FORTSCHRITT-BERICHTE VDI

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United Kingdom

The GERG Databank of High Accuracy Compressibility Factor Measurements

Reihe **6**: Energieerzeugung Nr. **251**

VDI VERLAG

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This monograph provides a complete listing in a single document of the entire contents of the GERG compressibility factor databank. The databank comprises high-accuracy measurements of compressibility factor within specified ranges of pressure (0 to 12 MPa), temperature (265 to 335 K) and gas composition, and includes all of the data used in the development and testing of the GERG virial equation. For pure gases there are 36 distinct data sets critically selected for inclusion, yielding 2374 data points; for binary mixtures 107 data sets, 5847 points; for ternary mixtures 18 data sets, 620 points; for quaternary and other synthetic multicomponent mixtures 20 data sets, 492 points; and for natural gas and natural gas/manufactured gas mixtures 84 data sets, 4486 points. The grand total, as of 31 March 1988, is 13819 data points, all with a supposed accuracy of no worse than ± 0.1%.

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THE GERG DATABANK OF HIGH ACCURACY COMPRESSIBILITY FACTOR MEASUREMENTS

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Abstract

This Monograph provides a complete listing in a single document of the entire contents of the GERG compressibility factor databank. The databank comprises high-accuracy measurements of compressibility factor within specified ranges of pressure (0 to 12 MPa), temperature (265 to 335 K) and gas composition, and includes all of the data used in the development and testing of the GERG virial equation. For pure gases there are 36 distinct data sets critically selected for inclusion, yielding 2374 data points; for binary mixtures 107 data sets, 5847 points; for ternary mixtures 18 data sets, 620 points; for quaternary and other synthetic multicomponent mixtures 20 data sets, 492 points; and for natural gas and natural gas/manufactured gas mixtures 84 data sets, 4486 points. The grand total, as of 31 March 1988, is 13819 data points, all with a supposed accuracy of no worse than ± 0.1%. Although many of the data have been drawn from the pre-existing research literature, substantial proportions of the data - especially those measured in-house by GERG member companies - have not previously been the subject of formal publication.

Resumé

Cette monographie fournit en un seul document le contenu intégral de la banque de données du facteur de compressibilité du GERG. Celle-ci comporte des données expérimentales de cette grandeur dans la gamme de pressions 0 à 12 MPa et de températures 265 à 335 K pour des compositions de gaz spécifiques. Elle comporte toutes les données utilisées pour développer et tester l'équation de viriel du GERG. On y trouve des données rigoureusement sélectionnées concernant les gaz purs (36 ensembles de données fournissant 2374 points), des mélanges binaires (107 ensembles de données, 5847 points), des mélanges ternaires (18 ensembles de données, 620 points), des mélanges quaternaires ou d'autres mélanges synthétiques multi-composants (20 ensembles de données, 492 points) et des gaz naturels ou des mélanges gaz naturel-gaz manufacturé (84 ensembles de données, 4486 points). Cela donne donc un total de 13819 données expérimentales (31.3.1988) dont la précision est meilleure que 0.1%. Bien que de nombreuses données aient été tirées de la recherches bibliographiques, une proportion importante, en particulier celles qui ont été obtenues dans les laboratoroires des compagnies membres du GERG, n'ont pas fait l'objet de publications antérieures.

Zusammenfassung

Die Monographie stellt in einem einzigen Dokument eine komplette Liste des gesamten Inhalts der GERG-Realgasfaktordatenbank zusammen. Die Datenbank unfasst hochgenaue Messdaten von Realgasfaktoren innerhalb des folgenden Druck- (0-12 MPa) und Temperaturbereichs (265-335 K) für die angegebenen Gaszusammensetzungen. Die Datenbank enthält alle Daten die bei der Entwicklung und beim Testen der GERG-Virialgleichung benutzt worden sind. Vor der Aufnahme von Datensätzen in die Datenbank wurden diese kritisch bewertet; dabei wurden 36 verschiedene Sätze für reine Gase mit insgesamt 2,374 Datenpunkten, für binäre Gemische 107 Datensätze mit 5,847 Datenpunkten, für ternäre Gemische 18 Datensätze mit 620 Punkten, für quaternäre oder andere synthetische Vielstoffgemische

20 Datensätze mit 492 Messpunkten und für Erdgase oder Erdgas-Kokereigasgemische 84 Datensätze mit 4,486 Messpunkten aufgenommen. Die Gesamtzahl aller Messpunkte beträgt 13,819 (Stand der GERG-Datenbank 31. März 1988). Für alle Datenpunkte wurde eine Messunsicherheit angenommen, die nicht grösser als ± 0.1% ist. Obwohl viele der Daten von früheren Literaturrecherchen übernommen worden sind, so ist doch der überwiegende Anteil der Daten insbesondere jener, der in den Labors der GERG-Mitgliedsfirmen gemessen worden ist, bisher nicht in einer anderen Publikation veröffentlicht worden.

Riassunto

Questa monografia fornisce in un singolo documento una lista completa dell'intero contenuto della banca dati GERG del fattore di compressibilità.

La banca dati comprende le misurazioni molto accurate del fattore di compressibilità comprese nel campo specificato di pressione (0-12 MPa), temperatura (265-335 K) e composizione del gas, e comprende tutti i dati utilizzati nello svilippo e nella verifica dell'equazione viriale GERG.

Per i gas puri ci sono 36 distinte serie di dati selezionati con l'inclusione di 2374 valori; per miscele binarie 107 seri di dati, 5847 valori; per miscele ternarie 18 serie di dati, 620 valori; per miscele quaternarie ed altre miscele sintetiche multi-componenti 20 serie di dati, 492 valori; e per miscele di gas naturale e gas naturale manifatturato 84 serie di dati, 4486 valori. Il totale generale è di 13819 valori (31.3.1988), tutti con un'accuratezza ritenuta non peggiore di ± 0.1%.

Sebbene molti dati sono stati estratti dalla preesistente letteratura di ricerca, la parte sostanziale dei dati, specialmente quelli misurati presso le Società membre del GERG, non sono stati precedentemente oggetto di formale pubblicazione.

Samenvatting

Deze monograaf geeft een volledig overzicht van de gegevens die gebruikt zijn voor de ontwikkeling en het testen van de GERG-viriaalvergelijking. Deze databank bevat zeer nauwkeurige metingen van de compressibiliteitsfactor voor gespecificeerde gebieden van druk (0-12 MPa), temperatuur (265-335 K) en gassamenstelling. Voor pure gassen zijn 36 afzonderlijke datasets kritisch geselecteerd, resulterend in 2374 datapunten. Voor binaire mengsels zijn 107 datasets geselecteerd (5847 punten), voor ternaire mengsels 18 datasets (620 punten), voor quaternaire en andere synthetische multi-componenten systemen 20 datasets 492 punten), en voor aardgas-en synthetische aardgasmengsels 84 datasets (4486 punten). Totaal resulteert dit in 13819 datapunten (31.3.1988), alle met een geschatte nauwkeurigheid van beter dan ± 0.1%

Hoewel een deel van de gegevens overgenomen is uit de literatuur, is een aanzienlijk deel, gemeten door GERG-leden, niet eerder gepubliceerd in de open literatuur.

Acknowledgements

We wish again to express our due appreciation to Dr. A. Melvin (formerly Chairman) and to other members of the GERG Programme Committee No.1, for their continued support and encouragement throughout the course of the co-operative project concerning the prediction of compressibility factors for natural gases, for which the development of the GERG databank was such an important aspect.

We also wish to thank Dr. J.A. Schouten and Dr. J.P.J. Michels (University of Amsterdam) for their contracted work in support of GERG Working Group 1.1, during which they carried out the addition of much new data and re-cast the original GERG databank into its present 5-file format. Most of the newer experimental data were measured in the Gasunie and Ruhrgas laboratories; we thank in particular H.C. Reinhardus and H.M. Hinze for their contributions of high quality measurements. Finally we wish to thank H.P. Jülicher and H. Scheuren for recent updates to and maintenance of the databank.

1. INTRODUCTION

1.1 The GERG-88 Virial Equation

The recent development of the GERG-88 virial equation (references 1-7) has for the first time enabled the ready calculation of the compressibility factor Z_{mix} for natural gas and natural gas/manufactured gas mixtures (the latter possibly containing substantial amounts of hydrogen), for a wide range of compositions and conditions relevant to gas transmission and distribution applications, with an expectation accuracy of ±0.1%. The GERG-88 equation is conceptually simple, taking the form of a virial expansion in density truncated after the third term, viz.

$$Z_{mix}(p,T) = 1 + B_{mix}(T)\ \rho_m + C_{mix}(T)\ \rho_m^2 \qquad (1.1)$$

in which $\rho_m = p/Z_{mix}RT$ (1.2)

and (exactly)

$$B_{mix}(T) = \sum_{i=1}^{N} \sum_{j=1}^{N} x_i x_j\ B_{ij}(T) \qquad (1.3)$$

$$C_{mix}(T) = \sum_{i=1}^{N} \sum_{j=1}^{N} \sum_{k=1}^{N} x_i x_j x_k\ C_{ijk}(T) \qquad (1.4)$$

where (approximately)

$$B_{ij}(T) = b_{ij}^{(0)} + b_{ij}^{(1)}\ T + b_{ij}^{(2)}\ T^2 \qquad (1.5)$$

$$C_{ijk}(T) = c_{ijk}^{(0)} + c_{ijk}^{(1)}\ T + c_{ijk}^{(2)}\ T^2 \qquad (1.6)$$

The virial expansion (equations (1.1) to (1.4)) has a sound theoretical basis within the framework of classical statistical mechanics (8,9).

The general formulation given above applies equally to two distinct versions of the GERG-88 virial equation, as follows -

(a) The Master Equation (MGERG-88)

For the Master GERG-88 virial equation, the input requirement is a detailed molar composition analysis, comprising up to 13 specified components (C1 to C8 alkane hydrocarbons, carbon dioxide, nitrogen, hydrogen, carbon monoxide and helium), together with temperature and pressure. The summations in equations (1.3) and (1.4) are therefore to be taken for N=13; as a consequence of this, the number of second virial coefficients B_{ij} and third virial coefficients C_{ijk} involved is rather large, even though considerable rationalisation is possible.

(b) The Standard Equation (SGERG-88)

For the Standard GERG-88 virial equation, the input requirement is simplified. The total natural gas mixture is taken to comprise simply nitrogen and carbon dioxide as first and second components, a third pseudo-component, or "equivalent hydrocarbon" CH, and (if present) hydrogen as a fourth component. Both the mole fraction and the virial coefficients of the equivalent hydrocarbon are inferred through knowledge of the superior (gross) calorific value and relative density (specific gravity) of the whole natural gas. Thus, the input requirement is, in addition to the temperature and pressure, the hydrogen content and any three from calorific value, relative density, carbon dioxide content and nitrogen content: such information is more commonly available than a detailed analysis, and allows the summations of equations (1.3) and (1.4) to be much reduced (to N=4) without loss of accuracy in the final result.

These matters have been documented in detail elsewhere (6,7) and, therefore, need not be further elaborated here.

Both versions of the GERG-88 virial equation are easily implemented on a small personal computer. Validated programs are available on request from either of the present authors.

1.2 Evaluation of Second and Third Virial Coefficients

Given the simplicity of structure of the MGERG-88 virial equation, the major task in suiting it for the calculation of natural gas compressibility factors becomes the evaluation of the second and third virial coefficients B_{ij} and C_{ijk} (including their dependence upon temperature), with an appropriate level of accuracy, for each distinct type of bimolecular (ij) and termolecular (ijk) interaction. To best achieve this, each B_{ij} and C_{ijk} should be derived from experimental measurements of the volumetric properties of pure, binary and ternary gas mixtures. Details of the procedures involved have been given elsewhere (6), but in principle and in brief -

- measurements of compressibility factors of pure gases are used to determine each B_{ii} and C_{iii} by applying equations (1.1) to (1.6) to the single component (N=1) case;

- measurements on binary mixtures are then used, in conjunction with the now known values of B_{ii} and C_{iii}, to determine each B_{ij}, C_{iij} and C_{ijj} by applying equations (1.1) to (1.6) to the two component (N=2) case;

- measurements on ternary mixtures are finally used with the now known values of B_{ii}, B_{ij}, C_{iii}, C_{iij} and C_{ijj} to determine each C_{ijk} by applying equations (1.1) to (1.6) to the three component (N=3) case.

The above is a statement of the most satisfactory procedural strategy - in principle; practical considerations, however, particularly those concerning error propagation and cumulation (6), do not always allow such straightforward purity of evaluative technique. Very often, appropriately accurate data simply do not exist, so that B_{ij} and, particularly, C_{ijk} values must then be assessed by other means; equally, however, many of the B_{ij} and C_{ijk} are not critical to the final predictive accuracy and may justifiably be approximated, often to zero.

In any event, once a set of values for the various B_{ij} and C_{ijk} have been obtained, equations (1.1) and (1.2) may be used in a predictive mode to obtain values of $Z_{mix}(p,T)$, given the molar composition of a multicomponent mixture. Consequently, volumetric properties of more complex mixtures are needed as test data to check the accuracy of such predictions.

