FORTSCHRITT-BERICHTE VDI

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Supplement to the GERG Databank of High-Accuracy Compression Factor Measurements

GERG TM7 1996

Reihe 6: Energietechnik Nr. 355

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In GERG Technical Monograph TM4 (1990) a complete listing was given of the contents of the GERG databank of high-accuracy compression factor measurements as it stood at the original cut-off date of 31st March 1988, but also including a few additional data sets in the N-file up to 31st July 1990. In this new monograph we extend and update the databank in four main ways –
a) by the extension, for gas and gas mixture data sets already present in the databank, of the temperature range down to 218.5 K and up to 425.0 K (previously 265 to 335 K), and of the pressure range up to 60 MPa (previously 12 MPa);
b) by the addition, for the same extended ranges of temperature and pressure, of data sets for mixtures not previously present in the databank, most of these having been acquired by Ruhrgas in the interim for the specific purpose of testing the performance of the MGERG and SGERG equations close to the composition limits of their validity;
c) by inclusion of data sets gathered by several independent and renowned laboratories in a round-robin exercise organized by the Gas Research Institute of Chicago;
d) by the addition of data sets either overlooked in the pre-existing open research literature or appearing there since the 1988 deadline.
In these ways the databank has been increased in size to 36239 data points (previously 14183). The accuracy requirement for data to qualify for inclusion remains at ± 0.1%.

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SUPPLEMENT TO THE GERG DATABANK OF HIGH-ACCURACY COMPRESSION FACTOR MEASUREMENTS

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SUPPLEMENT TO THE GERG DATABANK OF HIGH-ACCURACY COMPRESSION FACTOR MEASUREMENTS

Abstract

In GERG Technical Monograph TM4 (1990) a complete listing was given of the contents of the GERG databank of high-accuracy compression factor measurements as it stood at the original cut-off date of 31st March 1988, but also including a few selected additions up to 31st July 1990. In this new monograph we extend and update the databank in four main ways -

(a) by the extension, for gas and gas mixture data sets already present in the databank, of the temperature range down to 218.5 K and up to 425.0 K (previously 265 to 335 K), and of the pressure range up to 60 MPa (previously 12 MPa);

(b) by the addition, for the same extended ranges of temperature and pressure, of data sets for mixtures not previously present in the databank, most of these having been acquired by Ruhrgas in the interim for the specific purpose of testing the performance of the MGERG and SGERG equations close to the composition limits of their validity;

(c) by inclusion of data sets gathered by several independent and renowned laboratories in a round-robin exercise organized by the Gas Research Institute of Chicago;

(d) by the addition of data sets either overlooked in the pre-existing open research literature or appearing there since the 1988 deadline.

In these ways the databank has been increased in size to 36239 data points (previously 14183). The accuracy requirement for data to qualify for inclusion remains at ±0.1%. We propose that the databank should be updated at 5-yearly intervals so as to continue to serve as a state-of-the-art research resource for the natural gas industry.

Zusammenfassung

Im GERG Technical Monograph TM4 (1990) ist die komplette GERG-Datenbank von sehr genauen Realgasfaktoren, so wie sie zum ursprünglichen Fertigstellungstermin am 31. März 1988 vorlag, aufgelistet. Einige ergänzende Daten sind bis zum 31. Juli 1990 hinzugefügt worden. In der vorliegenden Monographie ist die Datenbank durch vier Hauptzusätze ergänzt und aktualisiert worden:

(a) durch die Erweiterung der Datensätze für die Gase und Gasgemische, die schon vorher in der Datenbank aufgeführt waren, auf einen vergrößerten Temperaturbereich von 218,5 K bis 425,0 K (früher 265 K bis 335 K) und auf Drücke bis zu 60 MPa (früher 12 MPa);

(b) durch Hinzufügen von Datensätzen für Gemische, die früher nicht in der Datenbank vertreten waren. Die meisten dieser Daten sind in der Zwischenzeit bei Ruhrgas mit dem Ziel vermessen worden, die Genauigkeit der MGERG- und SGERG-Gleichung im Grenzbereich der erlaubten Gaszusammensetzungen zu testen;

(c) durch Aufnahme von Datensätzen, die von mehreren unabhängigen, anerkannten Labors im Rahmen eines Ringversuches an fünf Gasgemischen bestimmt wurden, der durch das Gas Research Institute Chicago organisiert worden war;

(d) durch Übernahme von Datensätzen, die entweder bisher in der Fachliteratur übersehen worden waren, oder seit dem ursprünglichen Fertigstellungstermin von 1988 erschienen sind.

Auf diese Weise ist die Datenbank auf eine Größe von insgesamt 36239 Datenpunkte (früher 14183) ausgedehnt worden. Die Anforderungen an die Genauigkeit, die zur einer Aufnahme der Daten in die Bank führen, blieb unverändert bei 0,1%. Wir schlagen vor, die Datenbank in einem 5-Jahres-Rhythmus zu überarbeiten, damit diese Datenquelle für Realgasfaktoren auch weiterhin den Stand der Technik für die Erdgasindustrie dastellt.

Further Information

In GERG TM4, a complete point-by-point listing of the contents of the 1990 GERG databank was given; now, however, because of the great increase in size, it has become impracticable to give a complete listing. Instead, the databank is available on disk by personal application to Dr Manfred Jaeschke at the following address -

Dr M Jaeschke
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Halterner Straße 125
D-46284 Dorsten
Federal Republic of Germany.

All other correspondence relating to the GERG databank should also be addressed to Dr Jaeschke.

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We are grateful to Peter Schley for his very careful work on the revision and extension of the GERG databank. The computational procedures developed by him have made it much easier to evaluate the new data, have permitted comprehensive statistical analyses of the various data records and have provided convenient formats for the presentation of information.

1 - INTRODUCTION

1.1 Calculation of Compression Factor

After a decade and more of focussed research effort in both Europe and the United States, the natural gas industry now has methods, currently proceeding towards international standardization [reference 1], which for the first time enable the accurate prediction of compression factor *Z(p,T)* for essentially all pipeline quality natural gases. Within the temperature T and pressure p ranges $263 \leq T/K \leq 338$ and $0 < p/MPa \leq 12$ respectively, the expected accuracy is about ±0.1%; outside of these primary ranges the accuracy inevitably degrades somewhat, but is at least partially established. For gases characterised by a complete molar analysis, the revised (1992) AGA-8 equation (more fully known as the AGA-8-92DC equation) would normally be the method of choice, particularly at high pressures; for gases with known calorific value, relative density and carbon dioxide content, the (1988) SGERG equation is used.

The recent development of the MGERG [2], SGERG [3] and revised AGA-8 [4] equations has depended crucially upon the concurrent accumulation of the GERG databank of high-accuracy compression factor measurements [5-7]. Without this unique databank, the last version of which was published in GERG Monograph TM4 (1990) [7], neither the initial development nor the subsequent detailed testing of the various equations would have been possible.

For both economic and operational reasons, increasingly accurate knowledge of the compression factor, as a measure of non-ideality, will continue to be sought throughout the natural gas industry, and for ever-wider ranging applications. Non-ideality intrudes ubiquitously into almost all aspects of natural gas measurement. It is clearly important, therefore, to maintain and extend the GERG databank as an ongoing state-of-the-art research resource for the worldwide community of natural gas engineers and scientists.

1.2 The 1990 GERG Databank

The 1990 GERG Databank is described in detail in GERG Monograph TM4 [7]. In brief, however, it comprises five large files: the A-File contains data for pure (i.e. single component) gases; the B-File contains data for binary gas mixtures; the C-File contains data for ternary mixtures; the D-File contains data for quaternary and other (mostly synthetic) multicomponent mixtures; finally, the N-File contains data both for true natural gases and for natural gases with various types of admixture. The databank is intended to contain only data having an accuracy of ±0.1% or better. The ranges of temperature and pressure adopted for the 1990 GERG databank are $265 \le T/\mathrm{K} \le 335$ and $0 < p/\mathrm{MPa} \le 12$ respectively. The major specific components of gas mixtures are identified and given code numbers in Table 1. In total the 1990 GERG databank contains 14183 points in 277 distinct sets of data. Some summary statistics are given in Table 2.

Table 1 : Components of Gases in the 1990 GERG Databank

Component Number	Chemical Identity
1	Methane CH_4
2	Nitrogen N_2
3	Carbon Dioxide CO_2
4	Ethane C_2H_6
5	Hydrogen H_2
6	Propane C_3H_8
7	Carbon Monoxide CO
8	Butanes C_4H_{10}
9	Helium He
10	Pentanes C_5H_{12}
11	Hexanes C_6H_{14}
12	Heptanes C_7H_{16}
13	Octanes C_8H_{18}

1.3 Composition Regions with Inadequate Test Data

Despite the apparently impressive statistics given in Table 2 for the 1990 GERG databank, it is nevertheless very easy to see that its coverage is far from comprehensive. For example, the number of component-distinct binary (B-file) systems which can be made from the top nine components listed in Table 1 is 36 (components 10 to 13 are excluded from consideration here as they can only be present in very small proportions, and are difficult to prepare and to analyse accurately; their effect on volumetric behaviour is, however, disproportionately significant). For ternary (C-file) systems the corresponding number is 84. Clearly the 1990 GERG databank comes nowhere near to the ideal of full coverage; it contains only 18 component-distinct binaries and just 5 component-distinct ternaries. And, of course, the number of compositionally-distinct mixtures (see footnote to Table 2) is limitless.

Table 2 : Summary Statistics for the 1990 GERG Databank

File	Number of Components	Number of Systems	Number of Distinct Mixtures*	Number of Data Sets	Number of Points
A	1	8	8	36	2374
B	2	18	68	107	5847
C	3	5	7	18	620
D	4+	6	18	20	492
N	-	1(!)	42	96	4850
Total		38	143	277	14183

* Mixtures very close to each other in composition (i.e. for which the molar compositions of all components match within about 1%) are, for present purposes, taken as compositionally-<u>in</u>distinct.

Fortunately it turns out that the development of useful predictive equations depends most critically on the availability of very accurate data for a limited number of important mixtures. Thus the 1990 GERG databank proved just about sufficient in most respects for the development of the GERG and AGA-8 equations.

Even so, some significant deficiencies in the 1990 GERG databank have long been acknowledged, mainly in respect of the data available with which to test the equations developed. For preference such test measurements should be for true natural gases (possibly enriched or diluted), since it is the proper aim of the equations to describe natural gases, not few-component synthetic mixtures. The GERG Monographs TM2 [2], TM4 [7] and TM5 [3] each addressed this question.

In GERG TM2, the authors deplored the paucity of good quality data for the ethane + propane and ethane + butane binary systems and for the methane + ethane + propane ternary system; this shortage of data led directly to undesirably large uncertainties in some of the coefficients of the MGERG equation.

Nevertheless, the main concern expressed in TM2 and, in essence, reiterated in TM4 and TM5 was the need for more extensive test data. In particular, the intention that the GERG equations should each predict the compression factor of natural gases, with an uncertainty no greater than 0.1%, for gases with nitrogen content up to 50%, carbon dioxide up to 30% or ethane up to 20%, in each case up to a pressure of 12 MPa, could not be fully tested. Reasonably adequate test data were available in each case for pressures up to 7 MPa; these verified the performance of the GERG equations for use at current normal gas transmission pressures, but at pressures up to 12 MPa the contents of the 1990 GERG databank allowed testing up to maxima of only 12% nitrogen, 5% carbon dioxide and 9½% ethane.

By the time GERG TM5 was published, Ruhrgas had set about removing these deficiencies by making measurements on a series of sixteen new diluted or enriched natural gas mixtures, containing up to approximately 49% nitrogen, 27% carbon dioxide, 19% ethane and 37% hydrogen. The results are reported in section 2.2 of this Monograph. Despite this major effort, however, there are still no extensive sets of data for the ethane + propane, ethane + butane and methane + ethane + propane systems.

The rest of chapter 2 deals with additions to the databank from a variety of other sources, most notably from a round-robin exercise organised by the Gas Research Institute (GRI), Chicago (see also chapter 4) and from the published research literature. One important feature of the GRI round-robin exercise was the wide range of state conditions (temperature and pressure) which it was designed to cover. This feature encouraged us in our decision to make significant extensions to both the temperature range (now $218.5 \leq T/K \leq 425.0$) and pressure range (now $0 < p/\text{MPa} \leq 60$) for the 1996 GERG databank (see Figure 1).

As a result of all these additions and extensions, the databank now contains 36239 data points; a summary of the main features and statistics for the revised databank is given in chapter 3.

Meanwhile, measurements on compression factor aimed at filling remaining gaps in knowledge continue. Notable among current work is a collaborative project, funded jointly by GRI and several hydrocarbon recovery companies and being carried out at the U.K. National Engineering Laboratory (NEL, East Kilbride, Scotland). The systems to be studied include binary mixtures of methane with n-hexane and simulated rich natural gases containing up to 18% ethane, 14% propane, 6% n-butane and 0.5% n-pentane.

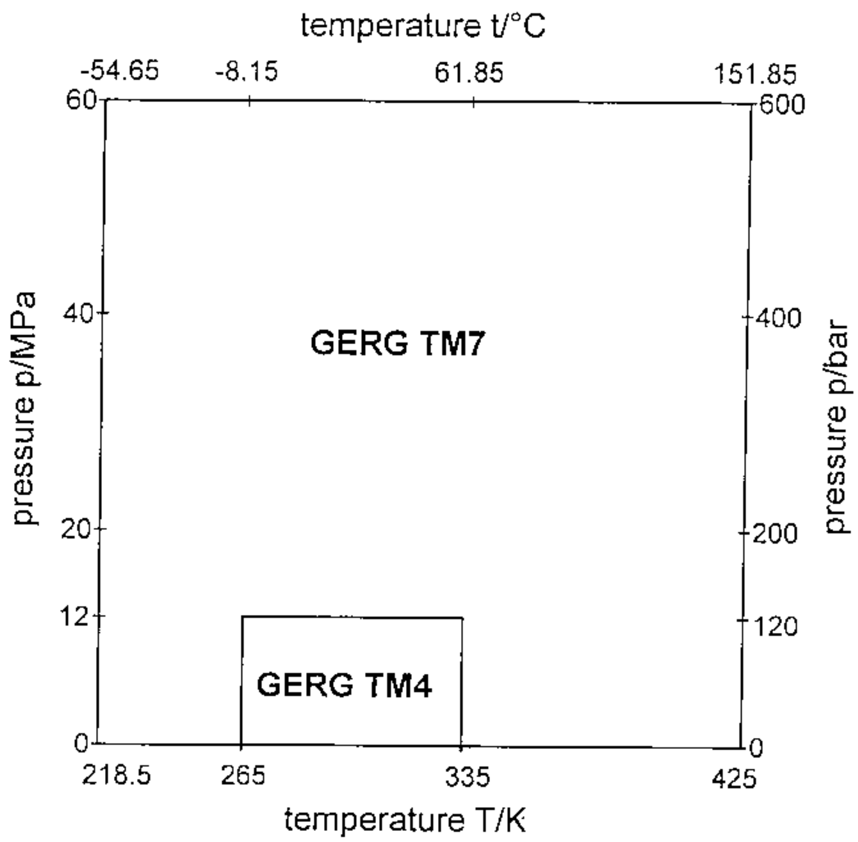

Figure 1 : Temperature and Pressure Ranges for the GERG Databank

TM4 = ranges covered in GERG Monograph TM4 (1990)

TM7 = supplemental ranges covered in this Monograph

(note: in a separate databank held in-house by Ruhrgas the upper limits of temperature and pressure are extended to 475 K and 120 MPa respectively).

2 - ADDITIONS TO THE COMPRESSION FACTOR DATABANK

2.1 Wider-Ranging Measurements for Existing Gases

2.1.1 Overview

The temperature and pressure ranges for the 1996 GERG databank have been extended from $265 \leq T/K \leq 335$ to $218.5 \leq T/K \leq 425.0$ and from $0 < p/\text{MPa} \leq 12$ to $0 < p/\text{MPa} \leq 60$ respectively. This implies that many data previously excluded, both from the published research literature and elsewhere, now fall within the ambit of the GERG databank.

The need to extend the temperature and pressure ranges of the databank so dramatically follows logically from perceived future (if not present!) requirements for the estimation of compression factor over much wider ranges of these state conditions than hitherto in the natural gas industry, and with known uncertainty. It is possible, for example, to foresee applications in salt-cavity storage studies, gas reservoir engineering and natural gas vehicle refuelling; typical conditions for such applications will in general be far from the transmission metering conditions which determined the ranges set for the original databank. These new applications may or may not require the development of new predictive methods but, either way, wide-ranging test data (at least) will be essential.

In the following subsections we provide only a brief review of the extended-range data added for those sets of data already present in the 1990 GERG databank, firstly for pure gases, then for binary mixtures and finally for multicomponent and natural gases. The source of each set of data may be identified by use of Appendix B, and a complete listing of the numbers of data points now present for each set of data is given in Appendix C. Totally new sets of data, containing measurements which fall within either the old or the extended ranges of temperature and pressure, are considered separately, in sections 2.2, 2.3 and 2.4.

For the period before about 1985 the published research literature occasionally contains data, previously excluded, which (because of the widening of the ranges of temperature and pressure) should certainly now be considered for acceptance into the databank. In some known cases of this type, consideration has indeed been given to relevant data, but it has been found impracticable to perform a comprehensive search for and evaluation of all such data.

2.1.2 Pure Gases

Many, indeed the great majority, of sets of compression factor measurements on pure gases included in GERG TM4 contain data which extend to a greater or lesser degree into the much wider ranges now under consideration.

For methane, data sets A1-4, A1-6, A1-7, A1-8, A1-9, A1-10 and A1-12 contain a total of 700 data points which have been added to the databank. Notably among these, dataset A1-4 [reference 72-01 in Appendix B] contains data which extend down to just below 220 K, but only up to 10 MPa; A1-6 [79-01] has data up to 373 K and 39 MPa; A1-8 [64-01] has data up to 398 K and 40 MPa; and A1-10 [91-06] alone has almost 300 data points at temperatures up to 353 K and pressures up to 28 MPa.

For nitrogen, data points have been added for sets A2-2, A2-3, A2-4, A2-5, A2-6 and A2-8. Set A2-2 [72-01] contains data for temperatures down to about 220 K, but to only about 10 MPa; set A2-6 [91-06] contains well over 300 points (more than two-thirds of those added) for temperatures up to 353 K and pressures up to 28 MPa.

For carbon dioxide, data sets A3-1, A3-2, A3-3 and A3-4 all contain extra data points for the extended ranges of temperature and pressure. In this case, about three-quarters of the total of well over 200 data points are from the single set A3-3 [90-03], which contains data up to 360 K and 30 MPa.

For ethane, a total of over 200 further data points have been added, for sets A4-1, A4-3 and A4-4, the preponderance being in the last of these. Set A4-1 [54-01] contains data up to 373 K and 14 MPa; set A4-4 [90-03] contains data up to 360 K and 27 MPa.

For hydrogen, just under 200 extra data points have been added, for sets A5-1, A5-2 and A5-3, the great majority again being in the last of these [90-03], and extending up to 360 K and 28 MPa. A few points have also been added for carbon monoxide and helium, at a temperature of 348 K and relatively low pressures, for sets A7-1 and A9-3 respectively.

2.1.3 Binary Mixtures

From among the 107 sets of binary mixture data present in the GERG TM4 (1990) version of the databank, no less than 73 contain data which fell outside of the limits set at that time for temperature and pressure, but which now fall within the extended limits. It is unnecessary to examine in detail here which mixtures fall into this category, and from which laboratories they originate; these details can readily be found by use of Appendices B and C. It is worthwhile to note, however, that 61 of the 73 sets for which new data have now been added to the databank were made at the Ruhrgas research laboratories in Dorsten, concurrently with the originally reported measurements. In general terms, the Ruhrgas measurements range in temperature from about 270 to 350 K and up to maximum pressures of about 30 MPa.

Of the remaining sets of data, B12-1, B12-2, B13-6, B14-14 to B14-16, and B23-4 contain measurements for temperatures which extend significantly below 270 K; for the first three of these, the data reach right down to 220 K. Dataset B13-6 [87-04] also contains data for pressures up to 48 MPa. The only other sets are B12-16 to B12-20 [86-01], for which the measurements extend up to 33 MPa, though for only a single temperature.

The total number of data points added to the B-file is close to 4700, of which almost 4000 have been measured using the optical interferometry method.

2.1.4 Multicomponent and Natural Gases

For the C-file, D-file and N-file, only 2 (of 18), 6 (of 20) and 23 (of 96) sets of data included in GERG TM4 contain measurements which fell outside of the original ranges of temperature and pressure set for the 1990 databank. All except two of these sets of compression factor measurements were made at the Ruhrgas research laboratories, the great majority using the optical interferometry method.

For the C-file (ternary mixtures), datasets C146-3 and C146-13 (methane + ethane + propane) contain some 200 measurements newly added to the databank. For the D-file (artificial multicomponent gases) a total of over 570 points have been added, including a few for mixture D-1 [72-01] which extend down to 220 K. For the N-file (natural gases) almost 1900 points have been added, including data for the TENP, NAM, Epe, Drohne, Ekofisk and Russian natural gases, and for natural gas with coke-oven gas admixture. In general the newly added measurements range up to about 350 K and 30 MPa.

2.2 New Ruhrgas Measurements

2.2.1 Overview

In response to the deficiencies identified in GERG TM5 (1991) and elsewhere (discussed here in section 1.3), Ruhrgas instituted at that time a substantial programme of work aimed at filling the more significant gaps in knowledge. The main objective was to create a pool of good quality compression factor measurements for natural gases and similar mixtures with which to test the performance of predictive equations, notably the SGERG-88 and revised AGA-8 (AGA-8-92DC) equations, towards the compositional limits of their supposed applicability. The strategy adopted was to take existing true natural gases and to dilute or enrich them with one or more relevant pure gases. The measurements, in order to be optimally useful, were generally taken at pressures up to about 28 MPa and at temperatures from about 270 to 350 K.

The measurements made are summarised in Table 3. This gives the approximate composition of the main components and the number of data points added to the GERG Databank in each case. One notable feature of these measurements is the very carefully detailed analyses of the higher hydrocarbons (i.e. C4+) which are included in the databank. Both the Burnett (BUR) and optical interferometry apparatus (OPT) available at Ruhrgas have been deployed. Together, these mixtures should provide severe tests of any predictive method for the estimation of compression factor, the most severe tests being provided by mixtures containing elevated amounts of those components (carbon dioxide and the hydrocarbons) which are

Table 3 : Approximate Compositions etc for New Ruhrgas Data

GERG-Code	Points	Method	Approximate Composition mole percent					
B29-1	26	BUR	N_2=75.0 He=25.0					
B29-2	337	OPT	N_2=75.0 He=25.0					
B29-3	30	BUR	N_2=50.0 He=50.0					
B29-4	274	OPT	N_2=50.0 He=50.0					
B29-5	22	BUR	N_2=25.1 He=74.9					
B29-6	337	OPT	N_2=25.1 He=74.9					
			CH_4	N_2	CO_2	C_2H_6		
D-21	228	OPT	66.1	13.1	11.1	9.7		
N-97	33	BUR	64.8	10.6	12.4	9.8	C3= 1.8	C4= 0.6
N-98	306	OPT	64.8	10.6	12.4	9.8	C3= 1.8	C4= 0.6
N-99	15	BUR	59.0	36.2	0.9	2.9	C3= 0.6	C4= 0.2
N-100	285	OPT	59.0	36.2	0.9	2.9	C3= 0.6	C4= 0.2
N-101	338	OPT	47.3	48.9	0.7	2.3	C3= 0.5	C4= 0.2
N-102	33	BUR	82.5	0.6	1.7	11.7	C3= 2.6	C4= 0.8
N-103	336	OPT	82.5	0.6	1.7	11.7	C3= 2.6	C4= 0.8
N-104	223	OPT	76.3	0.5	1.4	18.9	C3= 2.1	C4= 0.6
N-105	33	BUR	65.8	2.3	26.6	3.9	C3= 0.9	C4= 0.3
N-106	220	OPT	65.8	2.3	26.6	3.9	C3= 0.9	C4= 0.3
N-107	460	OPT	79.4	19.0	0.5	1.0	C3= 0.1	
N-108	187	OPT	80.0	1.1	1.0	16.0	C3= 1.4	C4= 0.4
N-109	322	OPT	80.0	3.0	15.0	1.3	C3= 0.3	C4= 0.1
N-110	360	OPT	27.9	29.8	3.7	0.2	H_2=36.8	CO= 1.0
N-111	90	OPT	70.8	13.1	4.9	1.0	C3= 9.6	C4= 0.2
N-112	100	OPT	81.0	10.5	1.2	3.3	C3= 0.6	C4= 3.2
N-113	173	OPT	79.6	10.3	1.2	3.3	C3= 5.3	C4= 0.2
N-114	125	OPT	76.8	9.9	1.1	3.0	C3= 8.8	C4= 0.2
N-115	342	OPT	81.5	11.8	1.2	2.8	C3= 0.6	O_2= 1.7
N-116	348	OPT	28.9	28.0	2.0	0.8	H_2=27.0	CO=13.0

individually less ideal than the others (nitrogen, hydrogen and carbon monoxide). More detailed discussions of the data obtained are given in the following subsections.

Note that a few series of measurements have also been made on mixtures which are not based on natural gas as a source; each of these has been carried out in order to fill a specific gap in the databank, but are not discussed further herein.

2.2.2 Gases Diluted with Nitrogen

The natural gases diluted with nitrogen are N-97 and N-98 (derived from Epe gas), N-99, N-100 and N-101 (derived from Gescher gas), N-107 (derived from Emsbüren gas), N-110 and N-116. The Epe gas has been further modified by the addition of substantial amounts of carbon dioxide and ethane, and the final two gases further modified by the addition of hydrogen and carbon monoxide so that these mixtures contain less than 30% methane. The remaining four gases have only nitrogen added, with the content thereof ranging up to just under 50%. Together with the data for gases N-111, N-112, N-113 and N-115, these measurements constitute a collection of over 2800 data points for natural gases containing more than 10% nitrogen, including over 1300 for gases containing in excess of 28%.

2.2.3 Gases Diluted with Carbon Dioxide

The natural gases diluted with carbon dioxide are N-97 and N-98 (derived from Epe gas), N-105 and N-106 (derived from TENP gas) and N-109. The maximum content of carbon dioxide is just under 27%. These measurements constitute a collection of over 900 data points for natural gases containing more than 12% carbon dioxide.

2.2.4 Gases Enriched with Ethane

The natural gases enriched with ethane are N-97 and N-98 (derived from Epe gas) and N-102, N-103, N-104 and N-108 (all derived from Ekofisk gas). The maximum content of ethane is just under 19%. These measurements constitute a collection of over 1100 data points for natural gases containing more than 9% ethane.

2.2.5 Gases Enriched with Higher Hydrocarbons

The natural gases enriched with propane are N-111, N-113 and N-114; the maximum propane content is just under 10%, and there is a total of almost 400 data points for natural gases containing over 5% propane. Only one gas, namely N-112 (derived from Gescher gas), is enriched with butane; this contains over 3% n-butane and there are 100 data points.

