INTERNATIONAL STANDARD

ISO 14164

First edition
1999-04-01

Stationary source emissions — Determination of the volume flowrate of gas streams in ducts — Automated method

Émissions de sources fixes — Détermination du débit-volume des courants gazeux dans des conduites — Méthode automatisée

Contents

1 Scope 1

2 Normative references 1

3 Terms and definitions 2

4 Measuring principles of commercially available AMS 3

5 Numerical performance characteristics and their applicability 6

6 Test report 6

Annex A (normative) **Determination of the main performance characteristics** 7

Annex B (informative) **Additional performance characteristics** 11

Bibliography 13

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet iso@iso.ch

Printed in Switzerland

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 3.

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.

International Standard ISO 14164 was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 1, *Stationary source emissions.*

Annex A forms a normative part of this International Standard. Annex B is for information only.

ISO **INTERNATIONAL STANDARD** © **ISO 14164:1999(E)**

Stationary source emissions — Determination of the volume flowrate of gas streams in ducts — Automated method

1 Scope

This International Standard describes the operating principles and the most important performance characteristics of automated flow-measuring systems for determining the volume flowrate in the ducts of stationary sources.

Procedures to determine the performance characteristics of automated volume flow-measuring systems are also contained in this International Standard.

The performance characteristics are general and not limited to specific measurement principles or instrument systems.

NOTE Commercial systems which use the operating principles described and meet the requirements of this International Standard are readily available.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 6879: 1995, *Air quality — Performance characteristics and related concepts for air quality measuring methods*.

ISO 7935:1992, *Air quality — Stationary source emissions — Determination of mass concentration of sulfur dioxide — Performance characteristics of automated measuring methods*.

ISO 9096:1992, *Stationary source emissions — Determination of concentration and mass flow rate of particulate material in gas-carrying ducts — Manual gravimetric method*.

ISO 9169:1994, *Air quality — Determination of performance characteristics of measurement methods.*

ISO 10155:1995, *Stationary source emissions — Automated monitoring of mass concentrations of particles — Performance characteristics, test methods and specifications*.

ISO 10780:1994, *Air quality — Stationary source emissions — Measurement of velocity and volume rate of flow of gas streams in ducts.*

ISO 10849:1996, *Stationary source emissions — Determination of the mass concentration of nitrogen oxides — Performance characteristics and calibration of automated measuring systems*.

ISO 12039: —[1], *Stationary source emissions — Determination of the volumetric concentration of CO, CO_2 and O_2 — Performance characteristics and calibration of automated measuring systems*.

---

[1] To be published.

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

3.1
automated flow-measuring system
AMS
system that may be attached to a duct to continuously measure and record the volume flow of a gas

3.2
analyzer
that part of an AMS that measures the parameters used to calculate the volume flow of a gas

3.3
duct
stack, chimney or final exit duct on a stationary process, used for the dispersion of residual process gases

3.4
comparative measurements
measurements of volume gas flow in the duct by the AMS under test (evaluation) and compared to volume flow simultaneously determined in the same duct in accordance with ISO 10780

3.5
comparative method
method for determination of volume gas flow in a duct in accordance with ISO 10780

NOTE Since the purpose of the comparative test is to demonstrate that the AMS under test yields an accurate estimate of the volume flow in the duct, it is necessary for the comparative method to measure the volume flow profile of the entire duct. An AMS cannot be used as the comparative method because all AMS used for measuring volume flow measure the velocity in a small area of the duct and then extrapolate this measurement to obtain the volume flow in the duct.

3.6
standard deviation
s_A
a measure of the working precision of the installed AMS

NOTE 1 It is derived using the differences between the pairs of volume flow values obtained by comparative testing of the AMS against ISO 10780 on the basis that a statistically sufficient number of comparative measurements are taken over the period of unattended operation (see annex A). The value of s_A is expressed as a function of the full-scale range of the AMS and is calculated on the assumption that s_A is an estimate of the precision of a normally distributed set of measurements.

NOTE 2 Whenever possible, the comparative method should measure the same portion of the gas flow as the AMS.

NOTE 3 It is not possible to determine directly the standard deviation of an AMS in a laboratory, because wind tunnels do not normally reproduce all the properties of stack gases and do not replicate all possible measurement conditions. This is the reason the standard deviation is determined after the AMS has been installed in the duct. Applying the comparative method in conjunction with the test for systematic errors (see A.4.2.3) ensures that the AMS has a satisfactory accuracy.

