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**Zemeljski plin - Izračun termodinamičnih lastnosti - 5. del: Izračun Joule-Thomsonovega koeficienta, isentropskega eksponenta in viskoznosti (ISO/DIS 20765-5:2020)**

Natural gas - Calculation of thermodynamic properties - Part 5: Calculation of viscosity, Joule-Thomson coefficient, and isentropic exponent (ISO/DIS 20765-5:2020)

Erdgas - Berechnung der thermodynamischen Eigenschaften - Teil 5: Berechnung der Viskosität, Joule-Thomson-Koeffizient und Isentropenexponent (ISO/DIS 20765-5:2020)

Gaz naturel - Calcul des propriétés thermodynamiques - Partie 5: Calcul de la viscosité, du coefficient de Joule-Thomson et de l'exposant isentropique (ISO/DIS 20765-5:2020)

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**ICS:**

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## Natural gas — Calculation of thermodynamic properties —

### Part 5: Calculation of viscosity, Joule-Thomson coefficient, and isentropic exponent

*Gaz naturel — Calcul des propriétés thermodynamiques —**Partie 5: Calcul de la viscosité, du coefficient de Joule-Thomson et de l'exposant isentropique*

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### Foreword

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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](http://www.iso.org/directives)).

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This document was prepared by Technical Committee ISO/TC 193, *Natural gas*, Subcommittee SC 1, *Analysis of Natural gas*.

A list of all parts in the ISO 20765 series can be found on the ISO website.

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](http://www.iso.org/members.html).

## Introduction

This document gives simplified methods for the calculation of (dynamic) viscosity, Joule-Thomson coefficient, and isentropic exponent for use in natural gas calculations in the temperature range  $-20\text{ }^{\circ}\text{C}$  to  $40\text{ }^{\circ}\text{C}$ , with absolute pressures up to 10 MPa, in the gas phase. For the Joule-Thomson coefficient and isentropic exponent, the uncertainty of the equations provided is greater than that obtained from a complete equation of state such as the GERG-2008 [equation \(1\)](#) (ISO 20765-2<sup>[2]</sup>) but is considered to be fit for purpose. The equations given here are very simple.

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# Natural gas — Calculation of thermodynamic properties —

## Part 5:

# Calculation of viscosity, Joule-Thomson coefficient, and isentropic exponent

## 1 Scope

This part of ISO 20765 specifies a method to calculate viscosity and other properties, excluding density, for use in the metering of natural gas flow.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 7504, *Gas analysis — Vocabulary*

ISO 14532, *Natural gas — Vocabulary*

ISO 20765-1, *Natural gas — Calculation of thermodynamic properties — Part 1: Gas phase properties for transmission and distribution applications*

ISO 20765-2, *Natural gas — Calculation of thermodynamic properties — Part 2: Single-phase properties (gas, liquid, and dense fluid) for extended ranges of application*

ISO 80000-5:2007, *Quantities and units — Part 5: Thermodynamics*

## 3 Terms and definitions

No terms and definitions are listed in this document.

## 4 Background

The main motivation for this standard is to provide simplified methods for the calculations required, according to ISO 5167, to measure flow of high-pressure natural gas with an orifice plate meter.

Useful references for the work herein are given below:

- a) ISO 5167-1:1991, *Measurement of fluid flow in closed conduits – Part 1. Pressure differential devices – Section 1.1: Specification for square-edged orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full*, (BS 1042:Section 1.1:1992).
- b) ISO 5167-1:1997, *Measurement of fluid flow by means of pressure differential devices – Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full*, (BS 1042-1.1:1992 renumbered, incorporating Amendment No.1 (renumbering the BS as BS EN ISO 5167-1:1997), and Amendment No.1 to BS EN ISO 5167-1:1997)
- c) ISO 5167-1:2003, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full – Part 1: General principles and requirements*

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- d) ISO 5167-2:2003, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full – Part 2: Orifice plates*

The basic mass flowrate equation is

$$q = \frac{C}{\sqrt{1-\beta^4}} \varepsilon \frac{\pi}{4} d^2 \sqrt{2 \cdot \Delta P \cdot \rho} \quad (1)$$

where

$C$  is a function of  $\beta$ ,  $Re$ , and the type of orifice pressure tapings;

$\varepsilon$  is a function of  $\beta$ ,  $P$ ,  $\Delta P$ , and  $\kappa$ .

