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Natural gas - Calculation of methane number of gaseous fuels for reciprocating internal combustion engines - Part 2: PKI method (ISO/DIS 17507-2:2024)

Erdgas - Berechnung der Methanzahl von gasförmigen Kraftstoffen für Verbrennungsmotoren - Teil 2: PKI-Verfahren (ISO/DIS 17507-2:2024)

Gaz naturel - Calcul de l'indice de méthane des combustibles gazeux pour les moteurs alternatifs à combustion interne - Partie 2: Méthode PKI (ISO/DIS 17507-2:2024)

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Part 2:
PKI 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.

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

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[1],[2] and.[3] 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 PKI method which is described in this document. ISO 17507-1[4] describes the MNc 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 ideally produce 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 PKI method has been developed by DNV in a consortium of engine Original Equipment Manufacturers (OEMs) and natural gas fuel suppliers. The method is based on the physics and chemistry of the air-fuel mixture during the compression and combustion phases of the engine working cycle that determine engine knock, using an experimentally verified engine combustion model.

The PKI method uses two polynomial functions to compute the methane number from the gaseous fuel composition input. The development and experimental verification of the PKI method is documented in a series of publications.[5-17] A more detailed history of the PKI method can be found in Annex F.

A version of the PKI method dedicated to LNG fuels is currently described in ANNEX A of ISO 23306 “Specification of liquefied natural gas as a fuel for marine applications”[18] and[19].

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

Part 2:
PKI 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 gas is, and vice versa.

This document defines the PKI 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 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
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 gaseous fuel to be examined.

[SOURCE: ISO 14532:2014, 2.6.6.1]

3.2

PKI methane number

MN_{PKI}

calculation of a numerical rating index indicating the knock resistance of a gaseous fuel according to ISO 17507-2

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

4 Symbols and abbreviated terms

MN	Methane Number
PKI	Propane Knock Index
MN_{PKI}	PKI Methane Number

5 MN_{PKI} 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 PKI method is in use by engine OEMs, gaseous fuel suppliers, engine operators, consulting engineers and engine control and gas analyser equipment OEMs, and has been adopted in ISO 23306[19]. When referring to a methane number value, the method used should be noted.

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

The PKI method thus can be used for the calculation of the methane number of any gaseous engine 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 PKI method are set out in this document.

The method is based on gaseous fuel compositions in mole fraction, expressed as a percentage. If the gas composition is available either as volume fraction or as mass fraction, conversion to mole fraction shall be performed using the methods in ISO 14912.

Calculation of the MN_{PKI} from the gas composition involves two polynomial functions, as described in 5.3. Numerical examples are provided to enable software developers to validate implementations of the method described in this document.

5.2 Applicability

5.2.1 Standard gaseous fuel composition range

The PKI 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 PKI method described in this document is applicable to gaseous fuels comprising the following components: methane, ethane, propane, n-butane, i-butane, n-pentane, i-pentane, neo-pentane, hexanes, hydrogen, carbon monoxide, carbon dioxide, nitrogen and hydrogen sulfide.

Upper and lower limits for gaseous fuels applied to this method are shown in Table 1.

Table 1 — Upper and lower limits of gaseous fuel components for the PKI method

Component	Amount of substance
	Mole fraction **%**
Methane	65 – 100
Ethane	0 – 20
Propane	0 – 20
n-Butane [a]	0 – 5
i-Butane [a]	0 – 5
n-Pentane [a]	0 – 2
i-Pentane [a]	0 – 2
neo-Pentane [a]	0 – 2
Hexanes^{+} [b]	0 – 1,5
Hydrogen	0 – 35
Carbon monoxide	0 – 10
Carbon dioxide	0 – 20
Nitrogen	0 – 20
Hydrogen sulfide	0 – 0,5

[a] The PKI method differentiates between the isomers of butane and pentane in recognition of their difference in knock propensity.

[b] The PKI method treats the sum of hexanes and higher hydrocarbons including their isomers (listed as hexanes^{+}) as n-hexane.

Gas composition analyses may comprise of (non-)hydrocarbon components not listed as valid gas input components for the PKI method as per Table 1. To provide guidance towards the correct use of and optimum results from the PKI method, instructions for the handling of a selection of such non-listed gas components is given in 5.2.2.

5.2.2 Handling of other gaseous fuel components

5.2.2.1 Oxygen and water vapour

Any oxygen and water vapour present in the gaseous fuel under investigation shall be ignored, meaning their fractions shall be set to equal zero (0). The resulting gas composition shall be normalized to obtain a sum of 100 %, or unity in the case of using fractions.

5.2.2.2 Argon and helium

Any argon or helium present in the gaseous fuel under investigation shall be assigned to the fraction of nitrogen, meaning their fractions shall be added to that of nitrogen. This assignment does not affect the sum total of the resulting gas composition. If needed, the resulting gas composition shall be normalized to obtain a sum of 100 %, or unity in the case of using fractions.

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 PKI method as per Table 1 and not listed in 5.2.2.1 or 5.2.2.2, shall be ignored, meaning their fractions shall be set to equal zero (0). The resulting gas composition shall be normalized to obtain a sum of 100 %, or unity in the case of using fractions.