INTERNATIONAL STANDARD

ISO 23159

First edition
2020-06

Non-destructive testing — Gamma ray scanning method on process columns

Essais non destructifs — Méthode de balayage de rayon gamma sur les colonnes de processus

Reference number
ISO 23159:2020(E)

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

Published in Switzerland

Contents

Page

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 of 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 5, *Radiographic testing*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Gamma ray scanning is a non-intrusive and non-destructive method, which is widely used in petrochemical and chemical process plants for troubleshooting and diagnosing purposes. Gamma ray scanning provides an indication of online conditions inside processing columns and vessels. Gamma ray scanning has proven itself as a method for the identification of plant and process problems, resulting in considerable economic savings. The gamma ray scanning method is an inspection which is carried out while the process is in operation, without interruption.

The benefits, obtained from the application of the gamma ray scanning method for problem solving, are many folds, such as safety improvement, environment pollution prevention and economic savings.

Gamma ray scanning is based on the gamma ray transmission techniques. When a gamma ray passes through a column, the intensity of the transmitted beam is related to the path length and density of the material through which the beam passes. An appropriate gamma source and a detector are aligned at the same elevation opposite to each other on the exterior of the column. Measurements of radiation intensity are taken at appropriate positions as the source and detector are moved together along the column. The source-detector data thus obtained are shown in plots of radiation intensity or material density as a function of the position. Detailed analysis of these data enables making assessments about the condition of internal structures and process materials within the column.

Non-destructive testing — Gamma ray scanning method on process columns

IMPORTANT — The electronic file of this document contains colours which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a colour printer.

1 Scope

This document is used for non-destructive testing by the gamma ray scanning method for troubleshooting and testing process columns in industries. This document is applicable to the testing of all kinds of separation processes columns and pipes. This includes columns with different tray configurations and with packed beds.

2 Normative references

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

ISO 5576, *Non-destructive testing — Industrial X-ray and gamma-ray radiology — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5576 and the following apply.

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

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

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

3.1
column
vertical cylindrical vessel used for facilitating the separation of a liquid mixture through distillation or extraction

3.2
demister
device, often fitted with vapour-liquid separator vessels, to enhance the removal of liquid droplets or mist entrained in a vapour stream

[SOURCE: ISO/TR 27912:2016, 3.25]

3.3
downcomer
device conveying liquid from one tray to the next one below it in a *column* (3.1)

3.4
entrainment
mist, fog droplets or particles transported by a fluid

[SOURCE: ISO 3857-4:2012, 2.37]

3.5
flooding
phenomenon that upsets the normal operation of a distillation *column* (3.1) due to an excessive speed of vapour travelling up the column, preventing liquid from flowing

[SOURCE: ISO 1998-4:1998, 4.10.052]

3.6
foaming
expansion of liquid that provides high interfacial liquid-vapor contact in a distillation *column* (3.1)

3.7
grid scanning
system of four or more individual scans in a grid pattern across equal quadrants of a *packed bed column* (3.8) to investigate the packing and liquid/vapor distribution quality through packed or structured trays beds

3.8
packed bed column
column (3.1) with one or more packed beds or structured trays beds that ensures the separation of two or more components of a mixture

3.9
weeping
phenomenon that the pressure exerted by the vapor is insufficient to hold up the liquid on the tray and the liquid leaks through perforations from one tray to the next one below

4 Personnel qualification

The personnel shall prove to have received additional training and qualification in gamma ray scanning.

NOTE Annex A provides recommendations for testing personnel.

5 Protection against ionizing radiation

WARNING — Exposure of any part of the human body to ionizing radiation can be highly injurious to health. Wherever radioactive sources are in use, it is the responsibility of the user of this document to identify the appropriate legal and safety requirements and regulations.

Further information can be found in the IAEA General Safety Requirements[9].

6 Equipment requirements

Equipment required for a column scan includes the following:

— a suitable sealed radiation source;

NOTE 1 The guidance for the selection of a sealed radiation source is provided in Annex B.

— a suitable source holder in which the source can be raised or lowered on the column; the source holder should be capable of giving a collimated beam and the position at which the beam emerges from the holder should be clearly indicated, see Annex C;

— a suitable radiation detection system (including data acquisition system) by which the radiation intensity at a given measurement time can be measured and recorded at different elevations on the column;

NOTE 2 E.g. the detector can be a sodium iodide crystal. A typical dimension is 5 cm × 5 cm (2'' × 2'').

— a suitable device (e.g. computer and software) for displaying the data as a scan profile;

— a suitable calibrated radiation monitor by which the radiation level can be monitored for radiation safety; the equivalent dose rate at the boundary of a controlled area is usually defined by national legislation;

— barriers and warning notices to cordon off the “controlled area”;

— appropriate handling tools for the safe transfer of the radioactive source from the transport container to the source holder to be used for scanning.

The equipment shall be tested before deployment to the site and securely packaged for transportation to the work site to ensure good working condition.

The sealed radiation source shall be transported to the worksite in an approved Type A container, labelled and documented, taking national and international regulations into account.

NOTE 3 This can include i.e.

— the vehicle equipment;

— a special driver qualification;

— a special personnel protective equipment;

— a transport permission.

