BSI Standards Publication

Gas infrastructure — Quality of gas — Group H

bsi.

National foreword

This British Standard is the UK implementation of EN 16726:2015.

BSI, as a member of CEN, is obliged to publish EN 16726:2015 as a British Standard. However, attention is drawn to the fact that during the development of this European Standard, the UK committee voted against its approval as a European Standard.

The UK committee voted against the adoption of EN 16726:2015 due to concerns with the specification in EN 16726:2015 relating to elemental components in natural gas. The UK committee cannot be sure how appliances currently in operation would perform if subject to a variation in gas specification. Furthermore, the committee is concerned about the potential costs of converting some 30 million gas appliances to burn any new gas safely and efficiently without detailed research. Installed gas appliances have been designed to be safe and to operate efficiently within historic UK gas specifications. The gas quality required for safe operation of gas appliances installed in the UK was stipulated in the *Gas Safety (Management) Regulations 1996 (Statutory Instrument 1996 No. 551)*.

The UK committee also had concerns about the legal framework of the standard, specifically the European Commission's proposal to amend the *Interoperability and Data Exchange Code* in 2016 to implement EN 16726:2015 by EU regulation. In view of the committee's concerns and bi-lateral gas supply commitments, the UK committee is considering the CEN/CENELEC internal regulations Part 3, relating to A-deviations and Special National Conditions. Further details about the UK committee's concerns can be found in National Annex NA.

Owing to widespread objections from the Member States after the Formal Vote, the EC subsequently withdrew their requirement to implement EN 16726 in the *Interoperability and Data Exchange Code*. At EC request, the European gas transportation stakeholders' group ENTSOG conducted an Impact Analysis on various options for implementing EN 16726:2015, in which the UK participated fully. ENTSOG has recommended that the Interoperability Code should not be amended to make EN 16726:2015 a binding provision. Work continues at CEN on finding a European Agreement on Wobbe Index and the UK committee reserves its position on A-deviations and Special National Conditions. The results of the now completed Oban Trial, which covers some 1100 existing customers and gases with an extended range of Wobbe Index, will inform this debate (https://www.sgn.co.uk/Oban/).

The UK participation in its preparation was entrusted to Technical Committee GSE/33, Gas supply.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2017.

Amendments/corrigenda issued since publication

Date	Text affected

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 16726

December 2015

ICS 75.060

English Version

Gas infrastructure - Quality of gas - Group H

Infrastructure gazière - Qualité du gaz - Groupe H

Gasinfrastruktur - Beschaffenheit von Gas - Gruppe H

This European Standard was approved by CEN on 24 October 2015.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Ref. No. EN 16726:2015 E

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European foreword

This document (EN 16726:2015) has been prepared by Technical Committee CEN/TC 234 "Gas infrastructure", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2016, and conflicting national standards shall be withdrawn at the latest by June 2016.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

The need for a European Standard concerning the specification of the quality of gases of group H is derived from the mandate M/400 issued to CEN by the European Commission.

According to this mandate the goal is to define specifications that are as wide as possible within reasonable costs. This means that the specifications enhance the free flow of gas within the internal EU market, in order to promote competition and security of supply minimizing the negative effects on gas infrastructure and gas networks, efficiency and the environment and allow appliances to be used without compromising safety.

Some requirements specified in this European Standard, Clause 5, cannot be applied in Germany, Hungary and the Netherlands due to existing conflicting national legislation. The related A-Deviations are listed in Annex G.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This European standard sets requirements for gas quality with the aim to allow the free flow of gas between the CEN member states and to enable the security of supply taking into account the impact on the whole value chain from gas production and supply to end uses.

However, at the moment of publication of this European standard, a common Wobbe Index range cannot be defined because of different regulations in CEN Member States and limited knowledge of the influence of broadening Wobbe Index range on integrity, efficiency and safe use of appliances in some countries (see Annex D).

In order to find a common Wobbe Index range, further studies, such as the Gas Quality Harmonization Implementation Pilot, are necessary. The Wobbe Index should be defined when the pending results of these studies are available. The common Wobbe Index range should be implemented in a revised standard in due time.

For hydrogen, at present it is not possible to specify a limiting value which would generally be valid for all parts of the European gas infrastructure (see Annex E).

Responsibility and liability issues in the context of this European standard are subject to European or national regulations.

1 Scope

This European standard specifies gas quality characteristics, parameters and their limits, for gases classified as group H that are to be transmitted, injected into and from storages, distributed and utilized.

NOTE   For information on gas families and gas groups see EN 437.

This European standard does not cover gases conveyed on isolated networks.

For biomethane, additional requirements indicated in prEN 16723-1 apply.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN ISO 13443, *Natural gas - Standard reference conditions (ISO 13443)*

EN ISO 14532, *Natural gas - Vocabulary (ISO 14532)*

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 EN ISO 14532 and the following apply.

3.1
isolated network
network where transmission, distribution and utilization of gas are combined and which is physically unconnected to other networks

3.2
entry point
point at which gas enters a gas distribution or gas transmission system

3.3
interconnection point
physical point connecting adjacent entry-exit systems or connecting an entry-exit system with an interconnector

[SOURCE: Commission Regulation (EU) No 984/2013, modified]

3.4
maximum operating pressure
maximum pressure at which a network can be operated continuously under normal conditions expressed as absolute pressure

Note 1 to entry: Normal conditions are: no fault in any device or stream.

[SOURCE: EN 1594:2013, 3.23, modified]

3.5
application
equipment that utilizes the transported and distributed gas

Note 1 to entry: Some examples of gas applications are: gas appliances (domestic or commercial), processes (chemical or industrial), power plants, vehicles, greenhouses etc.

4   Reference conditions and pressure units

Unless stated otherwise all volumes are given for the real dry gas at ISO standard reference conditions of 15 °C (288,15 K) and 1013,25 mbar (101,325 kPa). Unless otherwise stated all pressures are absolute pressures.

Whenever data on the volume, gross calorific value (GCV), energy and Wobbe Index are communicated, it shall be specified under which reference conditions these values were calculated.

In assessing compliance with this European standard parameters should be determined directly at ISO standard reference conditions. If the properties are only available at other reference conditions and the actual gas composition is not known then conversion to ISO standard reference conditions shall be carried out using the procedure described in EN ISO 13443.

NOTE   Besides the ISO standard reference conditions, particular in gas transmission, normal reference conditions (25/0 °C) are used according to the Network Code Interoperability and Data exchange. These are indicated in Table 1 for information.

5   Requirements

Gas shall comply with the requirements given in Table 1 and shall be accepted for conveyance.

Table 1 — Requirements

Parameter	Unit	Limits based on standard reference condition 15 °C/15°C		Limits based on normal reference condition 25°C /0°C (for information)		Reference standards for test methods[d] (informative)
		Min.	Max.	Min.	Max.	
Relative density	no unit	0,555	0,700	0,555	0,700	EN ISO 6976, EN ISO 15970
Total sulfur without odorant	mg/m^3	not applicable	20[a]	not applicable	21[a]	EN ISO 6326-5, EN ISO 19739
	For sulfur in high pressure networks and on interconnection points the maximum acceptable sulfur content for conveyance is 20 mg/m^3, where in high pressure networks non-odorized gas is current practice. However, for existing practices with respect to transmission of odorized gas between high pressure networks higher sulfur content value up to 30 mg/m^3 may be accepted. NOTE On distribution networks the odorization is considered as a national safety issue. Some information about sulfur odorant content is given in Annex B.						
Hydrogen sulphide + Carbonyl sulphide (as sulfur)	mg/m^3	not applicable	5[a]	not applicable	5[a]	EN ISO 6326-1, EN ISO 6326-3, EN ISO 19739

Parameter	Unit	Limits based on standard reference condition 15 °C/15°C		Limits based on normal reference condition 25°C /0°C (for information)		Reference standards for test methods[d] (informative)
		Min.	Max.	Min.	Max.	
Mercaptan sulfur without odorant (as sulfur)	mg/m^3	not applicable	6[a]	not applicable	6[a]	EN ISO 6326-3, EN ISO 19739
Oxygen	mol/mol	not applicable	0,001 % or 1 % (see below)	not applicable	0,001 % or 1 % (see below)	EN ISO 6974-3, EN ISO 6974-6, EN ISO 6975
	At network entry points and interconnection points the mole fraction of oxygen shall be no more than 0,001 %, expressed as a moving 24 hour average. However, where the gas can be demonstrated not to flow to installations sensitive to higher levels of oxygen, e.g. underground storage systems, a higher limit of up to 1 % may be applied.					
Carbon dioxide	mol/mol	not applicable	2,5 % or 4 % see below	not applicable	2,5 % or 4 % see below	EN ISO 6974 parts 1 to 6, EN ISO 6975
	At network entry points and interconnection points the mole fraction of carbon dioxide shall be no more than 2,5 %. However, where the gas can be demonstrated not to flow to installations sensitive to higher levels of carbon dioxide, e.g. underground storage systems, a higher limit of up to 4 % may be applied.					
Hydro carbon dew point[b,c] at any pressure from 0,1 to 7 MPa (70 bar) absolute pressure	°C	not applicable	−2	not applicable	−2	ISO 23874, ISO/TR 12148
Water dew point[b,c] at 7 MPa (70 bar) or, if less than 7 MPa (70 bar), at maximum operating pressure of the system in which the gas flows	°C	not applicable	−8	not applicable	−8	EN ISO 6327, EN ISO 18453, EN ISO 10101 parts 1 to 3
Methane number	no unit	65	not applicable	65	not applicable	see normative Annex A
Contaminants	The gas shall not contain constituents other than listed in Table 1 at levels that prevent its transportation, storage and/or utilization without quality adjustment or treatment.					

[a]   Figures are indicated without post-comma digits due to analytical uncertainty.

[b]   Under given climatic conditions, a higher water dew point and hydrocarbon dew point may be accepted at national level.

[c]   For further information on water dew point and hydrocarbon dew point see Annex C.

[d]   Test methods other than those listed in the reference standards indicated in Table 1 may be applied, provided their fitness for purpose can be demonstrated.

Gas quality shall not impede safety of gas appliances and operations of end users. Appropriate measures shall be taken.

NOTE   Applications are sensitive towards variations of the gas quality depending on the type of application and the degree of variation.

For sampling, reference is made to Annex F.

Annex A
(normative)

Calculation of methane number of gaseous fuels for engines

A.1 Introduction

The methane number of a gaseous fuel can be calculated from its composition according to several different methods, all of which can give different results. For the purposes of compliance with this European standard the methodology described in this Annex shall be employed.

The method is based on the original data of the research program performed by AVL Deutschland GmbH /1/ for FVV (the Research Association for Combustion Engines) but employs amendments implemented in 2005 and 2011 by MWM GmbH. These amendments have been unpublished until the publication of this European standard.

