INTERNATIONAL STANDARD

ISO 15970

First edition
2008-06-15

Natural gas — Measurement of properties — Volumetric properties: density, pressure, temperature and compression factor

Gaz naturel — Mesurage des caractéristiques — Caractéristiques volumétriques: masse volumique, pression, température et facteur de compression

Reference number
ISO 15970:2008(E)

Contents

Page

Foreword v
Introduction vi
1 Scope 1
2 Normative references 1
3 Terms and definitions 2
3.1 Terms and definitions for density at reference conditions 2
3.2 Terms and definitions for density at operating conditions 2
3.3 Terms and definitions for pressure 3
3.4 Terms and definitions for temperature 4
3.5 Terms and definitions for compression factor 4
4 Symbols and units 4
4.1 Symbols and subscripts for density at reference conditions 4
4.2 Symbols and subscripts for density at operating conditions 5
4.3 Symbols and subscripts for compression factor 5
5 Density at reference conditions 6
5.1 Principle of measurement 6
5.2 Performance assessment and acceptance tests 10
5.3 Sampling and installation guidelines 11
5.4 Calibration 11
5.5 Verification 11
5.6 Maintenance 12
5.7 Quality control 12
6 Density at operating conditions 12
6.1 Principle of measurement 12
6.2 Performance assessment and acceptance tests 13
6.3 Sampling and installation guidelines 16
6.4 Calibration 20
6.5 Verification 20
6.6 Maintenance 21
6.7 Quality control 21
7 Pressure 21
7.1 Principle of measurement 22
7.2 Performance assessment and acceptance tests 24
7.3 Sampling and installation guidelines 24
7.4 Calibration 27
7.5 Verification 28
7.6 Maintenance 28
7.7 Quality control 29
8 Temperature 29
8.1 Principle of measurement 29
8.2 Performance assessment and acceptance tests 30
8.3 Installation guidelines 31
8.4 Calibration 33
8.5 Verification 34
8.6 Maintenance 34
8.7 Quality control 34
9 Compression factor 34

9.1 Principle of measurement 34
9.2 Working principle 35
9.3 Performance assessment and acceptance tests 38
9.4 Sampling and installation guidelines 38
9.5 Calibration 39
9.6 Verification 40
9.7 Maintenance 40
9.8 Quality control 40

Annex A (informative) **Guidance for instrument selection, instrument test and operational procedures** 41

Annex B (informative) **Instrument documentation** 45

Bibliography 47

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 15970 was prepared by Technical Committee ISO/TC 193, *Natural gas*.

Introduction

The transmission of natural gas can involve passage across national boundaries; at border stations and elsewhere, knowledge of the physicochemical properties of the fluid is of great operational and economic importance. The energy flow and properties of the gas are required at several stages of the overall production and custody transfer process: production, blending, transmission, metering, distribution and supply.

International standardization of the performance specifications for various types of measuring instruments can facilitate comparison of, and increase confidence in, measurement results for contracting partners. In many cases, it is possible to calculate the properties of natural gas with sufficient accuracy, given the composition. However, it is often also possible to measure the property using techniques that do not require a compositional analysis for their implementation.

This International Standard considers only those methods for determining physical properties of natural gas that do not rely upon a detailed component analysis of the gas. Such measurements consider the “whole” sample of the gas.

This International Standard defines performance characteristics necessary to specify instrumentation for measurement of some natural gas properties. It provides guidelines for the installation, traceable calibration, performance, operation, maintenance and acceptance testing of these measurement instruments.

The principle of measurement of various properties included in this International Standard is typical for a number of applications.

It is required that the calibration of the instruments dealt with in this International Standard be traceable to national standards or International Standards.

It is required that the measuring instruments, including their installation and the devices used for field calibration, verification and maintenance comply with local legal regulations on application in hazardous areas.

Annex A presents general guidelines for instrument selection, instrument test and operational procedures of the instruments considered in this International Standard.

Annex B lists the data of particular importance for the instrument documentation.

Natural gas — Measurement of properties — Volumetric properties: density, pressure, temperature and compression factor

1 Scope

This international Standard gives requirements and procedures for the measurement of the properties of natural gas that are used mainly for volume calculation and volume conversion: density at reference and at operating conditions, pressure, temperature and compression factor.

Only those methods and instruments are considered that are suitable for field operation under the conditions of natural gas transmission and distribution, installed either in-line or on-line, and that do not involve the determination of the gas composition.

