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भारतीय मानक

प्राकृतिक गैस — गुणता अभिनाम

Indian Standard

NATURAL GAS — QUALITY DESIGNATION

ICS 75.060

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

April 2002

Price Group 14

Natural Gas Sectional Committee, PCD 24

NATIONAL FOREWORD

This Indian Standard which is identical with ISO 13686 : 1998 'Natural gas — Quality designation' issued by the International Organization for Standardization (ISO) was adopted by the Bureau of Indian Standards on the recommendation of the Natural Gas Sectional Committee and approval of the Petroleum, Coal and Related Products Division Council.

The text of ISO Standard has been proposed to be approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to one International Standard for which Indian Standard also exists. The corresponding Indian Standard, which is to be substituted in its place, is listed below along with its degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 6326-1 : 1989 Natural gas — Determination of sulphur compounds — Part 1: General introduction	Nil	—
ISO 6326-2 : 1981 Gas analysis — Determination of sulphur compounds in natural gas — Part 2: Gas chromatographic method using an electrochemical detector for the determination of odoriferous sulphur compounds	Nil	—
ISO 6326-3 : 1989 Natural gas — Determination of sulphur compounds — Part 3: Determination of hydrogen sulphide, mercaptan sulphur and carbonyl sulphide sulphur by potentiometry	Nil	—
ISO 6326-4: 1989 Natural gas — Determination of sulphur compounds — Part 4: Gas chromatographic method using a flame photometric detector for the determination of hydrogen sulphide, carbonyl sulphide and sulphur containing odorants	Nil	—
ISO 6326-5 : 1989 Natural gas — Determination of sulphur compounds — Part 5: Lingener combustion method	Nil	—
ISO 6327 : 1981 Gas analysis — Determination of water dew point of natural gas — Cooled surface condensation hygrometers	Nil	—
ISO 6568 : 1981 Natural gas — Simple analysis by gas chromatography	Nil	—
ISO 6750-1: 1983 Natural gas — Determination of potential hydrocarbon liquid content —	Nil	—

(*Continued on third cover*)

Indian Standard
NATURAL GAS — QUALITY DESIGNATION

1 Scope

This International Standard specifies the parameters required to describe finally processed and, where required, blended natural gas. Such gas is referred to subsequently in this text simply as "natural gas".

The main text of this standard contains a list of these parameters, their units and references to measurement standards. Informative annexes give examples of typical values for these parameters, with the main emphasis on health and safety.

In defining the parameters governing composition, physical properties and trace constituents, consideration has also been given to existing natural gases to ensure their continuing viability.

The question of interchangeability is dealt with in annex A clause A.2.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 6326-1:1989,	*Natural gas - Determination of sulfur compounds - Part 1: General introduction.*
ISO 6326-2:1981,	*Gas analysis - Determination of sulphur compounds in natural gas - Part 2: Gas chromatographic method using an electrochemical detector for the determination of odoriferous sulphur compounds.*
ISO 6326-3:1989,	*Natural gas - Determination of sulfur compounds - Part 3: Determination of hydrogen sulfide, mercaptan sulfur and carbonyl sulfide sulfur by potentiometry.*
ISO 6326-4:1994,	*Natural gas - Determination of sulfur compounds - Part 4: Gas chromatographic method using a flame photometric detector for the determination of hydrogen sulfide, carbonyl sulfide and other sulfur-containing odorants.*

ISO 6326-5:1989,	*Natural gas - Determination of sulfur compounds - Part 5: Lingener combustion method.*
ISO 6327:1981,	*Gas analysis - Determination of the water dew point of natural gas - Cooled surface condensation hygrometers.*
ISO 6568:1981,	*Natural gas - Simple analysis by gas chromatography.*
ISO 6570-1:1983,	*Natural gas - Determination of potential hydrocarbon liquid content - Part 1: Principles and general requirements.*
ISO 6570-2:1984,	*Natural gas - Determination of potential hydrocarbon liquid content - Part 2: Weighing method.*
ISO 6570-3:1984,	*Natural gas - Determination of potential hydrocarbon liquid content - Part 3: Volumetric method.*
ISO 6974:1984,	*Natural gas - Determination of hydrogen, inert gases and hydrocarbons up to* C_8 *- Gas chromatographic method*
ISO 6975:1997,	*Natural gas - Extended analysis - Gas chromatographic method.*
ISO 6976:1995,	*Natural gas - Calculation of calorific values, density, relative density and Wobbe index from composition.*
ISO 10101-1:1993,	*Natural gas - Determination of water by the Karl Fischer method - Part 1: Introduction.*
ISO 10101-2:1993,	*Natural gas - Determination of water by the Karl Fischer method - Part 2: Titration procedure.*
ISO 10101-3:1993,	*Natural gas - Determination of water by the Karl Fischer method - Part 3: Coulometric procedure.*
ISO 10715:1997,	*Natural gas - Sampling.*
ISO 11541:1997,	*Natural gas - Determination of water content at high pressure.*
ISO 12213-1:1997,	*Natural gas - Calculation of compression factor - Part 1: Introduction and guidelines.*
ISO 13443:1996,	*Natural gas - Standard reference conditions.*

3 Definitions

For the purposes of this International Standard, the following definitions and explanations apply.

3.1 natural gas

A gaseous fuel obtained from underground sources and consisting of a complex mixture of hydrocarbons, primarily methane, but generally also including ethane, propane and higher hydrocarbons in much smaller amounts. It generally also includes some inert gases, such as nitrogen and carbon dioxide, plus minor amounts of trace constituents.

Natural gas remains in the gaseous state under the temperature and pressure conditions normally found in service.
It is produced by processing raw gas or from liquefied natural gas and, if required, blended to give a gas suitable for direct use.
As pipeline quality natural gas it may then be transmitted within a local distribution system, within a country, or across national borders. It is subject to contractual requirements between buyer and seller, and in some cases to national or state requirements as to quality (see annex A, clause A.1).

3.2 liquefied natural gas

Natural gas which, after processing, has been liquefied for storage or transportation purposes. Liquefied natural gas is revapourized and introduced into pipelines for transmission and distribution as natural gas.

3.3 substitute natural gas

Manufactured or blended gas with properties which make it interchangeable with natural gas. Substitute natural gas is sometimes called synthetic natural gas.

3.4 raw gas

Unprocessed gas taken from well heads through gathering lines to processing facilities.

3.5 local distribution system

The gas mains and services which supply natural gas directly to consumers.

3.6 gas quality

The quality of a natural gas is defined by its composition and the following physical properties:
Major components: calorific value, Wobbe index
Minor components: density, compression factor
Trace constituents: relative density, dew points

3.7 reference conditions

The preferred reference conditions are referred to as standard reference conditions and denoted by the subscript "s" (see ISO 13443):

p_s = **101,325 kPa**
T_s = **288,15 K**

3.8 calorific values

Divided into two types: superior calorific value and inferior calorific value, defined as follows (see ISO 6976).

3.8.1 superior calorific value

The amount of heat which would be released by the complete combustion in air of a specified quantity of gas, in such a way that the pressure at which the reaction takes place remains constant, and all the products of combustion are returned to the same specified temperature as that of the reactants, all of these products being in the gaseous state except for water formed by combustion, which is condensed to the liquid state at the above mentioned temperature. The above mentioned pressure and temperature must be specified.

3.8.2 Inferior calorific value

The amount of heat which would be released by the complete combustion in air of a specified quantity of gas, in such a way that the pressure at which the reaction takes place remains constant, and all the products of combustion are returned to the same specified temperature as that of the reactants, all of these products being in the gaseous state. The above mentioned pressure and temperature must be specified.

Both superior and inferior calorific values, which differ by the heat of condensation of water formed by combustion, can be specified on a molar, mass or volumetric basis. For the volumetric basis the pressure and temperature shall be stated at standard reference conditions.

Calorific values can also be stated as dry or wet, depending on the water vapour content of the gas prior to combustion.

The effect of water vapour on the calorific values, either directly measured or calculated, is described in annex F of ISO 6976.
Normally, the calorific value is expressed as the superior, dry value specified on a volumetric basis under standard reference conditions.

3.9 density

The mass of a gas divided by its volume at specified pressure and temperature.

3.10 relative density

Often called specific gravity, it is the mass of natural gas, dry or wet, per unit volume divided by the mass of an equal volume of dry air, both at the same specified pressure and temperature (see ISO 6976).

3.11 Wobbe index

The Wobbe index is a measure of the heat input to gas appliances, derived from the orifice flow equation. It is defined as the specified calorific value, always on a volume basis, divided by the square root of the corresponding relative density. The heat input for different natural gas compositions is the same if they have the same Wobbe index and are used under the same gas pressure (see ISO 6976).

3.12 compression factor

The compression factor Z is the quotient of the volume of an arbitrary mass of gas, at a specified pressure and temperature, and that of the same gas under the same conditions as calculated from the ideal gas law.

The terms compressibility factor and *Z*-factor are synonymous with compression factor (see ISO 12213-1).

3.13 water dew point

The dew point defines the temperature above which no condensation of water occurs at a specified pressure. For any pressure lower than the specified pressure there is no condensation at this temperature
(see A.4.1 and ISO 6327).

3.14 hydrocarbon dew point

The dew point defines the temperature above which no condensation of hydrocarbons occurs at a specified pressure.
At a given dew point, there is a pressure range within which condensation occurs except at one point, the cricondentherm (see A.4.2).

3.15 molar composition

The molar composition of a gas is the term used when the proportion of each component is expressed as a molar (or mole) fraction, or molar (mole) percentage, of the whole.
Thus the mole fraction, x_i, of component i is the quotient of the number of moles of component i and the number of moles of the whole mixture present in the same arbitrary volume. One mole of any chemical species is the amount of substance which has the relative molecular mass in grams. A table of recommended values of relative molecular masses is given in ISO 6976.
For an ideal gas, the mole fraction (or percentage) is identical to the volume fraction (percentage), but this relationship cannot in general be assumed to apply to real gas behaviour.

3.16 gas composition

The concentrations of the major and minor components and trace constituents in natural gas as analysed.

3.17 gas analysis

The use of test methods and other techniques for determining the gas composition, as stated in this International Standard.

3.18 interchangeability

A measure of the degree to which the combustion characteristics of one gas resemble those of another gas. Two gases are said to be interchangeable when one gas may be substituted for the other without affecting the operation of gas burning appliances or equipment.

3.19 odorization

Natural gas is normally odourless. It is necessary to add an odorant to the gas fed into the distribution system for safety reasons. It permits the detection of the gas by smell at very low concentrations.

3.20 methane number

The methane number is a rating indicating the knocking characteristics of a fuel gas. It is comparable to the octane number for petrol.

The methane number expresses the volume percentage of methane in a methane/hydrogen mixture which, in a test engine under standard conditions, has the same tendency to knock as the fuel gas to be examined.

4 Symbols, abbreviations and units

Symbol/Abbreviation	**Meaning and units**
d	Relative density
$\bar{H}$	Molar basis calorific value (kJ/mol)
$\hat{H}$	Mass basis calorific value (MJ/kg)
$\tilde{H}$	Volumetric basis calorific value (MJ/m^3)
LDS	Local distribution system
M	Mass per mole (kg/kmol)
NG	Natural gas
p	(Absolute) pressure (kPa)
SNG	Substitute (synthetic) natural gas
t	Celsius temperature (°C)
T	Thermodynamic (absolute) temperature (K)
V	(Gas) volume (m^3)
W	Wobbe index (number) (MJ/m^3)
Z	Compression factor
d	Density (kg/m^3)
Subscripts	
d	(Gas volume) dry
I	Inferior (calorific value)
s	(Gas volume) saturated
S	Superior (calorific value)
w	(Gas volume) wet

Calorific value

Superior calorific value denoted by H_S; inferior calorific value denoted by H_I. The calorific value shall be specified under the combustion conditions. The volumetric calorific value shall be specified under standard reference conditions. The calorific value is normally stated as "dry".

