INTERNATIONAL STANDARD

# ISO 15403

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# Natural gas — Designation of the quality of natural gas for use as a compressed fuel for vehicles

*Gaz naturel — Désignation de la qualité de gaz naturel pour usage comme carburant comprimé pour véhicules*



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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 3.

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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 15403 was prepared by Technical Committee ISO/TC 193, *Natural gas*.

Annexes A to E of this International Standard are for information only.



 

## Introduction

Natural gas has been used to some extent as a fuel for internal combustion engines in compressor stations, co-generation systems, and vehicles of various types for many years now. However, the prerequisites for growth, i.e. economic viability and fuel availability, were generally not satisfied. Now, with the natural gas industry well established, supplying 20 % of the world's primary energy, and the need for alternative, low-emission fuels, the situation has improved considerably. During the past decade, natural gas vehicles have become a viable option with some one million units now in use around the world. Growth is continuing as many governments actively promote this clean-burning fuel with its environmental benefits. Many fleet operators are converting their vehicles, and vehicle manufacturers are developing and marketing dedicated natural gas equipment.

In the context of this standard, natural gas vehicles (NGVs) utilize compressed natural gas stored "on-board". The pressure of the gas stored in multiple containers is up to a maximum 25 000 kPa. Although the pressure has to be reduced before combustion, compression and storage gives NGVs an adequate range. While NGVs were initially equipped with converted gasoline or diesel engines, high-performance, dedicated natural gas engines are now being extensively developed and produced. Liquefied natural gas (LNG) may also be stored in the fuel tanks of natural gas vehicles. This, however, will be the subject of a separate International Standard.

This International Standard for the quality designation of compressed natural gas is designed to stipulate the international requirements placed on the natural gas used as a motor fuel. Engine and vehicle manufacturers must know these requirements so they can develop high-performance equipment which runs on compressed natural gas.

A technical report giving detailed data on the gas compositions used in ISO 15403 has been drafted and is being circulated as an addendum.

# Natural gas — Designation of the quality of natural gas for use as a compressed fuel for vehicles

## 1 Scope

The aim of this International Standard is to provide manufacturers, vehicle operators, fuelling station operators and others involved in the compressed-natural-gas vehicle industry with information on the fuel quality for natural gas vehicles (NGVs) required to develop and operate compressed-natural-gas vehicle equipment successfully.

Fuel meeting the requirements of this International Standard should:

a) provide for the safe operation of the vehicle and associated equipment needed for its fuelling and maintenance;

b) protect the fuel system from the detrimental effects of corrosion, poisoning, and liquid or solid deposition;

c) provide satisfactory vehicle performance under any and all conditions of climate and driving demands.



Some aspects of this International Standard may also be applicable for the use of natural gas in stationary combustion engines.



## 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 6326-1:1989, *Natural gas — Determination of sulfur compounds — Part 1: General introduction.*

ISO 6326-2:—[1)], *Natural gas — Determination of sulfur compounds — Part 2: Gas chromatographic method using an electrochemical detector*.

ISO 6326-3:1989, *Natural gas — Determination of sulfur compounds — Part 3: Determination of hydrogen sulfide, mercaptan sulfur and carbonyl sulfide sulfur by potentiometry.*

ISO 6326-4:1994, *Natural gas — Determination of sulfur compounds — Part 4: Gas chromatographic method using a flame photometric detector for the determination of hydrogen sulfide, carbonyl sulfide and sulfur-containing odorants.*

ISO 6326-5:1989, *Natural gas — Determination of sulfur compounds — Part 5: Lingener combustion method.*

ISO 6327:1981, *Gas analysis — Determination of the water dew point of natural gas — Cooled surface condensation hygrometers*.

1) To be published. (Revision of ISO 6326-2:1981)

ISO 6570-1:1983, *Natural gas — Determination of potential hydrocarbon liquid content — Part 1: Principles and general requirements.*

ISO 6570-2:1984, *Natural gas — Determination of potential hydrocarbon liquid content — Part 2: Weighing method.*

ISO 6974 (all parts), *Natural gas — Determination of composition with defined uncertainty by gas chromatography.*

ISO 6976:1995, *Natural gas — Calculation of calorific values, density, relative density and Wobbe index from composition.*

ISO 10101-1:1993, *Natural gas — Determination of water by the Karl Fischer method — Part 1: Introduction*.

