INTERNATIONAL STANDARD

**ISO 13686**

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# Natural gas — Quality designation

*Gaz naturel — Désignation de la qualité*



Reference number
ISO 13686:1998(E)

## Contents







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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 13686 was prepared by Technical Committee ISO/TC 193, *Natural gas*.

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

## Introduction

The need for an International Standard concerning the designation of natural gas quality was a basic reason for the establishment of ISO/TC 193 in 1989. Standardisation of the designation of quality is specifically stated in the scope of the TC. Natural gas, supplying 20 % of the world's primary energy, is likely to increase its market share greatly. Yet there is currently no generally accepted definition of natural gas quality.

To meet this need, it was decided that a general statement of the parameters (i.e. components and properties) required should be established and that the resulting International Standard would not specify values of, or limits for, these parameters.

Furthermore, it was decided that general-purpose natural gas transmitted to local distribution systems (LDS), referred to as "natural gas", should be the first consideration. Thus, this International Standard was developed. Informative annexes are attached as examples of actual natural gas quality specifications that already exist.

This International Standard does not impose any quality restrictions on raw gas transported via pipelines or gathering systems to processing or treating facilities.

It should be understood that this International Standard covers natural gas at the pipeline level prior to any treatment by LDS for peakshaving purposes. This covers the vast percentage of the natural gas that is sold in international trade and transmitted for custody transfer to local distribution systems.

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# 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 |
| $\overline{H}$ | 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 | | |
| Ethane | | |
| Propane | | |
| Butanes | | ISO 6568 |
| Pentanes | mol % | ISO 6974 |
| Hexanes plus | | ISO 6975 |
| Nitrogen | | |
| Carbon dioxide | | |

#### 5.1.2 Minor components

| Constituent | Units | Test methods |
|---|---|---|
| Hydrogen | | |
| Oxygen | | ISO 6975 |
| Carbon monoxide | mol % | ISO 6974 |
| 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<br>ISO 10101-2<br>ISO 10101-3<br>ISO 11541 |
| Hydrocarbon dew point | | °C (K) | |
| Hydrocarbon liquid content | | $mg/m^3$ | ISO 6570-1<br>ISO 6570-2<br>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:<br>A gas family is a collection of gases with common main constituents | Second family<br>NG or SNG |
| Gas group:<br>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:<br>A gas with which appliances operate under nominal conditions, when supplied at the corresponding normal pressure. | Gas in LDS |
| Limit gases:<br>Gases representative of extreme variations in the characteristics of the usable gases. | |
| Normal pressure:<br>The pressure at which appliances operate under nominal conditions, when they are supplied with the corresponding reference gas. | Pressure in LDS |
| Test pressures:<br>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.

