure ^{3}H, ^{63}Ni, and ^{14}C.

A detailed description of the liquid scintillation counting technique is given in Reference [8].

Emission can be detected by liquid scintillation counting with varying degrees of efficiency depending on the following:

- the type and energy of emission (X-rays and photons may escape from the scintillator without interacting);
- whether the sample is dissolved in the scintillator; in the form of particles; or retained in the wipe material;
- the effect of chemicals on the scintillator;
- absorption of the emitted light by colour or opacity of the sample before it reaches the photomultiplier(s);
- the orientation of the wipe in the sample vial.

NOTE Because of the variable geometry of wipes introduced into the sample vial, care is necessary to achieve accurate measurement unless the wipe is made to dissolve in the scintillation cocktail, such as expanded polystyrene [Polystyrene (PS) foam].

10 Calibration

10.1 Calibration of installed instruments

Installed measuring instruments (e.g. liquid scintillation counters calibrated according to ISO 9698) should be provided with an accredited traceable calibration certificate relating the instrument response to the activity on the wipe material.

10.2 Calibration of portable instruments

Portable instrument calibration shall be done by means of reference radiations provided by reference sources of known emission in accordance with ISO 8769. The portable instrument calibration should correspond to the calibration methods given in ISO 7503-3, Annex D.

11 Guidelines on wipe test sampling

11.1 General

Detection and evaluation of surface contamination can be carried out using one or more dry or wet wipe samples.

When taking wipe samples from large areas, the following points shall be taken into consideration.

a) Outline the required area to wipe using string or tape, for example, 100 cm^{2} for surface contamination guideline values[2] or 300 cm^{2} for surface contamination limits[3].

b) If a wetting agent is used for moistening the wipe material, this wetting agent should not exude from the material.

   WARNING — Since the contamination may be absorbed into the structure of the wipe material or may be covered by residual moisture, the use of a wetting agent may lead to a significant underestimation of the contamination in the case of alpha-emitters.

c) The radioactive material should be dissolved or suspended in the wetting agent. The wetting agent water should be used for tritium, dust and water-soluble compounds.

d) The wipe should be pressed moderately against the surface to be checked, using fingertips or, preferably, by means of a holder.

e) The entire area required by regulations shall be wiped.

f) After sampling, if using other methods than liquid scintillation counting, the wipe material shall be carefully dried in such a way that loss of activity is prevented. In case of contaminations of tritium, iodine isotopes or other volatile isotopes, drying of the wipe material shall be omitted.

g) Use extreme caution when handling potentially contaminated wipe materials in order to prevent cross-contamination.

11.2 Guidelines on sampling removable tritium contamination

The guidelines for tritium given in this subclause are also valid for iodine or other volatile radionuclides.

Detection and evaluation of removable tritium contamination should be carried out using wet wipe samples.

Where tritium contamination is present in a particulate form which is insoluble in liquid scintillators (e.g. metal hydrides), dry wipe materials may be used for tritium detection purposes.

The following points shall be taken into consideration when taking wipe samples.

a) If possible, the area to be wiped should measure 100 cm^2.

b) Where regulations permit larger areas to be wiped, such areas shall be used for sampling and their actual size shall be included in the calculation of the result in accordance with Clause 13; wiping of very large areas with a single wipe should be avoided since the removal factor decreases with increasing area.

c) The wipe shall be pressed moderately against the surface to be wiped, preferably by means of a holder which is designed to ensure uniform and constant pressure.

d) The entire area of 100 cm^2 or larger shall be wiped.

e) Unused wipe materials should be stored in a tritium free atmosphere.

f) The use of disposable gloves is recommended during wipe testing of highly contaminated surfaces; changing of gloves may be necessary to avoid cross-contamination of samples.

12 Measurement procedure

The operating instructions for the instruments used for measuring the wipe samples shall be followed. The background radiation level in the area where the wipes are counted should be low and constant. The following requirements shall be followed.

a) Before making a wipe measurement, the background count rate shall be determined at the place of measurement.

b) The background count rate shall be checked from time to time to account for changes in background levels.

c) The instrument shall have a current calibration status and shall be verified using a suitable check source. Frequency: daily for instruments in frequent use, otherwise before each use. Deviations of more than 25 % from the agreed value shall give rise to a recalibration of the instrument.

d) Instrument calibration factors suitable for the radionuclides to be measured should be available.

e) The geometry conditions during a measurement should be identical to those used during instrument calibration. For portable instruments, they should be as close as practicable to those used during instrument calibration; removable spacers may be used for this purpose.

f) For methods other than liquid scintillation counting, the sensitive area of the detector shall be larger than the wipe sample.

g) If a wipe sample with alpha or beta emitters should be measured, alpha-beta pulse discrimination is required.

