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Natural gas — Coalbed methane quality designation and the applicability of ISO/TC 193 current standards

Gaz naturel — Désignation de la qualité du méthane de houille et applicabilité des normes en vigueur ISO/TC 193

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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).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

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.

Introduction

Coalbed Methane (CBM) is an unconventional form of natural gas and refers to methane-rich gases that naturally exist in coal seams and surrounding rocks, see also Reference [31]. It is defined as a methane-rich gas naturally occurring in coal seams (and surrounding rock) typically comprising of 80 % to 95 % methane with lower proportions of ethane, propane, nitrogen and carbon dioxide (see ISO 18875).

At present, CBM is explored and developed in the United States, Canada, Australia, Russia, India, China and a few other countries.

Typical CBM contains 80 % to 95 % or more methane and a small portion of ethane, propane, nitrogen and carbon dioxide, but the composition of coalbed methane varies widely around the world. This document aims to promote communication and coordination among countries and support the smooth progress of unconventional natural gas exploration, development, production and custody transfer.

Natural gas — Coalbed methane quality designation and the applicability of ISO/TC 193 current standards

1 Scope

This document surveys the quality designation of CBM all around the world, and analyses whether ISO/TC 193 standards for sampling, test and calculation methods are applicable to CBM.

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 14532, *Natural gas — Vocabulary*

ISO 18875, *Coalbed methane exploration and development — Terms and definitions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14532, ISO 18875 and the following apply.

NOTE Specific coalbed methane or coal gas mine terms are given in national documents, such as GB/T 31537[30].

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
normal reference conditions
reference conditions of pressure, temperature, and humidity (state of saturation) equal to 101,325 kPa and 273,15 K for a gas in the dry state

[SOURCE: ISO 14532:2014, 2.6.1.3]

3.2
ISO standard reference conditions
reference conditions of pressure, temperature, and humidity (state of saturation) equal to 101,325 kPa and 288,15 K for a real gas in the dry state

[SOURCE: ISO 14532:2014, 2.6.1.4]

3.3
direct sampling
sampling in situations where there is a direct connection between the natural gas to be sampled and the analytical unit

[SOURCE: ISO 14532:2014, 2.3.1.1]

3.4
indirect sampling
sampling in situations where there is no direct connection between the natural gas to be sampled and the analytical unit

[SOURCE: ISO 14532:2014, 2.3.1.2]

3.5
representative sample
sample having the same composition as the natural gas sample when the latter is considered as ahomogeneous whole

[SOURCE: ISO 14532:2014, 2.3.4.2]

3.6
gas chromatographic method
GC method
method of analysis by which the components of a gas mixture are separated using gas chromatography

Note 1 to entry: The sample is passed in a stream of carrier gas through a column that has different retention properties relative to the components of interest. Different components pass through the column at different rates and are detected as they elute from the column at different times.

[SOURCE: ISO 14532:2014, 2.2.2.1]

3.7
main component
major component
component whose content influences physical properties

[SOURCE: ISO 14532:2014, 2.5.2.2.1]

3.8
trace component
trace constituent
component present at very low levels

[SOURCE: ISO 14532:2014, 2.5.2.2.3]

3.9
total sulfur
total amount of sulfur found in coal bed methane

[SOURCE: ISO 14532:2014, 2.5.2.3.14]

3.10
compression factor
ratio of the volume of an arbitrary mass of gas at a specified pressure and temperature to the volume of the same mass of gas under the same conditions as calculated from the ideal-gas law

[SOURCE: ISO 14532:2014, 2.6.2.2]

3.11
density
mass of gas divided by its volume at specified conditions of pressure and temperature

[SOURCE: ISO 14532:2014, 2.6.3.1]

3.12
relative density
ratio of the mass of a gas contained within an arbitrary volume to the mass of dry air of standard composition that would be contained in the same volume at the same reference conditions

[SOURCE: ISO 14532:2014, 2.6.3.2]

Note 1 to entry: The relative density is also defined in ISO 6976.

3.13
Wobbe index
calorific value on a volumetric basis at specified reference conditions, divided by the square root of the relative density at the same specified metering reference conditions

[SOURCE: ISO 14532:2014, 2.6.4.3]

3.14
water dew point
temperature at a specified pressure at which water vapour condensation initiates

Note 1 to entry: For any pressure lower than the specified pressure, there is no condensation of water vapours at this water dew point temperature.

[SOURCE: ISO 14532:2014, 2.6.5.1.1]

3.15
water content
mass concentration of the total amount of water contained in a gas

Note 1 to entry: Water content is expressed in units mass per unit volume.

Note 2 to entry: For gas below the water dew point, this means water in the form of both liquid and vapour; but for gas above the water dew point, this means only water vapour.

Note 3 to entry: Water content can be also expressed as mole or volume fraction.