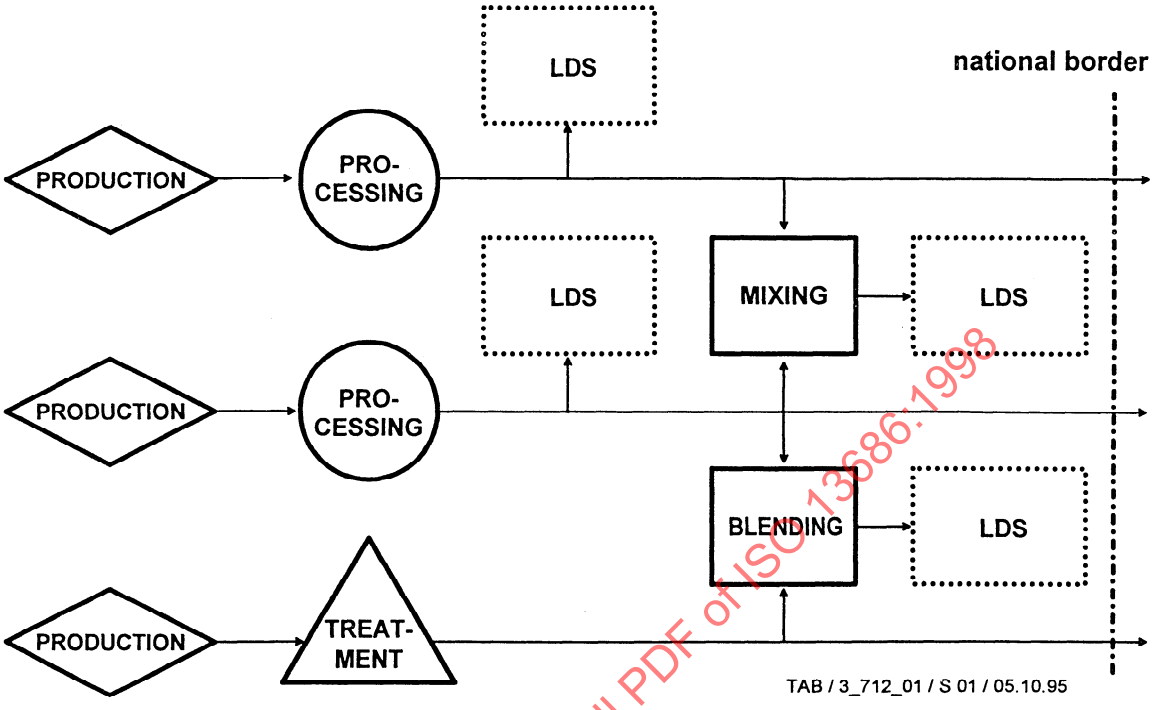
## A 2.5 French Method for Determining Gas Interchangeability (Delbourg Method) (see Annex G)

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

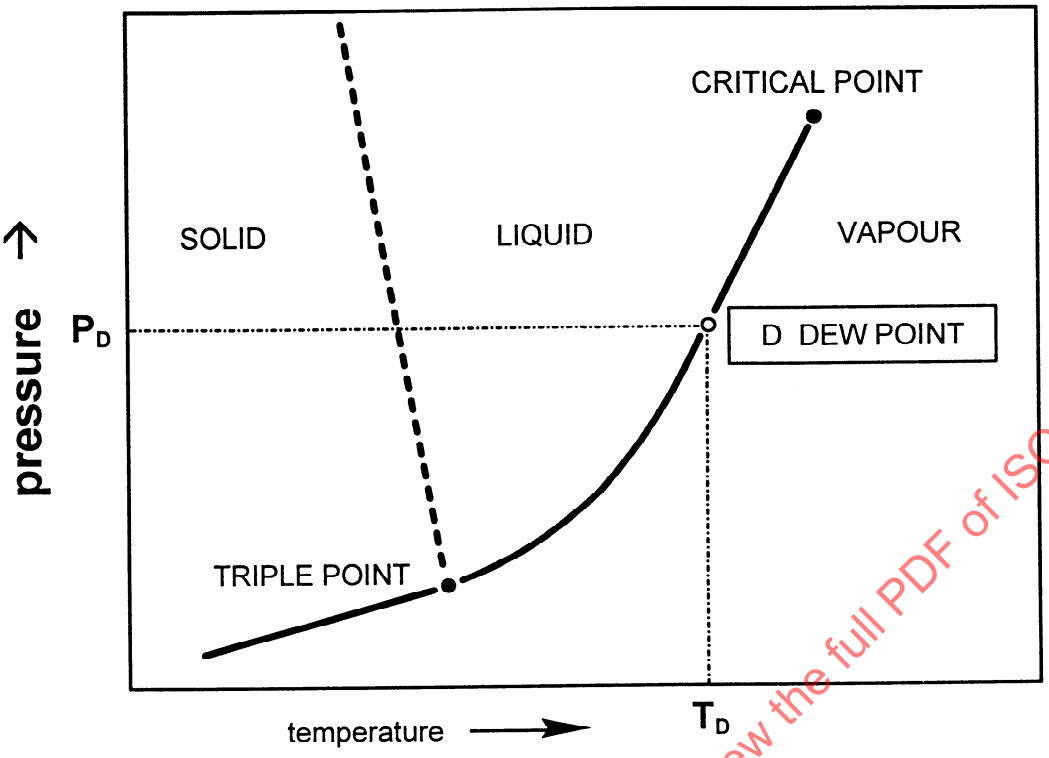
# A 3 Natural Gas , Local Distribution System



