
**Safety of machinery — Evaluation of the
emission of airborne hazardous
substances —**

**Part 2:
Tracer gas method for the measurement
of the emission rate of a given pollutant**

*Sécurité des machines — Évaluation de l'émission de substances
dangereuses véhiculées par l'air —*

*Partie 2: Méthode par gaz traceur pour le mesurage du taux d'émission
d'un polluant donné*



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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 29042-2 was prepared by Technical Committee ISO/TC 199, *Safety of machinery*.

ISO 29042 consists of the following parts, under the general title *Safety of machinery — Evaluation of the emission of airborne hazardous substances*:

- *Part 1: Selection of test methods*
- *Part 2: Tracer gas method for the measurement of the emission rate of a given pollutant*
- *Part 3: Test bench method for the measurement of the emission rate of a given pollutant*
- *Part 4: Tracer method for the measurement of the capture efficiency of an exhaust system*

The following parts are under preparation:

- *Part 5: Test bench method for the measurement of the separation efficiency by mass of air cleaning systems with unducted outlet*
- *Part 6: Test bench method for the measurement of the separation efficiency by mass of air cleaning systems with ducted outlet*
- *Part 7: Test bench method for the measurement of the pollutant concentration parameter*

A room method for the measurement of the pollutant concentration parameter and a decontamination index are to form the subjects of future parts 8 and 9.

Introduction

The structure of safety standards in the field of machinery is as follows:

- a) type-A standards (basic safety standards) giving basic concepts, principles for design, and general aspects that can be applied to all machinery;
- b) type-B standards (generic safety standards) dealing with one safety aspect or one type of safeguard that can be used across a wide range of machinery:
 - type-B1 standards on particular safety aspects (e.g. safety distances, surface temperature, noise);
 - type-B2 standards on safeguards (e.g. two-hand controls, interlocking devices, pressure-sensitive devices, guards);
- c) type-C standards (machine safety standards) dealing with detailed safety requirements for a particular machine or group of machines.

This part of ISO 29042 is a type-B standard as stated in ISO 12100-1.

The requirements of this document can be supplemented or modified by a type-C standard.

For machines which are covered by the scope of a type-C standard and which have been designed and built according to the requirements of that standard, the requirements of that type-C standard take precedence.

ISO/TC 199 has a mandate in this area to produce type-A and type-B standards, which will allow verification of conformity with the essential safety requirements.

ISO 29042-2 is based on EN 1093-2:2006, amended by Amendment 1:2008, published by the European Committee for Standardization (CEN).

Safety of machinery — Evaluation of the emission of airborne hazardous substances —

Part 2: Tracer gas method for the measurement of the emission rate of a given pollutant

1 Scope

This part of ISO 29042 specifies a method using tracer gas techniques to enable measurement of the emission rates of gaseous substances from a single machine whose operation can be controlled.

It is not applicable to machinery manufactured before the date of publication of this part of ISO 29042.

2 Normative references

The following referenced documents are indispensable for the application 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 12100-1:2003, *Safety of machinery — Basic concepts, general principles for design — Part 1: Basic terminology, methodology*

ISO 29042-1:2008, *Safety of machinery — Evaluation of the emission of airborne hazardous substances — Part 1: Selection of test methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12100-1 and ISO 29042-1 and the following apply.

3.1

tracer gas technique

use of gaseous substances with an aerodynamic behaviour comparable with the gaseous hazardous substance under consideration and for which concentrations can be reliably measured

4 Principle

The principle is based on the use of a tracer gas generated at a known and constant emission rate to provide the best representation of the pollutant source. The mean tracer gas and pollutant concentrations are measured in the vicinity of the source. Assuming that the aerodynamic behaviour of the pollutant is equal to that of the tracer gas, the pollutant emission rate can be determined.

5 Location of the machine

5.1 General

The method is intended to be used for a machine located either in a test room or in the field.

5.2 Room method

The general airflow patterns in the test room should be characterized to enable more precise control of the general and local ventilation to be achieved. The machine should be placed in the centre of the room.

5.3 Field method

Many machines cannot be tested in a test room because they are too large, too difficult to handle or have special installation or process requirements. Tests may be performed on machines in the places where they are installed, i.e. the workplace. For this purpose, it shall be ensured that pollutants from other emission sources present in the room shall not affect the measurements of the concentrations of the specific pollutant emitted from the machine under test.

