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Natural gas - Calculation of methane number of gaseous fuels for reciprocating internal combustion engines - Part 1: MNc method (ISO/DIS 17507-1:2024)

Erdgas-Berechnung der Methanzahl von gasförmigen Kraftstoffen für Verbrennungsmotoren-Teil 1: MNc-Verfahren (ISO/DIS 17507-1:2024)

Gaz naturel - Calcul de l'indice de méthane des combustibles gazeux pour les moteurs alternatifs à combustion interne - Partie 1: Méthode IMc (ISO/DIS 17507-1:2024)

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Natural gas — Calculation of methane number of gaseous fuels for reciprocating internal combustion engines —

Part 1: **MNc method**

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Foreword

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This document was prepared by Technical Committee ISO/TC 193, Natural gas.

A list of all parts in the ISO 17507 series can be found on the ISO website.

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Introduction

The globalization of the natural gas market and the drive towards sustainability are increasing the diversity of the supply of gases to the natural gas infrastructure. For example, the introduction of regasified LNG can result in higher fractions of non-methane hydrocarbons in the natural gas grid than the traditionally distributed pipeline gases for which these hydrocarbons have been removed during processing. Also, the drive towards the introduction of sustainable gaseous fuels such as hydrogen and gases derived from biomass results in the introduction of "new" gas compositions, containing components that do not occur in the traditional natural gas supply. Consequently, the increasing variations in gas composition affect the so-called knock resistance of the gas when used as a fuel which can affect the operational integrity of reciprocating internal combustion engines.

For the efficient and safe operation of gas engines, it is of great importance to characterize the knock resistance of gaseous fuels accurately. Engine knock is caused by autoignition of unburned fuel mixture ahead of this mixture being consumed by the propagating flame. Mild engine knock increases pollutant emissions accompanied by gradual build-up of component damage and complete engine failure if not counteracted. Severe knock causes structural damage to critical engine parts, quickly leading to catastrophic engine failure. To ensure that gas engines are matched with the expected variations in fuel composition, the knock resistance of the fuel is to be characterized, and subsequently specified, unambiguously.

Traditional methods for characterizing the knock resistance of gaseous fuels, such as the methane number method developed by AVL in the 1960s, relate the knock propensity of a given fuel with that of an equivalent methane/hydrogen mixture using a standardized test engine. Several other methane number methods have since been developed, sometimes based on the approach and/or data from the original experimental work performed by AVL.

In recognition of the need for standardizing a method for characterizing the knock resistance of gaseous fuels, several existing methods for calculating a methane number have been considered including the MNc method which is described in this document. ISO 17507-2[1] describes the PKI method.

Methods to calculate a methane number are based on the input of the gas composition under investigation. While methods may be fundamentally different in their development approach, the methods should produce ideally similar methane numbers for the range of gas compositions they are valid for. Yet, differences in outcome can be observed. Engine manufacturers typically determine the calculation method to be used when specifying a methane number value for their engines as part of their application and warranty statements. In all cases, when specifying a methane number based on either method, or any other method, the method used should be noted.

The MNc method is based on the original data of the research program performed by AVL Deutschland (AVL is based in Graz, Austria) GmbH[2] for FVV (the Research Association for Combustion Engines). The methodology first proposed by Deutz ("Klöckner-Humboldt-Deutz AG")[3],[4] was later amended in 2005 and 2011 by MWM ("Motoren-Werke Mannheim AG"). A more detailed history of the MNc method can be found in Annex E.

The MNc method takes the components of the gaseous fuel mixture and groups them together into several ternary and binary groups whose methane number has been experimentally determined. It then determines the overall methane number by applying optimization algorithms to the individual component groupings.

Natural gas — Calculation of methane number of gaseous fuels for reciprocating internal combustion engines —

Part 1: MNc method

1 Scope

The methane number of a gas quantifies the knock propensity of that gas when used as a fuel in a reciprocating internal combustion engine. The higher the methane number, the more knock resistant the gaseous fuel is, and vice versa.