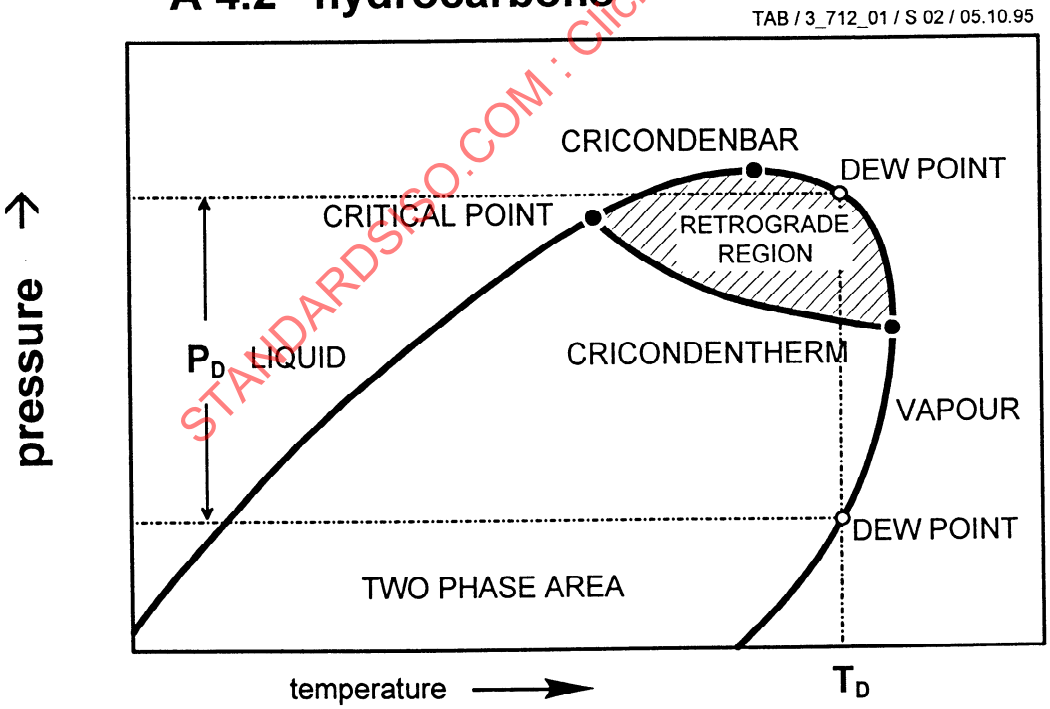

After PROCESSING the gas is suitable for use on LDS, after TREATMENT the gas is not suitable for use on LDS.
In the diagram MIXING relates to the mixing of two gases that are both suitable for use on an LDS. BLENDING has the purpose to produce an acceptable gas for distribution out of two gases where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

