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Natural gas — Calculation of compression factor —

Part 1:
Introduction and guidelines

Gaz naturel — Calcul du facteur de compression —

Partie 1: Introduction et lignes directrices

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

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

ISO 12213-1 was prepared by Technical Committee ISO/TC 193, *Natural gas*, Subcommittee SC 1, *Analysis of natural gas*.

This second edition cancels and replaces the first edition (ISO 12213-1:1997), of which it constitutes a minor revision (the year of publication of Reference [5] in the Bibliography has been corrected).

ISO 12213 consists of the following parts, under the general title *Natural gas — Calculation of compression factor*:

- *Part 1: Introduction and guidelines*
- *Part 2: Calculation using molar-composition analysis*
- *Part 3: Calculation using physical properties*

Natural gas — Calculation of compression factor —

Part 1:
Introduction and guidelines

1 Scope

ISO 12213 specifies methods for the calculation of compression factors of natural gases, natural gases containing a synthetic admixture and similar mixtures at conditions under which the mixture can exist only as a gas.

It is divided into three parts: this part of ISO 12213 gives an introduction and provides guidelines for the methods of calculation described in ISO 12213-2 and ISO 12213-3.

Part 2 gives a method for use where the detailed molar composition of the gas is known. Part 3 gives a method for use where a less detailed analysis, comprising superior calorific value (volumetric basis), relative density, carbon dioxide content and (if non-zero) hydrogen content, is available.

Both methods are applicable to dry gases of pipeline quality within the range of conditions under which transmission and distribution, including metering for custody transfer or other accounting purposes, are normally carried out. In general, such operations take place at temperatures between about 263 K and 338 K (approximately −10 °C to 65 °C) and pressures not exceeding 12 MPa (120 bar). Within this range, the uncertainty of prediction of both methods is about ± 0,1 % provided that the input data, including the relevant pressure and temperature, have no uncertainty.

NOTE Pipeline quality gas is used in this International Standard as a concise term for gas which has been processed so as to be suitable for use as industrial, commercial or domestic fuel. Although there is no formal international agreement upon the composition and properties of a gas which complies with this concept, some quantitative guidance is provided in 5.1.1. A detailed gas quality specification is usually a matter for contractual arrangements between buyer and seller.

The method given in Part 2 is also applicable (with increased uncertainty) to broader categories of natural gas, including wet or sour gases, within a wider range of temperatures and to higher pressures, for example for reservoir or underground storage conditions or for vehicular (NGV) applications.

The method given in Part 3 is applicable to gases with a higher content of nitrogen, carbon dioxide or ethane than normally found in pipeline quality gas. The method may also be applied over wider ranges of temperature and pressure but with increased uncertainty.

For the calculation methods described to be valid, the gas must be above its water and hydrocarbon dewpoints at the prescribed conditions.

This International Standard gives all of the equations and numerical values needed to implement both methods. It is planned to make verified computer programs available (see Annex B).

2 Normative references

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

ISO 6976, *Natural gas — Calculation of calorific values, density, relative density and Wobbe index from composition*

ISO 13443, *Natural gas — Standard reference conditions*

3 Terms and definitions

For the purposes of the various parts of this International Standard, the following terms and definitions apply.

3.1
compression factor
Z
ratio of the volume of an arbitrary mass of gas, at a specified pressure and temperature, to the volume of the same mass of gas under the same conditions as calculated from the ideal-gas law, as follows:

$$Z = V_\mathrm{m}(\mathrm{real})/V_\mathrm{m}(\mathrm{ideal}) \tag{1}$$

where

$$V_\mathrm{m}(\mathrm{ideal}) = RT/p \tag{2}$$

NOTE 1 Thus

$$Z(p, T, y) = pV_\mathrm{m}(p, T, y)/(RT) \tag{3}$$

where

p is the absolute pressure;

T is the thermodynamic temperature;

y is a set of parameters which uniquely characterizes the gas (in principle, the latter may be the complete molar composition or a distinctive set of dependent physico-chemical properties, or a mixture of both);

V_m is the molar volume of the gas;

R is the molar gas constant, in coherent units.