A check list shall be prepared, and all items be checked before shipment. See an example in Annex D.

7 Execution of work at site

7.1 Mechanical design of column and work permission

Prior to carrying out any work, the Level 3 should agree with the client the objectives of the work and scanning procedure. The Level 3

— will acquire details of the column diameter and wall thickness and details of the trays or packed beds;

— will acquire a suitable general arrangement drawing showing the location of features within the column;

— will ensure that there is suitable and safe access to the parts of the column where the scanning team needs to operate;

— will ensure that there are sufficient resources to carry out the work and that a suitable sealed radiation source can be used at the site.

The documentation of the mechanical designs shall:

— select a proper reference (zero) point (manhole, external pipe, etc.);

— determine all positions of internal and external structures and refer it to the point zero;

— generate a list of the characteristics of the column, see an example in Table 1;

Table 1 — Characteristics of the column

Type of the process	Type of the column	Identification of the column	Material of the wall	Internal diameters	Nominal wall thicknesses	Height of the column
				D_i	t	h
				mm	mm	mm
...	...	...	...	...	...	...

— show the orientation of downcomers and liquid flooding;

— ensure that a suitable permit to work is issued by the local supervisor (upon arrival at the work site by the Level 3 or the Level 2);

— inspect the work site;

— ensure that there is safe access;

— visually inspect the transport container;

— visually inspect the source holder;

— confirm by monitoring that the source is still present;

— immediately report any abnormalities to the Level 3, who shall decide on the required action.

7.2 Execution of scanning

The project team will carry out the scan in the agreed manner. Any deviation to the agreed scanning procedure shall be approved by the Level 3 after consultation with the client.

Record the count rate (i.e. counts per time interval) each 5 cm (or other intervals according to the distance between trays), either with a computer or a notebook. The count rates or dose measurements can be registered in a table, see an example in Table 2.

NOTE 1 The determination of time interval for the count rate measurement is described in Annex B.

NOTE 2 The selection of sources (detector orientations for scanning) is described in Annex E.

Table 2 — Record of count rate along the column height

Elevation	Counts per time interval[a]	Remarks[b]
mm		
...	...	...

[a] The counting time shall be documented.

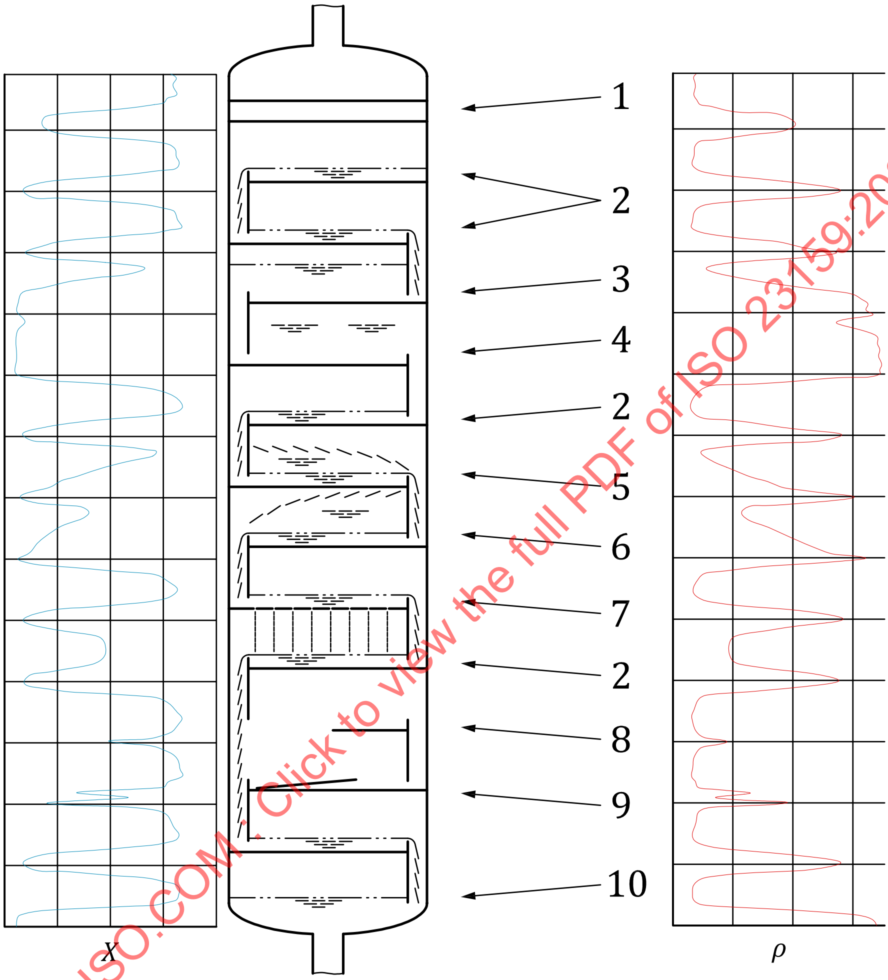
[b] Observations regarding obstacles or external structures shall be noted in the remarks. This will improve the interpretation of the data.