The method requires input of composition in the form of volume fractions at reference conditions of 0 °C and 101,325 kPa and expressed as a percentage. Composition is more likely to be available either as mole fraction (e.g. in the natural gas transmission and distribution industry) or as mass fraction (e.g. in the automotive fuel industry) and conversion to volume fraction shall be performed using the methods in ISO 14912.

Numerical examples are provided so as to enable software developers to validate implementations of the methodology described in this annex. As an aid to validation a relatively large number of decimal places has been retained. For expression of the final result rounding to zero decimal points is recommended.

A.2 Calculation of methane number

A.2.1 Applicability

The method described in this European Standard is applicable to gaseous fuels comprising the following gases: carbon monoxide; butadiene; butylene; ethylene; propylene; hydrogen sulphide; 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.

The numerical examples provided in this annex are appropriate to gases of the second family and hence consider mixtures comprising methane, ethane, propane, butane, nitrogen and carbon dioxide. Hydrogen is also included in one example because of the growing interest in injection of hydrogen into gas pipelines. During the preparation of this standard MWM GmbH has confirmed that the method is applicable to both 2H and 2L gases.

Oxygen and water vapour shall be ignored and the fuel gas composition shall be calculated on a dry, oxygen-free basis.

A.2.2 General approach

The methane number of a gaseous fuel is calculated from its composition in five steps. The steps are outlined below and discussed more fully in turn in A.3. Additional examples are discussed in A.4 and A.5. Table A.10 provides results of calculations 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 sulphide, hydrogen, propane, ethane, butane and methane.

For gases of the second family conveyed in pipeline systems carbon monoxide, ethylene, propylene, hydrogen sulphide are 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 fuel gas.

A.3 Example 1: 2H-gas

A.3.1 Simplification of the composition of the gaseous fuel

The description of the calculation is illustrated by reference to a 2H-gas of composition 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 amount of butanes by multiplying their quantities by 1.

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

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

In the case of example 1 the quantity of butanes

$= 0,2100 + 0,1900 + (0,0400 + 0,0500) \times 2,3 + 0,0600 \times 5,3$

$= 0,9250$ (Column 2)

The simplified mixture is then re-normalized to 100 % (Column 3).

A.3.2 Selection of the ternary systems

A.3.2.1   Ternary mixtures

The ternary mixtures are chosen from the following list:

— A1: Methane – Hydrogen – Ethane

— A2: Propane – Ethane – Butane

— A3: Hydrogen – Propane - Propylene

— A4: Methane – Ethane – Propane

— A5: Methane – Hydrogen – Propane

— A6: Methane – Hydrogen – Butane

— A7: Methane – Propane – Butane

— A8: Methane – Ethane – Butane

— A9: Methane – Ethylene – Butane

— A10:   Methane – Hydrogen Sulphide – Butane

— A11:   Methane – Ethane – Hydrogen Sulphide

— A12:   Methane – Propylene

— A13:   Ethane – Propylene

— A14:   Carbon Monoxide – Hydrogen

— A15:   Ethane – Ethylene

— A16:   Propane – Ethylene

— A17:   Butadiene

— A18:   Butylene

NOTE   Mixtures A12 – A16 are clearly not ternary systems; however, for ease of mathematical treatment the coefficients have been adjusted so as to allow the expression of the methane number using a single equation.

A.3.2.2   Range of applicability of ternary mixture data

The range of applicability of most ternary systems is wide (each component can vary from 0 to 100 %). However, for some ternary systems there is a reduced range of applicability. This is a major issue when selecting ternary mixtures. The range of applicability of each ternary system is specified in Table A.2, expressed as maximum and minimum content of each component.

A.3.2.3   Factors affecting the ternary system selection process

The ternary systems are selected in accordance with three main considerations:

a) The number of gases in the ternary system that are present in the simplified mixture. Priority is always given to ternary systems that have all three of their components present in the simplified mixture. Systems with two of their components present in the simplified mixture are acceptable if insufficient systems with three components present in the simplified mixture are available.

b) Where there is a choice of ternary systems, the system with the highest fitness, W_j, takes priority.

c) Each component in the simplified mixture shall be represented in at least two ternary systems.

Fitness of a system is calculated from the following formula:

$$W_j = \sum_{i=1}^{i=n} \frac{V_i, min\left(100, \left(Vmax_{i,j} + 15\right)\right)}{Vsum_i} \qquad (A.1)$$

where

n	is the number of components in the simplified mixture
V_i	is the volume fraction of component i in the simplified mixture
$Vmax_{i,j}$	is the maximum content of component i for the range of applicability of system j
$Vsum_i$	is the sum of all maximum contents of component i for the range of applicability of all systems, i.e.

$$Vsum_i = \sum_{i=1}^{j=18} min\left(100, \left(Vmax_{i,j} + 15\right)\right) \qquad (A.2)$$

Values of $Vsum_i$ are independent of the composition of the simplified mixture. However, W_j is dependent upon the composition of the simplified mixture and so shall be calculated prior to selection. Note that this also means that the choice of ternary mixtures may be different for mixtures containing the same components, but in different proportions.

***In the case of example 1**, the calculation of Vsum_i and W_j is shown in Tables A.3 and A.4.*

A.3.2.4   Description of the ternary system selection process

The aim is to identify the optimum number of ternary systems that meet the three criteria described in A.3.2.3 and this is achieved by consideration of each component present in the simplified mixture in the following sequence:

1) Carbon Monoxide

2) Butadiene

3) Butylene

4) Ethylene

5) Propylene

6) Hydrogen Sulphide

7) Hydrogen

8) Propane

9) Ethane

10) Butane

11) Methane

Step 1: For the first component in the simplified mixture, one ternary system that contains that component is selected. The priority of selection is as follows:

a) Ternary systems with all three components present in the simplified mixture have priority over systems having one or two components present.

b) The ternary mixture with the highest fitness has priority.

Step 2: Consideration is then given to the second component in the simplified mixture. If this component is not present in the ternary system selected for the first component, then a ternary system is selected for this component using the same priority of selection as in step 1. If, however, the ternary system selected for the first component contains the second component, then the selection proceeds for the third component (step 3).

Step 3: Consideration is then given to third, fourth, fifth, etc. components in the same manner as Steps 1-2.

Step 4: When all components in the simplified mixture have been examined once, steps 1-3 are repeated in the same component order. If any component is represented in only one selected ternary mixture, then an additional ternary mixture is selected, again using the same priority of selection as in step 1.

The selection process ends when all components in the simplified mixture are represented in at least two ternary systems.

In the case of example 1:

— *The first component in the simplified mixture is propane and this is present in four ternary systems that have all their components present in the simplified mixture – A2, A4, A7 and A8. In this case, A4 is selected because it has the largest value of fitness (i.e. 10,3138).*

— *The second component in the simplified mixture is ethane and this is already represented in system A4, so no ternary mixture is selected.*

— *The third component of the simplified mixture, butane, is not represented in system A4, so system selection continues and system A8 is selected because it has the highest value of fitness (10,2859).*

— *The fourth component in the simplified mixture is methane and this is already represented in systems A4 and A8, so no ternary mixture is selected.*

— *Selection is repeated with the first component in the simplified mixture, propane, and ternary system A7 is selected because it has the next highest value of fitness (9,6263; system A4 has already been selected).*

All components in the simplified mixture are now represented in at least two of the ternary systems selected and the selection process ends. The systems selected are therefore: A4, A7 and A8.

A.3.3 Sub-division of the inert-free mixture into the selected partial mixtures

The simplified mixture is divided into the selected partial ternary mixtures. A preliminary division of the simplified mixture is made by assigning each component equally between the ternary systems in which it is represented.

In the case of example 1, three ternary systems – A4, A7 and A8 – are selected. The preliminary division is made by assigning: methane equally between A4, A7 and A8; ethane equally between A4 and A8; propane equally between A4 and A7; and butanes equally between A7 and A8 (Columns 4, 6 and 8).

A.3.4 Calculation of the methane number of the partial mixtures

The methane number of each partial mixture is calculated from the general formula

$$MN_t = \sum_{i=0}^{i=7} \sum_{j=0}^{j=6} \left(a_{i,j} x^i y^j \right)$$

(A.3)

Where x and y are the volume fractions of the first and second components in each partial ternary mixture, expressed as a percentage. In order to calculate the methane number of each partial mixture, therefore, the composition of each is normalized to 100 %.

In the case of example 1 the composition of each partial mixture is calculated by renormalizing to 100 % (Columns 5, 7 and 9).

Table A.2 lists the values of coefficients a_{ij} for the partial ternary systems A1–A18.

In the case of example 1 application of Formula (A.3) for each preliminary composition of partial mixture results in calculated methane numbers of 76,2489, 77,3777 and 71,9706 for A4, A7 and A8 respectively (Columns 5, 7 and 9).

A.3.5 Adjustment of the composition and fraction of the partial mixtures

The composition and fraction (F_t) of each partial mixture is adjusted iteratively by varying the quantity of each component in each partial mixture so as to minimize the difference between the methane numbers of each partial mixture.

The value to be minimised is therefore:

$(MN_{\max} - MN_{\min})$,

where $MN_{\max}$ and $MN_{\min}$ are the maximum and minimum methane numbers for the selected partial mixtures.

In the case of example 1, three ternary partial mixtures are selected and hence there are nine quantities to be determined, however four of these may be obtained by material balance considerations.

$N_{A8, \text{methane}} = N_{\text{methane}} - N_{A4, \text{methane}} - N_{A7, \text{methane}}$

$N_{A8, \text{ethane}} = N_{\text{ethane}} - N_{A4, \text{ethane}}$

$N_{A7, \text{propane}} = N_{\text{propane}} - N_{A4, \text{propane}}$

$N_{A8, \text{butane}} = N_{\text{butane}} - N_{A7, \text{butane}}$

Where $N_{t,comp}$ *is the quantity of the respective component in partial mixture t.*

The composition and fraction of each partial mixture is therefore performed by adjustment of five quantities: the quantities of methane, ethane and propane in A4, and the quantity of methane and butane in A7.

During adjustment the volume fraction of any component in any partial mixture shall be within the range for which the coefficients of Formula (A.3) are valid. Table A.2 lists the ranges of validity.

The problem of adjusting the composition and fraction of each partial mixture is therefore a constrained minimization one and in principal any appropriate numerical procedure may be employed. For the examples described in this Annex, the Solver supplied with Microsoft Excel (using default settings) produces an acceptable solution.

Depending upon the ending criterion of the numerical method employed, slight differences in the value of $(MN_{max} - MN_{min})$ will result in slightly different values of methane number of the simplified mixture. In addition, the use of different starting values for the composition and fraction of each partial mixture will result in slightly different values of methane number of the simplified mixture. These differences are within the uncertainties of this method and it is recommended that the final value of methane number is rounded to zero decimal places before reporting.