1.3 The GERG Experimental Measurements and Databank of Compressibility Factors

It is clear from the foregoing that, in both the development and subsequent testing of the GERG-88 virial equation, there has been an essential requirement for large amounts of accurate compressibility factor data for pure gases, binary mixtures, ternary mixtures and more complex multicomponent mixtures. As a fundamental part of the entire project, therefore, an extensive programme of experimental work was initiated in order to produce high-accuracy compressibility factor data, both for pure gases and for binary and other more complex mixtures, especially such data as were evidently vital for the successful completion of correlational work leading to the final form of the GERG-88 virial equation.

Of similar importance for the work on the GERG-88 virial equation has been the provision of easy access to the large amounts of compressibility factor data finally used in both the correlation and subsequent testing of the equation. Consequently, a unique databank has been established with which to facilitate the various analyses involved. This started out in a small way in the early 80s (<1000 points), grew steadily until mid-decade (>3000 points), but in the last few years has expanded rapidly to its present size (>13000 points). It has been organised into a set of five computer files, as follows -

(a) The A-File

This file contains data for pure gases only. There are 36 distinct data sets critically selected for inclusion, comprising a total of 2374 data points. Further details are given in Section 3.2.

(b) The B-File

This file contains data for binary mixtures only. There are 107 data sets, comprising 5847 data points. Further details are given in Section 3.3.

(c) The C-File

This file contains data for ternary mixtures only. There are 18 data sets, comprising 620 data points. Further details are given in Section 3.4.

(d) The D-File

This file contains data for quaternary and other synthetic multicomponent mixtures. There are 20 data sets, comprising 492 data points. Further details are given in Section 3.5.

(e) The N-File

This file contains data for natural gas and natural gas/ manufactured (coke-oven) gas mixtures. There are 84 data sets, comprising 4486 points, plus an additional 12 data sets, comprising a further 364 data points, added since the original cut-off date of 31 March 1988. Further details are given in Section 3.6.

The purpose of this Monograph is mainly to act as a single, openly available, repository for all of the data contained in these files. Although many of the data have been drawn from the pre-existing research literature, substantial proportions of the data - especially those mentioned above which were recently measured in-house by GERG member companies, expressly for the purpose of supporting development of the GERG equation - have not previously been the subject of formal publication. This being so, some information concerning the in-house measurements, brief descriptions of the equipment used in their generation, and details of further work to supplement the GERG databank will be presented in the next section.

2. MEASUREMENTS MADE BY GERG MEMBER COMPANIES

2.1 Z-Meter Measurements

A large proportion of the databank consists of compressibility factors obtained from experiments undertaken with commercial "Z-meters", manufactured by Desgranges et Huot (DEH).

The DEH Z-meter is, in principle, a two-chamber isothermal expansion type meter but, unlike the more conventional and well-known Burnett apparatus (10), the DEH Z-meter uses a single-step expansion (11,12), from a high-pressure small-volume chamber into a low-pressure large-volume chamber. The six Z-meters owned and used by the six member companies of GERG Working Group 1.1 are operated with slightly different methodologies or protocols. The Z-meter principle and the main features of the different Z-meter apparatus used are described in a previous GERG Monograph (13). The accuracy is estimated to be some ± 0.1%.

2.2 Burnett Apparatus Measurements

High quality compressibility factor data available in the open research literature often derive from Burnett apparatus (BUR) measurements.

This apparatus comprises two fixed-volume test chambers. The gas sample is expanded isothermally from one chamber into the second (evacuated) chamber; this procedure is repeated several times, each successive expansion using only the gas remaining in the first chamber from the previous expansion. The pressures are measured before and after each expansion. The compressibility factor of the gas can be derived from the series of experimental pressure data. This use of the Burnett apparatus represents the classical experimental procedure for high quality determination of compressibility factor (see, for example, refs. 14-16).

The same procedure is applied to the Burnett apparatus at Ruhrgas A.G., as described by Jaeschke and Hinze (17). The Burnett apparatus constant (i.e. the volume ratio $(V_1 + V_2)/V_2$, where V_1 and V_2 are the volumes of the two chambers used) has a value of 1.315518 ± 0.000013. The accuracy is estimated to be some ± 0.07%.

A modified experimental procedure may be employed especially for measuring compressibility factors or densities near a phase-separation surface. The isochoric Burnett technique starts with gas at a density known from an isothermal expansion run. The density of the fluid in the Burnett apparatus is then kept constant while the state of the fluid is varied by increasing or decreasing the temperature, the pressure being recorded at each new equilibrium temperature. This valuable but very time-consuming procedure has been used, for example, by Holste *et al* (18).

2.3 Optical Interferometry Measurements

The optical interferometry apparatus (OPT) for compressibility factor determination consists essentially of two connected grating interferometers. One interferometer measures the refractive index of the sample gas as a function of pressure and temperature, while the second interferometer simultaneously measures the refractive index of nitrogen at a fixed temperature. The two instruments are interconnected through a pressure equilibrium chamber which adjusts the nitrogen pressure to equal that of the sample gas.

From the refractive index, measured with the first interferometer at a known pressure p and temperature T, the compressibility factor Z or density ρ can be derived by use of the Lorentz-Lorenz relation, which defines the molar refractivity as a function of refractive index and molar density. The refraction virial coefficients from the virial expansion of the molar refractivity in molar density may also be calculated.

The second interferometer is used as a pressure meter. It is calibrated, so as to yield a correlation between the refractive index of nitrogen for the 323.15 K isotherm and the pressure, by measuring simultaneously, at a given pressure, the fringe count of the interferometer filled with nitrogen and the pressure measured with a precision deadweight gauge. The latter is tested against a standard of the Physikalisch-Technische Bundesanstalt (PTB) in Brunswick (Federal Republic of Germany).

A general description of the grating interferometer and the experimental technique has been published (19-21). The apparatus, measurement and analysis procedure used at Ruhrgas A.G. are described elsewhere (17,22). The accuracy is estimated to be some ± 0.08%.

2.4 GERG Round-Robin Exercise

Six Z-meters manufactured by Desgranges et Huot were tested in the GERG round-robin exercise. The exercise was complemented by pVT measurements with two Burnett apparatus, one at Texas A&M University and the other at Ruhrgas A.G., and the interferometric device at Ruhrgas A.G. A full account of the work is given in a GERG Technical Monograph (13), based on an abbreviated version presented at the 10th International Symposium on Thermophysical Properties (Gaithersburg, 1988) and published in the International Journal of Thermophysics (23). The results are summarised in the Monograph as follows -

"Two gas mixtures were measured. One mixture contained 49.7 mole % of methane and 50.3 mole % of nitrogen, the second mixture 81.3 mole % of methane, 16.4 mole % of ethane and 2.3 mole % of propane. The test temperatures were mainly 280 and 300 K for the first mixture and 290 and 320 K for the second mixture. The maximum pressures were 8 MPa for Z-meters, and 12 MPa for the Burnett apparatus and the grating interferometer.

The experimental compressibility factors Z from the six Z-meters are generally in agreement within ± 0.05%. The agreement with the reference data from the Burnett apparatus and the interferometric device ..... is also within ± 0.05%. Only one isotherm for the binary mixture differs by as much as about 0.1% from the other data. Recent natural gas measurements show substantially the same general behaviour.

It is concluded that the use of a combination of Z-meter, Burnett and interferometer data in the development of the GERG virial equation of state does not prejudice its expected predictive accuracy of ± 0.1%."

The experimental pVT data from the GERG round-robin exercise are identified in Tables 3.3 and 3.4, which list codes and compositions for the binary and ternary mixtures respectively, by asterisks in the column headed "GERG-Code". The Texas A&M results (24) were published recently at the 1989 International Gas Research Conference (48).

2.5 Missing or Inadequate Data

2.5.1 Inadequate Source Data

Gaps in knowledge connected with the GERG-88 virial equation can arise from the lack or inadequacy of data required for development of the equation, for example binary and ternary mixture data. As explained in the Technical Monograph describing the GERG virial equation (6), the importance of such gaps can be assessed by estimating the relative magnitudes of their contributions to the compressibility factor of a typical natural gas mixture. In this way it was shown that the contribution to the compressibility factor due to uncertainties in the unlike interaction second virial coefficients for the ethane + propane and the ethane + butane systems can be significantly large. It is self-evident that it would be very useful to have more accurate data for these two mixtures. The same is true for the contribution of the third virial coefficient describing the interaction between methane + ethane + propane molecules. This latter deficiency was overcome as follows (6) -

"As no suitable experimental data are available, the value for $C(CH_4+C_2H_6+C_3H_8)$ (or $C_{146}(T)$) was derived by trial-and-error .... based on experimental data for natural gases. As a consequence of this strategy, uncertainties from other virial coefficients are gathered in and compensated by the value of $C_{146}(T)$. Thus, the value obtained might differ from the true physical value but it nevertheless helps to optimize the results of the equation.

At the current state-of-the-art, it therefore seems to be of little use to improve the determination of the parameters used for the equation, except for possible small adjustments of $C_{146}(T)$. This point of view might change, however, if new natural gas data become available to test the equation over wider ranges of the input variables."

2.5.2 Inadequate Test Data

A shortfall of such experimental data as would be required for testing the GERG-88 virial equation over its entire pressure, temperature and composition range of applicability has been discussed in GERG Technical Monograph TM2 (6) as follows -

"The GERG virial equation is tested very carefully in the temperature range from 265 to 335 K, the pressure range up to 12 MPa and for natural and coke-oven gases covering the following concentrations, viz.

mole fraction of nitrogen $x(N_2) < 0.120$
mole fraction of carbon dioxide $x(CO_2) < 0.050$
mole fraction of ethane $x(C_2H_6) < 0.095$
mole fraction of hydrogen $x(H_2) < 0.100$

A large amount of experimental data for gases with higher amounts of nitrogen or carbon dioxide are available, but only for the limited pressure and temperature ranges of 3 to 7 MPa and 280 to 300 K.

Consequently, additional experimental data are needed for testing the equation outside of the quoted concentration ranges, for pressures up to 12 MPa and in the temperature range 265 to 335 K if the equation is to be fully validated for the whole range of its supposed applicability."

For this reason additional measurements are under way at Ruhrgas A.G., to cover ranges of concentration for nitrogen up to 0.5 mole fraction, carbon dioxide up to 0.3 and ethane up to 0.2.

The pVT data of two nitrogen-rich natural gas mixtures (0.36 and 0.49 mole fraction), one carbon dioxide-rich natural gas mixture (0.26 mole fraction) and an ethane-rich mixture (0.12 mole fraction) will be measured covering the whole pressure and temperature range. A second ethane-rich natural gas mixture with some 0.18 mole fraction may additionally be explored. The results of these additional measurements will be presented elsewhere (25).

2.6 Supplement to the GERG Databank

A supplement to the GERG databank of high accuracy compressibility factor measurements will be published elsewhere (25). New data sets will be compiled and grouped in the supplement in three distinct subsets -

- additional natural gas compressibility factor data to validate the whole range of the GERG-88 virial equation, as described in the foregoing subsection;

- compressibility factor data outside the range of applicability of the GERG-88 virial equation especially for pressures between 120 and about 280 bar and temperatures between 270 and 360 K;

- results from four laboratories (two in the USA and two financed by GERG member companies in Europe), currently engaged in a pVT round-robin test on six simulated natural gas mixtures; all of the mixtures are being prepared at the National Institute of Standards and Technology (NIST) in Boulder, Colorado.

All these new data, when available, can be used to further verify the accuracy of the GERG-88 virial equation and substantiate the existing contents of the GERG databank. In the longer term it should be possible to establish an internationally accepted reference databank of compressibility factor measurements which, in large measure, might sensibly be based upon the current GERG databank.

3. THE GERG DATABANK

3.1 General Information

By way of introduction to the GERG databank, there follows a set of observations concerning the overall structure, general philosophy and content, which should clarify various matters of relevance to any potential user.

- The databank only includes data for pure gases and gas mixtures of specific relevance to the development and testing of the GERG-88 equation i.e. it is limited to mixtures containing only those 13 components noted in Section 1.1(a) (except, trivially, for other minor components usually only present in trace quantities in some N-file natural gases - see below). The allowable range of concentration for each of the 13 main components is shown in Table 3.1. Note that the databank does include gases in the A,B and C-files which are outside of the range of compositional validity of the GERG-88 equation; for example, methane is self-evidently the only pure gas which is compositionally within range of the equation, but data are included for most of the other 12 component gases - for obvious reasons relating to the evaluation of pure component virial coefficients. A single gas in the N-file is also compositionally out of range of the GERG-88 equation.

- The databank only includes data for temperatures and pressures which are within the respective ranges of validity of the GERG-88 virial equation, viz.

  $$265 \leq T/K \leq 335$$

  $$0 < p/MPa \leq 12$$

  (There are marginal exceptions to this for pure methane, hydrogen and helium in four data sets - 28 points in all - in the A-file.)