8 Data processing and reporting

8.1 Data processing and documentation

The measurement of the count rate obtained by the radiation detector is recorded in a table. A graphical representation (scan profile) shall be prepared. The gamma ray scanning profile provides information on the condition of the inside of the column, i.e. the internal structure, damages and liquid/gas phases distributions. Figure 1 shows typical gamma scan profiles in tray columns and Figure 2 for packed bed columns. The interpretation of the scan profile results in conclusions on the status of operating conditions of the column. Some examples of the interpretations of different scan profiles are shown in Annex F.

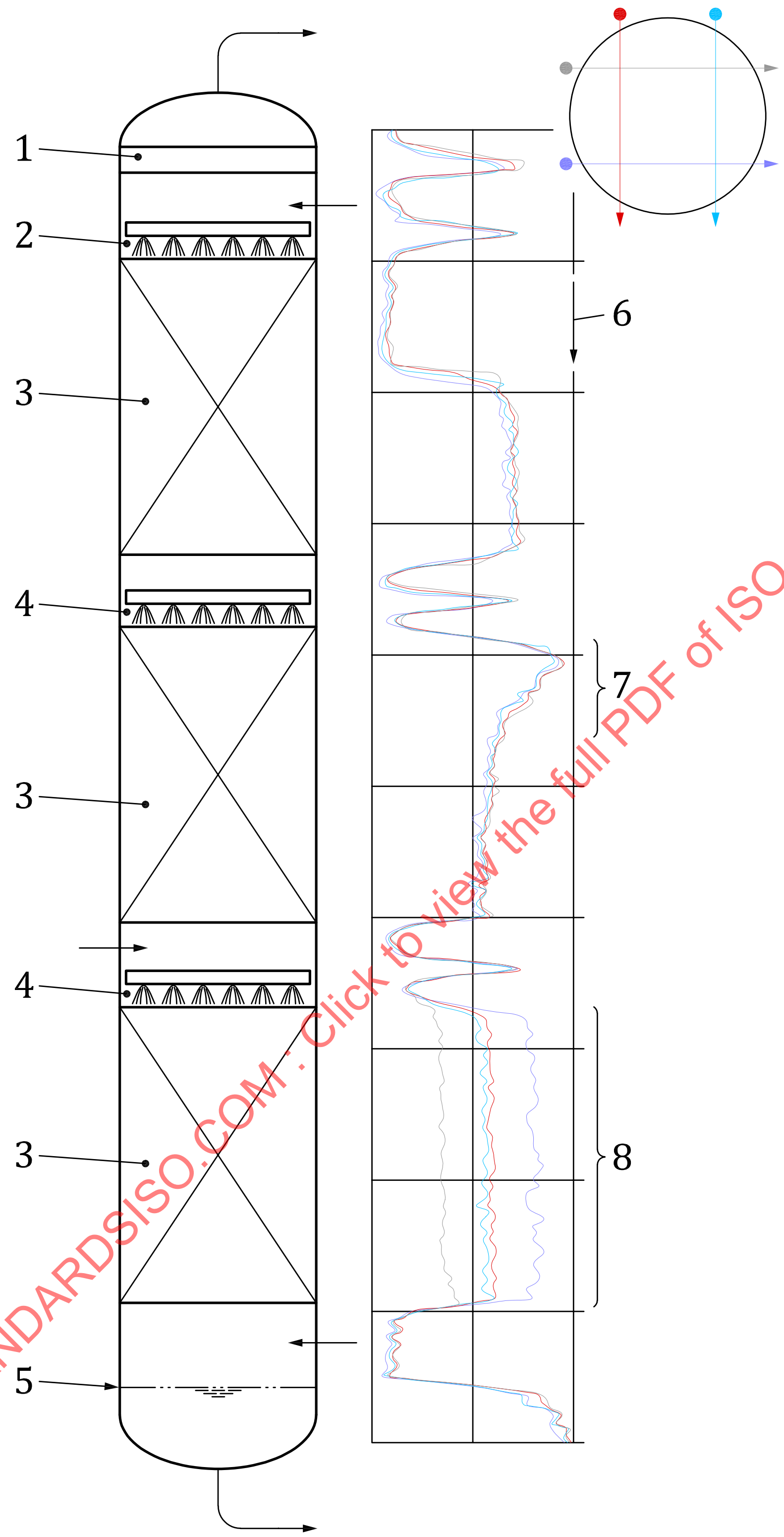
NOTE The client can decide on the provided report for further actions.



Key

1	demister pad	7	weeping tray
2	normal trays	8	missing tray
3	high liquid level	9	debris
4	flooding	10	base level
5	light foaming	X	counts per interval
6	heavy foaming	ρ	density (arbitrary unit)

Figure 1 — Typical gamma scan profiles in tray columns



Key

1 demister

2 liquid distributer

3 packed bed

7 fouled packing

8 mal liquid distribution

—— scan 1

4	liquid re-distributer		scan 2
5	base level		scan 3
6	missing packing		scan 4

Figure 2 — Example of gamma scan profiles in packed bed columns

8.2 Report

The result will be confirmed in a written report to the customer within the time frame agreed upon between the contracting parties. The report contains a detailed description of the column as well as the description of the scanning performances. The report shall include as minimum the following information:

- name of the testing body;
- reference to the contract;
  - names of the client;
  - number of the contract;
  - date of the contract;
- column reference and characteristic;
  - Table 1 and Table 2;
- performed scanning tests;
  - sealed radiation source and activity;
  - detector type and brand;
  - measurement time and detector settings (i.e. high voltage, thresholds);
  - source-to-detector distance and geometry;
  - data acquisition hardware and software;
  - photograph or drawing of the column and the setup;
- any deviation from this document;
- drawing of the scan profile;
- interpretation of the scan profile;
- dates of scanning and report;
- name and signature of the responsible person(s);
- annexes.