This International Standard gives examples for currently used instruments that are available commercially and of interest to the natural gas industry.

NOTE Attention is drawn to requirements for approval of national authorization agencies and to national legal regulations for the use of these devices for commercial or official trade purposes.

The density at reference conditions (sometimes referred to as normal, standard or even base density) is required for conversion of volume data and can be used for other physical properties.

Density at operating conditions is measured for mass-flow measurement and volume conversion using the observed line density and can be used for other physical properties. This International Standard covers density transducers based on vibrating elements, normally suitable for measuring ranges of 5 kg/m^3 to 250 kg/m^3.

Pressure measurement deals with differential, gauge and absolute pressure transmitters. It considers both analogue and smart transmitters (i.e. microprocessor based instruments) and, if not specified otherwise, the corresponding paragraphs refer to differential, absolute and gauge pressure transmitters without distinction.

Temperature measurements in natural gas are performed within the range of conditions under which transmission and distribution are normally carried out (253 K $< T <$ 338 K). In this field of application, resistance thermometer detectors (RTD) are generally used.

The compression factor (also known as the compressibility factor or the real gas factor and given the symbol Z) appears, in particular, in equations governing volumetric metering. Moreover, the conversion of volume at metering conditions to volume at defined reference conditions can properly proceed with an accurate knowledge of Z at both relevant pressure and relevant temperature conditions.

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 2186, *Fluid flow in closed conduits — Connections for pressure signal transmissions between primary and secondary elements*

ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principals and requirements*

ISO 6976, *Natural gas — Calculation of calorific values, density, relative density and Wobbe index from composition*

ISO 10715, *Natural gas — Sampling guidelines*

ISO 12213-1, *Natural gas — Calculation of compression factor — Part 1: Introduction and guidelines*

IEC 60079-0, *Explosive atmospheres — Part 0: Equipment — General requirements*

IEC 60079-1, *Explosive atmospheres — Part 1: Equipment protection by flameproof enclosures "d"*

IEC 60079-11, *Explosive atmospheres — Part 11: Equipment protection by intrinsic safety "i"*

IEC 60079-14, *Explosive atmospheres — Part 14: Electrical installations design, selection and erection*

IEC/TR 60079-15, *Electrical apparatus for explosive gas atmospheres — Part 15: Construction, test and marking of type of protection 'n' electrical apparatus*

IEC 60381-1, *Analogue signals for process control systems — Part 1: Direct current signals*

IEC 60381-2, *Analogue signals for process control systems — Part 2: Direct voltage signals*

IEC 60751, *Industrial platinum resistance thermometer sensors*

IEC 60770-1, *Transmitters for use in industrial-process control systems — Part 1: Methods for performance evaluation*

3 Terms and definitions

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

3.1 Terms and definitions for density at reference conditions

3.1.1
density at reference conditions
mass of a gas divided by its volume at specified reference conditions of pressure and temperature

3.1.2
relative density at reference conditions
ratio of the mass of a gas, contained within an arbitrary volume, to the mass of dry air of standard composition in accordance with ISO 6976, which would be contained in the same volume at the same references conditions

3.2 Terms and definitions for density at operating conditions

3.2.1
density
mass of a gas divided by its volume at operating conditions of pressure and temperature (operating and reference conditions)

3.2.2
vibrating element density transducer
device that contains a vibrating element that is maintained at its natural frequency, made such that the element contains or is surrounded by gas, the gas and the element forming a system where the density of the gas is the main property of the gas determining the natural frequency of the element

NOTE The natural frequency to the first approximation is determined by the gas density.

3.2.3
main density transducer constants
constants that, to a first approximation, define the relationship between the natural frequency of the vibrating element and the density of the gas

3.2.4
raw density
density as determined by a vibrating-element density transducer from its vibrating frequency by use of the main density transducer constants before any corrections for temperature, pressure and composition are applied

3.2.5
correction density transducer constants
constants applicable to a density transducer to correct for the deviation between the calibration condition under which the main constants were determined and the operating conditions

3.2.6
temperature-corrected density
raw density corrected for difference in temperature to which the vibrating element is exposed in operation and the temperature at which the density transducer was calibrated

3.2.7
compositional-corrected density
temperature-corrected density, corrected for difference in gas properties between gas to which the vibrating element is exposed in operation and the gas properties of the gas used for calibration

NOTE Normally, the gas property relevant for this purpose is velocity of sound, hence this term is often referred to as velocity-of-sound-corrected density.