Example:

Superior calorific value, specified on a volumetric basis, at standard reference conditions and stated as wet. For simplicity, the combustion conditions are not specified.

$\tilde{H}_{S,w}\,(p_S, T_S)$

Wobbe index

The Wobbe index, denoted by W, is expressed on a volumetric basis and given in MJ/m^3, where the volume is stated at standard reference conditions. The Wobbe index can be specified as superior or inferior, depending on the calorific value and as dry or wet, depending on the calorific value and the corresponding density.

Example:

Wobbe index, superior, specified on a volumetric basis, at standard reference conditions and stated as "wet"

$$W_{S,w}\left(p_s,T_s\right) = \frac{\tilde{H}_{S,w}\left(p_s,T_s\right)}{\sqrt{d_W\left(p_s,T_s\right)}}$$

5 Quality designation parameters

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

5.1 Gas composition

Natural gas is composed primarily of methane with smaller amounts of higher hydrocarbons and non combustible gases. Major and minor components and trace constituents may be determined as follows.
Limits are not given in this document, but analysis to determine the natural-gas properties may be specified in contracts and state and federal codes in some countries. (See informative annexes.)

5.1.1 Major components

Constituent	Units	Test methods
Methane	mol %	ISO 6568 ISO 6974 ISO 6975
Ethane		
Propane		
Butanes		
Pentanes		
Hexanes plus		
Nitrogen		
Carbon dioxide		

5.1.2 Minor components

Constituent	Units	Test methods
Hydrogen	mol %	ISO 6975 ISO 6974
Oxygen		
Carbon monoxide		
Helium		

5.1.3 Trace constituents

Constituent	Units	Test methods
Hydrogen sulfide		ISO 6326-1
Mercaptan sulfur		ISO 6326-2
Dialkyl (di) sulfide	mg/m^3	ISO 6326-3
Carbonyl sulfide		ISO 6326-4
Total sulfur		ISO 6326-5

5.2 Gas properties

5.2.1 Physical properties

Property		Units	Test methods
Molar calorific value	$\overline{H}$	MJ/mol	
Mass-basis calorific value	$\hat{H}$	MJ/kg	
Volumetric-basis calorific value	$\tilde{H}$	MJ/m^3	ISO 6976
Density	d	—	
Wobbe index	W	MJ/m^3	
Water dew point		°C (K)	ISO 6327
Water liquid content		mg/m^3	ISO 10101-1 ISO 10101-2 ISO 10101-3 ISO 11541
Hydrocarbon dew point		°C (K)	
Hydrocarbon liquid content		mg/m^3	ISO 6570-1 ISO 6570-2 ISO 6570-3

5.2.2 Other properties

Natural gas shall be technically free of:

- Water and hydrocarbons in liquid form;
- Solid particulate substances in amounts deleterious to the materials normally encountered in transportation and utilisation;
- Other gases that could adversely affect the transportation or utilisation of the gas.

Note:
Technically free means that there are no visible traces of the components mentioned under actual conditions.

6 Sampling

Natural gas shall be sampled at agreed upon points, using routines representing established good practice, for the purpose of applying the test methods required. See ISO 10715 for guidance on sampling.

Annex A
(informative)
Introduction to informative annexes

A 1 Quality specification

A 1.1 German regulations Code of Practice DVGW G 260/I: 1983; G 260/II: 1990

(Relevant parts for natural gases, see Annex B)

NOTE Deutscher Verein des Gas- und Wasserfaches (DVGW) is a scientific association whose prime task is the production of codes of practice for the entire gas and water industry. It is a member of DIN.

A 1.2 French regulations concerning gas quality

In France, gas quality is principally defined by two government regulatory texts (Arrétés Ministériels) the first of which specifies the superior calorific value and the second the water and sulfur contents. All other gas quality specifications should be defined if necessary by contractual documents signed between the companies involved in gas transportation, which are now Gaz de France, Elf Aquitaine Production and Société Nationale des Gaz du Sud Quest. The two governmental documents can be summed up as follows:

1. Arrété du 16 septembre 1977
Limits of variations of superior calorific value of natural gas. Reference conditions called normal conditions (n) are:
P : 1,013 bar T : 0 degree C

The superior calorific value of natural gas must be between 10,7 and 12,8 kWh/m^3 (n) in areas fed by high cal. gas (H Gas) and between 9,5 and 10,5 kWh/m^3 (n) in areas fed by low cal. gas (B Gas). In the actual regulatory text calorific values are expressed in thermie(th)/m^3 (n).

2. Arrété du 28 janvier 1981
Sulfur and sulfur components in natural gases:
The gas must not corrode the pipelines i.e. no component capable of reacting chemically with materials used in construction the pipelines or which modifies physical characteristics of these material can be allowed in natural gas.

Hydrogen sulfide
Instantaneous content of hydrogen sulfide must be less than 15 milligrams per cubic meter (n).
Hydrogen sulfide content must not exceed 12 milligrams per cubic meter (n) for more than 8 consecutive hours.
The average content of hydrogen sulfide for any period of 8 days must be less than 7 milligrams per cubic meter (n).

Sulfur
Instantaneous total sulfur content must be less than 150 milligrams per cubic meter (n).

Water
Water dew point must be less than - 5 °C at the maximum service pressure of the gas pipeline.

A 1.3 U.K. Statutory Legislation with respect to gas quality

Within the U.K. there are certain statutory requirements with respect to gas quality. This legislation stipulates standards of purity and odorosity that must be met by any supplier of gas through pipes.
These standards are as follows.

Purity
No person shall supply through pipes any gas which contains more than 5 milligrams of hydrogen sulphide per cubic metre.

Odour
No person shall supply through pipes any gas which does not possess a distinctive odour.

A 2 Interchangeability

The interchangeability of natural gases in a given LDS is not only dependent on the relevant gas parameters, but is also strongly dependent on the characteristics of the appliances used in the LDS and on the end use pressure of the gas.

Interchangeability can be defined as the ability of a distributed natural gas to be substituted by another without the need for adjustment at the customers equipment. The appliances will continue to operate safely and satisfactorily.
The criteria to be considered for interchangeability are as follows:

Thermal input:	Flow of gas through an orifice at constant pressure, a function of Wobbe index.
Flash back:	The tendency for the flame to contract towards the port and for the combustion to take place inside the burner.
Lifting:	Burning surface expands to the point where burning cea-

	ses at the port and burns above it.
Yellow Tipping:	Incomplete combustion where excess hydrocarbons could, but does not always, result in unacceptable levels of carbon monoxide. May result in soot deposition and a continuing deterioration of combustion.

The substituted gas may be deemed to be interchangeable when, without the need for adjustment of the appliances, it provides a thermal input comparable with that provided by the gas previously distributed, without the occurrence of flash back, lifting or yellow tipping.
For the examination of the interchangeability there are two routes which can be followed, namely:

Wobbe index or **gas composition based prediction methods**

A 2.1 Wobbe index (see Annex B, C)

Natural gases are included in the second gas family. Inside the second family different gas groups can be identified.
Each gas group is a collection of gases characterised by:

- a reference gas with which the appliances operate under nominal conditions, when supplied at the corresponding normal pressure;
- limit gases representative of the extreme variations in the characteristics of the usable gases;
- test pressures representative of the extreme variations in the appliance supply conditions.

Appliances adjusted on the reference gas, at the normal pressure, and judged to perform satisfactorily with the limit gases at the test pressures, are approved for use within this gas group. In this approach the Wobbe index is the primary gas parameter, whose range identifies the gas group.
This method is followed by the German regulations Code of Practice DVGW-G260/I; 1983, G260/II;1990 (see Annex B), and, for appliances, by the European Standard EN 437 (see Annex C).
The definitions in force for testing appliances and gas quality are given in table A.1.

Table A.1 Definitions for testing appliances and gas quality

Testing appliances	**Gas Quality**
Gas family: A gas family is a collection of gases with common main constituents	Second family NG or SNG
Gas group: A gas group is a collection of gases in one gas family, all around a reference gas having similar combustion characteristics and determined by limit gases and test pressures.	Range of Wobbe index in LDS
Reference gas: A gas with which appliances operate under nominal conditions, when supplied at the corresponding normal pressure.	Gas in LDS
Limit gases: Gases representative of extreme variations in the characteristics of the usable gases.	
Normal pressure: The pressure at which appliances operate under nominal conditions, when they are supplied with the corresponding reference gas.	Pressure in LDS
Test pressures: Pressures representative of the extreme variations in the appliance supply conditions.	Range of gas pressure in LDS

A 2.2 A.G.A. Index Method (see Annex D)

In this prediction method for interchangeability, the measured appliance characteristics in the LDS are translated to defined relevant gas parameters, based on gas composition. Wobbe index is basically a measure of heat input to the appliance. It is indicative of interchangeability, but not conclusive. When kept within the established limits as determined by appliance certification procedures, control of the Wobbe index provides a satisfactory measure.
However, where no such appliance certification regime exists, or for borderline cases of gas composition, alternative methods for determining interchangeability exist.

A 2.3 British Gas Hydrocarbon Equivalence method (see Annex E)

The British Gas method is a composition and Wobbe index based prediction method for determining gas interchangeability within the UK.

A 2.4 Weaver index method (see Annex F)

The Weaver index method introduces the flame speed into the equations particularly for lifting and flash back.

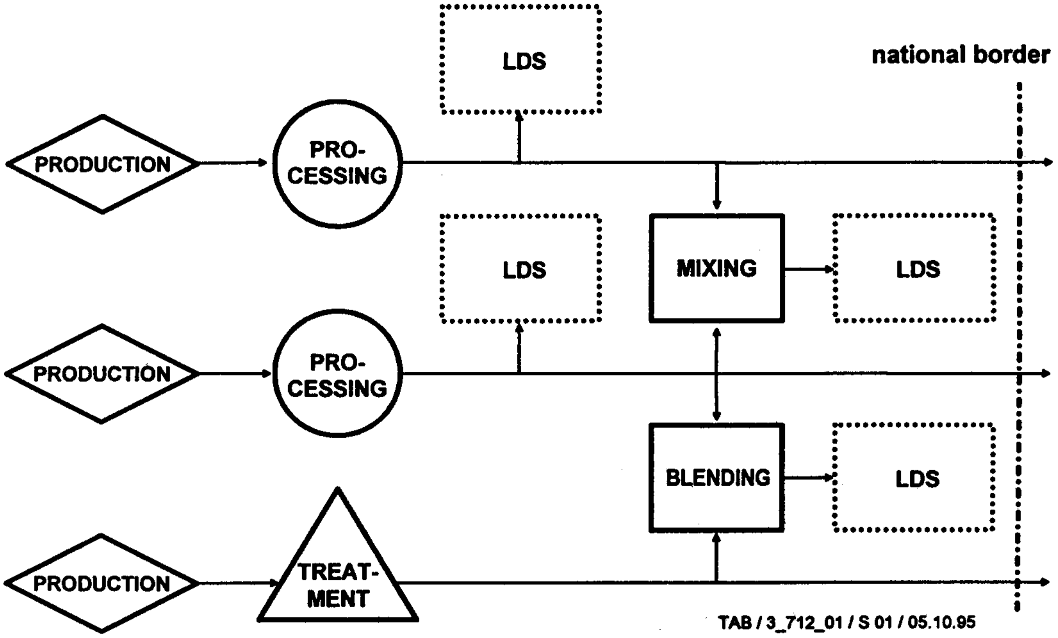
A 2.5 French Method for Determining Gas Interchangeability (Delbourg Method) (see Annex G)

The French method for determining gas interchangeability essentially continues to be the Delbourg method. The latter is based on the definition of interchangeability indices indicating the limits of gas combustion. In an appliance at reference conditions, the occurrence of a malfunction (incomplete combustion, flame lift, flashback, sooting ignition at the injector) corresponds to a precise index value. The ranges deemed satisfactory for different indices were suggested to operators in 1963 after studying a sample of representative appliances available then.