NOTE 2 The compression factor is a dimensionless quantity usually close to unity.

NOTE 3 The terms “compressibility factor” and “Z-factor” are synonymous with compression factor.

3.2
density
ρ
mass of a given quantity of gas divided by its volume at specified conditions of pressure and temperature

3.3
molar composition
term used when the proportion of each component in a homogeneous mixture is expressed as a mole (or molar) fraction, or mole (molar) percentage, of the whole

NOTE 1 Thus the mole fraction x_i of component i is the ratio of the number of moles of component i in a given volume of a mixture to the total number of moles of all the components in the same volume of the mixture. One mole of any chemical species is the amount of substance which contains the relative molecular mass in grams. A table of recommended values of relative molecular masses is given in ISO 6976.

NOTE 2 For an ideal gas, the mole fraction (or percentage) is identical to the volume fraction (or percentage), but this is not in general a sufficiently accurate approximation to real-gas behaviour for the purposes of this International Standard.

3.4
molar calorific value

H

amount of heat which would be released by the complete combustion in air of the hydrocarbons in one mole of natural 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 specified temperature

NOTE 1 The molar calorific value only includes the hydrocarbons in the natural gas, i.e. inert components (primarily nitrogen, carbon dioxide and helium) and other combustible components (such as hydrogen and carbon monoxide) are excluded.

NOTE 2 The specified temperature is 298,15 K (25 °C) and the reference pressure is 101,325 kPa.

NOTE 3 The term “molar heating value” is synonymous with “molar calorific value”.

3.5
superior calorific value (volumetric basis)

H_S

amount of heat which would be released by the complete combustion in air of all the combustible components in unit volume of natural 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 specified temperature

NOTE 1 The superior calorific value includes all the combustible components in the natural gas.

NOTE 2 The reference temperature at which the volume is measured is 273,15 K (0 °C) and the specified temperature at which combustion takes place is 298,15 K (25 °C). The reference pressure is 101,325 kPa.

NOTE 3 Annex D of ISO 12213-3:2006 gives conversion factors which enable superior calorific values and relative densities determined at other reference or specified temperatures, and other reference pressures, including the ISO standard reference conditions (see ISO 13443), to be used as input data for the calculation method described.

NOTE 4 The terms “gross”, “higher”, “upper” and “total calorific value” and “heating value” are synonymous with “superior calorific value”.

3.6
relative density

d

ratio of the mass of a given volume of natural gas to the mass of dry air of standard composition which would be contained in the same volume at the same reference conditions of pressure and temperature

NOTE 1 The relative density includes all the components of the natural gas.

NOTE 2 The standard composition of dry air is given in ISO 6976.

NOTE 3 In this International Standard, the reference temperature is 273,15 K (0 °C) and the reference pressure is 101,325 kPa (see Note 3 to 3.5).

NOTE 4 The term “specific gravity” is synonymous with “relative density”.

3.7
uncertainty of a predicted compression factor

$\pm \Delta Z$

range of values $Z - \Delta Z$ to $Z + \Delta Z$ within which the (unknown) true value is expected to lie with a confidence level of 95 %

NOTE 1 This uncertainty may be expressed either as an absolute value or as a percentage.

NOTE 2 Estimates of the 95 % confidence limits are, to the extent that this is practicable, established by comparison of test data of low uncertainty with calculated values of Z.

4 General principles

The methods recommended use equations which are based on the concept that any natural gas may be uniquely characterized for calculation of its volumetric properties either by component analysis or by an appropriate and distinctive set of measurable physical properties. These characteristics, together with the pressure and temperature, are used as input data for the methods.

In the sense that the volumetric behaviour of a gas mixture derives directly from the numbers and types of molecular interactions (collisions) which take place, a method which explicitly recognizes each molecular constituent of the mixture, and its proportion of the whole, is to some degree more fundamental than alternatives.