2.2.6 Gases Enriched with Hydrogen and Carbon Monoxide

The natural gases enriched with hydrogen and carbon monoxide are N-110 and N-116. Both these gases contain large amounts of diluent nitrogen and less than 30% methane. Nevertheless, the two gases are very different; N-110 contains nearly 37% hydrogen and only 1% carbon monoxide, whereas N-116 contains 27% hydrogen and 13% carbon monoxide. There are about 350 data points for each mixture. Taken together, the data for these two gases should provide a severe test of the ability of the SGERG-88 and AGA-8-92DC methods to handle the prediction of compression factor for low calorific value natural gases containing large amounts of coke-oven gas admixture.

2.3 GRI Round-Robin Measurements

2.3.1 Organization of the GRI Round-Robin

The GRI Round-Robin exercise was conceived at the Gas Research Institute in Chicago in 1990. In brief the primary objective was for a number of the world's best compression factor research laboratories to contribute sets of independent measurements, of the highest practicable accuracy (expected to be around ±0.05%), for a variety of simulated natural gases, so as to create a new, reference-quality, compilation of cross-checked data which would be of use to the industry far into the future.

The laboratories taking part in the exercise were -

(a) the National Institute of Science and Technology (NIST), Boulder (Colorado), who made measurements using a Burnett apparatus (BUR);

(b) Texas A+M University, College Station, who used both pycnometer (PYC) and Burnett apparatus (BUR);

(c) the van der Waals-Zeeman laboratorium (VDWL) at the University of Amsterdam, who used both a Burnett apparatus (BUR) and an isochoric Burnett apparatus (IBU); and

(d) Ruhrgas, Dorsten, using optical interferometry (OPT), a direct-weighing gas-density meter (GDM) and a Burnett apparatus (BUR).

The organization and administration was carried out by GRI, and the final evaluation report [9] was written under contract at the van der Waals laboratorium.

Five gas mixtures were examined, designated NIST-1 (simulated Gulf Coast high-CH_4 gas), NIST-2 (simulated Amarillo gas), GU-1 (a high-N_2 gas), GU-2 (a high-CO_2 gas) and RG-2 (simulated Ekofisk high-C_2H_6 gas). Each mixture was prepared gravimetrically in two batches (one for Europe and one for the U.S.) by NIST to the nominal molar compositions given in Table 4. Participants made measurements within the ranges 225 ≤ T/K ≤ 350 and to the highest

Table 4 : Nominal Compositions of GRI Round-Robin Gases

Component	NIST-1	NIST-2	GU-1	GU-2	RG-2
Methane	96.6	90.7	81.3	81.2	85.9
Nitrogen	0.3	3.1	13.6	5.7	1.0
Carbon Dioxide	0.6	0.5	1.0	7.6	1.5
Ethane	1.8	4.5	3.3	4.3	8.5
Propane	0.4	0.8	0.6	0.9	2.3
Butanes	0.2	0.3	0.2	0.3	0.7
Pentanes	0.1	0.1	0.0	0.0	0.1

pressures accessible with their apparatus; for the Texas A+M pycnometer this limit was over 60 MPa.

2.3.2 NIST-1 - Simulated Gulf Coast Natural Gas

Measurements on NIST-1 gas have been carried out over most of the 225-350 K temperature range by Texas A+M BUR (GERG-Code D-43, up to a maximum pressure of approximately 10 MPa), by Texas A+M PYC (D-44, 70 MPa), by NIST BUR (D-45, 34 MPa) and by VDWL IBU (D-46, 4 MPa). The measurements by Ruhrgas OPT (D-41, 28 MPa) cover the temperature range above about 270 K; the Ruhrgas GDM (D-42, 8 MPa) measurements are for 300 K only.

2.3.3 NIST-2 - Simulated Amarillo Natural Gas

For NIST-2 gas the overall picture is rather similar, except that in this case there are both BUR and IBU measurements from VDWL. The first set (D-52) extends to about 36 MPa and is, therefore, of potential help to interpretation at the higher pressures; the second set (D-53) gives data for lower temperatures, but only up to 4 MPa. The maximum pressures reached in the Ruhrgas OPT (D-47), Ruhrgas GDM (D-48), Texas A+M BUR (D-49), Texas A+M PYC (D-50) and NIST BUR (D-51) measurements are about the same as for NIST-1 gas.

2.3.4 GU-1 - Simulated NAM High-N_2 Natural Gas

The sets of measurements taken for GU-1 gas are designated D-22 (Ruhrgas OPT, maximum pressure of approximately 28 MPa), D-23 (Ruhrgas GDM, 5 MPa), D-24 (Texas A+M BUR, 10 MPa), D-25 (Texas A+M PYC, 69 MPa), D-26 (NIST BUR, 35 MPa), D-27 (VDWL BUR, 34 MPa) and D-28 (VDWL IBU, 4 MPa).

2.3.5 GU-2 - Simulated High-CO_2 Natural Gas

For GU-2 gas the sets of measurements taken are D-29 (Ruhrgas OPT, maximum pressure about 28 MPa), D-30 (Ruhrgas GDM, 8 MPa), D-31 (Texas A+M BUR, 11 MPa), D-32 (Texas A+M PYC, 70 MPa), D-33 (NIST BUR, 33 MPa) and D-34 (VDWL BUR, 36 MPa).

2.3.6 RG-2 - Simulated Ekofisk Natural Gas

For RG-2 gas the sets of measurements taken are D-35 (Ruhrgas BUR, maximum pressure about 22 MPa), D-36 (Ruhrgas OPT, 28 MPa), D-37 (Ruhrgas GDM, 6 MPa), D-38 (Texas A+M BUR, 10 MPa), D-39 (Texas A+M PYC, 69 MPa) and D-40 (NIST BUR, 33 MPa). Note that there are no VDWL measurements for this gas.

2.4 Data from the Research Literature

2.4.1 Overview

For the decade 1985-1995, Appendix B records 64 publications in the scientific research literature which report compression factor measurements, together with 20 sources of unpublished material. Some of the available sets of data, from about the first half of this period, were already present in the 1990 version of the GERG databank, but other important sets were not.

Several groups of workers have made valuable contributions to the literature; the more important of these are discussed in the following subsections. The first three groups are those which (together with Ruhrgas, whose contributions are discussed in section 2.2) took part in the GRI round-robin (section 2.3).

2.4.2 National Institute of Science and Technology (NIST)

The National Institute of Science and Technology (formerly the United States National Bureau of Standards) in Boulder (Colorado) has contributed four important collections of data [see references 88-07, 89-04, 89-11 and 92-08 in Appendix B]. In each case, NIST reports extensive and good quality data on binary mixtures containing carbon dioxide, the second component being either methane, ethane or nitrogen. The most recent paper is especially useful, reporting data on carbon dioxide with ethane for three widely differing compositions for pressures up to 10 MPa, though for only a single temperature. All of these data have been added to the databank, including the less important sets of data for pure components also reported in three of the papers.

2.4.3 Texas A+M University

Only one paper [89-10] from Texas A+M University containing data not previously accepted into the GERG databank has recently been published. This single contribution, however, reports important measurements, up to pressures in excess of 10 MPa, for binary mixtures of carbon dioxide with methane (four compositionally distinct mixtures), ethane (five mixtures) and nitrogen (five mixtures), which have now been added to the databank together with some pure component measurements.

2.4.4 Van Der Waals Laboratorium

Somewhat surprisingly, again only a single paper [90-13] reporting data not previously entered into the GERG databank has recently been published by the van der Waals laboratory (excluding, of course, the evaluation report [9] for the GRI round-robin exercise discussed in section 2.3). However, this paper contains important measurements on two simulated natural gases at 15 and 50 °C for pressures up to 16 MPa.

2.4.5 Bochum University

Excluding the Ruhrgas contribution, the most prolific source by far of new data for the GERG databank is the group led by Wolfgang Wagner at the Ruhr-Universität Bochum (Germany). Not only has this group published large numbers of important measurements, but they are also of the very highest quality. In 1986 Kleinrahm and Wagner [10] introduced a new variant of the method by which density is inferred from measurement of the buoyant force on an immersed "sinker". In the modified method, two sinkers of equal mass and surface area, but substantially different volumes (constructed as a sphere and a flat ring respectively), are used; as a consequence systematic errors caused by surface forces, suspension effects etc can be eliminated by making differential buoyancy measurements. This method is now coming into more widespread use.

The Bochum group has now reported many measurements, mostly for pure gases (including some not covered by the GERG databank). Some of the earlier measurements had already been collected for the GERG TM4 (1990) databank, but others have been added at this update, for methane [92-01], nitrogen [91-03] and carbon dioxide [90-10, 90-11 and 92-06]. Early measurements with the two-sinker apparatus covered the temperature range from below 220 up to about 320 K and the pressure range up to about 8 MPa, but recent modifications have enabled the latest results to be reported at temperatures up to 360 K and pressures up to 13 MPa.

2.4.6 University of Canterbury

In recent years, McElroy and his co-workers at the University of Canterbury at Christchurch (New Zealand) have published several papers reporting measurements of compression factor. This group has adopted the conceptually simple method whereby the mass of gas contained at known temperature and pressure in a known volume is determined directly by weighing. The range of temperatures covered is about 303 to 343 K, with pressures ranging up to about 12 MPa. One drawback of the method as it stands is that a new mixture has to be made up for each new isotherm, leading to inevitably (if only slightly) different compositions.

The group has studied mostly binary mixtures which were felt to be of interest for possible future developments to the MGERG and SGERG equations. These include methane + carbon dioxide [89-07], methane + ethane [94-03], carbon dioxide + ethane [90-09], carbon dioxide + hydrogen [93-02] and ethane + carbon monoxide [94-02]. Unfortunately, none of these data have been judged sufficiently reliable to add to the databank at this update, for a variety of reasons. Firstly, there is some doubt as to whether an accuracy of 0.1% has always been achieved; secondly, the purity of the source gases seems generally to have been poor (indeed in one case this led us to reclassify a series of notionally binary CH_4+CO_2 mixtures as a series of CH_4+N_2+CO_2 ternaries); and, finally, there seem to be an unfortunate number of misprints scattered around within these publications.

2.5 Corrections to the 1990 GERG Databank

A few errors have been detected in the previously published (1990) GERG TM4 version of the databank; the opportunity has been taken to correct these at this update, as follows -

(a) Dataset A1-4: 7 of the 14 data points listed are below the temperature range set for GERG TM4, and have therefore been removed; however these points now reappear in the databank due to the downward extension of the temperature range.

(b) Dataset A1-10: 5 of the 153 data points listed are marginally above the upper pressure limit set for TM4, and have been removed; these also now reappear in the databank as a result of the upward extension of the pressure range.

(c) Dataset A5-1: 11 of the 26 data points fall outside of the limits of the previous temperature range (7 below, 4 above), and have been removed; again, these reappear upon widening the temperature range.

(d) Dataset A6-1: the entire data set of 26 points has been removed. These data are not experimental in origin and, therefore, have no place in the GERG databank. Were it not for the addition at this update of an extensive, though not particularly new, set of data for propane from the research literature [82-03], this exclusion would have left no compression factor values in the databank for this important component of natural gas.

(e) Dataset A7-1: this set of data contains only 15 points within the pressure and temperature ranges set previously, not 20 as given in the summary listing to be found in GERG TM4 and elsewhere.

(f) Dataset A9-3: 5 of the 20 data points listed in TM4 are above the upper limit of the original temperature range, and have been removed; these now reappear due to the widening of the range.

(g) Datasets B14-14 and B14-15: on the basis of the discussion given in TM4, now confirmed, 5 data points have been moved from B14-14 to B14-15. In addition, one apparently erroneous point has been removed from B14-15.

(h) Dataset B23-4: this set of data contains 7 duplicated points (present also in the original source) which have now been removed from the databank.

The net result of the above corrections is to lower the number of valid data points in GERG TM4 by 67, from 14183 to 14116, although 33 of the points now reappear in the databank. These corrections to the original databank are taken into account in both Appendix B and Appendix C.

3 - REVIEW OF THE REVISED GERG DATABANK

3.1 Summary Statistics for the 1996 GERG Databank

In this chapter we summarise the contents of the revised GERG databank in a variety of ways, and provide some statistics. To start with, Table 5 presents a summary, for the revised databank, in exactly the same format as Table 2 gives for the 1990 databank. Some interesting features are evident.

For the A-file (pure components) there is a three-fold increase in size (to almost 7000 points), but only about a 50% increase in the number of datasets, from 36 to 56. The explanation of this apparent anomaly is two-fold; firstly, some of the new datasets are rather large (A1-13 [92-04] contains over 650 points) and, secondly, many of the new data are additions to pre-existing datasets, qualifying now for inclusion because of the widening of the ranges of temperature and pressure.

For the B-file (binary mixtures), the number of datasets is up from 107 to 133, and the number of data points is more than doubled, to over 12000. However, the number of component-distinct systems (pairs) is up only by one, from 18 to 19, still falling far short of the 36 available for the top nine components listed in Table 1. The one additional binary system is nitrogen + helium, for which three compositionally-distinct mixtures have been measured. Clearly, there is still useful work to be done, even for many quite simple binary systems.

The C-file (ternary mixtures), though increasing in size by 50% or so, has made even less progress. There are no new ternary systems at all, and only one new dataset (C124-2 [91-04]). At least this is a reasonably extensive set of data for an important ternary (methane + ethane + nitrogen) and for a distinct new composition .

It is very different for the D-file (synthetic multicomponent mixtures). In this case, the number of datasets is tripled, from 20 to 59, and the number of points has almost a ten-fold increase to nearly 5000. Mostly responsible for this large and welcome

Table 5 : Summary Statistics for the 1996 GERG Databank

File	Number of Components	Number of Systems	Number of Distinct Mixtures*	Number of Data Sets	Number of Points
A	1	8	8	56	6993
B	2	19	84	133	12508
C	3	5	8	19	925
D	4+	8	28	59	4751
N	-	1(!)	58	116	11062
Total		41	186	383	36239

* Mixtures very close to each other in composition (i.e. for which the molar compositions of all components match within about 1%) are, for present purposes, taken as compositionally-<u>in</u>distinct.

expansion is the GRI round-robin exercise; this alone contributes 32 datasets, for five distinct and well-chosen simulated natural gas mixtures, totalling well over 3000 data points.

For the N-file (natural gases etc) too there has been a welcome expansion. The number of datasets is increased from 96 to 116 (all 20 new sets having been measured by Ruhrgas), and the number of points is more than doubled, to about 11000. More importantly, of the 20 new sets of data (all of which are for a specific natural gas either enriched or diluted with at least one other component), 16 are compositionally distinct from each other and from any of the original 96 sets.

Overall the expansion of the GERG databank is from 277 to 383 datasets and from over 14000 to over 36000 data points.

Next, Table 6 repeats the overall data counts for the updated A-file, B-file, C-file, D-file and N-file, but now gives more detail by splitting each up into various temperature and pressure domains. The temperature domains correspond to (a) temperatures below the range covered in GERG Monograph TM4, (b) temperatures within the range of TM4, and (c) temperatures above the range of TM4; likewise the pressure domains correspond to (a) pressures

Table 6 : Summary Statistics by File for the 1996 GERG Databank

A-File	218.5-265 K	265-335 K	335-425 K	218.5-425 K
0-12 MPa	271	3772	1198	5241
12-30 MPa	1	1232	404	1637
30-60 MPa	0	70	45	115
0-60 MPa	272	5074	1647	6993 [2374]

B-File	218.5-265 K	265-335 K	335-425 K	218.5-425 K
0-12 MPa	162	7016	1029	8207
12-30 MPa	41	3367	804	4212
30-60 MPa	3	85	1	89
0-60 MPa	206	10468	1834	12508 [5847]

C-File	218.5-265 K	265-335 K	335-425 K	218.5-425 K
0-12 MPa	0	676	47	723
12-30 MPa	0	160	37	197
30-60 MPa	0	3	2	5
0-60 MPa	0	839	86	925 [620]

D-File	218.5-265 K	265-335 K	335-425 K	218.5-425 K
0-12 MPa	374	2122	260	2756
12-30 MPa	99	1389	299	1787
30-60 MPa	53	121	34	208
0-60 MPa	526	3632	593	4751 [492]

N-File	218.5-265 K	265-335 K	335-425 K	218.5-425 K
0-12 MPa	46	6732	570	7348
12-30 MPa	43	3007	652	3702
30-60 MPa	0	9	3	12
0-60 MPa	89	9748	1225	11062 [4850]

All Files	218.5-265 K	265-335 K	335-425 K	218.5-425 K
0-12 MPa	853	20318	3104	24275
12-30 MPa	184	9155	2196	11535
30-60 MPa	56	288	85	429
0-60 MPa	1093	29761	5385	36239 [14183]

within the range covered by TM4, (b) pressures above the range of TM4 and up to 30 MPa, and (c) pressures above 30 and up to 60 MPa. For the range covered in TM4, the numbers of data points present in TM4 are given in square brackets [...] for comparison. Similar information is presented in the form of bar-charts in Figure 2.

3.2 Detailed Contents of the 1996 GERG Databank

A more complete summary of the contents of the updated GERG databank is given in Appendix C. The various tables which together form Appendix C give the following information:

Table C.1 Listing of Data Sets for Pure Gases

This table lists, for each of the 56 datasets for pure gases, the unique GERG identification code, the number of data points, the minimum and maximum experimental pressure and temperature, the primary author, the source reference (which may be located in Appendix B), the institution at which the work was carried out (abbreviations explained in Table C.9) and the experimental method (abbreviations explained in Table C.10).

Table C.2 Listing of Data Sets and Compositions (by Mole Fraction of the Second Component) for Binary Mixtures

This table gives similar information for the 133 binary mixture datasets, with the addition of the composition of the mixture, given as the mole fraction of the second component.

Table C.3 Listing of Data Sets for Ternary Mixtures

This table again provides similar information for the 19 ternary mixture datasets, but in this case only the mixture components, not the complete composition, is given; the corresponding compositions are given in Table C.6.

Table C.4 Listing of Data Sets for Quaternary Mixtures and Synthetic Gas Mixtures

This table provides the same information for the 59 quaternary and synthetic multicomponent mixture datasets except that, in the cases of the multicomponents, an identification "name" is given rather than the mixture components; the complete compositions of all the mixtures are given in Table C.7.

Table C.5 Listing of Data Sets for Natural Gases

This table provides the same information for the 116 natural gases (including enriched or diluted natural gases, and natural plus coke-oven gas mixtures); in this case, all of the gases are

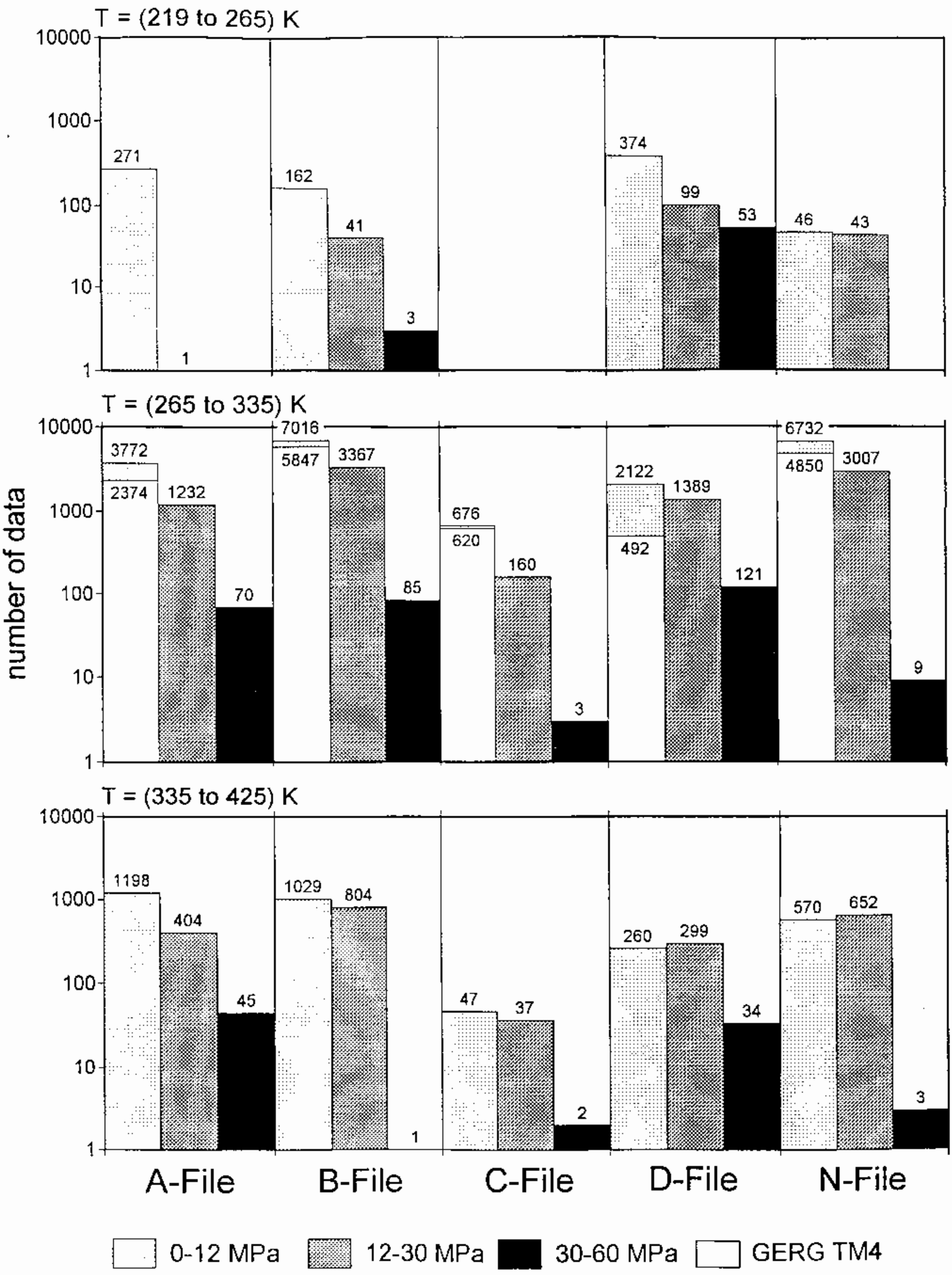

Figure 2 : Summary Statistics for the GERG Databank - Bar-Charts

identified by name (usually the gas-field of origin), and the complete compositions are given in Table C.8.

Table C.6 **Listing of Approximate Compositions (by Mole Percent) for Ternary Mixtures**

Table C.7 **Listing of Approximate Compositions (by Mole Percent) for Quaternary Mixtures and Synthetic Gas Mixtures**

Table C.8 **Listing of Approximate Compositions (by Mole Percent) for Natural Gases**

Table C.9 **Abbreviations for Institutes (In) used in Tables C.1 - C.5**

Table C.10 **Abbreviations for Methods of Measurement (App) used in Tables C.1 - C.5**

4 - DISCUSSION OF THE GRI ROUND-ROBIN DATA

4.1 Introduction

The general objectives of the GRI round-robin exercise were two-fold; first, to establish a large collection of compression factor measurements for a number of distinctive synthetic mixtures close in composition to typical natural gases and, second, to compare measurements between the various contributing laboratories.

There is no doubt that the first objective has been admirably achieved, with over 3000 data points for five distinctive gas mixtures. The comparison between laboratories is, however, the more important part of the exercise. If all laboratories can be shown to produce results which are concordant within, say, 0.10% (or better) in Z, then a number of benefits follow, namely (a) it can reasonably be taken that the various measurements are correct i.e. that none of the various methods used by the participants has a significant systematic bias, (b) this being so, all the sets of data for each gas can effectively be given equal status, and combined to form a single set of so-called reference-quality data, and (c) future sets of data from the participating laboratories may be taken, almost automatically, to be of good quality without the need for too much critical evaluation.

The main question, then, is whether or not this happy situation has been achieved. The answer seems to be "almost", but with a few provisos, as a review of the data will demonstrate.

The data produced in the GRI round-robin exercise have already been introduced very briefly in subsections 2.3.2 to 2.3.6; we now turn towards their interpretation and, more particularly, we seek any inferences which might be drawn from intercomparisons between the data from the various sources.

The discussions which follow are largely based upon graphical comparisons presented in the GRI project evaluation report [9]. For a more detailed discussion of all aspects of the measurements, the reader is referred back to that source.