The interchangeability diagram drawn then shows the range in a system of co-ordinates (corrected Wobbe number, combustion potential) within which all appliances will function satisfactorily. Any gas of a different composition is positioned on the basis of the 1963 reference values. The method of calculation and the interchangeability diagram are shown in Annex G.
Whenever gas conversion becomes necessary, the likely scenario can be determined with the aid of the interchangeability indices. Deschamps defined in a general manner the indices for second-family gases. This new method was employed during the 1970s during the changeover from Groningen to Lacq gas.

NOTE Existing approaches to interchangeability are based essentially on experience and studies with atmospheric burner, natural draft appliances. The technology of gas appliances and equipment is changing rapidly. Many advanced efficiency units incorporate power burners with much less excess air allowance. Internal combustion engines used for cogeneration systems are growing in numbers. Natural gas vehicles, fuel cells, and other end-use applications are coming into use. Thus, interchangeability parameters and techniques must be constantly reviewed and updated as natural gas utilisation becomes more complex and sophisticated with time.
The European test gas procedures, as embodied in EN 437, provide continuous interchangeability proof for equipment by means of appliance

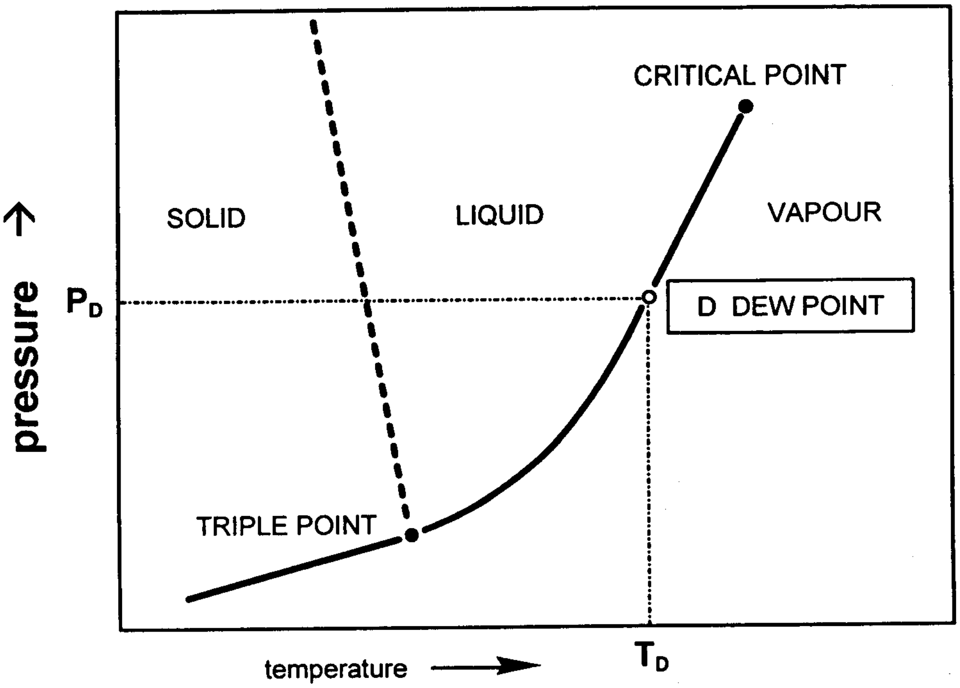
A 3 Natural Gas , Local Distribution System



After PROCESSING the gas is suitable for use on LDS, after TREATMENT the gas is not suitable for use on LDS.
In the diagram MIXING relates to the mixing of two gases that are both suitable for use on an LDS. BLENDING has the purpose to produce an acceptable gas for distribution out of two gases where of at least one is not suitable for distribution.

A 4 condensation curves

A 4.1 water



A 4.2 hydrocarbons

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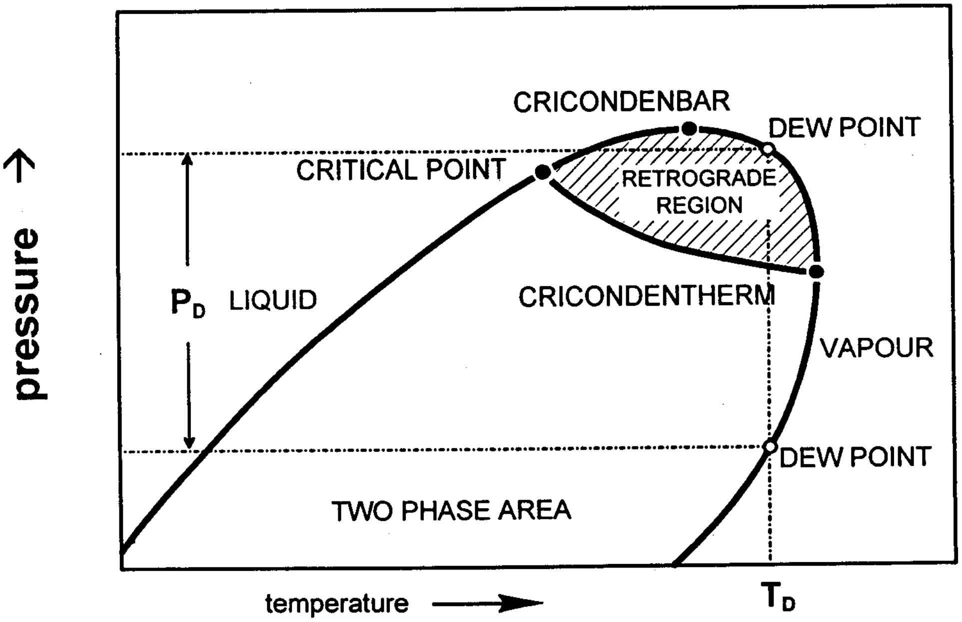


A 5 Odorization

Natural gas is odorized upon entering the local distribution system so that consumers will be alerted to its presence. An alert level consisting in an intensity of odour equivalent to 2 olfactory degrees reached when the concentration of gas in air is below 1 %, is often specified (Wienke, K.; Ermittlung und überprüfung der Geruchsintensitätskurven von Gasen und Odoriermitteln. gas wärme international. Band 18(1969), Nr. 6. S. 223 - 232, und Nr. 11, S. 418 - 421). Other levels may be required in different areas. The following four different categories of odorant blends are generally used to odorize Natural gases:

1. Blends of Mercaptans, consisting predominantly of Tertiary Butyl Mercaptan (TBM) with lower concentrations of Iso Propyl Mercaptan (IPM) and Normal Propyl Mercaptan (NPM).
2. Blends of Mercaptans with Alkyl Sulfides, where Dimethyl Sulfide (DMS) and Methyl Ethyl Sulfide (MES) are the most commonly used Alkyl Sulfides.
3. Tetrahydrothiophene (THT): Cyclic Sulfide used in the gas industry as single component odorant.
4. Blends of THT with Mercaptans.

Odorant used for the odorization of natural gas have to meet the requirements mentioned in ISO/DIS 13734.
In Germany the practice of odorization, featuring the technique, safety aspects odorant requirement and dosage, is contained in code of practice DVGW G 280 and G 281, whilst products concerned as odorants or odorant containers are regulated by DIN standards (DIN 30650, DIN 30651).

A 6 Nominal range of natural gas components

A 6.1 European market

As relevant to the European market, 'Natural gas, dried' is determined by the components (all concentrations on a mass-to-mass basis) given in table A.2.

Table A.2 Natural gas components

methane	**70,0 - 98,0 % (w/w)**
ethane	**0,3 - 18,0 % (w/w)**
propane	**< 8,0 % (w/w)**
butane	**< 2,0 % (w/w)**
pentane	**< 0,5 % (w/w)**
nitrogen	**< 30,0 % (w/w)**
carbon dioxide	**< 15,0 % (w/w)**

The content of each of all other components and constituents is less than 0,1 % (w/w).
Existing Substances Regulation No 793/93 /EEC of 23 March 1993, Natural gas, dried, EINECS no 270-085-9, CAS no 68410-63-9)

A 6.2 United States

A 6.2.1 National Overview

Natural gas composition to end-use customers in the U.S. is a complex issue, with no particularly 'correct' answer. There are certainly differences in the chemical constituents present in natural gas as well as in the key indices used to measure natural gas 'quality' and value - heating value, specific gravity, and Wobbe index. Existing gas industry practices acquired over the years provide a measure of self-regulating control and are complemented by contract terms for gas sales, regulatory oversight, desire for product quality, and the pragmatic need to account for gas volumes and their economic value. These and other factors tend to bring the key measures of natural gas to a common level.
The overwhelming majority of natural gas delivered in this country is nondescript; that is, there are no distinguishing features in these gases that would raise a concern. However, there are instances where gas utilities deliver a composition of natural gas that is different from the norm. This occurs most often for short periods at a select number of utilities (e.g., high demand points in the winter) or, in one instance, is characteristic of the daily deliveries by a gas utility. The key factor in these cases is whether such compositions represent a significant variation from the norm for a particular application. A concerted effort has been made to include in this database cities that represent the industry 'norm' as well as extremes.
Twenty-six target cities in 19 states were identified for collection of data on gas composition. The cities represent the regions and states given in table A.3.

Table A.3 Regions and states

Region	States
Northeast:	New York, New Jersey, Pennsylvania, Rhode Island, Massachusetts, Connecticut
Southeast:	Maryland, Georgia, Virginia
North Central:	Illinois, Ohio, Michigan, Wisconsin
South Central:	Texas, Oklahoma, Louisiana
Mountain:	Colorado
Pacific:	California, Washington

Figure A.1 graphically shows the distribution of these target areas throughout the U.S.

A 6.2.2 Summary National Statistics

The methodology used to collect these data was described in the previous section, including the issue of weighting based on volumetric gas deliveries for statistics for all of the 26 cities. In total, these data constitute over 6.800 gas analyses. The Mean column in Table A.4 shows typical composition and physical property data for end-use delivered natural gas. The Minimum and Maximum columns illustrate the absolute extremes identified in the data, while the 10th and 90th percentile columns show relative extremes.

Table A.4 also indicates that the principal components of natural gas are methane, ethane, propane, and inert gases - with relatively trace levels of butane or heavier hydrocarbons. This fact is clearly illustrated in Figure A.2, showing average percent levels of non-methane constituents found in natural gas for each of the 26 cities (in mole percent or essentially equivalent volume percent). The values in Table A.4 also note several extreme values that were set by propane - air peakshaving gas compositions. The consideration of peakshaving gases in three cities noticeably affects the maximum and minimum national values, as previously noted. The mean and percentile values, however, show little or no difference compared to when the propane-air peakshaving gases are not considered.

Table A.4 Natural gas composition and physical properties.