In the case of example 1, *the composition and fraction of partial mixtures is provided in Table A.5 (Columns 4 – 9). For clarity, the five adjusted quantities are shown in underlined text.*

A.3.6 Calculation of the methane number of the simplified mixture

The methane number of the simplified mixture is determined from the weighted average of the methane number of the relevant partial ternary mixtures:

$$MN' = \sum_{t=1}^{t=N_{sys}} \left(MN_t \cdot F_t \right) \tag{A.4}$$

Where

MN' is the methane number of the simplified mixture

MN_t is the methane number of partial mixture t

F_t is the fraction of the partial mixture t

N_{sys} is the number of ternary systems selected

In the case of example 1, *this results in a methane number of the simplified mixture of MN' = 74,9018.*

A.3.7 Calculation of the methane number of the gaseous fuel

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 fuel gas:

$$MN = MN' + MN_{inerts} - MN_{methane} \tag{A.5}$$

In the original work of AVL/1/MN_{inerts} is the methane number of a methane-carbon dioxide–nitrogen mixture having the same inerts content as that of the original mixture. However in the amendment of MWM the MN_{inerts} is calculated for a methane-carbon dioxide-nitrogen mixture containing only carbon dioxide and methane. $MN_{methane}$ is calculated for a methane-carbon dioxide-nitrogen mixture containing pure methane and is equal to 100,0003.

The methane number of the methane-carbon dioxide-nitrogen mixture is calculated using Formula (A.3). Table A.2 lists the appropriate coefficients (system A20).

In the case of example 1, the methane-carbon dioxide-nitrogen mixture comprises methane (97,8750 volumes, the sum of the volumes of combustible components in the simplified mixture), nitrogen (1,0400 volumes) and carbon dioxide (1,4600 volumes) (Table A.5, column 10), which is normalized to a nitrogen-free mixture comprising methane (98,5302 % vol/vol) and carbon dioxide (1,4698 % vol/vol) (Table A.5, column 11). Application of Formula (A.3) results in a methane number of $MN_{inerts} = 101,4201$.

Application of Formula (A.5) results in a methane number of the gaseous fuel of

> *74,9018 + 101,4201 – 100,0003 = 76,33217.*

The value of methane number is reported as 76.

A.4 Example 2: enriched biomethane

A.4.1 Simplification of the composition of the gaseous fuel

This example illustrates the calculation for a biomethane derived from anaerobic digestion that has been enriched by addition of propane. The composition is shown in Table A.6.

In the case of example 2 the quantity of butanes

> *= 0,1461 + 0,0292 × 2,3 + 0,0000 × 5,3*

> *= 0,2133 (Column 2)*

The simplified mixture is then re-normalized to 100 % (Column 3).

A.4.2 Calculation of fitness of the ternary systems

Application of Formula (A.1) to example 2 results in the values of W_j shown in Table A.7.

A.4.3 Selection of ternary mixtures

The first component in the simplified mixture is propane and this is present in ternary systems that have all their components present in the simplified mixture – A2, A4, A7 and A8. In this case, A7 is selected because it has the largest value of fitness (10,6652).

The second component in the simplified mixture is ethane and this is not represented in system A7, so system selection continues and system A4 is selected because it has the highest value of fitness (10,6380).

The third and fourth components of the simplified mixture are represented in system A7 (butane and methane) and A4 (methane) so the selection process restarts.

The selection process is repeated with the first component in the simplified mixture (propane), which is already represented in selected systems A4 and A7.

Selection continues with the second component in the simplified mixture (ethane), which is represented in only one selected system (A4), so system A8 is selected because it has the next highest value of fitness (9,0508).

All components of the simplified mixture are represented in at least two systems and so selection ends. The systems selected are therefore: A4, A7 and A8.

A.4.4 Calculation of the methane number

After preliminary division of the simplified mixture the calculation of methane number according to the methods in A.3.3 to A.3.7 the methane number of the gaseous fuel of example 2 is shown in Table A.5. Again, for clarity, the five adjusted quantities are shown in underlined text. The value of methane number obtained (69,0336) is reported as 69.

A.5 Example 3: 2H-gas with hydrogen addition

A.5.1 Simplification of the composition of the gaseous fuel

This example illustrates the calculation for the 2H-gas of composition of example 1 to which hydrogen has been added. The composition is shown in Table A.8.

In the case of example 3 *the quantity of butanes*

= 0,1909 + 0,1727 + (0,0364 + 0,0455) × 2,3 + 0,0545 × 5,3

= 0,8408 (Column 2)

The simplified mixture is then re-normalized to 100 % (Column 3).

A.5.2 Calculation of fitness of the ternary systems

Application of Formula (A.1) to example 3 results in the values of W_j shown in Table A.9.

A.5.3 Selection of ternary mixtures

The first component in the simplified mixture is hydrogen and this is present in ternary systems that have all their components present in the simplified mixture – A1, A5 and A6. In this case, A1 is selected because it has the largest value of fitness (10,5906).

The second component in the simplified mixture is propane and this is not represented in system A1, so system selection continues and system A5 is selected because it has the largest value of fitness (9,9921).

The third component in the simplified mixture is ethane and this is already represented in system A1, so no additional system is selected.

The fourth component in the simplified mixture is butane and this is not represented in the systems already selected. System A6 is selected because it has the largest value of fitness (9,9668).

The fifth component of the simplified mixture (methane) is represented in all three of the systems already selected, so no additional system is required.

Selection is repeated with the first component in the simplified mixture (hydrogen) and this is already represented in systems A1, A5 and A6, so no additional system is required.

Selection is continued with the second component in the simplified mixture (propane) and ternary system A4 is selected because it has the largest value of fitness (9,7749).

The third component in the simplified mixture (ethane) is represented in systems A1 and A4, so no additional system is required.

The fourth component in the simplified mixture (butane) is represented in one system (A6) and so system A8 is selected because it has the next largest value of fitness (7,9495).

All components in the simplified mixture are now represented in at least two of the ternary systems selected and the selection process ends. The systems selected are therefore: A1, A4, A5, A6 and A8.

A.5.4 Calculation of the methane number

In the case of example 3, five ternary partial mixtures are selected and hence there are 15 quantities to be determined, however five of these may be obtained by material balance considerations.

$N_{A8, methane} = N_{methane} - N_{A1, methane} - N_{A4, methane} - N_{A5, methane} - N_{A6, methane}$

$N_{A8, ethane} = N_{ethane} - N_{A1, ethane} - N_{A4, ethane}$

$N_{A5, propane} = N_{propane} - N_{A4, propane}$

$N_{A8, butane} = N_{butane} - N_{A6, butane}$

$N_{A6, hydrogen} = N_{hydrogen} - N_{A5, hydrogen} - N_{A1, hydrogen}$

The composition and fraction of each partial mixture is therefore determined by adjustment of 10 quantities: the quantities of methane, ethane and hydrogen in A1, the quantities of methane, ethane and propane in A4, the quantities of methane and hydrogen in A5 and the quantities of methane and butane in A6.

After preliminary division of the simplified mixture and calculation of methane number according to the methods in A.3.3 to A.3.7 the methane number of the gaseous fuel of example 3 is shown in Table A.8. For clarity, the 10 adjusted quantities are shown in underlined text. The value of methane number obtained (75,695) is reported as 76.

A.5.5 Additional numerical examples

Table A.10 provides the results of calculations for a variety of compositions for additional software validation purposes.

Table A.1 — Worked example of methane number calculation (example 1) – preliminary assignment of partial mixtures

	1	2	3	mix A4		mix A7		mix A8	
				4	5	6	7	8	9
				$N_{A4,i}$	$V_{A4,i}$	$N_{A7,i}$	$V_{A7,i}$	$N_{A8,i}$	$V_{A8,i}$
	% vol/vol		% vol/vol		% vol/vol		% vol/vol		% vol/vol
methane	90,0900	90,0900	92,0460	30,6820	89,7490	30,6820	96,3968	30,6820	90,2818
ethane	5,5400	5,5400	5,6603	2,8301	8,2785			2,8301	8,3277
propane	1,3200	1,3200	1,3487	0,6743	1,9725	0,6743	2,1186		
butanes	0,9250	0,9250	0,9451			0,4725	1,4846	0,4725	1,3905
i-butane	0,2100								
n-butane	0,1900								
i-pentane	0,0400								
n-pentane	0,0500								
hexanes+	0,0600								
nitrogen	1,0400								
carbon dioxide	1,4600								
hydrogen	0,0000								
total	100,0000	97,8750	100,0000	34,1865	100,0000	31,8289	100,0000	33,9847	100,0000
Fraction, F_t					0,3419		0,3183		0,3398
MN_t					76,2489		77,3777		71,9706

Table A.2 — Components, coefficients and their ranges of validity of Formula (A.1) for the ternary partial mixtures

