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Mesure de débit de gaz au moyen de Venturi-tuyères en régime critique (ISO 9300:2005)

Durchflussmessung von Gasen mit Venturidüsen bei kritischer Strömung (ISO 9300:2005)

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Foreword

This document (EN ISO 9300:2005) has been prepared by Technical Committee ISO/TC 30 "Measurement of fluid flow in closed conduits" in collaboration with CMC.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2006, and conflicting national standards shall be withdrawn at the latest by February 2006.

This document supersedes EN ISO 9300:1995.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Endorsement notice

The text of ISO 9300:2005 has been approved by CEN as EN ISO 9300:2005 without any modifications.

Measurement of gas flow by means of critical flow Venturi nozzles

1 Scope

This International Standard specifies the geometry and method of use (installation in a system and operating conditions) of critical flow Venturi nozzles (CFVN) used to determine the mass flow-rate of a gas flowing through a system. It also gives the information necessary for calculating the flow-rate and its associated uncertainty.

It is applicable to Venturi nozzles in which the gas flow accelerates to the critical velocity at the throat (this being equal to the local sonic velocity), and only where there is steady flow of single-phase gases. At the critical velocity, the mass flow-rate of the gas flowing through the Venturi nozzle is the maximum possible for the existing upstream conditions while CFVN can only be used within specified limits, e.g. limits for the nozzle throat to inlet diameter ratio and throat Reynolds number. This International Standard deals with CFVN for which direct calibration experiments have been made in sufficient number to enable the resulting coefficients to be used with certain predictable limits of uncertainty.

Information is given for cases where the pipeline upstream of the CFVN is of circular cross-section, or it can be assumed that there is a large space upstream of the CFVN or upstream of a set of CFVN mounted in a cluster. The cluster configuration offers the possibility of installing CFVN in parallel, thereby achieving high flow-rates.

For high-accuracy measurement, accurately machined Venturi nozzles are described for low Reynolds number applications.

2 Terms and definitions

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

2.1 Pressure measurement

2.1.1
wall pressure tapping
hole drilled in the wall of a conduit in such a way that the edge of the hole is flush with the internal surface of the conduit

NOTE The tapping is achieved such that the pressure within the hole is the static pressure at that point in the conduit.

2.1.2
static pressure of a gas
actual pressure of the flowing gas which can be measured by connecting a pressure gauge to a wall pressure tapping

NOTE Only the value of the absolute static pressure is used in this International Standard.

2.1.3
stagnation pressure
pressure which would exist in a gas in a flowing gas stream if the stream were brought to rest by an isentropic process

NOTE Only the value of the absolute stagnation pressure is used in this International Standard.

2.2 Temperature measurement

2.2.1
static temperature
actual temperature of a flowing gas

NOTE Only the value of the absolute static temperature is used in this International Standard.

2.2.2
stagnation temperature
temperature which would exist in a gas in a flowing gas stream if the stream were brought to rest by an isentropic process

NOTE Only the value of the absolute stagnation temperature is used in this International Standard.

2.3 Venturi nozzles

2.3.1
Venturi nozzle
convergent/divergent restriction inserted in a system intended for the measurement of flow-rate

2.3.2
normally machined Venturi nozzle
Venturi nozzle machined by a lathe and surface polished to achieve the desired smoothness

2.3.3
accurately machined Venturi nozzle
Venturi nozzle machined by a super-accurate lathe to achieve a mirror finish without polishing

2.3.4
throat
section of minimum diameter of a Venturi nozzle

2.3.5
critical flow Venturi nozzle
CFVN
Venturi nozzle for which the nozzle geometrical configuration and conditions of use are such that the flow-rate is critical at the nozzle throat

2.4 Flow

2.4.1
mass flow-rate
q_m
mass of gas per unit time passing through the CFVN

NOTE In this International Standard, the term flow-rate always refers to *mass flow-rate*.

2.4.2
throat Reynolds number
Re_{nt}
dimensionless parameter calculated from the gas flow-rate and the gas dynamic viscosity at nozzle inlet stagnation conditions

NOTE The characteristic dimension is taken as the throat diameter at stagnation conditions. The throat Reynolds number is given by the formula:

$$Re_{\text{nt}} = \frac{4q_m}{\pi d \mu_0}$$

2.4.3
isentropic exponent
κ
ratio of the relative variation in pressure to the corresponding relative variation in density under elementary reversible adiabatic (isentropic) transformation conditions

NOTE 1 The isentropic exponent is given by the formula:

$$\kappa = \frac{\rho}{p}\left(\frac{\mathrm{d}p}{\mathrm{d}\rho}\right)_{\mathrm{s}} = \frac{\rho c^2}{p}$$

where

p is the absolute static pressure of the gas;

ρ is the density of the gas;

c is the local speed of sound;

s signifies “at constant entropy”.

NOTE 2 For an ideal gas, κ is equal to the ratio of specific heat capacities γ and is equal to 5/3 for monatomic gases, 7/5 for diatomic gases, 9/7 for triatomic gases, etc.

NOTE 3 In real gases, the forces exerted between molecules as well as the volume occupied by the molecules have a significant effect on the gas behaviour. In an ideal gas, intermolecular forces and the volume occupied by the molecules can be neglected.