# A 4 condensation curves

## A 4.1 water




## A 4.2 hydrocarbons



## 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

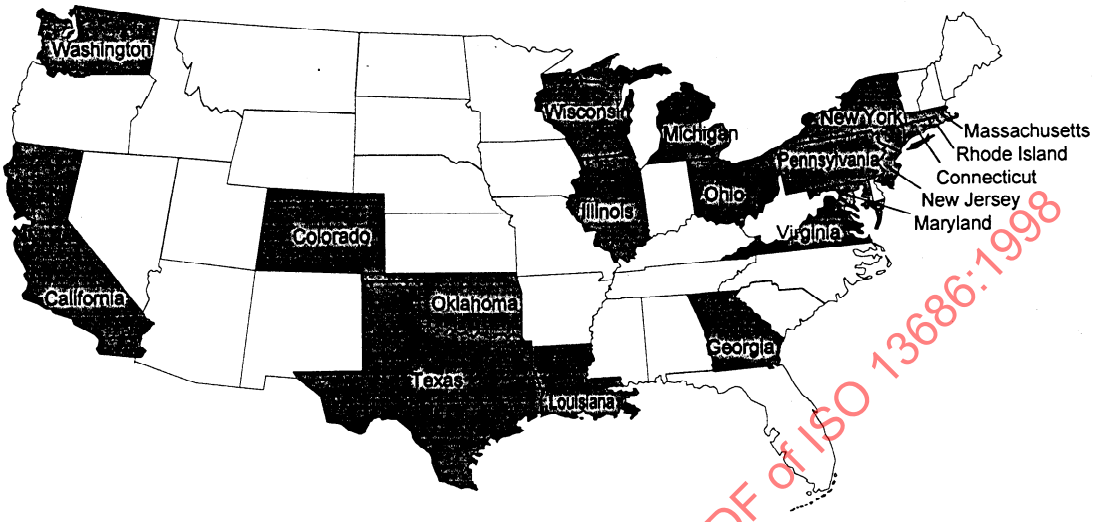
The methodology used to collect these data was described in the previous section, including the issue of weighting based on volumetric gas deliveries for statistics for all of the 26 cities. In total, these data constitute over 6.800 gas analyses. The Mean column in Table A.4 shows typical composition 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.

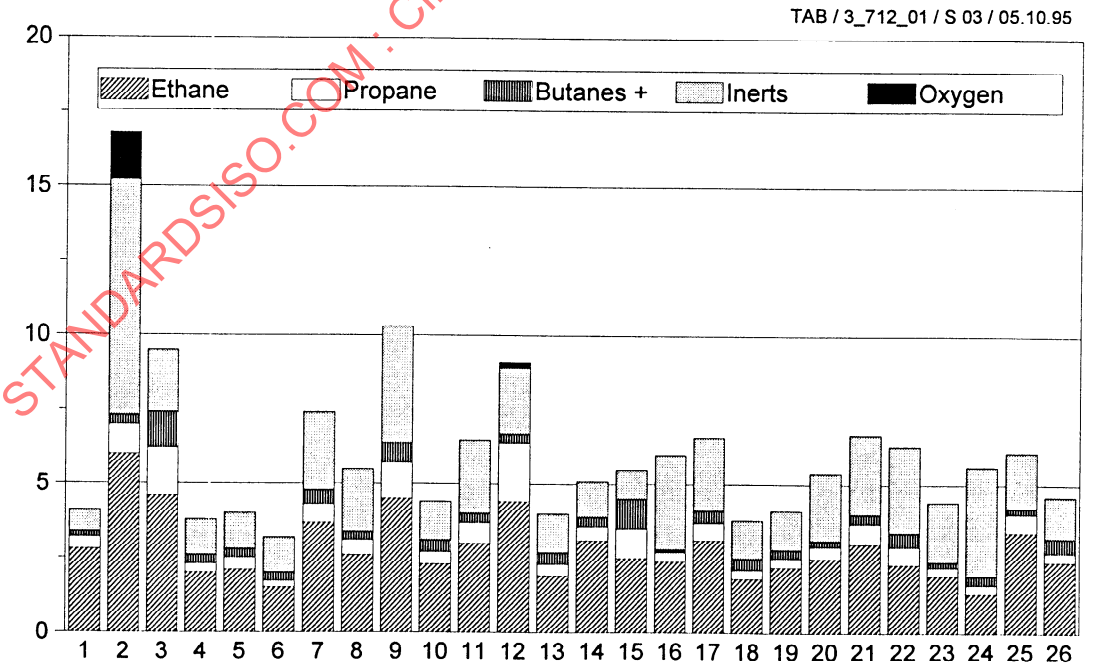
Table A.4 Natural gas composition and physical properties.

| | 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
$P_D = \psi \cdot p_s$;
$\psi$ 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
$\psi$ 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/m³, MJ/m³