The method given in Part 2 of this International Standard uses a detailed molar-composition analysis in which all constituents present in amounts exceeding a mole fraction of 0,000 05 should be represented. The sum of the mole fractions used should be unity to within 0,000 1. For a typical distributed (pipeline quality) gas, this includes all alkane hydrocarbons up to about C_7 or C_8 together with nitrogen, carbon dioxide and helium. For gases containing a synthetic admixture, hydrogen, carbon monoxide and ethylene are also likely to be significant components. For broader categories of gas, other components such as water vapour and hydrogen sulfide need to be taken into consideration.

The equation recommended is known as the AGA8 detailed characterization equation, and will be referred to hereafter as the AGA8-92DC equation [1] (see Bibliography). It is a revision of the equation described in AGA Report No. 8 [2].

The method given in Part 3 of this International Standard uses two distinct physical properties, namely superior calorific value and relative density, together with the carbon dioxide content.

NOTE In principle, any three from superior calorific value, relative density, carbon dioxide content and nitrogen content may be used, the calculation methods being essentially equivalent. However, the set comprising the first three is preferred for this International Standard. The reader interested in the use of alternative input variables is referred to the GERG TM5 documentation [3].

This method is particularly useful in the common situation where a complete molar composition is not available, but may also be preferred for its relative simplicity. For gases containing a synthetic admixture, the amount of hydrogen needs to be known.

The equation recommended is known as the SGERG-88 equation [3]. This equation is derived from the MGERG-88 equation [4], which uses a detailed molar analysis to characterize the gas.

The evaluation of both the AGA8-92DC and the SGERG-88 equations has been carried out using a large databank of high-accuracy (± 0,1 %) compression factor measurements (most of which are traceable to the relevant international metrological standards), compiled for the purpose by the Groupe Européen de Recherches Gazières [5] and the Gas Research Institute [6], [7]. Within the transmission and distribution pressure and temperature ranges, the equations are of essentially identical performance.

5 Guidelines

5.1 Pipeline quality natural gases

5.1.1 Pipeline quality gas

To make a definitive quantitative specification of what does or does not represent pipeline quality natural gas is, for several reasons, an elusive and contentious objective. Nevertheless, most transmission and distribution engineers are familiar with the general concept and will normally know whether any particular natural gas falls within the scope of this term. The following is therefore intended simply to provide summary guidance for any other users, rather than to formalize criteria for pipeline quality gas.

Pipeline quality gas is taken to consist predominantly (mole fraction greater than 0,70) of methane and to have a superior calorific value normally within the range 30 $MJ \cdot m^{-3}$ to 45 $MJ \cdot m^{-3}$ (see Table 1). Nitrogen and carbon dioxide are the main diluents (each up to a mole fraction of about 0,20).

Ethane (up to a mole fraction of about 0,10), propane, butanes, pentanes and higher alkanes will usually be present in steadily decreasing amounts. Minor amounts of helium, benzene and toluene may be present at mole fractions of less than 0,001. For natural gases with a synthetic admixture, hydrogen and carbon monoxide may be present in mole fractions of up to about 0,10 and 0,03, respectively, and there may be small amounts of ethylene. No other component, such as those found in wet and sour gases (for example water vapour, hydrogen sulfide or oxygen), is normally present in greater than trace amounts, and there should be no aerosol, liquid or particulate matter present. Minor and trace components should be treated as specified in Part 2 of this International Standard.

This way of defining pipeline quality gas is not intended to exclude natural gases of other compositions from being transported through pipelines.

The limits allowable for the purpose of this International Standard are given in Table 1.

Table 1 — Allowable limits for mole fractions of components

Component	Mole fraction
Main components	
Methane	$\geqslant 0{,}70$
Nitrogen	$\leqslant 0{,}20$
Carbon dioxide	$\leqslant 0{,}20$
Ethane	$\leqslant 0{,}10$
Propane	$\leqslant 0{,}035$
Butanes	$\leqslant 0{,}015$
Pentanes	$\leqslant 0{,}005$
Hexanes	$\leqslant 0{,}001$
Heptanes	$\leqslant 0{,}000\,5$
Octanes and above	$\leqslant 0{,}000\,5$
Hydrogen	$\leqslant 0{,}10$
Carbon monoxide	$\leqslant 0{,}03$
Helium	$\leqslant 0{,}005$
Water	$\leqslant 0{,}000\,15$
Minor and trace components	
Ethylene	$\leqslant 0{,}001$
Benzene	$\leqslant 0{,}000\,5$
Toluene	$\leqslant 0{,}000\,2$
Argon	$\leqslant 0{,}000\,2$
Hydrogen sulfide	$\leqslant 0{,}000\,2$
Oxygen	$\leqslant 0{,}000\,2$
Total unspecified components	$\leqslant 0{,}000\,1$