2.4.4
discharge coefficient
$C_{\mathrm{d}'}$
dimensionless ratio of the actual flow-rate to the ideal flow-rate of non-viscous gas that would be obtained with one-dimensional isentropic flow for the same upstream stagnation conditions

NOTE This coefficient corrects for viscous and flow field curvature effects. For each type of nozzle design and installation conditions specified in this International Standard, it is only a function of the throat Reynolds number.

2.4.5
critical flow
maximum flow-rate for a particular Venturi nozzle, which can exist for the given upstream conditions

NOTE When critical flow exists, the throat velocity is equal to the local value of the speed of sound (acoustic velocity), the velocity at which small pressure disturbances propagate.

2.4.6
critical flow function
C_*
dimensionless function which characterises the thermodynamic flow properties of an isentropic and one-dimensional flow between the inlet and the throat of a Venturi nozzle

NOTE It is a function of the nature of the gas and of stagnation conditions (see 4.2).

2.4.7
real gas critical flow coefficient
C_{R}
alternative form of the critical flow function, more convenient for gas mixtures

NOTE It is related to the critical flow function as follows:

$$C_{\mathrm{R}} = C_* \sqrt{Z}$$

2.4.8
critical pressure ratio
r_*
ratio of the static pressure at the nozzle throat to the stagnation pressure for which the gas mass flow-rate through the nozzle is a maximum

NOTE This ratio is calculated in accordance with the equation given in 8.5.

2.4.9
back-pressure ratio
ratio of the nozzle exit static pressure to the nozzle upstream stagnation pressure

2.4.10
Mach number
Ma
⟨at nozzle upstream static conditions⟩ ratio of the mean axial fluid velocity to the velocity of sound at the location of the upstream pressure tapping

2.4.11
compressibility factor
Z
correction factor expressing numerically the deviation from the ideal gas law of the behaviour of a real gas at given pressure and temperature conditions

NOTE It is defined by the formula:

$$Z = \frac{pM}{\rho RT}$$

where R, the universal gas constant, equals 8,314 51 J/(mol·K).

2.5
uncertainty
parameter, associated with the results of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

3 Symbols

Symbol	Description	Dimension	SI unit
A_2	Cross-sectional area of Venturi nozzle exit	L^2	m^2
A_{nt}	Cross-sectional area of Venturi nozzle throat	L^2	m^2
$C_{d'}$	Coefficient of discharge	Dimensionless	
C_R	Critical flow coefficient for one-dimensional flow of a real gas	Dimensionless	
C_*	Critical flow function for one-dimensional flow of a real gas	Dimensionless	
C_{*i}	Critical flow function for one-dimensional isentropic flow of a perfect gas	Dimensionless	
D	Diameter of the upstream conduit	L	m
d	Diameter of Venturi nozzle throat	L	m
M	Molar mass	M	kg mol^{-1}
Ma_1	Mach number at the location of the upstream pressure tapping	Dimensionless	
p_1	Absolute static pressure of the gas at nozzle inlet	$ML^{-1}T^{-2}$	Pa
p_2	Absolute static pressure of the gas at nozzle exit	$ML^{-1}T^{-2}$	Pa
p_0	Absolute stagnation pressure of the gas at nozzle inlet	$ML^{-1}T^{-2}$	Pa
p_{nt}	Absolute static pressure of the gas at nozzle throat	$ML^{-1}T^{-2}$	Pa
p_{*i}	Absolute static pressure of the gas at nozzle throat for one-dimensional isentropic flow of a perfect gas	$ML^{-1}T^{-2}$	Pa
$(p_2/p_0)_i$	Ratio of nozzle exit static pressure to inlet stagnation pressure for one-dimensional isentropic flow of a perfect gas	Dimensionless	
q_m	Mass flow-rate	MT^{-1}	$kg \cdot s^{-1}$
q_{mi}	Mass flow-rate for one-dimensional isentropic flow of an inviscid gas	MT^{-1}	$kg \cdot s^{-1}$
R	Universal gas constant	$M L^2T^{-2}\Theta^{-1}$	$J \cdot mol^{-1}K^{-1}$
Re_{nt}	Nozzle throat Reynolds number	Dimensionless	
r_c	Radius of curvature of nozzle inlet	L	m
r_*	Critical pressure ratio p_{nt}/p_0	Dimensionless	
U'	Relative uncertainty	Dimensionless	
T_1	Absolute temperature of the gas at nozzle inlet	Θ	K
T_0	Absolute stagnation temperature of the gas at nozzle inlet	Θ	K
T_{nt}	Absolute static temperature at nozzle throat	Θ	K
v_{nt}	Throat sonic flow velocity; critical flow velocity at nozzle throat	LT^{-1}	$m \cdot s^{-1}$
Z	Compressibility factor	Dimensionless	
β	Diameter ratio d/D	Dimensionless	
γ	Ratio of specific heat capacities	Dimensionless	
δ	Absolute uncertainty	[a]	[a]
κ	Isentropic exponent	Dimensionless	
μ_0	Dynamic viscosity of the gas at stagnation conditions	$ML^{-1}T^{-1}$	Pa·s
μ_{nt}	Dynamic viscosity of the gas at nozzle throat	$ML^{-1}T^{-1}$	Pa·s
ρ_0	Gas density at stagnation conditions at nozzle inlet	ML^{-3}	$kg \cdot m^{-3}$
ρ_{nt}	Gas density at nozzle throat	ML^{-3}	$kg \cdot m^{-3}$

M = mass

L = length

T = time

Θ = temperature

[a] Same as the corresponding quantity.