[SOURCE: ISO 14532:2014, 2.6.5.1.2]

3.16
hydrocarbon dew point
HCDP
temperature at a specified pressure at which hydrocarbon vapour condensation initiates

Note 1 to entry: In chemical thermodynamics, the “true” hydrocarbon dew point is the temperature (at a stated pressure) at which the fugacity of the gas and liquid phases is identical. Since measurement of the dew point involves reduction of the system temperature, this equates to the temperature at which the first appearance of the liquid phase occurs. At this point, the quantity of liquid phase is infinitesimally small. Since no instrument or observer is able to detect this infinitesimally small amount, the measured value by a chilled mirror instrument (measured hydrocarbon dew point) differs from the “true” hydrocarbon dew point. Depending on the gas composition and the sensitivity of the detection system of the automatic hydrocarbon-dew-point chilled-mirror instrument or the observer (manual chilled mirror instrument), the measured hydrocarbon dew point can be considerably lower than the “true” hydrocarbon dew point.

[SOURCE: ISO 14532:2014, 2.6.5.2.1]

3.17
potential hydrocarbon liquid content
PHLC
property of natural gas defined as the amount of the condensable liquid (in milligrams) at the pressure, *p*, and temperature, *T*, per unit volume of gas at normal conditions, that is, at a temperature of 0 °C and a pressure of 101,325 kPa obtained by passing a representative sample of the gas through an apparatus where it is first brought to the pressure, *p*, and then cooled to the temperature, *T*

Note 1 to entry: It is necessary to take care that only gas, not a two-phase mixture, has been withdrawn from the pipeline.

[SOURCE: ISO 14532:2014, 2.6.5.2.3]

4 Symbols, abbreviations and units

4.1 Symbols and units

Symbol	Meaning and units
d	Relative density
H_c	Molar basis calorific value (kJ/mol)
H_m	Mass basis calorific value (MJ/kg)
H_V	Volumetric basis calorific value (MJ/m^3)
M	Mass per mole (kg/kmol)
p	(Absolute) pressure (kPa)
T	Celsius temperature (°C)
T_{abs}	Thermodynamic (absolute) temperature (K)
V	(Gas) volume (m^3)
W	Wobbe index (number) (MJ/m^3)
Z	Compression factor
ρ	Density (kg/m^3)

4.2 Abbreviations

Abbreviations	Meaning
CBM	Coalbed methane

5 Applicability of sampling standard

ISO 10715 provides concise guidelines for the collection, conditioning and handling of representative samples of processed natural gas streams. It also contains guidelines for sampling strategy, probe location and the handling and design of sampling equipment. According to ISO 10715, the factors affecting sampling representativeness include sampling material and equipment, sample containers, sampling method, heavy hydrocarbon condensate and flow characteristics of gas sources.

NOTE Specific CBM sampling standards exist at national level[5].

CBM is a kind of unconventional natural gas, which falls into the category of natural gas. It is basically free of heavy hydrocarbon and organic sulfur compounds. The composition of CBM is simpler than that of natural gas.

Therefore, ISO 10715 is applicable to the direct and indirect sampling of CBM.

6 Applicability of test and calculation standard

6.1 General

This clause deals with the various parameters which may be referred to in a designation of the quality of CBM. The parameters actually selected will depend upon the purpose for which the designation is required and it is unlikely that all the parameters listed in this document will be used.

6.2 Gas composition

6.2.1 General

CBM is composed primarily of methane and ethane with smaller amounts of propane, butane and of non-combustible gases, carbon dioxide and nitrogen, the approximate content of each component is shown in Table 1. The relevant ISO/TC 193 test standards for major and minor components and trace constituents and whether these standards are applicable to CBM are shown in Table 2, 3 and 4.

Limits are not given in this document, but limits on CBM components or properties are given in Chinese national standard GB/T 26569:2011[26] and GB/T 26127:2010[27], Chinese energy industry standard NB/T 10035:2006, Australian standard AS 4564-2011[28], New Zealand Standard NZS 5442:2008[29] (for more information, see Annex A and Bibliography).

Table 1 — Approximate content of each component of CBM

Component	Unit	Approximate content range
Methane	mol%	50 to 99
Ethane	mol%	0,1 to 5
Propane	mol%	0 to 1
Butanes	mol%	0 to 1
Pentanes	mol%	0 to 0,5
Nitrogen	mol%	0,1 to 40
Carbon dioxide	mol%	0,1 to 15
Hydrogen	mol%	0 to 0,1
Oxygen	mol%	0 to 5
Carbon monoxide	mol%	0 to 1
Helium	mol%	0 to 0,5
Argon	mol%	0 to 0,5
Sulfur hydrogen	mg/m^3	0 to 20
Total sulfur	mg/m^3	0 to 20

6.2.2 Major components

Table 2 presents the main components of coalbed methane.

