INTERNATIONAL STANDARD

ISO 17089-2

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Measurement of fluid flow in closed conduits — Ultrasonic meters for gas —

Part 2: Meters for industrial applications

Mesurage de débit des fluides dans les conduites fermées — Compteurs à ultrasons pour gaz —

Partie 2: Compteurs pour applications industrielles

Reference number
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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 17089-2 was prepared by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*, Subcommittee SC 5, *Velocity and mass methods*.

ISO 17089 consists of the following parts, under the general title *Measurement of fluid flow in closed conduits — Ultrasonic meters for gas*:

— *Part 1: Meters for custody transfer and allocation measurement*

— *Part 2: Meters for industrial applications*

Introduction

Ultrasonic meters (USMs) for gas flow measurement have penetrated the market for meters rapidly since 2000 and have become one of the prime flowmeter concepts for operational use as well as custody transfer and allocation measurement. As well as offering high repeatability and high accuracy, ultrasonic technology has inherent features like: negligible pressure loss, high rangeability and the capability to handle pulsating flows.

USMs can deliver extended diagnostic information through which it may be possible to verify not only the functionality of a USM, but also several other components within the system, such as the gas chromatograph, and the pressure and temperature transmitters. Due to the extended diagnostic capabilities, this part of ISO 17089 advocates the addition and use of automated diagnostics instead of labour-intensive quality checks.

This part of ISO 17089 focuses on meters for industrial gas applications (class 3 and class 4). Meters for custody transfer and allocation measurement are the subject of ISO 17089-1.

Typical performance factors of the classification scheme are:

Class	Typical applications	Typical uncertainty 95 % confidence level (volume flow rate)[a]	Reference
1	Custody transfer	±0,7 %	ISO 17089-1
2	Allocation	±1,5 %	ISO 17089-1
3	Utilities and process	±1,5 % to 5 % for $q_V > q_{V,\mathrm{t}}$[b]	This part of ISO 17089
4	Flare gas and vent gas	±5 % to 10 % for $q_V > q_{V,\mathrm{t}}$	This part of ISO 17089

[a]Meter performance, inclusive of total meter uncertainty, repeatability, resolution and maximum peak-to-peak error, depends upon a number of factors which include pipe inside diameter, acoustic path length, number of acoustic paths, gas composition and speed of sound, as well as meter timing repeatability.

[b]By specific flow conditioning or when multi-path meters are employed, lower uncertainties may be achieved.

The special application note(s) as presented in Clause 7 as well as information in parentheses are informative.

Measurement of fluid flow in closed conduits — Ultrasonic meters for gas —

Part 2:
Meters for industrial applications

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 part of ISO 17089 specifies requirements and recommendations for ultrasonic gas meters (USMs), which utilize acoustic signals to measure the flow in the gaseous phase in closed conduits.

This part of ISO 17089 is applicable to transit time USMs and is focused towards industrial flow measurement. Included are meters comprising meter bodies as well as meters with field-mounted transducers.

There are no limits on the size of the meter. It can be applied to the measurement of almost any type of gas; such as but not limited to air, hydrocarbon gases, and steam.

This part of ISO 17089 specifies performance, calibration (when required), and output characteristics of USMs for gas flow measurement and deals with installation conditions.

NOTE It is possible that national or other regulations apply which can be more stringent than those in this part of ISO 17089.

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 4006, *Measurement of fluid flow in closed conduits — Vocabulary and symbols*

3 Terms, definitions, and symbols

3.1 Terms and definitions

3.1.1 General

For the purposes of this document, the terms and definitions given in ISO 4006 and the following apply.

3.1.2 Quantities

3.1.2.1
volume flow rate
q_V

$$q_V = \frac{dV}{dt}$$

where

V is volume;

t is time.

NOTE Adapted from ISO 80000-4:2006,[8] 4-30.

3.1.2.1.1
actual flow rate
volume of fluid per time at metering conditions

3.1.2.1.2
corrected flow rate
volume of fluid per time measured at metering conditions, but converted to equivalent volume at base conditions

3.1.2.2
indication
flow rate indicated by the meter

3.1.2.3
working range
set of values of quantities of the same kind that can be measured by a given measuring instrument or measuring system with specified instrumental uncertainty, under defined conditions

NOTE 1 Adapted from ISO/IEC Guide 99:2007,[10] 4.7, "working interval".