Annex A
(informative)

Recommendations for testing personnel

A.1 General

To enable column scans to be carried out efficiently, the qualification and responsibilities should be defined prior to any work taking place as follows.

A.2 Level 3 (project manager)

The Level 3 is the person responsible for the planning and execution of the entire job. This includes defining the work scope and allocating sufficiently trained and competent personnel and resources to conduct the work. The Level 3 is responsible for

— ensuring compliance with any statutory legislation for the protection of the workforce, members of the public and the environment;

— interpretation of the data obtained;

— supplying a suitable report to the customer within the agreed period.

The Level 3 has demonstrated the following competence to perform direct gamma ray scanning operations:

a) the competence to evaluate and interpret results in terms of existing standards, codes, and specifications;

b) sufficient practical knowledge of product technology to select the scanning suitable procedure and assist in establishing acceptance criteria where none are otherwise available;

Level 3 personnel shall be authorized to:

a) take full responsibility for a test team and the administration of the contracted work;

b) establish reviews for editorial and technical correctness and validate instructions and procedures;

c) interpret standards, specifications and procedures;

d) carry out and supervise all tasks at all levels;

e) provide guidance for the testing personnel at all levels.

A.3 Level 2 (senior field technician)

The Level 2 is the person on site responsible for carrying out the instructions of the Level 3 and is responsible for ensuring that the site work is carried out safely and in accordance with the agreed work scope.

The Level 2 technician has demonstrated competence to perform gamma ray scanning in according with this document and shall be authorized by the employer to:

a) select the suitable scanning method to be used;

b) define the limitations of application of the scanning method;

c) translate testing standards, specifications and procedures into instructions adapted to the actual working conditions;

d) set up and verify equipment settings;

e) perform and supervise tests;

f) interpret and evaluate results according to applicable standards, specifications or procedures;

g) carry out and supervise all tasks at Level 1;

h) provide guidance for personnel at Level 1;

i) report the results of testing.

A.4 Level 1 (junior field technician)

Depending upon the particular column and work scope there will be one or more Level 1 technicians who are responsible for safely and efficiently carrying out the instructions of the senior field technician.

The Level 1 Technician has demonstrated competence to carry out gamma ray scanning according to written instructions and under the supervision of Level 2 or Level 3 personnel. Level 1 personnel may be authorized by the employer to perform the following in accordance with the instructions:

a) set up gamma scanning equipment;

b) perform the testing;

  1) checking the correct function of the testing equipment;

  2) noting remarks on any external influences that affects the scanning profile;

c) record the results of the testing according to written instructions;

d) report the results.

Level 1 personnel shall neither be responsible for the choice of test method or technique to be used, nor for the interpretation of test results.

The client should supply to the service provider sufficient information to enable the work to be carried out, safely and efficiently in an agreed manner. It is expected that the client will provide such help and assistance as could reasonably be expected between contractors and should provide safe access and for issuing an appropriate work permit.

Annex B
(informative)

Selection of sealed radiation source and its activity

Selection of the gamma source (i.e. ^{60}Co, ^{137}Cs or ^{192}Ir) and its activity should be done based on the column diameter, internal configurations in relation to radiation absorption, and statistical limitations of radiation counting. All three factors are interrelated.

The activity required for the gamma scanning can be estimated using Formula (B.1):

$$A = \frac{\dot{H} \cdot {d_{SDD}}^2 \cdot 2^{w/d_{HVL}}}{\Gamma} \tag{B.1}$$

where

A	is the activity (MBq);
$\dot{H}$	is the equivalent dose rate required at the detector (practically accepted as 10 µSv/h);
d_{SDD}	is the source detector distance (m);
w	is the total column wall thickness traversed by the gamma beam (mm);
d_{HVL}	is the half-value layer thickness (mm) for steel and the source (e.g. 21,6 mm steel for ^{60}Co);
Γ	is the gamma constant for the gamma source (i.e. 0,37 mSv/h in 1 m distance in air for ^{60}Co source of 1 GBq, ^{137}Cs:0,10, ^{192}Ir:0,16).

NOTE If the activity is required in mCi the activity in MBq is based on the relation: 1 MBq = 0,027 mCi.

The value of $\dot{H}$, mentioned in Formula (B.1) corresponds to the transmitted radiation rate which will give some thousand cps (counts per second) in vapor space of the column (vapor base line); and will decrease to some hundreds cps in the tray level (liquid base line). This estimated count rate gives a good compromise between the contrast (between liquid & vapour phases) and the accuracy of counting.