Table 2 — Major components of CBM

Component	Unit	Relevant ISO/TC 193 standards	Whether applicable to CBM
Methane	mol%	ISO 6974 (all parts), ISO 23978	Yes
Ethane	mol%	ISO 6974 (all parts),ISO 23978	Yes
Propane	mol%	ISO 6974 (all parts), ISO 23978	Yes
Butanes	mol%	ISO 6974 (all parts)	Yes
Pentanes	mol%	ISO 6974 (all parts)	Yes
Nitrogen	mol%	ISO 6974 (all parts), ISO 23978	Not exactly
Carbon dioxide	mol%	ISO 6974 (all parts), ISO 6975, ISO 23978	Not exactly

a) Methane

ISO 6974-4, ISO 6974-5, ISO 6974-6, and ISO 23978 are suitable for the determination of methane in the range of 75 % to 100 %, 34 % to 100 %, 40 % to 100 %, and 50 % to 100 %, respectively.

Generally, the methane content in CBM is basically above 80 %, also above 50 % in some CBM with high nitrogen or oxygen content. There is no case in which methane content in CBM is lower than 34 %.

Therefore, ISO 6974-4, ISO 6974-5, ISO 6974-6 and ISO 23978 are able to meet and applicable to the determination of methane content in CBM. ISO 6974-1, ISO 6974-2, and ISO 6974-3 are also applicable to the determination of methane content in CBM.

b) Ethane

ISO 6974-4, ISO 6974-5, ISO 6974-6 and ISO 23978 are suitable for the determination of ethane in the range of 0,001 % to 10 %, 0,1 % to 23 %, 0,002 % to 15 %, and 0,02 % to 20 %, respectively.

Generally, the ethane content in CBM is basically lower than 5 %, and in a few exceptions, not higher than 23 %.

Therefore, ISO 6974-4, ISO 6974-5, ISO 6974-6 and ISO 23978 are able to meet and applicable to the determination of ethane content in CBM. ISO 6974-1, ISO 6974-2 and ISO 6974-3 are also applicable to the determination of ethane content in CBM.

c) Propane

ISO 6974-4, ISO 6974-5, ISO 6974-6 and ISO 23978 are suitable for the determination of propane in the range of 0,001 % to 3 %, 0,05 % to 10 %, 0,001 % to 5 % and 0,02 % to 10 %, respectively.

Generally, the propane content in CBM is basically lower than 1 %, and in a few exceptions, not higher than 10 %.

Therefore, ISO 6974-4, ISO 6974-5, ISO 6974-6 and ISO 23978 are able to meet and applicable to the determination of propane content in CBM. ISO 6974-1, ISO 6974-2 and ISO 6974-3 are also applicable to the determination of propane content in CBM.

d) Butanes

ISO 6974-4, ISO 6974-5 and ISO 6974-6 are suitable for the determination of butanes in the range of 0,001 % to 1 %, 0,01 % to 2 % and 0,000 1 % to 1 % respectively.

Generally, the butanes content in CBM is basically lower than 1 %, usually not higher than 2 %.

Therefore, ISO 6974-4, ISO 6974-5, and ISO 6974-6 are able to meet and applicable to the determination of butanes content in CBM. ISO 6974-1, ISO 6974-2, and ISO 6974-3 are also applicable to the determination of butanes content in CBM.

e) Pentanes

ISO 6974-4, ISO 6974-5, and ISO 6974-6 are suitable for the determination of pentanes in the ranges of 0,001 % to 0,5 %, 0,005 % to 0.35 %, and 0,000 1 % to 0,5 %, respectively.

Generally, CBM does not contain pentanes. Pentanes are contained in some CBM but the content is basically below 0,5 %.

Therefore, ISO 6974-4, ISO 6974-5 and ISO 6974-6 are able to meet and applicable to the determination of pentanes content in CBM. ISO 6974-1, ISO 6974-2, and ISO 6974-3 are also applicable to the determination of pentanes content in CBM.

f) Nitrogen

ISO 6974-4, ISO 6974-5, ISO 6974-6 and ISO 23978 are suitable for the determination of nitrogen in the ranges of 0,001 % to 15 %, 0,1 % to 22 %, 0,007 % to 40 %, and 0,02 % to 10 %, respectively.

Nitrogen content in CBM varies greatly. It's common from less than 0,1 % to 40 %. In some CBM, the nitrogen content is as high as 50 % or so.