NOTE 2 For the purposes of this part of ISO 17089, the "set of values of quantities of the same kind" are volume flow rates whose values are bounded by a maximum flow rate, $q_{V,\,\mathrm{max}}$, and a minimum flow rate, $q_{V,\,\mathrm{min}}$; the "given measuring instrument" is a meter.

NOTE 3 The terms "rangeability" and "turndown" can often be found in flowmeter data sheets in connection with the working range of the meter. These terms are sometimes used interchangeably although their exact meanings are different and may not mean the same as working range. For example, it is possible to find a stated flowmeter rangeability derived from the highest measurable flow divided by the minimum measurable flow (typically with flow expressed in terms of flow velocity).

3.1.2.4
metering pressure
p
absolute gas pressure in a meter at flowing conditions to which the indicated volume of gas is related

3.1.2.5
average velocity
v
volume flow rate divided by the cross-sectional area

3.1.3 Meter design

3.1.3.1
meter body
pressure-containing structure of the meter

3.1.3.2
acoustic path
path travelled by an acoustic wave between a pair of ultrasonic transducers

3.1.3.3
axial path
path travelled by an acoustic wave entirely in the direction of the main pipe axis

NOTE An axial path can be both on or parallel to the centre-line or long axis of the pipe.

See Figure 1.

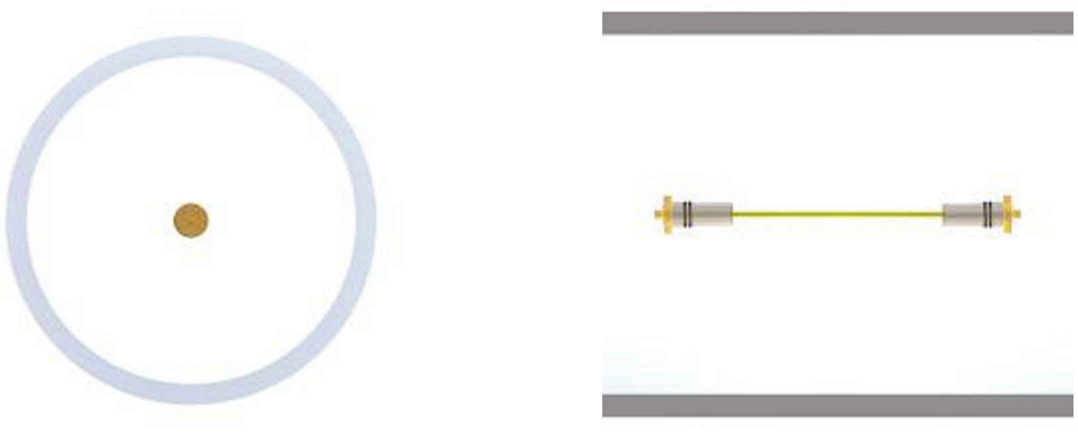

Figure 1 — Axial path

3.1.3.4
diametrical path
acoustic path whereby the acoustic wave travels through the centre-line or long axis of the pipe

See Figure 2.

Figure 2 — Diametrical paths

3.1.3.5
chordal path
acoustic path whereby the acoustic wave travels parallel to the diametrical path

See Figure 3.

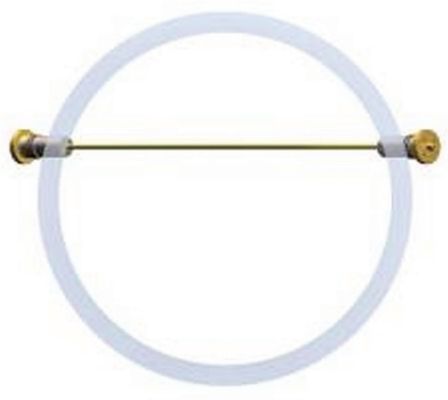

Figure 3 — Chordal paths

3.1.4 Thermodynamic conditions

3.1.4.1
metering conditions
conditions, at the point of measurement, of the fluid whose volume is to be measured

NOTE 1 Metering conditions include gas composition, temperature, and pressure also known as uncorrected conditions.