ISO 10101-2:1993, *Natural gas — Determination of water by the Karl Fischer method — Part 2: Titration procedure*.

ISO 10101-3:1993, *Natural gas — Determination of water by the Karl Fischer method — Part 3: Coulometric procedure.*

ISO 11541:1997, *Natural gas — Determination of water content at high pressure*.

ISO 13734:1998, *Natural gas — Organic sulfur compounds used as odorants — Requirements and test methods.*

ISO 14532:—[2)], *Natural gas — Terminology*.

## 3 Terms and definitions



For the purposes of this International Standard, the following terms and definitions apply. Definitions were taken from ISO 14532 whenever possible.



**3.1**
**natural gas**
complex mixture of hydrocarbons, primarily methane, but generally also including ethane, propane and higher hydrocarbons in much smaller amounts and some non-combustible gases, such as nitrogen and carbon dioxide

NOTE 1 Natural gas generally also includes minor amounts of trace constituents.

NOTE 2 Natural gas is produced and processed from the raw gas or liquefied natural gas and, if required, blended to the extent suitable for direct use (for example as gaseous fuel).

NOTE 3 Natural gas remains in the gaseous state under the temperature and pressure conditions normally found in service.

NOTE 4 Natural gas consists predominantly of methane (mole fraction greater than 0,70), and has a superior calorific value normally within the range 30 MJ/$m^3$ to 45 MJ/$m^3$. It contains also ethane (typically up to 0,10 mole fraction), propane, butanes and higher alkanes in steadily decreasing amounts. Nitrogen and carbon dioxide are the principal non-combustible components, each present at levels which typically vary from less than 0,01 mole fraction to 0,20 mole fraction.

Natural gas is processed from the raw gas so as to be suitable for use as industrial, commercial, residential fuel or as a chemical feedstock. The processing is intended to reduce the contents of potentially corrosive components, such as hydrogen sulfide and carbon dioxide, and of other components, such as water and higher hydrocarbons, potentially condensable in the transmission and distribution of the gas. Hydrogen sulfide, organic sulfur compounds and water are then reduced to trace amounts, and high carbon dioxide contents are likely to be reduced to below 0,05 mole fraction.

Natural gas is normally technically free from aerosol, liquid and particulate matter.

2) To be published.

In some circumstances natural gas may be blended with town gas or coke oven gas, in which case hydrogen and carbon monoxide will be present in amounts up to 0,10 mole fraction and 0,03 mole fraction respectively. In this case, small amounts of ethylene may also be present.

Natural gas may also be blended with LPG[3)]/air mixtures, in which case oxygen will be present, and the levels of propane and butanes will be considerably enhanced.

NOTE 5 Pipeline quality natural gas is one which has been processed so as to be suitable for direct use as industrial, commercial, residential fuel or as a chemical feed stock.

The processing is intended to reduce the corrosive and toxicity effects of certain components, and to avoid condensation of water or hydrocarbons in the transmission and distribution of the gas.

Hydrogen sulfide and water should only be present in trace amounts, and high carbon dioxide content is likely to be reduced.

[ISO 14532]

**3.2**
**substitute natural gas**
manufactured or blended gas which is interchangeable in its properties with natural gas

NOTE Manufactured gas is sometimes called synthetic natural gas.

[ISO 14532]

**3.3**
**compressed natural gas**
natural gas used as a fuel for vehicles, typically compressed up to 20 000 kPa in the gaseous state [ISO 14532]



NOTE The maximum pressure for natural gas stored in a container is 25 000 kPa.



**3.4**
**gas quality**
attribute of natural gas defined by its composition and its physical properties [ISO 14532]

**3.5**
**normal reference conditions**
reference conditions of pressure, temperature and humidity (state of saturation) equal to: 101,325 kPa and 273,15 K for a real, dry gas

**3.6**
**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, dry gas

NOTE 1 Good practice requires that the reference conditions are incorporated as part of the symbol, and not of the unit, for the physical quantity represented.