- The databank specifies the gas composition as detailed in the original source documentation. Generally, as implied above, this consists of a sub-set of the 13 main components together with any minor (usually trace) components of the mixture. In the survey Tables 3.2 to 3.7 for the various files only the 13 main components are given, the minor components having been re-assigned beforehand to an appropriate main component, in accordance with the specifications given in Table 3.1, which is taken from ref.6.

- The databank is restricted to data which are believed to be of the highest quality in respect of precision, accuracy, composition assignment, experimental technique and traceability. In numerical terms this means that the "guaranteed" uncertainty in compressibility factor is always within ±0.1%, although for some pure gases in particular the accuracy of the best measurements has been assessed as up to a factor of three better than this (6). (Despite this, it is only fair to add that there are a few data sets included about which we harbour suspicions that they are not of the declared accuracy; these will remain in the databank until such times as our suspicions are either confirmed or refuted. Some of our reservations are discussed in ref.6.)

- Apart from any data which may have been inadvertently overlooked, the only "within-range" data to be excluded are those for which it has been possible to demonstrate a lack of sufficient accuracy, or where there is internal or external inconsistency. Such judgements - about which it is right to acknowledge that there is sometimes a marginal element of subjectivity - have been made independently of any claims for accuracy made in the original source publications.

- Not all of the data present in the databank have been used either in building up or in assessing the GERG-88 virial equation. In particular, we have usually used the "best" data - even at the expense of other "good" data - in the development of the GERG-88 Master equation (6). Again, there is inevitably some slight degree of subjectivity in the selections.

- The formal cut-off date for new data for inclusion in the GERG compressibility factor databank was 31 March 1988. (Some new data have, however, been added to the N-file since the completion of work on the development and assessment of the GERG-88 equation. These data are in the sets labelled N85 onwards; they are included in Appendix 5, but the counts given in the main text stop at N84.)

- As implied by the discussion in Section 2.6, we believe it to be a most worthwhile exercise to continue to add appropriate new data to the databank (and perhaps to remove some data too!), so that it can continue to serve the scientific community as a state-of-the-art repository, and correspondingly valuable resource, for information on the volumetric behaviour of gases, particularly natural gases. For that reason, a supplement to the databank is in preparation. If indeed the GERG databank is to continue its growth (under the auspices of whatever company or agency) consideration should also be given to the widening of its ranges of pressure, temperature and composition.

3.2 Pure Gases : the A-File

The A-File, as previously noted, consists of 36 sets of compressibility factor data, comprising 2374 data points, for pure gases. Details of each data set are summarised in Table 3.2. Each data set is coded in the format An xx , where the index n identifies the individual pure gas in question (1 = CH_4, 2 = N_2, 3 = CO_2, 4 = C_2H_6, 5 = H_2, 6 = C_3H_8, 7 = CO, 8 = C_4H_{10}, 9 = He, 10 = C_5H_{12}, 11 = C_6H_{14}, 12 = C_7H_{16}, 13 = C_8H_{18}), and the serial qualifier xx identifies a particular data set for a given gas. An abbreviated literature reference is given, where available, for each data set; the full references are given in Section 4. For those data sets which have not yet been published elsewhere an additional internal GERG coding is given instead; this identifies the source (e.g. Ruhrgas A.G., Ned. Gasunie), possibly the measurement technique (e.g. DEH, BUR, OPT) and the actual sample (a pure number).

The full details of each data point within the A-File are given in

Appendix 1. For each data set the printed version of the A-File begins on a new page and comprises the following -

(a) sample identity at the head of the page,

(b) column 1 gives the temperature in kelvins (K), to 2 or 3 decimal places depending on the precision given by the source document,

(c) column 2 gives the pressure in megapascals (MPa), to 3, 4 or 5 decimal places,

(d) column 3 gives the experimental compressibility factor Z(expt), to 4 or 5 decimal places,

(e) column 4 gives the compressibility factor Z(calc) calculated from the GERG-88 Master equation,

(f) column 5 gives the quantity

$$Z(\text{diff})\ \% = 100 \times [Z(\text{calc}) - Z\ (\text{expt})]/Z(\text{expt}).$$

Data in columns 4 and 5 are omitted if Z(expt) is less than 0.6, since Z(diff) is often spuriously large (and of no relevance to the development or evaluation of the GERG equation) for these cases.

Each page contains a maximum of 50 data points arranged in blocks of 10.

3.3 Binary Mixtures : the B-File

The B-File consists of 107 data sets, comprising 5847 data points, for binary mixtures. Details of each data set are summarised in Table 3.3. The general format is almost identical to that of the A-File; the only differences are that each data set is now coded as Bnm xx, where the indices n and m now identify the two components of the binary mixture, and the composition of the mixture is indicated by means of the mole percentage of component m.

The full details of each data point are given in Appendix 2, comprising sample identity, composition, temperature, pressure, experimental compressibility factor, calculated (MGERG-88) compressibility factor and percentage difference. The general layout is identical to that of Appendix 1.

3.4 Ternary Mixtures : the C-File

The C-File consists of 18 data sets, comprising 620 data points, for ternary mixtures. Details of each data set are summarised in Table 3.4. Again the overall format is very similar, except that each data set is now coded Cnmℓ xx, where the indices n, m and ℓ identify the three components of the ternary mixture, and the composition of the mixture is indicated by means of the mole percentages of components m and ℓ.

The full details of each data point are given in Appendix 3, which is formatted in exactly the same way as Appendix 2.

3.5 Quaternary and Synthetic Multicomponent Mixtures : the D-File

The D-File consists of 20 data sets, comprising 492 data points, for quaternary and synthetic multicomponent mixtures. Details of each data set are summarised in Table 3.5. In this case each data set is identified simply as D xx, there being no coding attached to identify the component gases. The detailed composition of each mixture is given by the mole percentages of all main components (except methane), with any minor components present already re-assigned appropriately. Complete compositions are, of course, given in the databank proper; the composition of up to the first five components is also printed out as part of Appendix 4, where all the other information for the D-File is given in the by now familiar format.

3.6 Natural Gas and Natural Gas/Manufactured Gas Mixtures : the N-File

At the original cut-off date of 31 March 1988, the N-File consisted of 84 data sets, comprising 4486 data points, for natural gas and natural gas/manufactured (coke-oven) gas mixtures. Since then, however, 12 further data sets have been added, extending the number of data points by 364. Details of each data set are summarised in Tables 3.6, 3.7 and 3.8. Table 3.6 is in the familiar general format but, as for the D-File, no attempt is made to identify the component gases for each mixture as part of the coding; consequently each data set is simply specified as N xx. Furthermore, no indication of even approximate composition is given in Table 3.6, each gas instead being identified by a not necessarily unique familiar name (usually indicative of the gas field of its origin) and a gas analysis number, in addition to its GERG and possible alternative codes. The detailed composition - up to 13 main components - of each gas is given by mole percent in Table 3.7, and the composition of up to the first five components is also given in Appendix 5, where all the other information for the N-File is given in the familiar format.

In Table 3.7 and Appendix 5 the component concentrations given are those obtained after re-assignment of any minor or trace components (as specified in Table 3.1) to one of the 13 main components. In other words, Table 3.7 could be used as input to the MGERG-88 equation.

By contrast, Table 3.8 lists the superior calorific value (reference conditions: combustion at 25°C, metering at 0°C, 101.325 kPa), relative density at 0°C (both calculated in accordance with ISO 6976 (ref. 49)), carbon dioxide content and hydrogen content for each N-file gas. This is known as the "reduced" composition. In order to form valid input to the SGERG-88 equation, each of these must be calculated from the complete composition before re-assignment of minor components. In practice, the only significant re-assignment is of the ethylene in coke-oven gas mixtures to carbon dioxide; for this reason the carbon dioxide percentages given in Tables 3.7 and 3.8 do not correspond for such gases.

3.7 Computer Documentation

The current and definitive version of the GERG databank of high-accuracy compressibility factors is presently held on the Ruhrgas computer system at Dorsten. Appendices 1-5 are derived from the databank proper but, rather than being simply reprinted, there are layout and other minor changes. In the databank itself, each line of code is given in the following format (Table 3.9 shows two typical non-consecutive pages reproduced directly from the databank without modification) -

The first four characters represent a Ruhrgas identification (gas analysis) number. Thus, for example, 0043 denotes pure methane (the first A-File entry) and 0283 denotes a particular natural gas (the last N-File entry, N84); these numbers are reproduced in the headings for individual data sets in the Appendices. The next character is either T, G or M -

- T indicates that the line contains textual material relevant to the gas or gas mixture. The set of characters which follows is either A n xx , B nm xx, C nmℓ xx, D xx or N xx, which identifies the particular gas or gas mixture, including (for the A, B and C files) its components encoded as explained in Sections 3.2 to 3.6. Finally, for convenience, there is further textual identification - in words or chemical symbols - firstly, of the gas or gas mixture, and secondly, of the source (company or primary author), and this information is again reproduced in the headings given in the Appendices. There is one such line for each gas sample.

- G indicates that the line contains details of the gas composition; more than one such line may be required for a given gas sample. The gas composition is given here in its original form as obtained, for example, from gas chromatographic analysis, and is not reduced or re-assigned in any way to the 13 major components specified in Table 3.1. Consequently, for some gases, the isomers of butane and pentane are listed individually, and there may be small amounts of other gases such as oxygen and ethylene. Therefore, particularly for N-File gases, there may be more than 13 components, plus trace components, listed in the databank proper. Compositions, for components identified by chemical formula, are given in mole percent, with four digits after the decimal point. Up to five component concentrations (usually the most abundant) are identified and reproduced in the Appendices; the values given there are those from the listing of compositions in Table 3.7 which, as noted earlier, shows the gas composition values which result from the re-assignment of minor or trace gases as appropriate for use as input to the MGERG virial equation.

- M indicates that the line contains actual experimental compressibility factor data referring to the sample described in the preceding "T" and "G" lines; there are, of course, typically many such lines for any given gas or gas mixture. The first column gives the temperature in degrees Celsius (3 decimal places), the second column the absolute pressure in bar (4 decimal places) and the third column the compressibility factor (5 decimal places). (The temperature is converted to kelvin, the pressure converted to megapascal and the compressibility factor rounded appropriately before printing in Appendices 1-5.) Finally, there is a 17-character coding assigned uniquely to each data point which need not concern the user, but which in fact contains a brief indication of the measurement technique, the apparatus location etc, part of which is reproduced for each sample in the Appendix headings.

The entire databank (approximately 940 kbyte) can be fitted on to one double-sided, high-density 5¼" (1.6 Mbyte) flexible diskette, and can be made available upon request to GERG. The current version is dated 31 July 1990.

List of Tables

Table 3.1 Assignment of Minor (Trace) Components in Natural Gases and Ranges of Compositional Validity

Group	Major Component	Range (mole %)	Minor Components and Comments
1	CH_4	≥50.0	–
2	N_2	≤50.0	O_2,Ar
3	CO_2	≤30.0	C_2H_4, C_2H_2, H_2O, H_2S
4	C_2H_6	≤20.0	–
5	H_2	≤10.0	–
6	C_3H_8	≤ 5.0	C_3H_6 (propene), C_3H_4(propadiene)
7	CO	≤ 3.0	–
8	C_4H_{10}	≤ 1.5	Both n- and iso-isomers; C_4H_8(butenes), C_4H_6(butadienes)
9	He	≤ 0.5	–
10	C_5H_{12}	≤ 0.5	n-, iso- and neo- isomers; C_6H_6(benzene), C_5H_{10} (cyclopentane, pentenes)
11	C_6H_{14}	≤ 0.1	All isomers; C_6H_{12} (cyclohexane), C_8H_{10} (ethylbenzene, xylenes)
12	C_7H_{16}	≤ 0.1	All isomers; C_7H_{14} (cycloheptane), C_7H_8(toluene)
13	C_8H_{18}	≤ 0.1	All isomers; all higher hydrocarbons

Table 3.2 Listing of Codes for Pure Gases

Data-Reference	Gas	GERG-CODE	No. of Points
Ruhrgas AG GERG Gas DEH09	CH4	A1 1	19
Literature Achtermann [26] (1982)	CH4	A1 2	68
Literature Achtermann [26] (1982)	CH4	A1 3	71
Brit.Gas, Roe, Thesis [14] (1972)	CH4	A1 4	14
Literature Hoover [27] (1965)	CH4	A1 5	14
Literature Trappeniers[28] (1979)	CH4	A1 6	119
Literature Schamp [15] (1958)	CH4	A1 7	45
Literature Douslin [16] (1964)	CH4	A1 8	45
Ruhrgas AG GERG Gas BUR02 [17]	CH4	A1 9	124
Ruhrgas AG GERG Gas OPT02 [17]	CH4	A1 10	153
Literature Kleinrahm [29] (1988)	CH4	A1 11	168
Literature Achtermann [20] (1986)	CH4	A1 12	17
Ned.Gasunie GERG Gas GU035	N2	A2 1	94
Brit.Gas, Roe, Thesis [14] (1972)	N2	A2 2	12
Literature Crain [30] (1966)	N2	A2 3	17
Literature A. Michels [31] (1934)	N2	A2 4	24
Ruhrgas AG GERG Gas BUR03 [17]	N2	A2 5	72
Ruhrgas AG GERG Gas OPT03 [17]	N2	A2 6	173
Literature Duschek [32] (1986)	N2	A2 7	127
Literature Achtermann [20] (1986)	N2	A2 8	17
Literature A. Michels [33] (1936)	CO2	A3 1	55
Literature Holste [18] (1987)	CO2	A3 2	139
Ruhrgas AG GERG Gas OPT17	CO2	A3 3	146
Ruhrgas AG GERG Gas BUR19	CO2	A3 4	124
Literature A. Michels [34] (1954)	C2H6	A4 1	33
Literature Douslin [35] (1973)	C2H6	A4 2	18
Ruhrgas AG GERG Gas BUR11	C2H6	A4 3	48
Ruhrgas AG GERG Gas OPT16	C2H6	A4 4	99
Literature A. Michels [36] (1959)	H2	A5 1	26
Ruhrgas AG GERG Gas BUR13	H2	A5 2	43
Ruhrgas AG GERG Gas OPT13	H2	A5 3	72
Literature Starling [37] (1984)	C3H8	A6 1	26
Literature A. Michels [38] (1952)	CO	A7 1	20
Ruhrgas AG GERG Gas DEH10	HE	A9 1	18
Ned.Gasunie GERG Gas GU029	HE	A9 2	94
Literature A. Michels [39] (1941)	HE	A9 3	20