Normally the detector sensitivity (5 cm × 5 cm (2'' × 2'') NaI/Tl) for ^{60}Co is 7 500 cps/(10 µSv/h). The NaI(Tl) detector sensitivity is determined by placing a sealed source of ^{60}Co or of ^{137}Cs at a distance where the dose rate is 10 µSv/h. The NaI(Tl) detector sensitivity for the ^{60}Co is lower than that for the ^{137}Cs, because the detector NaI(Tl) is more sensitive to low energies of ^{137}Cs than to high energies of ^{60}Co.

In deciding the dose rate that is required at the detector, consideration needs to be given to the sensitivity of the detection system and the number of counts per second required from the detector to give sufficient statistical accuracy. Typically it has been found that if a scintillator detector NaI(Tl) 5 cm × 5 cm (2'' × 2'') is used, then it is estimated that at the dose rate level of $\dot{H}$ = 10 µSv/h, the relative standard deviation of a radiation measurement would be less than 10 %.

An example of source activity calculation is as follows:

A gamma source is needed to scan a distillation column, which has the following parameters:

— internal diameter = 3,1 m;

— wall thickness = 15 mm.

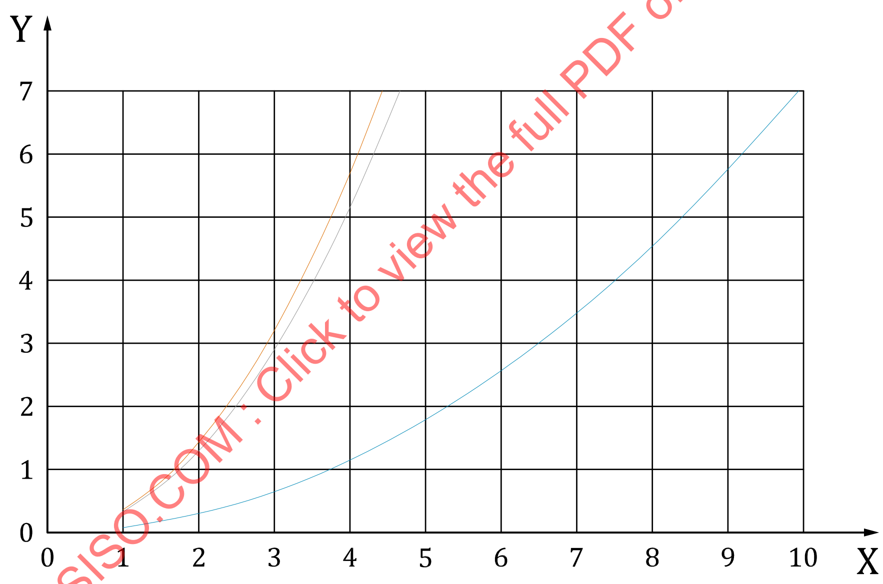
Calculation of the ^{60}Co activity for scanning a column of 3,1 m internal diameter gives:

$$A=\frac{10\cdot(3{,}1+0{,}03)^{2}\cdot 2^{30/21{,}6}}{0{,}37}=771 \tag{B.2}$$

Figure B.1 gives the ^{60}Co, ^{137}Cs and ^{192}Ir activity in function of the column diameter (wall thickness of 15 mm and the dose rate of 10 µSv/h) with the values of Table B.1.

Table B.1 — Half value layer and gamma constant of ^{60}Co, ^{137}Cs and ^{192}Ir

	Half value layer d_{HVL} mm	Gamma constant Γ mSv · m²/(h · GBq)
^{60}Co	21,6	0,370
^{137}Cs	16	0,103
^{192}Ir	12,7	0,160



Key

X source-detector distance [m]

Y source activity [GBq]

^{60}Co

^{137}Cs

^{192}Ir

Figure B.1 — Optimal source activity as function of source-detector distance for the scanning of a column with 15 mm wall thickness of steel

Annex C
(informative)

Scanning equipment

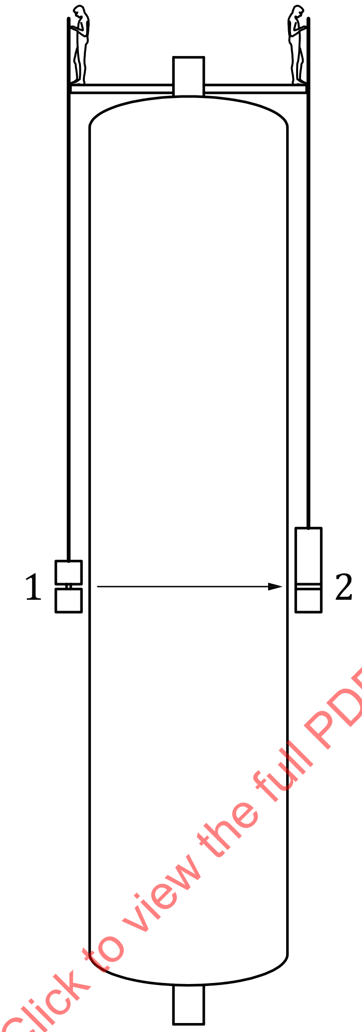
The scanning equipment consists of the radiation source system, the radiation detection system and the scanning system.