	Mean	Minimum WithP/A	Minimum W/OP/A	Maximum WithP/A	Maximum W/OP/A	10th %-ile	90th %-ile
Methane (Mole %)	93,9	55,8	74,5	98,1	98,1	89,6	96,5
Ethane (Mole %)	3,2	,5	,5	13,3	13,3	1,5	4,8
Propane (Mole %)	,7	,0	,0	23,7	2,6	,2	1,2
C_4 + (Mole %)	,4	,0	,0	2,1	2,1	,1	,6
CO_2 + N_2 (Mole %)	2,6	,0	,0	15,1	10,0	1,0	4,3
Heating Value (MJ/m^3)	38,46	36,14	36,14	45,00	41,97	37,48	39,03
Heating Value (BTU/scf)	1033	970	970	1208	1127	1006	1048
Specific Gravity	,598	,563	,563	,883	,698	,576	,623
Wobbe Number (MJ/m^3)	49,79	44,76	44,76	52,85	52,85	49,59	50,55
Wobbe Number (BTU/scf)	1336	1201	1201	1418	1418	1331	1357
Air/Fuel Ratio (Mass)	16,4	12,7	13,7	17,1	17,1	15,9	16,8
Air/Fuel Ratio (Volume)	9,7	9,1	9,1	11,4	10,6	9,4	9,9
Molecular Weight	17,3	16,4	16,4	25,5	20,2	16,7	18,0
Critical Compression Ratio	13,8	9,7	12,5	14,2	14,2	13,4	14,0
Methane Number	90,0	34,1	73,1	96,2	96,2	84,9	93,5
Lower Flammability Limit, %	5,00	4,30	4,56	5,25	5,25	4,84	5,07
Hydrogen: Carbon Ratio	3,92	3,24	3,68	3,97	3,97	3,82	3,95

FIGURE A.1 Regional Distribution of Gas Composition Survey Areas

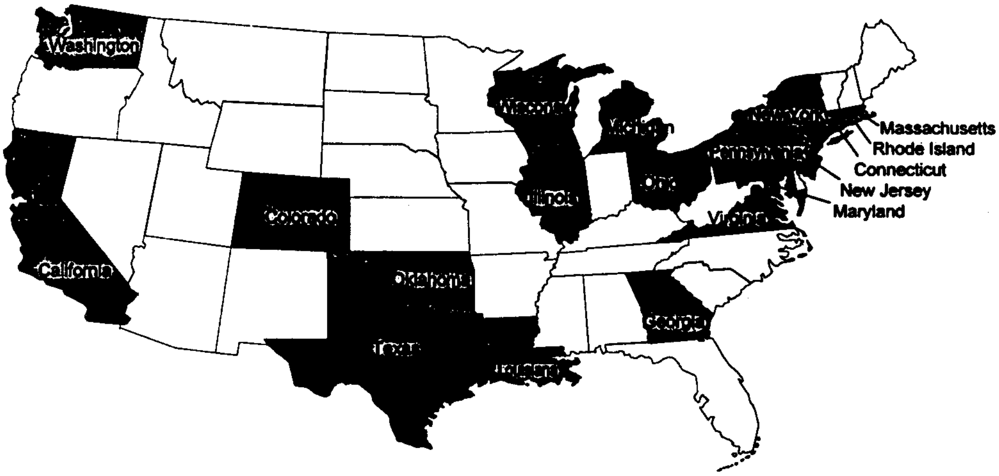
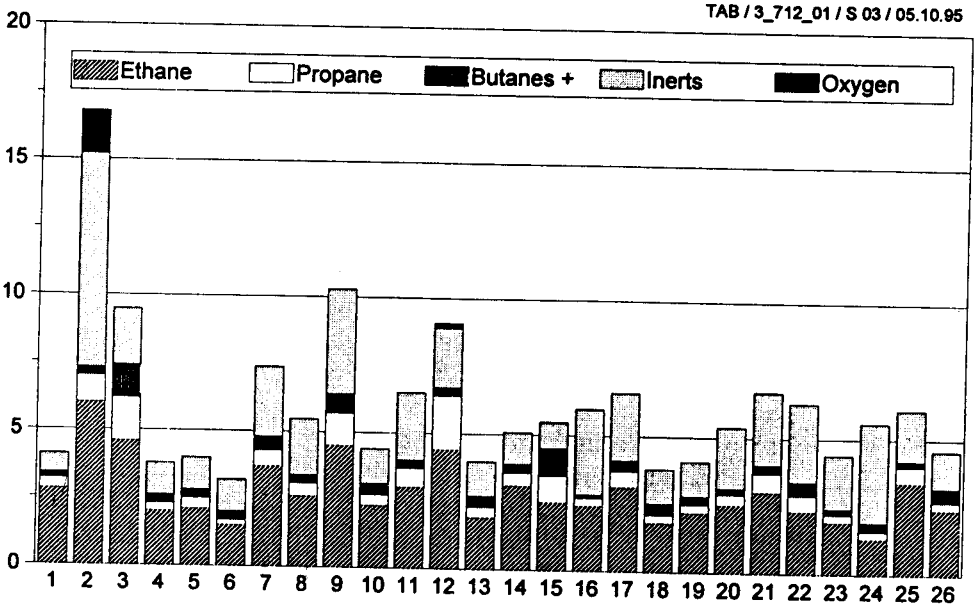


FIGURE A.2 Non-Methane Constituents in Natural Gas



Annex B
(informative)
German Regulations Code of Practice DVGW G 260 I: 1983, G 260/II: 1990
Extract of the relevant parts for natural gases

B 1 Basic gases, substitute gases, additive gases

Basic gases are the gases usually distributed in a supply area.
To be able to meet the requirements in peak gas supply gas conditioning in some cases is necessary. This can be done either with:

- Substitute gases, which are gas mixtures that despite having a composition different from that of basic gas and, sometimes, having different characteristic data, have an equivalent behaviour in the burner to the basic gas, at the same pressure and with the equipment setting unchanged. They can be used in place of the supplied gases without limitation.
- Additive gases, which are gas mixtures that in composition and technical combustion characteristics differ considerably from the basic gas. They can be added to the basic gas in limited quantities, whereby the requirement for an equal performance of the mixture in the burner determines the level of the additive.

B 2 Standard state

For comparison of the values which depend upon the state, the standard state shall be used. It is indicated by using the letter n as an index.
Standard pressure p_n= 1,01325 bar, Standard temperature T_n= 273,15 K (=0 °C).

B 3 Standard values

Volume V; Unit: m^3
Pressure p; Unit: bar, mbar
In this case the water vapour pressure is frequently given as
$P_D = \psi \cdot p_s$;
ψ relative humidity and
p_s saturation pressure

Temperature T, t; Unit: K, or °C

The gas temperature t measured in °C. The following relationship exists between the absolute temperature T in Kelvin and the measured temperature t:
$t = T - T_n$ $T_n = 273{,}15$ K

T_n	is the standard temperature
T	is the temperature in the operating state
p_{amb}	is the air pressure
p_e	is the effective gas pressure
p_n	is the standard pressure
ψ	is the saturation grade of the humidity
p_s	is the saturation pressure of the humidity
K	is the compressibility coefficient
n	is the amount of substance in kmol
R	is the general gas constant

B 4 Gas families, groups

In the public gas supply fuel gases which to considerable extent have the same combustion characteristics are divided into gas families. Where the technical requirements of the equipment demand, gas families are also sub-divided into groups.

- The 1st gas family includes all hydrogen-rich gases. It is divided, in accordance with the Wobbe index, into Group A "Town gas" and Group B "Grid gas".
- The 2nd gas family includes all gases rich in methane. This includes synthetic natural gases (SNG) from naturally occurring natural gases as well as their substitute gases. The second gas family is divided, in accordance with the Wobbe index, into Groups L (low) and H (high) (refer to Table B.1 DVGW G 260/I: 1983 2nd Gasfamily, Page 35).
- The 3rd gas family includes all liquid gases in accordance with DIN 51622.
- The 4th gas family includes all hydrocarbon/air mixtures manufactured from liquid or natural gases and air.

B 5 Gas composition

Gases contain chief constituents and gas secondary substances.

- The chief constituents of a gas are specified as volumetric, molecular or mass proportions in percentage. They also determine the allocation of the fuel gases to the gas families.
- Gas secondary substances can be present as a gas, liquid or solid. The concentration is specified in mg/m^3, cm^3/m^3 (also vppm), mg/kg (also ppm) for the majority of gas secondary substances, or a specification can be used which relates to the behaviour of the gas during transport.

B 5.1 Wobbe index W_o, W_u; Unit: kWh/m^3, MJ/m^3

The Wobbe index is the characteristic value for the heat load:
Fuel gases of various compositions with the same Wobbe index produce almost the same heat load at the burner under the same pressure (flow pressure). It is as a rule related to the standard state. The "upper" Wobbe index $W_{o,n}$ is the quotient from the gross calorific value $H_{o,n}$ and the square root of the relative density d.
The "lower" Wobbe index Wu,n is the quotient from the net calorific value $H_{u,n}$ and the square root of the relative density d.

$$W_{o,n} = \frac{H_{o,n}}{\sqrt{d}} \text{ or } W_{u,n} = \frac{H_{u,n}}{\sqrt{d}}$$

B 5.2 Extended Wobbe index $W_{o,e}$; $W_{u,e}$

In addition to the substance values already included in the Wobbe index, the extended Wobbe index takes account of the flow pressure p_e (in mbar) in its effect on the gas outflow and, therefore, on the heat load.

$$W_{o,e} = W_{o,n} \times \sqrt{P_e} \text{ or } W_{u,e} = W_{u,n} \times \sqrt{P_e}$$

B 5.3 Relative Wobbe index

In the relative Wobbe index $W_{o,rel}$ or $W_{u,rel}$ the Wobbe index of a gas is relative to that of methane. As a dimensionless number it provides the direct comparison of various fuel gases. The relative Wobbe index of methane is by definition therefore equal to unity.

B 6 Notes on the technical burning data

B 6.1 Wobbe index, gross calorific value

For the various gas families or their groups, total ranges, rated values and fluctuating ranges are stipulated, which are firstly orientated to the burning behaviour of the gas in gas appliances of standard or usual design and are relative to the Wobbe index or the gross calorific value of the gas.

- The total range of a gas family or group is specified by the upper and lower limit value. Exceeding the upper limit is permissible in no case, and to go below the lower limit is permissible only in specific conditions (see below).
- The rated value is a characteristic Wobbe index or gross calorific value in each case in accordance with the gas family or group. In the 2nd gas family it should be based on the setting of the gas appliance.
- The fluctuating range means the range within which the Wobbe index or gross calorific value may generally fluctuate. It is related to the rated value or to a specified value which in an individual case may deviate from this.

If gas appliances in the 2nd gas family are adjusted to the rated value of a group, the upper limit of the total range of this group and the upper limit of the fluctuating

range are therefore identical. If a lower setting for the gas appliance is chosen in an individual case on special grounds, the part of the total range above the upper limit of the fluctuating range must not be used for the relevant supply area.
The Wobbe Index or the gross calorific value in a supply area may deviate downwards to the lower limit of the total range provided the technical preconditions for a trouble-free operation of the gas appliance are met; under corresponding conditions it is also permitted to go below this limit up to a limited amount.

B 7 Notes on the gas constituents and gas secondary substances

The main gas constituents of the fuel gases, which are distributed in the public gas supply, are, e.g. hydrogen, methane or liquid gases. In addition, a series of gas secondary substances may be contained which are present either as a gas, liquid or solid. They are either contained naturally in the gas, originate from some manufacturing process which has been used, are added to the gas as a substance to have a deliberate effect or arise during transport of the gas.