5.1.2 Transmission and distribution metering

The main use of this International Standard is expected to be for the calculation of compression factors in applications concerned with transmission and distribution of pipeline quality gases. The range of conditions encountered in such applications varies from country to country, but almost all will be covered by the limits

$$263 \text{ K} \leqslant T \leqslant 338 \text{ K}$$

$$0 \text{ MPa} < p \leqslant 12 \text{ MPa}$$

The methods given in Parts 2 and 3 apply with equal validity for all conditions within these limits.

5.1.3 Calculation using a molar-composition analysis

The AGA8-92DC equation may be used for any pipeline quality gas for which a detailed molar-composition analysis is available. The components which the analysis should include are: methane, nitrogen, carbon dioxide, carbon monoxide, hydrogen, helium, ethane, propane, butanes, pentanes, hexanes, and (if present at mole fractions greater than 0,000 05) higher hydrocarbons up to C_{10}. The amount of each minor or trace component specified in the lower part of Table 1 should be demonstratably within the relevant limit. Any non-negligible amount of a minor or trace component should be treated in the manner specified in Part 2 of this International Standard.

Within the ranges quoted in 5.1.2, the calculated compression factor values have the same status (i.e. equal validity) as those calculated from superior calorific value, relative density and carbon dioxide content.

The method may be used in all applications where the composition is subject to regular or semi-continuous determination.

5.1.4 Calculation using physical properties

The SGERG-88 equation may be used for any pipeline quality natural gas having a superior calorific value in the range 30 $\text{MJ}\cdot\text{m}^{-3}$ to 45 $\text{MJ}\cdot\text{m}^{-3}$, a relative density in the range 0,55 to 0,80, a known carbon dioxide content and a known hydrogen content.

Within the range quoted in 5.1.2, the calculated compression factor values have the same status (i.e. equal validity) as those calculated from a complete molar-composition analysis.

The method may be used in all applications where H_S and d are subject to regular or continuous determination.

5.1.5 Manufactured gases

Neither the AGA8-92DC method given in Part 2 nor the SGERG-88 method given in Part 3 is specifically intended for use with manufactured (synthetic) gases, as these may contain substantial amounts of chemical species which are atypical of natural gases, or common species in atypical proportions (see 5.2.3).

Either method may, however, be used if it can be demonstrated that the composition of the synthetic gas closely matches that of a possible true natural gas, all of the components falling within the ranges of concentration given in 5.1.1, with hydrocarbons above butane (C_4) either absent or decreasing regularly with increasing carbon number. In the sense that hydrocarbons above C_4 are virtually absent, liquefied natural gas may fall within this category.

In addition, the SGERG-88 method may be used with natural gases containing a coke-oven gas mixture up to the specified concentration limit for hydrogen. The method may not, however, be used with “undiluted” coke-oven gas.

5.1.6 Predictive uncertainty

Given exact values of all of the relevant input variables, the methods given in Parts 2 and 3 are both expected to achieve an uncertainty of prediction of ± 0,1 % in the compression factor for the entire ranges of composition and physical properties given in 5.1.1 for pipeline quality gas, and of pressure and temperature quoted in 5.1.2 for transmission and distribution applications.

The only exceptions to this are as follows. For the prediction of Z, by the method given in Part 3, for gases containing more than a 0,15 mole fraction of nitrogen or 0,05 of carbon dioxide (up to the relevant limits of 0,20), an uncertainty within ± 0,10 % is only maintained up to about 10 MPa for nitrogen and 6 MPa for carbon dioxide (see 5.2.2).