Collimators for source and detector shall be used to minimize the effect of scattered radiation on the detector and radiation equipment installed (if any) on the process units near the test site.

A scanning system should be designed so that source and detector collimators openings always remain aligned in the same horizontal plane during the whole process of scanning. The scanning system can be manual, winch-based or automatic (motor-controlled). Great care shall be taken to minimise the swing of source and detector particularly while examining columns with a small diameter or with multi pass trays. These efforts will reduce the measurement errors of transmitted radiation intensity at a given measurement time and improve the reliability of the scanning data.

The collimator can be made using tungsten or depleted uranium instead of lead, to reduce the weight of the holders.

Figure C.1 shows an example of manual gamma ray scanning preparation on a column platform.



Key

1 source and source holder with collimator

2 detector and detector holder

Figure C.1 — Example of manual gamma ray scanning preparation on a column platform

Annex D
(informative)

Preparation of the scanning equipment

D.1 Check list

D.1.1 General

The following items should be at least part of the check list and be available on the work site.

D.1.2 Radiation source system

The following items should be available for the radiation source system:

— sealed radiation source (i.e. ^{60}Co, ^{137}Cs or ^{192}Ir);

— source holder with panoramic collimation;

— transport container (A-type);

— source handling tools.

D.1.3 Radiation detection system

The following items should be available for the radiation detection system:

— detector holder with collimator;

— scintillation detectors (NaI(Tl) or others);

— counter and connection cables;

— data logger and display (computer or others).

D.1.4 Scanning system

The following items should be available for the scanning system:

— manual scanner;

  — tape measure × 2;

  — guide rope × 4;

— winch scanner;

  — winch with wire × 2;

  — marker pen × 2;

  — guide rope × 4;

  — pulley × 2;

  — rode × 2;

  — carabines;

  - — tables;
  - — chairs;
- — automatic scanner;
  - — source operator;
  - — detector operator;
  - — tensioner × 2;
  - — control box(es);
  - — computer;
  - — connection cables;
  - — pulley × 2;
  - — rode × 2;
  - — carabines.

D.1.5 Radiological safety equipment

The following items should be available for the radiological safety system:

- — survey meter;
- — personal dosimeters;
- — tape for marking the radiation area.

D.1.6 Others

The following items should also be available:

- — mechanical drawing of the column;
- — markers;
- — communication equipment (complying with industrial safety requirements);
- — individual protection and safety equipment;
- — extra battery for the computer and detection equipment.

D.2 Verification of the operational condition of the detection system

The radiation detection system needs to be set up before usage in the field and tested with a suitable source.

D.3 Field preparation

The following actions shall be considered in the field preparation:

- — mark the scanning lines on column wall at the start and end point;
- — install the guide steel cable for guiding the source and detector along the scanning line (optional);
- — install the source holder and the detector holder;

— align the two holders at the start level;

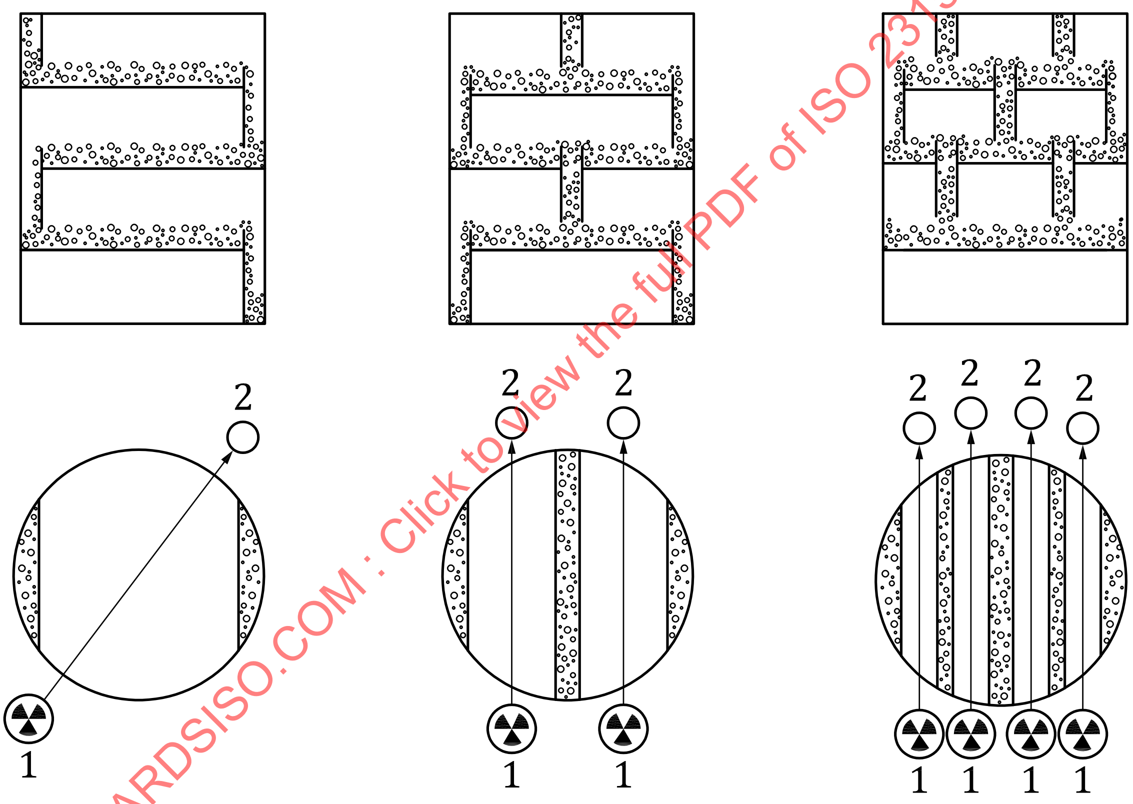
— check the functionality of the radiation detection system and the scanning system.