6 Apparatus and materials

6.1 Tracer gas emitter, capable of providing a release of the tracer gas in the same manner as the pollutant emission.

The shape of the emitter should resemble the shape of the real pollutant source. A distinction is generally drawn between

- point sources (e.g. welding operations, localized leaks from gaskets and flanges, localized spraying, such as a painting jet),
- plane sources (e.g. open vessel or tank containing liquid or melted solid liable to evaporate or sublimate, such as galvanizing baths and electroplating baths), and
- volumetric sources (e.g. closed machine with distributed leaks, rubber making machine, printing machine, degreaser, dry-cleaning machine, diffuse spraying such as plant-care products in agriculture).

Point sources should be simulated by opened tubes producing jets of variable aerodynamic characteristics or by sintered materials diffusing the tracer gas at a low initial velocity. Plane and volumetric sources should be simulated by a network of point sources or perforated tubes that are suitably distributed.

6.2 Tracer gas flow rate measuring device, capable of measuring tracer gas flow rates in the appropriate range.

NOTE The tracer gas flow rate depends on the sensitivity of the tracer gas analyser. For most applications, a device calibrated to measure flow rates in the range from 1 l·min⁻¹ to 10 l·min⁻¹ is suitable.

6.3 Tracer gas flow rate adjusting device, e.g. valve.

6.4 Gas analyser(s), preferably direct-reading.

An alternative method of measuring the pollutant concentration is to collect the gas on vapour absorption tubes for later analysis in the laboratory using gas analyser(s).

The gas analyser(s) should be selected so as to avoid any interference from any chemical substances present, other than the pollutant and tracer gas, in the test room or workplace where the machine under test is situated. Calibrations shall be carried out in accordance with an appropriate International Standard.

The choice of gas analyser depends upon the tracer gas and pollutant to be measured. Suitable analysers include infrared, electron capture, FID analysers, or mass spectrometer. Their performances should be checked before use. The analysers used should not be susceptible to change in environmental conditions such as temperature and relative humidity.

6.5 Connecting piping, for connection of the sampled tracer gas and pollutant gas to the analysers.

The piping length should be as short as possible and the material chosen to limit adsorption on the piping walls, e.g. PTFE. If the machine is located in a dirty workplace, atmosphere particle filters should be fitted. For vapour adsorption tubes, the piping length upstream should be shorter.

6.6 Tracer gas, required to be selected using the following criteria:

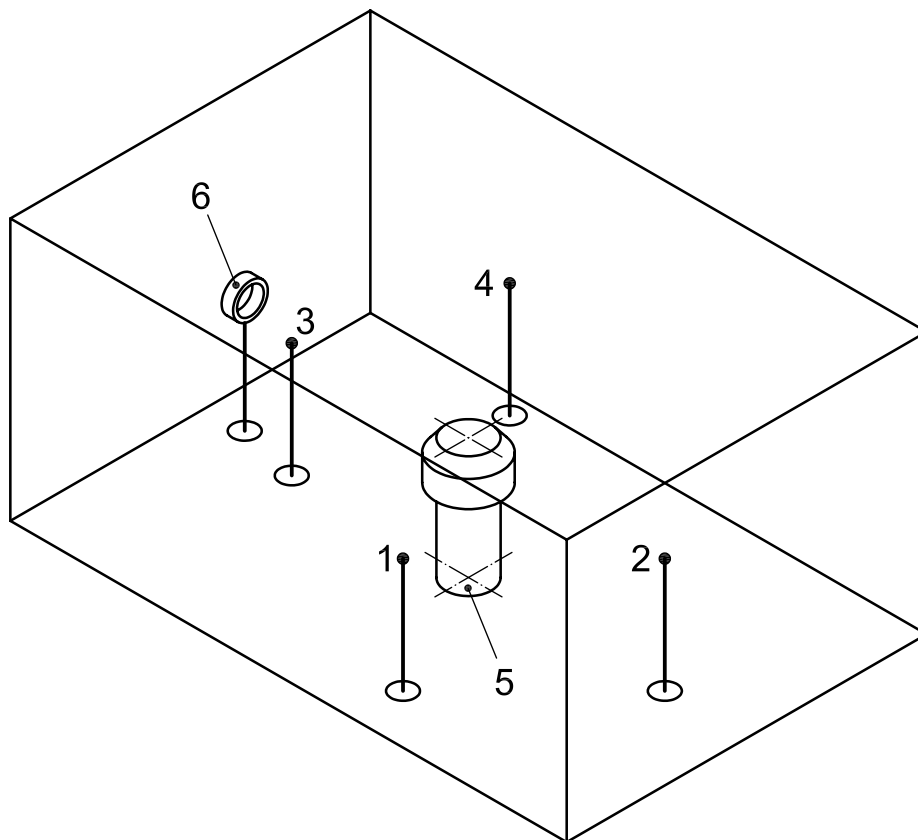
- d) nil or very low toxicity;
- e) chemical stability at the intended process temperature;
- f) easily measurable at low concentrations;
- g) non-interference with pollutants present in the room;
- h) low background level.