B 7.1 Hydrocarbons

The amount of the higher saturated and unsaturated as well as aromatic hydrocarbons in gases is to be limited relative to the gas distribution and the burning behaviour of the gases. The concentration permissible for a trouble-free combustion depends not only the type of hydrocarbons but also on the hydrogen and oxygen content of the gas. Carbon dioxide also favours the combustion of unsaturated and aromatic hydrocarbons in comparison to nitrogen, particularly in diffusion burners.
Gases of the 1st gas family with concentrations of up to 10 g/m^3 of benzene hydrocarbons burn satisfactorily, if the hydrogen content by volume is at least 50 %. Where the hydrogen content is lower either the concentration of benzene hydrocarbons must be reduced or the oxygen content increased. Benzene hydrocarbons means the sum of liquid hydrocarbons at room temperature, which is determined by means of gas chromatography to be C_{6+} hydrocarbons. "Naphthalene" is the sum of the aromatic hydrocarbons analytically occurring as picrate.
Gases of the 2nd gas family can contain condensable hydrocarbons, including aromatic hydrocarbons, under operating conditions depending upon the origin and method of preparation. They can precipitate (retrograde condensation) under certain operating conditions when the gas is expanded under the pressure of the preparation process.
Gas/air mixtures containing liquid gas are to be invariably composed to ensure that condensation is precluded under the pressure and temperature conditions prevailing in distribution systems.
The condensation of hydrocarbons is determined by the type and quantity of the condensable components contained in the gas, and by the pressure and temperature. The limitation is usually determined by the stipulation of the condensation point, i.e. of a temperature above which no condensation of hydrocarbons should occur at a stipulated pressure or in a stipulated pressure range.

B 7.2 Water

Gases subject to high and medium pressure should be dry as possible, i.e. should have a relative humidity of less than 60 %, to avoid corrosion and the formation of gas hydrate.
Specifications are made, in the case of hydrocarbons, as a rule by giving the dew point, i.e. a temperature above which no condensation of water should occur at a specified pressure.

B 7.3 Oxygen

The oxygen in gases containing water vapour is corrosive. The permissible oxygen content depends, therefore, on the relative humidity of the gas.
The upper limit of the ranges given in Table B.1 DVGW G260/I:1983 2nd gas family can be exceeded if hydrocarbon/air mixtures are used as substitute or additive gases.

B 7.4 Carbon monoxide

The CO content depends upon the raw material from which the gas is produced and the operating conditions during gas production. The CO content is limited in the 1st gas family. The guide value may be exceeded in existing installations.
Gas from reforming plants or coal gasification plants should have a CO content of less than 3 % by volume.

B 7.5 Carbon dioxide

Carbon dioxide can be present either due to the gas production process or occur naturally in the gases. In damp gases carbon dioxide can promote corrosion. Gas drying to remove the H_2O is preferred as a preventative measure.

B 7.6 Mist, dust

The presence of mist (tar, oils, glycol or other viscous liquids) in gas depends upon the method of preparation used. Compressor installations can also, in certain circumstances, cause oil mist in gas.
If liquids are introduced into the gases as a mist to rectify leaks in sleeve and spigot joints and to bind dust in the pipe system, this additive shall be limited sufficiently to ensure that the combustion characteristics of the gases and the functioning of the gas appliances are not adversely affected.
Dust can occur during the production of gases. Furthermore, the formation of dust in the pipelines due to chemical reaction and corrosion cannot be fully avoided. Adequate measure shall be provided for subsequent separation or binding. The formation of dust in distribution systems can only be reduced by ensuring that the guide values for corrosion-promoting gas secondary substances are not exceeded.

Technically free means that condensation, mist and dust is sufficiently removed to ensure the operation of gas appliances and technical gas equipment of standard or normal construction. A precise control of mist and dust content and, therefore, the specification of limits is not possible at this time.

B 7.7 Nitrogen oxides, ammonia, hydrocyanic acid

Gases of the 1st gas family can contain nitrogen oxides, ammonia and hydrocyanic acid, the amount of which, with normal gas purifying, is determined in relation to the composition of the raw materials from which the gas is produced and the operating conditions under which the gas is produced.
When using waste gas as an additive gas for conditioning, attention is to be paid to the nitrogen oxides content.

B 7.8 Hydrogen Sulfide

Sulfureous secondary gas substances include hydrogen sulfide, carbon oxides, sulfides, carbon bisulfide, disulfides, mercaptans and thiophenes.
The hydrogen sulfide content in produced gases depends upon the raw material used and the gas purification; for natural gases it depends upon the gas deposits and on the method of preparation. The sulfur content of gases adversely affects the life of pipelines and consumer appliances; it is, therefore, limited for all fuel gases.

B 8 Data and guide values for the gas quality

Gases shall comply with the values given in Table B.1 with regard to their technical burning data and their main gas constituents and secondary gas substance content.

All gases which are supplied to domestic consumers as part of the public supply system shall have a warning smell.

Table B.1 DVGW G260/I: 1983 2nd gas family
Technical burning data

Designation	Abb.	Unit	Group L	Group H
Wobbe index	$W_{u,n}$			
Total range		kWh/m^3	10,5 to 13,0	12,8 to 15,7
		MJ/m^3	37,8 to 46,8	46,1 to 56,5
Rated value		kWh/m^3	12,4	15,0
		MJ/m^3	44,6	54,0
Fluctuation range in local supply area	$W_{o,n}$	kWh/m^3	+ 0,6 - 1,2	+ 0,7 - 1,4
Gross calorific value	$H_{o,n}$	kWh/m^3	8,4 to 13,1	
		MJ/m^3	30,2 to 47,2	
Relative density	d		0,55 to 0,70	
Connecting pressure	p_e			
Total range		mbar	18 to 24	
Rated value		mbar	20	

Table B.2 Gas secondary substances; Maximum guide values

Condensable hydrocarbons		Ground temp.	)
condensation point	°C		) at actual
Water			) pipe pressure
Dew point	°C	Ground temp.	)
Mist, dust, liquid		Technically free	
Oxygen content by volume			
in dry supply networks	%	3	
in damp supply networks	%	0,5	
Total sulfur	mg/m^3	120	
short term	mg/m^3	150	
Mercaptan sulfur	mg/m^3	6*)	
short term	mg/m^3	16	
Hydrogen sulfide	mg/m^3	5	

*) The guide value for the mercaptan sulfur content of 6 mg/m^3 can at present not be maintained for all natural gases.

Annex C
(informative)
European standard EN 437 "Test gases, test pressures and categories of appliances"

Appliances using combustible gases.

Table C.1 Test pressures for gas groups in the 2nd family according to EN 437

GAS GROUP	Test pressure (mbar)		
	Pnom	Pmin	Pmax
H	20	17	25
E	20	17	25
E s	20	17	25
E i	25	20	30
L	25	20	30
L L	20	18	25

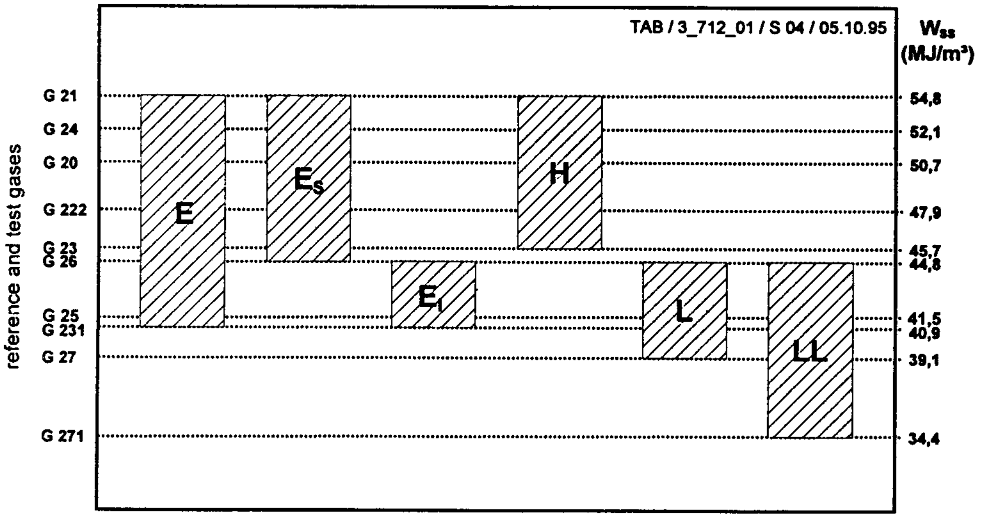


FIGURE C.1 Gas groups and test gases in the 2nd family (NG) according to EN 437

Table C.2 Test gases for gas groups in the 2nd family according to EN 437

GAS DESIGNATION	COMPOSITION BY VOL. %				W_{ss}	H_{ss}	d_s	Type of Gas
	CH_4	H_2	C_3H_8	N_2	MJ/m^3	MJ/m^3		
G 20	100	-	-	-	50,72	37,78	0,555	Reference gas Group H-E-ES
G 21	87	-	13	-	54,76	45,28	0,684	Incompl. comb. Group H-E-ES
G 222	77	23	-	-	47,87	31,86	0,443	Light back Group H-E-LL-Es
G 23	92,5	-	-	7,5	45,66	34,95	0,586	Flame lift Group H
G 231	85	-	-	15	40,90	32,11	0,617	Flame lift Group E-Ei
G 24	68	20	12	-	52,09	39,55	0,577	Overheating Group H-E
G 25	86	-	-	14	41,52	32,49	0,612	Reference gas Group L-LL-Ei
G 26 *)	80	-	7	13	44,83	36,91	0,678	Incompl. comb. Group L-LL-Ei
G 27	82	-	-	18	39,06	30,98	0,629	Flame lift Group L
G 271	74	-	-	26	34,36	27,96	0,662	Flame lift Group LL

*) Flame lift, group ES

Annex D
(informative)
Interchangeability A.G.A. Index Method

The A.G.A. Interchangeability Program, Catalogue No. XH 8810, uses the Index Method based on A.G.A. Research Bulletin 36 "Interchangeability of other fuel gases with natural gas" (1952, 2nd edition), the Weaver Index Method, and the Knoy Constant techniques to determine compatibility of gases. All methods involve an adjustment gas and a substitute gas. The A.G.A. and Weaver Index methods require a complete analysis of gas components, but the Knoy constant method uses only the superior, dry calorific value and relative density. Only the A.G.A. Index method is covered for this explanation.

Interchangeability in the A.G.A. program is determined by calculating indexes for lifting, flashback, and yellow tipping (complete combustion), and by establishing preferable and objectional limits for each. The equations used for the individual indices were derived experimentally by the Bulletin 36 work. An exactly interchangeable gas, that is, if the adjustment gas and the substitute gas were of the same composition, would yield values of I_l, I_f and I_y equal to 1,0. The preferable limits are pegged at this value. The objectionable limits are values which just provide satisfactory performance. Such values are determined by testing a variety of appliances, by setting them up on the adjustment gas, and by changing gas mixtures until the three interchangeability criteria occur, namely, lifting, flashback and yellow tipping.

D 1 Example for a calculation

D 1.1 Natural gas of the second Family

Group H compositions of Adjustment (Reference) and Limit Gases, as stated in EN 437, are put into the A.G.A. Program. The compositions of these gases are given under the heading "test gases". Extracts from the original program worksheets are attached and the limiting Index values noted. See worksheet 1,2 and 3.