	A1	A2	A3	A4	A5	A6	A7
x:	methane	propane	hydrogen	methane	methane	methane	methane
y:	hydrogen	ethane	propane	ethane	hydrogen	hydrogen	propane
z:	ethane	butane	propylene	propane	propane	butane	butane
a(0, 0)	4,3628190E+01	1,0245130E+01	1,8627940E+01	3,3539090E+01	3,4758040E+01	1,2299020E+01	1,0169140E+01
a(1, 0)	-9,2508870E-02	8,5906610E-02	-1,2035810E-01	-1,0282240E-01	-5,1949050E-01	-7,5182070E-01	4,3666120E-01
a(0, 1)	-1,0488580E-02	1,4982130E-01	1,0871090E-01	2,0683750E-01	5,4737050E-02	-4,5103700E-01	3,8170960E-02
a(2, 0)	1,6449270E-02	7,3843960E-03	1,9298010E-02	2,3981410E-02	4,4054460E-02	5,1433330E-02	-8,7264540E-02
a(1, 1)	-2,5007730E-03	9,5705040E-03	-1,3050630E-03	3,3161370E-03	2,6425310E-02	5,1261470E-02	-7,9478640E-03
a(0, 2)	-4,3202740E-03	5,1369710E-03	1,7985000E-03	-3,5536890E-03	-1,0567810E-02	1,7866300E-02	1,0365010E-02
a(3, 0)	-3,1191690E-04	-1,0036620E-04	-1,3018080E-03	-9,5847460E-04	-8,7433290E-04	-1,0241590E-03	5,9397950E-03
a(2, 1)	-6,0486960E-05	-2,0203270E-04	2,9904470E-05	-2,4096040E-04	-1,0846450E-03	-1,6406520E-03	3,2678860E-04
a(1, 2)	-5,3528010E-05	-4,5802770E-05	8,5613760E-05	3,9418400E-05	-3,5553270E-04	-1,0022400E-03	2,3714910E-04
a(0, 3)	6,8507420E-05	-5,6856150E-05	-2,5836670E-05	5,0018560E-05	2,2897690E-04	-1,4279120E-04	-1,6152150E-04
a(4, 0)	2,1223340E-06	4,1273050E-07	4,1692950E-05	2,0052880E-05	5,4767420E-06	6,6995630E-06	-1,8541270E-04
a(3, 1)	2,1993700E-06	1,2511380E-06	2,0011240E-07	3,4585100E-06	1,1309800E-05	1,5561210E-05	-3,3085860E-07
a(2, 2)	1,2109690E-06	3,1147030E-07	-6,8546460E-07	8,0364540E-07	7,9874880E-06	1,5763060E-05	-4,9758630E-06
a(1, 3)	2,9706580E-07	-3,1401570E-07	-6,2626130E-07	-4,3338760E-07	7,4860850E-07	5,2498880E-06	-8,7822910E-07
a(0, 4)	-6,7138020E-07	2,4039480E-07	1,1987890E-07	-2,5042560E-07	-1,6340240E-06	0,0000000E+00	7,7408400E-07
a(5, 0)	0,0000000E+00	0,0000000E+00	-6,9526380E-07	-2,1154170E-07	0,0000000E+00	0,0000000E+00	2,9565980E-06
a(6, 0)	0,0000000E+00	0,0000000E+00	5,7989840E-09	9,0540200E-10	0,0000000E+00	0,0000000E+00	-2,3370740E-08
a(7, 0)	0,0000000E+00	0,0000000E+00	-1,9133740E-11	0,0000000E+00	0,0000000E+00	0,0000000E+00	7,3223480E-11
a(0, 5)	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00
a(0, 6)	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00
x(max), % vol/vol	100,0	100,0	100,0	100,0	100,0	100,0	100,0
x(min), % vol/vol	0,0	0,0	0,0	0,0	0,0	0,0	0,0
y(max), % vol/vol	100,0	100,0	100,0	100,0	100,0	100,0	100,0
y(min), % vol/vol	0,0	0,0	0,0	0,0	0,0	0,0	0,0
z(max), % vol/vol	100,0	100,0	100,0	100,0	100,0	100,0	100,0
z(min), % vol/vol	0,0	0,0	0,0	0,0	0,0	0,0	0,0

Table A.2 *(continued)*

	A8	A9	A10	A11	A12	A13	A14
x:	methane	methane	methane	methane	methane	ethane	carbon monoxide
y:	ethane	ethylene	hydrogen sulphide	ethane	propylene	propylene	hydrogen
z:	butane	butane	butane	hydrogen sulphide			
$a(0,0)$	1,0777610E+01	−1,2408570E+05	1,8388506E+05	−1,1788466E+05	5,9095515E+01	3,1550700E+01	0,0000000E+00
$a(1,0)$	1,6474900E-01	1,1938458E+04	−1,5396773E+04	1,1251043E+04	1,0602705E-01	7,9749400E-02	1,5000000E+00
$a(0,1)$	−1,4050070E-01	−1,9962282E+02	−1,4160386E+01	−2,6712519E+02	−3,4069240E+00	−1,7706875E-01	0,0000000E+00
$a(2,0)$	−5,1987300E-02	−4,8574811E+02	5,4158924E+02	−4,5492745E+02	−3,1884830E-03	4,8659675E-04	−7,5000000E-03
$a(1,1)$	−7,0448690E-03	7,8748002E+00	5,6775484E-01	1,0645736E+01	0,0000000E+00	0,0000000E+00	−7,5000000E-03
$a(0,2)$	1,6154370E-02	2,5929804E+00	1,1942148E+00	3,6669421E+00	1,5370325E-01	4,8659675E-04	0,0000000E+00
$a(3,0)$	3,9913150E-03	1,0855881E+01	−1,0358971E+01	1,0120505E+01	−1,0801210E-04	0,0000000E+00	0,0000000E+00
$a(2,1)$	1,4794820E-04	−1,0266703E-01	−7,7071033E-03	−1,3986048E-01	0,0000000E+00	0,0000000E+00	0,0000000E+00
$a(1,2)$	3,3848030E-04	−6,9109752E-02	−2,4873835E-02	−9,7497566E-02	0,0000000E+00	0,0000000E+00	0,0000000E+00
$a(0,3)$	−1,7546700E-04	−1,4504600E-02	−3,1209902E-02	−2,4662769E-02	−3,6748700E-03	0,0000000E+00	0,0000000E+00
$a(4,0)$	−1,2774870E-04	−1,4417120E-01	1,1603083E-01	−1,3401172E-01	8,4599300E-06	0,0000000E+00	0,0000000E+00
$a(3,1)$	2,7564440E-06	4,4431373E-04	3,3083382E-05	6,0764355E-04	0,0000000E+00	0,0000000E+00	0,0000000E+00
$a(2,2)$	−4,0416670E-06	4,5679208E-04	1,7311782E-04	6,4613035E-04	0,0000000E+00	0,0000000E+00	0,0000000E+00
$a(1,3)$	−1,9710210E-06	1,9871610E-04	4,1754490E-06	3,1927693E-04	0,0000000E+00	0,0000000E+00	0,0000000E+00
$a(0,4)$	6,0752130E-07	2,6937182E-05	1,5364226E-03	7,6292913E-05	4,6273625E-05	0,0000000E+00	0,0000000E+00
$a(5,0)$	2,0157030E-06	1,1395330E-03	−7,5743018E-04	1,0579750E-03	−1,3928745E-07	0,0000000E+00	0,0000000E+00
$a(6,0)$	−1,5580170E-08	−4,9703336E-06	2,6462473E-06	−4,6175613E-06	7,1638300E-10	0,0000000E+00	0,0000000E+00
$a(7,0)$	4,7976930E-11	9,2406348E-09	−3,7606039E-09	8,6063163E-09	0,0000000E+00	0,0000000E+00	0,0000000E+00
$a(0,5)$	0,0000000E+00	0,0000000E+00	−3,5650030E-05	0,0000000E+00	−2,9054230E-07	0,0000000E+00	0,0000000E+00
$a(0,6)$	0,0000000E+00	0,0000000E+00	3,0668448E-07	0,0000000E+00	7,1638300E-10	0,0000000E+00	0,0000000E+00
x(max), % vol/vol	100,0	100,0	100,0	100,0	100,0	100,0	100,0
x(min), % vol/vol	0,0	75,0	75,0	75,0	0,0	0,0	0,0
y(max), % vol/vol	100,0	25,0	25,0	25,0	100,0	100,0	100,0
y(min), % vol/vol	0,0	0,0	0,0	0,0	0,0	0,0	0,0
z(max), % vol/vol	100,0	25,0	25,0	25,0			
z(min), % vol/vol	0,0	0,0	0,0	0,0			

Table A.2 *(continued)*

	A15	A16	A17	A18	A20
x:	ethane	propane	butadiene	butylene	methane
y:	ethylene	ethylene			carbon dioxide
z:					nitrogen
$a(0,0)$	2,9655595E+01	2,4494755E+01	1,2000000E+01	2,0000000E+01	2,9917430E+02
$a(1,0)$	1,7064685E-01	1,3676575E-01	0,0000000E+00	0,0000000E+00	-1,5119580E+01
$a(0,1)$	-1,2344405E-01	-5,4597900E-02	0,0000000E+00	0,0000000E+00	-3,1156360E-01
$a(2,0)$	-2,3601400E-04	-4,1083915E-04	0,0000000E+00	0,0000000E+00	7,6359480E-01
$a(1,1)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	4,5480690E-02
$a(0,2)$	-2,3601400E-04	-4,1083915E-04	0,0000000E+00	0,0000000E+00	1,1230410E-02
$a(3,0)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	-2,3762630E-02
$a(2,1)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	-7,8562940E-04
$a(1,2)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	6,5557090E-04
$a(0,3)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	-2,1468550E-03
$a(4,0)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	4,3554940E-04
$a(3,1)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	3,8606680E-06
$a(2,2)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	1,3816990E-06
$a(1,3)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	-7,9339020E-06
$a(0,4)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	6,6993640E-05
$a(5,0)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	-4,6077260E-06
$a(6,0)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	2,6105700E-08
$a(7,0)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	-6,1439140E-11
$a(0,5)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	-8,3693870E-07
$a(0,6)$	0,0000000E+00	0,0000000E+00	0,0000000E+00	0,0000000E+00	3,9280730E-09
$x(max)$, % vol/vol	100,0	100,0	100,0	100,0	100,0
$x(min)$, % vol/vol	0,0	0,0	100,0	100,0	50,0
$y(max)$, % vol/vol	100,0	100,0			30,0
$y(min)$, % vol/vol	0,0	0,0			0,0
$z(max)$, % vol/vol					50,0
$z(min)$, % vol/vol					0,0

Table A.3 — Calculation of Vsum$_i$

System	min(100,(Vmax$_{ij}$ + 15)) CO	Butadiene	Butylene	Ethylene	Propylene	H$_2$S	Hydrogen	Propane	Ethane	Butane	Methane
1	0	0	0	0	0	0	100	0	100	0	100
2	0	0	0	0	0	0	0	100	100	100	0
3	0	0	0	0	100	0	100	100	0	0	0
4	0	0	0	0	0	0	0	100	100	0	100
5	0	0	0	0	0	0	100	100	0	0	100
6	0	0	0	0	0	0	100	0	0	100	100
7	0	0	0	0	0	0	0	100	0	100	100
8	0	0	0	0	0	0	0	0	100	100	100
9	0	0	0	40	0	0	0	0	0	40	100
10	0	0	0	0	0	40	0	0	0	40	100
11	0	0	0	0	0	40	0	0	40	0	100
12	0	0	0	0	100	0	0	0	0	0	100
13	0	0	0	0	100	0	0	0	100	0	0
14	100	0	0	0	0	0	100	0	0	0	0
15	0	0	0	100	0	0	0	0	100	0	0
16	0	0	0	100	0	0	0	100	0	0	0
17	0	100	0	0	0	0	0	0	0	0	0
18	0	0	100	0	0	0	0	0	0	0	0
Vsum$_i$:	100	100	100	240	300	80	500	600	640	480	1000

Table A.4 — Calculation of fitness, W_j (example 1)