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/m³<br>MJ/m³ | 10,5 to 13,0<br>37,8 to 46,8 | 12,8 to 15,7<br>46,1 to 56,5 |
| Rated value | | kWh/m³<br>MJ/m³ | 12,4<br>44,6 | 15,0<br>54,0 |
| Fluctuation range in local supply area | $W_{o,n}$ | kWh/m³ | + 0,6<br>- 1,2 | + 0,7<br>- 1,4 |
| Gross calorific value | $H_{o,n}$ | kWh/m³<br>MJ/m³ | 8,4 to 13,1<br>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/m³ | 120 | |
| short term | mg/m³ | 150 | |
| Mercaptan sulfur | mg/m³ | 6*) | |
| short term | mg/m³ | 16 | |
| Hydrogen sulfide | mg/m³ | 5 | |

*) The guide value for the mercaptan sulfur content of 6 mg/m³ 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 |

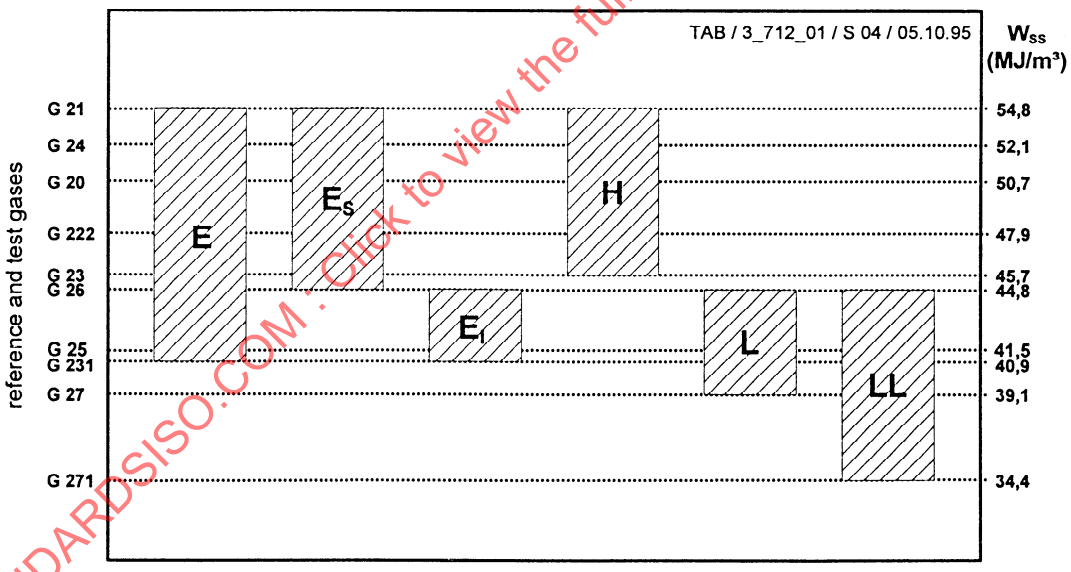



**FIGURE C.1 Gas groups and test gases in the 2nd family (NG) according to EN 437**

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**: | | | Limit Value |
| Heat Rate ratio | 1,078 | JH | |
| 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