Two tables result from each calculation of a given adjustment gas - limit gas set. Table 1 presents the Index values calculated for both the A.G.A. and Weaver Methods. Any violation of the Index range that has been established will be printed out alongside the Index in question. Note that the Yellowtip Index is cited as A.G.A. 36 predicting problems. This note is not appropriate for the H gas calculation since its criteria were based on a different adjustment gas - limit gas regimen.

One of the features of the program is the ability to insert new limiting index values which would be the case here since G 21 is the Yellow tip limit gas. Thus, the note would no longer show at an I_y of 0,762 (worksheet 1). Table 2 prints out values for various properties pertaining to the adjustment and substitute gases. These include superior, dry calorific value, relative density, Wobbe index, and numerous other factors used in the interchangeability calculations. The equations used for the

A.G.A. calculations are not reproduced here, but are available through A G.A. if desired.

For ease of understanding, this concept is put into Interchangeability Limit Box format for H gas (Graph 1). One constructs the Limit Box by treating the A.G.A. Indices as co-ordinates, using the reciprocal of I_y as the abscissa. The preferred values form the inner box. The objectional values form the limits. Gas compositions falling inside the limits are substitutable, those outside are not. Each gas has two plot points, namely, I_l versus $1/I_y$ and I_f versus $1/I_y$.

As a corollary to the Interchangeability Limit Box, it is also necessary to determine that the Wobbe Index of the substitute gas is within limits. Wobbe-index relates directly to the BTU/hr (MJ/h) input to gas appliances. The ratio of Wobbe-indexes between adjustment and substitute gases yield the percent change (plus or minus) in input. Wobbe Index is often thought of as a measure of interchangeability, but it is indicative rather than conclusive. However, it is a positive measure of the ability of the appliance to perform its function, and thus must remain within limits. The rule of thumb in the USA is a maximum plus or minus 10 % change. European limits are somewhat narrower as derived from the limit gas compositions. The Wobbe Index Limit Box is shown in Graph 2 for H gas.

Table D.1 Test gases used for the example to explain the A.G.A. Method

H Gas Reference and Limit Gases					
Reference	G 20	Methane	100 %		
Yellow tipping	G 21	Methane	87 %,	Propane	13 %
Flash back	G 222	Methane	77 %,	Hydrogen	23 %
Lifting	G 23	Methane	92,5 %,	Nitrogen	7,5 %

A.G.A. Worksheet 1
Yellow tipping - G 20 (reference gas), G 21 (substitute gas)

Interchangeability indices

A.G.A. BULLETIN 36:			
Lifting Index I_l	0,941		
Flashback Ind. I_f	1,034		
Yellowtip Ind. I_y	0,762	A.G.A. 36	PREDICTS YELLOWTIPPING PROBLEMS
1/Iy	1,312		
WEAVER:			
Heat Rate ratio	1,078	JH	Limit Value
Prim. Air ratio	1,078	JA	
Lifting	1,118	JL	WEAVER JH OUT OF RANGE
Flashback	0,073	JF	
Yellowtipping	0,314	JY	
Incomplete Comb.	0,116	JI	
			WEAVER JY INDICATES YELLOWTIPPING
			WEAVER JI INDICATES INC: COMB:

Gas values

	ADJUST GAS	SUBSTITUTE GAS
Compressibility	0,99801	0,99678
Calorific value	1014,0	1212,2
Mol. Weight	index	19,690
Relative density	0,5547	0,6817
Wobbe index	1361,4	1468,2 Limit Values
Knoy Factor	1126,5	1256,2
Primary Air (ft3)	9,52	11,38
H/C Ratio	4,00	3,59
N (C per 100)		26
Flame Speed, S	14,06	14,58
Lifting Constant	0,670	0,834
Yellowtip Const	218	317
Lifting Lim. K	1,208	1,223
Prim Air f (#36)	0,7345	0,6811
Air per 100 Btu	0,9392	0,9389
Yellowtip limit Y	22,89	27,86

A.G.A. Worksheet 2

FLASH BACK - G 20 (reference gas) G 222 (substitute gas)

Interchangeability indices

A.G.A. BULLETIN 36:			
Lifting Index I_l	0,868		
Flashback Ind. I_f	1,198		Limit Value
Yellowtip Ind. I_y	1,160		
1/Iy	0,862		
WEAVER:			
Heat Rate ratio	0,944	JH	WEAVER JH OUT OF RANGE
Prim. Air ratio	0,926	JA	
Lifting	1,423	JL	
Flashback	0,640	JF	WEAVER JF INDICATES
Yellowtipping	- 0,074	JY	FLASHBACK
Incomplete Comb.	- 0,128	JI	

GAS VALUES

	ADJUST GAS	SUBSTITUTE GAS
Compressibility	0,99801	0,99897
Calorific value	1014,0	854,8
Mol. Weight	16,043	12,817
Relative density	0,5547	0,4428
Wobbe index	1361,4	1284,7 Limit Value
Knoy Factor	1126,5	1021,7
Primary Air (ft3)	9,52	7,88
H/C Ratio	4,00	4,60
N (C per 100)		
Flame Speed, S	14,06	21,61
Lifting Constant	0,670	0,654
Yellowtip Const	218	168
Lifting Lim. K	1,208	1,477
Prim Air f (#36)	0,7345	0,7784
Air per 100 Btu	0,9392	0,9219
Yellowtip limit Y	22,89	21,30

A.G.A. Worksheet 3

LIFTING - G 20 (reference gas), G 23 (substitute gas)

INTERCHANGEABILITY INDICES

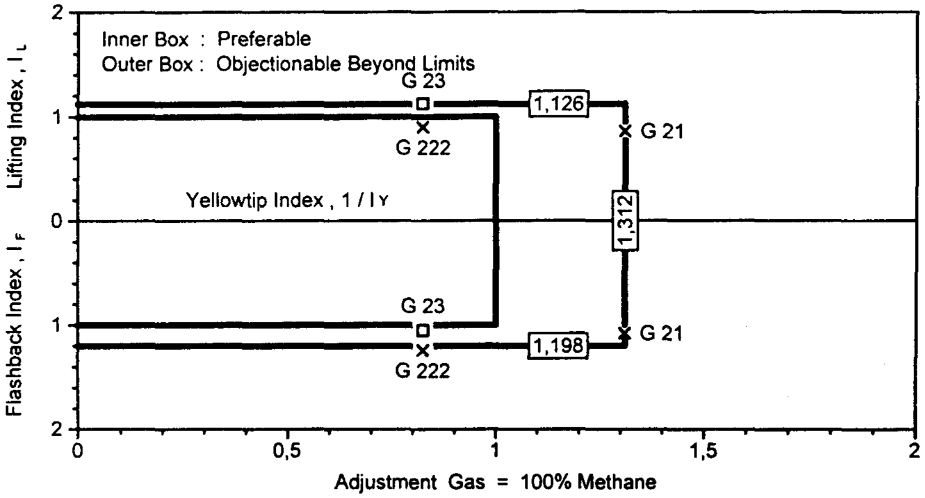
A.G.A. BULLETIN 36:			
Lifting Index I_l	1,126	A.G.A. 36	PREDICTS LIFT PROB LIMIT VALUE
Flashback Ind. I_f	1,021		
Yellowtip Ind. I_y	1,177		
1/ly	0,850		
WEAVER:			
Heat Rate ratio	0,900	JH	WEAVER JH OUT OF RANGE
Prim. Air ratio	0,900	JA	
Lifting	0,860	JL	
Flashback	0,095	JF	
Yellowtipping	- 0,100	JY	
Incomplete Comb.	- 0,100	JI	

GAS VALUES

	ADJUST GAS	SUBSTITUTE GAS
Compressibility	0,99801	0,99817
Calorific value	1014,0	937,8
Mol. Weight	16,043	16,941
Relative density	0,5547	0,5857
Wobbe index	1361,4	1225,4 Limit Value
Knoy Factor	1126,5	996,4
Primary Air (ft3)	9,52	8,81
H/C Ratio	4,00	4,00
N (C per 100)		
Flame Speed, S	14,06	13,44
Lifting Constant	0,670	0,671
Yellowtip Const	218	202
Lifting Lim. K	1,208	1,146
Prim Air f (#36)	0,7345	0,8161
Air per 100 Btu	0,9392	0,9394
Yellowtip limit Y	22,89	21,60

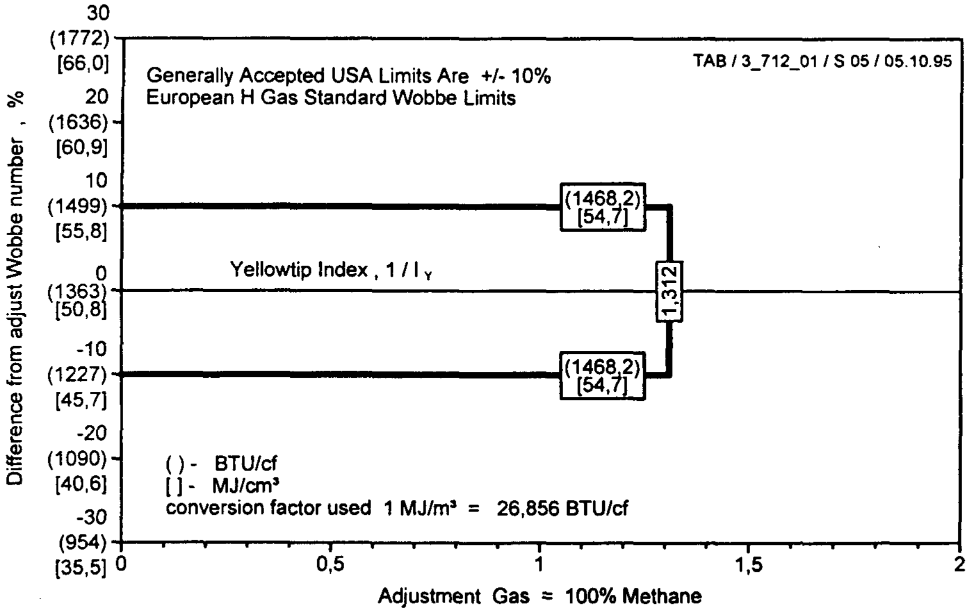
AGA Index Method Interchangeability Limit Box

Applied to the European Test Gases of the H Group (Annex B)



AGA Index Method - Wobbe Index Limit Box

Applied to the European Test Gases of the H Group (Annex B)



Annex E
(informative)
British Gas Hydrocarbon Equivalence Method

E 1 Composition-based prediction

After extensive study within the United Kingdom it became clear that the occurrence of incomplete combustion and sooting with natural gas cannot be satisfactorily predicted on the basis of using Wobbe Index and Weaver Flame Speed Factor as the only two variables. This problem can be overcome to a large extent by relating appliance malfunction, such as sooting, to the composition of the gas. A composition-based prediction system has been developed by Dutton *) at the British Gas Watson House Research Station and is now widely used in the prediction of gas interchangeability within the UK. To illustrate the basic features of the composition-based prediction system, a typical gas composition is examined as shown in Table E.1.

Table E.1 Composition and physical properties

Component	Methane	Ethane	Propane	Butane	Pentane	Nitrogen	Carbon dioxide
Composition (mol%)	93,76	3,14	0,62	0,20	0,07	2,03	0,18

Superior calorific value: 38,58 MJ/m^3 Relative density: 0,593
The prediction system assumes that the gas can be regarded as a four-component mixture consisting of:

- methane
- other hydrocarbons (i. e. the higher hydrocarbons ethane, propane, etc)
- hydrogen
- inerts (nitrogen and carbon dioxide)

In order to express the amounts of the other hydrocarbons in the same component, it is necessary to use the concept of an equivalent gas. The proportions of the individual components of the equivalent gas are selected to produce the same major properties as the gas itself. The other hydrocarbons are expressed as an equivalent amount of propane and methane. The inerts are expressed as an equivalent amount of a standard inert, i. e. nitrogen.

