



SLOVENSKI STANDARD
kSIST ISO/FDIS 23431:2021

01-februar-2021

Zunanji zrak - Merjenje kakovosti zraka v cestnih tunelih

Measurement of road tunnel air quality

Mesurage de la qualité de l'air du tunnel routier

Ta slovenski standard je istoveten z: ISO/FDIS 23431

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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 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 146, *Air quality*, Subcommittee SC 3, *Ambient atmospheres*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC216, *Gas detectors*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

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.

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Introduction

The objective of this document is to provide road tunnel owners and operators with standard methods for checking and calibrating instruments used in road tunnels to continuously monitor air speed, carbon monoxide (CO), nitric oxide (NO) and nitrogen dioxide (NO₂) concentrations and visibility.

Data from these instruments enables tunnel operators to manage the ventilation system in real time or to take emergency measures (e.g. closure to traffic).

This document has been developed as a performance-based standard that allows for use of a number of direct-reading instruments. Statements expressed in mandatory terms in notes to tables and figures are deemed to be requirements of this document.

In order to improve traffic flow in central business districts and through sensitive environments, road tunnels are increasingly used throughout the world to achieve the desired outcomes. There are a large number of tunnels in operation, with a number of others in the planning stages.

Road tunnel projects are subject to environmental and/or planning approval conditions by regulatory authorities that specify the parameters to be monitored in-tunnel, typically including air speed, CO, NO, NO₂ and visibility, with NO measured as a surrogate for NO₂, with, historically, 10 % of total nitrogen oxides assumed to be NO₂. However, this assumption is no longer considered appropriate, given the increased proportion of diesel fuelled vehicles in vehicle fleets. It can also be a requirement that the tunnel ventilation system is controlled to:

- a) reduce CO and NO₂ concentrations within the tunnel environment to enable conformance with in-tunnel air quality criteria for various averaging periods;
- b) prevent or reduce portal emissions and resultant environmental impacts;
- c) ensure appropriate visibility for different tunnel operating conditions; and
- d) control smoke and improve the self-rescue time and security of tunnel users in emergency situations such as fires.

Conformance with in-tunnel air quality criteria is typically determined by averaging measured CO and measured or estimated NO₂ concentrations from a number of instruments located on possible travel paths throughout the tunnel system.

The number of instruments required to adequately characterise the tunnel environment is dependent on a number of factors, including:

- a) tunnel length and number of gradient changes and entry and exit ramps;
- b) volume of traffic and types of vehicles;
- c) exhaust ventilation system flowrate and control regime; and
- d) regulatory requirements.

Consequently, this aspect is not addressed in this document. It is noted, however, that computational fluid dynamics modelling can be used as a design tool to assist in the placement of instruments, ensuring that indicative maximum and average concentrations are measured.

Measurement of road tunnel air quality

1 Scope

This document describes methods for determining air speed and flow direction, CO, NO and NO₂ concentrations and visibility in road tunnels using direct-reading instruments. This document specifically excludes requirements relating to instrument conformance testing.

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 5802, *Industrial fans — Performance testing in situ*

ISO 6145, *Gas analysis — Preparation of calibration gas mixtures using dynamic methods*

ISO 10780, *Stationary source emissions — Measurement of velocity and volume flowrate of gas streams in ducts*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Guide 98-3: 2008 Part 3: Guide to the expression of uncertainty in measurement*

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

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3 Terms and definitions

For the purposes of this document, the following terms and definitions 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 <http://www.electropedia.org/>

3.1 calibration

set of operations that establish, under specified conditions, the relationship between the value indicated by a measuring instrument and the corresponding known value of a reference standard

3.2 certified reference material

reference material, characterized by a metrologically valid procedure for one or more specified properties, accompanied by a reference material certificate that provides the value of the specified property, its associated uncertainty, and a statement of metrological traceability

3.3 check

confirmation of acceptable instrument response, without adjustment

3.4 fall time

time interval, after a step decrease in input concentration, between initial instrument response and 10 % of initial instrument response

ISO/FDIS 23431:2020(E)**3.5****full scale****FS**

nominated maximum concentration for which an instrument has been calibrated

Note 1 to entry: The full scale (FS) is selected to cover the normal range of values expected in the sampling environment.

3.6**interference equivalent**

positive or negative instrument response caused by a substance other than the one being measured

3.7**linearity**

deviation of an instrument's output from a linear best fit line when subjected to varying reference test atmospheres

3.8**lower detectable limit**

minimum pollutant concentration that produces a signal of exactly three times the repeatability standard deviation

Note 1 to entry: See ISO 5725-1.

3.9**parameter**

one of the characteristics related to an air sample

EXAMPLE Concentration of pollutant or other quantifiable property (e.g. air speed).

3.10**ppm**

parts per million

ratio expressing the volume of gaseous pollutant contained in 1 000 000 volumes of atmosphere

Note 1 to entry: It may be expressed in terms of millilitres per cubic metre as the values are identical. Alternatively, it is one million times the ratio of the partial pressure of gaseous pollutant to the pressure of the atmosphere in which it is contained.