It is stressed, however, that any uncertainty in the input variables adds further uncertainty to the result. The sensitivity of the result to the accuracy of the input variables depends significantly, and in a complicated manner, upon:

a) the magnitude of each input variable;

b) the degree of independence of each input variable from the values of other input variables.

In most cases, the greatest sensitivity of the result towards all of the input variables is found at the upper extremity of the pressure range (12 MPa) and the lower extremity of the temperature range (263 K).

As a general guideline only, uncorrelated uncertainties of the variables listed in Table 2 may contribute to an additional uncertainty of the result of about ± 0,1 % at 6 MPa and within the temperature range 263 K to 338 K.

Table 2 — Allowable uncertainties of input variables for $\Delta Z < 0{,}1$ %

Input variable	Allowable uncertainty
Calorific value	± 0,06 MJ·m^{-3}
Relative density	± 0,001 3
Temperature	± 0,15 K
Pressure	± 0,02 MPa
Mole fraction of	
inerts	± 0,001
methane	± 0,001
ethane	± 0,001
propane	± 0,000 5
butane	± 0,000 3
pentanes plus higher hydrocarbons	± 0,000 1
hydrogen and carbon monoxide	± 0,001

Thus, the choice of calculation method should take into account not only the availability of an appropriate form of input data, but also its accuracy. In circumstances where it is unclear whether the instrumental accuracy is sufficient, the user should carry out sample calculations of the compression factor at the highest pressure and lowest temperature of interest in order to establish, for gases typical of the application in question, the sensitivity to independent small variations of all input variables.

5.1.7 Wider ranges of pressure and temperature

Both the AGA8-92DC and SGERG-88 equations degrade in accuracy outside the primary ranges of pressure and temperature given in 5.1.2.

However, the AGA8-92DC equation is generally expected to extrapolate beyond these ranges more accurately than the SGERG-88 equation, and consequently would often be the preferred alternative for applications outside the normal range of transmission and distribution conditions.

The predictive uncertainty of the AGA8-92DC equation depends strongly upon both the composition of the gas and the conditions under consideration. Further advice is given in Part 2 concerning the uncertainty of prediction to be expected at any selected conditions. This uncertainty may sometimes be almost as low as that for the transmission and distribution region, but at extremes of temperature or pressure will be significantly greater. Because of the lack of high-accuracy test data, it is extremely difficult to assess the uncertainty.

5.2 Other gases and other applications

5.2.1 Introduction

Not all fluids with which the gas engineer may typically have to deal, and for which he may need to know compression factors, are natural gases of pipeline quality. For example, unprocessed (well-head) or partially processed natural gases do not normally fall within the scope of the term pipeline quality gas as defined in 5.1.1, for which this International Standard is primarily intended. Nor do manufactured gases.

Nevertheless, the methods recommended in Parts 2 and 3 can be applied, with certain restrictions and with increased uncertainty, to such gases. Although such gases may not usually be distributed to end-users, many of the applications for which calculations are required are for pressure and temperature values which fall within the ranges specified in 5.1.2.

Self-evidently, the guidelines which can be given (as well as the calculation uncertainties) become less definitive as limitations on the allowable pressure, temperature and composition ranges are relaxed.

5.2.2 Lean and rich gases

Some natural gases exist, and are distributed, which contain nitrogen, carbon dioxide, ethane or higher hydrocarbons in amounts which exceed the limits for which an uncertainty of ± 0,1 % can properly be claimed. In this context, gases which contain more than a 0,15 mole fraction of nitrogen or a 0,05 mole fraction of carbon dioxide are termed “lean”, and gases which contain more than a 0,10 mole fraction of ethane or 0,035 of propane, and so on, are termed “rich”.

The methods recommended in Parts 2 and 3 can both be applied to these types of lean and rich gases, but with some increase in uncertainty of prediction.

For example, the method given in Part 3 may be applied to give an uncertainty within ± 0,2 % for natural gases containing up to about a 0,50 mole fraction of nitrogen, 0,18 of carbon dioxide or 0,13 of ethane at pressures up to 10 MPa. A more detailed estimate of the uncertainty for each method as a function of component mole fraction is given in Parts 2 and 3 where plots are given which show, for a wide range of temperatures, the pressure versus mole fraction surfaces for nitrogen, carbon dioxide, ethane and propane, respectively, with uncertainty of prediction as a parameter. The major problem in providing such plots is the paucity of high-accuracy test data.

