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Measurement of road tunnel air quality

Mesure de la qualité de l'air du tunnel routier

ICS: 93.060; 13.040.20

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Foreword

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The committee responsible for this document is ISO/TC 146/SC3/WG22.

Introduction

The objective of this Standard is to provide regulatory and testing bodies with standard methods for continuously monitoring air in road tunnels for air speed, carbon monoxide (CO), nitric oxide (NO) and nitrogen dioxide (NO_2) concentrations and visibility.

This Standard 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 Standard.

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, NO_2 and visibility, with NO measured as a surrogate for NO_2, with, historically, 10% of total nitrogen oxides assumed to be NO_2. However, this may no longer be a conservative assumption, 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 exposure to CO and NO_2 concentrations within the tunnel, enabling conformity with criteria for various averaging periods;

b) prevent or reduce portal emissions and resultant environmental impacts; and

c) ensure appropriate visibility for different tunnel operating conditions.

Compliance with the first requirement is typically determined by averaging CO and measured or estimated NO_2 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 Standard. It is noted, however, that computational fluid dynamics modelling could 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 Standard describes methods for determining air speed and flow direction, carbon monoxide (CO), nitric oxide (NO) and nitrogen dioxide (NO_2) concentrations and visibility in road tunnels using direct-reading instruments. This Standard 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.

EN 14211, *Ambient air - Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence*

EN 14626, *Ambient air - Standard method for the measurement of the concentration of carbon monoxide by non-dispersive infrared spectroscopy*

ISO 4224, *Ambient air — Determination of carbon monoxide — Non-dispersive infrared spectrometric method*

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

ISO 7996, *Ambient air — Determination of the mass concentration of nitrogen oxides — Chemiluminescence method*

ISO/IEC Guide 98, *Uncertainty of measurement — Guide 98-3: 2008 Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

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

3 Terms and definitions

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

3.5
full scale
the nominated maximum concentration for which an instrument has been calibrated. 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
the deviation of an instrument's output from a linear best fit line when subjected to varying reference test atmospheres

3.8
lower detectable limit
the minimum pollutant concentration that produces a signal of exactly three times the repeatability standard deviation (e.g. ISO 5725-1)

3.9
parameter
one of the characteristics related to an air sample, for example, concentration of pollutant or other quantifiable property (e.g. air speed)

3.10
parts per million (ppm)
a ratio expressing the volume of gaseous pollutant contained in 1 000 000 volumes of atmosphere. 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
a test atmosphere containing a known concentration of pollutant, typically generated by diluting the contents of a cylinder containing a gaseous certified reference material

3.14
rise time
the time interval, after a step increase in input concentration, between instrument initial response and 90% of final instrument response

3.15
road tunnel
any fully enclosed length of roadway with a minimum length ranging between 90 m (e.g. National Fire Protection Association) and 150 m (e.g. UK Design Manual for Roads and Bridges)

3.16
span drift
the percentage change in instrument response to an on-scale pollutant concentration over a period of continuous unadjusted operation

3.17
U_{95}
a measurement of 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
the change in 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

This clause describes continuous, direct-reading instruments for determining air speed and flow direction in road tunnels.

4.2 Principle

Air speed and flow direction in road tunnels are typically measured as average values over the tunnel width using ultrasonic flow sensors, with transceiver pairs installed on opposing walls at an angle of 45° to 60° to the tunnel axis, at various locations along the tunnel length, including portals and exit ramps. Single point ultrasonic flow sensors can also be used in road tunnels, however it should be recognized that the potential for error in the instantaneous measurement of both air speed and flow direction is increased due to turbulence created by vehicular traffic.

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 are used to control the direction of operation and speed of the axial flow jet fans installed on the roof of the tunnel. Depending on their location, the jet fans either assist the movement of polluted air in the direction of traffic flow, typically towards the ventilation stack, or reduce or eliminate pollutant emissions from the tunnel portals by creating air movement in the opposite direction to traffic flow.