3.2.8
line density
compositional-corrected density, corrected for difference in operating conditions, e.g. pressure and temperature, to which the vibrating element is exposed and the operating conditions in the line where the density is measured

3.3 Terms and definitions for pressure

3.3.1
pressure transmitter
device that responds to a measured pressure to produce a standard output signal for transmission, which has a prescribed continuous relationship to the value of the measured pressure

3.3.2
lower range value
LRV
lowest value of the pressure that a transmitter is adjusted to measure

3.3.3
upper range value
URV
highest value of the pressure that a transmitter is adjusted to measure

3.3.4
span
algebraic difference between the upper and lower range values

3.3.5
static pressure
pressure that would be measured by a pinpoint observer travelling with a particle of the fluid

3.3.6
absolute static pressure
static pressure of a fluid measured with reference to an absolute vacuum

3.3.7
gauge pressure
difference between the absolute static pressure of a fluid and the atmospheric pressure at the place and time of the measurement

3.4 Terms and definitions for temperature

3.4.1
temperature transmitter
device that responds to a measured temperature to produce a standard output signal for transmission, which has a prescribed continuous relationship to the value of the measured temperature

3.5 Terms and definitions for compression factor

3.5.1
least squares method
method used to compute the coefficients of the equation when a particular form of equation is chosen for fitting a curve data

NOTE The principle of least squares is the minimization of the sum of squares of deviations of the data from the curve.

4 Symbols and units

4.1 Symbols and subscripts for density at reference conditions

Symbol	Quantity	Unit
k_Z	Ratio of $Z(p, T)$ and Z_n	—
p	Absolute pressure	Pa
ρ	Density	kg/m^3
T	Thermodynamic temperature	K
Z	Compression factor	—

	Subscripts
A	Standard air
m	Measured gas/measuring chamber
n	Reference conditions
r	Reference chamber

4.2 Symbols and subscripts for density at operating conditions

Symbol	Quantity	Unit
C	Velocity of sound	m/s
C_c	Velocity of sound in calibration gas	m/s
C_g	Velocity of sound in gas in density transducer	m/s
F	Frequency	s^{-1}
K_1 K_2 K_N [a]	Density transducer constants	[b]
ρ_r	Raw density	kg/m^3
ρ_t	Temperature corrected density	kg/m^3
ρ_c	Compositional corrected density	kg/m^3
ρ_L	Line density	kg/m^3
T_c	Calibration temperature	K
t_c	Calibration temperature	°C
T_d	Temperature in density transducer	K
T_L	Temperature in pipe	K
t_d	Temperature in density transducer	°C
t_L	Temperature in pipe	°C
p_d	Pressure in density transducer	Pa
p_L	Pressure in pipe	Pa

[a] The number of constants (n) can vary for the different types of density transducers. The manufacturers are allowed to use a numbering system for constants different from the one used throughout this International Standard.

[b] The unit of the various constants shall be such that all terms in Equations (4) and (5) come out with unit kg/m^3.

Subscripts

L	Pipe or line
d	Density transducer

4.3 Symbols and subscripts for compression factor

Symbol	Quantity	Unit
V_1	Volume of the small vessel in the Z-meter	m^3
V_2	Volume of the large vessel in the Z-meter	m^3
V_3	Sum of volumes V_1 and V_2	m^3
p_1	Line pressure	Pa
p_2	Pressure before expansion	Pa
p_3	Pressure after expansion	Pa
Z_1	Compression factor at conditions p_1 and T	—
Z_2	Compression factor at conditions p_2 and T	—

Z_3	Compression factor at conditions p_3 and T	—
k_V	Ratio of volumes V_2 and V_1	—
$B_1(T),B_2(T)$	Coefficients of the polynomial of the compression factor as a function of the pressure	a
T	Temperature of the Z-meter	K
t	Temperature of the Z-meter	°C
Z	Compression factor	—
k_Z	Ratio of $Z(p,T)$ and Z_n	—
a, b	Coefficients in the function for the transfer in temperature	—
e, f, g	Coefficients in the function for the transfer in pressure	b

[a] The units of $B(T)$ and $C(T)$ shall be such that all resulting terms in Equations (9) and (10) are dimensionless.

[b] The units of e, f and g shall be such that all resulting terms in Equation (12) are dimensionless.