	CO	Butadiene	Butylene	Ethylene	Propylene	H$_2$S	Hydrogen	Propane	Ethane	Butane	Methane	
V_i	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	1,3487	5,6603	0,9451	92,0460	

$$\frac{V_i \cdot Vmax_{i,j}}{Vsum_i}$$

System	CO	Butadiene	Butylene	Ethylene	Propylene	H$_2$S	Hydrogen	Propane	Ethane	Butane	Methane	W_j
1	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,8844	0,0000	9,2046	10,0890
2	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,2248	0,8844	0,1969	0,0000	1,3061
3	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,2248	0,0000	0,0000	0,0000	0,2248
4	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,2248	0,8844	0,0000	9,2046	10,3138
5	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,2248	0,0000	0,0000	9,2046	9,4294
6	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,1969	9,2046	9,4015
7	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,2248	0,0000	0,1969	9,2046	9,6263
8	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,8844	0,1969	9,2046	10,2859
9	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0788	9,2046	9,2834
10	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0788	9,2046	9,2834
11	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,3538	0,0000	9,2046	9,5584
12	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	9,2046	9,2046
13	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,8844	0,0000	0,0000	0,8844
14	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
15	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,8844	0,0000	0,0000	0,8844
16	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,2248	0,0000	0,0000	0,0000	0,2248
17	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
18	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000

Table A.5 — Worked example of methane number calculation (composition 1) – final calculation

	1	2	3	4	5	6	7	8	9	10	11
				mix A4		mix A7		mix A8		mix A20	
				$N_{A4,i}$	$V_{A4,i}$	$N_{A7,i}$	$V_{A7,i}$	$N_{A8,i}$	$V_{A8,i}$	$N_{A20,i}$	$V_{A20,i}$
	% vol/vol		% vol/vol		% vol/vol		% vol/vol		% vol/vol		% vol/vol
methane	90,0900	90,0900	92,0460	27,9390	88,7108	27,3417	95,8205	36,7653	91,9793	97,8750	98,5302
ethane	5,5400	5,5400	5,6603	2,9012	9,2119			2,7590	6,9025		
propane	1,3200	1,3200	1,3487	0,6542	2,0773	0,6944	2,4337				
butanes	0,9250	0,9250	0,9451			0,4982	1,7458	0,4469	1,1181		
i-butane	0,2100										
n-butane	0,1900										
i-pentane	0,0400										
n-pentane	0,0500										
hexanes+	0,0600										
nitrogen	1,0400									1,0400	0,0000
carbon dioxide	1,4600									1,4600	1,4698
hydrogen	0,0000	0,0000	0,0000								
total	100,0000	97,8750	100,0000	31,4944	100,0000	28,5343	100,0000	39,9713	100,0000	100,3750	100,0000
Fraction, F_t					0,3149		0,2853		0,3997		
MN_t					74,9017		74,9019		74,9019		101,4201

ΔMN	0,000262
MN'	74,9018
MN	76,3217

Table A.6 — Worked example of methane number calculation (example 2) – final calculation

	1	2	3	4	5	6	7	8	9	10	11
				mix A4		mix A7		mix A8		mix A20	
	% vol/vol		% vol/vol	$N_{A4,i}$	$V_{A4,i}$ % vol/vol	$N_{A7,i}$	$V_{A7,i}$ % vol/vol	$N_{A8,i}$	$V_{A8,i}$ % vol/vol	$N_{A20,i}$	$V_{A20,i}$ % vol/vol
methane	86,6475	86,6475	89,8575	41,1188	88,8181	46,3797	90,6616	2,3590	92,5995	96,4277	96,3911
ethane	0,1169	0,1169	0,1212	0,0585	0,1263			0,0628	2,4632		
propane	9,4500	9,4500	9,8001	5,1182	11,0556	4,6819	9,1520				
butanes		0,2133	0,2212			0,0954	0,1864	0,1258	4,9373		
i-butane	0,0000										
n-butane	0,1461										
i-pentane	0,0000										
n-pentane	0,0292										
hexanes+	0,0000										
nitrogen	0,0000	0,0000								0,0000	0,0000
carbon dioxide	3,6103									3,6103	3,6089
hydrogen	0,0000	0,0000	0,0000								
total	100,0000	96,4277	100,0000	46,2955	100,0000	51,1569	100,0000	2,5476	100,0000	100,0380	100,0000
Fraction, F_t					0,4630		0,5116		0,0255		
MN_t					65,3039		65,3059		65,3039		103,7290

ΔMN 0,002016

MN' 65,3049

MN 69,0336

Table A.7 — Calculation of fitness, W_j (example 2)

	CO	Butadiene	Butylene	Ethylene	Propylene	H$_2$S	Hydrogen	Propane	Ethane	Butane	Methane	
V_i	0,0000	0,000	0,0000	0,0000	0,0000	0,0000	0,0000	9,8001	0,1212	0,2212	89,8575	

$$\frac{V_i \cdot Vmax_{i,j}}{Vsum_i}$$

System	CO	Butadiene	Butylene	Ethylene	Propylene	H$_2$S	Hydrogen	Propane	Ethane	Butane	Methane	W_j
1	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0189	0,0000	8,9858	9,0047
2	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	1,6333	0,0189	0,0461	0,0000	1,6984
3	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	1,6333	0,0000	0,0000	0,0000	1,6333
4	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	1,6333	0,0189	0,0000	8,9858	10,6380
5	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	1,6333	0,0000	0,0000	8,9858	10,6191
6	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0461	8,9858	9,0318
7	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	1,6333	0,0000	0,0461	8,9858	10,6652
8	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0189	0,0461	8,9858	9,0508
9	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0184	8,9858	9,0042
10	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0184	8,9858	9,0042
11	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0076	0,0000	8,9858	8,9933
12	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	8,9858	8,9858
13	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0189	0,0000	0,0000	0,0189
14	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
15	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0189	0,0000	0,0000	0,0189
16	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	1,6333	0,0000	0,0000	0,0000	1,6333
17	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
18	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000

Table A.8 — Worked example of methane number calculation (example 3) – final calculation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
				mix A1		mix A4		mix A5		mix A6		mixA8		mix A20	
	% vol/vol		% vol/vol	$N_{A1,i}$	$V_{A1,i}$ % vol/vol	$N_{A4,i}$	$V_{A4,i}$ % vol/vol	$N_{A5,i}$	$V_{A5,i}$ % vol/vol	$N_{A6,i}$	$V_{A6,i}$ % vol/vol	$N_{A8,i}$	$V_{A8,i}$ % vol/vol	N_{A20i}	$V_{A20,i}$ % vol/vol
methane	85,991	85,991	87,685	14,001	80,221	16,424	88,778	14,270	84,092	15,601	89,710	27,389	92,258	98,068	98,665
ethane	5,036	5,036	5,136	1,667	9,549	1,599	8,645					1,870	6,298		
propane	1,200	1,200	1,224			0,477	2,577	0,747	4,402						
butanes	0,841	0,841	0,857							0,429	2,465	0,429	1,444		
i-butane	0,191														
n-butane	0,173														
i-pentane	0,036														
n-pentane	0,046														
hexanes+	0,055														
nitrogen	0,946													0,946	0,000
carbon dioxide	1,327													1,327	1,335
hydrogen	5,000	5,000	5,099	1,785	10,229			1,952	11,506	1,361	7,824				
total	100,000	98,068	100,000	17,453	100,000	18,500	100,000	16,969	100,000	17,391	100,000	29,687	100,000	100,341	100,000
Fraction, F_t					0,175		0,185		0,170		0,174		0,297		
MN_t					74,411		74,411		74,411		74,411		74,411		101,284

ΔMN	0,00012
MN'	74,411
MN	75,695

Table A.9 — Calculation of fitness, W_j (example 3)

	CO	Butadiene	Butylene	Ethylene	Propylene	H$_2$S	Hydrogen	Propane	Ethane	Butane	Methane	
V_i	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	5,0985	1,2236	5,1356	0,8574	87,6849	

$$\frac{V_i \cdot Vmax_{i,j}}{Vsum_i}$$

System	CO	Butadiene	Butylene	Ethylene	Propylene	H$_2$S	Hydrogen	Propane	Ethane	Butane	Methane	W_j
1	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	1,0197	0,0000	0,8024	0,0000	8,7685	10,5906
2	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,2039	0,8024	0,1786	0,0000	1,1850
3	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	1,0197	0,2039	0,0000	0,0000	0,0000	1,2236
4	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,2039	0,8024	0,0000	8,7685	9,7749
5	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	1,0197	0,2039	0,0000	0,0000	8,7685	9,9921
6	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	1,0197	0,0000	0,0000	0,1786	8,7685	9,9668
7	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,2039	0,0000	0,1786	8,7685	9,1510
8	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,8024	0,1786	8,7685	9,7495
9	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0714	8,7685	8,8399
10	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0714	8,7685	8,8399
11	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,3210	0,0000	8,7685	9,0895
12	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	8,7685	8,7685
13	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,8024	0,0000	0,0000	0,8024
14	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	1,0197	0,0000	0,0000	0,0000	0,0000	1,0197
15	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,8024	0,0000	0,0000	0,8024
16	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,2039	0,0000	0,0000	0,0000	0,2039
17	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
18	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000

Table A.10 — Additional numerical examples for software validation purposes

Component	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6	Mix 7	Mix 8	Mix 9	Mix 10	Mix 11	Mix 12	Mix 13	Mix 14	Mix 15	Mix 16
carbon dioxide		1,00	0,20	2,30	2,00		3,90									
nitrogen	13,00	13,00	0,20	0,80	0,74	3,70	0,40									
oxygen																
hydrogen								70	5	5	65	5	50	5	20	90
carbon monoxide													20			
methane	83,53	82,43	94,68	86,30	87,34	84,62	85,58	15	80	70	10	65	5	75	55	4
ethylene										5	5	5	5			
ethane	3,47	3,00	3,20	8,70	7,00	8,00	5,70	5	5	5	5	5	5	5	5	2
propylene										5	5	5	5			
propane		0,20	1,05	1,60	2,20	1,70	2,10	5	5	5	5	5	5	5	5	2
butylene																
butane		0,27	0,47	0,30	0,41	1,47	0,90	5	5	5	5	5	5	5	5	2
pentane		0,10	0,20		0,11	0,51	0,82									
hexanes+					0,20		0,60									
hydrogen sulphide												5		5	10	
total	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100	100	100	100	100	100	100	100	100
methane number	90,02	85,03	80,00	75,03	70,02	65,00	59,97	21,55	53,20	41,25	19,59	35,01	23,89	44,15	30,45	10,04
Ternary mixtures selected	A1, A4	A4, A7, A8	A4, A7, A8	A4, A7, A8	A4, A7, A8	A4, A7, A8	A4, A7, A8	A1, A3, A5, A6, A8	A1, A5, A6, A7, A8	A1, A6, A7, A8, A9, A12	A1, A3, A6, A7, A12, A15, A16	A6, A7, A8, A9, A10, A11, A12	A1, A2, A3, A6, A13, A14, A15, A16	A5, A6, A7, A8, A10, A11	A1, A5, A6, A7, A10, A11	A1, A3, A5, A6, A8

Annex B
(informative)

Sulfur

B.1 General

Gas contains usually a small amount of sulfur as result of the decay of organic substances. This can come as hydrogen sulphide, carbonyl sulphide, mercaptans, and/or other kind of sulphides, depending on the origin of the gas and of its treatment.