EXAMPLE

$$\tilde{H}_{\mathrm{S}}\left[p_{\mathrm{crc}}, T_{\mathrm{crc}}, V\left(p_{\mathrm{mrc}}, T_{\mathrm{mrc}}\right)\right]$$

where

$\tilde{H}_{\mathrm{S}}$ superior calorific value on volumetric basis;

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3) LPG = liquefied petroleum gas

 

| | |
|---|---|
| $T_{crc}$ | temperature of the combustion reference conditions; |
| $p_{crc}$ | pressure of the combustion reference conditions; |
| $V(p_{mrc}, T_{mrc})$ | volume at temperature and pressure of the metering reference conditions. |

NOTE 2 Standard reference conditions are also referred to as metric standard conditions.

NOTE 3 The abbreviation s.t.p. (standard temperature and pressure) replaces the abbreviation N.T.P. (Normal Temperature and Pressure), as formerly used, and is defined as the condition of pressure and temperature equal to: 101,325 kPa and 288,15 K. No restriction is given on the state of saturation.

[ISO 14532]

**3.7**
**superior calorific value**
energy released as heat by the complete combustion in air of a specified quantity of gas, in such a way that the pressure $p_1$ at which the reaction takes place remains constant, and all the products of combustion are returned to the same specified temperature $T_1$ as that of the reactants, all of these products being in the gaseous state except for water formed by combustion, which is condensed to the liquid state at $T_1$ [ISO 14532]

NOTE 1 Where the quantity of gas is specified on a molar basis, the calorific value, expressed in MJ/mol, is designated as:

$$\bar{H}_S(p_1, T_1)$$

On a mass basis the calorific value, expressed in MJ/kg, is designated as:



$$\hat{H}_S(p_1, T_1)$$



Where the quantity of gas is specified on a volumetric basis, the calorific value, expressed in MJ/m$^3$, is designated as:

$$\tilde{H}_S\left[p_1, T_1, V(p_2, T_2)\right]$$

where $p_2$ and $T_2$ are the gas volume (metering) reference conditions.

The volumetric based calorific value should be specified to normal or standard reference conditions.

NOTE 2 The terms gross, higher, upper and total calorific value, or heating value, are synonymous with superior calorific value.

NOTE 3 The calorific value should be specified to the combustion conditions.

NOTE 4 The calorific value is normally stated as dry.

EXAMPLE $\tilde{H}_{S,w}(p_{src}, T_{src})$ designates the superior calorific value, specified on a volumetric basis, at standard reference conditions and stated as wet. For simplicity, the combustion conditions are not specified.

**3.8**
**inferior calorific value**
energy released as heat by the complete combustion in air of a specified quantity of gas, in such a way that the pressure $p_1$ at which the reaction takes place remains constant, and all the products of combustion are returned to the same specified temperature $T_1$ as that of the reactants, all of these products being in the gaseous state

 

NOTE 1 Superior calorific value differs from inferior calorific value by the heat of condensation of water formed by combustion.

NOTE 2 Where the quantity of gas is specified on a molar basis, the calorific value, expressed in MJ/mol, is designated as:

$$\bar{H}_{\mathrm{I}}(p_1, T_1)$$

On a mass basis the calorific value, expressed in MJ/kg, is designated as:

$$\hat{H}_{\mathrm{I}}(p_1, T_1)$$

Where the quantity of gas is specified on a volumetric basis, the calorific value, expressed in MJ/m$^3$, is designated as:

$$\tilde{H}_{\mathrm{I}}\left[p_1, T_1, V(p_2, T_2)\right]$$

where $p_2$ and $T_2$ are the gas volume (metering) reference conditions.

NOTE 3 The terms net and lower calorific value, or heating value, are synonymous with inferior calorific value.

NOTE 4 Superior and inferior calorific values can also be stated as dry or wet (denoted by the subscript "w") depending on the water vapour content of the gas prior to combustion.

The effects of water vapour on the calorific values, either directly measured or calculated, are described in annex F of ISO 6976:1995.