For the measurement of wipe samples by liquid scintillation counting, the following requirements shall be complied with.

a) For watery wipe samples, appropriate scintillation cocktails are required.

b) Tritium wipe samples should be placed into the counting vial already containing an appropriate amount of scintillation cocktail.

c) Wet tritium wipe samples shall be placed directly in the scintillation cocktail for about 20 min prior to counting in order to approach equilibrium distribution of the tritium activity and dark adaption.

d) Care should be taken that the introduction of the wipe sample into the scintillation cocktail does not cause excessive losses of light due to the mass of the material or to quenching effects, and does not introduce spurious scintillations due to brightening agents.

13 Evaluation of measurement data

13.1 Calculation of the activity per unit area for measurement results of installed instruments

Using installed instruments, the activity per unit area of the removable contamination of the wiped surface can be derived from the activity measurement result of the wipe material.

For installed instruments, the activity per unit area a_r of the removable contamination of the wiped surface, expressed in Bq cm^{-2}, in relation to the activity a_w of the wipe sample, is given by Formula (1):

$$a_\mathrm{r} = \frac{a_\mathrm{w}}{S_\mathrm{w} \cdot \varepsilon_\mathrm{w}} \tag{1}$$

where

a_w is the measured activity of the wipe sample in Bq;

S_w is the wiped surface area in cm^2;

ε_w is the wiping efficiency.

Determining the wiping efficiency experimentally involves time and effort. Usually, a conservative value of 0,1 is used which assumes the wipe material only picks up 10 % of the available removable contamination[5].

13.2 Calculation of the activity per unit area for measurement results of portable instruments

Portable instruments calibrated according to ISO 7503-3, Annex D can be used to determine the activity per unit area a_r of the removable contamination of the wiped surface, expressed in Bq cm^{-2}, according to Formula (2):

$$a_\mathrm{r} = C(A)^{ind} \cdot \left(\rho_\mathrm{g} - \rho_0\right) \tag{2}$$

where

$C(A)^{ind}$ is the activity calibration factor in (Bq·cm^{-2})/s^{-1};

ρ_g is the measured total count rate in s^{-1};

ρ_0 is the background count rate in s^{-1}.

13.3 Application of ISO 11929

The calculation of the characteristic limits (decision threshold, detection limit and limits of the confidence interval) according to ISO 11929 is given in ISO 7503-3, Annex F.

14 Wipe test uncertainties

The uncertainties in assessing the levels of contamination from wipe tests are great and are affected by many factors including, but not limited to the following:

- the type of wipe material used;
- the pressure applied by the person when making the wipe;
- the area wiped;
- the contamination distribution;
- the porosity, chemical composition, texture and cleanliness of the surface.

Reference [6] demonstrates wiping efficiency can vary enormously and is almost impossible to assess accurately. The uncertainties in the wiping efficiency are an order of magnitude larger than other uncertainties in the measurement. Consequently, it has been common practice to allocate a value of conservative 10 % to the wiping efficiency, as essentially a “best guess”.

15 Test report

The test report has to conform to the requirements of ISO/IEC 17025 and has to contain the following information:

- date;
- location and sub-location;
- type of surface;
- instrument used, serial number;
- reference to the measurement and evaluation procedure used;
- reference of the calibration standard employed;
- identification of the sample;

— units in which the results are expressed;

— test result, $a_r \pm u$ or $a_r \pm U$, with the associated k value.

Complementary information, many of which are according to ISO 11929, should be included for the benefit of the user such as the following:

a) wipe material (dry or wet);

b) wetting agent;

c) area of wipe;

d) wiping efficiency for indirect measurement (measured or assumed);

e) instrument efficiency, calibration date;

f) reference source: traceability of source calibration results;

g) measuring times for sample and background;

h) instrument reading of the wipe sample;

i) instrument reading of the background;

j) notes on the extent of the contamination;

k) other observations (presence of volatile radioactivity, etc.);

l) operator's name;

m) probabilities α, β and $(1 - \gamma)$;

n) decision threshold and detection limit;

o) depending on the customer request, there are different ways to present the result:

    1) when the surface activity concentration a_r is compared with the decision threshold, in agreement with ISO 11929, the result of the measurement should be expressed as $\leq a_r^*$ when the result is below the decision threshold;

    2) when the surface activity concentration a_r is compared with the detection limit, the result of the measurement can be expressed as $\leq a_r^\#$ when the result is below the detection limit. If the detection limit exceeds the guideline value, it shall be documented that the method is not suitable for the measurement purpose.

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1) Withdrawn. This International Standard has been replaced by ISO 80000-1, *Quantities and units — Part 1: General.*

2) Withdrawn. This International Standard has been replaced by ISO 80000-10, *Quantities and units — Part 10: Atomic and nuclear physics.*

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