*) B.C. Dutton, Communication 1246. 50th Autumn Meeting of the I.G.E., 1984.

E 1.1 Equivalent Gas for the other Hydrocarbons

The equivalent gas for the other hydrocarbons is the volume of propane and methane which has the same ideal volume and the same average number of carbon atoms per molecule as the gas under consideration.

For example the equivalent for ethane is:

$C_2H_6 = C_3H_8 + CH_4$

The equivalence factors for ethane in terms of propane and of methane are therefore, 0,5 and 0,5 respectively.

Other hydrocarbons are expressed in equivalents in Table E.2. Please note that it is acceptable to use negative signs if appropriate.

Table E.2 Equivalence factors for hydrocarbons

	Equivalent	
Hydrocarbon	**methane**	**propane**
Methane	1,0	
Ethane	0,5	0,5
Propane		1,0
Butane	- 0,5	1,5
Pentane	- 1,0	2,0
Hexane	- 1,5	2,5

E 1.2 The Inerts

The inert gases are expressed as an equivalent amount of nitrogen based on their relative effect on combustion properties. Then a further, small, adjustment to the N_2 component is needed so that the Wobbe index of the equivalent mixture matches that of the complete composition.

E 2 Prediction of Interchangeability

In order to predict the interchangeability of the gas in Table E.1 we need to:

- work out its Wobbe index
- express the composition of gas A in terms of a four-component mixture
- assess its interchangeability by plotting it on a prediction diagram

The Wobbe index of the gas is given by the ratio of superior calorific value and the square root of relative density:

$W = 50{,}10\ MJ/m^3$

Table E.3 shows the method used for the determination of the equivalent four component mixture.

Table E.3 Equivalent four-component mixture for gas

Composition A	Equivalent methane			Equivalent propane		
(Southern North Sea)	Equivalence factor	%	Equivalent methane	Equivalence factor	%	Equivalent propane
Methane	1,0	93,76	93,76	-	93,76	
Ethane	0,5	3,14	1,57	0,5	3,14	1,57
Propane		0,62		1,0	0,62	0,62
Butane	- 0,5	0,20	- 0,10	1,5	0,20	0,30
Pentanes plus	- 1,0	0,07	- 0,07	2,0	0,07	0,14
		Total	95,16		Total	2,63

Applying the correction referred to above for nitrogen and carbon dioxide content, and normalising the composition to 100 %, the example gives a total propane plus nitrogen equivalent of 4.90 %.

E 3 Three Dimensional Prediction Diagram

Now that the gas is expressed as an equivalent four-component mixture (methane, propane, nitrogen and hydrogen), interchangeability can be evaluated by representing it as a point within a three-dimensional prediction diagram (Figure E.1). The prediction diagram plots Wobbe index against the sum of equivalent propane plus nitrogen against hydrogen content. A plot of experimentally derived measurements of flame lift, sooting, etc. results in a three dimensional volume of interchangeability. The outer surface of the volume represents the emergency limits for utilisation of gases; those plotting outside of the volume are unsuitable at any time.

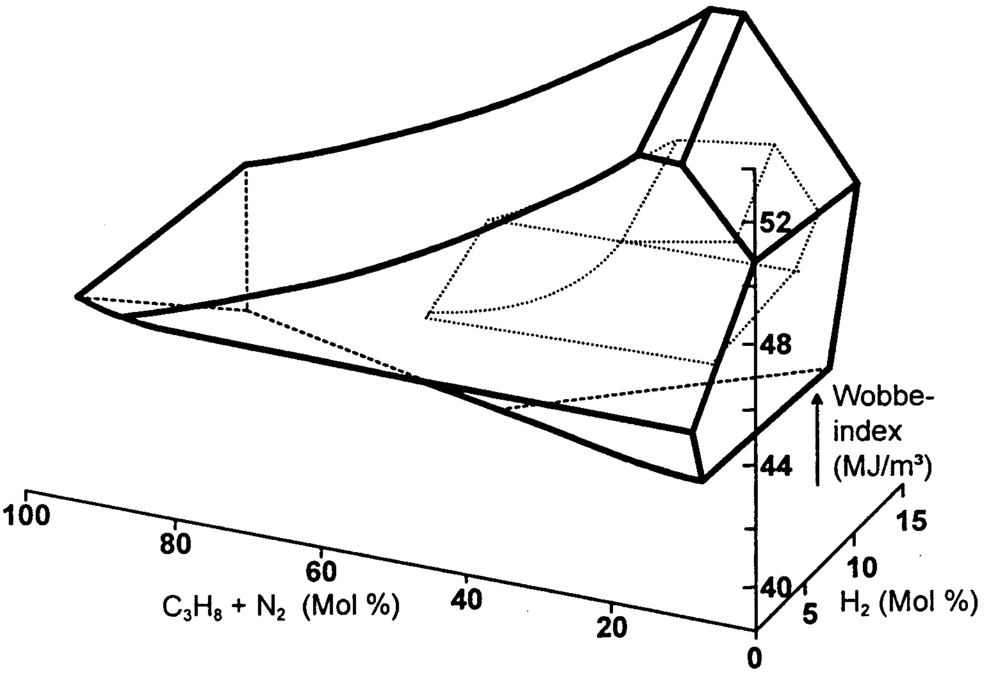


FIGURE E.1
Volume of interchangeability showing inner and outer limits

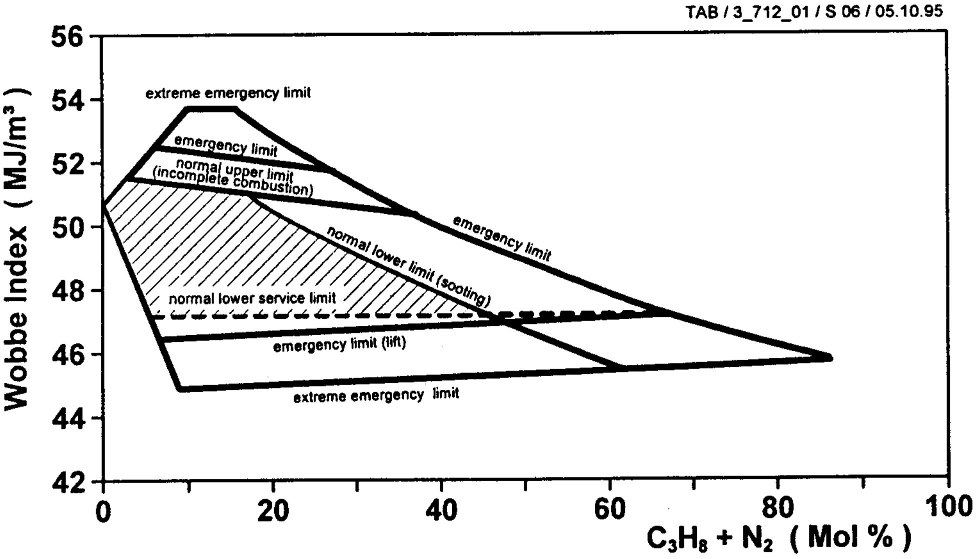

TAB / 3_712_01 / S 06 / 05.10.95

FIGURE E.2
The two dimensional interchangeability diagram

Annex F
(informative)
Weaver Index Method

Another Index Method for predicting interchangeability was developed by E.R. Weaver, circa 1951. A novel aspect of this work was the introduction of flame speed into the equations particularly for lifting and flash back. By assigning flame speed factors to the various components of adjustment and substitute gases a summation by volume percent of each component produces flame speed factors for each gas. The result is a series for six Indices as follows:

Heat Rate Ratio, J_H - The ratio of Wobbe Indexes for the substitute to the adjustment gases determines how the change in gas composition affects the heat rate input to the appliance.
Primary Air ratio, J_A - Determines the change in primary air requirement for complete combustion from the substitute to adjustment gases.
Lifting Index, J_K - Evaluates the tendency for lifting of flames from the burner ports. Linked to primary air ratio and flame speeds of the substitute to adjustment gases.
Flash back Index, J_F - Evaluates the tendency for flash back (lightback) to occur. Also linked to JA and flame speeds of the substitute of adjustment gases.
Yellow Tipping Index, J_Y - Evaluates tendency to produce yellow flames and free carbon. Related to J_A and carbon content of fuel.
Incomplete Combustion Index, J_I - Evaluates tendency to generate carbon monoxide. Related to J_A and the ratio of hydrogen to carbon atoms in the substitute to adjustment gases.

The equations used for the Weaver Index Calculations are not reproduced here, but are available through A.G.A. if desired.
Weaver established limits for the various Indices in his original work. These are used to indicate problems in the A.G.A. Worksheets (see A.G.A. Worksheets, 1, 2 and 3) as part of the A.G.A. Interchangeability Program (Annex D). Note that many of the Group H limit gases show indications of problems with these criteria. Obviously, since appliances pass the test gas certification procedures required by EN 437, the Weaver limits are too restrictive for this protocol.
At least one utility in the U.S. has done extensive work with the Weaver Index Method, and successfully applied it to a system which uses refinery/NG mixtures, refinery/landfill methane/ NG mixtures, Propane-air peakshaving with NG, and revaporized LNG storage as peakshaving. Their experience resulted in a revised set of limit values. The calculations on the attached Worksheets establish a set of Weaver Index limits applicable to the Group H situation. The various sets of criteria are listed in table F.1.

Table F.1 Weaver Index limits

INDEX	WEAVER	UTILITY	GROUP H
J_H	0,95 - 1,05	0,95 - 1,03	0,90 - 1,08
J_A	-	-	0,89 - 1,08
J_L	>0,64	>0,64	>0,86
J_F	<0,08	<0,26	<1,06
J_Y	<0,14	<0,05	<0,12
J_Z	<0	<0,05	<0,12

Two conclusions are drawn from these results:

1. The best assurance of interchangeability is a standard test gas routine applied to all appliances for certification, and keeping gas quality within the parameters of the test gases.
2. Otherwise, interchangeability requires extensive testing and knowledge of the appliances on a local distribution system. The appearance of new or altered gas compositions will always be a problem for the Utility to prove acceptability.