This document defines the MNc method for the calculation of the methane number of a gaseous fuel, using the composition of the gas as sole input for the calculation.

This document applies to natural gas (and biomethane) and their admixtures with hydrogen, see Clause 5.

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 14532:2014, *Natural gas — Vocabulary*

ISO 14912, *Gas analysis — Conversion of gas mixture composition data*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14532 and the following apply. ISO and IEC maintain terminology 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
methane number
MN
numerical rating indicating the knock resistance of a gaseous fuel

Note 1 to entry: It is analogous to the octane number for petrol. The methane number is the volume fraction expressed as percentage of methane in a methane-hydrogen mixture, that in a test engine under standard conditions has the same knock resistance as the fuel gaseous fuel to be examined.

[SOURCE: ISO 14532:2014, 2.6.6.1]

3.2
Calculated methane number
MNc
calculation of a numerical rating index indicating the knock resistance of a gaseous fuel according to ISO 17507-1

Note 1 to entry: This analytical estimate of a methane number is based on using volume fraction gaseous fuel composition as input.

4 Symbols and abbreviated terms

— MN Methane Number

— MNc Calculated Methane Number

5 MNc method

5.1 Introduction

The methane number of a gaseous fuel is calculated from its composition according to several different methods, all of which can give different results. The MNc method (the so-called "MWM Method") is in use by engine Original Equipment Manufacturers (OEMs), gaseous fuel suppliers, engine operators, consulting engineers and engine control gas analyser equipment OEMs and has been adopted in EN 16726[5] and as the ASTM D8221.[6] When referring to a methane number value, the method used should be noted.

NOTE The MNc method is cited as a test method in ISO 23306[7].

The MNc method described in this document has been developed for a range of gas compositions exceeding the typical composition range of natural gas-based fuels used in reciprocating internal combustion engines shown in Table D.1.

The MNc method thus can be used for the calculation of the methane number of any gaseous fuel as long as the gas composition input ranges, shown in Table 1, and further boundary conditions of this method are adhered to. The boundary conditions for the MNc method are set out in this document.

The method is based on gaseous fuel compositions in volume fraction at reference conditions of 0 °C and 101,325 kPa and expressed as a percentage. If the gas composition is available either as mole fraction or as mass fraction, conversion to volume fraction shall be performed using the methods in ISO 14912[8].

Numerical examples are provided to enable software developers to validate implementations of the methodology described in this document. As an aid to validation a relatively large number of decimal places has been retained.

5.2 Applicability

5.2.1 Standard gaseous fuel composition range

The MNc method described in this document has been developed for and is applicable to all reciprocating internal combustion engines using a gaseous fuel.

In general, the use of any method for calculating the methane number of a gaseous fuel requires careful consideration and/or consultation with specialist industry parties such as engine suppliers, fuel suppliers and consulting firms.

The method described in this document is applicable to gaseous fuels comprising the following gases: carbon monoxide; butadiene; butylene; ethylene; propylene; hydrogen sulfide; hydrogen; propane; ethane; butane; methane; nitrogen and carbon dioxide. The method treats hydrocarbons other than those specified as butane and is therefore applicable to gaseous fuels containing such higher hydrocarbons.

Upper limits for gaseous fuels applied to this method are shown in Table 1. Lower limits are zero for all components.

Table 1 — Upper limits of gaseous fuel components for the MNc method

Component	Amount of substance		
	Volume fraction % (normative)	Mole fraction[b] % (informative)	Mass fraction[b] % (informative)
Methane	100	100	100
Ethylene	100	100	100
Ethane	100	100	100
Propylene	100	100	100
Propane	100	100	100
Butanes	100	100	100
Pentanes [a]	3	3,23	13,04
Hexanes+ [a]	3	3,34	15,66
Nitrogen	100	100	100
Carbon dioxide	60	60,11	80,52
Carbon monoxide	100	100	100
Hydrogen	100	100	100
Hydrogen sulfide	25	25,15	41,65

[a] The MNc method for compositions including pentanes (C5), and hexanes and higher (C6+) is limited to C5 and C6+ volume fraction of 3 % each and a total of 5 %.