NOTE 4 In addition to random error, s_A contains the effect that local site variables such as changes in the gas steams temperature, fluctuations in the electrical power supplied to the AMS and zero and span drift have on the overall precision of the AMS. It also includes the standard deviation of the comparative method. s_A is an estimate of the upper limiting value for the precision of the AMS.

NOTE 5 The procedure in this International Standard is suitable for finding the uncertainty of the data obtained from the AMS, as long as the standard deviation of the measured values of the comparative method, s_C, is significantly smaller than the standard deviation, s_D, of the difference between the pairs of measured values.

3.7
period of unattended operation
period for which given values of the performance characteristics of an instrument can be guaranteed to remain within 95 % probability without servicing or adjustment

[ISO 6879]

NOTE For long-term monitoring installations, a minimum of seven days of unattended operation is required.

3.8
response time
time it takes the AMS to display 90 % of the high-level calibration value on the data acquisition system, starting from the time of initiation of the high-level calibration cycle

NOTE The response time may be determined either in the laboratory or after the AMS is installed.

3.9
stationary source emission
gas emitted by a stationary plant or process and transported to a duct for dispersion into the atmosphere

3.10
calibration
<of an AMS> the setting and checking of the installed AMS before determining its performance characteristics or before beginning any volume flow measurement

3.11
calibration function
correlation over the span range of the AMS between the volume flowrate of the duct as measured by the installed AMS and as measured in accordance with the reference flowrate

NOTE 1 ISO 10780 is an example of a reference flow standard.

NOTE 2 A nonlinear calibration function is acceptable, provided this nonlinearity is compensated for in the output of the AMS.

3.12
linearity
measure of the degree of agreement between the measurements of the comparative method (ISO 10780) and the AMS when the differences between the AMS and the comparative method across a range of volume flows are subjected to a linear regression

3.13
span
difference between the AMS output (reading) for a known flowrate and a zero flowrate

3.14
zero drift
change in the output of the AMS over a stated time interval when exposed to an unchanging zero flowrate

3.15
span drift
change in the output of the AMS over a stated time interval when exposed to an unchanging flowrate near the span value

3.16
AMS location
point in the duct where the AMS is installed

4 Measuring principles of commercially available AMS

4.1 General

Most commercially available AMS operate on one of the following three principles: pressure differential, rate of heat loss, or change in the speed of a sound wave. A brief description of each common type of AMS and the advantages and disadvantages of each are presented below.

Before selecting a specific type of AMS for installation, the characteristics of the flow profile shall be established at the location in the duct where the AMS is to be installed (see clause A.2 in annex A). Volume flow-measuring AMS systems should not be used in ducts where non-uniform, asymmetrical, developing, swirling and/or stratified flow is present.

4.2 Differential pressure-sensing systems

4.2.1 Single Pitot tube methods

ISO 10780, the manual reference method for measuring velocity and volume flow in ducts, uses Pitot tubes, the traditional means used to determine flow in ducts. A number of Pitot tubes are available, but the Type-S and Type-L Pitot tubes specified in ISO 10780 are those used for the vast majority of flow measurements in ducts. Some Pitot tube-based AMS simply combine devices which continuously record the pressure differential and the stack temperature, an automated data reduction system such as a data-logger or a computer, and a Pitot tube to yield a continuous measurement of flowrate.

Pitot tubes use the temperature of the gas stream and the difference in pressure measured at two or more points on the Pitot’s surface to determine the velocity of the gas stream at individual points across a cross-section of the duct. The volume flowrate is then determined by multiplying the average velocity across the cross-section by the area of this cross-section.

These systems are simple and relatively inexpensive to install, operate and maintain, but are subject to the same errors as the Pitot tubes described in clause 6 of ISO 10780:1994. For example, unless special precautions are taken, Pitot tubes can give erroneous results when used to measure gas streams having any of the following conditions:

a) Reynolds numbers less than 1 200;

b) velocities less than 5 m/s or greater than 50 m/s;

c) cyclonic or angular flow;

d) irregular pressure fluctuations; and

e) high concentrations of particles and/or aerosols.

These latter two problem areas frequently can be avoided by ensuring that the Pitot tube does not vibrate and by periodically back-purging through the Pitot tube. Gas stream pressure fluctuations can be compensated for by employing a damping device in the measurement system.