The tracer gas chosen should have a relative density close to 1. The tracer gas can be mixed with an appropriate gas.

NOTE The choice of the tracer gas and associated analyser depends, in particular, on the desired accuracy, measurement range and cost. The gases normally used are helium, sulphur hexafluoride and nitrous oxide.

7 Measurement points

There should be at least three measurement points around the machine (see Figure 1). These should be positioned close to the machine, e.g. between 1 m and 3 m, and at the height at which the pollutant is generated. At each measurement point, both tracer gas and pollutant concentrations are measured. The measurement points should be determined by pre-testing to ensure that they are in zones of measurable emission.



Key

- 1 to 4 measurement points
- 5 pollutant source
- 6 mixing fan

Figure 1 — Example of location of four measurement points in a test room

8 Procedure

- 8.1** Prepare the machine in accordance with the manufacturer's instructions.
- 8.2** Position the tracer gas emitter as close to the source of the pollutant from the machine as possible so that the tracer gas will be mixed with the pollutant before emission into the atmosphere.
- 8.3** Ensure that the air exhausted from the room is not re-circulated.
- 8.4** Switch on the gas analysers and allow to stabilize according to the instructions for use.
- 8.5** Connect the cylinder of tracer gas to its flow meter and adjusting device, and to the tracer gas emitter.
- 8.6** Set up the tracer gas and pollutant measurement points. Ensure that for each measurement point the tracer gas and pollutant samplers are positioned as close to one another as possible. If the measurements are to be carried out in a dirty atmosphere, fit particle filters to the tracer gas and pollutant sample lines.
- 8.7** Measure the background concentrations of the pollutant and tracer gas before and after the test.
- 8.8** Switch on the machine and tracer gas supply. A preliminary test should be carried out to ensure that the pollutant and tracer gas concentrations are within the calibrated range of the analysers. If this is not achieved, either move the measurement point until it is within range, or in the case of the pollutant gas analyser, adjust

the range. For the tracer gas, adjust the flow rate until it is within the calibrated range of the tracer gas analyser.

8.9 Switch off the machine and tracer gas supply and allow the tracer gas concentrations to return to a stable level (zero or background).

8.10 Record the tracer gas and pollutant concentrations.

8.11 Switch on the machine and the tracer gas supply.

8.12 Record the tracer gas flow rate.

8.13 Record the increase of the tracer gas concentration at the measurement points until stable concentrations have been achieved.

NOTE The time for this depends upon the time constant of the test room (equals inverse of air exchange rate). A typical sampling period is of the order of three time constants of the test room.

8.14 When stable concentrations have been achieved, carry on recording the pollutant concentration and tracer gas concentration for a suitable time.

The measurement time shall be sufficient to collect concentration data representative of the normal operational cycles of the machines. The concentration data to be processed for the determination of the emission rates (average values, peak values) are specified in the relevant type-C standards. If a type-C standard is not available, the test conditions shall be recorded in the test report.

8.15 Record the temperature, t , in degrees Celsius ($^{\circ}\text{C}$), the atmospheric pressure p , in hectopascals (hPa), and the relative humidity, in percent (%), in the test room or workplace.

8.16 Repeat the procedure (8.11 to 8.15) a further two times.

9 Data analysis

Calculate the mean tracer gas concentration and the mean pollutant concentration for each measurement point and for each test.

NOTE Where an adsorption tube is used, a single value is obtained equivalent to this mean.

10 Expression of results

10.1 The pollutant emission rate, q_P , can be expressed in units of volume per unit time ($\text{l}\cdot\text{min}^{-1}$) or in mass per unit time ($\text{mg}\cdot\text{s}^{-1}$).

10.2 The volume pollutant emission rate, $(q_P)_V$, expressed in litres per minute ($\text{l}\cdot\text{min}^{-1}$), is determined for each test by Equation (1):

$$(q_P)_V = (q_T)_V \cdot \frac{\sum_i (\bar{C}_{P_i})_V}{n \cdot (\bar{C}_{T_i})_V} \quad (1)$$

where

$(q_T)_V$ is the volume tracer gas flow rate in litres per minute ($\text{l}\cdot\text{min}^{-1}$);

$(\bar{C}_{P_i})_V$ is the mean pollutant concentration (volume fraction) at measurement point i ;

$(\bar{C}_{T_i})_V$ is the mean tracer gas concentration (volume fraction) at measurement point i ;

n is the number of measurement points.