5.2.3 Wet and sour gases

This category of gases is taken to comprise those gases which fall short of qualifying as pipeline quality natural gases only by the inclusion of undesirable components. Typically, such gases may be unprocessed (well-head) or partially processed natural gases and may contain, for example, water vapour (“wet” gases), hydrogen sulfide (“sour” gases) or oxygen in amounts significantly greater than those quoted in 5.1.1, perhaps also with traces of carbonyl sulfide and process-fluid vapours such as methanol or glycols.

The method given in Part 2 is applicable to any such gas, provided that the unwanted components are limited to water vapour, hydrogen sulfide and oxygen. The uncertainty of prediction is, however, substantially increased. The method given in Part 3 should not be applied to such gases.

5.2.4 Manufactured gases

Manufactured gases fall into two distinct categories, as follows:

a) those which are intended as synthetic or substitute natural gases, and which closely match true natural gases in both composition and properties;

b) those which, whether or not intended to replace or enhance natural gas in service, do not closely match natural gases in composition.

In case a), it is clear that, if the composition is such that the gas is indistinguishable from that of a possible true natural gas, then the methods given in Parts 2 and 3 apply with no increase in uncertainty (see 5.1.5). This is, however, rarely likely to be the case. More often, the manufactured gas, even if it contains inert and lower hydrocarbons in satisfactory proportions, will not exhibit the distinctive hydrocarbon "tail" of a true natural gas and may additionally contain small but significant amounts of non-alkane hydrocarbons. It is difficult to assess the effects of this upon the uncertainty of prediction.

Case b) includes gases such as town gas, (undiluted) coke-oven gas, and LPG-air mixtures, none of which is compositionally similar to a true natural gas (even though, in the latter case, it may be operationally interchangeable with natural gas). The method given in Part 3 should not be applied to any such gases. The method given in Part 2 may be applied, but the uncertainty of prediction is extremely difficult to assess.