Subscripts

i	initial conditions
f	final conditions
n	reference conditions

5 Density at reference conditions

5.1 Principle of measurement

5.1.1 General

Two basic principles are used for measuring the density at reference conditions:

a) direct measurement, for example determining the buoyancy force of a defined volume of gas with a balance system;

b) indirect measurement, for example determining the natural frequency of a vibrating element, which is influenced by the density of the medium in which the element vibrates.

5.1.2 Balance system

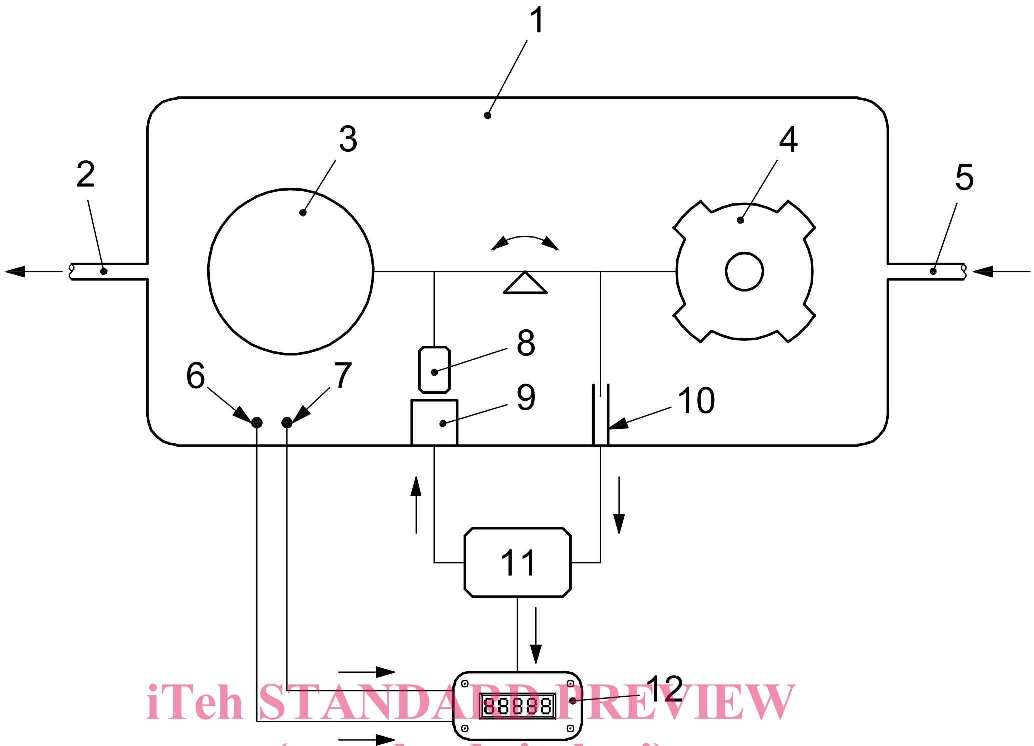
The apparatus measures the buoyancy force of a closed, gas-filled glass bulb in an atmosphere of gas whose density at reference conditions is being determined (see Figure 1).

The glass bulb is fitted to a balance beam with an open glass bulb as a counterweight. This weighing system is mounted in a chamber through which the gas being tested is passed. Either the displacement of the balance beam or the force that is necessary to compensate the displacement can be taken as a measure for the density.

A correcting system compensates for the temperature and pressure fluctuations of the measuring chamber.