Therefore, ISO 6974-4, ISO 6974-5, ISO 6974-6 and ISO 23978 are basically able to meet and applicable to the determination of nitrogen content in CBM in most cases. ISO 6974-1, ISO 6974-2, and ISO 6974-3 are also applicable to the determination of nitrogen content in CBM. However, when the nitrogen content in CBM is above 40 %, its concentration exceeds the upper detection limit of ISO 6974. In this case, the applicability of ISO 6974 (all parts) to CBM detection needs to be tested and verified.

g) Carbon dioxide

ISO 6974-4, ISO 6974-5, ISO 6974-6 and ISO 23978 are suitable for the determination of carbon dioxide in the range of 0,001 % to 10 %, 0,05 % to 15 %, 0,001 % to 10 % and 0,02 % to 30 %, respectively.

Carbon dioxide content in CBM also varies greatly. It's common from less than 0,1 % to 15 %. In a few cases, the carbon dioxide content in CBM is higher than15 %.

Therefore, ISO 6974-4, ISO 6974-5, ISO 6974-6 and ISO 23978 are basically able to meet and applicable to the determination of carbon dioxide content in CBM in most cases. ISO 6974-1, ISO 6974-2, and ISO 6974-3 are also applicable to the determination of carbon dioxide content in CBM. However, when the carbon dioxide content in CBM is above 15 %, its concentration exceeds the upper detection limit of ISO 6974. In this case, the applicability of ISO 6974 (all parts) to CBM detection needs to be tested and verified.

6.2.3 Minor components

Table 3 presents the minority parts of coalbed methane.

Table 3 — Minor components of CBM

Component	Unit	Relevant ISO/TC 193 standards	Whether applicable to CBM
Hydrogen	mol%	ISO 6974-6, ISO 6975	Yes
Oxygen	mol%	ISO 6974-6, ISO 6975	Not exactly
Carbon monoxide	mol%	ISO 6974-6	Yes
Helium	mol%	ISO 6974-6, ISO 6975	Yes
Argon	mol%	ISO 6975	Yes

a) Hydrogen

The scopes of ISO 6974-4 and ISO 6974-5 do not include the determination of hydrogen. Both ISO 6974-6 and ISO 6975 are suitable for the determination of hydrogen in the range of 0,001 % to 0,5 %.

Generally, the hydrogen content in CBM is not higher than 0,1 %.

Therefore, ISO 6974-6 and ISO 6975 are applicable to the determination of hydrogen content in CBM. ISO 6974-1, ISO 6974-2, and ISO 6974-3 are also applicable to the determination of hydrogen content in CBM.

b) Oxygen

The scopes of ISO 6974-4 and ISO 6974-5 do not include the determination of oxygen. ISO 6974-6 and ISO 6975 are suitable for the determination of oxygen in the range of 0,007 % to 5 %, and 0,001 % to 0,5 %, respectively.

Generally, the oxygen content in CBM is not higher than 5 %. The cases that the oxygen content exceeds 5 % may be due to the introduction of air during exploration and development.

Therefore, ISO 6974-6 and ISO 6975 are applicable to the determination of oxygen content in CBM in the range of 0,001 % to 5 %. ISO 6974-1, ISO 6974-2, and ISO 6974-3 are also applicable to the determination of oxygen content in CBM. However, when the oxygen content in CBM is above 5 %, its concentration exceeds the upper detection limit of ISO 6974. In this case, ISO 6974 (all parts) are not applicable to CBM any more.

It is suggested that an international, special standard for oxygen content determination will be developed, so as to accurately determine higher oxygen content in conventional and unconventional natural gas. New test methods for oxygen are developed at the same time to further improve the standard system.

Note 1 to entry It is necessary to warn that if the oxygen content in natural gas is high, there can be safety problems related to explosion and so on.

c) Carbon monoxide

The scopes of ISO 6974-4 and ISO 6974-5 do not include the determination of carbon monoxide. ISO 6974-6 is suitable for the determination of carbon monoxide in the range of 0,001 % to 1 %.

A small amount of CBM contains carbon monoxide which is less than 1 %.

Therefore, ISO 6974-6 is applicable to the determination of carbon monoxide content in CBM. ISO 6974-1, ISO 6974-2, and ISO 6974-3 are also applicable to the determination of carbon monoxide content in CBM.

d) Helium

The scopes of ISO 6974-4 and ISO 6974-5 do not include the determination of helium. ISO 6974-6 and ISO 6975 are suitable for the determination of helium in the range of 0,002 % to 0,5 % and 0,001 % to 0,5 %, respectively.

Generally, the helium content in CBM is less than 0,5 %.

Therefore, ISO 6974-6 and ISO 6975 are applicable to the determination of helium content in CBM. ISO 6974-1, ISO 6974-2, and ISO 6974-3 are also applicable to the determination of helium content in CBM.

e) Argon

The scopes of ISO 6974-4, ISO 6974-5 and ISO 6974-6 do not include the determination of argon. ISO 6975 is suitable for the determination of argon in the range of 0,001 % to 0,5 %.

Generally, the argon content in CBM is less than 0,5 %.