Annex E
(informative)

Selection of sources — Detector orientations for scanning

E.1 Scanning of tray columns

The selection of the scanning lines depends on the orientation of the downcomers, as well as of the types of the column trays. As a guideline, the scanning lines should avoid tray downcomers directions, as shown in Figure E.1.



a) Single-pass trays   b) Double-pass trays   c) Quadruple-pass trays

Key

1 radioactive source

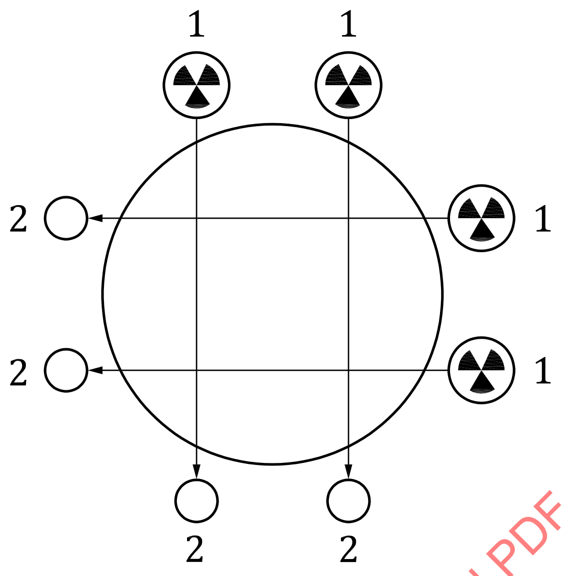
2 detector

Figure E.1 — Typical orientations of source and detector for tray columns

However, scanning lines can be selected to go through the downcomers of trays when the information about the inside structural integrity of the columns or downcomers flooding are required.

E.2 Scanning of packed bed columns

To inspect packed beds, the grid scanning is applied. This technique can also be used for the inspection of the correct installation of distributors as well as the distribution of incoming liquid feed. The schematic of grid scanning is shown in Figure E.2.



Key

1 radioactive source

2 detector

Figure E.2 — Typical orientations of source and detector for packed bed columns

In general, four grids are recommended for the inspection of packed bed columns. However, the number can be increased depending upon the information required.

The following steps need to be taken for grid scanning:

— check the mechanical design of the column;

— design the scan line directions avoiding external structures;

— select the reference point (zero point) in order to perform comparable profiles;

— mark the scan lines on the wall of the column;

— carry out the measurement of the scan profiles using the same source and detector.

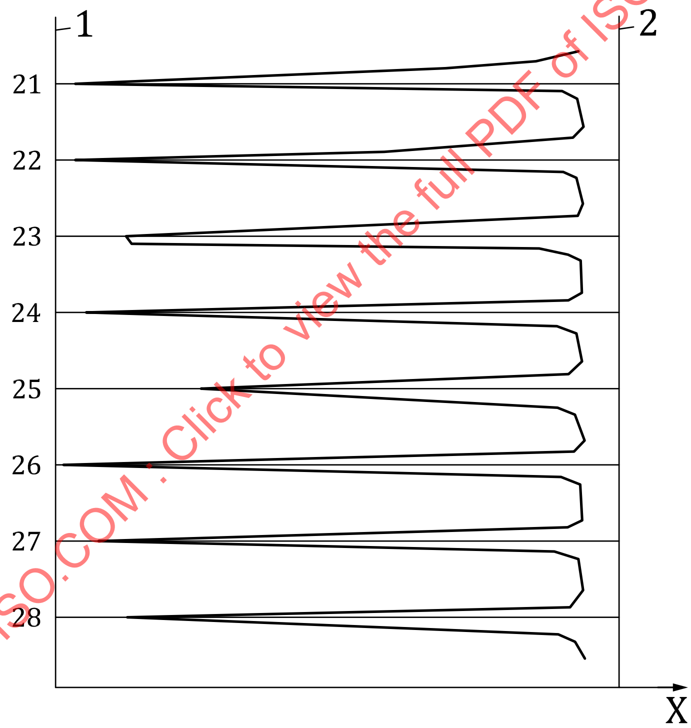
Annex F
(informative)

Interpretation of the scanning data

F.1 Models of reference profiles for a tray column

F.1.1 Scanning profile of a normally operating distillation column

In Figure F.1 the scanning lines are as expected, they do not cross the downcomers. Between the trays, the counts per time interval is the same as those of vapour line. No anomaly is shown besides tray 25 which is not identical with the other trays. This difference is not significant to identify an anomaly which could stop the column. The liquid level is almost the same in each tray.