NOTE 2 Adapted from ISO 9951:1993,[5] 3.1.6.

3.1.4.2
base conditions
conditions to which the measured volume of the gas is converted

NOTE 1 Base conditions include base temperature and base pressure.

NOTE 2 Adapted from ISO 9951:1993,[5] 3.1.7.

NOTE 3 Preferred alternatives include reference conditions, standard conditions, normal conditions.

NOTE 4 Metering and base conditions relate only to the volume of the gas to be measured or indicated, and should not be confused with rated operating conditions and reference operating conditions (see ISO/IEC Guide 99:2007,[10] 4.9 and 4.11), which refer to influence quantities (see ISO/IEC Guide 99:2007,[10] 2.52).

3.1.4.3
specified conditions
conditions of the fluid at which performance specifications of the meter are given

NOTE Adapted from ISO 9951:1993,[5] 3.1.8.

3.1.5 Statistics

3.1.5.1
measurement error
error of measurement
error
measured quantity value minus a reference quantity value

[ISO/IEC Guide 99:2007,[10] 2.16]

EXAMPLE Difference between the indication of the meter under test and the indication of the reference measurement.

3.1.5.2
error curve
interconnection of the curve (e.g. polynomial) fitted to a set of error data as a function of the flow rate of the reference meter

3.1.5.3
maximum peak-to-peak error
maximum difference between any two error values

3.1.5.4
repeatability
measurement precision under a set of repeatability conditions of measurement

[ISO/IEC Guide 99:2007,[10] 2.21]

EXAMPLE The closeness of agreement among a number of consecutive measurements of the output of the test meter for the same reference flow rate under the same metering conditions.

NOTE The repeatability corresponds to the 95 % confidence interval of the error.

3.1.5.5
resolution
smallest difference between indications of a meter that can be meaningfully distinguished

NOTE Adapted from ISO 11631:1998,[6] 3.28.

3.1.5.6
velocity sampling interval
time interval between two consecutive gas velocity measurements

3.1.5.7
zero flow reading
flowmeter indication when the gas is at rest, when both axial and non-axial velocity components are essentially zero

Figure 4 shows the flow rates in relation to the uncertainty budget.

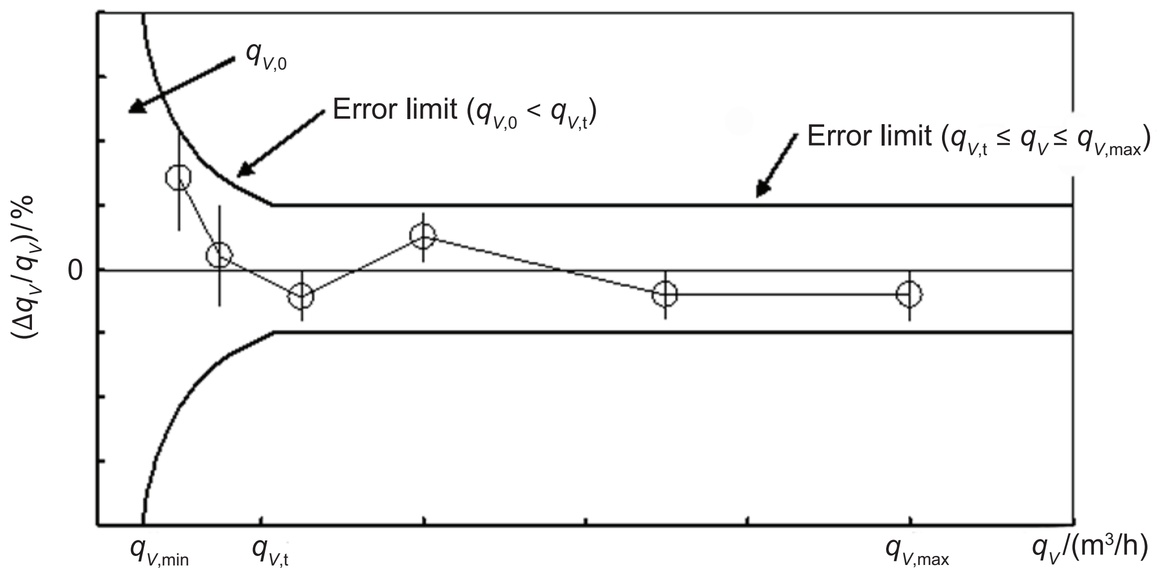

Figure 4 — Typical error curve as function of the flow rate

3.2 Symbols and subscripts

The symbols and subscripts used in this part of ISO 17089 are given in Tables 1 and 2. Examples of uses of the volume flow rate symbol are given in Table 3.