Table 7.2 : D-File Statistical Analysis for the AGA-8 Equation; Restricted to Pipeline Quality Gases for the Ranges 265 to 335 K and 0 to 12 MPa (continued)

GERG-Code	n	p/MPa min	p/MPa max	T/K min	T/K max	b %	aav %	s %	rms %
D 44	9	3.5	10.9	275	325	-0.107	0.114	0.091	0.137
D 45	18	2.2	10.9	275	325	-0.015	0.016	0.010	0.018
D 46	16	0.6	4.1	273	273	-0.005	0.005	0.003	0.006
D 47	92	0.5	12.0	275	325	0.017	0.018	0.014	0.022
D 48	11	0.5	3.8	300	300	-0.015	0.015	0.008	0.017
D 49	58	0.2	9.6	275	325	0.004	0.016	0.022	0.022
D 50	9	3.4	10.4	275	325	-0.123	0.123	0.093	0.151
D 51	18	2.2	10.8	275	325	0.000	0.020	0.026	0.025
D 52	105	0.1	11.1	273	323	-0.020	0.052	0.072	0.074
D 53	10	1.3	4.1	273	273	-0.001	0.001	0.001	0.001
D 54	31	0.1	11.3	298	323	-0.004	0.013	0.015	0.015
D 56	79	0.1	11.9	290	315	-0.020	0.057	0.076	0.078
D 58	13	1.1	5.3	300	300	-0.037	0.037	0.010	0.038
D 59	32	1.1	6.3	289	300	0.018	0.020	0.019	0.026
total	1822					-0.008	0.028	0.046	0.047

Table 8.1 : N-File Statistical Analysis for the AGA-8 Equation; Complete File

GERG Code	n	p/MPa min	p/MPa max	T/K min	T/K max	b %	aav %	s %	rms %
N 1	18	2.0	7.0	273	293	-0.073	0.086	0.058	0.092
N 2	18	2.0	7.0	273	293	-0.009	0.028	0.033	0.033
N 3	18	2.0	7.0	273	293	-0.070	0.070	0.031	0.076
N 4	18	2.0	7.0	273	293	-0.013	0.048	0.057	0.057
N 5	24	2.0	7.0	273	303	-0.043	0.052	0.042	0.059
N 6	24	2.0	7.0	273	303	-0.013	0.021	0.024	0.027
N 7	24	2.0	7.0	273	303	-0.062	0.063	0.028	0.068
N 8	23	2.0	7.0	273	303	-0.034	0.047	0.049	0.059
N 9	67	0.2	8.6	273	293	0.016	0.030	0.039	0.042
N 10	68	0.2	8.7	273	293	-0.011	0.021	0.024	0.026
N 11	69	0.2	8.6	273	293	0.000	0.017	0.021	0.021
N 12	69	0.2	8.6	273	293	0.004	0.021	0.029	0.029
N 13	74	0.1	7.7	273	293	0.016	0.021	0.024	0.029
N 14	74	0.1	7.8	273	293	0.038	0.038	0.033	0.050
N 15	73	0.1	7.7	273	293	0.022	0.055	0.069	0.072
N 16	74	0.1	7.7	273	293	0.018	0.032	0.039	0.043
N 17	76	0.1	7.8	273	293	0.029	0.043	0.049	0.057
N 18	68	0.1	7.9	273	293	-0.007	0.035	0.048	0.048
N 19	73	0.1	7.7	273	293	-0.024	0.045	0.053	0.058
N 20	77	0.1	7.9	273	293	0.011	0.035	0.052	0.053
N 21	12	0.4	7.0	274	291	-0.138	0.138	0.112	0.175
N 22	15	0.2	10.2	273	294	-0.078	0.078	0.080	0.110
N 23	18	2.0	7.0	279	298	-0.041	0.056	0.047	0.061
N 24	12	2.0	7.0	278	298	-0.044	0.061	0.053	0.067
N 25	10	1.0	4.5	288	293	0.016	0.045	0.074	0.072
N 26	5	1.0	4.5	284	284	0.012	0.110	0.152	0.136
N 27	5	1.0	4.5	279	279	0.015	0.123	0.169	0.152
N 28	64	3.8	6.4	280	300	-0.020	0.030	0.029	0.035
N 29	53	3.7	6.4	281	300	-0.008	0.022	0.025	0.026
N 30	52	3.7	6.4	281	300	-0.029	0.030	0.022	0.036
N 31	53	3.7	6.4	280	300	-0.046	0.046	0.019	0.050
N 32	54	3.7	6.5	280	300	-0.028	0.031	0.024	0.037
N 33	64	3.7	6.5	279	300	0.002	0.020	0.028	0.028
N 34	52	3.7	6.4	281	300	-0.006	0.031	0.038	0.038
N 35	55	3.8	6.4	281	300	0.067	0.067	0.039	0.077
N 36	55	3.8	6.5	281	300	-0.021	0.027	0.022	0.030
N 37	64	3.7	6.5	280	300	-0.054	0.063	0.052	0.075
N 38	65	3.7	6.6	280	300	-0.059	0.060	0.034	0.068

Table 8.1 : N-File Statistical Analysis for the AGA-8 Equation; Complete File (continued)

GERG Code	n	p/MPa min	p/MPa max	T/K min	T/K max	b %	aav %	s %	rms %
N 39	55	3.7	6.5	280	300	0.020	0.024	0.025	0.032
N 40	54	3.7	6.5	281	300	-0.057	0.058	0.023	0.061
N 41	16	3.8	5.5	279	294	-0.071	0.071	0.015	0.072
N 42	44	3.8	6.5	280	300	-0.075	0.076	0.056	0.093
N 43	66	3.7	6.5	280	300	0.029	0.033	0.026	0.039
N 44	66	3.8	6.5	280	300	-0.035	0.040	0.048	0.059
N 45	66	3.7	6.4	280	300	0.023	0.042	0.040	0.046
N 46	65	3.7	6.5	280	300	-0.078	0.078	0.050	0.092
N 47	65	3.7	6.4	280	300	-0.071	0.071	0.034	0.079
N 48	65	3.7	6.5	280	300	-0.050	0.059	0.054	0.073
N 49	33	3.8	6.4	280	286	0.070	0.070	0.018	0.072
N 50	22	3.7	6.4	280	283	-0.059	0.059	0.010	0.060
N 51	31	0.6	30.1	273	313	0.067	0.067	0.068	0.095
N 52	54	0.3	27.0	313	313	0.086	0.086	0.042	0.096
N 53	47	0.4	30.2	273	353	0.031	0.034	0.048	0.057
N 54	113	0.3	28.2	273	353	0.038	0.041	0.038	0.054
N 55	98	0.3	27.3	275	330	0.022	0.023	0.035	0.041
N 56	175	0.4	29.6	270	330	0.061	0.062	0.040	0.073
N 57	30	0.4	25.1	290	290	0.013	0.013	0.015	0.020
N 58	116	0.5	29.0	280	290	0.034	0.034	0.014	0.037
N 59	34	0.3	26.0	310	310	0.034	0.036	0.040	0.052
N 60	342	0.4	29.4	270	350	0.087	0.088	0.058	0.105
N 61	36	0.2	26.0	310	310	0.008	0.008	0.006	0.010
N 62	311	0.4	28.8	270	350	0.015	0.015	0.008	0.017
N 63	62	0.3	26.8	310	330	-0.015	0.017	0.021	0.026
N 64	336	0.5	28.0	270	350	-0.043	0.045	0.039	0.058
N 65	60	0.4	26.8	275	280	0.018	0.022	0.032	0.036
N 66	333	0.3	28.1	270	350	0.030	0.035	0.035	0.046
N 67	68	0.4	9.2	273	303	0.030	0.034	0.037	0.047
N 68	69	0.4	9.2	273	303	-0.001	0.010	0.015	0.015
N 69	70	0.4	9.2	273	303	-0.016	0.018	0.014	0.021
N 70	68	0.4	9.2	273	303	0.030	0.033	0.044	0.053
N 71	70	0.4	9.2	273	303	-0.008	0.012	0.013	0.015
N 72	67	0.4	9.2	273	303	-0.015	0.019	0.018	0.023
N 73	31	0.5	26.1	310	310	0.009	0.010	0.012	0.015
N 74	342	0.4	28.5	270	350	0.028	0.035	0.038	0.047
N 75	331	0.4	28.3	270	350	-0.007	0.024	0.030	0.031

Table 8.1 : N-File Statistical Analysis for the AGA-8 Equation; Complete File (continued)

GERG Code	n	p/MPa min	p/MPa max	T/K min	T/K max	b %	aav %	s %	rms %
N 76	135	0.1	8.0	273	323	-0.017	0.021	0.018	0.025
N 77	11	3.7	7.2	296	297	0.007	0.057	0.068	0.065
N 78	19	3.6	6.5	295	297	0.057	0.057	0.031	0.064
N 79	21	3.0	5.4	296	297	-0.065	0.065	0.046	0.079
N 80	44	3.7	6.4	280	294	0.069	0.070	0.051	0.085
N 81	42	3.8	6.4	280	294	0.023	0.031	0.035	0.042
N 82	57	0.6	26.2	310	330	0.016	0.017	0.020	0.025
N 83	353	0.3	28.8	270	350	0.037	0.038	0.029	0.047
N 84	37	1.0	8.0	283	313	-0.057	0.057	0.029	0.064
N 85	48	2.9	7.4	280	298	-0.010	0.034	0.041	0.042
N 86	10	1.0	15.0	303	303	-0.083	0.083	0.025	0.086
N 87	7	4.9	5.3	289	289	-0.017	0.022	0.023	0.027
N 88	40	1.0	6.0	283	313	-0.051	0.053	0.023	0.056
N 89	42	1.5	6.6	284	313	-0.013	0.015	0.014	0.019
N 90	35	1.5	5.5	284	313	-0.052	0.052	0.022	0.056
N 91	32	1.0	5.1	283	313	-0.063	0.065	0.036	0.072
N 92	26	1.0	4.0	283	313	-0.017	0.024	0.022	0.027
N 93	8	1.0	5.2	303	303	0.042	0.042	0.011	0.043
N 94	26	3.0	7.8	286	286	-0.040	0.040	0.011	0.041
N 95	44	2.9	7.2	280	298	0.018	0.028	0.033	0.037
N 96	48	2.8	7.7	280	298	-0.049	0.049	0.017	0.052
N 97	33	0.4	25.7	310	310	0.010	0.029	0.042	0.043
N 98	306	0.5	28.4	270	350	0.051	0.069	0.082	0.096
N 99	15	0.6	26.9	290	290	-0.006	0.012	0.013	0.014
N100	285	0.4	28.0	270	350	-0.018	0.022	0.018	0.025
N101	338	0.5	28.5	270	350	-0.017	0.021	0.018	0.025
N102	33	0.4	26.1	290	290	0.038	0.041	0.065	0.074
N103	336	0.5	28.6	270	350	0.099	0.105	0.076	0.125
N104	223	0.5	28.0	270	350	-0.015	0.035	0.042	0.045
N105	33	0.4	26.3	330	330	0.056	0.060	0.068	0.087
N106	220	0.5	28.6	270	350	0.124	0.124	0.106	0.163
N107	460	0.5	29.3	265	350	0.000	0.014	0.019	0.019
N108	187	0.5	20.0	270	350	0.060	0.060	0.055	0.081
N109	322	0.5	30.0	265	350	0.002	0.039	0.053	0.053
N110	360	0.5	30.0	270	350	-0.048	0.058	0.058	0.075
N111	90	0.4	4.9	270	350	-0.008	0.009	0.010	0.013
N112	100	0.4	6.8	270	350	-0.062	0.062	0.059	0.085

Table 8.1 : N-File Statistical Analysis for the AGA-8 Equation; Complete File (continued)

GERG Code	n	p/MPa min	p/MPa max	T/K min	T/K max	b %	aav %	s %	rms %
N113	173	0.4	14.0	270	350	-0.025	0.025	0.019	0.031
N114	125	0.4	8.5	270	350	0.000	0.010	0.014	0.014
N115	342	0.5	28.4	270	350	-0.092	0.092	0.045	0.102
N116	348	0.4	28.5	270	350	-0.253	0.253	0.176	0.308
total	11062					-0.003	0.051	0.084	0.084

Table 8.2 : N-File Statistical Analysis for the AGA-8 Equation; Restricted to Pipeline Quality Gases for the Ranges 265 to 335 K and 0 to 12 MPa

GERG-Code	n	p/MPa min	p/MPa max	T/K min	T/K max	b %	aav %	s %	rms %
N 1	18	2.0	7.0	273	293	-0.073	0.086	0.058	0.092
N 2	18	2.0	7.0	273	293	-0.009	0.028	0.033	0.033
N 3	18	2.0	7.0	273	293	-0.070	0.070	0.031	0.076
N 4	18	2.0	7.0	273	293	-0.013	0.048	0.057	0.057
N 5	24	2.0	7.0	273	303	-0.043	0.052	0.042	0.059
N 6	24	2.0	7.0	273	303	-0.013	0.021	0.024	0.027
N 7	24	2.0	7.0	273	303	-0.062	0.063	0.028	0.068
N 8	23	2.0	7.0	273	303	-0.034	0.047	0.049	0.059
N 9	67	0.2	8.6	273	293	0.016	0.030	0.039	0.042
N 10	68	0.2	8.7	273	293	-0.011	0.021	0.024	0.026
N 11	69	0.2	8.6	273	293	0.000	0.017	0.021	0.021
N 12	69	0.2	8.6	273	293	0.004	0.021	0.029	0.029
N 13	74	0.1	7.7	273	293	0.016	0.021	0.024	0.029
N 14	74	0.1	7.8	273	293	0.038	0.038	0.033	0.050
N 15	73	0.1	7.7	273	293	0.022	0.055	0.069	0.072
N 16	74	0.1	7.7	273	293	0.018	0.032	0.039	0.043
N 17	76	0.1	7.8	273	293	0.029	0.043	0.049	0.057
N 18	68	0.1	7.9	273	293	-0.007	0.035	0.048	0.048
N 19	73	0.1	7.7	273	293	-0.024	0.045	0.053	0.058
N 20	77	0.1	7.9	273	293	0.011	0.035	0.052	0.053
N 21	12	0.4	7.0	274	291	-0.138	0.138	0.112	0.175
N 22	15	0.2	10.2	273	294	-0.078	0.078	0.080	0.110
N 23	18	2.0	7.0	279	298	-0.041	0.056	0.047	0.061
N 24	12	2.0	7.0	278	298	-0.044	0.061	0.053	0.067
N 25	10	1.0	4.5	288	293	0.016	0.045	0.074	0.072
N 26	5	1.0	4.5	284	284	0.012	0.110	0.152	0.136
N 27	5	1.0	4.5	279	279	0.015	0.123	0.169	0.152
N 28	64	3.8	6.4	280	300	-0.020	0.030	0.029	0.035
N 29	53	3.7	6.4	281	300	-0.008	0.022	0.025	0.026
N 30	52	3.7	6.4	281	300	-0.029	0.030	0.022	0.036
N 31	53	3.7	6.4	280	300	-0.046	0.046	0.019	0.050
N 32	54	3.7	6.5	280	300	-0.028	0.031	0.024	0.037
N 34	52	3.7	6.4	281	300	-0.006	0.031	0.038	0.038
N 36	55	3.8	6.5	281	300	-0.021	0.027	0.022	0.030
N 37	64	3.7	6.5	280	300	-0.054	0.063	0.052	0.075

Table 8.2 : N-File Statistical Analysis for the AGA-8 Equation; Restricted to Pipeline Quality Gases for the Ranges 265 to 335 K and 0 to 12 MPa (continued)

GERG-Code	n	p/MPa min	p/MPa max	T/K min	T/K max	b %	aav %	s %	rms %
N 38	65	3.7	6.6	280	300	-0.059	0.060	0.034	0.068
N 39	55	3.7	6.5	280	300	0.020	0.024	0.025	0.032
N 40	54	3.7	6.5	281	300	-0.057	0.058	0.023	0.061
N 41	16	3.8	5.5	279	294	-0.071	0.071	0.015	0.072
N 42	44	3.8	6.5	280	300	-0.075	0.076	0.056	0.093
N 43	66	3.7	6.5	280	300	0.029	0.033	0.026	0.039
N 44	66	3.8	6.5	280	300	-0.035	0.040	0.048	0.059
N 45	66	3.7	6.4	280	300	0.023	0.042	0.040	0.046
N 49	33	3.8	6.4	280	286	0.070	0.070	0.018	0.072
N 50	22	3.7	6.4	280	283	-0.059	0.059	0.010	0.060
N 51	25	0.6	11.8	273	313	0.049	0.049	0.055	0.073
N 52	23	0.3	11.6	313	313	0.045	0.045	0.029	0.053
N 53	25	0.4	11.9	273	313	0.024	0.028	0.042	0.048
N 54	38	0.3	11.9	273	313	0.024	0.027	0.027	0.036
N 55	83	0.3	11.1	275	330	0.010	0.012	0.021	0.023
N 56	71	0.4	12.0	270	330	0.022	0.024	0.024	0.032
N 57	27	0.4	11.9	290	290	0.010	0.010	0.011	0.015
N 58	48	0.5	12.0	280	290	0.026	0.026	0.014	0.029
N 59	28	0.3	11.0	310	310	0.019	0.021	0.023	0.030
N 60	117	0.4	12.0	270	330	0.052	0.054	0.053	0.074
N 61	30	0.2	11.1	310	310	0.007	0.007	0.006	0.009
N 62	109	0.4	12.0	270	330	0.017	0.017	0.008	0.019
N 63	50	0.3	11.4	310	330	-0.008	0.009	0.009	0.012
N 64	117	0.5	12.0	270	330	-0.014	0.018	0.016	0.021
N 65	54	0.4	10.2	275	280	0.011	0.015	0.023	0.025
N 66	120	0.4	12.0	270	330	0.007	0.017	0.021	0.022
N 67	68	0.4	9.2	273	303	0.030	0.034	0.037	0.047
N 68	69	0.4	9.2	273	303	-0.001	0.010	0.015	0.015
N 69	70	0.4	9.2	273	303	-0.016	0.018	0.014	0.021
N 70	68	0.4	9.2	273	303	0.030	0.033	0.044	0.053
N 71	70	0.4	9.2	273	303	-0.008	0.012	0.013	0.015
N 72	67	0.4	9.2	273	303	-0.015	0.019	0.018	0.023
N 73	25	0.5	11.0	310	310	0.004	0.005	0.006	0.007
N 74	121	0.6	12.0	270	330	0.017	0.024	0.036	0.040
N 75	132	0.4	12.0	270	330	-0.026	0.026	0.021	0.033

Table 8.2 : N-File Statistical Analysis for the AGA-8 Equation; Restricted to Pipeline Quality Gases for the Ranges 265 to 335 K and 0 to 12 MPa (continued)

GERG-Code	n	p/MPa min	p/MPa max	T/K min	T/K max	b %	aav %	s %	rms %
N 76	135	0.1	8.0	273	323	-0.017	0.021	0.018	0.025
N 77	11	3.7	7.2	296	297	0.007	0.057	0.068	0.065
N 78	19	3.6	6.5	295	297	0.057	0.057	0.031	0.064
N 79	21	3.0	5.4	296	297	-0.065	0.065	0.046	0.079
N 81	42	3.8	6.4	280	294	0.023	0.031	0.035	0.042
N 82	45	0.6	11.1	310	330	0.007	0.007	0.008	0.011
N 83	123	0.3	12.0	270	330	0.016	0.019	0.027	0.031
N 85	48	2.9	7.4	280	298	-0.010	0.034	0.041	0.042
N 87	7	4.9	5.3	289	289	-0.017	0.022	0.023	0.027
N 88	40	1.0	6.0	283	313	-0.051	0.053	0.023	0.056
N 89	42	1.5	6.6	284	313	-0.013	0.015	0.014	0.019
N 90	35	1.5	5.5	284	313	-0.052	0.052	0.022	0.056
N 91	32	1.0	5.1	283	313	-0.063	0.065	0.036	0.072
N 92	26	1.0	4.0	283	313	-0.017	0.024	0.022	0.027
N 93	8	1.0	5.2	303	303	0.042	0.042	0.011	0.043
N 94	26	3.0	7.8	286	286	-0.040	0.040	0.011	0.041
N 95	44	2.9	7.2	280	298	0.018	0.028	0.033	0.037
N107	115	0.5	12.0	270	330	-0.005	0.010	0.011	0.012
N109	114	0.5	11.5	270	330	0.009	0.020	0.023	0.025
N115	114	0.5	11.5	270	330	-0.058	0.059	0.034	0.067
total	4742					-0.004	0.032	0.046	0.046

the ranges of conditions for which it can achieve high accuracy will be as wide. The actual accuracy attained (as tested against the 1990 GERG databank plus much of the additional material contained herein) may be summarised as follows [1,3]:

(1) For the temperature range 270-330 K and pressures up to 12 MPa, and for nitrogen content up to 14%, carbon dioxide up to 8%, ethane up to 9% and hydrogen up to 10%, comprehensive testing has shown the accuracy to be within 0.1% in Z (this is the same as for the AGA-8 equation, but with a slightly reduced temperature range);

(2) In terms of the physical properties used as input variables, the tested ranges for 0.1% accuracy (within the same ranges of temperature and pressure) are 34.2 to 44.7 MJ m^{-3} for calorific value (at "25/0" reference conditions [11]) and 0.55 to 0.69 for relative density;

(3) For the temperature range 263-338 K and pressures up to 10 MPa, less comprehensive testing suggests that this accuracy is maintained for nitrogen up to 20%, carbon dioxide up to 8%, ethane up to 10% and propane up to 3½%;

(4) If the accuracy requirement is relaxed to 0.2% then, for pressures up to 10 MPa, the limiting composition is at least 50% for nitrogen and 12% for carbon dioxide; however, the method tends to degrade in accuracy rather rapidly outside any of these boundaries of temperature, pressure and composition.

As for the AGA-8 method, the new databank affords the possibility of making further tests for the SGERG method. Consequently, in Tables 9 and 10, we present results of such tests for all the D-file and N-file gases of pipeline quality (as defined in 5.2 above) for pressures up to 12 MPa and for the temperature range 265 to 335 K; these tables are directly comparable with Tables 7.2 and 8.2 respectively for the AGA-8 method. Because of the acknowledged limitations of the method outside of its primary ranges of application it is not meaningful to include the complete range of state conditions covered by the updated databank i.e.

Table 9 : D-File Statistical Analysis for the SGERG Equation; Restricted to Pipeline Quality Gases for the Ranges 265 to 335 and 0 to 12 MPa

GERG- Code	n	p/MPa min	p/MPa max	T/K min	T/K max	b %	aav %	s %	rms %
D 1	7	0.4	9.9	273	273	0.095	0.095	0.099	0.132
D 2	5	3.0	7.0	283	293	0.002	0.032	0.046	0.041
D 3	6	3.0	7.0	283	293	0.051	0.051	0.022	0.055
D 4	6	3.0	7.0	283	293	0.133	0.133	0.032	0.136
D 6	6	3.0	7.0	283	293	0.025	0.031	0.033	0.039
D 7	6	3.0	7.0	284	294	0.080	0.080	0.019	0.082
D 10	7	3.0	7.0	283	293	0.150	0.150	0.074	0.165
D 12	6	3.0	7.0	283	293	-0.206	0.206	0.080	0.219
D 15	18	2.0	7.0	273	293	-0.014	0.022	0.023	0.026
D 16	40	0.4	11.8	273	313	0.039	0.040	0.042	0.057
D 17	71	0.4	11.8	273	313	0.030	0.048	0.055	0.062
D 19	93	0.3	12.0	275	330	0.057	0.061	0.086	0.103
D 20	47	0.4	12.0	290	330	0.044	0.051	0.060	0.074
D 22	94	0.5	12.0	275	325	0.027	0.042	0.042	0.050
D 23	13	0.5	5.0	300	300	0.008	0.009	0.007	0.010
D 24	57	0.2	10.4	275	325	-0.002	0.017	0.026	0.026
D 25	9	3.5	10.6	275	325	0.002	0.108	0.131	0.124
D 26	18	2.2	11.3	275	325	0.014	0.037	0.043	0.044
D 27	128	0.2	11.7	273	323	0.009	0.028	0.037	0.038
D 28	16	0.7	4.1	273	273	0.030	0.030	0.013	0.033
D 29	95	0.5	12.0	275	325	0.041	0.042	0.035	0.054
D 30	13	0.5	8.0	300	300	0.011	0.012	0.019	0.021
D 31	63	0.2	11.2	275	325	0.023	0.026	0.045	0.050
D 32	6	3.5	11.1	275	325	-0.004	0.131	0.166	0.152
D 33	18	2.2	10.6	275	325	0.013	0.026	0.033	0.035
D 34	95	0.3	11.5	273	323	0.016	0.029	0.037	0.040
D 35	15	0.3	9.9	300	300	0.014	0.014	0.027	0.030
D 36	96	0.5	12.0	275	325	0.042	0.042	0.040	0.058
D 37	9	0.5	6.0	300	300	-0.013	0.013	0.008	0.015
D 38	61	0.2	10.2	275	325	-0.011	0.015	0.019	0.022
D 39	8	2.8	11.1	275	325	-0.025	0.084	0.126	0.120
D 40	19	2.2	11.6	275	325	-0.001	0.020	0.027	0.026
D 41	98	0.5	12.0	275	325	-0.010	0.013	0.018	0.021
D 42	15	0.5	8.0	300	300	-0.013	0.013	0.006	0.014
D 43	57	0.2	10.3	275	325	-0.015	0.015	0.017	0.023

Table 9 : D-File Statistical Analysis for the SGERG Equation; Restricted to Pipeline Quality Gases for the Ranges 265 to 335 and 0 to 12 MPa (continued)

GERG-Code	n	p/MPa min	p/MPa max	T/K min	T/K max	b %	aav %	s %	rms %
D 44	9	3.5	10.9	275	325	-0.114	0.122	0.091	0.143
D 45	18	2.2	10.9	275	325	-0.022	0.022	0.012	0.025
D 46	16	0.6	4.1	273	273	0.000	0.001	0.001	0.001
D 47	92	0.5	12.0	275	325	0.043	0.043	0.034	0.055
D 48	11	0.5	3.8	300	300	-0.012	0.012	0.005	0.013
D 49	58	0.2	9.6	275	325	0.012	0.021	0.032	0.034
D 50	9	3.4	10.4	275	325	-0.093	0.101	0.093	0.128
D 51	18	2.2	10.8	275	325	0.027	0.037	0.045	0.051
D 52	105	0.1	11.1	273	323	-0.005	0.040	0.054	0.054
D 53	10	1.3	4.1	273	273	0.018	0.018	0.008	0.020
D 54	31	0.1	11.3	298	323	-0.012	0.018	0.020	0.023
D 56	79	0.1	11.9	290	315	0.009	0.050	0.077	0.077
D 58	13	1.1	5.3	300	300	-0.045	0.045	0.011	0.046
D 59	32	1.1	6.3	289	300	0.035	0.036	0.028	0.045
total	1822					0.016	0.037	0.055	0.058

Table 10: N-File Statistical Analysis for the SGERG Equation; Restricted to Pipeline Quality Gases for the Ranges 265 to 335 K and 0 to 12 MPa

GERG-Code	n	p/MPa min	p/MPa max	T/K min	T/K max	b %	aav %	s %	rms %
N 1	18	2.0	7.0	273	293	-0.098	0.105	0.053	0.111
N 2	18	2.0	7.0	273	293	-0.020	0.033	0.032	0.037
N 3	18	2.0	7.0	273	293	-0.095	0.095	0.039	0.102
N 4	18	2.0	7.0	273	293	-0.039	0.057	0.051	0.063
N 5	24	2.0	7.0	273	303	-0.029	0.044	0.041	0.050
N 6	24	2.0	7.0	273	303	-0.015	0.024	0.025	0.029
N 7	24	2.0	7.0	273	303	-0.040	0.044	0.030	0.050
N 8	23	2.0	7.0	273	303	-0.021	0.040	0.045	0.049
N 9	67	0.2	8.6	273	293	0.009	0.027	0.037	0.038
N 10	68	0.2	8.7	273	293	-0.023	0.035	0.046	0.051
N 11	69	0.2	8.6	273	293	-0.013	0.022	0.024	0.027
N 12	69	0.2	8.6	273	293	-0.010	0.021	0.028	0.030
N 13	74	0.1	7.7	273	293	0.008	0.016	0.021	0.022
N 14	74	0.1	7.8	273	293	0.021	0.042	0.056	0.059
N 15	73	0.1	7.7	273	293	0.005	0.061	0.075	0.075
N 16	74	0.1	7.7	273	293	-0.001	0.037	0.062	0.062
N 17	76	0.1	7.8	273	293	0.021	0.037	0.045	0.049
N 18	68	0.1	7.9	273	293	-0.031	0.059	0.080	0.085
N 19	73	0.1	7.7	273	293	-0.041	0.063	0.069	0.080
N 20	77	0.1	7.9	273	293	-0.009	0.049	0.072	0.072
N 21	12	0.4	7.0	274	291	-0.159	0.159	0.135	0.205
N 22	15	0.2	10.2	273	294	-0.100	0.100	0.103	0.141
N 23	18	2.0	7.0	279	298	-0.009	0.032	0.039	0.039
N 24	12	2.0	7.0	278	298	-0.005	0.029	0.032	0.031
N 25	10	1.0	4.5	288	293	0.011	0.048	0.078	0.075
N 26	5	1.0	4.5	284	284	0.007	0.118	0.161	0.144
N 27	5	1.0	4.5	279	279	0.016	0.129	0.178	0.160
N 28	64	3.8	6.4	280	300	-0.039	0.041	0.028	0.048
N 29	53	3.7	6.4	281	300	0.038	0.039	0.025	0.045
N 30	52	3.7	6.4	281	300	-0.038	0.038	0.021	0.043
N 31	53	3.7	6.4	280	300	-0.036	0.036	0.020	0.041
N 32	54	3.7	6.5	280	300	-0.040	0.041	0.023	0.046
N 34	52	3.7	6.4	281	300	0.004	0.026	0.031	0.031
N 36	55	3.8	6.5	281	300	-0.037	0.037	0.021	0.042
N 37	64	3.7	6.5	280	300	-0.101	0.104	0.072	0.124

Table 10: N-File Statistical Analysis for the SGERG Equation; Restricted to Pipeline Quality Gases for the Ranges 265 to 335 K and 0 to 12 MPa (continued)