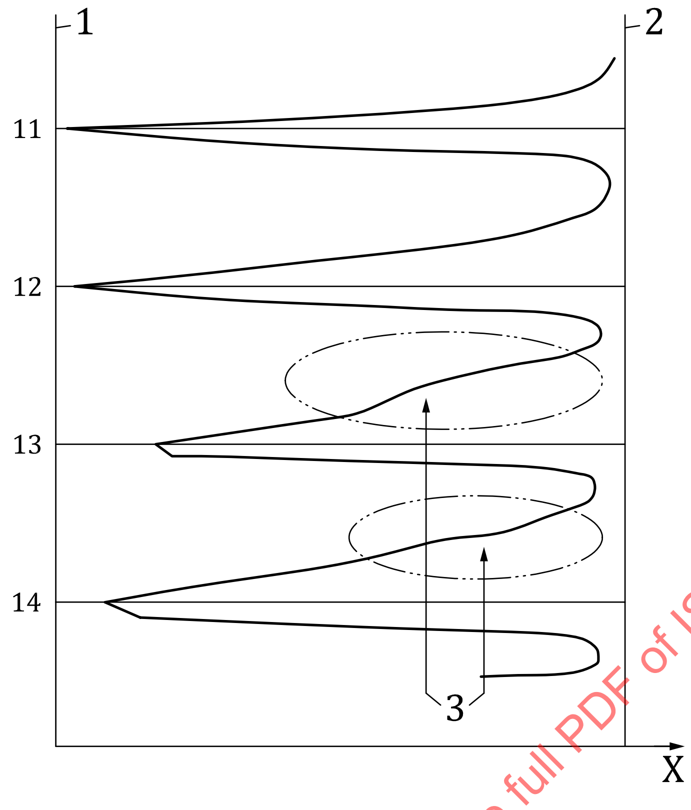
Key

1	liquid base line	X	counts per time interval
2	vapour base line	21 to 28	tray number

Figure F.1 — Example of a scanning profile of a normally operating distillation column

F.1.2 Gamma scanning profile of a column part with foaming

A slight foaming appears on the two identical trays of the scan profile shown in Figure F.2. The slope change appears just above the tray. There are no liquid entrainment or obstructions because there is no deviation from the vapour base line. More details can be obtained if an additional gamma profile is performed with lower energy sources.



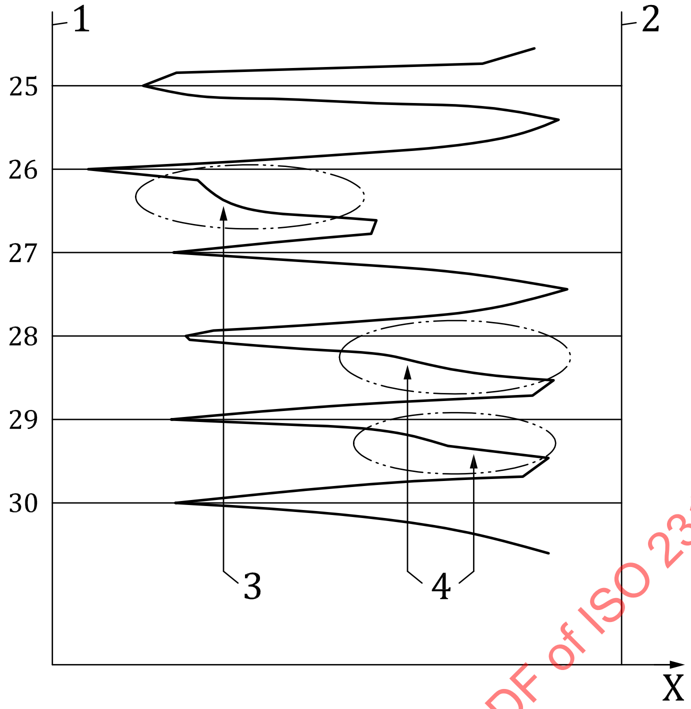
Key

1	liquid base line	X	counts per time interval
2	vapour base line	11 to 14	tray number
3	foaming		

Figure F.2 — Example of a gamma scanning profile of a column part with foaming

F.1.3 Gamma profile of a column part with "weeping" (shower)

Weeping is difficult to identify. An additional scan profile performed with a weak energy source is necessary to observe these phenomena better. The slope changes from the upper tray to next bottom tray. Two slight weeping areas are shown on two trays in Figure F.3. Weeping is more evident in tray 26 and may be caused due to the flooding of the tray.



Key

1 liquid base line
2 vapour base line
3 heavy weeping
4 slight weeping
X counts per time interval
25 to 30 tray number

Figure F.3 — Example of a gamma profile of a column part with "weeping" (shower)

F.1.4 Scanning profile through the downcomers

Figure F.4 shows that the detected counts per time interval of the vapour phase is lower under even trays (22, 24 and 26) than under the odd trays. The scan of even trays partially crosses the downcomers and the signals are absorbed more. A bad separation liquid/vapour is observed between tray 27 and tray 28. This means that there is slight liquid entrainment from tray 28 to tray 27. The liquid level on tray 28 is higher. Liquid weeping is visible at tray 28.