3.11**precision**

variation about the mean of repeated measurements of the same pollutant concentration on the same instrument, expressed as one standard deviation about the mean

3.12**range**

nominal minimum and maximum concentrations that a method is capable of measuring

Note 1 to entry: The nominal range is specified by the lower and upper range limits in concentration units, e.g. 0 to 250 ppm.

3.13**reference test atmosphere**

test atmosphere containing a known concentration of pollutant, typically generated by diluting the contents of a cylinder containing a gaseous *certified reference material* (3.2)

3.14**rise time**

time interval, after a step increase in input concentration, between the instrument initial response and 90 % of the final instrument response

3.15**road tunnel**

any fully enclosed length of roadway with a minimum length ranging between 90 m and 150 m

EXAMPLE National Fire Protection Association and UK Design Manual for Roads and Bridges.

3.16**span drift**

percentage change in the instrument response to an on-scale pollutant concentration over a period of continuous unadjusted operation

3.17**U₉₅**

measurement of expanded uncertainty at a confidence interval of 95 % according to ISO/IEC Guide 98-3

3.18**zero air**

air free from contaminants likely to cause a detectable response on the test instrument

3.19**zero drift**

change in the instrument response to a zero-pollutant concentration over a period of continuous unadjusted operation

4 Test parameter — Air speed and flow direction**4.1 General**

[Clause 4](#) describes continuous, direct-reading instruments for determining air speed and flow direction in road tunnels. Providing the instrument performance is within the specifications given in [Table 1](#), alternate methods may be used within the context of this document.

4.2 Principle

Air speed and flow direction in modern road tunnels are typically measured using ultrasonic flow sensors.

Ultrasonic sensor systems are based on the principle that the speed of air movement changes the transit time of a sound pulse across a fixed distance, allowing calculation of the air speed and determination of flow direction.

Instrument outputs may be used to control mechanical ventilation in a tunnel during both routine and emergency operation.

The measurement of flow in road tunnels is important for emergency operation (e.g. vehicle fire), enabling the control of air flow such that fumes are not dispersed in the tunnel tube. The choice of cross section or single point air flow measurements for this purpose is dependent on local technical practices.

Air flow measurement can also be important for the management of mechanical ventilation, either to dilute pollutants, or to control the atmospheric discharges at the portals.

Ultrasonic sensors are either open path or single point instruments, installed at various locations along the tunnel length, including portals and exit ramps.

Open path ultrasonic flow sensors measure the average value over the tunnel width, with transceiver pairs installed on opposing walls at an angle of 45° to 60° to the tunnel axis. In order to eliminate potential measurement errors caused by variations in ultrasonic sound speed due to temperature and pressure, the transceiver units shall be installed on each side of the tunnel wall, with the transit time measured in both directions.

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Single point ultrasonic flow sensors use the same measurement principle as open path sensors, measuring changes in the transit time of a sound pulse across a fixed distance, but in this case the distance evaluated is within the instrument casing.

NOTE 1 Open path ultrasonic flow sensors are typically located high on tunnel walls; consequently, it is possible that the measured air speed is not representative of the average speed for the overall tunnel cross-section. Similarly, single point ultrasonic flow sensors measure air speed close to the tunnel wall (or ceiling) and nearer the pavement, consequently it is possible that the measured air speed is not representative of the average speed for the tunnel cross-section, with the added potential, under normal operating conditions, for increased error due to turbulence created by vehicular traffic.

4.3 Apparatus

4.3.1 Instrument

A continuous direct-reading instrument that meets or exceeds the specifications given in [Table 1](#). The manufacturer's published performance specifications shall be deemed as acceptable evidence of conformance to the given requirements, if accompanied by a statement of measurement uncertainty issued by an organization that meets the requirements of ISO/IEC 17025.

Table 1 — Instrument performance specifications for tunnel air speed systems

Parameter	Minimum requirements
Range	(-20 to 20) m/s
Expanded measurement uncertainty	2 % of reading or 0,2 m/s ^a
Resolution	≤ 0,1 m/s
^a Whichever is the greater.	

4.3.2 Reference path length measurement device (open path instruments only)

A metrologically traceable reference path length measurement device with an uncertainty of 0,5 % U_{95} is required to make an accurate determination of the path length. The reference path length measurement device shall be checked over a path length of at least the instrument measurement path length.

Organizations performing the tests outlined in this clause shall meet the requirements of ISO/IEC 17025.

4.3.3 Transfer standard flow sensor

A metrologically traceable hand-held vane or hot-wire anemometer, or equivalent, of similar or higher specification to the air speed sensor, with an uncertainty of 2 % U_{95} is required to check the operation of air speed sensors. The transfer standard flow sensor shall be calibrated over a range exceeding the maximum air flow experienced in the tunnel.

Organizations performing the tests outlined in this clause shall meet the requirements of ISO/IEC 17025.

4.4 Procedure

The procedure shall be as follows:

- For open path ultrasonic flow sensors, ensure that the transceivers are installed such that the path for the sonic pulse is unimpeded by tunnel equipment or other obstructions, including vehicular traffic, whilst allowing ease of access for instrument maintenance and calibration.
- For open path ultrasonic flow sensors check instrument horizontal and vertical alignment and beam angle, in accordance with the manufacturer's instructions.
- For open path ultrasonic flow sensors, accurately measure and record the distance between the transceivers using a reference path length measurement device ([4.3.2](#)).