The final result is the mean value of the volume pollutant emission rate for each test.

10.3 The mass pollutant emission rate, $(q_P)_m$, expressed in milligrams per second ($\text{mg}\cdot\text{s}^{-1}$), is determined for each test, similarly to Equation (1), by Equation (2):

$$(q_P)_m = (q_T)_m \cdot \frac{\sum_i \frac{(\bar{C}_{P_i})_m}{(\bar{C}_{T_i})_m}}{n} \quad (2)$$

where $(q_T)_m$ is the mass tracer gas flow rate in milligrams per second ($\text{mg}\cdot\text{s}^{-1}$) calculated by Equation (3):

$$(q_T)_m = (q_T)_V \cdot \frac{M_T \cdot 1\,000}{V_{m(t,p)} \cdot 60} \quad (3)$$

where

M_T is the molar mass of the tracer gas in grams per mole ($\text{g}\cdot\text{mol}^{-1}$);

$V_{m(t,p)}$ is the molar volume of gas at temperature t and pressure p of the experiment, in litres per mole ($\text{l}\cdot\text{mol}^{-1}$);

$(\bar{C}_{P_i})_m$ is the mean mass concentration of pollutant, in milligrams per cubic metres ($\text{mg}\cdot\text{m}^{-3}$), at measurement point i ;

$(\bar{C}_{T_i})_m$ is the mean mass concentration of tracer gas, in milligrams per cubic metres ($\text{mg}\cdot\text{m}^{-3}$), at measurement point i ;

n is the number of measurement points.

These two concentrations are measured as a volume fraction using a direct reading analyser. They are then converted to mass concentrations ($\text{mg}\cdot\text{m}^{-3}$) using Equations (4) and (5).

$$(\bar{C}_{P_i})_m = (\bar{C}_{P_i})_V \cdot \frac{M_P}{V_{m(t,p)}} \quad (4)$$

$$(\bar{C}_{T_i})_m = (\bar{C}_{T_i})_V \cdot \frac{M_T}{V_{m(t,p)}} \quad (5)$$

where M_P is the molar mass of the pollutant, in grams per mole ($\text{g}\cdot\text{mol}^{-1}$).

For the test report, the mass pollutant emission rate can be calculated directly from Equation (6):

$$(q_P)_m = (q_T)_V \cdot \frac{M_P}{V_{m(t,p)}} \cdot \frac{1\,000}{60} \cdot \frac{\sum_i \frac{(\bar{C}_{P_i})_V}{(\bar{C}_{T_i})_V}}{n} \quad (6)$$

The final result is the mean value of the mass pollutant emission rate for each test.

11 Test report

The test report shall include at least the following information:

- a) reference to this part of ISO 29042 (i.e. “ISO 29042-2:2009”) and to any associated type-C standard(s);
- b) description of the machine tested (manufacturer, model, type, version, design, size, year of manufacture, serial number, etc.) — for the machine itself and for each additional piece of equipment;
- c) operational data during tests (machine running parameters, machine settings, etc.), including tools used with the machine and material processed on the machine;
- d) description of the pollution control system (type, design, operational data, etc.), if fitted;
- e) identification of the pollutant(s) emitted from the machine;
- f) tracer gas used;
- g) volume tracer gas flow rate, in litres per minute ($\text{l}\cdot\text{min}^{-1}$);
- h) number and position of the measurement points;
- i) mean mass concentration of tracer gas ($\text{mg}\cdot\text{m}^{-3}$) and measurement time (min);
- j) mean mass concentration of pollutant ($\text{mg}\cdot\text{m}^{-3}$) and measurement time (min);
- k) atmospheric pressure (hPa), temperature ($^{\circ}\text{C}$) and relative humidity (% RH) in the test room or workplace at the time of the test;
- l) description of the test room or workplace, sketch with dimensions and position of the machine;
- m) calculated emission rate of the pollutant in litres per minute ($\text{l}\cdot\text{min}^{-1}$) or milligrams per second ($\text{mg}\cdot\text{s}^{-1}$);
- n) name of the test person responsible;
- o) date(s) the test(s) were carried out;
- p) any comments on deviations from any relevant standards;
- q) any additional comments.

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