Furthermore, the majority of artificial odorants is based on sulfur organic compounds. These odorants are added to nearly all distribution grids and also to some transmission grids to give gas a smell for the purpose of leak detection.

Usually, high pressure networks contain non-odorized gas. At the time being, nothing prevents existing practices with respect to transmission of odorized gas between high pressure networks to continue.

In some gas storage facilities, higher sulfur contents can lead to serious problems such as increased corrosion rates, degradation of glycol, disposal of produced water and higher sulfur dioxide content in exhaust gases.

B.2 Total sulfur from Odorants

In all European countries, distributed gas is odorised for safety reasons. As most odorants used are sulfur based molecules, odorization increases the amount of sulfur in the gas.

In some countries the addition of odorant is done upstream of the distribution grid. For some European countries, the natural gas odorization practices including odorants concentrations are given in Table B.1, provided by Marcogaz – Technical association of the European natural gas industry.

Table B.1 — Natural Gas odorization practices in Europe – Odorants concentration
(Source: Marcogaz – Technical association of the European natural gas industry, March 2015)

Country	Odorant	Percent consumption	Minimum concentration mg/m³	Maximum concentration mg/m³	Typical concentration mg/m³	Unit[a]: Standard or Normal reference condition mg/m³	Customers receiving non-odorized gas: specify what type of industry is receiving non odorised gas	Odorised gas in Salt cavern	Odorised gas in lined cavern	Odorised gas in aquiferous storage	Odorised gas in depleted field
AT	THT	93	9,0	As required at the end point	12–14	Normal	Industry: glass, ceramics, chemical, power plants	No	No	No	No
	Other odorants	5	–		–						
	Sulfur Free Odorant	2	8,0		10						
BE	THT	–	17	34	20	Normal	Chemical Industry and power plants	No	No	No	No
	TBM+IPM+NPM		5,4	7,1	6						
CH	THT	100 %	10	30	15–30	Normal	some Industry	No	No	No	No
CZ	THT	10	10	30	12	Normal	Chemical Industry	No	No	No	No
	TBM+DMS	89	5	30	10						
	Sulfur Free Odorant	1	8,8	8,8	8,8						
DE	THT	55 – 70 %	10	20	15 – 18	Normal	Industries: glass, ceramics, chemical	No	No	No	No
	Other odorants mixtures	2 %	Not specified	-	-						
	THT + EA		8	-	11 - 15						
	Sulfur Free Odorant	25 %	8,8	16	11 - 15						
DK	THT	100 %	10,5 (at consumer location)	Not specified	11–17	Normal	Not allowed in Denmark. All gas is odorized	No	No	No	No
EL	THT	100 %	15	35	20	Normal					

Country	Odorant	Percent consumption	Minimum concentration mg/m³	Maximum concentration mg/m³	Typical concentration mg/m³	Unit[a]: Standard or Normal reference condition mg/m³	Customers receiving non-odorized gas: specify what type of industry is receiving non odorised gas	Odorised gas in Salt cavern	Odorised gas in lined cavern	Odorised gas in aquiferous storage	Odorised gas in depleted field
ES	THT	100 %	15-trans. 18-dist.	-	22	Normal	No	None	None	Yes	Yes
FR	THT	100 %	15	40	25	Normal	None	Yes	None in France	Yes	Yes
HU	THT + TBM	100 %	13	25	16		Every customer receives odorized gas	(16)	No	No	No
IE	TBM+DMS	100 %	3	10	6	Standard	Every customer receives odorized gas	None	None	None	Yes
IT	THT	50 %	32	-	-	Standard	Industry	No	No	No	Yes
	TBM+IPM+NPM	50 %	8								
NL	THT	100 %	10	36	18	Normal	Industry Power plant Dedicated Pipe	No	No	No	No
NO	THT	100 %	12	15	-		Industry				
PL	THT	100 %	Not specified	Not specified	25	Standard	Industry				
PT	THT	100 %	8	40	24	Normal	Combined Cycle Power Plants	Yes	No	No	No
RO	EM	100 %	3	30	8		Some Industry	No	No	No	No
SK	THT	99 %	8 mg/Nm³	40	18	Normal	Chemical industry and some technological customers	No	No	No	No
	THT + TBM	1 %	2,1 mg/Nm³	15	7						

Country	Odorant	Percent consump-tion	Minimum concen-tration mg/m³	Maximum concen-tration mg/m³	Typical concentration mg/m³	Unit^a: Standard or Normal reference condition mg/m³	Customers receiving non-odorized gas: specify what type of industry is receiving non odorized gas	Odorised gas in Salt cavern	Odorised gas in lined cavern	Odorised gas in aquifer-ous storage	Odorised gas in depleted field
TR					no information available						
UK	TBM+DMS	100 %	5	8	6	Standard	Any before injection	Yes	No	No	No

a   The unit can be expressed in reference to normal or standard conditions: the difference is related to the temperature to which the volume is expressed. (see EN ISO 13443)

NOTE   The information and data included in Table B.1 have been compiled by MARCOGAZ from a variety of sources from its Members. MARCOGAZ will not accept any liability for the data accuracy and completeness.

Annex C

(informative)

Water dew point and hydrocarbon dew point

C.1 Water dew point

Technically, the water dew point can be measured by using cooled surface condensation hygrometers. For details about the measurement method see EN ISO 6327.

The water content is the mass concentration of the total amount of water contained in a gas. The water content is expressed in milligrams per cubic metre. Technically, the water content can be measured by using Karl Fischer method see ISO 10101-3.

The correlation between water content and water dew point is given in EN ISO 18453.

There are several industrial metering instruments available on the market measuring the water content of the gas and calculating the water dew point at defined pressure.

The working principle of these instruments is different from Karl Fisher method (optical, electrolytic, capacitance, piezoelectric, etc.) and the calculation of the water dew point from the water content might be different from the EN ISO 18453 method.

To achieve unified measurement results from the different measurement methods it is recommended to calibrate the metering instruments traceable to national/international calibration standards.

C.2 Hydrocarbon dew point

Hydrocarbon dew point shall be measured directly (e.g. using instruments according to ISO/TR 12148) or calculated from a detailed composition in accordance with the guidance provided in ISO 23874.

It should be noted that the relationship between the hydrocarbon dew point and the potential hydrocarbon liquid condensate is less straightforward than the relationship between the water dew point and the water content.

Since the chilled mirror type instruments used for monitoring the hydrocarbon dew point need a minimum amount of condensate liquid to be formed on the mirror for detection occurs, the measured hydrocarbon dew point is equivalent to a temperature where the necessary amount of liquid is formed for the detection. For this reason it is not possible to measure the true hydrocarbon dew point for most real gases. The required amount of liquid condensate to trigger the trip value of the chilled mirror type instruments affects the measured hydrocarbon dew point for the same gas composition.

The calibration of cooled surface condensation type instruments according ISO/TR 12148 is recommended.

Annex D
(informative)

Background for not including a Wobbe Index range into this standard

D.1 General

D.1.1 Introduction

One of the objectives of this standard was to define a common CEN Wobbe index range

— that would have the presumption "to enhance the free flow of gas within the internal EU market, in order to promote competition and security of supply minimizing negative effects on gas infrastructure and gas networks, efficiency and the environment and allow the maximum number of appliances to be used without compromising safety" in accordance with M/400 (Art. 2. Description of the mandated work) and

— that would have the support of the CEN members to progress to publication.

After many controversial discussions and manifold approaches, the CEN/TC 234 and the involved stakeholders/partner organisations concluded that the definition of a commonly accepted European Wobbe index range is not possible at the moment and that further analyses are required prior to setting minimum and/or maximum values. The EU Commission DG ENERGY monitored the discussions and formally accepted the CEN/TC 234 conclusion.

This annex aims at explaining to the user of the standard the main issues which resulted in the given conclusion.

D.1.2 Regional differences in gas composition

Due to the different gas supply portfolios and gas system configurations, the H-gases that are delivered to end users do not have the same composition and variations in their composition in all regions of the CEN member countries. Some regions are used to H-gases with a higher Wobbe index, whereas other regions are used to H-gases with a lower Wobbe index. Furthermore due to the different situations, some regions in Europe are used to a relatively narrow Wobbe index bandwidth, while in other regions the actual distributed gases have a relatively wide Wobbe index bandwidth.

D.1.3 Regional differences in installation and service practices

As far as gas applications – domestic, commercial and industrial – are concerned, the practices of putting into service, the setting, and the maintenance and inspection routines of the gas applications differ within the CEN member countries.

— For some countries, regions and/or gas applications it is common practice to adjust the settings of the gas application using the distributed gas that is available at the moment of installation or putting into service. The installation and maintenance instructions given by the manufacturer specify how the gas application is to be set.

— For some countries, regions and/or gas applications it is common practice to adjust the setting of the gas application for a specific Wobbe index that represents the average gas composition of the bandwidth of the regionally distributed gases. The installation and maintenance instructions given by the manufacturer specify how the setting is to be adjusted for a specific Wobbe index, for

example by adoption of the burner pressure, installation of a Wobbe specific restriction or measurement of carbon monoxide, carbon dioxide or dioxygen in the flue gases

— For some countries, regions and/or gas applications it is common practice to use on the gas application a factory pre-setting for a specific Wobbe index that is not to be modified in the field. If the setting of the gas application has drifted due to wear and tear, the maintenance instructions specify that components are replaced by new – factory preset – components.

— In some countries periodical inspection of some gas applications by a qualified third party is required by law, however, in other countries this is not a requirement.

Applications that are set for a specific Wobbe index are -in theory- able to deal with a wider Wobbe index bandwidth than applications that are set using the currently distributed gas. This suggests that harmonizing the installation and service practices would support defining a common European Wobbe index range.

The experience feedback shows that all the practices described above have resulted in an acceptable safety and reliability with the normal variations of gas composition that occur in the region where the gas application is installed and put into service. In each region there is sufficient evidence that a gas application can operate within expectations when it is installed, set, maintained and inspected according to regional practices, using gases of the regional bandwidth of gas compositions.

However, there is a lack of knowledge on the impact of expanding the regional bandwidth on the safety and reliability of gas applications that are already in service, in particular old or retrofitted ones. Before defining a common European Wobbe index range, it should be clear to what extent the current regional bandwidth can be modified and what measures and related costs are necessary to mitigate the impact of a modification of the Wobbe index bandwidth.