4.2.2 Multiple-point Pitot tube (MPPT) method

The MPPT is a modified form of the Pitot tube; it contains three or more openings (ports) in a pipe, located at the traverse points corresponding to the centres of equal areas of the stack cross-section. The openings facing in the direction of flow give the average impact pressure across the stack diameter, while those facing away from the direction of flow give the average wake pressure. A divider in the centre of the tube separates the two pressure legs of the MPPT. The average impact and wake pressures are compared using an electrical pressure transducer or other differential pressure-sensing device. Since the orifice locations are different for each installation, stack dimensions shall be carefully specified before the MPPT is constructed.

AMS systems based on the MPPT approach suffer from the same limitations as the single-Pitot AMS systems. They can also yield erroneous measurements where the velocity varies substantially acrosst. This latter error results because secondary flows in the MPPT affect the average pressure differentials measured.

4.3 Temperature-sensing systems

These systems, which are frequently referred to as thermal anemometers, operate on the phenomenon that a flowing gas can cool a heated body. The most widely used systems employ two thermal convection mass flow sensors; one of which is heated and the other maintained at ambient temperature. Both sensors are inserted into the gas stream. The temperature differential (measured in terms of voltage or current) between the two sensors is used to determine the flowrate of the gas stream.

Two basic types of thermal convection mass flow sensors are in general use today: the constant-power sensor (CP) and the constant-temperature sensor (CT). The CP-based systems are not widely used because they:

a) are slow to respond to changes in velocity and temperature;

b) do not have a stable “zero”; and

c) have a limited range of temperature compensation.

Because of the above limitations, most thermal-differential AMS systems use the CT approach. In this system, a solid-state feedback control circuit is used to maintain the heated sensor at a constant temperature. The current required to maintain this temperature is measured and converted to mass flow units based on calculations which employ the transport properties of the gas stream. CT-based systems have a much faster response to velocity changes than CP systems, because in the CT-based system only the outer surface of the heated sensor is dependent on its thermal inertia, that is, the centre is already at constant temperature. CT-based systems usually have response times of 5 s or less.

Temperature-differential-based AMS have the following advantages: high-level electronic signal output; accurate at very low gas-stream velocities; no moving parts; and good repeatability from 0 °C to 450 °C. However, the output of the sensor is not linear, and it is necessary to fine-tune the factory-calibrated AMS after it is installed to compensate for differences between the properties of the actual gas stream and the gas stream generated in the manufacturer's wind tunnel at the factory. This fine-tuning is generally done using one of the Pitot tubes described in ISO 10780.

Thermal sensor-based AMS cannot be used in ducts where condensing liquid droplets are present in the gas stream, nor can they be used in cases where the velocity vector of the gas stream differs by more than 10° from the duct’s primary axis. Buildup of particulate coating on the sensor or corrosion can also cause significant measurement error.

Suppliers of thermal sensor-based AMS generally recommend installing and operating the AMS for a minimum of seven days before attempting to fine-tune the AMS. This allows the AMS sensors and electronics to come to equilibration with conditions in the duct.

Most of these AMS use multiple sensors located at predetermined points in the duct to yield an average velocity for the gas stream. This average velocity is multiplied by the stack cross-section to yield the volume flowrate of the gas in the duct. Since each sensor makes an independent measurement, multi-sensor systems can be used to monitor the distribution of the gas flow across the cross-section of the duct.

4.4 Sound-based systems

These systems determine flowrate by comparing the time it takes for a sound pulse to travel in the general direction of gas flow to the time it takes for an identical sound pulse to travel along the same path in the opposite direction. In this type of AMS, two transceivers are located opposite each other on the stack and offset at a known angle. In each transceiver, a piezoelectric transducer transmits ultrasonic pulses to the opposite transceiver. Each transducer converts electrical signals to acoustic signals and acoustic signals to electrical signals. The speed at which the pulse crosses the stack is dependent upon whether it travels with or against the flow.

Since this type of AMS transmits the sound pulse across the stack, it is extremely important to confirm that there are no obstructions present that will interfere with the passage of the pulses across the duct. For highest accuracy, it is also important to locate the AMS at a point where vibration in the duct walls is not present and to ensure that the optical windows remain clean. However, if an air purge is used to keep the transceivers clean, care shall be taken to correct the AMS response for any effect the purge air has on the gas velocity near the transceivers.

These systems have the following advantages: non-intrusive measurement, no moving parts, easily accessible components and stable precision over a wide range of flowrates.