Table 3.3 Listing of Codes and Compositions (by mole percent of the second component) for Binary Mixtures
* round robin gas (see ref. 13)

Data-Reference	Gas	GERG-CODE	No. of Points
British Gas, Roe[14](1972)	CH4-N2(51.60 %)	B12 1	7
British Gas, Roe[14](1972)	CH4-N2(28.10 %)	B12 2	7
Ned.Gasunie GERG Gas GU036	CH4-N2(9.156%)	B12 3	52
Ned.Gasunie GERG Gas GU039	CH4-N2(20.10 %)	B12 4	32
Ned.Gasunie GERG Gas GU040	CH4-N2(30.155%)	B12 5	33
Ned.Gasunie GERG Gas GU041	CH4-N2(49.683%)	B12 6	32
Ruhrgas AG GERG Gas BUR04	CH4-N2(19.979%)	B12 7	13
Ruhrgas AG GERG Gas OPT04	CH4-N2(19.979%)	B12 8	90
Ruhrgas AG GERG Gas BUR06	CH4-N2(75.01 %)	B12 9	19
Ruhrgas AG GERG Gas OPT06	CH4-N2(75.01 %)	B12 10	95
Ruhrgas AG GERG Gas BUR21	CH4-N2(50.20 %)	B12 11*	27
Ruhrgas AG GERG Gas OPT33	CH4-N2(50.20 %)	B12 12*	89
British Gas GERG Gas BG001	CH4-N2(50.34 %)	B12 13*	39
GazdeFrance GERG Gas GF018	CH4-N2(50.32 %)	B12 14*	14
Distrigaz GERG Gas DI001	CH4-N2(50.30 %)	B12 15*	20
Lit.Achtermann [20](1986)	CH4-N2(74.98 %)	B12 16	23
Lit.Achtermann [20](1986)	CH4-N2(10.24 %)	B12 17	23
Lit.Achtermann [20](1986)	CH4-N2(61.31 %)	B12 18	23
Lit.Achtermann [20](1986)	CH4-N2(86.48 %)	B12 19	23
Lit.Achtermann [20](1986)	CH4-N2(50.08 %)	B12 20	23
Ruhrgas AG GERG Gas BUR05	CH4-N2(50.009%)	B12 21	13
Ruhrgas AG GERG Gas OPT05	CH4-N2(50.009%)	B12 22	139
SNAM GERG Gas SN001	CH4-N2(50.29 %)	B12 23*	12
Ruhrgas AG GERG Gas ADH56	CH4-N2(50.30 %)	B12 24*	24
Lit. Brugge [48](1989)	CH4-N2(49.94 %)	B12 25*	39
Ned.Gasunie GERG Gas GU067	CH4-N2(50.30 %)	B12 26*	22
Ned.Gasunie GERG Gas GU034	CH4-CO2(9.615%)	B13 1	52
Ned.Gasunie GERG Gas GU046	CH4-CO2(19.48 %)	B13 2	32
Ned.Gasunie GERG Gas GU049	CH4-CO2(30.067%)	B13 3	32
Ruhrgas AG GERG Gas OPT47	CH4-CO2(31.45 %)	B13 4	104
Ruhrgas AG GERG Gas BUR34	CH4-CO2(31.45 %)	B13 5	40
Literatur Esper [40](1987)	CH4-CO2(47.608%)	B13 6	64
Ned.Gasunie GERG Gas GU053	CH4-CO2(24.574%)	B13 7	33
Ned.Gasunie GERG Gas GU031	CH4-C2H6(9.341%)	B14 1	49
Ned.Gasunie GERG Gas GU043	CH4-C2H6(5.112%)	B14 2	33
Ned.Gasunie GERG Gas GU044	CH4-C2H6(20.229%)	B14 3	30
Ruhrgas AG GERG Gas BUR33	CH4-C2H6(30.03 %)	B14 4	24
Ruhrgas AG GERG Gas OPT46	CH4-C2H6(30.03 %)	B14 5	101
Ruhrgas AG GERG Gas BUR41	CH4-C2H6(12.09 %)	B14 6	79

Table 3.3 (cont) Listing of Codes and Compositions (by mole percent of the second component) for Binary Mixtures
* round robin gas (see ref. 13)

Data-Reference		Gas	GERG-CODE		No. of Points
Ruhrgas AG	GERG Gas OPT52	CH4-C2H6(12.09 %)	B14	7	96
Ruhrgas AG	GERG Gas BUR42	CH4-C2H6(8.065%)	B14	8	53
Ruhrgas AG	GERG Gas OPT53	CH4-C2H6(8.065%)	B14	9	118
Ruhrgas AG	GERG Gas BUR43	CH4-C2H6(4.034%)	B14	10	26
Ruhrgas AG	GERG Gas OPT54	CH4-C2H6(4.034%)	B14	11	118
Ruhrgas AG	GERG Gas BUR44	CH4-C2H6(15.90 %)	B14	12	74
Ruhrgas AG	GERG Gas OPT55	CH4-C2H6(15.90 %)	B14	13	118
Lit. Haynes	[41](1985)	CH4-C2H6(49.783%)	B14	14	67
Lit. Haynes	[41](1985)	CH4-C2H6(65.472%)	B14	15	59
Lit. Haynes	[41](1985)	CH4-C2H6(31.474%)	B14	16	41
Ruhrgas AG	GERG Gas BUR15	CH4-H2(15.02 %)	B15	1	40
Ruhrgas AG	GERG Gas OPT15	CH4-H2(15.02 %)	B15	2	46
Ruhrgas AG	GERG Gas OPT39	CH4-H2(25.309%)	B15	3	72
Ruhrgas AG	GERG Gas BUR12	CH4-H2(50.266%)	B15	4	56
Ruhrgas AG	GERG Gas OPT38	CH4-H2(50.266%)	B15	5	64
Ruhrgas AG	GERG Gas BUR14	CH4-H2(74.94 %)	B15	6	54
Ruhrgas AG	GERG Gas OPT37	CH4-H2(74.94 %)	B15	7	72
Ned.Gasunie	GERG Gas GU032	CH4-C3H8(4.009%)	B16	1	54
Ruhrgas AG	GERG Gas BUR28	CH4-C3H8(7.019%)	B16	2	14
Ruhrgas AG	GERG Gas OPT28	CH4-C3H8(7.019%)	B16	3	105
Ned.Gasunie	GERG Gas GU042	CH4-C3H8(4.976%)	B16	4	44
Ruhrgas AG	GERG Gas BUR26	CH4-CO(2.994%)	B17	1	38
Ruhrgas AG	GERG Gas OPT26	CH4-CO(2.994%)	B17	2	94
Ned.Gasunie	GERG Gas GU033	CH4-C4H10(1.20 %)	B18	1	72
Ruhrgas AG	GERG Gas BUR30	CH4-C4H10(1.50 %)	B18	2	14
Ruhrgas AG	GERG Gas OPT30	CH4-C4H10(1.50 %)	B18	3	106
Lit.Ellington	[42](1986)	CH4-C4H10(4.243%)	B18	4	27
Ned.Gasunie	GERG Gas GU058	CH4-C5H12(.269%)	B110	1	21
Ruhrgas AG	GERG Gas OPT56	CH4-C5H12(.290%)	B110	2	94
Ruhrgas AG	GERG Gas OPT57	CH4-C6H14(.092%)	B111	1	119
Ned.Gasunie	GERG Gas GU059	N2-CO2(25.121%)	B23	1	21
Ruhrgas AG	GERG Gas BUR35	N2-CO2(28.59 %)	B23	2	40
Ruhrgas AG	GERG Gas BUR36	N2-CO2(25.38 %)	B23	3	82
Literatur Esper	[40](1987)	N2-CO2(44.696%)	B23	4	65
GazdeFrance	GERG Gas GF020	N2-CO2(10.098%)	B23	5	19
GazdeFrance	GERG Gas GF021	N2-CO2(31.814%)	B23	6	20

Table 3.3 (cont) Listing of Codes and Compositions (by mole percent of the second component) for Binary Mixtures
* round robin gas (see ref. 13)

Data-Reference		Gas	GERG-CODE		No. of Points
Ruhrgas AG	GERG Gas OPT43	N2-C2H6(75.15 %)	B24	1	65
Ruhrgas AG	GERG Gas OPT44	N2-C2H6(50.04 %)	B24	2	96
Ruhrgas AG	GERG Gas OPT45	N2-C2H6(25.03 %)	B24	3	107
Ned.Gasunie	GERG Gas GU066	N2-C2H6(25.16 %)	B24	4	30
Ruhrgas AG	GERG Gas BUR16	N2-H2(14.95 %)	B25	1	38
Ruhrgas AG	GERG Gas OPT11	N2-H2(14.95 %)	B25	2	72
Ruhrgas AG	GERG Gas OPT42	N2-H2(24.99 %)	B25	3	72
Ruhrgas AG	GERG Gas BUR23	N2-H2(50.02 %)	B25	4	50
Ruhrgas AG	GERG Gas OPT41	N2-H2(50.02 %)	B25	5	69
Ruhrgas AG	GERG Gas BUR24	N2-H2(74.97 %)	B25	6	44
Ruhrgas AG	GERG Gas OPT40	N2-H2(74.97 %)	B25	7	74
Lit. Michels	[43](1948)	N2-H2(75.20 %)	B25	8	37
Ned.Gasunie	GERG Gas GU055	N2-C3H8(5.105%)	B26	1	43
Ruhrgas AG	GERG Gas BUR27	N2-C3H8(7.023%)	B26	2	8
Ruhrgas AG	GERG Gas OPT27	N2-C3H8(7.023%)	B26	3	102
Ruhrgas AG	GERG Gas BUR25	N2-CO(3.009%)	B27	1	37
Ruhrgas AG	GERG Gas OPT25	N2-CO(3.009%)	B27	2	93
Ruhrgas AG	GERG Gas BUR29	N2-C4H10(1.50 %)	B28	1	13
Ruhrgas AG	GERG Gas OPT29	N2-C4H10(1.50 %)	B28	2	100
Ruhrgas AG	GERG Gas OPT18	CO2-C2H6(71.55 %)	B34	1	52
Ruhrgas AG	GERG Gas OPT19	CO2-C2H6(22.67 %)	B34	2	64
Ruhrgas AG	GERG Gas OPT20	CO2-C2H6(45.69 %)	B34	3	67
Ruhrgas AG	GERG Gas OPT21	CO2-C2H6(69.92 %)	B34	4	62
Lit.Lemming	[44](1989)	CO2-C2H6(89.957%)	B34	5	46
Lit.Lemming	[44](1989)	CO2-C2H6(74.834%)	B34	6	55
Lit.Lemming	[44](1989)	CO2-C2H6(50.755%)	B34	7	44
Lit.Lemming	[44](1989)	CO2-C2H6(26.022%)	B34	8	55
Lit.Lemming	[44](1989)	CO2-C2H6(9.633%)	B34	9	54
Ruhrgas AG	GERG Gas BUR39	CO2-H2(50.050%)	B35	1	113
Ruhrgas AG	GERG Gas BUR40	CO2-H2(74.905%)	B35	2	100
Ruhrgas AG	GERG Gas BUR37	C2H6-H2(50.27 %)	B45	1	43
Ruhrgas AG	GERG Gas BUR38	C2H6-H2(75.16 %)	B45	2	113

Table 3.4 Listing of Codes and Compositions for Ternary Mixtures
* round robin gas (sample 1), (see ref. 13)
** round robin gas (sample 2), (see ref. 13)