Therefore, ISO 6975 is applicable to the determination of argon content in CBM.

6.2.4 Trace constituents

The traces that can usually be found in coalbed methane are listed in Table 4.

Table 4 — Trace constituents of CBM

Constituent	Unit	Relevant ISO/TC 193 standards	Whether applicable to CBM
Hydrogen sulfide	mg/m^3	ISO 19739, ISO 23978	Yes
Total sulfur	mg/m^3	ISO 16960, ISO 20729	Yes
Mercury	µg/m^3	ISO 6978-1, ISO 6978-2	Yes

a) Hydrogen sulfide

There are several methods for the determination of sulfur compounds described in annexes of ISO 19739, of Which Annex C "GC method using capillary column and FPD" and Annex H "GC method using capillary column and SCD" are both suitable for the determination of hydrogen sulfide in the range of 0,5 mg/m^3 to 600 mg/m^3. Annex D "GC method using ED" and Annex E "GC method using MSD" are both suitable for the determination of hydrogen sulfide in the range of 0,1 mg/m^3 to 100 mg/m^3. Annex F "GC method using AED", Annex G "GC methods using column switching and FPD", and Annex I "GC method using capillary column and PFPD" are all applicable to the determination of hydrogen sulfide, but do not specify the detection ranges.

ISO 23978 are suitable for the determination of hydrogen sulfide in the range of 0,02 % to 10 %.

Generally, the hydrogen sulfide content in CBM is less than 6 mg/m^3,and about 20 mg/m^3 when it is higher.

Therefore, ISO 19739 and ISO 23978 are applicable to the determination of hydrogen sulfide in CBM.

b) Total sulfur

ISO 16960 and ISO 20729 are suitable for the determination of total sulfur content in CBM in the range of 1 mg/m^3 to 200 mg/m^{3}and 1 mg/m^{3}to 150 mg/m^3, respectively.

Generally, the total sulfur content in CBM is less than 6 mg/m^3, and about 20 mg/m^3 when it is higher.

Therefore, ISO 16960 and ISO 20729 are both applicable to the determination of total sulfur in CBM.

c) Mercury

Mercury in CBM has not been reported in the literature. On the one hand, there may be few cases that CBM contains mercury; On the other hand, mercury content may not be tested as an index. If there is a need for mercury detection, ISO 6978-1 and ISO 6978-2 are both applicable to CBM.

ISO 6978-1 specifies a method for the determination of total mercury content in natural gas using a sampling method at pressures up to 40 MPa by chemisorption on iodine-impregnated silica gel. This sampling method is suitable for the determination of mercury content within the range of 0,1 µg/m^3 to 5,000 µg/m^3 in natural gas. This method is applicable to sampled gas volumes containing less than 20 mg hydrogen sulfide (absolute content) and less than a total liquid hydrocarbon condensate of 10 g/m^3 under the sampling conditions. The collected mercury is determined by measuring the absorbance or fluorescence of mercury vapor at 253,7 nm.

There are two issues with ISO 6978-1. Firstly, this standard specifies that the mixed solution of 15 % potassium hydroxide (KOH) and 0,5 % stannous chloride ($SnCl_2$) is used as the reducing solution; as 15 % potassium hydroxide (KOH) is an alkaline solution with high concentration, it is easy to cause injury if there is an operation mistake during its use. Secondly, the concentration of the mercury standard solution is 1,000 g/l as specified. However, a solution with lower concentration could reduce the error caused by multistage dilution.

Therefore, revising ISO 6978-1 by adding an alkaline solution with lower concentration as the basic reducing solution and relaxing the concentration requirements for mercury standard solutions makes the standard more operable.

6.3 Gas properties

6.3.1 General

Physical properties and whether the relevant ISO/TC 193 standards are applicable to CBM are shown in Table 5.

Table 5 — Physical properties of CBM

Properties	Unit	Relevant ISO/TC 193 standards	Whether applicable to CBM
Molar basis calorific value, H_c	MJ/mol	ISO 6976, ISO 15971	Yes
Mass basis calorific value, H_m	MJ/kg	ISO 6976, ISO 15971	Yes
Volumetric basis calorific value, H_V	MJ/m^3	ISO 6976, ISO 15971	Yes
Relative density, ρ	-	ISO 6976, ISO 15970	Yes
Wobbe number, W	MJ/m^3	ISO 6976, ISO 15971	Yes
Water dew point	°C[K]	ISO 6327, ISO 18453	Yes
Water content	mg/m^3	ISO 10101-1, ISO 18453 ISO 10101-2 ISO 10101-3 ISO 11541	Yes
Hydrogen dew point	°C[K]	ISO 23874	Yes
Liquid hydrocarbon content	mg/m^3	ISO 6570	Yes

6.3.2 Calorific value, relative density and Wobbe number

ISO 6976 specifies methods for the calculation of gross calorific value, net calorific value, density, relative density, gross Wobbe index and net Wobbe index of natural gases, natural gas substitutes and other combustible gaseous fuels when the composition of the gas by mole fraction is known. The methods specified provide the means of calculating the properties of the gas mixture at normal reference conditions.