GERG-Code	n	p/MPa min	p/MPa max	T/K min	T/K max	b %	aav %	s %	rms %
N 38	65	3.7	6.6	280	300	-0.021	0.028	0.031	0.037
N 39	55	3.7	6.5	280	300	-0.003	0.017	0.020	0.020
N 40	54	3.7	6.5	281	300	-0.051	0.053	0.025	0.057
N 41	16	3.8	5.5	279	294	-0.045	0.045	0.012	0.046
N 42	44	3.8	6.5	280	300	-0.050	0.054	0.054	0.073
N 43	66	3.7	6.5	280	300	0.019	0.026	0.026	0.032
N 44	66	3.8	6.5	280	300	-0.040	0.041	0.048	0.062
N 45	66	3.7	6.4	280	300	0.008	0.032	0.039	0.040
N 49	33	3.8	6.4	280	286	0.049	0.050	0.022	0.054
N 50	22	3.7	6.4	280	283	-0.031	0.031	0.010	0.033
N 51	25	0.6	11.8	273	313	0.035	0.035	0.026	0.043
N 52	23	0.3	11.6	313	313	0.053	0.053	0.030	0.061
N 53	25	0.4	11.9	273	313	0.010	0.020	0.028	0.029
N 54	38	0.3	11.9	273	313	-0.004	0.037	0.053	0.052
N 55	83	0.3	11.1	275	330	-0.009	0.014	0.027	0.028
N 56	71	0.4	12.0	270	330	-0.024	0.032	0.045	0.051
N 57	27	0.4	11.9	290	290	0.007	0.011	0.015	0.016
N 58	48	0.5	12.0	280	290	0.018	0.024	0.021	0.027
N 59	28	0.3	11.0	310	310	0.016	0.019	0.019	0.025
N 60	117	0.4	12.0	270	330	0.024	0.036	0.037	0.044
N 61	30	0.2	11.1	310	310	0.005	0.007	0.008	0.009
N 62	109	0.4	12.0	270	330	0.003	0.019	0.024	0.024
N 63	50	0.3	11.4	310	330	0.008	0.018	0.027	0.028
N 64	117	0.5	12.0	270	330	0.022	0.029	0.028	0.036
N 65	54	0.4	10.2	275	280	-0.007	0.012	0.020	0.021
N 66	120	0.4	12.0	270	330	-0.009	0.021	0.030	0.031
N 67	68	0.4	9.2	273	303	0.027	0.029	0.028	0.039
N 68	69	0.4	9.2	273	303	0.008	0.011	0.016	0.018
N 69	70	0.4	9.2	273	303	-0.005	0.010	0.013	0.014
N 70	68	0.4	9.2	273	303	0.028	0.030	0.035	0.045
N 71	70	0.4	9.2	273	303	0.000	0.010	0.014	0.014
N 72	67	0.4	9.2	273	303	-0.003	0.010	0.014	0.014
N 73	25	0.5	11.0	310	310	0.012	0.013	0.010	0.015
N 74	121	0.6	12.0	270	330	0.010	0.024	0.033	0.034
N 75	132	0.4	12.0	270	330	0.000	0.014	0.021	0.021

Table 10: N-File Statistical Analysis for the SGERG Equation; Restricted to Pipeline Quality Gases for the Ranges 265 to 335 K and 0 to 12 MPa (continued)

GERG-Code	n	p/MPa min	p/MPa max	T/K min	T/K max	b %	aav %	s %	rms %
N 76	135	0.1	8.0	273	323	-0.032	0.040	0.040	0.051
N 77	11	3.7	7.2	296	297	0.036	0.062	0.065	0.072
N 78	19	3.6	6.5	295	297	0.048	0.049	0.032	0.057
N 79	21	3.0	5.4	296	297	-0.065	0.066	0.046	0.079
N 81	42	3.8	6.4	280	294	0.026	0.029	0.028	0.038
N 82	45	0.6	11.1	310	330	-0.006	0.009	0.014	0.015
N 83	123	0.3	12.0	270	330	-0.018	0.020	0.023	0.029
N 85	48	2.9	7.4	280	298	0.015	0.029	0.038	0.040
N 87	7	4.9	5.3	289	289	-0.035	0.035	0.022	0.040
N 88	40	1.0	6.0	283	313	-0.067	0.069	0.027	0.072
N 89	42	1.5	6.6	284	313	0.001	0.017	0.020	0.020
N 90	35	1.5	5.5	284	313	-0.065	0.065	0.027	0.070
N 91	32	1.0	5.1	283	313	-0.075	0.076	0.040	0.085
N 92	26	1.0	4.0	283	313	-0.007	0.020	0.023	0.024
N 93	8	1.0	5.2	303	303	0.063	0.063	0.017	0.065
N 94	26	3.0	7.8	286	286	-0.018	0.018	0.010	0.020
N 95	44	2.9	7.2	280	298	-0.021	0.042	0.049	0.053
N107	115	0.5	12.0	270	330	0.017	0.048	0.056	0.058
N109	114	0.5	11.5	265	330	0.062	0.082	0.092	0.111
N115	114	0.5	11.5	270	330	0.012	0.032	0.036	0.038
total	4742					-0.006	0.035	0.052	0.052

tables which correspond with Tables 7.1 and 8.1. As before, the tables list the number of data points, the minimum and maximum pressure, the minimum and maximum temperature, the bias, the average absolute deviation, standard deviation and root-mean-square deviation for each of the 49 sets of data in the D-file (59 minus 10 outside of the pipeline quality range) and 90 sets in the N-file (116 minus 26) respectively.

5.4 Summary and Conclusions

Tables 7 to 10 leave no room for doubt about the utility and overall accuracy, in terms of whichever of the various statistical measures is chosen, of either the AGA-8 or the SGERG method; without going into detail, the performance statistics are uniformly impressive. There are, however, a few sets of data which display relatively poor performance against the methods. The following sets particularly stand out:

D-8 and **D-12** : these are small sets of measurements made by Gaz de France using a DEH Z-Meter.

D-14 : a set of DEH Z-Meter measurements from Gasunie.

D-32, **D-39**, **D-44** and **D-50** : these datasets are pycnometer measurements made at Texas A+M University on the GRI round-robin gases with test data above 30 MPa (see also sections 4.2 and 4.3).

N-21 : this set of Burnett data was identified previously as suspect [7], probably due to insufficient accuracy of the compositional analysis; the companion dataset N-22 does not now really stand out as particularly problematical, but D-1 may be.

N-106 and **N-116** : these are Ruhrgas OPT measurements on gases which contain (1) about 27% carbon dioxide and 66% methane, and (2) 28% nitrogen, 27% hydrogen and only 29% methane.

Some of these sets of data might be of suspect quality i.e. fail to meet our criterion of ±0.1% in Z. For D-32, D-39, D-44 and D-50, however, many (but not all) of the data are for extremes of temperature and/or pressure, and for N-106 and N-116 the data are for extremes of composition. In cases such as these, it certainly remains possible that the poor performance observed is caused by the calculational methods rather than the data.

6 - REFERENCES

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[7] M Jaeschke and A E Humphreys
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GERG Technical Monograph TM4 (1990), 477 pp

[8] D Ambrose
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ESDU Memorandum No 79 (ESDU International, London) 10 pp (Oct 1991)

[9] J A Schouten and J P J Michels
Evaluation of the PVT Reference Data on Natural Gas Mixtures
Univ Amsterdam (contracted to GRI) unpublished report (Sep 1992) 108 pp

[10] R Kleinrahm and W Wagner
Measurement and Correlation of the Equilibrium Liquid and Vapour Densities and the Vapour Pressure along the Coexistence Curve of Methane
J Chem Thermo 18 (8) 739-760 (1986)

[11] ISO TC193
Draft International Standard DIS-13443 (1995)
Natural Gas - Standard Reference Conditions

7 - NOMENCLATURE

Symbol	First Use	SI Unit	Meaning
aav	page 33	%	Absolute average deviation
b	33	%	Bias
d	34	-	Relative density
H_S	34	MJ m^{-3}	Superior calorific value
n	33	-	Number of data points in a set
p	1	MPa	Absolute pressure
R	55	J mol^{-1} K^{-1}	Gas constant = 8.314510
rms	33	%	Root-mean-square deviation
S	57	K^{-1}	Sensitivity coefficient
s	33	%	Standard deviation
T	1	K	Thermodynamic temperature
V_m	55	m^3 mol^{-1}	Molar volume
x	56	-	Mole fraction
Z	1	-	Compression factor = $p\ V_m\ /\ R\ T$

Additional Subscripts

48	Value on the 1948 International Temperature Scale
68	Value on the 1968 International Practical Temperature Scale
90	Value on the 1990 International Temperature Scale

APPENDIX A - Note on Temperature Scales

High-accuracy measurements of compression factor have been made over a time span of several decades, starting perhaps with those made (and rarely bettered) as density determinations by Michels and co-workers in the thirties. Consequently, the GERG Databank contains measurements made using a variety of internationally adopted temperature scales, namely ITS-27, ITS-48 and IPTS-68. More recently the 1990 International Temperature Scale (ITS-90), which postdates the initial publication of the databank, has come into use. None of these scales reproduces the true thermodynamic temperature, though ITS-90 is very close. It is proper, therefore, to ask whether corrections to temperatures should be applied when taking reported values of compression factor from the research literature into the databank, in order that all data are stored on the same basis.

In principle, the answer to this question is necessarily positive. In practice, however, the answer depends upon the sensitivity of the dependent variable (compression factor) to the independent variable (temperature) at fixed values of the other independent variables (pressure and composition) i.e. to $(\partial Z/\partial T)_{p,x}$.

We have therefore carried out test calculations, using the AGA-8-92DC equation, of $(\partial Z/\partial T)_{p,x}$ for a variety of pressures up to the new maximum for the 1996 databank of 60 MPa. The results for the Ekofisk gas N-75 are shown in Table A.1. Although this is not a rigorous test, it is clear from the values in the last two rows of this table that an incorrect assignment of temperature scale is unlikely, at the current state-of-the-art for compression factor determination, to result in significant errors; the only possible exceptions would be for any top quality pre-1968 measurements made towards the lower end of the temperature range. As a consequence, we conclude that there is presently no need to apply temperature scale corrections to the contents of the GERG databank; nevertheless, good practice demands that generators, collators and analysts of compression factor data should all take care to specify clearly the temperature scale to which they work, and to have a good reason if this is not ITS-90!

Table A.1 : Sensitivity *S* of Compression Factor to Temperature Scale as a Function of Temperature and Pressure

Ekofisk gas (N-75) $S = (\partial Z/\partial T)_{p,x}/\mathrm{K}^{-1}$

	T/K =	240	270	300	330
p/MPa =	0.1	0.00006	0.00004	0.00003	0.00002
	1.0	0.00067	0.00042	0.00028	0.00019
	3.0	0.00242	0.00138	0.00086	0.00058
	7.0	0.00895	0.00377	0.00213	0.00136
	12.0	0.00471	0.00516	0.00328	0.00210
	20.0	0.00138	0.00250	0.00267	0.00218
	30.0	-0.00003	0.00079	0.00122	0.00132
	40.0	-0.00101	-0.00022	0.00026	0.00050
	50.0	-0.00187	-0.00102	-0.00048	-0.00016
	60.0	-0.00267	-0.00172	-0.00111	-0.00071
$(T_{90}-T_{68})$/K [8]		0.007	0.001	-0.006	-0.015
$(T_{90}-T_{48})$/K [8]		0.027	0.002	-0.015	-0.025
maximum absolute values					
$(T_{90}-T_{68})(\partial Z/\partial T)$		0.00006	0.00001	0.00002	0.00003
$(T_{90}-T_{48})(\partial Z/\partial T)$		0.00024	0.00001	0.00005	0.00005

APPENDIX B - Complete Listing of Sources for the GERG Databank

The listing given below is a complete bibliography, in reverse-chronological order, of all those studies reporting experimental data considered for inclusion in the GERG databank.

Firstly, and most importantly of course, it provides a full set of the original (i.e. primary) source references for the data that make up the current 1996 version of the databank, including those inadvertently overlooked in the original compilation. Secondly (mostly towards the front) it includes a few recent sources which, when properly evaluated, may prove of sufficient quality for future inclusion in the databank.

The listing also includes sources of data which, for a variety of reasons, have been deliberately excluded from the databank. The intention here is mainly to assert that these sources were *not* overlooked; exclusion is not necessarily an indication of poor quality data. No claim for completeness is made in respect of this category.

Measurements made before about 1930 are, of course, rarely serious candidates for inclusion in the databank; nevertheless, references which predate this have been included in the listing for reasons of historical interest.

Note that when we write of "data" we expressly mean measurements of compression factor, density, gas-law deviation coefficient or some equivalent quantity. Consequently, it has been our intention to exclude sources which report only measurements or derivations of virial coefficients, even when they have been derived from good-quality, but unreported, primary data.

The opportunity has been taken at this time to assign each entry in the listing a permanent reference code. This is of the form 00-00x; the first two digits (plus 1900 - except for pre-1900 references!) identify the year of publication, and the remaining digits are assigned serially for each year. The suffix letter has the following meaning -

a = reference contains data present in GERG TM4
b = reference contains only data added at this update
c = reference contains data awaiting evaluation
d = reference not used as a source of data

After each complete reference further information is given. Each set of data included in the 1996 GERG Databank is summarised in a single line entry containing the following information -

Column 1 = GERG-Code
Column 2 = number of data points in GERG TM4 (1990) and, in square brackets, the number of data points added at this update, including those for the extended ranges of T and p
Column 3 = comments (especially for N-File natural gases)

The "GERG-Code" identifies the file to which the set of data is assigned and, for the A, B and C files, the components of the gas, together with a unique (serially assigned) number which identifies the set within the relevant file. For more details of how this coding is assigned and interpreted, see GERG TM4 [7].

For sources which contain compression factor measurements not accepted into the collection, the single line entry for each set of data provides a brief explanation.

The authors invite readers to let them know of any errors and remaining inadvertent omissions.

96-01d **E Kiran, H Pöhler and Yan Xiong**
Volumetric Properties of Pentane + Carbon Dioxide at High Pressures
J Chem Eng Data <u>41</u> (2) 158-165 (1996)

A3 data : supercritical fluid data; not ±0.1%
A10 data : supercritical fluid data; not ±0.1%
B310 data : supercritical fluid data; not ±0.1%

96-02c **H Hou, J C Holste, K R Hall, K N Marsh and B E Gammon**
Second and Third Virial Coefficients for Methane + Ethane + Carbon Dioxide at (300 and 320) K
J Chem Eng Data <u>41</u> (2) 344-353 (1996)

A1 data : 47 points (Burnett apparatus) within range
A4 data : 44 points (Burnett apparatus) within range
B14 data : 135 points for three mixtures within range
C134 data : 86 points for two mixtures within range

96-03d **Z Gokmenoglu, Yan Xiong and E Kiran**
Volumetric Properties of Carbon Dioxide + Sulfur Hexafluoride at High Pressures
J Chem Eng Data <u>41</u> (2) 354-360 (1996)

A3 data : supercritical fluid data; not ±0.1%

96-04c **O Le Noë, J Goyette, T K Bose and D Ingrain**
Determination of the Compressibility Factor and Measurement of Traces of Water in Methane by a Microwave Method
Fluid Phase Equilibria <u>114</u> (1-2) 135-145 (1996)

A1 data : 23 points at 298.15 K and up to 16 MPa

95-01c **A Fenghour, W A Wakeham, A C Scott and J T R Watson**
Amount-of-Substance Density of CH_4 at Temperatures from 322.5 K to 700 K and Pressures up to 35 MPa
J Chem Thermo <u>27</u> (2) 213-218 (1995)

A1 data : 47 points within range awaiting evaluation

95-02c **A Fenghour, W A Wakeham and J T R Watson**
Amount-of-Substance Density of CO_2 at Temperatures from 329 K to 698 K and Pressures up to 34 MPa

J Chem Thermo 27 (2) 219-223 (1995)

A3 data : 36 points within range awaiting evaluation

95-03c **H A Duarte-Garza, J C Holste, K R Hall, K N Marsh and B E Gammon**
Isochoric *pVT* and Phase Equilibrium Measurements for Carbon Dioxide + Nitrogen
J Chem Eng Data 40 (3) 704-711 (1995)

B23 data : 51 points (pycnometer) for three compositions

95-04d **J M St-Arnaud, R Okambawa, T K Bose and D Ingrain**
Determination of the Compressibility Factor $Z(p,T)$ of Three Methane-Ethane Mixtures using the Dielectric Constant Method
Int J Thermophys 16 (1) 177-184 (1995)

Up to 12 MPa at 298.15 K, but detailed results not given

95-05c **W Blanke and R Weiss**
Virial Coefficients of Methane-Ethane Mixtures in the Temperature Range from 0 to 60 °C determined with an Automated Expansion Apparatus
Int J Thermophys 16 (3) 643-653 (1995)

B14 data : 129 points up to 7 MPa for three compositions

94-01d **P Malbrunot, J Vermesse, D Vidal, T K Bose, A Hourri and J M St-Arnaud**
Determination of Densities and Dielectric Polarizabilities of Methane at 298.15 K for Pressures up to 710 MPa
Fluid Phase Equilibria 96 173-183 (1994)

A1 data : 21 points not used

94-02d **P J McElroy and B D Ababio**
Compression Factors and Virial Equation of State Coefficients for the System Carbon Monoxide + Ethane
J Chem Eng Data 39 (2) 327-329 (1994)

B47 data : 10 points (63% CO) impure (air?), not used
B47 data : 11 points (58% CO) impure, not used
B47 data : 9 points (64% CO) impure, not used
B47 data : 11 points (64% CO) impure, not used
B47 data : 10 points (52% CO) impure, not used
B47 data : 13 points (53% CO) impure, not used

94-03d **P J McElroy and Ji Fang**
Compression Factors and Virial Coefficients of (Methane + Ethane)
J Chem Thermo 26 (6) 617-623 (1994)

B14 data : 132 points (for 13 compositions) but not ±0.1%

94-04b **Ruhrgas BUR (Jaeschke et al)**
Unpublished

D-35 [18] RG-2 (simulated Ekofisk gas)

N-97 [33] Epe gas with N_2+CO_2+C_2H_6 admixture
N-99 [15] Gescher gas with N_2 diluent
N-102 [33] Ekofisk gas with C_2H_6 enrichment
N-105 [33] TENP gas with CO_2 diluent

94-05b Ruhrgas OPT (Jaeschke et al)
Unpublished

D-21 [228] CH_4+N_2+CO_2+C_2H_6
N-98 [306] Epe gas with N_2+CO_2+C_2H_6 admixture
N-100 [285] Gescher gas with N_2 diluent
N-101 [338] Gescher gas with N_2 diluent
N-103 [336] Ekofisk gas with C_2H_6 enrichment
N-104 [223] Ekofisk gas with C_2H_6 enrichment
N-106 [220] TENP gas with CO_2 diluent
N-107 [460] Emsbüren gas with N_2 diluent
N-108 [187] Ekofisk gas with C_2H_6 enrichment
N-109 [322] Natural gas with CO_2 diluent
N-110 [360] Natural gas with N_2+H_2+CO admixture
N-111 [90] Natural gas with C_3H_8 enrichment
N-112 [100] Gescher gas with C_4H_{10} enrichment
N-113 [173] Gescher gas with C_3H_8 enrichment
N-114 [125] Gescher gas with C_3H_8 enrichment
N-115 [342] Gescher gas with O_2 diluent
N-116 [348] DDR gas with N_2+H_2+CO admixture

93-01b A Fenghour, W A Wakeham, D Ferguson, A C Scott and J T R Watson
Automated Isochoric Apparatus for the Measurement of Density of Fluid Mixtures at Temperatures from 298.15 K to 773.15 K and Pressures up to 40 MPa : Results for Helium and Nitrogen
J Chem Thermo 25 (7) 831-845 (1993)

A2 data : 20 points not used
A9-6 [15]

93-02d B D Ababio and P J McElroy
(Pressure, Amount-of-Substance Density, Temperature) of $\{(1-x)CO_2 + xH_2\}$ Using a Direct Method
J Chem Thermo 25 (12) 1495-1501 (1993)

B35 data : 13 points (49% H_2) not used
B35 data : 11 points (43% H_2) not used
B35 data : 11 points (38% H_2) not used
B35 data : 9 points (40% H_2) not used
B35 data : 9 points (36% H_2) not used

93-03d J Obriot, J Ge, T K Bose and J M St-Arnaud
Determination of the Density from Simultaneous Measurements of the Refractive Index and the Dielectric Constant of Gaseous CH_4, SF_6 and CO_2
Fluid Phase Equilibria 86 315-350 (1993)

A1 data : 2 × 148 points within range
A3 data : 2 × 208 points, but some of dubious accuracy

93-04d J M St-Arnaud, T K Bose, R Okambawa and D Ingrain
Precise Determination of the Compressibility Factor by Using Dielectric Constant Measurements
Fluid Phase Equilibria 88 137-149 (1993)

A1 data : 27 points not used

93-05b J C Holste and K R Hall
Thermodynamic Properties of Natural Gas Mixtures
Final Report (February 1987 - September 1992)
Report Number GRI-93/0006, Gas Research Institute, Chicago (Feb 1993) 31 pp (incorporating ref 92-02, 108 pp)

D-22	[279]	GU-1 Ruhrgas OPT (simulated high-N_2 NAM gas)
D-23	[13]	GU-1 Ruhrgas GDM
D-24	[78]	GU-1 Texas A+M University Burnett
D-25	[91]	GU-1 Texas A+M University pycnometer
D-26	[65]	GU-1 NIST (Boulder) Burnett
D-27	[155]	GU-1 van der Waals Laboratory Burnett
D-28	[64]	GU-1 van der Waals Lab (for Gaz de France)
D-29	[271]	GU-2 Ruhrgas OPT (simulated high-CO_2 gas)
D-30	[13]	GU-2 Ruhrgas GDM
D-31	[85]	GU-2 Texas A+M University Burnett
D-32	[89]	GU-2 Texas A+M University pycnometer
D-33	[70]	GU-2 NIST (Boulder) Burnett
D-34	[119]	GU-2 van der Waals Laboratory Burnett
D-36	[275]	RG-2 Ruhrgas OPT (simulated Ekofisk gas)
D-37	[9]	RG-2 Ruhrgas GDM
D-38	[61]	RG-2 Texas A+M University Burnett
D-39	[87]	RG-2 Texas A+M University pycnometer
D-40	[65]	RG-2 NIST (Boulder) Burnett
D-41	[280]	NIST-1 Ruhrgas OPT (simulated Gulf Coast)
D-42	[15]	NIST-1 Ruhrgas GDM
D-43	[77]	NIST-1 Texas A+M University Burnett
D-44	[82]	NIST-1 Texas A+M University pycnometer
D-45	[66]	NIST-1 NIST (Boulder) Burnett
D-46	[64]	NIST-1 van der Waals Lab (for Gaz de France)
D-47	[278]	NIST-2 Ruhrgas OPT (simulated Amarillo gas)
D-48	[11]	NIST-2 Ruhrgas GDM
D-49	[78]	NIST-2 Texas A+M University Burnett
D-50	[66]	NIST-2 Texas A+M University pycnometer
D-51	[67]	NIST-2 NIST (Boulder) Burnett
D-52	[135]	NIST-2 van der Waals Laboratory Burnett
D-53	[40]	NIST-2 van der Waals Lab (for Gaz de France)

92-01b G Händel, R Kleinrahm and W Wagner
Measurement of the (Pressure, Density, Temperature) Relation of Methane in the Homogeneous Gas and Liquid Regions in the Temperature Range from 100 K to 260 K and at Pressures up to 8 MPa
J Chem Thermo 24 (7) 685-695 (1992)

A1-14 [56]

92-02d J A Schouten and J P J Michels
Evaluation of the *PVT* Reference Data on Natural Gas Mixtures
Univ Amsterdam (contracted to GRI) unpublished report (Sep 1992) 108 pp

Same data given in 93-05

92-03b W Zhang, J A Schouten, H M Hinze and M Jaeschke
PVT-x Behavior of He-N_2 Mixtures from 270 to 353 K and up to 280 bar
J Chem Eng Data 37 (1) 114-119 (1992) (data available as supplementary material)

A9-4	[86]	Ruhrgas BUR
A9-5	[263]	Ruhrgas OPT
B29-1	[26]	Ruhrgas BUR 25% He
B29-2	[337]	Ruhrgas OPT 25% He
B29-3	[30]	Ruhrgas BUR 50% He
B29-4	[274]	Ruhrgas OPT 50% He
B29-5	[22]	Ruhrgas BUR 75% He
B29-6	[337]	Ruhrgas OPT 75% He

92-04b H J Achtermann, J Hong, W Wagner and A Pruss
Refractive Index and Density Isotherms for Methane from 273 to 373 K and at Pressures up to 34 MPa
J Chem Eng Data 37 (4) 414-418 (1992)

A1-13 [654]

92-05b J P M Trusler and M Zarari
The Speed of Sound and Derived Thermodynamic Properties of Methane at Temperatures between 275 K and 375 K and Pressures up to 10 MPa
J Chem Thermo 24 (9) 973-991 (1992)

A1-16 [90] derived from speed of sound measurements

92-06b R Gilgen, R Kleinrahm and W Wagner
Supplementary Measurements of the (Pressure, Density, Temperature) Relation of Carbon Dioxide in the Homogeneous Region at Temperatures from 220 K to 360 K and Pressures up to 13 MPa
J Chem Thermo 24 (12) 1243-1250 (1992)

A3-5 [203] but liquid phase points excluded

92-07d J M St-Arnaud, T K Bose, R Okambawa and D Ingrain
Application of the Dielectric Constant Measurements to Study the Influence of Water Vapor on the Compressibility Factor of Methane
Int J Thermophys 13 (4) 685-697 (1992)

A1 data : 28 points not used

92-08b L A Weber
Measurement of the Virial Coefficients and Equation of State of the Carbon Dioxide + Ethane System in the Supercritical Region
Int J Thermophys 13 (6) 1011-1032 (1992)

A3-10	[11]	
A4-5	[11]	
B34-11	[102]	26% C_2H_6

B34-12 [81] 51% C_2H_6
B34-13 [70] 75% C_2H_6

91-01a M Jaeschke, H M Hinze, H J Achtermann and G Magnus
PVT Data from Burnett and Refractive Index Measurements for the Nitrogen-Hydrogen System from 270 to 353 K and Pressures to 30 MPa
Fluid Phase Equilibria 62 (1-2) 115-139 (1991)

B25-1	38	[9]	15% H_2
B25-2	72	[158]	15% H_2
B25-3	72	[116]	25% H_2
B25-4	50	[29]	50% H_2
B25-5	69	[116]	50% H_2
B25-6	44	[27]	75% H_2
B25-7	74	[125]	75% H_2

91-02a H J Achtermann, G Magnus, H M Hinze and M Jaeschke
PVT Data from Refractive Index Measurements for the Ethane + Nitrogen System from 270 to 350 K and Pressures to 28 MPa
Fluid Phase Equilibria 64 263-280 (1991)

B24-1	65	[68]	75% C_2H_6
B24-2	96	[68]	50% C_2H_6
B24-3	107	[76]	25% C_2H_6

91-03b N Pieperbeck, R Kleinrahm, W Wagner and M Jaeschke
Results of (Pressure, Density, Temperature) Measurements on Methane and on Nitrogen in the Temperature Range from 273.15 K to 323.15 K at Pressures up to 12 MPa Using a New Apparatus for Accurate Gas-Density Measurements
J Chem Thermo 23 (2) 175-194 (1991)