Data-Reference		Gas	GERG-CODE		No. of Points
Ned.Gasunie	GU047	CH4-N2(24.974%)-CO2(24.816%)	C123	1	33
Ned.Gasunie	GU045	CH4-N2(24.898%)-C2H6(25.134%)	C124	1	22
Ned.Gasunie	GU048	CH4-CO2(24.768%)-C2H6(24.837%)	C134	1	22
Ned.Gasunie	GU052	CH4-CO2(20.265%)-C2H6(20.140%)	C134	2	33
Ned.Gasunie	GU054	CH4-CO2(20.190%)-C3H8(5.084%)	C136	1	21
Ned.Gasunie	GU057	CH4-C2H6(20.12%)-C3H8(5.18%)	C146	1	32
Ruhrgas AG	BUR22	CH4-C2H6(16.54%)-C3H8(2.26%)	C146	2*	29
Ruhrgas AG	OPT22	CH4-C2H6(16.54%)-C3H8(2.26%)	C146	3*	155
GazdeFrance	GF019	CH4-C2H6(16.59%)-C3H8(2.26%)	C146	4*	14
Distrigaz	DI002	CH4-C2H6(16.55%)-C3H8(2.26%)	C146	5*	17
British Gas	BG003	CH4-C2H6(16.24%)-C3H8(2.44%)	C146	6**	9
Ned.Gasunie	GU069	CH4-C2H6(16.20%)-C3H8(2.44%)	C146	7**	22
Ruhrgas AG	ADH57	CH4-C2H6(16.19%)-C3H8(2.44%)	C146	8**	24
SNAM	SN002	CH4-C2H6(16.22%)-C3H8(2.44%)	C146	9**	12
Lit.Hall [24](1987)		CH4-C2H6(16.56%)-C3H8(2.26%)	C146	10*	40
Ruhrgas AG	ADH55	CH4-C2H6(16.54%)-C3H8(2.26%)	C146	11*	30
Ned.Gasunie	GU068	CH4-C2H6(16.62%)-C3H8(2.25%)	C146	12*	11
Ruhrgas AG	OPT59	CH4-C2H6(16.16%)-C3H8(2.44%)	C146	13**	94

Table 3.5 Listing of Codes and Compositions for Quaternary Mixtures and Synthetic Gas Mixtures

Data-Reference		Gas	GERG CODE	No. of Points
Brit.Gas Roe,Thesis		CH4-N2(15.6 %)-C2H6(7.2 %)	D 1	7
GazdeFrance	GF001	CH4-N2(3.01 %)-C2H6(3.01 %)-C3H8(1.05 %)	D 2	5
GazdeFrance	GF002	CH4-N2(3.115%)-C2H6(6.155%)-C3H8(1.020%)	D 3	6
GazdeFrance	GF003	CH4-N2(3.04 %)-C2H6(9.12 %)-C3H8(1.04 %)	D 4	6
GazdeFrance	GF004	CH4-N2(3.15 %)-C2H6(12.09 %)-C3H8(1.04 %)	D 5	6
GazdeFrance	GF005	CH4-N2(2.94 %)-C2H6(6.10 %)-C3H8(2.12 %)	D 6	6
GazdeFrance	GF006	CH4-N2(2.85 %)-C2H6(9.25 %)-C3H8(3.13 %)	D 7	6
GazdeFrance	GF007	CH4-N2(2.95 %)-C2H6(11.83 %)-C3H8(3.90 %)	D 8	6
GazdeFrance	GF013	CH4-N2(17.87 %)-C2H6(11.46 %)-C3H8(3.74 %)	D 9	6
GazdeFrance	GF014	CH4-N2(1.0 %)-C2H6(6.0 %)-H2 (2.9 %)	D 10	7
GazdeFrance	GF015	CH4-N2(22.6 %)-C2H6(11.7 %)-C3H8(3.9 %)	D 11	6
GazdeFrance	GF016	CH4-N2(13.7 %)-C2H6(3.3 %)-C3H8(1.1 %)	D 12	6
GazdeFrance	GF017	CH4-N2(22.0 %)-C2H6(3.1 %)-C3H8(1.0 %)	D 13	6
Ned.Gasunie	GU050	CH4-N2(25.00 %)-CO2(25.16 %)-C2H6(24.66 %)	D 14	22
Ruhrgas AG	DEH08	CH4-N2 (1.859%)-C2H6(1.910%)-C3H8(0.788%)	D 15	18
Ruhrgas AG	BUR10	CH4-CO2(2.005%)-C2H6(8.921%)-C3H8(3.054%) -C4H10(1.237%)	D 16	40
Ruhrgas AG	OPT10	CH4-CO2(2.005%)-C2H6(8.921%)-C3H8(3.054%) -C4H10(1.237%)	D 17	71
Ruhrgas AG	OPT58	CH4-N2(12.66 %)-CO2(12.60 %)-C2H6(12.97 %)	D 18	122
Ruhrgas AG	OPT50	CH4-N2 (0.681%)-C2H6(8.686%)-C3H8(1.511%) -C4H10(0.494%)-C5H12(0.026%)	D 19	93
Ruhrgas AG	OPT51	CH4-N2 (0.617%)-C2H6(8.696%)-C3H8(1.515%) -C4H10(0.494%)-C5H12(0.026%)	D 20	47

Table 3.6 Listing of Codes for Natural Gases

Data-Reference	Gas	Gas No.	GERG CODE	No. of Points
Ruhrgas AG GERG Gas DEH03	EKOFISK-H	49	N 1	18
Ruhrgas AG GERG Gas DEH05	UDSSR-H	58	N 2	18
Ruhrgas AG GERG Gas DEH06	TENP-H	57	N 3	18
Ruhrgas AG GERG Gas DEH07	EPE-H	56	N 4	18
Ruhrgas AG GERG Gas DEH11	MIXTURE+H2-H	85	N 5	24
Ruhrgas AG GERG Gas DEH12	MIXTURE+H2-H	86	N 6	24
Ruhrgas AG GERG Gas DEH13	MIXTURE+H2-L	87	N 7	24
Ruhrgas AG GERG Gas DEH14	MIXTURE+H2-L	88	N 8	23
Lit.Achtermann [26](1982)	UDSSR-H	71	N 9	67
Lit.Achtermann [26](1982)	EKOFISK-H	70	N 10	68
Lit.Achtermann [26](1982)	TENP-H	64	N 11	69
Lit.Achtermann [26](1982)	EPE-H	65	N 12	69
Lit.Achtermann [26](1982)	UDSSR-H	71	N 13	74
Lit.Achtermann [26](1982)	EKOFISK-H	70	N 14	74
Lit.Achtermann [26](1982)	TENP-H	64	N 15	73
Lit.Achtermann [26](1982)	EPE-H	65	N 16	74
Lit.Achtermann [45](1981)	UDSSR-H	67	N 17	76
Lit.Achtermann [45](1981)	EKOFISK-H	69	N 18	68
Lit.Achtermann [45](1981)	TENP-H	66	N 19	73
Lit.Achtermann [45](1981)	EPE-H	68	N 20	77
Brit.Gas, Roe [14](1972)	SOUTH.N.SEA-H	37	N 21	12
Brit.Gas, Roe [14](1972)	BACTON-H	38	N 22	15
GazdeFrance GERG Gas GF008	GRONINGEN-L	30	N 23	18
GazdeFrance GERG Gas GF009	LACQ-H	31	N 24	12
GazdeFrance GERG Gas GF010	EKOFISK-H	34	N 25	10
GazdeFrance GERG Gas GF011	EKOFISK-H	35	N 26	5
GazdeFrance GERG Gas GF012	EKOFISK-H	36	N 27	5
Ned.Gasunie GERG Gas GU008	STATENZIJL-H	110	N 28	64
Ned.Gasunie GERG Gas GU009	URETERP-L	111	N 29	53
Ned.Gasunie GERG Gas GU010	AMBACHT-H	112	N 30	52
Ned.Gasunie GERG Gas GU011	PLACID-H	113	N 31	53
Ned.Gasunie GERG Gas GU012	MIDDENM.-H	114	N 32	54
Ned.Gasunie GERG Gas GU013	MID.MIX-L	115	N 33	64
Ned.Gasunie GERG Gas GU014	MID.ZECH.-L	116	N 34	52
Ned.Gasunie GERG Gas GU015	MID.ROTL.-M	117	N 35	55
Ned.Gasunie GERG Gas GU016	BOCHOLTZ-H	118	N 36	55
Ned.Gasunie GERG Gas GU017	EKOFISK-H	119	N 37	64
Ned.Gasunie GERG Gas GU018	GARYP-L	120	N 38	65
Ned.Gasunie GERG Gas GU019	GRAVENV.-H	121	N 39	55
Ned.Gasunie GERG Gas GU020	TIETJERK-L	122	N 40	54
Ned.Gasunie GERG Gas GU021	SLOCHTEREN-L	123	N 41	16
Ned.Gasunie GERG Gas GU022	SLOCHTEREN-L	124	N 42	44
Ned.Gasunie GERG Gas GU023	BALGZAND-H	125	N 43	66
Ned.Gasunie GERG Gas GU024	AMOCO-H	126	N 44	66
Ned.Gasunie GERG Gas GU025	ANNERVEEN-H	127	N 45	66
Ned.Gasunie GERG Gas GU026	ROSWINKEL-L	128	N 46	65
Ned.Gasunie GERG Gas GU027	SLEEN-ROSW.-M	129	N 47	65
Ned.Gasunie GERG Gas GU028	SLEEN-M	130	N 48	65
Ned.Gasunie GERG Gas GU038	STATENZIJL-H	274	N 49	33
Ned.Gasunie GERG Gas GU051	GRONINGEN-L	275	N 50	22

Table 3.6 (cont) Listing of Codes for Natural Gases

Data-Reference		Gas	Gas No.	GERG CODE	No. of Points
Ruhrgas AG	GERG Gas BUR07	EPE-H	65	N 51	25
Ruhrgas AG	GERG Gas OPT07	EPE-H	65	N 52	23
Ruhrgas AG	GERG Gas BUR08	EPE-H	68	N 53	25
Ruhrgas AG	GERG Gas OPT08	EPE-H	68	N 54	38
Ruhrgas AG	GERG Gas BUR09	EPE-H	212	N 55	83
Ruhrgas AG	GERG Gas OPT09	EPE-H	212	N 56	71
Ruhrgas AG	GERG Gas BUR17	UDSSR+NAM-H	211	N 57	27
Ruhrgas AG	GERG Gas OPT35	UDSSR+NAM-H	211	N 58	48
Ruhrgas AG	GERG Gas BUR18	NAM-L	223	N 59	28
Ruhrgas AG	GERG Gas OPT36	NAM-L	223	N 60	117
Ruhrgas AG	GERG Gas BUR20	UDSSR-H	210	N 61	30
Ruhrgas AG	GERG Gas OPT34	UDSSR-H	210	N 62	109
Ruhrgas AG	GERG Gas BUR31	DROHNE-L	224	N 63	50
Ruhrgas AG	GERG Gas OPT31	DROHNE-L	224	N 64	117
Ruhrgas AG	GERG Gas BUR32	EKOFISK-H	225	N 65	54
Ruhrgas AG	GERG Gas OPT32	EKOFISK-H	225	N 66	120
Ruhrgas AG	GERG Gas BUR49	MIXTURE+H2-H	86	N 67	68
Ruhrgas AG	GERG Gas BUR50	MIXTURE+H2-H	85	N 68	69
Ruhrgas AG	GERG Gas BUR51	MIXTURE+H2-L	87	N 69	70
Ruhrgas AG	GERG Gas BUR52	MIXTURE+H2-H	137	N 70	68
Ruhrgas AG	GERG Gas BUR53	MIXTURE+H2-H	241	N 71	70
Ruhrgas AG	GERG Gas BUR54	MIXTURE+H2-L	242	N 72	67
Ruhrgas AG	GERG Gas BUR47	MIXTURE+H2-L	242	N 73	25
Ruhrgas AG	GERG Gas OPT60	MIXTURE+H2-L	242	N 74	121
Ruhrgas AG	GERG Gas OPT48	EKOFISK-H	240	N 75	132
Lit.Duschek	[46](1989)	EKOFISK-H	278	N 76	135
Ned.Gasunie	GERG Gas GU001	SLOCHTEREN-L	22	N 77	11
Ned.Gasunie	GERG Gas GU002	STATENZIJL-H	23	N 78	19
Ned.Gasunie	GERG Gas GU003	EKOFISK-H	16	N 79	21
Ned.Gasunie	GERG Gas GU006	MID.ROTL.-M	62	N 80	44
Ned.Gasunie	GERG Gas GU007	MID.ZECH.-L	63	N 81	42
Ruhrgas AG	GERG Gas BUR48	TENP-H	243	N 82	45
Ruhrgas AG	GERG Gas OPT61	TENP-H	243	N 83	123
British Gas	GERG Gas BG004	BACTON+H2-H	283	N 84	37
Ned.Gasunie	GERG Gas GU071	EKOFISK-H	344	N 85	48
Lit.Hannisdal	[47](1987)	STATOIL-H	322	N 86	8
Lit.Ellington	[42](1986)	GULF COAST-H	323	N 87	7
British Gas	GERG Gas BG002	LEMAN BANK-H	321	N 88	40
British Gas	GERG Gas BG007	HAMILTON-L	324	N 89	42
British Gas	GERG Gas BG008	ARCO(THAMES)-H	325	N 90	35
British Gas	GERG Gas BG009	S.MORECAMBE-L	326	N 91	32
British Gas	GERG Gas BG010	FRIGG-H	327	N 92	26
British Gas	GERG Gas BG011	BRENT-H	315	N 93	8
Ned.Gasunie	GERG Gas GU072	EKOFISK-H	345	N 94	26
Ned.Gasunie	GERG Gas GU073	EKOFISK-H	346	N 95	44
Ned.Gasunie	GERG Gas GU074	ROSWINKEL-L	347	N 96	48