5.2.5 Summary of predictive uncertainty

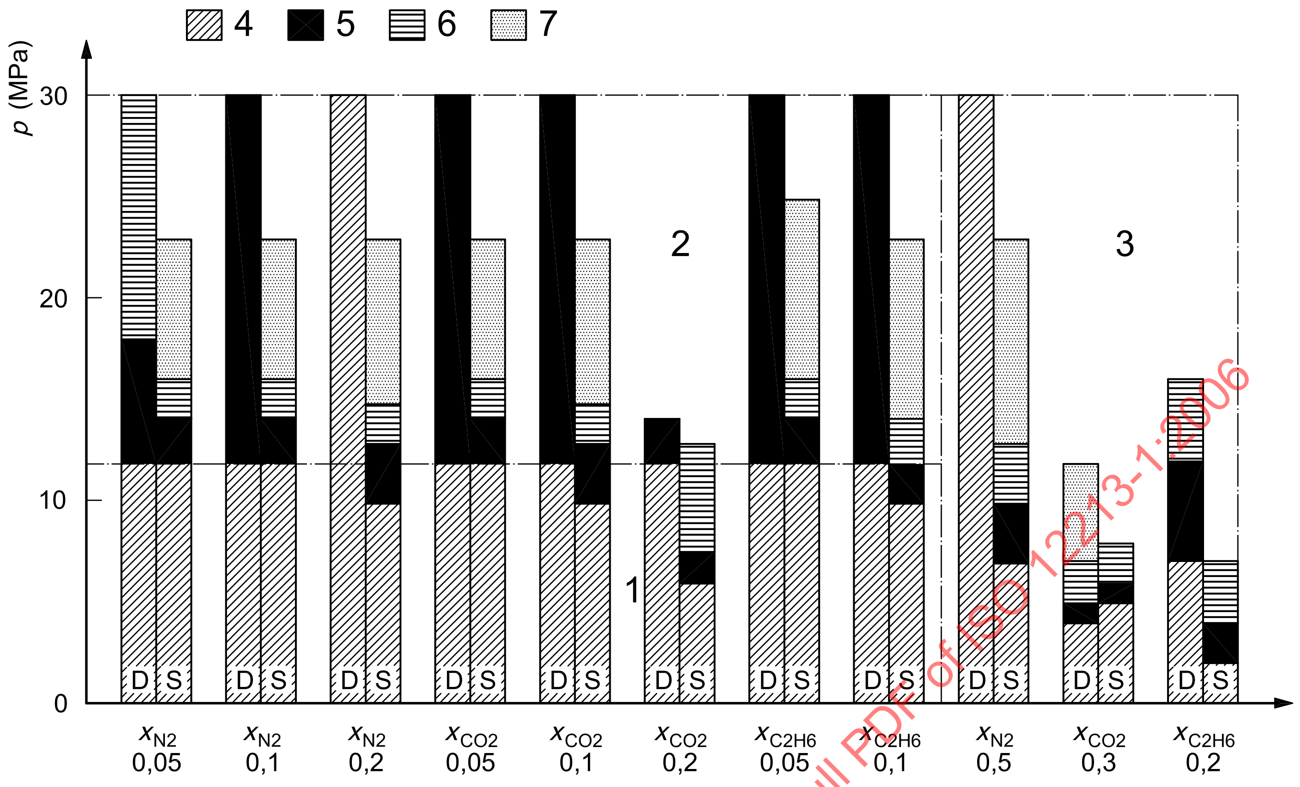
The expected uncertainties of the calculation methods given in Part 2 and Part 3 are summarized in Figure 1. The uncertainties are given as pressure versus mole fraction bar charts for various contents of nitrogen, carbon dioxide and ethane. Results are summarized for

a) pipeline quality natural gases within the normal ranges of temperature and pressure for transmission and distribution applications (263 K to 338 K; 0 MPa to 12 MPa);

b) pipeline quality natural gases for the same range of temperature, but for a wider range of pressure (up to 30 MPa);

c) wider ranges of gas composition (up to 0,5 N_2, 0,3 CO_2 and 0,2 C_2H_6) for the same ranges of temperature and pressure.

The more detailed information on which these bar charts are based is given in Annex E of Part 2 and Annex F of Part 3. Information concerning the performance outside the primary range of temperature and pressure is given in Figure 1 of Parts 2 and 3.



Key

p	pressure
x	mole fraction
D	AGA8-DC92 calculation method (Part 2) using molar-composition analysis
S	SGERG-88 calculation method (Part 3) using physical properties
1	pipeline quality natural gases (263 K to 338 K; 0 MPa to 12 MPa)
2	pipeline quality natural gases (263 K to 338 K; 12 MPa to 30 MPa)
3	wider ranges of gas composition (263 K to 338 K; 0 MPa to 30 MPa)
4	expected uncertainty $\leqslant \pm 0,1$ %
5	expected uncertainty $\pm 0,1$ % to $\pm 0,2$ %
6	expected uncertainty $\pm 0,2$ % to $\pm 0,5$ %
7	expected uncertainty $\pm 0,5$ % to $\pm 3,0$ %

Figure 1 — Expected uncertainty of the calculation methods given in Parts 2 and 3

5.2.6 Calculation of related properties

Although the express purpose of this International Standard is to permit calculations of compression factors, it is appropriate to note that other properties of natural-gas-type fluids may also be calculated by means of the methods described in Parts 2 and 3. Self-evidently, the molar density ρ_m, being simply the reciprocal of the molar volume V_m(real), is always available from Equations (1) and (2) once $Z(p, T)$ is known. The (mass) density ρ is also available, as the product of ρ_m and the mean molar mass M (molecular weight), if the latter is known, as is the case for any fluid characterized by a molar-composition analysis.

If the molar composition is not known, the mass density can instead be calculated by using the compression factors at pipeline and normal conditions together with the relative density and known mass density of dry air at normal conditions [see Part 3, Equation (B.42)].