The symbols are defined in [Annex A](#). The standards above differ in the functions for  $C$  and  $\varepsilon$ . Although  $q$  is given by [equation \(1\)](#), iteration is required since  $C$  is a function of  $Re$ , and  $Re$  is a function of  $q$ . Similarly, given  $q$  in [equation \(1\)](#) does not directly give  $\Delta P$  since  $\varepsilon$  is a function of  $\Delta P$ .

The use of the equations in ISO-5167 (2003) for calculating flowrate ( $q$ ) for an orifice plate meter, over a typical input range of temperature, pressure, differential pressure, and gas composition, gives the following uncertainty equation (when the only source of uncertainties is considered to be in the calculation of the required gas thermophysical properties):

$$\begin{aligned} [u(q)/q]^2 &= [0.5 \pm 0.0002]^2 \cdot [u(\rho)/\rho]^2 && \text{(molar or mass density)} \\ &+ [0.0006 \pm 0.0002]^2 \cdot [u(\eta)/\eta]^2 && \text{(viscosity)} \\ &+ [0.002 \pm 0.0012]^2 \cdot [u(\kappa)/\kappa]^2 && \text{(isentropic exponent)} \\ &+ [-0.0004 \pm 0.0002]^2 \cdot [u(\mu)/\mu]^2 && \text{(Joule-Thomson coefficient)} \end{aligned} \quad (2)$$

This equation can be used to estimate the required uncertainty for the calculation of the properties that are part of this standard.

For the mass flowrate expanded uncertainty ( $U$ ) (coverage factor  $k=2$ , with a 95 % confidence interval) to be less than 0.1 % it is required that

$$\begin{aligned} U(\rho)/\rho &< 0.1 \% \\ U(\eta)/\eta &< 85 \% \\ U(\kappa)/\kappa &< 25 \% \\ U(\mu)/\mu &< 125 \% \end{aligned} \quad (3)$$

For the uncertainty contribution to be less than 0.02 % requires that

$$\begin{aligned} U(\rho)/\rho &< 0.02 \% \\ U(\eta)/\eta &< 17 \% \\ U(\kappa)/\kappa &< 5 \% \\ U(\mu)/\mu &< 25 \% \end{aligned} \quad (4)$$

Thus, density needs to be calculated as accurately as possible, while the uncertainty in the calculation of the other properties can be much higher, with a target uncertainty no better than about 25 % for a 0.1 % uncertainty in the flowrate ( $k=2$ ). The use of the GERG-2008 equation of state provides calculations of density that are generally within the required 0.1 % uncertainty.

## 5 Viscosity ( $\eta$ )

### 5.1 Viscosity as a function of temperature, pressure, and composition

There are many methods for the calculation of gas phase (dynamic) viscosity, some of which that are based on theory are quite complicated (see reference 11 for details). The Lohrenz-Bray-Clark method is relatively simple, requires minimal component data, and is a method that is widely implemented, and is the method recommended here. One disadvantage is the sensitivity to the input density; but for the application considered here, accurate densities will be available. The original reference is given in [3].

This method requires that the gas composition is available. With inputs of temperature, pressure, and composition, the GERG-2008 equation of state (ISO 20765-2) [1,2] can be used to obtain the molar density required in the equations below. When the composition is not known, the methods in Section 3.2 can be used.

The equations needed to implement this method are outlined below (Annex B contains an example Visual Basic program), where the required parameters consist of the following pure fluid values:

molar mass	$M_i$	[g/mol]
critical temperature	$T_{c,i}$	[K]
critical pressure	$P_{c,i}$	[MPa]
critical density	$\rho_{c,i}$	[mol/dm <sup>3</sup> ]

These mixture parameters can be estimated with the following equations:

$$M_{\text{mix}} = \sum_{i=1}^N x_i M_i \quad (5)$$

$$T_{c,\text{mix}} = \sum_{i=1}^N x_i T_{c,i} \quad (6)$$

$$P_{c,\text{mix}} = \sum_{i=1}^N x_i P_{c,i} \quad (7)$$

$$V_{c,\text{mix}} = \sum_{i=1}^N \frac{x_i}{\rho_{c,i}} \quad (8)$$

The pure fluid values can be obtained from any suitable source, e.g., ISO 20765-2 (Annex B).

The viscosity of a natural gas mixture can be calculated as

$$\eta = \eta_{\text{mix}} + \xi (\delta^4 - 1) \quad (9)$$

The generalized mixture viscosity, which is based on the pure fluid viscosities, is

$$\eta_{\text{mix}} = \frac{\sum_{i=1}^N x_i \eta_i \sqrt{M_i}}{\sum_{i=1}^N x_i \sqrt{M_i}} \quad (10)$$

where

$x_i$  is the component mole fraction.