Table 3.7 Listing of Compositions (by mole percent) for Natural Gases

GERG Code	CH4	N2	CO2	C2H6	H2	C3H8	CO	C4H10	HE	C5H12	C6H14	C7H16	C8H18
N 1	84.3346	0.4390	1.9285	8.8946	0.0015	3.1919		0.9844	0.0032	0.1825	0.0325	0.0061	0.0012
N 2	95.5340	1.6004	0.2331	1.8790		0.4926		0.1511		0.0587	0.0309	0.0168	0.0034
N 3	85.1473	5.6769	1.4546	5.4174		1.5968		0.5073		0.1449	0.0391	0.0138	0.0019
N 4	85.4814	0.6224	1.8643	8.0607		2.8624		0.8695		0.1891	0.0398	0.0096	0.0008
N 5	80.1984	5.4710	1.8292	5.5031	4.1947	1.6910	0.3826	0.5457	0.0229	0.1157	0.0296	0.0128	0.0033
N 6	82.1692	5.3302	1.7802	5.6763	2.3094	1.7778	0.2019	0.5667	0.0249	0.1175	0.0309	0.0116	0.0034
N 7	73.6405	10.0017	1.6182	3.3093	9.3919	0.7661	0.9067	0.2456		0.0744	0.0239	0.0149	0.0068
N 8	78.7092	10.3370	1.3977	3.5876	4.2885	0.8272	0.4137	0.2704	0.0417	0.0779	0.0257	0.0154	0.0080
N 9	95.5192	1.6052	0.2339	1.8835		0.4933		0.1518		0.0591	0.0326	0.0176	0.0038
N 10	84.4678	0.4278	1.8497	8.8604		3.1831		0.9668		0.1999	0.0369	0.0068	0.0008
N 11	85.1666	5.6760	1.4579	5.4022		1.5922		0.5061		0.1451	0.0385	0.0134	0.0020
N 12	85.4915	0.6122	1.8630	8.0626		2.8576		0.8709		0.1902	0.0404	0.0100	0.0016
N 13	95.5192	1.6052	0.2339	1.8835		0.4933		0.1518		0.0591	0.0326	0.0176	0.0038
N 14	84.4678	0.4278	1.8497	8.8604		3.1831		0.9668		0.1999	0.0369	0.0068	0.0008
N 15	85.1666	5.6760	1.4579	5.4022		1.5922		0.5061		0.1451	0.0385	0.0134	0.0020
N 16	85.4915	0.6122	1.8630	8.0626		2.8576		0.8709		0.1902	0.0404	0.0100	0.0016
N 17	95.5480	1.6032	0.2299	1.8724		0.4883		0.1497		0.0577	0.0312	0.0164	0.0032
N 18	84.4333	0.4293	1.8647	8.8669		3.1897		0.9697		0.2011	0.0377	0.0072	0.0004
N 19	85.1784	5.6680	1.4349	5.4163		1.5962		0.5071		0.1451	0.0387	0.0131	0.0022
N 20	85.4620	0.6137	1.8710	8.0768		2.8634		0.8712		0.1902	0.0405	0.0101	0.0011
N 21	92.2794	2.2937	0.0401	3.7252		0.9170		0.4361	0.0598	0.1483	0.0654	0.0115	0.0235
N 22	93.0357	2.6334	0.0402	3.1217		0.6420		0.2816	0.0399	0.1155	0.0436	0.0229	0.0235
N 23	81.2125	14.3770	0.9940	2.8090		0.3800		0.1292		0.0554	0.0237	0.0161	0.0031
N 24	90.8251	2.4630	1.5280	4.4050		0.6420		0.1129		0.0231	0.0003	0.0006	
N 25	83.9520	0.4040	1.9870	9.1380		3.2590		0.9890		0.2090	0.0473	0.0139	0.0008
N 26	83.8681	0.4050	2.0270	9.1800		3.2790		0.9760		0.2049	0.0459	0.0136	0.0005
N 27	83.7500	0.3940	1.9730	9.3490		3.3080		0.9680		0.1996	0.0447	0.0133	0.0004
N 28	88.9650	1.2330	1.9820	5.4550		1.6160		0.5130	0.0300	0.1630	0.0310	0.0120	
N 29	75.7200	13.7510	7.1770	2.5220		0.4110		0.1430	0.1580	0.0730	0.0230	0.0190	0.0030
N 30	87.9810	4.1240	1.5730	4.8020		0.9080		0.3140	0.0710	0.1550	0.0450	0.0260	0.0010
N 31	92.7220	1.8580	1.9860	2.7990		0.3430		0.1030	0.0500	0.1070	0.0150	0.0170	
N 32	88.8020	5.0460	0.5810	4.1500		0.8580		0.2990	0.0780	0.1220	0.0400	0.0220	0.0020

Table 3.7 (cont) Listing of Compositions (by mole percent) for Natural Gases

GERG Code	CH4	N2	CO2	C2H6	H2	C3H8	CO	C4H10	HE	C5H12	C6H14	C7H16	C8H18
N 33	68.7140	2.0650	25.4370	2.8070		0.5540		0.2020	0.0580	0.0990	0.0390	0.0240	0.0010
N 34	80.8760	2.9080	11.2480	3.7680		0.7040		0.2390	0.0660	0.1210	0.0430	0.0240	0.0030
N 35	65.6860	1.8580	28.9430	2.5520		0.5360		0.2010	0.0530	0.1020	0.0410	0.0270	0.0010
N 36	86.6460	4.9040	1.6030	4.9600		1.2440		0.4030	0.0440	0.1440	0.0340	0.0170	0.0010
N 37	84.0050	0.4230	2.1250	8.7790		3.2380		1.0790		0.2790	0.0590	0.0130	
N 38	79.3180	16.8100	0.5550	2.6710		0.4050		0.1280	0.0230	0.0540	0.0230	0.0130	
N 39	87.9700	2.4340	1.7790	5.5520		1.5120		0.4920	0.0410	0.1640	0.0360	0.0190	0.0010
N 40	79.6150	14.7670	1.4720	3.0380		0.6150		0.2330	0.0920	0.1040	0.0380	0.0230	0.0030
N 41	81.5920	13.7870	0.9780	2.9160		0.4120		0.1500	0.0470	0.0710	0.0250	0.0190	0.0030
N 42	81.4780	13.9310	0.9800	2.8990		0.3960		0.1480	0.0480	0.0680	0.0280	0.0200	0.0040
N 43	86.4450	5.4550	1.7960	4.7560		0.9140		0.3310	0.0850	0.1430	0.0460	0.0260	0.0030
N 44	92.3210	2.4480	0.9750	3.2850		0.5690		0.1850	0.0570	0.1000	0.0350	0.0230	0.0020
N 45	90.4400	4.0710	0.7040	3.5110		0.7500		0.2840	0.0520	0.1190	0.0410	0.0250	0.0030
N 46	75.1050	23.7320	0.1180	0.8670		0.0580		0.0190	0.0810	0.0120	0.0070	0.0010	
N 47	70.3170	28.5000	0.1080	0.8940		0.0560		0.0190	0.0870	0.0110	0.0070	0.0010	
N 48	45.2360	53.5570	0.0590	0.9510		0.0480		0.0130	0.1220	0.0080	0.0050	0.0010	
N 49	88.0480	1.0140	2.0360	6.2390		1.8390		0.6130	0.0230	0.1520	0.0260	0.0080	0.0020
N 50	81.5500	13.9300	0.9580	2.8630		0.4030		0.1440	0.0430	0.0650	0.0220	0.0210	0.0010
N 51	85.4915	0.6122	1.8630	8.0626		2.8576		0.8709		0.1902	0.0404	0.0100	0.0016
N 52	85.4915	0.6122	1.8630	8.0626		2.8576		0.8709		0.1902	0.0404	0.0100	0.0016
N 53	85.4620	0.6137	1.8710	8.0768		2.8634		0.8712		0.1902	0.0405	0.0101	0.0011
N 54	85.4620	0.6137	1.8710	8.0768		2.8634		0.8712		0.1902	0.0405	0.0101	0.0011
N 55	85.3453	0.6039	1.9051	8.1433		2.8692		0.8975	0.0139	0.1745	0.0345	0.0117	0.0011
N 56	85.3453	0.6039	1.9051	8.1433		2.8692		0.8975	0.0139	0.1745	0.0345	0.0117	0.0011
N 57	94.6077	3.7581	0.2609	1.0118		0.2128		0.0762	0.0343	0.0244	0.0086	0.0044	0.0008
N 58	94.6077	3.7581	0.2609	1.0118		0.2128		0.0762	0.0343	0.0244	0.0086	0.0044	0.0008
N 59	82.5198	11.7266	1.1093	3.4611		0.7645		0.2539	0.0538	0.0746	0.0225	0.0110	0.0029
N 60	82.5198	11.7266	1.1093	3.4611		0.7645		0.2539	0.0538	0.0746	0.0225	0.0110	0.0029
N 61	98.2722	0.8858	0.0668	0.5159		0.1607		0.0592	0.0157	0.0157	0.0055	0.0016	0.0009
N 62	98.2722	0.8858	0.0668	0.5159		0.1607		0.0592	0.0157	0.0157	0.0055	0.0016	0.0009
N 63	89.4525	5.3701	4.8625	0.2353		0.0163		0.0064	0.0544	0.0020	0.0003	0.0002	
N 64	89.4525	5.3701	4.8625	0.2353		0.0163		0.0064	0.0544	0.0020	0.0003	0.0002	

Table 3.7 (cont) Listing of Compositions (by mole percent) for Natural Gases

GERG Code	CH4	N2	CO2	C2H6	H2	C3H8	CO	C4H10	HE	C5H12	C6H14	C7H16	C8H18
N 65	85.4541	0.4275	1.7708	8.4983	0.0019	2.7421		0.8951	0.0038	0.1673	0.0315	0.0068	0.0008
N 66	85.4541	0.4275	1.7708	8.4983	0.0019	2.7421		0.8951	0.0038	0.1673	0.0315	0.0068	0.0008
N 67	82.1692	5.3302	1.7802	5.6763	2.3094	1.7778	0.2019	0.5667	0.0249	0.1175	0.0309	0.0116	0.0034
N 68	80.1984	5.4710	1.8292	5.5031	4.1947	1.6910	0.3826	0.5457	0.0229	0.1157	0.0296	0.0128	0.0033
N 69	73.6405	10.0017	1.6182	3.3093	9.3919	0.7661	0.9067	0.2456		0.0744	0.0239	0.0149	0.0068
N 70	82.2373	5.3206	1.7745	5.6871	2.2770	1.7596	0.1960	0.5597	0.0246	0.1174	0.0309	0.0119	0.0034
N 71	80.1543	5.4722	1.8318	5.4932	4.2203	1.7111	0.3863	0.5480	0.0230	0.1151	0.0297	0.0117	0.0033
N 72	73.5015	10.0214	1.6245	3.3152	9.4918	0.7657	0.9142	0.2458		0.0740	0.0241	0.0148	0.0070
N 73	73.5015	10.0214	1.6245	3.3152	9.4918	0.7657	0.9142	0.2458		0.0740	0.0241	0.0148	0.0070
N 74	73.5015	10.0214	1.6245	3.3152	9.4918	0.7657	0.9142	0.2458		0.0740	0.0241	0.0148	0.0070
N 75	85.9284	0.9617	1.5021	8.4563		2.3022		0.6985		0.1218	0.0228	0.0057	0.0005
N 76	84.3769	0.4233	1.9201	8.8749	0.0020	3.1776		1.0022	0.0031	0.1812	0.0310	0.0065	0.0012
N 77	81.3140	14.1790	0.9890	2.8290		0.3910		0.1400	0.0500	0.0620	0.0248	0.0192	0.0020
N 78	88.2210	1.1760	1.8560	6.1190		1.8840		0.5890	0.0250	0.0930	0.0230	0.0130	0.0010
N 79	83.4177	0.3379	1.8816	9.5284	0.0010	3.5694		1.0365	0.0028	0.1828	0.0327	0.0081	0.0011
N 80	65.6961	1.8530	28.9263	2.5547		0.5395		0.2045	0.0527	0.0995	0.0425	0.0299	0.0013
N 81	80.8753	2.9080	11.2419	3.7681		0.7038		0.2400	0.0657	0.1221	0.0448	0.0263	0.0040
N 82	84.4872	5.9990	1.3984	5.9271		1.5364		0.5089		0.1057	0.0251	0.0101	0.0021
N 83	84.4872	5.9990	1.3984	5.9271		1.5364		0.5089		0.1057	0.0251	0.0101	0.0021
N 84	57.6930	1.4200	0.0330	1.7800	35.6310	3.2000		0.1450		0.0420	0.0560		
N 85	85.9610	0.6370	1.4550	8.7390		2.3870		0.6680	0.0060	0.1220	0.0210	0.0040	
N 86	82.7100	0.6200	0.7900	14.7000		1.0400		0.1200		0.0100	0.0100		
N 87	96.5016	0.2501	0.5990	1.7490		0.4003		0.1999		0.2000	0.1001		
N 88	95.0220	1.1200	0.0600	2.9190		0.4900		0.1900	0.0240	0.0920	0.0410	0.0300	0.0120
N 89	87.4320	11.1140	0.2100	0.9100		0.1600		0.0500	0.0630	0.0280	0.0170	0.0090	0.0070
N 90	93.6200	2.1390	0.3200	2.9390		0.5500		0.2100	0.0410	0.0950	0.0470	0.0280	0.0110
N 91	85.2970	7.7470	0.6000	4.5080		1.0600		0.5000	0.0360	0.1720	0.0620	0.0150	0.0030
N 92	95.6160	0.5100	0.3000	3.4800		0.0440		0.0140	0.0040	0.0060	0.0100	0.0090	0.0070
N 93	94.2320	1.6100	0.8500	3.1500		0.1500			0.0080				
N 94	85.9230	0.6640	1.4400	8.7770		2.3800		0.6640	0.0060	0.1210	0.0210	0.0040	
N 95	85.9030	0.5890	1.4380	8.7660		2.3870		0.6690	0.0050	0.1220	0.0210	0.1000	
N 96	75.2030	23.6960	0.1320	0.7830		0.0590		0.0180	0.0860	0.0130	0.0080	0.0020	