Mole fractions by definition sum to unity. Guidance on the achievement of this requirement by gas chromatograph analysis is available in ISO 6974-1 and ISO 6974-2.

The methods of calculation require values for various physical properties of the pure components; these values, together with associated uncertainties, are provided in tables and their sources are identified.

Methods are given for estimating the standard uncertainties of calculated properties.

The methods of calculation of the values of properties on either a molar, mass or volume basis are applicable to any natural gas, natural gas substitute or other combustible fuel that is normally gaseous, except that for properties on the volume basis the method is restricted to mixtures for which the compression factor at normal reference conditions is greater than 0,9.

Example calculations are given in ISO 6976:2016, Annex D for the methods of calculation as listed in that same document.

ISO 6976 is applicable to the calculation of calorific value, relative density and Wobbe number of CBM.

In addition, ISO 15970 is applicable to the calculation of relative density of CBM, and ISO 15971 is applicable to the calculation of calorific value and Wobbe number of CBM.

6.3.3 Water dew point and water content

ISO 6327 describes a method for determination of water dew point of natural gas by cooled surface condensation hygrometers, which is applicable to the determination of water dew point of natural gas and similar gases. The water dew point of processed natural gases in transmission lines normally lies between −25 °C and +5 °C, which corresponds to water concentrations of 50 µl/l to 200 µl/l (volume fraction), according to the pressure of the gas.

ISO 6327 and ISO 18453, ISO 10101-1, ISO 10101-3, ISO 10101-3, ISO 11541 are all able to and applicable to the determination and conversion of water dew point and water content.

Chinese experts detecting water dew point in recent years found that the results of water dew point determination of natural gas treated by triethylene glycol dehydration process are not accurate, especially by chilled mirror method which is often disturbed by triethylene glycol droplets, causing a large deviation in measurement results.

6.3.4 Hydrogen dew point and Hydrocarbon liquid content

ISO 23874 describes the performance requirements for analysis of treated natural gas of transmission or pipeline quality in sufficient detail so that the hydrocarbon dewpoint temperature can be calculated using an appropriate equation of state. It can be applied to gases that have maximum dewpoint temperatures (cricondentherms) between 0 °C and −50 °C. The pressures at which these maximum dewpoint temperatures are calculated are in the range 2 MPa (20 bar) to 5 MPa (50 bar). Major components are measured using ISO 6974 (all parts) and the ranges of components that can be measured are as defined in ISO 6974-1.

The procedure given in ISO 23874 covers the measurement of hydrocarbons in the range C5 to C12. n-Pentane, which is quantitatively measured using ISO 6974 (all parts), is used as a bridge component and all C6 and higher hydrocarbons are measured relative to n-pentane.

CBM basically does not contain C6 and C6+. Therefore, ISO 23874 is applicable to CBM.

ISO 6570 describes the principles of, and general requirements for, two gravimetric methods for the determination of the potential hydrocarbon liquid content of natural gas, or similar gas, at a given pressure and temperature. Two methods are specified in ISO 6570 to determine the amount of condensate in a sample gas:

— Method A: a manual weighing method;

— Method B: an indirect automatic weighing method based on the indication of the pressure difference caused by the accumulation of condensate in a vertical tube.

The manual weighing method is a reference method for the indirect automatic method. The indirect automatic method is suitable for semi-continuous control.

ISO 6570 is applicable to CBM.

ISO/TR 11150 is applicable to CBM and describes three means of estimating hydrocarbon dew point and hydrocarbon content of natural gas. The first one is cooled mirror method determining hydrocarbon dew point and hydrocarbon content, including visual method and automatic measurement method. The second one is the gas chromatographic method, by which the composition of gas is analyzed and used to calculate the hydrocarbon dew point; And the third one is the gravimetric method to determine the potential hydrocarbon liquid content.

At present, commercial instruments for hydrocarbon dew point determination of natural gas by visual or automatic measurement methods have been widely used. The Chinese national standard GB/T 27895[33] uses cooled mirror method to determine the hydrocarbon dew point of natural gas. There is no corresponding ISO standard. An ISO standard for the determination of hydrocarbon dew point of CBM is therefore missing and may well be developed.

6.4 Solid particulate matter

The solid particulate matter in CBM has an impact on the safe transportation, utilization and accuracy of gas metering. It is necessary to accurately determine the solid particulate matter in CBM and natural gas. For more information about solid particulate matter in CBM, refer to Annex B of this document.