NOTE 5 Normally the calorific value is expressed as the superior, dry value specified on volumetric basis under normal or standard reference conditions.

[ISO 14532]



**3.9**
**density**
mass of gas divided by its volume at specified conditions of pressure and temperature

NOTE In a mathematical representation the density is given by:

$$\rho(p, T) = \frac{m}{V(p, T)}$$

[ISO 14532]

**3.10**
**relative density**
quotient of the mass of a gas, contained within an arbitrary volume, and the mass of dry air of standard composition (defined in ISO 6976:1995) which would be contained in the same volume at the same reference conditions

NOTE 1 An equivalent definition is given by the ratio of the density of the gas $\rho_{\mathrm{g}}$ to the density of dry air of standard composition $\rho_{\mathrm{a}}$ at the same reference conditions.

$$d = \frac{\rho_{\mathrm{g}}(p_{\mathrm{src}}, T_{\mathrm{src}})}{\rho_{\mathrm{a}}(p_{\mathrm{src}}, T_{\mathrm{src}})}$$

NOTE 2 Density can be expressed in terms of the real gas law:

$$\rho = \frac{M \cdot p}{Z \cdot R \cdot T}$$

 

With this relation the relative density, when both gas and air are considered as real fluids, becomes:

$$d = \frac{\dfrac{M_\mathrm{g} \cdot p_\mathrm{src}}{Z_\mathrm{g}\left(p_\mathrm{src}, T_\mathrm{src}\right) \cdot R \cdot T_\mathrm{src}}}{\dfrac{M_\mathrm{a} \cdot p_\mathrm{src}}{Z_\mathrm{a}\left(p_\mathrm{src}, T_\mathrm{src}\right) \cdot R \cdot T_\mathrm{src}}} = \frac{M_\mathrm{g} \cdot Z_\mathrm{a}\left(p_\mathrm{src}, T_\mathrm{src}\right)}{M_\mathrm{a} \cdot Z_\mathrm{g}\left(p_\mathrm{src}, T_\mathrm{src}\right)}$$

For ideal gas behaviour of the gases, when both gas and air are considered as fluids which obey the ideal gas law, the relative density becomes:

$$d = \frac{M_\mathrm{g}}{M_\mathrm{a}}$$

NOTE 3 In former times, the above ratio $M_\mathrm{g}/M_\mathrm{a}$ was called specific gravity of a gas, which has the same value as the relative density if ideal behaviour of the gases is assumed. The term relative density should now replace the term specific gravity.

[ISO 14532]

**3.11**
**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

NOTE 1 The volume is stated at normal or standard reference conditions.



NOTE 2 The Wobbe index is specified as superior (denoted the subscript "S") or inferior (denoted the subscript "I"), depending on the calorific value, and as dry or wet (denoted by the subscript "w") depending on the calorific value and the corresponding density.



EXAMPLE

Wobbe index, superior, specified on a volumetric basis, at standard reference conditions and stated as wet (denoted by the supscript "w")

$$W_\mathrm{S}\left(p_\mathrm{src}, T_\mathrm{src}\right) = \frac{\tilde{H}_\mathrm{S,w}\left(p_\mathrm{src}, T_\mathrm{src}\right)}{\sqrt{d_\mathrm{w}\left(p_\mathrm{src}, T_\mathrm{src}\right)}}$$

NOTE 3 The Wobbe index is a measure of heat input to gas appliances derived from the orifice flow equation. Heat input for different natural gas compositions is the same if they have the same Wobbe index, and operate under the same gas pressure (see ISO 6976).

[ISO 14532]

**3.12**
**compression factor**
quotient of the actual (real) volume of an arbitrary mass of gas, at a specified pressure and temperature, and the volume of the same gas, under the same conditions, as calculated from the ideal gas law

NOTE 1 The terms compressibility factor and $Z$-factor are synonymous with compression factor.

NOTE 2 The formula for the compression factor is as follows:

$$Z = \frac{V_\mathrm{m}(\mathrm{real})}{V_\mathrm{m}(\mathrm{ideal})}$$