[b] Limits expressed as mole fractions and mass fractions, other than 100 %, are converted from the limits in volume fraction according to ISO 14912. Because the conversion is composition-dependant, the calculation assumes the component is present as a binary mixture with methane. Limits expressed as mole fractions and mass fractions, other than 100 %, are therefore informative.

5.2.2 Handling of other gaseous fuel components

5.2.2.1 Oxygen and water vapour

Oxygen and water vapour shall be ignored, and the gaseous fuel composition shall be normalized as an oxygen-free composition.

5.2.2.2 Argon and helium

Any volume fractions of argon or helium present in the gaseous fuel under investigation shall be assigned to the fraction of nitrogen.

5.2.2.3 Other non-listed gaseous fuel components

Any component present in the gaseous fuel under investigation not listed as valid gas input component for the MNc method as per Table 1 and not listed in 5.2.2.1 or 5.2.2.2, shall be ignored, and the gaseous fuel composition shall be normalized without that component.

5.3 Methodology to calculate the MNc

The methane number of a gaseous fuel is calculated from its composition in five steps. The steps are outlined below and described more fully in turn in an example composition in 6.1. Additional examples are discussed in 6.2 and 6.3 and Annex A contains the numerical values and results of those calculations. Table A.10 provides results of calculations for more example compositions for further software validation purposes.

a) The composition of the gaseous fuel is simplified by converting it into an inert-free mixture comprising the combustible compounds carbon monoxide, ethylene, propylene, hydrogen sulfide, hydrogen, propane, ethane, butane and methane.

For gases conveyed in pipeline systems carbon monoxide, ethylene, propylene, hydrogen sulfide is unlikely to be present at concentrations that would impact on methane number and can be ignored.

b) The simplified mixture is sub-divided further into a number of partial ternary mixtures. The number and particular partial ternary mixtures chosen is decided by inspection of available ternary systems in a given order, including those systems that contain the relevant combustible compounds. Selection is ceased when all combustible compounds are contained in at least two ternary systems.

c) The composition and fraction of the selected partial mixtures is adjusted iteratively so as to minimize the difference between the methane numbers of each partial mixture.

d) The methane number of the simplified mixture is determined from the weighted average of the methane number of the selected partial mixtures.

e) Finally, the methane number of the gaseous fuel is calculated by correcting the methane number of the simplified mixture to allow for the presence of inerts in the original gaseous fuel.

5.4 Expression of results

For expression of the final result, the calculated methane number, is expressed as an integer and the method used should be noted. E.g., 74 MNc per ISO 17507-1. Rounding to an integer value according to ISO 80000-1[9] is recommended as a higher numerical resolution of the MNc value is not relevant in practice.

5.5 Uncertainty error and bias

The MNc is calculated from the volume fraction composition of the gaseous fuel under review as sole input. The calculation uses fixed-value coefficients based on the particular composition of the gaseous fuel under review, meaning that for a given gaseous fuel composition there can only be one MNc value. For the purpose of this standard, the MNc values thus calculated are deemed to be exact according to the MNc method. Hence, any error or bias in an MNc value arise solely from errors in the gaseous fuel compositions used as input.

The resulting uncertainty shall be estimated according to Annex C.

6 Example calculations

6.1 Example 1

6.1.1 Simplification of the composition of the gaseous fuel

The description of the calculation is illustrated by reference to a gaseous fuel composition typical of natural gas as shown in Table A.1. The composition of the gas (column 1) is simplified by increasing the quantity of butanes to allow for the presence of butadiene, butylene, pentanes and hydrocarbons of carbon number greater than 5. The adjustment made is as follows:

— Butadiene and butylene are replaced with an equivalent number of butanes by multiplying their quantities by 1.

— Pentanes are replaced with an equivalent number of butanes by multiplying the quantity of pentanes by 2,3.

— Hydrocarbons of carbon number greater than 5 ("hexanes+") are replaced with an equivalent number of butanes by multiplying the quantity of hexanes+ by 5,3.

In the case of example 1 the quantity of butanes