Annex G
(informative)
French Method for Determining Gas Interchangeability (Delbourg Method)

Guide for Determining the Interchangeability of Second-family Gases
Calculation of indices and diagram for appliances supplied with Lacq gas at 20 mbar

G 1. Calculation of Interchangeability Indices on the Basis of Chemical Composition of the Gas

G 1.1 Primary Indices

To deal with traditional phenomena of incomplete combustion (production of CO), flame lift and lightback, the following are used simultaneously:

- Corrected Wobbe index
- combustion potential

G 1.1.1 Corrected Wobbe index

$$W = K_1 \times K_2 \frac{gcv}{\sqrt{d}}$$

K_1: obtained from the curve in fig. G.1 as a function of the share of hydrocarbons (except methane) in the gross calorific value

K_2: obtained from the curve in fig. G.2 as a function of the parameter:

$$1000 \times \frac{CO + 4O_2 - 0{,}5CO_2}{gcv}$$

gcv: gross calorific value in kcal/m^3 one m^3 is measured in dry condition at 0 °C and with 760 mm mercury column.

d: relative density (air = 1)

G 1.1.2 Combustion Potential

$$C = u \times \frac{H_2 + 0.7CO + 0.3CH_4 + v\Sigma aC_nH_m}{\sqrt{d}}$$

u: correction coefficient as a function of the oxygen content and the gcv (obtained from fig. G.3)

H_2, CO, CH_4, C_nH_m:
content of each combustible constituent (in %) (C_nH_m: all hydrocarbons except CH_4)

v: correction coefficient depending on the value of the corrected Wobbe index expressed in kcal/m^3(n) (obtained from fig. G.4)

a: specific coefficient of each hydrocarbon shown in the table G.1

G 1.2 Secondary Indices

G 1.2.1 Yellow Tip Index

This index makes it possible to determine the occurrence of yellow tips in aerated flames and thus to avoid sooting.

$$Ij = \frac{\Sigma jA}{\sqrt{d}}\left(1 - 100\frac{O_2}{gcv}\right)$$

A: content of gas, in % (CH_4 and C_nH_m)
O_2: oxygen content of gas, in %
j: specific coefficient of each hydrocarbon shown in the table G.1
d: relative density

G 1.2.2 Index for Indirect Ignition at the Injector

This index makes it possible to predict a particular form of ignition at the injector which takes place, on certain types of hot water appliance, through primary air entrained at the burner ports when the hot water valve is operated. This index has a value equal to the hydrogen content of the gas, expressed in %.

G 2. Interchangeability Limits for Second-family Gases for Domestic Appliances at 20 mbar

G 2.1 Complete Combustion and Flame Stability

The area common to all appliances is shown as continuous line in figure G.5. However, to take account of both variations in supply pressure and fluctuations in appliance control, it is advisable to limit the interchangeability range to the hatched part in figure G.5. If point K is located inside this zone, combustion will be complete and the flame stable.

G 2.2 Variations in Heat Input

The heat input is proportional to the semi-corrected Wobbe number K, W. The latter is equal to the W ordinate of the assured point in the diagram if the gas does not contain any oxygen and contains only little CO or CO_2. In this case, to limit the variations in heat input to
10 % on the basis of the nominal value obtained with reference gas, the interchangeability range in fig. 5 is limited to the lower section.

G 2.3 Yellow Tip Index

Index Ij should be lower than 230 and preferably below 210.

G 2.4 Index for Indirect Ignition at the Injector

The hydrogen content in the mixture must be below 10 %.

Table G.1 Gas properties

		gcv kcal/m^3	d density	a combustion potential	j Yellow tip indices
carbon monoxide	CO	3 020	0,967	-	0
hydrogen	H_2	3 050	0,070	-	0
methane	CH_4	9 530	0,554	-	1
ethane	C_2H_6	16 860	1,049	0,95	2,85
propane	C_3H_8	24 350	1,562	0,95	4,80
n-butane	$n\text{-}C_4H_{10}$	32 060	2,091	1,10	6,80
i-butane	$i\text{-}C_4H_{10}$	31 570	2,064	1,10	6,80
pentane	C_5H_{12}	40 600	2,675	1,15	8,80
hexane	C_6H_{14}	45 600	2,97	1,15	12
heptane	C_7H_{10}	52 900	3,45	1,15	15
acetylene	C_2H_2	13 980	0,906	3	2,40
ethylene	C_2H_4	15 180	0,975	1,75	2,65
propylene	C_3H_6	22 430	1,481	1,25	4,80
n-butene	$n\text{-}C_4H_8$	29 050	1,937	1,50	6,80
i-butene	$i\text{-}C_4H_8$	28 880	1,937	1,50	6,80
butadiene	C_4H_6	26 500	1,87	2,70	6,10
benzene	C_6H_6	35 250	2,697	0,90	20
toluene	C_7H_8	-	-	0,9	16
nitrogen	N_2	0	0,967	0	0
carbon dioxide	CO_2	0	1,529	0	0
oxygen	0_2	0	1,105	0	0

FIGURE G.1 **Correction coefficient " K1 " for Wobbe index** (second-family gases)

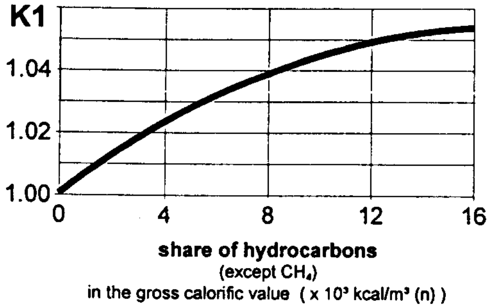


FIGURE G.2 **Correction coefficient " K2 " for Wobbe index** (second-family gases)

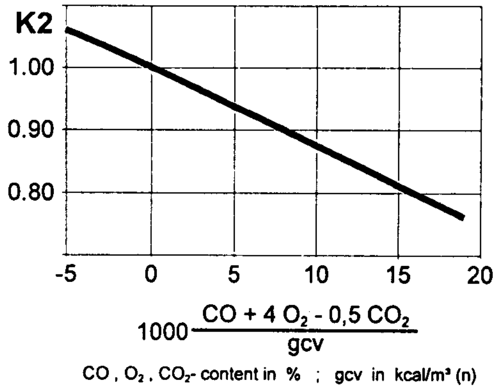


FIGURE G.3 **Correction coefficient " U " for combustion potential** (second-family gases)

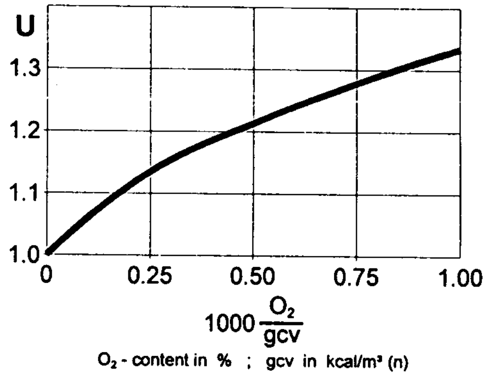


FIGURE G.4 **Mean correction coefficient for hydrocarbons higher than methane** (second-family gases)

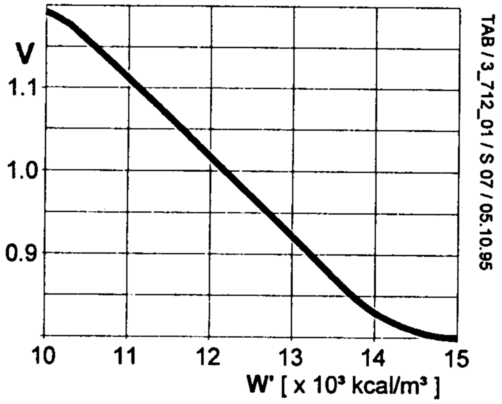
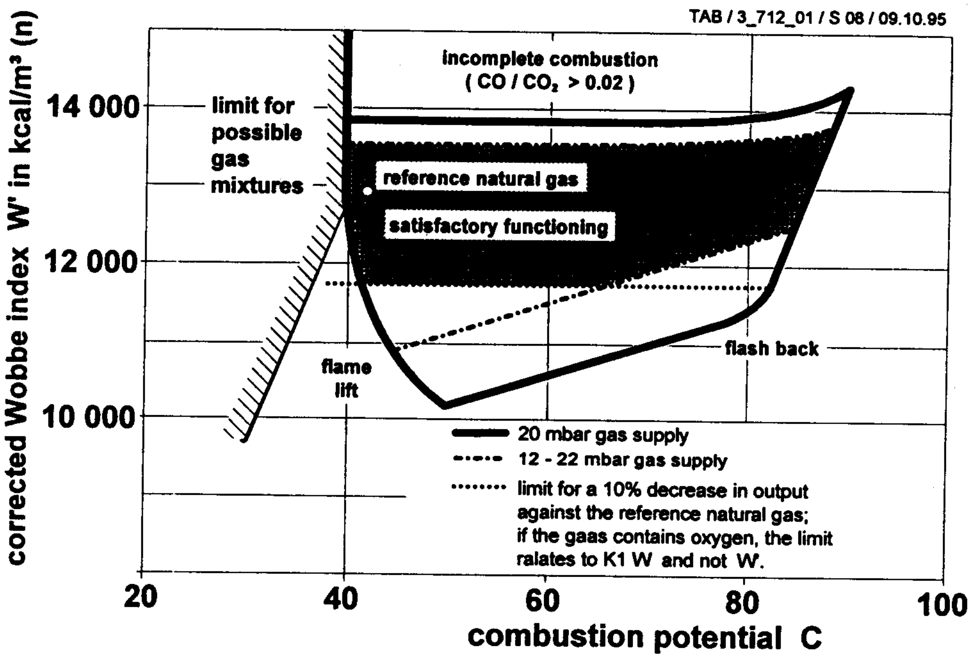


FIGURE G.5 Gas interchangeability diagram
(second-family gases)



Annex H
(informative)
Bibliography

ISO	1000:1992	*SI units and recommendations for the use of their multiples and of certain other units.*
ISO	6978:1992	*Natural gas - Determination of mercury.*
ISO	7504:1984	*Gas analysis - Vocabulary.*
ISO	10723:1995	*Natural gas - Performance evaluation.*
ISO	13275:-[1)]	*Natural gas - Preparation of calibration gas mixtures - Gravimetric method.*
ISO	13734:-[1)]	*Natural gas - Organic sulfur compounds used as odorants - Requirements and test methods.*
ISO	14111:1997	*Natural gas - Guidelines for traceability in analysis of natural gas.*
ISO	14532:-[1)]	*Natural gas - Terminology.*

[1)] To be published

(Continued from second cover)

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
ISO 6750-2 : 1984 Natural gas — Determination of potential hydrocarbon liquid content — Part 2: Weighing method	Nil	—
ISO 6750-3 : 1984 Natural gas — Determination of potential hydrocarbon liquid content — Part 3: Volumetric method	Nil	—
ISO 6974 : 1984 Natural gas — Determination of hydrogen, inert gases and hydrocarbons up to C_8 — Gas chromatographic method	Nil	—
ISO 6975 : 1997 Natural gas — Extended analysis — Gas chromatographic method	Nil	—
ISO 6976 : 1995 Natural gas — Calculation of calorific values, density, relative density and Wobbe index from composition	IS 14504 :1997	Identical
ISO 10101-1 : 1993 Natural gas — Determination of water by Karl Fischer method — Part 1: Introduction	Nil	—
ISO 10101-2 : 1993 Natural gas — Determination of water by Karl Fischer method — Part 2: Titration procedure	Nil	—
ISO 10101-3 : 1993 Natural gas — Determination of water by Karl Fischer method — Part 3: Coulometric procedure	Nil	—
ISO 10715 : 1997 Natural gas — Sampling guidelines	IS 15125 : 2002	Identical
ISO 11541 : 1997 Natural gas — Determination of water content at high pressure	Nil	—
ISO 12213-1 : 1997 Natural gas — Calculation of compression factor — Part 1: Introduction and guidelines	Nil	—
ISO 13443 : 1996 Natural gas — Standard reference conditions	IS 15126 : 2002	Identical

The Technical Committee responsible for the preparation of this standard will review the provisions of ISO 6326-1, ISO 6326-2, ISO 6326-3, ISO 6326-4, ISO 6326-5, ISO 6327, ISO 6568, ISO 6750-1, ISO 6750-2, ISO 6750-3, ISO 6974, ISO 6975, ISO 10101-1, ISO 10101-2, ISO 10101-3, ISO 11541, and ISO 12213-1 and will decide whether they are acceptable for use in conjunction with this standard.

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