Phase 1 of mandate M/400, the GASQUAL project aimed at evaluating the impact of gas quality variations on domestic GAD compliant appliances. The study showed that most of the investigated appliances that are set for G20 while using G20 for the setting [50,72 MJ/m^3; 15/15 °C; 101,325 kPa], see EN 437) are able to cope with gas variations within the range investigated. However a number of applications are sensitive to the highest range of Wobbe index tested. Applications that are set using the currently distributed gas support a narrower Wobbe index bandwidth than appliances set for the G20 Wobbe index. Moreover, adjustable applications may cause problems due to adjustment tolerances and potential maladjustments. The GASQUAL project shows that not only gas quality but the simultaneous variations of Wobbe index, gas pressure and mains voltage is the issue. This means that there are, for some gas applications, technical solutions to reduce the impact of gas quality variation in the future (gas pressure regulators, lambda control, no adjustments) but those measures have a cost and/or take time to implement.

However it should also be noted that the GASQUAL project was performed using new appliances, for a relative short time period, without any wear or tear, at laboratory conditions where the temperature and humidity of the combustion of air and gas is relatively stable compared to the variations in temperature and humidity that is to be expected in the field.

As the GASQUAL project was focusing on the domestic appliances compliant with the Gas Appliance Directive (2009/142/EC); mostly new appliances were tested at laboratory conditions, pilot studies are now being carried out in some CEN member countries to better understand the impact of harmonizing the Wobbe index bandwidth on pre-GAD, post-GAD and non-GAD applications. These studies intend to identify acceptable Wobbe index bandwidth for domestic, commercial and industrial applications, including safety and cost aspects.

D.2 A common European Wobbe index range

The difficulty for establishing a common European Wobbe index range in this EN standard at this moment is that:

— No acceptance for a common European Wobbe index range is found.

— All discussed ranges would require that in some regions specific measures would have to be taken in order:

— to modify or restrict the available gas portfolio to comply with the common European Wobbe index range or

— to modify or restrict the installed applications to ensure a safe and reliable use with a common European Wobbe index range.

These measures would result in (regional) costs, while there is no short-term (regional) benefit identifiable. The benefits of the implementation of the standard are mostly on a CEN level and long term which is also making it difficult for the different stakeholders to move forward.

— For the safety and reliability of applications it is not the (regional) level of Wobbe index but the variation of the Wobbe index at the users' location that is decisive. General recognized statements on all applications in accordance with operative installation and service practices, are not possible at this stage, as no extensive and traceable feedback of the impact of variations on installed applications is available. While some regions are used to variations of the Wobbe index, others have experienced distributed gases with a quite stable Wobbe index in the past. A too wide common European Wobbe index bandwidth would reduce the number of applications that can cope with that gas safely and reliably if no curative action is implemented.

— A too narrow common European Wobbe index range would exclude a part of the current LNG supplies and also a part of the potential sources to be imported into Europe. In the same way, some biomethane injection, already a reality in some CEN member countries, some Power-to-Gas projects and some low Wobbe H gas fields that are in production today for regional use, would also be impacted by a too narrow common European Wobbe index range. Treatment of some of the aforementioned gases prior to entry into the European grid would be necessary and add costs. A too narrow common European Wobbe index range would therefore imply a reduction in the diversification and flexibility of European supplies, impacting the security of supply in case of natural gas shortage from current sources if no curative action is implemented.

Annex E
(informative)

Hydrogen - Admissible Concentrations in natural gas systems

There are proposals to inject hydrogen (H_2) from renewable sources in the natural gas network. This measure would allow the very large transport and storage capacities of the existing infrastructure, particularly underground storage facilities and high-pressure pipelines, to be used for indirect electricity transport and storage.

The results of the GERG study "Admissible Hydrogen Concentrations in Natural Gas Systems" (see Bibliography) show that an admixture of up to 10 % by volume of hydrogen to natural gas is possible in some parts of the natural gas system. However there are still some important areas where issues remain (GERG is the European Gas Research Group, Brussels):

— underground porous rock storage: hydrogen is a good substrate for sulfate-reducing and sulfur-reducing bacteria. As a result, there are risks associated with: bacterial growth in underground gas storage facilities leading to the formation of dihydrogensulfide; the consumption of hydrogen, and the plugging of reservoir rock. A limit value for the maximum acceptable hydrogen concentration in natural gas cannot be defined at the moment. (hydrogen-related aspects concerning wells have not been part of this project);

— steel tanks in natural gas vehicles: specification UN ECE R 110 stipulates a limit value for hydrogen of 2 vol%;

— gas turbines: most of the currently installed gas turbines were specified for a hydrogen fraction in natural gas of 1 vol% or even lower. 5 vol % may be attainable with minor modification or tuning measures. Some new or upgraded types will be able to cope with concentrations up to 15 vol%;

— gas engines: it is recommended to restrict the hydrogen concentration to 2 vol%. Higher concentrations up to 10 vol% may be possible for dedicated gas engines with sophisticated control systems if the methane number of the natural gas/hydrogen mixture is well above the specified minimum value;

— many process gas chromatographs will not be capable of analysing hydrogen.

Investigations have been conducted to evaluate the impact of hydrogen as related to the above topics. At present it is not possible to specify a limiting hydrogen value which would generally be valid for all parts of the European gas infrastructure and, as a consequence, it is recommended a case by case analysis.

Annex F
(informative)

Sampling

Determination of parameters in Table 1 is based on representative samples of gas. Guidance is provided by EN ISO 10715.

Annex G
(informative)

A–deviations

A- deviation: National deviation due to regulations, the alteration of which is for the time being outside the competence of the CEN/ CENELEC member:

This European Standard does not fall under any Directive of the EU.

In the relevant CEN/ CENELEC countries these A- deviations are valid instead of the provisions of the European Standard until they have been removed.

Germany:

Clause	Deviation
5, Table 1 Sulfur	According to The German ordinance on the quality of automotive fuels "Zehnte Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes" (Kurztitel Verordnung über die Beschaffenheit und die Auszeichnung der Qualitäten von Kraft- und Brennstoffen) The legal limits of Gas Group H for sulfur in natural gas (and in biomethane) used as automotive fuel are significantly lower as specified in EN 16726:2015, therefore this European Standard in conflict with German legislation.

In the following, the relevant parameters and limit values are taken from the regulation in comparison with values defined in EN 16726:2015:

Parameter	EN 16726:2015	German legislation
total sulfur, as sulfur,	max. 20 mg/m^3 (without odorisation)	max. 10 mg/kg = approx. 8 mg/m^3 (including odorisation) for automotive fuel, in natural gas (and in biomethane)

Hungary:

Clause	Deviation
5, Table 1 different parameters, see below:	Government Decree No 19/2009 (I.30.) on the implementation of the Act on Natural Gas Supply (Act XL of 2008): The legal limits of Natural gas H parameters are in conflict with article 66/A (1) of Government Decree No 19/2009 (I.30.) on the implementation of the Act on Natural Gas Supply (Act XL of 2008). Article 66/A (1) states "Natural gas producers shall not inject into a transmission or distribution line natural gas the quality of which does not comply with Annex 11, including the parameters indicated below..

In the following, the relevant parameters and limit values are taken from the regulation in comparison with values defined in EN 16726:2015:		
Parameter	EN 16726:2015	**Hungarian legislation**
Relative density (no unit)	0,555–0,700	directly not limited, but limited indirectly by the Wobbe Index
Hydrogen sulphide (mg/m^3)	5,0	20,0
Oxygen (mol%)	0,001	0,2
Water dew point	−8 °C at 70 bar(a)	maximum 0,17 g/m^3
Hydrocarbon dew point	−2 °C at 1–70 bar	4 °C at 4 MPa
Carbon dioxide (mol %)	2,5	directly not limited, but limited indirectly by the Wobbe Index
	The legal limits of Natural gas H parameters are in conflict with article 66/A (1) of Government Decree No 19/2009 (I.30.) on the implementation of the Act on Natural Gas Supply (Act XL of 2008).	In this regulation it is confirmed that the natural gas H parameters are allowed till the given limits.

The Netherlands

Clause	Deviation
5, Table 1 different parameters, see below:	The Gas Act (Gaswet) specifies the requirements for economic operators active in the Dutch territories involved in the injection, transportation, distribution, storage and trading of gas. Staatsblad van het Koninkrijk de Nederlanden, *Wet van 22 juni 2000, houdende regels omtrent het transport en de levering van gas (Gaswet)* (Stb 305) Staatsblad van het Koninkrijk de Nederlanden, *Wet van 18 december 2013 tot wijziging van de Elektriciteitswet 1998, de Gaswet en de Warmtewet (wijzigingen samenhangend met het energierapport 2011) (Stb 573)* Staatsblad van het Koninkrijk de Nederlanden, *Besluit van 18 december 2013, houdende vaststelling van het tijdstip van inwerkingtreding van de wet van 18 december 2013, tot Wijziging van de Elektriciteitswet 1998, de Gaswet en de Warmtewet (wijzigingen samenhangend met het energierapport 2011) (Stb. 573)* Staatscourant, Officiële uitgave van het Koninkrijk der Nederlanden sinds 1814, Regeling van de Minister van Economische Zaken van 11 juli 2014, nr. WJZ/13196684, tot vaststelling van regels voor de gaskwaliteit (Regeling gaskwaliteit) De Minister van Economische Zaken, Gelet op de artikelen 11 en 12, derde lid, van de Gaswet Note: The indicated legislation sets requirements for other gas quality parameters than those specified in this standard, EN 16726:2015

Parameter	EN 16726:2015 **maximum value**	MR Gaskwaliteit[a,b,c,d,e]	
		location	**maximum value**
Total sulfur without odorant	20 mg S/m^3 (n)	H-gas connection points[f]	30 mg S/m^3 (n)
		H-gas border points	20 mg S/m^3 (n)
Oxygen	0,001 mol-% expressed as a moving 24 hour average. However, where the gas can be demonstrated not to flow to installations sensitive to higher levels of oxygen, e.g. underground storage systems, a higher limit of up to 1 % may be applied.	H-gas injection points HP-grid	0,0005 mol-%
		H-gas exit points HP-grid	0,5 mol-%
		H-gas exit points HP-grid (storages)	0,001 mol-%
		H-gas exit point Storage Grijpskerk	0,0005 mol-%
		H-gas injection points MP and LP grid	0,5 mol-%
		H-gas border stations HP-grid	0,001 mol-% daily average
		H-gas border stations MP-grid	0,5 mol-%
Carbon dioxide	At network entry points and cross border points the mole fraction of carbon dioxide shall be no more than 2,5 %. However, where the gas can be demonstrated to not flow to installations sensitive to higher levels of carbon dioxide, e.g. underground storage systems, a higher limit of up to 4 % may be applied.	H-gas connection points[e]	2,5 mol-%
		H-gas border stations	2,5 mol-%
Hydrocarbon dew point	−2 °C at any pressure from 0,1 to 7 MPa (70 bar) absolute pressure	H-gas connection points	*Not specified* Instead a specification on Potential Hydrocarbon Liquid Content is defined (see below)
		H-gas border stations	*Not specified*. Instead a specification on Potential Hydrocarbon Liquid Content is defined (see below)