A1-15 [175]
A2-9 [124]

91-04b A Staby and J M Mollerup
Measurement of the Volumetric Properties of a Nitrogen-Methane-Ethane Mixture at 275, 310 and 345 K at Pressures to 60 MPa
J Chem Eng Data 36 (1) 89-91 (1991)

C124-2 [99] 63-12-25% mixture

91-05d T Søgaard, W Gutfeld and M Tambo
Determining the Mole Mass of Gas: Verification of a Method that can be used in Quality Control of Reference Gas Mixtures
Internal Report, FORCE Institutes - Dantest Gas Density Lab 10 pp + 6 Annexes (Oct 1991)

B12 data : 1 point (20% N_2) not used
D data : 1 point not used

91-06a M Jaeschke and M Hinze
Ermittlung des Realgasverhaltens von Methan und Stickstoff und deren Gemische im Temperaturbereich von 270 K bis 353 K und Drücken bis 30 MPa

Fortschritt-Berichte VDI series 3 no 262 (1991)

A1-9	124	[45]	BUR
A1-10	148	[404]	OPT
A2-5	72	[57]	BUR
A2-6	173	[341]	OPT
B12-7	13	[16]	20% N_2 BUR
B12-8	90	[181]	20% N_2 OPT
B12-9	19	[6]	75% N_2 BUR
B12-10	95	[186]	75% N_2 OPT
B12-11	27	[6]	50% N_2 BUR round-robin gas from 89-01
B12-12	89	[64]	50% N_2 OPT round-robin gas from 89-01
B12-21	13	[3]	50% N_2 BUR
B12-22	139	[258]	50% N_2 OPT

90-01a Ruhrgas DEH (Jaeschke, Hinze, Jülicher, Scheuren)
Unpublished (except in GERG TM4 (1990) [7])

A9-1	18

90-02a Ruhrgas BUR (Jaeschke, Hinze, Jülicher, Scheuren)
Unpublished (except in GERG TM4 (1990) [7])

A3-4	124	[27]	
A4-3	48	[38]	
A5-2	43	[25]	
B13-5	40	[6]	31% CO_2
B14-4	24	[6]	30% C_2H_6
B14-6	79	[4]	12% C_2H_6
B14-8	53	[6]	8% C_2H_6
B14-10	26	[6]	4% C_2H_6
B14-12	74	[7]	1½% C_2H_6
B15-1	40	[28]	15% H_2
B15-4	56	[27]	40% H_2
B15-6	54	[29]	75% H_2
B16-2	14	[16]	7% C_3H_8
B17-1	38	[23]	3% CO
B18-2	14	[15]	1½% C_4H_{10}
B23-2	40	[6]	29% CO_2
B23-3	82	[27]	25% CO_2
B26-2	8	[14]	7% C_3H_8
B27-1	37	[19]	3% CO
B28-1	13	[9]	1½% C_4H_{10}
B35-1	113	[15]	50% H_2
B35-2	100	[36]	75% H_2
B45-1	43	[6]	50% H_2
B45-2	113	[31]	75% H_2
D-16	40	[9]	
N-51	25	[6]	Epe gas
N-53	25	[22]	Epe gas
N-55	83	[15]	Epe gas
N-57	27	[3]	UdSSR + NAM mixture
N-59	28	[6]	NAM (Nederlandse Aardolie Maatschappij)
N-61	30	[6]	UdSSR gas
N-63	50	[12]	Drohne (Lower Saxony) gas
N-65	54	[6]	Ekofisk gas
N-67	68		H-Gas + H_2 mixture
N-68	69		H-Gas + H_2 mixture

N-69	70		L-Gas + H_2 mixture
N-70	68		H-Gas + H_2 mixture
N-71	70		H-Gas + H_2 mixture
N-72	67		L-Gas + H_2 mixture
N-73	25	[6]	L-Gas + H_2 mixture
N-82	45	[12]	TENP gas

90-03a Ruhrgas OPT (Jaeschke, Hinze, Jülicher, Scheuren)
Unpublished (except in GERG TM4 (1990) [7])

A3-3	146	[174]	
A4-4	99	[136]	
A5-3	72	[149]	
B13-4	104	[148]	31% CO_2
B14-5	101	[106]	30% C_2H_6
B14-7	96	[43]	12% C_2H_6
B14-9	118	[167]	8% C_2H_6
B14-11	118	[225]	4% C_2H_6
B14-13	118	[188]	16% C_2H_6
B15-2	46	[120]	15% H_2
B15-3	72	[116]	25% H_2
B15-5	64	[62]	50% H_2
B15-7	72	[113]	75% H_2
B16-3	105	[83]	7% C_3H_8
B17-2	94	[190]	3% CO
B18-3	106	[133]	1½% C_4H_{10}
B110-2	94	[37]	¼% C_5H_{12}
B111-1	119	[39]	
B26-3	102	[121]	7% C_3H_8
B27-2	93	[194]	3% CO
B28-2	100	[122]	1½% C_4H_{10}
B34-1	52	[28]	72% C_2H_6
B34-2	64	[34]	23% C_2H_6
B34-3	67	[35]	46% C_2H_6
B34-4	62	[42]	70% C_2H_6
D-17	71	[97]	
D-18	122	[152]	
D-19	93	[191]	Montoir LNG (from Algeria-Arzew)
D-20	47	[106]	Montoir LNG
N-52	23	[31]	Epe gas
N-54	38	[75]	Epe gas
N-56	71	[104]	Epe gas
N-58	48	[68]	UdSSR + NAM mixture
N-60	117	[225]	NAM gas
N-62	109	[202]	UdSSR gas
N-64	117	[219]	Drohne gas
N-66	120	[213]	Ekofisk gas
N-74	121	[221]	L-Gas + H_2 mixture
N-75	132	[199]	Ekofisk gas
N-83	123	[230]	TENP gas

90-04a Gasunie (Reintsema, Reinhardus, Rensen, Bouw, Joosten)
Unpublished (except in GERG TM4 (1990) [7])

A2-1	94	
A9-2	94	
B12-3	52	9% N_2
B12-4	32	20% N_2

B12-5	33	30% N_2
B12-6	32	50% N_2
B13-1	52	10% CO_2
B13-2	32	19% CO_2
B13-3	32	30% CO_2
B13-7	33	25% CO_2
B14-1	49	9% C_2H_6
B14-2	33	5% C_2H_6
B14-3	30	20% C_2H_6
B16-1	54	4% C_3H_8
B16-4	44	5% C_2H_6
B18-1	72	1% C_4H_{10}
B110-1	21	¼% C_5H_{12}
B23-1	21	25% CO_2
B24-4	30	25% C_2H_6
B26-1	43	5% C_3H_8
C123-1	33	
C124-1	22	
C134-1	22	
C134-2	33	
C136-1	21	
C146-1	32	
D-14	22	
N-28	64	Statenzijl (Netherlands onshore) gas
N-29	53	Ureterp (Netherlands onshore) gas (NAM)
N-30	52	Ambacht (Netherlands onshore)
N-31	53	Placid (Netherlands North Sea) gas
N-32	54	Middenmeer (North Holland) gas (Petroland)
N-33	64	Middelie Zechstein-Rotliegendes mixture
N-34	52	Middelie Zechstein gas
N-35	55	Middelie Rotliegendes gas
N-36	55	Bocholtz (Netherlands onshore) gas
N-37	64	Ekofisk gas
N-38	65	Garyp (Friesland) gas (NAM)
N-39	55	S'Gravenvoerden gas
N-40	54	Tietjerksteradeel (Friesland) gas (NAM)
N-41	16	Slochteren (Groningen) gas
N-42	44	Slochteren gas
N-43	66	Balgzand (Netherlands onshore) gas
N-44	66	Tor (Norwegian sector) gas (Amoco)
N-45	66	Annerveen (north-east Netherlands) gas (NAM)
N-46	65	Roswinkel (south-east Drenthe) gas (NAM)
N-47	65	Sleen-Roswinkel mixture
N-48	65	Sleen (south-east Drenthe) gas (NAM)
N-49	33	Statenzijl gas
N-50	22	Groningen (north-east Netherlands) gas (NAM)
N-77	11	Slochteren gas
N-78	19	Statenzijl gas
N-79	21	Ekofisk gas
N-80	44	Middelie Rotliegendes gas
N-81	42	Middelie Zechstein gas
N-85	48	Ekofisk
N-94	26	Ekofisk
N-95	44	Ekofisk
N-96	48	Roswinkel

90-05a Gaz de France (Audibert)
Unpublished (except in GERG TM4 (1990) [7])

B23-5	19	10% CO_2
B23-6	20	32% CO_2
D-2	5	
D-3	6	
D-4	6	
D-5	6	
D-6	6	
D-7	6	
D-8	6	
D-9	6	
D-10	7	
D-11	6	
D-12	6	
D-13	6	
N-23	18	Groningen gas
N-24	12	Lacq (south-west France) gas (Elf Aquitaine)
N-25	10	Ekofisk gas
N-26	5	Ekofisk gas
N-27	5	Ekofisk gas

90-06a **British Gas (Cowan, Kimpton, McElroy, Armisen, Gonzales, Humphreys)**
Unpublished (except in GERG TM4 (1990) [7])

N-88	40	Leman Bank (southern North Sea) gas (Shell)
N-89	42	Hamilton (Esmond-Forbes-Gordon fields) gas
N-90	35	Thames (southern North Sea) gas (Arco)
N-91	32	South Morecambe (Irish Sea) gas to Barrow
N-92	26	Frigg (northern North Sea) gas (Total)
N-93	8	Brent (northern North Sea) gas (Shell)

90-07b **S Glowka**
Determination of Volumetric Properties of Ammonia between 298 and 473 K and Carbon Dioxide between 304 and 423 K using the Burnett Method
Polish J Chem <u>64</u> (7-12) 699-709 (1990)

A3-11 [11] and further data available from the author

90-08b **S Jiang, Y Wang and J Shi**
Determination of Compressibility Factors and Virial Coefficients for the Systems Containing N_2, CO_2 and $CHClF_2$ by the Modified Burnett Method
Fluid Phase Equilibria <u>57</u> (1-2) 105-117 (1990)

A2 data : 12 points (calibration data?) not used
A3 data : 10 points not used

B23-13	[10]	27% CO_2
B23-14	[9]	47% CO_2
B23-15	[11]	54% CO_2
B23-16	[11]	70% CO_2

90-09d **P J McElroy, M K Dowd and R Battino**
Compression-Factor Measurements on Ethane and (Ethane + Carbon Dioxide) Using a Direct Method
J Chem Thermo <u>22</u> (5) 505-512 (1990)

A4 data : 44 points available but sample rather impure
B34 data : 11 points (63% C_2H_6) impure, not used

B34 data : 11 points (63% C_2H_6) impure, not used
B34 data : 11 points (64% C_2H_6) impure, not used
B34 data : 11 points (64% C_2H_6) impure, not used
B34 data : 11 points (46% C_2H_6) impure, not used
B34 data : 11 points (57% C_2H_6) impure, not used
B34 data : 11 points (44% C_2H_6) impure, not used
B34 data : 11 points (41% C_2H_6) impure, not used
B34 data : 11 points (25% C_2H_6) impure, not used
B34 data : 10 points (24% C_2H_6) impure, not used
B34 data : 11 points (27% C_2H_6) impure, not used
B34 data : 11 points (23% C_2H_6) impure, not used

90-10b **W Duschek, R Kleinrahm and W Wagner**
Measurement and Correlation of the (Pressure, Density, Temperature) Relation of Carbon Dioxide I. The Homogeneous Gas and Liquid Regions in the Temperature Range from 217 K to 340 K at Pressures up to 9 MPa
J Chem Thermo 22 (9) 827-840 (1990)

A3-6 [253] but liquid phase points excluded

90-11b **W Duschek, R Kleinrahm and W Wagner**
Measurement and Correlation of the (Pressure, Density, Temperature) Relation of Carbon Dioxide II. Saturated Liquid and Saturated Vapour Densities and the Vapour Pressure along the Entire Coexistence Curve
J Chem Thermo 22 (9) 841-864 (1990)

A3-7 [26] on saturation line

90-12d **B V Mallu and D S Viswanath**
Compression Factors and Second Virial Coefficients of H_2, CH_4, $\{xCO_2 + (1-x)H_2\}$ and $\{xCO_2 + (1-x)CH_4\}$
J Chem Thermo 22 (10) 997-1006 (1990)

B13 data : 56 points (48% CO_2) but not raw data, not used
B35 data : 65 points (86% H_2) but not raw data, not used
B35 data : 65 points (23% H_2) but not raw data, not used

90-13b **S N Biswas, S A R C Bominaar, J A Schouten, J P J Michels and C A ten Seldam**
Compressibility Isotherms of Simulated Natural Gases
J Chem Eng Data 35 (1) 35-38 (1990)

D-54 [33] simulated natural gas (Shell A)
D-55 [35] simulated natural gas (Shell B)

90-14c **P Nebendahl**
Dynamik einer rechnergestützten Versuchsanlage zur Präzisionsmessung der thermischen Zustandsgleichung von Fluiden und Fluidgemischen
Fortschritt-Berichte VDI series 3 no 212 (1990)

A3 data : unchecked

89-01a **M Jaeschke, P van Caneghem, M Fauveau, A E Humphreys, R Janssen-van Rosmalen and Q Pellei**
GERG Round-Robin Test of Z-Meters, Burnett Apparatus and an Interferometric Device for *pVT* Measurements

GERG Technical Monograph TM3 (1989) 76 pp
Fortschritt-Berichte VDI series 6 no 238 (1989)

B12-11	27 point	subset subsumed in 91-06	50% N_2
B12-12	89 point	subset subsumed in 91-06	50% N_2
B12-13	39		50% N_2 Humphreys et al (British Gas)
B12-14	14		50% N_2 Fauveau (Gaz de France)
B12-15	20		50% N_2 van Caneghem (Distrigaz)
B12-23	12		50% N_2 Pellei (SNAM)
B12-24	24		50% N_2 Jaeschke (Ruhrgas ADH)
B12-25	39		50% N_2 Hall, Holste et al (Texas A+M)
B12-26	22		50% N_2 Janssen-van Rosmalen (Gasunie)
C146-2	29		Jaeschke (Ruhrgas BUR)
C146-3	155	[192]	Jaeschke (Ruhrgas OPT) (114 in GERG TM3)
C146-4	14		Fauveau (Gaz de France)
C146-5	17		van Caneghem (Distrigaz)
C146-6	9		Humphreys and Kimpton (British Gas)
C146-7	22		Janssen-van Rosmalen (Gasunie)
C146-8	24		Jaeschke (Ruhrgas ADH)
C146-9	12		Pellei (SNAM)
C146-10	40		Hall, Holste et al (Texas A+M)
C146-11	30		Jaeschke (Ruhrgas ADH)
C146-12	11		Janssen-van Rosmalen (Gasunie)
C146-13	94	[14]	Jaeschke (Ruhrgas OPT)

89-02d **H B Brugge, C-A Hwang, K N Marsh, J C Holste, K R Hall and J L Savidge**
Experimental Density Measurements for a Methane + Nitrogen Mixture: Effect of Composition Uncertainties
Proc 4th (1989) IGRC (Tokyo), Government Institutes Inc Rockville (1990, ed T L Cramer)

Same data given as B12-25 in 89-01

89-03a **W Lemming**
Experimentelle Bestimmung akustischer und thermische Virialkoeffizienten von Arbeits-stoffen der Energietechnik
Fortschritt-Berichte VDI series 19 no 32 (1989)

B13-9	[28]	10% CO_2
B34-5	46	90% C_2H_6
B34-6	55	75% C_2H_6
B34-7	44	51% C_2H_6
B34-8	55	26% C_2H_6
B34-9	54	10% C_2H_6

89-04b **J F Ely, W M Haynes and B C Bain**
Isochoric (p,V_m,T) Measurements on CO_2 and on $(0.982\ CO_2 + 0.018\ N_2)$ from 250 to 330 K at Pressures to 35 MPa
J Chem Thermo 21 (8) 879-894 (1989)

A3-8	[48]	but liquid phase points excluded
B23-12	[64]	98% CO_2 (11 points excluded)

89-05d **B V Mallu, G Natarajan and D S Viswanath**
(p,V_m,T,x) and Virial Coefficients of $\{xCO_2 + (1-x)CO\}$
J Chem Thermo 21 (9) 989-996 (1989)

B37 data : 75 points (70% CO) but not raw data, not used

B37 data : 75 points (20% CO) but not raw data, not used

89-06a **W Duschek, R Kleinrahm, W Wagner and M Jaeschke**
Measurement of the (Pressure, Density, Temperature) Relation of Ekofisk Natural Gas in the Temperature Range from 273.15 K to 323.15 K at Pressures up to 8 MPa
J Chem Thermo 21 (10) 1069-1078 (1989)

N-76 135 Ekofisk gas

89-07d **P J McElroy, R Battino and M K Dowd**
Compression Factor Measurements on Methane, Carbon Dioxide and (Methane + Carbon Dioxide) Using a Weighing Method
J Chem Thermo 21 (12) 1287-1300 (1989)

A1 data : 22 points not used (0.10% N_2 and not ±0.1%)
A3 data : 44 points not used (0.02% N_2 and not ±0.1%)
C123 data : 44 points not used
C123 data : 11 points not used
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C123 data : 11 points not used

89-08d **G J Esper, D M Bailey, J C Holste and K R Hall**
Volumetric Behavior of Near-Equimolar Mixtures for CO_2+CH_4 and CO_2+N_2
Fluid Phase Equilibria 49 35-47 (1989)

B13-6 48% CO_2 data reported in 87-04
B23-4 45% CO_2 data reported in 87-04

89-09d **S K Kimpton**
Improvements to the Z-Meter Apparatus, and New Measurements of Compressibility Factor for GERG Round-Robin Gases
British Gas R+D LRS T 988 (Feb 1989) 36 pp

B12-13 50% N_2 data reported in 89-01
C146-6 data reported in 89-01

89-10b **H B Brugge, C-A Hwang, W J Rogers, J C Holste, K R Hall, W Lemming, G J Esper, K N Marsh and B E Gammon**
Experimental Cross Virial Coefficients for Binary Mixtures of Carbon Dioxide with Nitrogen, Methane and Ethane at 300 and 320 K
Physica A 156 (1) 382-416 (1989)

A1-17 [40]
A2-10 [40]
B13-10 [35] 10% CO_2
B13-11 [40] 30% CO_2

B13-12 [40] 68% CO_2
B13-13 [40] 90% CO_2
B23-7 [38] 11% CO_2
B23-8 [40] 25% CO_2
B23-9 [40] 50% CO_2
B23-10 [40] 71% CO_2
B23-11 [38] 91% CO_2
B34 data : 40 points (90% C_2H_6) subset of data in 89-03
B34 data : 44 points (75% C_2H_6) subset of data in 89-03
B34 data : 35 points (51% C_2H_6) subset of data in 89-03
B34 data : 44 points (26% C_2H_6) subset of data in 89-03
B34 data : 43 points (10% C_2H_6) subset of data in 89-03

89-11b **G J Sherman, J W Magee and J F Ely**
PVT Relationships in a Carbon Dioxide-Rich Mixture with Ethane
Int J Thermophys <u>10</u> (1) 47-59 (1989)

B34-10 [83] 1% C_2H_6 (6 points excluded)

89-12c **J Hoinkis**
Untersuchungen zum thermischen Verhalten von binären Gasgemischen mit Kohlendioxid
Dissertation Univ Karlsruhe (1989)

A3 data : unchecked

89-13d **H B Brugge**
PVT Measurements of Carbon Dioxide + Nitrogen and an Equation of State Development for Natural and Hydrocarbon Gases
PhD Thesis, Texas A+M Univ (May 1989)

B23 data : presumably the same as 89-10

88-01a **R Kleinrahm, W Duschek, W Wagner and M Jaeschke**
Measurement and Correlation of the (Pressure, Density, Temperature) Relation of Methane in the Temperature Range from 273.15 K to 323.15 K at Pressures up to 8 MPa
J Chem Thermo <u>20</u> (5) 621-631 (1988)

A1-11 168 [1]

88-02d **R Kleinrahm, W Duschek, M Jaeschke and W Wagner**
Measurements and Correlation of Gas Density of Methane in the Temperature Range of 0-50° and Pressures up to 80 bar
gwf-gas/erdgas <u>129</u> (2) 77-82 (1988)

Same data reported as A1-11 in 88-01

88-03a **W Duschek, R Kleinrahm, W Wagner and M Jaeschke**
Measurement and Correlation of the (Pressure, Density, Temperature) Relation of Nitrogen in the Temperature Range from 273.15 to 323.15 K at Pressures up to 8 MPa
J Chem Thermo <u>20</u> (9) 1069-1077 (1988)

A2-7 127

88-04b **W Blanke, M Jescheck and D Rimkus**
Die thermischen Zustandsgrößen des Stickstoffs im Temperaturbereich von 280 K bis 360 K bei Drücken bis 12 MPa
PTB-Mitteilungen 98 (3) 187-192 (1988)

A2-11 [104]

88-05c **W Blanke and R Weiß**
Pressure-Volume-Temperature Properties and Adsorption Behavior of Natural Gas at Temperatures between 260 K and 330 K and Pressures up to 3 MPa
Erdöl-Erdgas-Kohle 104 (10) 412-417 (1988)

Unchecked - includes Ekofisk gas

88-06d **M Jaeschke**
Realgasverhalten - Einheitliche Berechnungsmöglichkeiten von Erdgas L und H
gwf-Gas/Erdgas 129 (1) 30-37 (1988)

N-11	23 point subset subsumed into 82-02
N-60	24 point subset subsumed into 90-03
N-62	24 point subset subsumed into 90-03
N-64	24 point subset subsumed into 90-03
N-72	23 point subset subsumed into 90-02
N-75	29 point subset subsumed into 90-03

88-07b **J W Magee and J F Ely**
Isochoric (p,V,T) Measurements on CO_2 and (0.98 CO_2+ 0.02 CH_4) from 225 to 400 K and Pressures up to 35 MPa
Int J Thermophys 9 (4) 547-559 (1988)

A3 data : 8 points not used
B13-8 : [65] 98% CO_2 (18 points excluded)

88-08d **P Cowan, P J McElroy and A E Humphreys**
Gas Mixture Compressibility Factors Using a "Z-Meter"
British Gas R+D LRS T 927 (Jan 1988) 35 pp

B12-13	25 point subset subsumed into 89-09 50% N_2
N-84	37 Bacton feeder gas + H_2 mixture

88-09d **C-A Hwang**
PVT Measurements of Carbon Dioxide + Methane Mixtures and an Equation of State Development
PhD Thesis, Texas A+M Univ (Aug 1988)

B13 data : presumably the same as 89-10

87-01d **B V Mallu, G Natarajan and D S Viswanath**
Compression Factors and Second Virial Coefficients of CO_2, CO and {xCO + $(1-x)CO_2$}
J Chem Thermo 19 (5) 549-554 (1987)

B37 data : 75 points (43% CO) but not raw data, not used

87-02a **J C Holste, K R Hall, P T Eubank, G Esper, M Q Watson, W Waronwy, D M Bailey, J G Young and M T Bellomy**
Experimental (P,V_m,T) for Pure CO_2 between 220 and 450 K
J Chem Thermo 19 (12) 1233-1251 (1987)

A3-2   139 [76] but liquid phase points excluded

87-03a **N-E Hannisdal**
Gas-Compression Equations Evaluated
Oil Gas J 85 (18) 38-42 (1987)

N-86   8 [2] Statfjord (Norwegian sector) gas (Statoil)

87-04a **G J Esper**
Direkte und Indirekte *p-V-T*-Messungen an Fluiden
PhD Dissertation, Ruhr-Univ Bochum
Fortschritte-Berichte VDI series 3 no 148 (1987)

A3-9   [63] but liquid phase points excluded
B13-6   64 [54]   48% CO_2
B23-4   58 [48+40] 45% CO_2 (7 duplicate points deleted)

87-05d **D Tang, Y Wang and X Wu**
Measurement of Methane Compressibilities
J China Univ Sci Technol 17 (supp) 111-114 (1987)

A1 data : 20 points of apparently poor quality

87-06d **W Duschek, R Kleinrahm and W Wagner**
Messung der Gasdichten von Ekofisk-Erdgas im Temperaturbereich von 0 °C bis 50 °C und Drücken bis 80 bar
Internal report, Ruhr-Universität Bochum (Jan 1987) 45 pp

Same data as 89-06 (extra value is a clear misprint)

86-01a **H J Achtermann, T K Bose, H Rögener and J M St-Arnaud**
Precise Determination of the Compressibility Factor of Methane, Nitrogen, and Their Mixtures from Refractive Index Measurements
Int J Thermophys 7 (3) 709-720 (1986)

A1-12   17 [18]
A2-8   17 [18]
B12-16   23 [43] 75% N_2
B12-17   23 [43] 10% N_2
B12-18   23 [43] 62% N_2
B12-19   23 [43] 86% N_2
B12-20   23 [43] 50% N_2

86-02a **R T Ellington**
Unpublished? (private communication, Univ Oklahoma)

B18-4   27   4% C_4H_{10}
N-87   7 Amarillo (Texas) gas

86-03d **J W Magee and R Kobayashi**
Isochoric (p,ρ_n,T) Measurements on $(0.2005\ H_2 + 0.7995\ CH_4)$ at Temperatures from 140 to 273 K and Pressures to 70 MPa

J Chem Thermo 18 (9) 847-858 (1986)

B15 data : 90 points (20% H_2) poor quality, not used

86-04d **R Kleinrahm, W Duschek and W Wagner**
Messung und Korrelation der Gasdichte von Methan im Temperaturbereich von 0 - 50 °C und Drucken bis 80 bar
Internal report, Ruhr-Universität Bochum (Jan 1986) 33 pp

Same data reported as A1-11 in 88-01

86-05b **R T Ellington, K E Starling, M J Hill and J L Savidge**
High Quality Compressibility Factors Prove Accuracy of New Correlation
Proc 65th Annual Conv Gas Process Assoc (1986) 193-201

D-58	[13]	simulated Gulf Coast gas
D-59	[32]	simulated Amarillo gas

86-06d **R T Ellington, M J Hill and S Narayanan**
Research Data from a Industrial Compressibility Factor Instrument for Improved Correlations
Proc 3rd 1986 IGRC (Toronto) 418-427, Government Institutes Inc, Rockville (1987, ed T L Cramer)

C146 data : 9 points not used

86-07c **W W R Lau**
A Continuously Weighed Pycnometer Providing Densities for Carbon Dioxide + Ethane Mixtures between 240 and 350 K at Pressures up to 35 MPa
PhD Thesis, Texas A+M Univ (Dec 1986) 125 pp

A4 data : unchecked
B34 data : unchecked

86-08d **T K Bose, J M St-Arnaud, H J Achtermann and R Scharf**
Improved Method for the Precise Determination of the Compressibility Factor from Refractive Index Measurements
Rev Sci Instrum 57 (1) 26-32 (1986)

A1 data : 35 points not used (same data given in 86-01)

85-01a **W M Haynes, R D McCarty, B E Eaton and J C Holste**
Isochoric (p,V_m,x,T) Measurements on (Methane + Ethane) from 100 to 320 K at Pressures to 35 MPa
J Chem Thermo 17 (3) 209-232 (1985)

B14-14	62 [58+6]	50% C_2H_6	(5 points moved to B14-5)
B14-15	63 [24+1]	65% C_2H_6	(5 points added, 1 removed)
B14-16	41 [56+29]	31% C_2H_6	

85-02b **J Mollerup**
Measurement of the Volumetric Properties of Methane and Ethene at 310 K at Pressures to 70 MPa and of Propene from 270 to 345 K at Pressures to 3 MPa by the Burnett Method
J Chem Thermo 17 (5) 489-499 (1985)

A1-18 [49]

85-03b **J Mollerup and P Angelo**
Measurement and Correlation of the Volumetric Properties of a Synthetic Natural Gas Mixture
Fluid Phase Equilibria 19 (3) 259-271 (1985)

D-56 [133] (CH_4+C_2H_6+C_3H_8+N_2) mixture A
D-57 [47] (CH_4+C_2H_6+C_3H_8+N_2) mixture B

85-04d **J W Magee, A G Pollin, R J Martin and R Kobayashi**
Burnett-Isochoric *P-V-T* Measurements of a Nominal 20 Mol% Hydrogen - 80 Mol% Methane Mixture at Elevated Temperatures and Pressures
Fluid Phase Equilibria 22 (2) 155-173 (1985)

B15 data : 119 points (20% H_2) poor quality, not used

85-05d **H M Hinze and M Jaeschke**
Messung der Dichte von Erdgasen nach der Wägemethode und mit Betriebsdichte-aufnehmern
Fortschritt-Berichte VDI series 6 no 162 (1985)

A1 data (and others) : presumably same as 90-02 and 90-03

84-01a **M Jaeschke and H P Jülicher**
Real Gas Behaviour of Natural Gases
Brennst-Wärme-Kraft 36 (11) 445-451 (1984)

A1-1	19	
D-15	18	simulated Russian UdSSR gas
D data :	18	points simulated Ekofisk gas not used
N-1	18	Ekofisk gas (Krummhörn)
N-2	18	Russian UdSSR gas
N-3	18	TENP gas
N-4	18	Epe gas
N-5	24	H-Gas + coke-oven gas (Paffrath)
N-6	24	H-Gas + coke-oven gas (Paffrath)
N-7	24	L-Gas + coke-oven gas (Paffrath)
N-8	23	L-Gas + coke-oven gas (Paffrath)

84-02d **W Blanke and R Weiß**
Thermisches Zustandverhalten von Erdgas mit hohem Brennwert
Brennst-Wärme-Kraft 36 (11) 452-456 (1984)

A1 data : not used (see 88-01)
Also Ekofisk gas

84-03d **R T Ellington, K E Starling, K H Kumar, V Oswal, T Pham, J Zakaria, M Hill and S Narayanan**
Measurement of Gas Compressibility Factor Data for Natural Gas and Synthetic Gas Components and Their Mixtures
GRI Report No 84/0095 (May 1984)

A1, A3, B12 and B13 data : not used (preliminary data?)