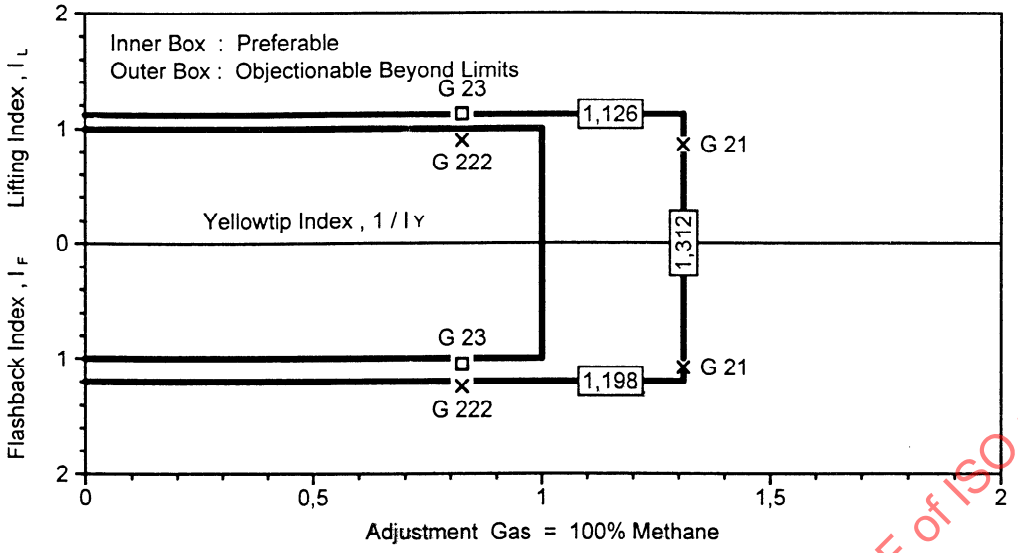
| | | | |
|---|---|---|---|
| A.G.A. BULLETIN 36: | | | |
| Lifting Index $I_l$ | 1,126 | A.G.A. 36 | PREDICTS LIFT PROB LIMIT VALUE |
| Flashback Ind. $I_f$ | 1,021 | | |
| Yellowtip Ind. $I_y$ | 1,177 | | |
| 1/Iy | 0,850 | | |
| **WEAVER**: | | | |
| Heat Rate ratio | 0,900 | JH | WEAVER JH OUT OF 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 |

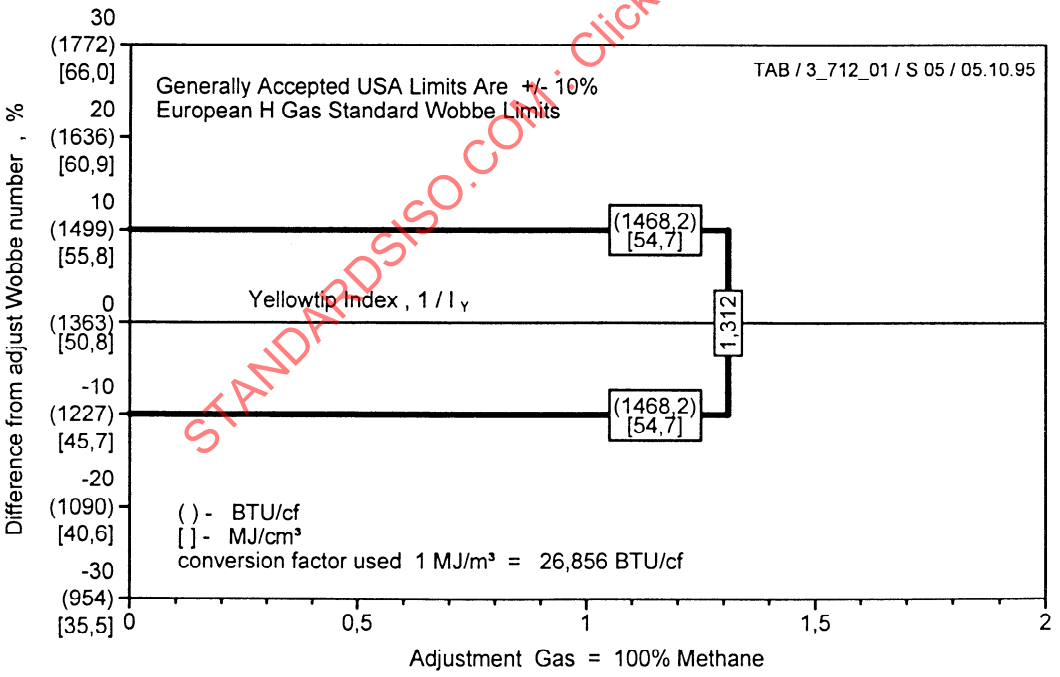
## AGA Index Method Interchangeability Limit Box

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

| Hydrocarbon | Equivalent | |
|---|---|---|
| | 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:
$W = 50,10\ MJ/m^3$