NOTE 1 Ultrasonic flow sensors are typically located high on tunnel walls; consequently the measured air speed may not be representative of that for the overall tunnel cross-section.

NOTE 2 In order to eliminate potential measurement errors caused by variations in ultrasonic sound speed due to temperature and pressure, the transceiver units need to be installed on each side of the tunnel wall, with the transit time measured in both directions.

Providing the instrument performance is within the specifications given in Table 4.3.1, alternate methods may be used within the context of this Standard.

4.3 Apparatus

4.3.1 Instrument

A continuous direct-reading instrument that meets or exceeds the specifications given in Table 4.3.1. 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 a laboratory that meets the requirements of ISO/IEC 17025.

Table 4.3.1 — 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

A reference path length measurement device traceable to national standards 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.

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

NOTE Accreditation bodies who are signatories to the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA) for testing laboratories are able to offer accreditation against the requirements of ISO/IEC 17025. A listing of ILAC signatories is available from the ILAC website (www.ilac.org).

4.3.3 Transfer standard flow sensor

A hand-held vane or hot-wire anemometer, or equivalent, of similar or higher specification to the air speed sensor traceable to national standards 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.

The transfer standard sensor shall be calibrated as required such that it is traceable to required reference standards. This calibration shall be evidenced by a calibration certificate which states the sensitivity of the device by a procedure which establishes traceability to a recognized standard and for which a measurement uncertainty is given at a stated level of confidence, and the period during which the calibration is valid.

4.4 Procedure

The procedure shall be as follows:

a) 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.

b) Check instrument horizontal and vertical alignment, in accordance with the manufacturer's instructions.

c) Accurately measure and record the distance between the transceivers using a reference path length measurement device (Clause 4.3.2).

d) Set up the instrument and carry out initial checks in accordance with the manufacturer's instructions (e.g. setting the path length, configuring and scaling of analogue outputs, setting of alarm values and level of damping) and the requirements of Clause 4.5.

e) Take measurements in accordance with the manufacturer's instructions and ensure that the values obtained relate to the correct date and time.

4.5 Instrument checks and calibrations

4.5.1 General

Calibration of an instrument establishes the quantitative relationship between the air speed and the instrument's response.

Instrument checks and calibrations shall be carried out in accordance with the frequencies specified in Table 4.5.6.

In addition, operational precision checks shall be carried out as follows:

a) Prior to decommissioning or physical relocation of the instrument, if operational.

b) Following physical relocation of the instrument.

c) After any repairs that might affect the instrument's response.

d) Upon any indication of an instrument malfunction or change in response that may cause the instrument to drift by more than the values given in Table 4.5.6.

NOTE The air flow and direction monitor may incorporate an automatic daily zero and span check function for daily quality control and assurance purposes.

4.5.2 Measurement path length

The measurement path length is normally defined as the distance between the faces of opposing transceiver units, however, this should be confirmed with the manufacturer. The measurement path length shall be determined upon installation (see Table 4.5.6) using a reference distance measurement device as described in Clause 4.3.2.

A check of the measurement path length shall also be conducted whenever an instrument is reinstalled following maintenance or repair, if the maintenance or repair could result in a change of measurement path length.

4.5.3 Initial check

Conduct an initial check on the ultrasonic flow sensor prior to road tunnel opening using a collocated transfer standard (CTS) method at a minimum of three air velocities evenly spread over the tunnel design operational range.

For open path ultrasonic flow sensors, measurements shall be taken at a minimum of two points per trafficable lane over the measurement path. For a single point ultrasonic flow sensor, the CTS needs to be within 1 m of the subject sensor in the horizontal and 0.5 m in the vertical, but the same distance from the tunnel wall.

The CTS method requires a calibrated hand held vane or hot-wire anemometer, or equivalent, of similar or higher specification to the ultrasonic flow sensor, located in the vicinity of the measurement path for the sensor being assessed.

For both single point and open path ultrasonic flow sensors it is important to site the CTS to be representative of the air flow at the subject sensor, without interfering with either instrument's response.