83-01d **L Rosenkilde and M Tambo**
Calibration and Examination of Gas Density Meters
Dantest report TR 133/360.81.368 (Jun 1983)

A1 data : 9 points not used (0.18% C_2H_4 impurity)
B12 data : 8 points (22% N_2) not used
B14 data : 8 points (2% C_2H_6) not used
B14 data : 8 points (4% C_2H_6) not used
B14 data : 8 points (6% C_2H_6) not used
B14 data : 8 points (8% C_2H_6) not used
D data : 8 points simulated Danish natural gas not used
D data : 5 points simulated Tyra (Danish sector) gas
D data : 5 points simulated Ekofisk gas not used

83-02d **R D Goodwin**
Carbon Monoxide Compressibility Data from 100 to 300 K; Derived Virial Coefficients, Orthobaric Densities, and Heats of Vaporization
Cryogenics 23 (8) 403-414 (1983)

A7 data : unchecked

82-01a **H J Achtermann, F Klobasa and H Rögener**
Realfaktoren von Erdgasen Teil I : Bestimmung von Realgasfaktoren aus Brechungsindex-Messungen
Brennst-Wärme-Kraft 34 (5) 266-271 (1982)

A1-3 71
N-13 74 Russian UdSSR gas
N-14 74 Ekofisk gas (Krummhörn)
N-15 73 TENP gas
N-16 74 Epe gas

82-02a **H J Achtermann, F Klobasa and H Rögener**
Realgasfaktoren von Erdgasen Teil II : Messungen mit einer Verbesserten Burnett-Apparatur
Brennst-Wärme-Krafte 34 (5) 311-314 (1982)

A1-2 68
N-9 67 Russian UdSSR gas
N-10 68 Ekofisk gas
N-11 69 TENP gas
N-12 69 Epe gas

82-03b **R H P Thomas and R H Harrison**
Pressure-Volume-Temperature Relations of Propane
J Chem Eng Data 27 (1) 1-11 (1982)

A6-1 [358] includes many points in the critical region

81-01a **H J Achtermann, F Klobasa and H Rögener**
Unpublished? (Univ Hannover internal report (1981))

N-17 76 Russian UdSSR gas via Austria to Waidhaus (FRG)
N-18 68 Ekofisk (Norwegian sector) to Emden-Krummhörn
N-19 73 TENP (Slochteren-Ekofisk) gas
N-20 77 Epe (Slochteren-Ekofisk) salt-cavern gas

81-02d **H Mansoorian, K R Hall, J C Holste and P T Eubank**
The Density of Gaseous Ethane and Fluid Methyl Chloride, and the Vapor Pressure of Methyl Chloride
J Chem Thermo 13 (11) 1001-1024 (1981)

A4 data : 65 points within range, presumably same as 77-04

80-01d **G C Straty and D E Diller**
(p,V,T) of Saturated and Compressed Fluid Nitrogen
J Chem Thermo 12 (10) 927-936 (1980)

A2 data : 39 points within range

80-02d **G C Straty and D E Diller**
(p,V,T) of Compressed and Liquefied (Nitrogen + Methane)
J Chem Thermo 12 (10) 937-953 (1980)

B12 data : 67+29+35 points for 3 compositions within range

80-03d **G C Straty, D E Diller and R D McCarty**
PVTx Properties and Equation of State for Compressed and Liquefied Nitrogen-Methane Mixtures
EFCE Pub Ser 11 (Phase Equilibria Fluid Props Chem Ind) 18-23 (1980)

B12 data : presumably same as 80-02

79-01a **N J Trappeniers, T Wassenaar and J C Abels**
Isotherms and Thermodynamic Properties of Methane at Temperatures between 0 and 150 C and at Densities up to 570 Amagat
Physica A 98 (1-2) 289-297 (1979)

A1-6 119 [167]

78-01d **D D Dillard, M Waxman and R L Robinson jr**
Volumetric Data and Virial Coefficients for Helium, Krypton and Helium-Krypton Mixtures
J Chem Eng Data 23 (4) 269-274 (1978)

A9 data : not used (see GERG TM2)

78-02d **J G Young**
MS Thesis, Texas A+M Univ (1978)

A4 data : unchecked

78-03d **H Mansoorian**
Pressure-Volume-Temperature Relations of Ethane, of Methyl Chloride and of the Equimolar Mixture Using the Burnett Isochoric Method
Thesis, Texas A+M Univ (1978) 209 pp

Presumably same data as in 77-04

77-01d **R Simon, C J Fesmire, R M Dicharry and F H Vorhis**
Compressibility Factors for CO_2-Methane Mixtures
J Petrol Technol 29 (1) 81-85 (1977)

D data : 60 points (90% CO_2) no accuracy statement

77-02d **R L Mills, D H Liebenberg, J C Bronson and L C Schmidt**
Equation of State of Fluid n-Hydrogen from *P-V-T* and Sound

Velocity Measurements to 20 kbar
J Chem Phys 66 (7) 3076-3084 (1977)

A5 data : not used (see GERG TM2)

77-03d **S Mihara, H Sagara, Y Arai and S Saito**
The Compressibility Factors of Hydrogen-Methane, Hydrogen-Ethane and Hydrogen-Propane Gaseous Mixtures
J Chem Eng Japan 10 (5) 395-399 (1977)

A1 data : not used (see 88-01)
B15 data : not used (see GERG TM2)
B45 data : unchecked
B56 data : unchecked

77-04d **H Mansoorian, K R Hall and P T Eubank**
Vapor Pressure and *PVT* Measurements Using the Burnett-Isochoric Method
Proc 7th Symp Thermophys Props (ASME, New York) 456-460 (1977)

A4 data : unchecked

76-01d **G C Straty and R Tsumura**
PVT and Vapor Pressure Measurements on Ethane
J Res NBS 80A (1) 35-39 (1976)

A4 data : not used (see GERG TM2)

76-02d **N E Khazanova, E E Sominskaya, A V Zakharova and M B Rozovskii**
Thermodynamic Properties of the Ethane-Carbon Dioxide System and the Pressure-Volume-Temperature-Normality Data
Teplofiz Svoistva Veshchestv i Materialov (10) 213-219 (1976)

B34 data : not used (see GERG TM2)

76-03d **A K Pal, G A Pope, Y Arai, N F Carnahan and R Kobayashi**
Experimental Pressure-Volume-Temperature Relations for Saturated and Compressed Fluid Ethane
J Chem Eng Data 21 (4) 394-397 (1976)

A4 data : several dense gas points but mainly liquid

75-01d **S L Rivkin**
Experimental Investigations of the Compressibility of Gases; Nitrogen and Nitrogen-and-Carbon Dioxide Mixtures
Thermophysical Properties of Matter and Substances (Moscow, ed V A Rabinovich) 8 190-209 (1975)

A2 data : not used (see 88-03)
B23 data : unchecked

74-01d **R D Goodwin**
The Thermophysical Properties of Methane, from 90 to 500°K at Pressures to 700 bar
NBS Tech Note 653, 274 pp (Boulder, 1974)

A1 data : probable systematic error (see 88-01)

74-02d **D S Rasskazov, E K Petrov, G A Spiridonov and E R Ushmaikin**
Pressure-Volume-Temperature Dependence of Carbon Dioxide in the 248-303°K and 5-60 bar Ranges
Teploenergetika 21 (1) 80-82 (1974)

A3 data : unchecked

73-01a **D R Douslin and R H Harrison**
Pressure, Volume, Temperature Relations of Ethane
J Chem Thermo 5 (4) 491-512 (1973)

A4-2 18 (many more data points available)

73-02d **M Waxman, H A Davis and J R Hastings**
Determination of the Second Virial Coefficient of Carbon Dioxide at Temperatures between 0° and 150°, and an Evaluation of Its Reliability
Proc 6th Symp Thermophys Props, Atlanta (ASME, New York) 245-255 (1973)

A3 data : presumably same as 71-02

72-01a **D R Roe**
Thermodynamic Properties of Gases and Gas Mixtures at Low Temperatures and High Pressures
PhD Thesis, Imperial College, Univ London (1972) 328 pp

A1-4	7	[33]	
A2-2	12	[46]	
B12-1	7	[17]	52% N_2
B12-2	7	[16]	28% N_2
D-1	7	[17]	
N-21	12		Hewett-Lower Bunter (southern North Sea)
N-22	15		Bacton feeder 4 gas (air contaminated)

72-02d **E P Kholodov, N I Timoshenko and A L Yamnov**
Determination of the Density and Polarizability of Carbon Dioxide based on Refractive Index Experimental Data
Teploenergetika 19 (3) 84-85 (1972)

A3 data : not used (see 90-10)

72-03d **G A Pope**
Calculation of Argon, Methane and Ethane Virial Coefficients at Low Reduced Temperature Based on Data Obtained from Isochorically Coupled Burnett Experiments
Thesis, Rice Univ, Houston (1972) 228 pp

A1,A4 data : unchecked

72-04d **E P Kholodov, N I Timoshenko and A L Yamnov**
Compressibility of Gaseous Carbon Dioxide in the 243.15 - 283.15°K Range to Saturation Pressure Studied from Measurements of the Refractive Index
Teploenergetika 19 (4) 84-86 (1972)

A3 data : unchecked

72-05d **J M H Levelt-Sengers and W T Chen**
Vapor Pressure, Critical Isochore, and Some Metastable States of Carbon Dioxide
J Chem Phys 56 (1) 595-608 (1972)

A3 data : critical region only; not used

71-01d **Y Arai, G Kaminishi and S Saito**
Experimental Determination of the *P-V-T-X* Relations for the Carbon Dioxide-Nitrogen and Carbon Dioxide-Methane Systems
J Chem Eng Japan 4 (2) 113-122 (1971)

B13 data : not used (see GERG TM2)
B23 data : unchecked

71-02d **M Waxman and J R Hastings**
Burnett Apparatus for the Accurate Determination of Gas Compressibility Factors and Second Virial Coefficients, and an Evaluation of Its Capability Based on Some Results for Argon and Carbon Dioxide
J Res NBS C 75 (3-4) 165-176 (1971)

A3 data : unchecked

71-03d **V M Miniovich and G A Sorina**
The *p-v-T-N* Relation in Dilute Solutions of Propane in Ethane near the Critical Point of Ethane I. *p-v-T* Relation of Ethane near its Critical Point
Zh Fiz Khim 45 (3) 552-555 (1971)

A4 data : unchecked

70-01d **A J Vennix, T W Leland jr and R Kobayashi**
Low-Temperature Volumetric Properties of Methane
J Chem Eng Data 15 (2) 238-243 (1970)

A1 data : 118 points within range; not used

70-02d **R C Lee and W C Edmister**
Compressibilities and Virial Coefficients for Methane, Ethylene and their Mixtures
AIChE J 16 (6) 1047-1054 (1970)

A1 data : not used (see GERG TM2)

70-03d **A L Blancett, K R Hall and F B Canfield**
Isotherms for the Helium-Argon System at 50°, 0° and -50° up to 700 Atm
Physica 47 (11) 75-91 (1970)

A9 data : not used (see GERG TM2)

70-04d **M P Vukalovich, N I Timoshenko and V P Kobelev**
Experimental Investigation of Carbon Dioxide Density at Temperatures below 0°C
Teploenergetika 17 (12) 59-60 (1970)

A3 data : unchecked

70-05d **V A Kirillin, S A Ulybin and E P Zherdev**
Carbon Dioxide Density in the -50 to +200° Range at up to 500 bars
Teplofiz Svoistva Gazov, Mater Vses Teplofiz Konf Svoistvam Veshchestv Vys Temp 3rd (1968, pub 1970) 136-141

A3 data : presumably same as 69-02

70-06d **V A Kirillin, S A Ulybin and E P Zherdev**
Experimental Determination of the Density of Carbon Dioxide at 0 to -50° and <500 bars
Teploenergetika 17 (5) 69-70 (1970)

A3 data : unchecked

70-07d **T C Briggs**
Compressibility Data for Helium over the Temperature Range -5° to 80°C and at Pressures to 800 Atmospheres
USBM Report No 7352 (1970) 39 pp

A9 data : unchecked

69-01d **R C Lee**
Compressibility Factors and Virial Coefficients for Methane, Ethylene, and their Mixtures Using an Isothermal Expansion Ratio Apparatus
Thesis, Oklahoma Univ (1969) 226 pp

A1 data : presumably same as 70-02

69-02d **V A Kirillin, S A Ulybin and E P Zherdev**
Experimental Investigation of Carbon Dioxide Density at Temperatures from -50 to 200°C and Pressures to 500 bar
Proc Int Conf Calorimetry and Thermodynamics, Warsaw (1969)

A3 data : unchecked

69-03d **H G McMath jr and W C Edmister**
Experimental Determination of the Volumetric Properties and Virial Coefficients of the Methane-Ethylene System
AIChE J 15 (3) 370-378 (1969)

A1 data : unchecked

69-04d **V N Popov and V I Chernyshev**
Experimental Determination of the Compressibility of Nitrogen-Helium Mixtures
Teploenergetika 16 (2) 82-84 (1969)

B29 data : presumably same as 68-02 and 68-03

69-05d **P Sliwinski**
Lorentz-Lorenz Function of Gaseous and Liquid Ethane, Propane and Butane
Z Phys Chem (Frankfurt) 63 (5-6) 263-279 (1969)

A4,A6,A8 data : vapour density at saturation; not used

69-06d **V A Kirillin, S A Ulybin and E P Zherdev**
Carbon Dioxide Density on the 35, 30, 20 and 10° Isotherms and at Pressures up to 500 bars
Teploenergetika 16 (6) 92-93 (1969)

A3 data : unchecked

69-07d **T C Briggs, D J Dalton and R E Barieau**
Compressibility Data for Helium at 0° and Pressures to 800 Atmospheres
USBM Report No 7287 (1969) 54 pp

A9 data : unchecked

69-08d **H Beer**
Compressibility Factors for the Argon-Carbon Dioxide System
Canad J Chem Eng 47 (1) 92-94 (1969)

B13 data : same as 59-04; poor accuracy

68-01d **M P Vukalovich, V P Kobelev and N I Timoshenko**
Density of Carbon Dioxide at 0-35° and up to 300 bars
Teploenergetika 15 (4) 81-83 (1968)

A3 data : unchecked

68-02d **V N Popov and V I Chernyshev**
Experimental Study of the Compressibility of Helium-Nitrogen Mixtures I
Izv Akad Nauk SSSR, Energ Transp (4) 148-157 (1968)

B29 data : unchecked

68-03d **V N Popov and V I Chernyshev**
Experimental Study of the Compressibility of Helium-Nitrogen Mixtures II
Izv Akad Nauk SSSR, Energ Transp (5) 112-117 (1968)

B29 data : unchecked

67-01d **Peh Sun Ku and B F Dodge**
Compressibility of the Binary Systems: Helium-Nitrogen and Carbon Dioxide-Ethylene
J Chem Eng Data 12 (2) 158-164 (1967)

A2 data : 29 points within range; not used
A3 data : 13 points within range; not used
A9 data : 30 points within range; not used
B29 data : 94 points for 7 compositions within range

67-02d **A Sass, B F Dodge and R H Bretton**
Compressibility of Gas Mixtures. Carbon Dioxide-Ethylene System
J Chem Eng Data 12 (2) 168-176 (1967)

A3 data : not used (see GERG TM2)

67-03d **D R Douslin, R H Harrison and R T Moore**
Pressure-Volume-Temperature Relations in the System Methane-Tetrafluoromethane I. Gas Densities and the Principle of Corresponding States
J Phys Chem 71 (11) 3477-3488 (1967)

A1 data : same as 64-01

67-04d **A E Jones and W B Kay**
The Phase and Volumetric Relations in the Helium-n-Butane System Part II. Second Virial Coefficients for Helium-n-Butane Mixtures
AIChE J 13 (4) 720-725 (1967)

A8 data : data deposited at Library of Congress; not used
B89 data : data deposited at Library of Congress; not used

67-05d **H G McMath jr**
Volumetric Properties and Virial Coefficients of the Methane-Ethylene System, Using the Technique of Isochoric Changes of Pressure with Temperature
Thesis, Oklahoma Univ (1967) 247 pp

A1 data : presumably same as 69-03

66-01a **R W Crain jr and R E Sonntag**
The *P-V-T* Behavior of Nitrogen, Argon and their Mixtures
Adv Cryogen Eng 11 379-391 (1966)

A2-3 17 [5]

66-02d **A L Blancett**
Volumetric Behavior of Helium-Argon Mixtures at High Pressure and Moderate Temperature
Thesis, Univ Oklahoma (1966) 228 pp

A9 data : presumably same as 70-03

66-03d **R W Crain jr**
P-V-T Behavior in the Argon-Nitrogen System
Thesis, Univ Michigan (1966) 213 pp

A2 data : presumably same as 66-01

66-04d **N N Kalfoglou**
Compressibility Factor Measurements of Gas Mixtures at Temperatures where Repulsive Forces Play a Significant Role
Thesis, Univ Pennsylvania (1966) 149 pp

A9 data : unchecked

65-01a **A E Hoover**
Virial Coefficients of Methane and Ethane
PhD Thesis, Rice Univ, Houston, Texas (1965) 192 pp

A1-5 14

A4 data : unchecked
B14 data : not used (see GERG TM2)

65-02d **L Deffet and F Ficks**
Compressibility and Fugacity of Methane up to 3000 Atmospheres and 150°
Proc 3rd Symp Thermophys Props (Lafayette, Indiana) Advances in Thermophysical Properties at Extreme Temperatures and Pressures (ASME, New York) 107-113 (1965)

A1 data : presumably same as 64-02

65-03d **F B Canfield, T W Leland and R Kobayashi**
Compressibility Factors for Helium-Nitrogen Mixtures
J Chem Eng Data 10 (2) 92-96 (1965)

A2 data : 52 points within range; not used
A9 data : 51 points within range; not used
B29 data : 309 points for 6 compositions; not used

65-04d **A J Vennix**
Low Temperature Volumetric Properties and the Development of an Equation of State for Methane
Thesis, Rice Univ, Houston, Texas (1965) 173 pp

A1 data : presumably same as 70-01

64-01a **D R Douslin, R H Harrison, R T Moore and J P McCullough**
P-V-T Relations for Methane
J Chem Eng Data 9 (3) 358-363 (1964)

A1-8 45 [126]

64-02d **L Deffet, L Liliane and F Ficks**
The Compressibility of Methane up to 3000 kg/cm^2 and 150°C
Ind Chim Belge 29 (9) 879-888 (1964)

A1 data : unchecked

63-01d **F B Canfield, T W Leland jr and R Kobayashi**
Volumetric Behavior of Gas Mixtures at Low Temperatures by the Burnett Method: Helium-Nitrogen System, 0 to -140°
Adv Cryogen Eng 8 146-157 (1963)

A2 data : not used (see GERG TM2 and 88-03)

63-02d **J G Hust and R B Stewart**
Thermodynamic Property Values for Gaseous and Liquid Carbon Monoxide from 70 to 300°K with Pressures to 300 Atmospheres
NBS Tech Note No 202 (1963) 113 pp

A7 data : not used (see GERG TM2)

63-03d **C W Solbrig and R T Ellington**
The *P-V-T* Behavior of Hydrogen-Methane and Hydrogen-Ethane Mixtures
Chem Eng Prog, Symp Ser 59 (44) 127-136 (1963)

B15 data : not used (see GERG TM2)
B45 data : unchecked

63-04d M P Vukalovich, V V Altunin and N I Timoshenko
Experimental Determination of Specific Volumes of Carbon Dioxide at Temperatures of 40-150° and under Pressures up to 600 kg/sq cm
Teploenergetika <u>10</u> (1) 85-88 (1963)

A3 data : unchecked

62-01d D R Douslin
Pressure-Volume-Temperature Relations and Intermolecular Potentials for Methane and Tetrafluoromethane
Progress in International Research on Thermodynamic and Transport Properties (eds J F Masi and D H Tsai)
Proc 2nd Symp Thermophysical Props (ASME, New York) 135-146 (1962)

A1 data : 34 points; presumably subset of 64-01

61-01d D McA Mason and B E Eakin
Calculation of Heating Value and Specific Gravity of Fuel Gases
IGT Research Bulletin No 32 (Dec 1961) 18 pp

A8 data : 1 point for the n-isomer; not used
A8 data : 1 point for the i-isomer; not used
B12 data : 1 point (50% N_2) not used
B12 data : 1 point (51% N_2) not used
B13 data : 1 point (50% CO_2) not used
B13 data : 1 point (49% CO_2) not used
B14 data : 1 point (49% C_2H_6) not used
B14 data : 1 point (49% C_2H_6) not used
B15 data : 1 point (50% H_2) not used
B15 data : 1 point (50% H_2) not used
B16 data : 1 point (50% C_3H_8) not used
B16 data : 1 point (50% C_3H_8) not used
B17 data : 1 point (50% CO) not used
B17 data : 1 point (50% CO) not used
B18 data : 1 point (51% $i-C_4H_{10}$) not used
B18 data : 1 point (50% $i-C_4H_{10}$) not used
B18 data : 1 point (28% $n-C_4H_{10}$) not used
B18 data : 1 point (25% $n-C_4H_{10}$) not used
B18 data : 1 point (25% $n-C_4H_{10}$) not used
B18 data : 1 point (52% $n-C_4H_{10}$) not used
B18 data : 1 point (51% $n-C_4H_{10}$) not used
B18 data : 1 point (76% $n-C_4H_{10}$) not used
B18 data : 1 point (76% $n-C_4H_{10}$) not used
B18 data : 1 point (75% $n-C_4H_{10}$) not used
B110 data : 1 point (40% $i-C_5H_{12}$) not used
B110 data : 1 point (40% $i-C_5H_{12}$) not used
B110 data : 1 point (41% $n-C_5H_{12}$) not used
B110 data : 1 point (40% $n-C_5H_{12}$) not used
B110 data : 1 point (40% $n-C_5H_{12}$) not used
B23 data : 1 point (50% CO_2) not used
B23 data : 1 point (50% CO_2) not used
B24 data : 1 point (50% C_2H_6) not used

B24 data : 1 point (50% C_2H_6) not used
B26 data : 1 point (52% C_3H_8) not used
B26 data : 1 point (50% C_3H_8) not used
B28 data : 1 point (50% n-C_4H_{10}) not used
B28 data : 1 point (51% n-C_4H_{10}) not used
B34 data : 1 point (51% C_2H_6) not used
B34 data : 1 point (51% C_2H_6) not used
B36 data : 1 point (51% C_3H_8) not used
B36 data : 1 point (50% C_3H_8) not used
B38 data : 1 point (25% n-C_4H_{10}) not used
B38 data : 1 point (51% n-C_4H_{10}) not used
B38 data : 1 point (50% n-C_4H_{10}) not used
B38 data : 1 point (75% n-C_4H_{10}) not used
B45 data : 1 point (51% H_2) not used
B45 data : 1 point (51% H_2) not used
B46 data : 1 point (49% C_3H_8) not used
B46 data : 1 point (50% C_3H_8) not used
B48 data : 1 point (50% n-C_4H_{10}) not used
B48 data : 1 point (50% n-C_4H_{10}) not used
B56 data : 1 point (49% C_3H_8) not used
B56 data : 1 point (50% C_3H_8) not used
B58 data : 1 point (72% n-C_4H_{10}) not used
B58 data : 1 point (51% n-C_4H_{10}) not used
B58 data : 1 point (50% n-C_4H_{10}) not used
B58 data : 1 point (24% n-C_4H_{10}) not used
B510 data : 1 point (36% n-C_5H_{12}) not used
B510 data : 1 point (35% n-C_5H_{12}) not used
B68 data : 1 point (50% n-C_4H_{10}) not used
B68 data : 1 point (50% n-C_4H_{10}) not used

61-02d **D McA Mason and B E Eakin**
Compressibility Factor of Fuel Gases at 60°F and 1 Atm
J Chem Eng Data 6 (4) 499-504 (1961)

Same data as 61-01

61-03d **W H Mueller, T W Leland jr and R Kobayashi**
Volumetric Properties of Gas Mixtures at Low Temperatures and High Pressures by the Burnett Method : the Hydrogen-Methane System
AIChE J 7 (2) 267-272 (1961)

A1 data : not used (see GERG TM2)
B15 data : 4 compositions; not used (see GERG TM2)

61-04d **K Date, G Kobuya and H Iwasaki**
Proc Chem Res Inst Non-Aqueous Solutions 10 67-.. (1961)

A1 data : unchecked

61-05d **J E Miller, L W Brandt and L Stroud**
Compressibility Factors for Helium and Helium-Nitrogen Mixtures
USBM Report No 5845 (1961) 11 pp