Table 3.8 Listing of Reduced Composition for Natural Gases

GERG CODE	Hs MJ/m3	d	CO2 Mol %	H2 Mol %
N 1	44.6451	0.6691	1.9285	0.0015
N 2	40.2484	0.5825	0.2331	
N 3	40.2860	0.6462	1.4546	
N 4	44.0697	0.6606	1.8643	
N 5	39.1117	0.6305	1.7006	4.1947
N 6	39.8375	0.6402	1.7126	2.3094
N 7	34.4055	0.5983	1.3360	9.3919
N 8	35.9256	0.6235	1.2641	4.2885
N 9	40.2538	0.5826	0.2339	
N 10	44.6788	0.6682	1.8497	
N 11	40.2756	0.6461	1.4579	
N 12	44.0777	0.6606	1.8630	
N 13	40.2538	0.5826	0.2339	
N 14	44.6788	0.6682	1.8497	
N 15	40.2756	0.6461	1.4579	
N 16	44.0777	0.6606	1.8630	
N 17	40.2409	0.5823	0.2299	
N 18	44.6832	0.6686	1.8647	
N 19	40.2958	0.6459	1.4349	
N 20	44.0812	0.6609	1.8710	
N 21	41.2805	0.6037	0.0401	
N 22	40.6147	0.5968	0.0402	
N 23	35.0186	0.6454	0.9940	
N 24	40.0834	0.6098	1.5280	
N 25	44.8211	0.6725	1.9870	
N 26	44.8096	0.6730	2.0270	
N 27	44.8880	0.6733	1.9730	
N 28	41.8664	0.6334	1.9820	
N 29	32.7174	0.7016	7.1770	
N 30	40.0952	0.6288	1.5730	
N 31	39.5915	0.6032	1.9860	
N 32	39.8305	0.6182	0.5810	
N 33	30.4479	0.8356	25.4370	
N 34	36.1967	0.7087	11.2480	
N 35	29.0616	0.8676	28.9430	
N 36	40.0687	0.6370	1.6030	
N 37	44.8158	0.6749	2.1250	
N 38	34.1724	0.6504	0.5550	
N 39	41.4358	0.6359	1.7790	
N 40	35.0288	0.6577	1.4720	
N 41	35.3364	0.6442	0.9780	
N 42	35.2666	0.6446	0.9800	
N 43	39.4656	0.6363	1.7960	
N 44	40.1505	0.6021	0.9750	
N 45	39.9134	0.6111	0.7040	
N 46	30.6213	0.6591	0.1180	
N 47	28.7276	0.6787	0.1080	
N 48	18.7491	0.7814	0.0590	
N 49	42.3779	0.6401	2.0360	
N 50	35.2546	0.6440	0.9580	

Table 3.8 (cont) Listing of Reduced Composition for Natural Gases

GERG CODE	Hs MJ/m3	d	CO2 Mol %	H2 Mol %
N 51	44.0777	0.6606	1.8630	
N 52	44.0777	0.6606	1.8630	
N 53	44.0812	0.6609	1.8710	
N 54	44.0812	0.6609	1.8710	
N 55	44.0877	0.6614	1.9051	
N 56	44.0877	0.6614	1.9051	
N 57	38.7655	0.5818	0.2609	
N 58	38.7655	0.5818	0.2609	
N 59	36.5601	0.6443	1.1093	
N 60	36.5601	0.6443	1.1093	
N 61	39.7824	0.5646	0.0668	
N 62	39.7824	0.5646	0.0668	
N 63	35.8238	0.6254	4.8625	
N 64	35.8238	0.6254	4.8625	
N 65	44.2231	0.6595	1.7708	0.0019
N 66	44.2231	0.6595	1.7708	0.0019
N 67	39.8375	0.6402	1.7126	2.3094
N 68	39.1117	0.6305	1.7006	4.1947
N 69	34.4055	0.5983	1.3360	9.3919
N 70	39.8399	0.6400	1.7080	2.2770
N 71	39.1119	0.6305	1.7022	4.2203
N 72	34.3700	0.5980	1.3390	9.4918
N 73	34.3700	0.5980	1.3390	9.4918
N 74	34.3700	0.5980	1.3390	9.4918
N 75	43.5956	0.6506	1.5021	
N 76	44.6529	0.6689	1.9201	0.0020
N 77	35.1137	0.6449	0.9890	
N 78	42.2822	0.6374	1.8560	
N 79	45.1735	0.6759	1.8816	0.0010
N 80	29.0816	0.8676	28.9263	
N 81	36.2102	0.7088	11.2419	
N 82	40.2259	0.6477	1.3984	
N 83	40.2259	0.6477	1.3984	
N 84	32.2710	0.4318	0.0330	35.6310
N 85	43.8431	0.6504	1.4550	
N 86	44.4628	0.6493	0.7900	
N 87	40.8264	0.5835	0.5990	
N 88	40.9434	0.5859	0.0600	
N 89	35.7904	0.6107	0.2100	
N 90	40.4927	0.5937	0.3200	
N 91	39.2539	0.6376	0.6000	
N 92	40.6423	0.5783	0.3000	
N 93	39.8880	0.5866	0.8500	
N 94	43.8407	0.6504	1.4400	
N 95	44.0502	0.6530	1.4380	
N 96	30.6071	0.6587	0.1320	

Table 3.9 Example Pages from the GERG Databank

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0230 M     26.850   10.0000    0.97489    Z MGFDEH019H300008
0230 M     26.840   20.0000    0.94896    Z MGFDEH019H300009
0230 M     26.840   30.0000    0.92308    Z MGFDEH019H300010
0230 M     26.850   40.0000    0.89749    Z MGFDEH019H300011
0230 M     26.840   50.0000    0.87221    Z MGFDEH019H300012
0230 M     26.840   60.0000    0.84738    Z MGFDEH019H300013
0230 M     26.840   70.0000    0.82333    Z MGFDEH019H300014
0228 T C146  5     CH4-C2H6-C3H8  DISTRIGAZ
0228 G CH4       = 81.1900  C2H6      = 16.5500  C3H8      =  2.2600
0228 M     10.020   31.0260    0.90153    Z MDIDEH002H300001
0228 M      9.990   41.0310    0.86866    Z MDIDEH002H300002
0228 M      9.960   51.0350    0.83595    Z MDIDEH002H300003
0228 M      9.930   61.0400    0.80363    Z MDIDEH002H300004
0228 M      9.900   71.0450    0.77220    Z MDIDEH002H300005
0228 M      9.980   77.0480    0.75479    Z MDIDEH002H300006
0228 M     19.860   31.0260    0.91317    Z MDIDEH002H300007
0228 M     19.820   31.0280    0.91311    Z MDIDEH002H300008
0228 M     19.860   41.0300    0.88480    Z MDIDEH002H300009
0228 M     19.830   41.0320    0.88473    Z MDIDEH002H300010
0228 M     19.860   51.0350    0.85677    Z MDIDEH002H300011
0228 M     19.960   51.0360    0.85698    Z MDIDEH002H300012
0228 M     19.860   61.0400    0.82937    Z MDIDEH002H300013
0228 M     19.960   61.0410    0.82953    Z MDIDEH002H300014
0228 M     19.870   71.0440    0.80302    Z MDIDEH002H300015
0228 M     19.940   71.0450    0.80311    Z MDIDEH002H300016
0228 M     19.900   77.0470    0.78793    Z MDIDEH002H300017
0282 T C146  6     CH4-C2H6-C3H8  BRITISH GAS
0282 G CH4       = 81.3200  C2H6      = 16.2400  C3H8      =  2.4400
0282 M     20.520   20.0269    0.94479    Z MBGDEH003H300001
0282 M     20.520   30.0316    0.91677    Z MBGDEH003H300002
0282 M     20.520   40.0366    0.88879    Z MBGDEH003H300003
0282 M     20.520   48.0405    0.86675    Z MBGDEH003H300004
0282 M     39.540   20.0310    0.95591    Z MBGDEH003H300005
0282 M     39.540   30.0365    0.93419    Z MBGDEH003H300006
0282 M     39.540   40.0416    0.91267    Z MBGDEH003H300007
0282 M     39.540   50.0465    0.89163    Z MBGDEH003H300008
0282 M     39.540   60.0514    0.87125    Z MBGDEH003H300009
0280 T C146  7     CH4-C2H6-C3H8  NED. GASUNIE
0280 G CH4       = 81.3600  C2H6      = 16.2000  C3H8      =  2.4400
0280 M     17.020   32.1000    0.90650    Z MGUDEH069H300001
0280 M     17.020   34.5300    0.89940    Z MGUDEH069H300002
0280 M     17.020   37.5800    0.89040    Z MGUDEH069H300003
0280 M     17.020   40.8600    0.88080    Z MGUDEH069H300004
0280 M     17.020   44.4800    0.87020    Z MGUDEH069H300005
0280 M     17.020   48.3500    0.85890    Z MGUDEH069H300006
0280 M     17.020   52.5800    0.84660    Z MGUDEH069H300007
0280 M     17.020   57.2800    0.83320    Z MGUDEH069H300008
0280 M     17.020   62.3400    0.81880    Z MGUDEH069H300009
0280 M     17.020   67.7500    0.80390    Z MGUDEH069H300010
0280 M     17.020   72.7800    0.79040    Z MGUDEH069H300011
0280 M     40.100   28.9400    0.93620    Z MGUDEH069H300012
0280 M     40.100   30.6100    0.93260    Z MGUDEH069H300013
0280 M     40.100   32.6700    0.92810    Z MGUDEH069H300014
0280 M     40.100   34.8800    0.92340    Z MGUDEH069H300015
0280 M     40.090   37.3200    0.91820    Z MGUDEH069H300016
0280 M     40.090   39.9100    0.91270    Z MGUDEH069H300017
0280 M     40.090   42.5900    0.90700    Z MGUDEH069H300018
0280 M     40.100   45.5300    0.90090    Z MGUDEH069H300019
0280 M     40.100   48.7100    0.89430    Z MGUDEH069H300020
0280 M     40.070   51.9100    0.88780    Z MGUDEH069H300021
0280 M     40.040   55.1800    0.88110    Z MGUDEH069H300022
0284 T C146  8     CH4-C2H6-C3H8  RUHRGAS
0284 G CH4       = 81.3700  C2H6      = 16.1900  C3H8      =  2.4400
0284 M      6.840   19.9950    0.93414    Z MRGADH057H300001
0284 M      6.840   29.9970    0.90070    Z MRGADH057H300002
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Table 3.9 (cont) Example Pages from the GERG Databank