In the following, the relevant parameters and limit values are taken from the regulation in comparison with values defined in EN 16726:2015:

In the following, the relevant parameters and limit values are taken from the regulation in comparison with values defined in EN 16726:2015:			
Parameter	**EN 16726:2015 maximum value**	**MR Gaskwaliteit**[a,b,c,d,e]	
		location	**maximum value**
Potential Hydrocarbon Liquid Content	*Not specified.* Instead a specification on Hydrocarbon dew temperature is defined (see above)	H-gas connection points	5 mg/m^3 (n) at −3 °C at every pressure.
		H-gas border stations	5 mg/m^3 (n) at −3 °C at every pressure.
Water dew point	−8 °C at 7 MPa (70 bar) or, if less than 7 MPa (70 bar), at maximum operating pressure of the system in which the gas flows	H-gas connection points	−8 °C at 70 bar(a)
		H-gas border stations	−8 °C at 70 bar(a)

[a] MR Gaskwaliteit is the abbreviation for the following "Regeling": Staatscourant, Officiële uitgave van het Koninkrijk der Nederlanden sinds 1814, Regeling van de Minister van Economische Zaken van 11 juli 2014, nr. WJZ/13196684, tot vaststelling van regels voor de gaskwaliteit (Regeling gaskwaliteit) De Minister van Economische Zaken, Gelet op de artikelen 11 en 12, derde lid, van de Gaswet

[b] This is just a summary of the "Regeling van de Minister van Economische Zaken van 11 juli 2014, nr. WJZ/13196684, tot vaststelling van regels voor de gaskwaliteit (Regeling gaskwaliteit)", the current specifications found in the current gas law and the current "Regeling van de Minister van Economische Zaken, tot vaststelling van regels voor de gaskwaliteit (Regeling gaskwaliteit)". Both may be modified without notice.

[c] For the specific Botlek H gas grid (Annex 8 of the MR Gaskwaliteit) other specifications apply.

[d] In the MR Gaskwaliteit the reference conditions are normal conditions (273,15 K/0 °C and 101,325 kPa) whereas in the standard ISO Standard Reference conditions of 15 °C and 101,325 kPa are used.

[e] In the standard, Table 1, is mentioned that "the gas quality shall not impede safety of gas appliances and operations of end users. Appropriate measures shall be taken." Because of this clause, it is of importance to take note that the MR Gaskwaliteit specifies regional Wobbe indexes and that for Sulfur the following values are indicated:

Parameter	**EN 16726:2015 maximum value**	**MR Gaskwaliteit**[a,b,c,d,e]	
		location	**maximum value**
Total sulfur without odorant	21 mg S/m^3 (n)	H gas that flows into the G gas mixing plants (peek value)	20 mg S/m^3 (n)
		H gas that flows into the G gas mixing plants (annual average)	5,5 mg S/m^3 (n) yearly average

[f] Connection' means both entry and exit.

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National Annex NA
(informative)

UK Technical Committee GSE/33's concerns regarding EN 16726

NA.1 GSE/33's proposed text for suggested application for a Special National Condition (SNC)

UK Technical Committee GSE/33 considers that the UK should be seeking a SNC with the following proposed text:

'In the UK the gas quality required for safe operation of gas appliances installed in the UK was determined many years ago based on the gas in common use then. Installed gas appliances have been designed to be safe and to operate efficiently with the historic gas specifications, related to the geological nature of the UK. There is no knowledge as to how the appliances currently in operation would perform if subject to a variation in the gas specification nor whether the maintenance requirements would continue to provide for safe operation. The specification for Gas Quality for gas carried in the UK pipeline network as supplied to installed appliances is described in The Gas (Safety) Management Regulations 1996 (Statutory Instrument 1996 No. 551) for transparency.

Additionally, gas is currently permitted to enter the UK at some locations with a specification outside of the limits specified in EN 16726. The UK would wish to continue to use these natural resources as part of their strategy to ensure security of supply. Any measure which damages UK supply security would also have an indirect, knock-on effect on Ireland as they are physically dependent on the UK for their gas supply, and there are long standing bilateral supply arrangements that exist between the two States.'

NA.2 General committee concerns regarding EN 16726

The UK committee believes that the current lack of clarity around the future legal framework for EN 16726 means that the UK is unable to support its adoption at this time, as the impact on the UK internal supply network, including installed appliances, is unclear.

A major concern following the adoption of the standard was that the European Commission proposed to amend the Interoperability and Data Exchange Code in 2016 to include standard EN 16726. It was unclear what the effect will be on the legal framework, as to whether the standard would be legally binding at interconnection points only or across the entirety of the EU networks. Until the amendments were determined, it was not technically possible to understand the effects that the specification of the gas detailed in EN 16726 will have on the infrastructure, distribution and utilisation in the UK network.

It was not confirmed whether the legal framework would restrict member states to only accepting gas of this specification or whether it will be an obligation not to refuse gas of this specification, but still allow member states to accept gas outside the specification laid down in EN 16726. In addition, there was uncertainty about how any relaxations to permit higher limits for oxygen and carbon dioxide would be assessed, decided and managed over time as flow patterns change. Without this clarity, there was a risk that upstream supplies would be constrained and the cost of new field developments increased, to the detriment of UK security of supply. Any changes to the Interoperability and Data Exchange Code would have also needed to clarify how the changes will interact with existing provisions in this EU Code, which already provides an appropriate process for resolving cross-border gas quality issues.

In October 2016, the EC announced its intention not to proceed with making EN 16726 legally binding on member states at this stage.

Much of the technical content of EN 16726 also relates to the specification of elemental components in the natural gas and should only support the necessary flexibilities required for gas supply to ensure continued safety and security. The UK remains concerned that any implementation of EN 16726 needs to avoid the unintended consequences of its technical requirements restricting gas availability and flexibility, e.g. potential gas production locked into the geological strata and/or from pipelines.

In support of the above position, the gas quality required for safe operation of gas appliances installed in the UK was determined many years ago based on the gas in common use then. Installed gas appliances have been designed to be safe and to operate efficiently with the historic gas specifications, which are related to the indigenous gas in the UK geology. At present we cannot be sure how the appliances currently in operation would perform if subject to a variation in the gas specification nor whether the maintenance requirements would continue to provide for safe and efficient operation. The specification for gas quality for gas carried in the UK pipeline network as supplied to installed appliances is described in *The Gas (Safety) Management Regulations 1996 (Statutory Instrument 1996 No. 551)*. The UK gas transportation network is heavily cross-connected to ensure the safety and security of supply of the specified gas to UK towns and cities; some 22 million domestic consumers, plus industrial and commercial users including power generation. Additionally, gas is currently permitted to enter the UK at some locations with a specification outside of the limits specified in EN 16726. The UK would wish to continue to use these natural resources as part of their strategy to ensure security of supply. Any measure which damages UK supply security would also have an indirect knock-on effect on the Republic of Ireland, which is heavily dependent on the UK for its gas supply, and there are long standing bilateral supply arrangements that exist between the two Member States.

The UK will continue to engage in European discussions about any further appropriate development of EN 16726 and looks forward to the outcome of the *Opening up the Gas Market* trial (https://www.sgn.co.uk/Oban/Why/), which is being conducted in the Scottish town of Oban on its closed gas supply pipe network to 1100 premises. Testing commenced with a range of Wobbe Index gases outside the UK gas quality specifications in 2015 until July 2016. The current version of EN 16726 was supported only by limited testing of brand new gas appliances and only under laboratory conditions and only a small proportion of legacy appliance stock is brand new. Consequently, confidence is limited in attempting to scale up these results to ensure the safety and efficiency of legacy UK stock. Determining the potential impacts of gas quality changes on legacy gas appliance stock in some 22 million UK premises requires test results that can be scaled up with confidence to customers' gas heating and cooking appliances of all ages. The Oban trial is important in this respect as it has tested appliances of varying ages and conditions in a domestic setting and is continually examining the potential impact of gas with a Wobbe Index outside UK gas quality specifications on these appliances. The Oban results for Wobbe Index should also support the debate on Wobbe Index in EN 16726; a parameter which is absent from EN 16726 at the moment.

NA.3 Committee concerns regarding Table 1, Requirements

NA.3.1 Total sulphur without odorant

Total sulphur without odorant is set to 20 mg/m^3 and the UK committee previously advised that indicative data should be provided in Annex B to allow consumers to understand the likely maximum amount of sulphur in gas as consumed. However, the committee is of the opinion that Annex B contains unnecessary and incomplete information and advises that a table listing for each country the additional sulphur that might be expected from odourization would be more beneficial.

NA.3.2 Oxygen and Carbon dioxide

NA.3.2.1 The committee is concerned that a source of supply may be "connected" to oxygen sensitive or carbon dioxide sensitive installations, but the gas from that source may not ever reach that destination owing to the possible variations in gas flows through a meshed pipe network.

Furthermore, it seems unclear how the application of a higher limit than 10 ppm for Oxygen and 2.5% mol for Carbon dioxide would be decided, who would make that decision, how the potential impact of changes in supply/demand patterns over time would be managed and what constitutes a "sensitive site".

NA.3.2.2 The UK committee advises that further discussion in consultation with industry experts is required on the higher (1%) limit for O_2 in view of the possibility that gas may flow to another member state.

NA.3.2.3 The 2.5% proposed limit for Carbon dioxide may restrict current gas supplies to the UK as well as constrain development from some current and future UK Continental Shelf fields, which impacts negatively on maximising economic recovery from the UK Continental Shelf fields and security of supply. It is possible for the upstream to build facilities to remove the CO_2 before entering the National Transmission System, but this would incur costs that may make development of fields uneconomical, and would potentially lead to more CO_2 emissions through the process of removal.

Conversely, operators of power generation plants have suggested that carbon dioxide levels in transmitted/distributed gas may contribute to EU Emission Trading Scheme (EU ETS) allowances and hence lead to increased cost of compliance. For this reason a limit of 2.5% is considered appropriate – but higher levels than this may cause problems. The UK committee would therefore advise that it is confirmed whether EU ETS compliance for large-scale plants may be affected by proposals to increase carbon dioxide above 2.5%.

NA.3.3 Hydro carbon and Water dew points

Operators of power generation plants using gas turbines have advised that UK plants commonly work to −2°C for hydrocarbon and −10°C for water dew point at 85 bar(g). In addition, they have suggested that there may be a problem with the presence of greater quantities of higher (C5+) hydrocarbons, which measurement systems may only report as cumulative C5 or C. Hence the "true" WI and dew point may be higher than the gas transporter thinks. This may be an issue for power generation plant operators in all Member States. The UK committee, therefore, suggests that dew point values are discussed further in consultation with industry experts.

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