Table 1 — Symbols

Quantity	Symbol	Dimensions[a]	SI unit
Cross-sectional area	A	L^2	m^2
Speed of sound in fluid	c	LT^{-1}	m/s
Inside diameter of the meter body	D	L	m
Weighting factors (live inputs)	f_i	1[b]	—
Integers (1,2,3, …)	i,n	1[b]	—
Calibration factor	K	1[b]	—
Flow profile correction factor	k_n	1[b]	—
Valve noise	$L_{p,\mathrm{N,v}}$	1[b]	dB
Path length	l_p	L	m
Attenuation factor	N_d	1[b]	—
Valve weighting factor	N_v	1[b]	—
Number of samples used in the signal processing.	n_s	1[b]	—
Absolute pressure	p	$ML^{-1}T^{-2}$	Pa
Emitted acoustic pressure	p_n	$ML^{-1}T^{-2}$	Pa
Pressure difference	Δp	$ML^{-1}T^{-2}$	Pa
Mass flow rate	q_m	MT^{-1}	kg/s
Volume flow rate	q_V	L^3T^{-1}	m^3/s
Transit time	t	T	s
Average velocity	v	LT^{-1}	m/s
Velocity of the acoustical path i	v_i	LT^{-1}	m/s
Weighting factors (fixed value)	w_i	1[b]	—
Path angle	ϕ	—	rad
Density of the fluid	ρ	ML^{-3}	kg/m^3

[a] M ≡ mass; L ≡ length; T ≡ time ; Θ ≡ temperature.

[b] ”Dimensionless” quantity.

Table 2 — Subscripts

Subscript	Meaning
min	minimum
max	maximum
t	transition

Table 3 — Examples of flow rate symbols

Symbol	Meaning
$q_{V,\mathrm{max}}$	Designed maximum flow rate
$q_{V,\mathrm{min}}$	Designed minimum flow rate
$q_{V,\mathrm{t}}$	Transition flow rate for defining accuracy requirements

3.3 Abbreviations

ES	electronic system
FAT	factory acceptance test
FC	flow conditioner
MSOS	measured speed of sound
SNR	signal-to-noise ratio
SOS	speed of sound
TSOS	theoretical speed of sound
USM	ultrasonic flowmeter
USMP	USM package, including upstream pipe, flow conditioner and thermo-well when bi-directional

4 Principles of measurement

4.1 Transit time ultrasonic meters

Figure 5 outlines the basic system setup to demonstrate the transit time principle. A pair of transducers capable of transmitting and receiving ultrasonic pulses is located on both sides of the pipe at positions A and B. The transducers transmit and receive pulses sequentially. Under zero flow conditions, the time taken for an ultrasonic pulse to travel from A to B, t_{AB}, is equal to that from B to A, t_{BA}, and there is no difference in time.

When a flow is introduced, the ultrasonic pulse from A to B is assisted by the flow, and as a result the time taken decreases. In addition, the pulse from B to A is opposed by the flow and subsequently the time taken increases. The resulting measured difference in transit time is directly proportional to the axial velocity of the flowing gas. Providing that the distance between the transducers is known, the axial gas velocity passing between transducer A and B can be measured. Ignoring second order effects such as path curvature, the travel times of the acoustic pulse, t_{AB} and t_{BA}, can be shown to be given by:

$$t_{AB} = \frac{l_p}{(c + v\cos\phi)} \quad (1)$$

and

$$t_{BA} = \frac{l_p}{(c - v\cos\phi)} \quad (2)$$

where

l_p is the path length;

c is the speed of sound (SOS) in the gas;

v is the average velocity of the gas;

ϕ is the path angle.