5.1.3 Vibrating element system

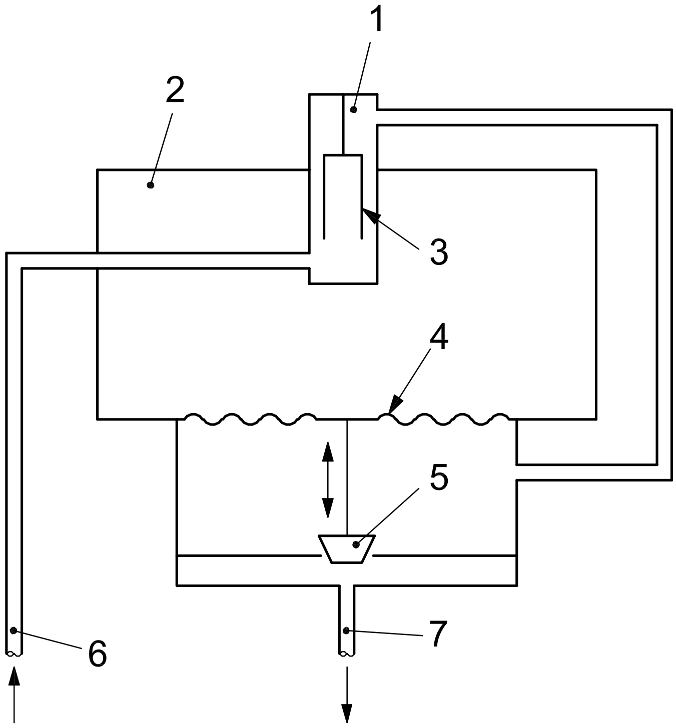
Two different systems are commonly used. Each consists of two chambers. One chamber is filled with a reference gas that is similar to the gas being measured and sealed from the atmosphere. The gas being tested is continuously passed through the other chamber. A pressure equalizer ensures that the pressure in the measuring chamber is equal to the pressure in the reference chamber. The housings of the systems are designed in such a way that both gas chambers have the same temperature (see Figures 2 and 3).



Key

1 instrument housing
2 gas outlet
3 closed glass bulb
4 open glass bulb
5 gas inlet
6 pressure sensor
7 temperature sensor
8 magnet
9 compensation coil
10 photo sensor
11 PID regulator
12 display

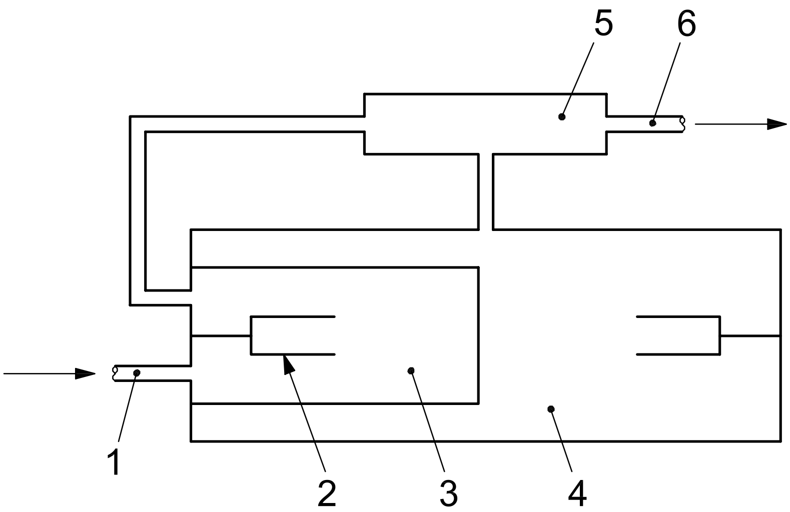
Figure 1 — Gas density balance system



Key

1 measuring chamber
2 reference chamber
3 vibrating element
4 diaphragm
5 pressure control valve
6 gas inlet
7 gas outlet

Figure 2 — Gas densitometer with one vibrating element



Key

1 gas inlet
2 vibrating element
3 measuring chamber
4 reference chamber
5 pressure equalizer
6 gas outlet

Figure 3 — Gas densitometer with two vibrating elements

Generally, the density, ρ, is as given by Equation (1):

$$\rho = \rho_n \frac{T_n}{p_n} \frac{p}{T} \frac{1}{k_Z} \qquad (1)$$

where

p is the pressure;

T is the thermodynamic temperature;

k_Z is the ratio (Z/Z_n) of the compression factors;

n is the subscript indicating that the values are at reference conditions.

With equal pressure and temperature in the reference chamber (subscript r) and measuring chamber (subscript m), the ratio of the respective densities is given by Equation (2):

$$\frac{\rho_m}{\rho_r} = \frac{\rho_{n,m}}{\rho_{n,r}} \frac{k_r}{k_m} \qquad (2)$$

Assuming that k_r / k_m is a constant, which is a good approximation for low pressures and means that the gases are similar, the quotient of the densities of the gas to be measured and of the reference gas is directly proportional to the density at reference conditions, as given in Equation (3):

$$\rho_{n,m} = \frac{\rho_m}{\rho_r} \frac{k_m}{k_r} \rho_{n,r} = k \cdot \frac{\rho_m}{\rho_r} \qquad (3)$$