China has developed the national standard GB/T 27893[32], which specifies the method for determination of particles content in natural gas by membrane weighing method. The measurement pressure range is between 0,1 MPa and 6 MPa. The measurement range is 0,1 mg/m^3 to 100 mg/m^3. If the membrane trap and the entire sampling and trapping system can withstand higher pressures, the measurement pressure can also be increased to the corresponding pressure.

ISO/TC 193 has no corresponding standard method.

Annex A
(informative)

Technical requirements and test methods for CBM

This annex gives the quality designations as well as the test methods on CBM components or properties according to the Chinese national standards GB 26569[26], GB/T 26127[27] and Chinese energy industry standard NB/T 10035[38]. The tables are given for information and are incomplete in terms of footnotes and additional requirements and instructions.

Besides, the quality designations and test methods in Australian standard AS 4564-2011[28] and New Zealand Standard NZS 5442:2008[29] may also be adaptable to CBM as indicated in the scope of these two standards.

Chinese standards mainly give requirement on methane content fraction, superior calorific value, hydrogen sulfide, total sulfur and water dew point of CBM (see Table A.1, A.2 and A.3), while Australian and New Zealand standards (see Table A.4 and A.5) give requirement on Wobbe Index, relative density, hydrogen sulfide, total sulfur, and water dew point of general natural gas.

Table A.1 — Quality designations and test methods in GB 26569:2011

Items	Class I	Class II	Class III	Class IV
Methane content fraction, *y* ,%	≥90	≥83~90	≥50~83	≥30~50
Superior calorific value, MJ/m³	≥34,0	≥31,4~34	≥22,3~31,4	≥15,5~22,3
Hydrogen sulfide,mg/m³	≤6			
Total sulfur (calculated with sulfur), mg/m³	≤100			
Water dew point,°C	Under the pressure of the custody transfer point, the water dew point is 5 °C lower than the minimum ambient temperature under the transportation condition,			

Table A.2 — Quality designations and test methods in GB/T 26127:2010

Items	Class I	Class II
Methane content fraction, *y* ,%	≥90	≥83~90
Superior calorific value, MJ/m³	≥34	≥31,4~34
Total sulfur (calculated with sulfur), mg/m³	≤150	
Hydrogen sulfide,mg/m³	≤12	
Water dew point,°C	Under the pressure of the custody transfer point, the water dew point is 5 °C lower than the minimum ambient temperature under the transportation condition.	

Table A.3 — Quality designations and test methods in NB/T 10035:2006

Items	Class I	Class II
Superior calorific value, MJ/m³	≥36,0	≥31,4
Hydrogen sulfide, mg/m³	≤6	≤20
Carbon dioxide, y, %	≤2,0	≤3,0

Table A.3 *(continued)*

Items	Class I	Class II
Total sulfur (calculated with sulfur), mg/m³	≤60	
Particles	5 µm filter is installed in the natural gas pipeline into which CBM is injected	
Water dew point,°C	Under the pressure of the custody transfer point, the water dew point is 5 °C lower than the minimum ambient temperature under the transportation condition.	

Table A.4 — Quality designations and test methods in AS 4564-2011

Characteristics and components	Limit [a]	Test or calculation methods
Wobbe Index [c]	Minimum...........46,0 MJ/m³ Maximum...........52,0 MJ/m³	ISO 6974 ISO 6975 ISO 6976
Oxygen	Maximum.............0,2 mol%	ISO 6974
Hydrogen	Maximum............ 0,1 mol%	ISO 6975
Hydrogen sulfide	Maximum............ 5,7 mg/m³	ISO 6326
Total sulfur (calculated with sulfur) [d]	Maximum.........50 mg/m³	ISO 6326
Water content	Maximum dewpoint 0 °C at the highest MAOP in the relevant transmission system(in any case,no more than 112,0 mg/m³)	ISO 10101 ASTM D1142[41]
Hydrocarbon dewpoint temperature	Maximum........2 °C at 3 500 kPa gauge	ISO 6975 with an appropriate equation of state
Total inert gas [e]	Maximum............7,0 mol%	

[a] ISO standard reference conditions apply for the measurement of all gas properties listed in this table except hydrocarbon dewpoint temperature.

[c] The Wobbe Index and relative density limits in this specification imply a calorific value range of (35,2 to 46,5) MJ/m³.

[d] limit for total sulfur applies after odorant addition.

[e] The total halogen test is required only for non-petroleum-based gases.

Table A.5 — Quality designations and test methods in NZS 5442

Characteristics and components	Limit [a]	Test or calculation methods
Wobbe Index [c]	Minimum...........46,0 MJ/m³ Maximum...........52,0 MJ/m³	ISO 6974 ISO 6975 ISO 6976
Relative density [c]	Maximum.............0,80	ISO 6974 ISO 6975 ISO 6976 ASTM D1070[40]

[a] ISO standard reference conditions apply for the measurement of all gas properties listed in this table except hydrocarbon dewpoint temperature.