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0278 M      50.000   80.0098    0.86124   Z MDUWAE002H 00135
0022 T N 77         SLOCHTEREN-L    NED.GASUNIE
0022 G CO2       =  0.9890  N2        = 14.1790  HE         =  0.0500
0022 G CH4       = 81.3140  C2H6      =  2.8290  C3H8       =  0.3910
0022 G I-C4H10   =  0.0650  N-C4H10   =  0.0750  NEO-C5H12=    0.0070
0022 G I-C5H12   =  0.0170  N-C5H12   =  0.0180  N-C6H14    =  0.0228
0022 G N-C7H16   =  0.0130  N-C8H18   =  0.0020  C6H6       =  0.0200
0022 G C7H8      =  0.0062  C-C6H12   =  0.0020             =
0022 M      23.380   37.0420    0.93980   Z MGUDEH001L 00001
0022 M      23.490   40.6440    0.93520   Z MGUDEH001L 00002
0022 M      23.350   45.0460    0.92770   Z MGUDEH001L 00003
0022 M      23.340   49.4490    0.92160   Z MGUDEH001L 00004
0022 M      23.480   51.0490    0.92030   Z MGUDEH001L 00005
0022 M      23.300   57.0530    0.91170   Z MGUDEH001L 00006
0022 M      23.480   61.0540    0.90700   Z MGUDEH001L 00007
0022 M      23.290   65.0560    0.90050   Z MGUDEH001L 00008
0022 M      23.470   70.6590    0.89350   Z MGUDEH001L 00009
0022 M      23.240   71.8600    0.89280   Z MGUDEH001L 00010
0022 M      23.260   71.8600    0.89270   Z MGUDEH001L 00011
0023 T N 78         STATENZIJL-H   NED.GASUNIE
0023 G CO2       =  1.8560  N2        =  1.1660  O2         =  0.0100
0023 G HE        =  0.0250  CH4       = 88.2210  C2H6       =  6.1190
0023 G C3H8      =  1.8840  I-C4H10   =  0.2120  N-C4H10    =  0.3770
0023 G I-C5H12   =  0.0590  N-C5H12   =  0.0020  N-C6H14    =  0.0230
0023 G N-C7H16   =  0.0130  N-C8H18   =  0.0010  C6H6       =  0.0320
0023 M      22.440   47.0520    0.89330   Z MGUDEH002H 00001
0023 M      22.300   56.0360    0.87430   Z MGUDEH002H 00002
0023 M      22.240   65.0620    0.85570   Z MGUDEH002H 00003
0023 M      23.090   37.2440    0.91590   Z MGUDEH002H 00004
0023 M      22.840   47.0490    0.89460   Z MGUDEH002H 00005
0023 M      24.160   36.0500    0.91940   Z MGUDEH002H 00006
0023 M      23.990   37.6970    0.91570   Z MGUDEH002H 00007
0023 M      23.980   37.6970    0.91560   Z MGUDEH002H 00008
0023 M      24.170   43.4140    0.90400   Z MGUDEH002H 00009
0023 M      24.040   45.6310    0.89880   Z MGUDEH002H 00010
0023 M      24.170   51.1380    0.88790   Z MGUDEH002H 00011
0023 M      24.170   55.1400    0.87960   Z MGUDEH002H 00012
0023 M      24.170   59.4420    0.87100   Z MGUDEH002H 00013
0023 M      24.100   59.4980    0.87030   Z MGUDEH002H 00014
0023 M      24.110   61.4590    0.86640   Z MGUDEH002H 00015
0023 M      24.140   62.3440    0.86420   Z MGUDEH002H 00016
0023 M      24.140   62.3440    0.86430   Z MGUDEH002H 00017
0023 M      24.110   63.3400    0.86250   Z MGUDEH002H 00018
0023 M      24.110   65.3000    0.85880   Z MGUDEH002H 00019
0016 T N 79         EKOFISK-H      NED.GASUNIE
0016 G CO2       =  1.8816  N2        =  0.3350  O2         =  0.0014
0016 G H2        =  0.0010  HE        =  0.0028  AR         =  0.0015
0016 G CH4       = 83.4177  C2H6      =  9.5284  C3H8       =  3.5694
0016 G I-C4H10   =  0.3777  N-C4H10   =  0.6588  I-C5H12    =  0.0933
0016 G N-C5H12   =  0.0869  N-C6H14   =  0.0326  N-C7H16    =  0.0075
0016 G N-C8H18   =  0.0007  N-C9H20   =  0.0002  N-C10H22 =    0.0002
0016 G C6H6      =  0.0026  C7H8      =  0.0006  C2H5-C6H5=    0.0001
0016 M      23.490   30.4110    0.91980   Z MGUDEH003H 00001
0016 M      23.460   34.0460    0.90940   Z MGUDEH003H 00002
0016 M      23.480   34.0460    0.91000   Z MGUDEH003H 00003
0016 M      23.430   36.4390    0.90360   Z MGUDEH003H 00004
0016 M      23.450   36.4400    0.90350   Z MGUDEH003H 00005
0016 M      23.390   39.0410    0.89650   Z MGUDEH003H 00006
0016 M      23.400   39.0410    0.89760   Z MGUDEH003H 00007
0016 M      23.370   41.8420    0.88910   Z MGUDEH003H 00008
0016 M      23.380   41.8420    0.88950   Z MGUDEH003H 00009
0016 M      23.330   44.9440    0.88090   Z MGUDEH003H 00010
0016 M      23.350   44.9440    0.88180   Z MGUDEH003H 00011
0016 M      23.310   47.6650    0.87360   Z MGUDEH003H 00012
0016 M      23.320   47.6650    0.87410   Z MGUDEH003H 00013
```

4. REFERENCES

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5. GLOSSARY

Symbol	S.I. Unit	Meaning
$b^{(0)}$	$m^3\ mol^{-1}$	Zero-th order (constant) term in the expansion of B in temperature (equation (1.5)).
$b^{(1)}$	$m^3\ mol^{-1}\ K^{-1}$	Coefficient of the first order (linear) term in the expansion of B in temperature (equation (1.5)).
$b^{(2)}$	$m^3\ mol^{-1}\ K^{-2}$	Coefficient of the second order (quadratic) term in the expansion of B in temperature (equation (1.5)).
B	$m^3\ mol^{-1}$	Second virial coefficient (equations (1.1),(1.3)).
$c^{(o)}$	$m^6\ mol^{-2}$	Zero-th order (constant) term in the expansion of C in temperature (equation (1.6)).
$c^{(1)}$	$m^6\ mol^{-2}\ K^{-1}$	Coefficient of the first order (linear) term in the expansion of C in temperature (equation (1.6)).
$c^{(2)}$	$m^6\ mol^{-2}\ K^{-2}$	Coefficient of the second order (quadratic) term in the expansion of C in temperature (equation (1.6)).
C	$m^6\ mol^{-2}$	Third virial coefficient (equations (1.1), (1.4)).
d	-	Relative density (table 3.8).
H_S	$MJ\ m^{-3}$	Superior calorific value (table 3.8).

Symbol	S.I. Unit	Meaning
N	-	Number of components in a mixture.
p	Pa	(Absolute) pressure.
R	J mol^{-1} K^{-1}	Universal gas constant ($R=8.314510$ J mol^{-1} K^{-1}).
T	K	Thermodynamic (absolute) temperature.
x	-	Mole fraction.
Z	-	Compressibility (or compression) factor; defined by equation (1.2).
ρ_m	mol m^{-3}	Molar density.

Additional Subscripts

Symbol	Meaning
i	Identifier of i-th component in a mixture.
j	Identifier of j-th component in a mixture.
k	Identifier of k-th component in a mixture.
ij	For the binary interaction of component i with component j.
ijk	For the ternary interaction of components i,j and k.
mix	For a mixture.

Measurement Methodology Abbreviations used in Appendices

ADH	Automatic DEH Apparatus
BUR	Burnett Apparatus
DEH	Desgranges et Huot Z-Meter
EXP	Dantest Expansion Apparatus
OPT	Optical Interferometry Method
PZO	Piezometer Method
SUP	Calculation from GRI SuperZ Equation
WAE	Wagner Two-Sinker Method

APPENDICES

Table A1 1 METHANE RUHRGAS DEH 009 H1

43	CH4
mol%	100.00

T/K	p/MPa	Z(expt)	Z(calc)	Z(diff)/%
273.16	2.0006	0.9532	0.9529	-0.031
273.17	3.0006	0.9297	0.9295	-0.023
273.18	4.0005	0.9065	0.9063	-0.020
273.15	4.9998	0.8836	0.8835	-0.011
273.16	6.0005	0.8612	0.8613	0.016
273.15	7.0004	0.8398	0.8400	0.026
273.16	8.0005	0.8197	0.8199	0.026
283.17	2.0002	0.9587	0.9586	-0.007
283.17	3.0002	0.9385	0.9383	-0.026
283.17	4.0002	0.9184	0.9182	-0.019
283.16	5.0003	0.8989	0.8987	-0.026
283.16	6.0002	0.8799	0.8798	-0.015
283.16	7.0002	0.8619	0.8617	-0.022
293.15	2.0000	0.9640	0.9636	-0.039
293.15	3.0000	0.9461	0.9459	-0.025
293.16	4.0000	0.9287	0.9285	-0.019
293.14	4.9999	0.9119	0.9117	-0.024
293.15	5.9999	0.8957	0.8955	-0.019
293.15	6.9999	0.8803	0.8801	-0.017

Table B12 1 CH4-N2 ROE BUR 003 K2

	CH4	N2
60		
mol%	48.40	51.60

T/K	p/MPa	Z(expt)	Z(calc)	Z(diff)/%
291.40	0.27122	0.99752	0.99751	-0.001
291.40	0.49451	0.99551	0.99549	-0.002
291.40	0.90055	0.99191	0.99187	-0.004
291.40	1.63635	0.9856	0.9855	-0.006
291.40	2.96320	0.9750	0.9749	-0.013
291.40	5.34369	0.9586	0.9585	-0.015
291.40	9.64011	0.9395	0.9390	-0.054

Table C123 1 CH4-N2-CO2 NED. GASUNIE DEH 047 K3

	299	CH4	N2	CO2
	mol%	50.21	24.97	24.82

T/K	p/MPa	Z(expt)	Z(calc)	Z(diff)/%
279.41	3.7308	0.91582	0.91597	0.016
279.41	3.9305	0.91127	0.91156	0.032
279.41	4.1386	0.90664	0.90699	0.039
279.41	4.3594	0.90187	0.90217	0.033
279.41	4.5915	0.89670	0.89712	0.047
279.41	4.8347	0.89143	0.89187	0.049
279.41	5.0927	0.88577	0.88633	0.063
279.41	5.3633	0.87990	0.88058	0.077
279.41	5.6484	0.87390	0.87457	0.077
279.41	5.9489	0.86762	0.86831	0.079
279.41	6.2666	0.86103	0.86177	0.087
293.33	3.8025	0.92923	0.92936	0.014
293.34	3.9970	0.92573	0.92590	0.018
293.34	4.2029	0.92202	0.92225	0.025
293.34	4.4171	0.91816	0.91848	0.035
293.33	4.6418	0.91416	0.91455	0.042
293.33	4.8684	0.91010	0.91062	0.057
293.33	5.0653	0.90665	0.90724	0.065
293.34	5.2696	0.90311	0.90377	0.073
293.34	5.4932	0.89929	0.89999	0.078
293.34	5.7250	0.89542	0.89611	0.078
293.34	5.9574	0.89168	0.89227	0.066
308.38	3.7649	0.94259	0.94297	0.040
308.37	3.9328	0.94018	0.94056	0.041
308.37	4.1236	0.93746	0.93785	0.042
308.37	4.3231	0.93460	0.93504	0.047
308.37	4.5317	0.93163	0.93213	0.054
308.37	4.7501	0.92856	0.92911	0.059
308.37	4.9787	0.92536	0.92598	0.067
308.37	5.2179	0.92203	0.92274	0.077
308.37	5.4687	0.91863	0.91938	0.082
308.37	5.7319	0.91516	0.91591	0.082
308.37	6.0216	0.91144	0.91214	0.077

Table D 1 CH4-N2-C2H6 ROE BUR 005 L4

40	CH4	N2	C2H6
mol%	76.80	16.00	7.20

T/K	p/MPa	Z(expt)	Z(calc)	Z(diff)/%
273.02	0.3962	0.9908	0.9908	0.000
273.02	0.6983	0.9837	0.9838	0.009
273.02	1.2241	0.9715	0.9716	0.011
273.02	2.1261	0.9506	0.9508	0.021
273.02	3.6372	0.9161	0.9164	0.037
273.02	6.0821	0.8630	0.8635	0.061
273.02	9.9382	0.7945	0.7950	0.067

This is a 4-component mixture with 0.4 % oxygen re-assigned to nitrogen in the above listing.

Table N 1 EKOFISK-H RUHRGAS DEH 003 H

49	CH4	N2	CO2	C2H6	C3H8
mol%	84.33	0.44	1.93	8.89	3.19

T/K	p/MPa	Z(expt)	Z(calc)	Z(diff)/%
273.15	2.0001	0.9303	0.9309	0.064
273.18	3.0001	0.8957	0.8953	-0.045
273.15	4.0000	0.8597	0.8590	-0.078
273.15	5.0000	0.8233	0.8225	-0.102
273.15	6.0000	0.7868	0.7860	-0.101
273.15	7.0000	0.7507	0.7504	-0.040
283.17	2.0000	0.9397	0.9390	-0.071
283.17	3.0000	0.9088	0.9080	-0.085
283.17	4.0000	0.8778	0.8769	-0.105
283.16	5.0000	0.8471	0.8458	-0.156
283.17	5.9999	0.8163	0.8152	-0.136
283.16	6.9999	0.7863	0.7855	-0.101
293.11	1.9930	0.9472	0.9463	-0.098
293.10	2.9930	0.9203	0.9192	-0.122
293.16	3.9942	0.8936	0.8923	-0.150
293.15	4.9961	0.8670	0.8656	-0.166
293.15	5.9941	0.8407	0.8396	-0.132
293.15	6.9911	0.8157	0.8146	-0.131