A9 data : presumably same as 60-03
B29 data : presumably same as 60-02

60-01d **D White, T Rubin, P Camky and H L Johnston**
The Virial Coefficients of Helium from 20 to 300°K
J Phys Chem 64 (11) 1607-1612 (1960)

A9 data : 18 points in range along 3 isotherms; not used

60-02d **J E Miller, L Stroud and L W Brandt**
Compressibility of Helium-Nitrogen Mixtures
J Chem Eng Data 5 (1) 6-9 (1960)

B29 data : 15 compositions; unchecked

60-03d **L Stroud, J E Miller and L W Brandt**
Compressibility of Helium at -10° to 130°F and Pressures to 4000 PSIA
J Chem Eng Data 5 (1) 51-52 (1960)

A9 data : not used (see GERG TM2)

59-01a **A Michels, W de Graaff, T Wassenaar, J M H Levelt and P Louwerse**
Compressibility Isotherms of Hydrogen and Deuterium at Temperatures between -175°C and +150°C (at Densities up to 960 Amagat)
Physica 25 25-42 (1959)

A5-1 15 [11] (207 more data points available)

59-02d **I H Silberberg, J J McKetta and K A Kobe**
Compressibility of Isopentane with the Burnett Apparatus
J Chem Eng Data 4 (4) 323-329 (1959)

A10 data : 20 points below 4 bar; not used

59-03d **D L Timrot and N V Pavlovich**
Thermodynamic Properties of Methane at Low Temperatures and High Pressures
Nauch Doklady Vysshei Shkoly, Energet 1959 No 1 137-148

A1 data : unchecked

59-04d **H Beer**
Chem-Ing-Tech 31 784-... (1959)

B13 data : unchecked

59-05d **J Gapp**
Uber die Abweichung realer Gase und Gasgemische vom idealen Gasgesetz und deren Auswirkung auf die Gasdichte, die Gleichgewichtskonstanten und die Verbrennungsrechnung
Dissertation Aachen T H (1959)

B15, B17, B35, B37 data : unchecked

58-01a **H W Schamp jr, E A Mason, A C B Richardson and A Altman**
Compressibility and Intermolecular Forces in Gases: Methane
Phys Fluids 1 (4) 329-337 (1958)

A1-7 45 [23]

58-02d **N V Pavlovich and D L Timrot**
The Experimental Investigation of *pvT* Data of Gaseous and Liquid Methane
Teploenergetika 4 ...-... (1958)

A1 data : unchecked

58-03d **R D Gunn**
MS Thesis, Univ California, Berkeley (1958)

B23 data : unchecked

58-04d **I H Silberberg**
Compressibility of Gaseous Isopentane
Thesis, Univ Texas, Austin (1958) 303 pp

A10 data : presumably same as 59-02; not used

58-05d **J R Saurel**
Determination of the Equations of State of Compressed Gases at Elevated Temperatures. Application to the Study of Nitrogen to 1000 kg/sq cm and 1000°
J Res CNRS (Lab Bellevue, Paris) No 42 21-60 (1958)

A2 data : unchecked

56-01d **P W Townsend**
Pressure-Volume-Temperature Relations of Binary Gaseous Mixtures
PhD Dissertation, Columbia Univ, New York (1956) 409 pp

Includes A2 data : 34 points not used (see 88-03)

56-02d **R H Wentdorf jr**
Isotherms in the Critical Regions of Carbon Dioxide and Sulfur Hexafluoride
J Chem Phys 24 (3) 607-615 (1956)

A3 data : critical region only; not used

56-03d **R C Harper jr**
An Investigation of the Compressibility Factors of Gaseous Mixtures of Carbon Dioxide and Helium
PhD Dissertation, Univ Pennsylvania, Philadelphia (1956) 52 pp

B39 data : unchecked

55-01d **B E Eakin, R T Ellington and D C Gami**
Physical-Chemical Properties of Ethane-Nitrogen Mixtures
IGT Research Bulletin No 26 (Jul 1955)

B24 data : unchecked

54-01a **A Michels, W van Straaten and J Dawson**
Isotherms and Thermodynamic Functions of Ethane at Temperatures between 0° and 150°C and at Pressures up to

200 Atm
Physica 20 17-23 (1954)

A4-1 33 [34]

54-02d G C Kennedy
Pressure-Volume-Temperature Relations in Carbon Dioxide at Elevated Temperatures and Pressures
Amer J Sci 252 225-241 (1954)

A3 data : unchecked

53-01d O T Bloomer, D C Gami and J D Parent
Physical-Chemical Properties of Methane-Ethane Mixtures
IGT Research Bulletin No 22 (Jul 1953) 39 pp

B14 data : 4 mixtures; unchecked

53-02d D Cook
The Carbon Dioxide - Nitrous Oxide System in the Critical Region
Proc Roy Soc A219 (1137) 245-256 (1953)

A3 data : 6 points on the vapour pressure line; not used

52-01a A Michels, J M Lupton, T Wassenaar and W de Graaff
Isotherms of Carbon Monoxide between 0° and 150° and at Pressures up to 3000 Atmospheres
Physica 18 121-127 (1952)

A7-1 15 [5]

52-02d H H Reamer, F T Selleck, B H Sage and W N Lacey
Phase Equilibria in Hydrocarbon Systems. Volumetric Behavior of the Nitrogen-Ethane System
Ind Eng Chem 44 (1) 198-201 (1952)

B24 data : not used (see GERG TM2)

52-03d I H Silberberg, P K Kuo and J J McKetta jr
Investigations with Gas Density Balance II. Compressibility Isotherms of Methane, Ethane, Propane and n-Butane at Low Pressures
Petrol Eng 24 C9-10, 13-14, 15-20 (1952)

A1 data : unchecked
A4 data : unchecked
A6 data : unchecked
A8 data : unchecked

51-01d O T Bloomer
Bean and Burnett Apparatus for Measuring Gas Law Deviation Factors
Proc Amer Gas Assoc 33 476-488 (1951)

A2 and N data : unchecked

50-01d **G A Bottomley, D S Massie and R Whytlaw-Gray**
A Comparison of the Compressibilities of Some Gases with that of Nitrogen at Pressures below One Atmosphere
Proc Roy Soc A200 (1061) 201-218 (1950)

A3, A6 and A7 data : not used

50-02d **H L Johnston and D White**
Pressure-Volume-Temperature Relationships of Gaseous Normal Hydrogen from its Boiling Point to Room Temperature and from 0 to 1000 Atmospheres
Trans ASME 72 785-787 (1950)

A5 data : not used (see GERG TM2)

50-03d **H H Reamer, B H Sage and W N Lacey**
Phase Equilibria in Hydrocarbon Systems. Volumetric and Phase Behavior of the Methane-Propane System
Ind Eng Chem 42 (3) 534-539 (1950)

B16 data : 4 compositions but raw data not given

50-04d **A S Friedman**
Pressure-Volume-Temperature Relationships of Gaseous Hydrogen, Nitrogen and a Hydrogen-Nitrogen Mixture
PhD Dissertation, Univ Ohio (1950)

A2 data : not used (see 88-03)
A5 data : unchecked
B25 data : unchecked

50-05d **H L Johnston, I J Bezmann, T Rubin, L Jensen, D White and A S Friedman**
Gaseous Data of State for Hydrogen between 1 and 200 Atmospheres from 20 to 300°K
Phys Rev 79 235 (1950)

A5 data : unchecked

49-01d **W G Schneider**
Compressibility of Gases at High Temperatures I. Methods of Measurement and Apparatus
Canad J Res 27B 339-352 (1949)

A9 data : preliminary data only; not used

49-02d **R H Olds, H H Reamer, B H Sage and W N Lacey**
Phase Equilibria in Hydrocarbon Systems IL. The n-Butane-Carbon Dioxide System
Ind Eng Chem 41 (3) 475-482 (1949)

B38 data : 5 compositions; not used

49-03d **H H Reamer, B H Sage and W N Lacey**
Phase Equilibria in Hydrocarbon Systems L. Volumetric Behavior of Propane
Ind Eng Chem 41 (3) 482-484 (1949)

A6 data : unchecked

49-04d **B J Cherney, H Marchman and R York jr**
Equipment for Compressibility Measurements. Data on Propane
Ind Eng Chem 41 (11) 2653-2658 (1949)

A6 data : unchecked

49-05a **A Michels and T Wassenaar**
Isotherms of a Nitrogen-Hydrogen Mixture between 0°C and 150°C up to 340 Atmospheres
Appl Sci Res 1A 258-262 (1949)

B25-8 37 (more data points available?) 75% H_2

49-06d **F L Casado, D S Massie and R Whytlaw-Gray**
The Molecular Weight and Limiting Density of Propane
J Chem Soc 1746-1752 (1949)

A6 data : not used

49-07d **D S Massie and R Whytlaw-Gray**
The Normal Density of Propane and its Expansion Coefficients between 0° and 20°
J Chem Soc 2874-2877 (1949)

A6 data : not used

48-01d **B H Sage, R H Olds and W N Lacey**
Two Gaseous Mixtures Containing Hydrogen and Nitrogen: Thermodynamic Properties
Ind Eng Chem 40 (8) 1453-1459 (1948)

D data : CH_4-N_2-CO_2-H_2-CO mixture with 61% H_2; not used

47-01d **H H Reamer, K J Korpi, B H Sage and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XLVIII. Volumetric Behavior of Methane-n-Butane System at Higher Pressures
Ind Eng Chem 39 (2) 206-209 (1942)

B18 data : unchecked

45-01d **H H Reamer, R H Olds, B H Sage and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XLV. Volumetric Behavior of Ethane-Carbon Dioxide System
Ind Eng Chem 37 (7) 688-691 (1945)
Fundamental Research on Occurrence and Recovery of Petroleum 18-24 (1944-5); API, New York (1946)

B34 data : 5 compositions; not used (see GERG TM2)

44-01d **H H Reamer, R H Olds, B H Sage and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XLI. Methane-Carbon Dioxide System in the Gaseous Region
Ind Eng Chem 36 (1) 88-90 (1944)
Fundamental Research on Occurrence and Recovery of Petroleum 33-36 (1943); API, New York (1944)

A3 data : not used (see GERG TM2)

B13 data : 4 compositions; not used (see GERG TM2)

44-02d **R H Olds, H H Reamer, B H Sage and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XLII. Volumetric Behavior of n-Butane
Ind Eng Chem 36 (3) 282-284 (1944)
Fundamental Research on Occurence and Recovery of Petroleum 37-39 (1943); API, New York (1944)

A8 data : unchecked

44-03d **H H Reamer, R H Olds, B H Sage and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XLIV. Volumetric Behavior of Ethane
Ind Eng Chem 36 (10) 956-958 (1944)
Fundamental Research on Occurrence and Recovery of Petroleum 14-17 (1944-5); API, New York (1946)

A4 data : not used (see GERG TM2)

44-04d **R E D Haney and H Bliss**
Compressibilities of Nitrogen-Carbon Dioxide Mixtures
Ind Eng Chem 36 (11) 985-989 (1944)

B23 data : 2 compositions; not used (see GERG TM2)

43-01d **R H Olds, H H Reamer, B H Sage and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XXXIX. Volumetric Behavior of Methane
Ind Eng Chem 35 (8) 922-924 (1943)
Fundamental Research on Occurrence and Recovery of Petroleum 20-23 (1943); API, New York (1944)

A1 data : not used (see GERG TM2)

42-01d **B H Sage and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XXXIII. Thermodynamic Properties of n-Pentane
Ind Eng Chem 34 (6) 730-737 (1942)

A10 data : unchecked

42-02d **W E Vaughan and F C Collins**
P-V-T-x Relations of the System Propane-Isopentane
Ind Eng Chem 34 (7) 885-890 (1942)

B610 data : 5 compositions; not used

42-03d **B H Sage, H H Reamer, R H Olds and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XXXV. Volumetric and Phase Behavior of Methane-n-Pentane System
Ind Eng Chem 34 (9) 1108-1117 (1942)

B110 data : unchecked

41-01d **A Michels and M Goudeket**
Compressibilities of Hydrogen between 0° and 150°C up to 3000 Atmospheres
Physica 8 (3) 347-352 (1941)

A5 data : superseded by values in 59-01; not used

41-02a **A Michels and H Wouters**
Isotherms of Helium between 0° and 150° up to 200 Amagat
Physica <u>8</u> (8) 923-932 (1941)

A9-3 15 [5] (99 more data points available)

41-03d **J A Beattie, W H Stockmayer and H G Ingersoll**
The Compressibilities of Gaseous Mixtures of Methane and Normal Butane. The Equation of State for Gas Mixtures
J Chem Phys <u>9</u> (12) 871-874 (1941)

B18 data : 3 compositions; T_{min}= 75 °C, p_{max}= 10 atm

40-01d **I R Krichevskii and V P Markov**
The Compressibility of Gas Mixtures I. The *P-V-T* Data for Binary and Ternary Mixtures of Hydrogen, Nitrogen and Carbon Dioxide
Acta Phys-Chim URSS <u>12</u> 59-66 (1940)

B23 data : 3 compositions; unchecked
B25 data : unchecked
B35 data : not used (see GERG TM2)
C235 data : unchecked

40-02d **W B Kay**
Pressure-Volume-Temperature Relations for n-Butane
Ind Eng Chem <u>32</u> (3) 358-360 (1940)

A8 data : unchecked

40-03d **W W Deschner and G G Brown**
P-V-T Relations for Propane
Ind Eng Chem <u>32</u> (6) 836-840 (1940)

A6 data : poor purity and only smoothed data; not used

40-04d **B A Sage and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XXX. Propane-n-Pentane System
Ind Eng Chem <u>32</u> (7) 992-996 (1940)

B68 data : not used

40-05d **B H Sage, R A Budenholzer and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XXXII. Methane-n-Butane System in the Gaseous and Liquid Regions
Ind Eng Chem <u>32</u> (9) 1262-1277 (1940)

B18 data : unchecked

40-06d **W M Morris, B H Sage and W N Lacey**
Volumetric Behavior of iso-Butane
Trans Amer Inst Mining Met Eng <u>136</u> 158-164 (1940)

A8 data : unchecked

39-01d **B H Sage and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XXVI. The Methane - Ethane System in the Gaseous Region
Ind Eng Chem 31 (12) 1497-1509 (1939)

B14 data : not used (see GERG TM2)

39-02d **A Michels and G W Nederbragt**
Isotherms of Methane-Ethane Mixtures at 0°, 25° and 50°C up to 60 Atmospheres
Physica 6 656-662 (1939)

B14 data : not used (see GERG TM2)

39-03d **J A Beattie, G-J Su and G L Simard**
The Critical Constants of Ethane
J Amer Chem Soc 61 (4) 924-925 (1939)

A4 data : critical region densities; not used

39-04d **J A Beattie, G-J Su and G L Simard**
The Compressibility of Gaseous Ethane in the High Density Region
J Amer Chem Soc 61 (4) 926-927 (1939)

A4 data : extension to 35-01; not used

38-01d **J D Kemp and C J Egan**
Hindered Rotation of the Methyl Groups in Propane. The Heat Capacity, Vapor Pressure, Heats of Fusion and Vaporization of Propane. Entropy and Density of the Gas
J Amer Chem Soc 60 (7) 1521-1525 (1938)

A6 data : one value at 1 atm; not used

38-02d **R Wiebe and V L Gaddy**
The Compressibilities of Hydrogen and of Four Mixtures of Hydrogen and Nitrogen at 0, 25, 50, 100, 200 and 300° and to 1000 Atmospheres
J Amer Chem Soc 60 (10) 2300-2303 (1938)

A5 data : not used (see GERG TM2)
B25 data : not used

38-03d **F W Jessen and J H Lightfoot**
Compressibility of Butane-Pentane Mixtures Below One Atmosphere
Ind Eng Chem 30 (3) 312-314 (1938)

A8 data : not used
A10 data : not used
B810 data : 3 compositions; not used

38-04d **B H Sage and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XXI. Thermodynamic Properties of iso-Butane
Ind Eng Chem 30 (6) 673-681 (1938)

A8 data : unchecked

38-05d **B H Sage and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XXII. Equilibrium Constants for Methane in Several Hydrocarbon Systems
Ind Eng Chem 30 (11) 1296-1304 (1938)

B110 data : unchecked

37-01d **J A Beattie, W C Kay and J Kaminsky**
The Compressibility of and an Equation of State for Gaseous Propane
J Amer Chem Soc 59 (9) 1589-1590 (1937)

A6 data : unchecked

37-02d **A Michels, B Blaisse and C Michels**
The Isotherms of CO_2 in the Neighbourhood of the Critical Point and Around the Coexistence Line
Proc Roy Soc A160 (902) 358-375 (1937)

A3 data : unchecked

37-03d **B H Sage, D C Webster and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XVIII. Thermodynamic Properties of Ethane
Ind Eng Chem 29 (6) 658-666 (1937)

A4 data : not used

37-04d **B H Sage, D C Webster and W N Lacey**
Phase Equilibria in Hydrocarbon Systems XIX. Thermodynamic Properties of n-Butane
Ind Eng Chem 29 (10) 1188-1194 (1937)

A8 data : unchecked

36-01d **A Michels and G W Nederbragt**
Isotherms of Methane between 0 and 150 °C for Densities up to 225 Amagat. Calculated Specific Heat, Energy and Entropy in the Same Region
Physica 3 (7) 569-577 (1936)

A1 data : not used (see GERG TM2 and 88-01)

36-02d **A Michels, H Wouters and J de Boer**
Isotherms of Nitrogen between 200 and 3000 Atm and 0° and 150°C
Physica 3 (7) 585-589 (1936)

A2 data : not used (see GERG TM2)

36-03d **F W Jessen and J H Lightfoot**
Compressibility of Butane-Air Mixtures Below One Atmosphere
Ind Eng Chem 28 (7) 870-871 (1936)

A8 data : 30 °C only; not used

35-01d **J A Beattie, C Hadlock and N Poffenberger**
The Compressibility of and an Equation of State for Gaseous Ethane
J Chem Phys 3 (2) 93-96 (1935)

A4 data : 57 points within range; not used

35-02d **J A Beattie, N Poffenberger and C Hadlock**
The Critical Constants of Propane
J Chem Phys 3 (2) 96-97 (1935)

A4 data : density in critical region

35-03d **A Michels and G W Nederbragt**
Isotherms of Methane between 0° and 150°C and Densities 19 and 53 Amagat (Pressures between 20 and 80 Atm)
Physica 2 1000-1002 (1935)

A1 data : unchecked

35-04a **A Michels and C Michels**
Isotherms of CO_2 between 0° and 150°C and Pressures from 16 to 250 Atm (Amagat Densities 18-206)
Proc Roy Soc A153 (878) 201-214 (1935)

A3-1 55 [16] (119 more data points available)

35-05d **A Michels, C Michels and H Wouters**
Isotherms of CO_2 between 70 and 3000 Atmospheres (Amagat Densities between 200 and 600)
Proc Roy Soc A153 (878) 214-224 (1935)

A3 data : extension to 35-04; 107 points within range

35-06d **B H Sage, W N Lacey and J G Schaafsma**
Phase Equilibria in Hydrocarbon Systems VI. Thermodynamic Properties of Normal Pentane
Ind Eng Chem 27 (1) 48-50 (1935)

A10 data : not used

34-01a **A Michels, H Wouters and J de Boer**
Isotherms of Nitrogen between 0°and 150°C and at Pressures from 20 to 80 Atm
Physica 1 587-594 (1934)

A2-4 24 [18] (more data points available?)

34-02d **J Otto, A Michels and H Wouters**
Uber Isothermen des Stickstoffes zwischen 0° und 150°C bei Drucken bis zu 400 Atmospharen
Phys Zeit 35 97-100 (1934)

A2 data : not used (see GERG TM2)

34-03d **B H Sage, W N Lacey and J G Schaafsma**
Phase Equilibria in Hydrocarbon Systems II. Methane-Propane System
Ind Eng Chem 26 (2) 214-217 (1934)

B16 data : not used (see GERG TM2)

34-04d **B H Sage, J G Schaafsma and W N Lacey**
Phase Equilibria in Hydrocarbon Systems V. Pressure-Volume -Temperature Relations and Thermal Properties of Propane
Ind Eng Chem 26 (11) 1218-1224 (1934)

A6 data : unchecked

34-05d **W N Lacey**
Pressure-Density-Temperature Relations for the Methane - Propane System
Proc Calif Natural Gasoline Assoc 9 (1) 2-7 (1934)
Petrol World (Calif) 31 (3) 41 (1934)

B16 data : presumably same as 34-03

33-01d **W Cawood and H S Patterson**
Compressibilities of Certain Gases at Low Pressures and Various Temperatures
J Chem Soc 136 619-624 (1933)

A3 data : not used (see GERG TM2)

32-01d **A Michels, G P Nijhoff and A J J Gerver**
Isothermal Measurements on Hydrogen, between 0° and 100°C and up to 1000 Atmospheres
Ann Phys 12 562-568 (1932)

A5 data : unchecked

31-01d **D T A Townend and L A Bhatt**
Isotherms of Hydrogen, Carbon Monoxide and their Mixtures
Proc Roy Soc A134 (824) 502-512 (1931)

A5 data : unchecked
A7 data : not used (see GERG TM2)
B57 data : 3 compositions; unchecked

31-02d **H M Kvalnes and V L Gaddy**
The Compressibility Isotherms of Methane at Pressures to 1000 Atmospheres and at Temperatures from -70 to 200°
J Amer Chem Soc 53 (2) 394-399 (1931)

A1 data : not used (see 88-01)

31-03d **R Wiebe, V L Gaddy and C Heins jr**
Compressibility Isotherms of Helium at Temperatures from -70 to 200° and at Pressures to 1000 Atmospheres
J Amer Chem Soc 53 (5) 1721-1725 (1931)

A9 data : not used (see GERG TM2)

31-04d **F Freeth and T T H Verschoyle**
Physical Constants of the System Methane-Hydrogen
Proc Roy Soc A130 (814) 453-463 (1931)

A1 data : unchecked

31-05d **D LeB Cooper and O Maass**
The Density of Carbon Dioxide
Canad J Res 4 283-298 (1931)

A3 data : extension and revision of 30-04; not used

30-01d **E P Bartlett, H C Hetherington, H M Kvalnes and T H Tremearne**
The Compressibility Isotherms of Hydrogen, Nitrogen and a 3:1 Mixture of these Gases at Temperatures of -70, -50, -25 and 20° and at Pressures to 1000 Atmospheres
J Amer Chem Soc 52 (4) 1363-1373 (1930)

A2 data : unchecked
A5 data : unchecked
B25 data : unchecked

30-02d **E P Bartlett, H C Hetherington, H M Kvalnes and T H Tremearne**
The Compressibility Isotherms of Carbon Monoxide at Temperatures from -70° to 200° at Pressures to 1000 Atmospheres
J Amer Chem Soc 52 (4) 1374-1381 (1930)

A7 data : not used (see GERG TM2)

30-03d **D LeB Cooper and O Maass**
Density of Carbon Dioxide
Canad J Res 2 388-395 (1930)

A3 data : low pressure data; not used

30-04d **G P Nijhoff, A J J Gerver and A Michels**
Isotherms of Carbon Dioxide between 0° and 100°C
Proc Acad Sci Amsterdam 33 72-73 (1930)

A3 data : unchecked

30-05d **M Beckers**
Recherches sur l'Équation d'État des Hydrocarbures Facilement Liquéfiables IV. Poids du Litre et Coefficient de Compressibilité du Butane Normal
Bull Soc Chim Belge 39 (11) 470-495 (1930)

A8 data : historical

29-01d **C W Gibby, C C Tanner and I Masson**
The Pressure of Gaseous Mixtures II. Helium and Hydrogen, and their Intermolecular Forces
Proc Roy Soc A122 (789) 283-304 (1929)

A5 data : not used (see GERG TM2)
A9 data : not used
B59 data : several compositions; not used

29-02d **G A Scott**
Isotherms of Hydrogen, Carbon Monoxide and their Mixtures
Proc Roy Soc A125 (797) 330-344 (1929)

A5 data : 18 points at 25 °C; not used
A7 data : 18 points at 25 °C; not used
B57 data : 18 points at 25 °C for 3 mixtures; not used

29-03d **S Goig**
The Compressibility of Carbon Monoxide at 0°C and above 50 Atmospheres
Comptes Rendu Acad Sci 189 246-248 (1929)

A7 data : historical

29-04d **S Goig-Botella**
Compressibility of Carbon Monoxide at 0°C, at Surrounding Temperatures and at Pressures between 50 and 130 Atmospheres
Anales Soc España Fis Quim 27 315-350 (1929)

A7 data : historical

29-05d **G P Nijhoff**
The Second Virial Coefficient of Helium and Hydrogen
Comm Phys Lab Univ Leiden supp 64 17-27 (1929)

A5, A9 data : unchecked

28-01d **G P Nijhoff and W H Keesom**
Comm Phys Lab Univ Leiden 188d,e 31 (1928)

A5 data : not used (see GERG TM2)

28-02d **F G Keyes and H G Burks**
Equation of State for Binary Mixtures of Methane and Nitrogen
J Amer Chem Soc 50 (4) 1100-1106 (1928)

B12 data : 3 compositions; not used

28-03d **E P Bartlett, H L Cupples and T H Tremearne**
The Compressibility Isotherms of Hydrogen, Nitrogen and a 3:1 Mixture of these Gases at Temperatures between 0° and 400° and at Pressures to 1000 Atmospheres
J Amer Chem Soc 50 (5) 1275-1288 (1928)

A2 data : unchecked
A5 data : not used (see GERG TM2)

28-04d **G P Nijhoff and W H Keesom**
Isotherms of Diatomic Gases and their Binary Mixtures XXXIV. Isotherms of Hydrogen at Temperatures of 0° and 100°C
Proc Acad Sci Amsterdam 31 410-412 (1928)

A5 data : presumably same as 27-04

27-01d **E P Bartlett**
The Compressibility Isotherms of Hydrogen, Nitrogen and Mixtures of these Gases at 0° and Pressures up to 1000 Atmospheres

J Amer Chem Soc 49 (3) 687-701 (1927)

A2 data : about ±0.2%; not used
A5 data : about ±0.2%; not used
B25 data : 8 compositions; not used

27-02d **F G Keyes and H G Burks**
The Isometrics of Gaseous Methane
J Amer Chem Soc 49 (6) 1403-1410 (1927)

A1 data : historical

27-03d **E P Bartlett**
The Compressibility Isotherms of Hydrogen, Nitrogen and Mixtures of these Gases at 0° and Pressures up to 1000 Atmospheres (A Correction)
J Amer Chem Soc 49 (8) 1955-1957 (1927)

Correction to 27-01 (due to pressure gauge recalibration)

27-04d **G P Nijhoff and W H Keesom**
Isotherms of Diatomic Gases and their Binary Mixtures XXXIV. Isotherm of Hydrogen at Temperatures from 0° to 100°C
Verslag Akad Wetenschappen Amsterdam 36 1278-1280 (1927)

A5 data : unchecked

27-05d **L van Bogaert**
Recherches sur l'Équation d'État des Hydrocarbures Facilement Liquéfiables I. Le Poids du Litre du Butane Normal
Bull Soc Chim Belge 36 (5) 384-394 (1927)