[c] The Wobbe Index and relative density limits in this specification imply a calorific value range of (35,2 to 46,5) MJ/m³.

[d] The limit for total sulfur applies after odorant addition.

[e] The total halogen test is required only for non-petroleum-based gases.

Table A.5 *(continued)*

Characteristics and components	Limit [a]	Test or calculation methods
Oxygen – for gas to be transported through medium and low pressure systems only – in all other cases	Maximum............1,0 mol% Maximum...........0,1 mol%	ISO 6974
Hydrogen	Maximum...........0,1 mol%	ISO 6975
Hydrogen sulfide	Maximum...........5 mg/m³	ISO 6326
Total sulfur (calculated with sulfur) [d]	Maximum........ 50 mg/m³	ISO 6326
Water	Maximum........100 mg/m³	ISO 10101
Total halogens (calculated with Cl) [e]	Maximum........ 25 mg/m³	
Hydrocarbon dewpoint temperature	Maximum......2 °C at 5,0 MPa	ISO 6975 with an appropriate equation of state
Temperature	Minimum.............2 °C Maximum..........40 °C	—

[a] ISO standard reference conditions apply for the measurement of all gas properties listed in this table except hydrocarbon dewpoint temperature.

[c] The Wobbe Index and relative density limits in this specification imply a calorific value range of (35,2 to 46,5) MJ/m³.

[d] The limit for total sulfur applies after odorant addition.

[e] The total halogen test is required only for non-petroleum-based gases.

Annex B
(informative)

The issue of particulate matter in CBM

B.1 Source of particulate matter (PM) in CBM

Since CBM mining destroys the integrity of coal petrography, pulverized coal will inevitably be mixed into CBM. When the particle size of pulverized coal is less than 1 mm, it can enter the surface gathering and transportation pipeline network with the gas to form a gas-solid two-phase flow[34]. Affected by factors such as geological conditions and extraction methods, CBM is often carried with solid impurities such as pulverized coal and sand when CBM is transported from the wellhead to the surface gathering and transportation pipeline network[35]. Compared with the case where the gas in the conventional natural gas pipeline carries trace PM, the PM carried by the gas in the CBM surface gathering and transportation system features large fluctuation in mass concentration[35]. The PM content in CBM is usually much higher than that in conventional natural gas.

B.2 Size, content, and components of PM in CBM

After CBM is extracted, it goes from underground to single wells, well groups, gas gathering stations, processing plant, and to downstream pipelines and users. As PM is continuously deposited and removed by filtration equipment, its size and content will decrease successively. The typical size distribution of CBM dust from a gas gathering station in Jincheng, Shanxi: the size ranges from a few tenths of a micrometre to a few hundred micrometres, with a majority of tens of micrometres[36]. The PM content in the Shanxi CBM per cubic meter mainly ranges from a few milligrams to a few hundred milligrams[37].

The typical components of CBM include pulverized coal and inorganic minerals. Among them, inorganic minerals include quartz, plagioclase, microcline, hematite, mica, chlorite, calcite, magnetite, gypsum, and kaolin, dominated by quartz and plagioclase[35]. The specific composition is closely related to the geology of the gas production block. The chemical composition of the PM is mainly Al_2O_3, Fe_2O_3, SiO_2, and CaO, accompanied with elemental C and some impurities[36].

B.3 Sedimentation of CBM PM in surface gathering and transportation system and subsequent impact

After CBM is extracted, PM will deposit in the surface gathering and transportation system of single wells, well groups, gas gathering stations, and processing plant in sequence, such as wellhead valves and vents of single wells, surface gas pipelines, and compressor systems in gas gathering stations, as well as pipelines and processing equipment of processing plant, etc.

Due to the special occurrence characteristics of CBM and the adopted fracturing technology, a large amount of fine dust is inevitably mixed in the feed gas, which poses severe challenges to the surface gathering and transportation and downstream processing. Some PM will deposit in pipelines and erode valves, instruments, and other components. If micron-level impurities enter the compressor, they are easy to deposit on the cylinder and valve plate, causing abrasion of the cylinder or damage to the valve plate, resulting in production accidents such as abnormal shutdown of the compressor[35]. PetroChina Coalbed Methane Branch of Huabei Oilfield Company suffered serious accumulation of pulverized coal in the early stage of mining in Jincheng, Shanxi, which damaged compressor pistons and cylinders and caused instrument failure, causing a great impact on normal production[36].

During the development of CBM, some CBM not only carries PM, but also liquids such as free water. Sometimes, there is much more liquid than PM. These pulverized coal and droplets will deposit in pipelines and erode valves, instruments, and other components. Relevant studies have shown that: PM