A8 data : historical

27-06d **M Beckers**
Recherches sur l'Équation d'État des Hydrocarbures Facilement Liquéfiables II. Nouvelle Détermination du Poids du Litre du Butane Normal
Bull Soc Chim Belge 36 (12) 559-590 (1927)

A8 data : historical

26-01d **O Maass and J H Mennie**
Aberrations from the Ideal Gas Laws in Systems of One and Two Components
Proc Roy Soc A110 (753) 198-232 (1926)

A3 data : historical

26-02d **T T H Verschoyle**
Isotherms of Hydrogen, of Nitrogen and of Hydrogen-Nitrogen Mixtures at 0° and 20°C up to a Pressure of 200 Atmospheres
Proc Roy Soc A111 (759) 552-576 (1926)

A2 data : not used (see GERG TM2)
A5 data : unchecked

B25 data : unchecked

26-03d L B Smith and R S Taylor
Correction to the Equation of State for Nitrogen
J Amer Chem Soc 48 (12) 3122-3123 (1926)

A2 data : correction to 23-01

25-01d L Holborn and J Otto
The Isotherms of Various Gases between 400° and -183°
Z Phys 33 1-12 (1925)

A5 data : historical, includes data at -50 °C

24-01d L Holborn and J Otto
The Isotherms of Several Gases up to 400° and their Importance for the Gas Thermometer
Z Phys 23 77-94 (1924)

A2 data : historical

24-02d L Holborn and J Otto
The Isotherms of Helium, Nitrogen and Argon below 0°
Z Phys 30 320-328 (1924)

A2, A9 data : historical, includes data at -50 °C

24-03d H Kamerlingh Onnes and A Th van Urk
Isotherms of Nitrogen at Low Temperatures
Proc 4th Int Congress Refrig 1 75-7a (1924)
Comm Phys Lab Univ Leiden 169d,e 33 (1924)

A2 data : historical

23-01d L B Smith and R S Taylor
The Equation of State for Pure Nitrogen, Gas Phase
J Amer Chem Soc 45 (9) 2107-2124 (1923)

A2 data : historical

23-02d P-A Guye and T Batuecas
Sur la Compressibilité a 0° et Au-Dessous de 1 Atmosphère et l'Écart a la Loi d'Avogadro de Plusieurs Gaz I. Oxygène, Hydrogène et Anhydride Carbonique
J Chim Phys 20 308-336 (1922-3)

A3, A5 data : historical

22-01d F G Keyes, L B Smith and D B Joubert
The Equation of State for Methane Gas Phase
J Math Phys MIT 1 191-210 (1922)

A1 data : historical

22-02d L Holborn and J Otto
Isotherms of Nitrogen, Oxygen and Helium
Z Phys 10 367-376 (1922)

A2, A9 data : historical

22-03d **E Moles**
Sur la Densité Normale de l'Azote Chimique
J Chim Phys 19 283-289 (1921-2)

A2 data : historical

21-01d **G A Burrell and G W Jones**
Pressure-Volume Deviation of Methane, Ethane, Propane and Carbon Dioxide at Elevated Pressures
USBM Report No 2276 (1921) 6 pp

A1, A3, A4, A6 data : historical

20-01d **L Holborn**
Über die Isothermen des Wasserstoffs
Ann Phys [4] 63 674-680 (1920)

A5 data : historical

20-02d **J Timmermans**
Le Propane Pur; Poids du Litre Normal
J Chim Phys 18 133-141 (1920)

A6 data : historical

18-01d **K Stahrfoss**
Contribution Expérimentale a la Revision du Poids Atomique du Carbone a Partir des Densités des Gaz Acétylène, Éthylène et Éthane
J Chim Phys 16 175-200 (1918)

A4 data : historical

17-01d **G A Burrell and I W Robertson**
The Compressibility of Natural Gas and its Constituents, with Analyses of Natural Gas from Thirty-One Cities in the U.S.
USBM Report No 158 (1917) 17 pp

A1 data : historical

15-01d **L Holborn and H Schultz**
Über die Druckwage und die Isothermen von Luft, Argon und Helium zwischen 0 und 200°
Ann Phys [4] 47 1089-1111 (1915)

A9 data : historical

15-02d **H Kamerlingh Onnes, C Dorsmann and G Holst**
Isothermals of Di-Atomic Substances and their Binary Mixtures XVII. Preliminary Measurements Concerning the Isothermal of Hydrogen at Twenty Degrees Centigrade from Sixty to Ninety Atmospheres
Proc Akad Wetenschappen 18 458-464 (1915)

A5 data : historical

15-03d **H Kamerlingh Onnes, C A Crommelin and E I Smid**
Isothermals of Di-Atomic Substances and their Binary Mixtures XVIII. The Isothermal of Hydrogen from Sixty to Ninety Atmospheres
Proc Akad Wetenschappen 18 465-472 (1915)

A5 data : historical

15-04d **H Kamerlingh Onnes, C Dorsmann and G Holst**
Comm Phys Lab Univ Leiden 146a (1915)

A5 data : presumably same as 15-02

15-05d **H Kamerlingh Onnes, C A Crommelin and E J Smid**
Comm Phys Lab Univ Leiden 146c (1915)

A5 data : presumably same as 15-03

14-01d **P Kohnstamm and K W Walstra**
Measurements of the Isotherms of Hydrogen at 20° and 15.5°
Verslag Akad Wetenschappen Amsterdam 22 1366-1379 (1914)

A5 data : historical

14-02d **P Kohnstamm and K W Walstra**
Proc Roy Acad Sci Amsterdam 17 203-... (1914)

A5 data : presumably same as 14-01

13-01d **J P Kuenen and S W Visser**
The "Virial Coefficient *B*" for Normal Butane Vapor
Verslag Akad Wetenschappen Amsterdam 22 330-335 (1913)

B48 data : historical (butane with ethane impurity)

10-01d **S Young**
Sci Proc Roy Soc Dublin 12 374-... (1910)

A10 data : historical

09-01d **G Baume and F-L Perrot**
Sur la Densité Absolue du Méthane et de l'Éthane; Poids Atomique du Carbone
J Chim Phys 7 369-374 (1909)

A1, A4 data : historical

07-01d **H Kamerlingh Onnes and C Braak**
Comm Phys Lab Univ Leiden 100b 13 (1907)

A5 data : historical

05-01d **Witkowski**
Krakauer Anzeiger 305 (1905)

A5 data : historical

05-02d **P-A Guye and A Pintza**
Densités de l'Anhydride Carbonique, du Gaz Ammoniac et du Protoxyde d'Azote
Comptes Rendu Acad Sci 141 51-53 (1905)

A3 data : historical

02-01d **H Kamerlingh Onnes and F Hyndman**
Comm Phys Lab Univ Leiden 78 (1902)

A5 data : historical

01-01d **J C Schalkwijk**
Comm Phys Lab Univ Leiden 70 (1901)

A5 data : historical

00-01d **J Rose-Innes and S Young**
On the Thermal Properties of Normal Pentane
Phil Mag [5] 47 (287) 353-367 (1899)

A10 data : historical

00-02d **J Verschaffelt**
Comm Phys Lab Univ Leiden 4 45 and 47 (1898-9)

B35 data : historical

00-03d **A Leduc**
Recherches sur les Gaz
Ann Chim Phys [7] 15 5-114 (1898)

A2, A5, A7 data : historical

00-04d **Lord Rayleigh**
On an Anomaly Encountered in Determinations of the Density of Nitrogen Gas
Proc Roy Soc 55 (334) 340-344 (1894)

A2 data : historical work leading to discovery of argon

00-05d **E-H Amagat**
Mémoires sur l'Elasticité et la Dilatabilité des Fluides Jusqu'aux Très Hautes Pressions
Ann Chim Phys [6] 29 68-136 (1893)

A2, A5 data : historical

00-06d **Lord Rayleigh**
On the Densities of the Principal Gases
Proc Roy Soc A53 (322) 134-149 (1893)

A2, A5 data : historical

00-07d **E-H Amagat**
Sur la Détermination de la Densité des Gaz Liquéfiés et de leurs Vapeurs Saturées - Éléments du Point Critique de l'Acide Carbonique
Comptes Rendu Acad Sci 114 1093-1098 (1892)

A3 data : historical

00-08d **E-H Amagat**
Nouveau Réseau d'Isothermes de l'Acide Carbonique
Comptes Rendu Acad Sci 113 446-451 (1891)

A3 data : historical

00-09d **E-H Amagat**
Sur la Compressibilité des Gaz sous de Fortes Pressions, Deuxieme Mémoire: Influence de la Température et Coefficients de Dilation
Ann Chim Phys [5] 22 353-398 (1881)

A2, A3, A5 data : historical

00-10d **E-H Amagat**
Mémoire sur la Compressibilité des Gaz a des Pressions Élevées
Ann Chim Phys [5] 19 345-385 (1880)

A2, A5, A7 data : historical

00-11d **T Andrews**
Bakerian Lecture 1876 - On the Gaseous State of Matter
Phil Trans Roy Soc (London) 166 421-449 (1876)

A3 data : historical

00-12d **E-H Amagat**
Recherches sur la Dilation et la Compressibilité des Gaz
Ann Chim Phys [4] 29 246-285 (1873)

A3, A5 data : historical

00-13d **T Andrews**
Bakerian Lecture 1869 - On the Continuity of the Gaseous and Liquid States of Matter
Phil Trans Roy Soc (London) 159 575-590 (1869)

A3 data : historical critical region measurements

00-14d **J Natterer**
Gasverdichtungs-Versuche
Pogg Ann Phys Chem [4] 94 436-446 (1855)

A2, A5, A7 data : historical

Appendix C - Detailed Contents of the GERG Databank

Table C.1 Listing of Data Sets for Pure Gases

GERG-Code		Gas	n	p/MPa min	p/MPa max	T/K min	T/K max	Reference		In	App
A1	1	METHANE	19	2.0	8.0	273	293	Jaeschke	84-01	RG	DEH
A1	2	METHANE	68	0.1	8.6	273	293	Achtermann	82-02	TH	BUR
A1	3	METHANE	71	0.1	7.7	273	293	Achtermann	82-01	TH	OPT
A1	4	METHANE	40	0.3	10.0	219	291	Roe	72-01	BG	BUR
A1	5	METHANE	14	0.3	2.6	273	273	Hoover	65-01	HO	BUR
A1	6	METHANE	286	1.8	38.6	273	373	Trappeniers	79-01	VW	PZO
A1	7	METHANE	68	1.8	21.1	273	348	Schamp	58-01	SP	PZO
A1	8	METHANE	171	1.6	40.6	273	398	Douslin	64-01	DO	BUR
A1	9	METHANE	169	0.3	30.3	273	353	Jaeschke	91-06	RG	BUR
A1	10	METHANE	552	0.3	28.7	269	353	Jaeschke	91-06	RG	OPT
A1	11	METHANE	169	0.1	8.1	273	323	Kleinrahm	88-01	BO	DMA
A1	12	METHANE	35	1.1	28.7	323	323	Achtermann	86-01	TH	OPT
A1	13	METHANE	654	1.0	34.0	273	373	Achtermann	92-04	TH	OPT
A1	14	METHANE	56	0.5	8.0	220	260	Händel	92-01	BO	DMA
A1	15	METHANE	175	0.1	12.1	263	323	Pieperbeck	91-03	RG	GDM
A1	16	METHANE	90	1.0	10.0	275	375	Trusler	92-05	IC	SPS
A1	17	METHANE	40	0.2	9.8	300	320	Brugge	89-10	AM	BUR
A1	18	METHANE	49	0.2	49.0	310	310	Mollerup	85-02	MO	BUR
A2	1	NITROGEN	94	3.7	6.7	279	308	Gasunie	90-04	GU	DEH
A2	2	NITROGEN	58	0.2	10.4	219	291	Roe	72-01	BG	BUR
A2	3	NITROGEN	22	0.2	39.9	273	273	Crain	66-03	CR	BUR
A2	4	NITROGEN	42	1.9	34.7	273	348	Michels	34-01	MI	PZO
A2	5	NITROGEN	129	0.2	30.2	273	353	Jaeschke	91-06	RG	BUR
A2	6	NITROGEN	514	0.2	28.7	269	353	Jaeschke	91-06	RG	OPT
A2	7	NITROGEN	127	0.5	8.0	273	323	Duschek	88-03	BO	DMA
A2	8	NITROGEN	35	1.1	28.7	323	323	Achtermann	86-01	TH	OPT
A2	9	NITROGEN	124	0.1	12.1	273	323	Pieperbeck	91-03	RG	GDM
A2	10	NITROGEN	40	0.1	10.4	300	320	Brugge	89-10	AM	BUR
A2	11	NITROGEN	104	1.0	12.7	280	360	Blanke	88-04	PB	DEH
A3	1	CARBON DIOXIDE	71	1.7	6.1	273	373	Michels	35-04	MI	PZO
A3	2	CARBON DIOXIDE	215	0.0	47.7	220	423	Holste	87-03	AM	BUR
A3	3	CARBON DIOXIDE	320	0.3	28.3	260	360	Ruhrgas	90-03	RG	OPT
A3	4	CARBON DIOXIDE	151	0.2	30.3	273	353	Ruhrgas	90-02	RG	BUR
A3	5	CARBON DIOXIDE	203	0.5	13.5	280	360	Gilgen	92-06	BO	DMA
A3	6	CARBON DIOXIDE	253	0.3	9.0	220	340	Duschek	90-10	BO	DMA
A3	7	CARBON DIOXIDE	26	0.6	7.3	220	304	Duschek	90-11	BO	DMA

Table C.1 Listing of Data Sets for Pure Gases (continued)

GERG-Code		Gas	n	p/MPa min	p/MPa max	T/K min	T/K max	Reference		In	App
A3	8	CARBON DIOXIDE	48	2.2	34.2	300	330	Ely	89-04	NI	BUR
A3	9	CARBON DIOXIDE	63	0.1	47.7	246	320	Esper	87-04	AM	BUR
A3	10	CARBON DIOXIDE	11	0.4	6.0	320	320	Weber	92-08	NG	BUR
A3	11	CARBON DIOXIDE	11	0.2	6.5	304	304	Glowka	90-07	GL	BUR
A4	1	ETHANE	67	1.6	14.5	273	373	Michels	54-01	MI	PZO
A4	2	ETHANE	18	1.4	4.5	273	323	Douslin	73-01	DO	BUR
A4	3	ETHANE	86	0.2	26.3	280	348	Ruhrgas	90-02	RG	BUR
A4	4	ETHANE	235	0.1	26.8	260	360	Ruhrgas	90-03	RG	OPT
A4	5	ETHANE	11	0.3	4.3	320	320	Weber	92-08	NG	BUR
A5	1	HYDROGEN	26	0.7	4.7	248	348	Michels	59-01	MI	PZO
A5	2	HYDROGEN	68	0.2	26.3	273	353	Ruhrgas	90-02	RG	BUR
A5	3	HYDROGEN	221	0.5	28.1	273	353	Ruhrgas	90-03	RG	OPT
A6	1	PROPANE	358	1.6	37.0	323	424	Thomas	82-03	TS	PZO
A7	1	CARBON MONOXIDE	20	1.9	4.9	273	348	Michels	52-01	MI	PZO
A9	1	HELIUM	18	2.0	7.0	273	293	Ruhrgas	90-01	RG	DEH
A9	2	HELIUM	94	3.7	6.7	280	300	Gasunie	90-04	GU	DEH
A9	3	HELIUM	20	0.9	2.8	273	348	Michels	41-02	MI	PZO
A9	4	HELIUM	86	0.3	30.2	273	353	Zhang	92-03	RG	BUR
A9	5	HELIUM	263	0.7	28.4	273	353	Zhang	92-03	RG	OPT
A9	6	HELIUM	15	3.1	13.1	289	402	Fenghour	93-01	NE	IBU

Table C.2 Listing of Data Sets and Compositions (By Mole Fraction of the Second Component) for Binary Mixtures
* GERG round-robin gas

GERG- Code		Gas	n	p/MPa min	p/MPa max	T/K min	T/K max	Reference		In	App
B12	1	CH4-N2(.5160)	24	0,3	9,6	219	291	Roe	72-01	BG	BUR
B12	2	CH4-N2(.2810)	23	0,3	9,6	219	291	Roe	72-01	BG	BUR
B12	3	CH4-N2(.0916)	52	3,7	6,5	280	300	Gasunie	90-04	GU	DEH
B12	4	CH4-N2(.2010)	32	3,8	6,4	279	308	Gasunie	90-04	GU	DEH
B12	5	CH4-N2(.3015)	33	3,7	6,4	280	308	Gasunie	90-04	GU	DEH
B12	6	CH4-N2(.4968)	32	3,7	6,4	279	308	Gasunie	90-04	GU	DEH
B12	7	CH4-N2(.1998)	29	0,4	18,4	313	353	Jaeschke	91-06	RG	BUR
B12	8	CH4-N2(.1998)	271	0,4	28,6	270	353	Jaeschke	91-06	RG	OPT
B12	9	CH4-N2(.7501)	25	0,9	26,1	310	310	Jaeschke	91-06	RG	BUR
B12	10	CH4-N2(.7501)	281	0,4	28,1	270	350	Jaeschke	91-06	RG	OPT
B12	11*	CH4-N2(.5020)	33	0,3	26,1	290	290	Jaeschke	91-06	RG	BUR
B12	12*	CH4-N2(.5020)	153	0,5	28,0	280	310	Jaeschke	91-06	RG	OPT
B12	13*	CH4-N2(.5034)	39	1,0	7,0	283	313	Humphreys	89-01	BG	DEH
B12	14*	CH4-N2(.5032)	14	1,0	7,0	280	290	Fauveau	89-01	GF	DEH
B12	15*	CH4-N2(.5030)	20	3,1	7,7	283	293	v.Caneghem	89-01	DI	DEH
B12	16	CH4-N2(.7498)	66	1,0	33,5	323	323	Achtermann	86-01	TH	OPT
B12	17	CH4-N2(.1002)	66	1,0	33,5	323	323	Achtermann	86-01	TH	OPT
B12	18	CH4-N2(.6221)	66	1,0	33,5	323	323	Achtermann	86-01	TH	OPT
B12	19	CH4-N2(.8650)	66	1,0	33,5	323	323	Achtermann	86-01	TH	OPT
B12	20	CH4-N2(.5008)	66	1,0	33,5	323	323	Achtermann	86-01	TH	OPT
B12	21	CH4-N2(.5001)	16	0,4	26,2	310	310	Jaeschke	91-06	RG	BUR
B12	22	CH4-N2(.5001)	397	0,4	31,1	270	350	Jaeschke	91-06	RG	OPT
B12	23*	CH4-N2(.5029)	12	2,1	7,1	284	300	Pellei	89-01	SN	DEH
B12	24*	CH4-N2(.5030)	24	2,0	7,0	280	310	Jaeschke	89-01	RG	ADH
B12	25*	CH4-N2(.4994)	39	0,2	10,5	280	300	Brugge	89-02	AM	BUR
B12	26*	CH4-N2(.5030)	22	2,9	7,0	280	290	Janssen	89-01	GU	DEH
B13	1	CH4-CO2(.0961)	52	3,7	6,4	279	300	Gasunie	90-04	GU	DEH
B13	2	CH4-CO2(.1948)	32	3,8	6,3	280	308	Gasunie	90-04	GU	DEH
B13	3	CH4-CO2(.3007)	32	3,7	6,1	280	308	Gasunie	90-04	GU	DEH
B13	4	CH4-CO2(.3145)	252	0,2	28,4	270	350	Ruhrgas	90-03	RG	OPT
B13	5	CH4-CO2(.3145)	46	0,4	26,3	330	330	Ruhrgas	90-02	RG	BUR
B13	6	CH4-CO2(.4761)	118	0,1	48,3	220	320	Esper	87-04	AM	BUR
B13	7	CH4-CO2(.2457)	33	3,8	6,3	293	308	Gasunie	90-04	GU	DEH
B13	8	CH4-CO2(.9800)	65	2,1	31,3	280	400	Magee	88-07	NI	BUR
B13	9	CH4-CO2(.0983)	28	0,0	6,8	289	289	Lemming	89-03	AM	BUR
B13	10	CH4-CO2(.0999)	35	0,2	9,2	300	320	Brugge	89-10	AM	BUR
B13	11	CH4-CO2(.2986)	40	0,2	9,8	300	320	Brugge	89-10	AM	BUR

Table C.2 Listing of Data Sets and Compositions (By Mole Fraction of the Second Component) for Binary Mixtures (continued)
* GERG round-robin gas

GERG-Code		Gas	n	p/MPa min	p/MPa max	T/K min	T/K max	Reference		In	App
B13	12	CH4-CO2(.6761)	40	0,2	8,0	300	320	Brugge	89-10	AM	BUR
B13	13	CH4-CO2(.9011)	40	0,2	6,8	300	320	Brugge	89-10	AM	BUR
B14	1	CH4-C2H6(.0934)	49	3,8	6,4	279	300	Gasunie	90-04	GU	DEH
B14	2	CH4-C2H6(.0511)	33	3,8	6,3	280	308	Gasunie	90-04	GU	DEH
B14	3	CH4-C2H6(.2023)	30	3,7	6,3	280	308	Gasunie	90-04	GU	DEH
B14	4	CH4-C2H6(.3003)	30	0,6	26,1	330	330	Ruhrgas	90-02	RG	BUR
B14	5	CH4-C2H6(.3003)	207	0,2	28,4	270	350	Ruhrgas	90-03	RG	OPT
B14	6	CH4-C2H6(.1209)	83	0,2	26,0	290	330	Ruhrgas	90-02	RG	BUR
B14	7	CH4-C2H6(.1209)	139	0,3	13,5	270	350	Ruhrgas	90-03	RG	OPT
B14	8	CH4-C2H6(.0806)	59	0,3	26,0	290	330	Ruhrgas	90-02	RG	BUR
B14	9	CH4-C2H6(.0806)	285	0,4	29,0	270	350	Ruhrgas	90-03	RG	OPT
B14	10	CH4-C2H6(.0403)	32	0,4	25,8	330	330	Ruhrgas	90-02	RG	BUR
B14	11	CH4-C2H6(.0403)	343	0,5	29,0	270	350	Ruhrgas	90-03	RG	OPT
B14	12	CH4-C2H6(.1590)	81	0,4	26,1	290	330	Ruhrgas	90-02	RG	BUR
B14	13	CH4-C2H6(.1590)	306	0,4	28,4	270	350	Ruhrgas	90-03	RG	OPT
B14	14	CH4-C2H6(.4978)	126	1,7	34,4	240	320	Haynes	85-01	NI	BUR
B14	15	CH4-C2H6(.6547)	88	1,8	33,2	250	320	Haynes	85-01	NI	BUR
B14	16	CH4-C2H6(.3147)	126	1,7	34,5	230	320	Haynes	85-01	NI	BUR
B15	1	CH4-H2(.1502)	68	0,4	30,5	273	353	Ruhrgas	90-02	RG	BUR
B15	2	CH4-H2(.1502)	166	0,5	28,1	273	353	Ruhrgas	90-03	RG	OPT
B15	3	CH4-H2(.2531)	188	0,5	28,7	270	350	Ruhrgas	90-03	RG	OPT
B15	4	CH4-H2(.4027)	83	0,2	26,1	275	350	Ruhrgas	90-02	RG	BUR
B15	5	CH4-H2(.4027)	126	0,5	28,9	270	350	Ruhrgas	90-03	RG	OPT
B15	6	CH4-H2(.7494)	83	0,3	26,1	275	350	Ruhrgas	90-02	RG	BUR
B15	7	CH4-H2(.7494)	185	0,5	29,2	270	350	Ruhrgas	90-03	RG	OPT
B16	1	CH4-C3H8(.0401)	54	3,7	6,4	279	300	Gasunie	90-04	GU	DEH
B16	2	CH4-C3H8(.0702)	30	0,4	18,2	313	353	Ruhrgas	90-02	RG	BUR
B16	3	CH4-C3H8(.0702)	188	0,3	28,4	280	353	Ruhrgas	90-03	RG	OPT
B16	4	CH4-C3H8(.0498)	44	3,7	6,4	280	308	Gasunie	90-04	GU	DEH
B17	1	CH4-CO(.0299)	61	0,4	30,2	273	353	Ruhrgas	90-02	RG	BUR
B17	2	CH4-CO(.0299)	284	0,5	29,4	273	353	Ruhrgas	90-03	RG	OPT
B18	1	CH4-C4H10(.0121)	72	3,8	6,5	280	300	Gasunie	90-04	GU	DEH
B18	2	CH4-C4H10(.0150)	29	0,4	18,3	313	353	Ruhrgas	90-02	RG	BUR
B18	3	CH4-C4H10(.0150)	239	0,3	28,1	270	353	Ruhrgas	90-03	RG	OPT
B18	4	CH4-C4H10(.0424)	27	0,8	6,3	278	300	Ellington	86-02	OK	DEH
B23	1	N2-CO2(.2511)	21	3,8	6,0	293	308	Gasunie	90-04	GU	DEH

Table C.2 Listing of Data Sets and Compositions (By Mole Fraction of the Second Component) for Binary Mixtures (continued)
* GERG round-robin gas

GERG-Code		Gas	n	p/MPa min	p/MPa max	T/K min	T/K max	Reference		In	App
B23	2	N2-CO2(.2859)	46	0,2	26,2	330	330	Ruhrgas	90-02	RG	BUR
B23	3	N2-CO2(.2538)	109	0,2	12,0	275	350	Ruhrgas	90-02	RG	BUR
B23	4	N2-CO2(.4469)	146	0,1	48,4	220	320	Esper	87-04	AM	BUR
B23	5	N2-CO2(.1010)	19	2,0	7,0	279	308	GazdeFrance	90-05	GF	DEH
B23	6	N2-CO2(.3181)	20	2,0	7,0	278	308	GazdeFrance	90-05	GF	DEH
B23	7	N2-CO2(.1056)	38	0,2	9,8	300	320	Brugge	89-10	AM	BUR
B23	8	N2-CO2(.2515)	40	0,2	10,6	300	320	Brugge	89-10	AM	BUR
B23	9	N2-CO2(.5036)	40	0,3	10,2	300	320	Brugge	89-10	AM	BUR
B23	10	N2-CO2(.7110)	40	0,3	9,7	300	320	Brugge	89-10	AM	BUR
B23	11	N2-CO2(.9092)	38	0,2	7,3	300	320	Brugge	89-10	AM	BUR
B23	12	N2-CO2(.9820)	64	2,3	33,1	300	330	Ely	89-04	NI	BUR
B23	13	N2-CO2(.2712)	10	0,6	4,5	293	293	Jiang	90-08	JI	DEH
B23	14	N2-CO2(.4686)	9	0,6	4,1	293	293	Jiang	90-08	JI	DEH
B23	15	N2-CO2(.5399)	11	0,6	5,2	293	293	Jiang	90-08	JI	DEH
B23	16	N2-CO2(.7024)	11	0,6	4,7	293	293	Jiang	90-08	JI	DEH
B24	1	N2-C2H6(.7513)	133	0,5	28,1	270	350	Achtermann	91-02	RG	OPT
B24	2	N2-C2H6(.5004)	164	0,5	28,5	270	350	Achtermann	91-02	RG	OPT
B24	3	N2-C2H6(.2506)	183	0,2	28,7	270	350	Achtermann	91-02	RG	OPT
B24	4	N2-C2H6(.2516)	30	3,6	7,3	282	309	Gasunie	90-04	GU	DEH
B25	1	N2-H2(.1497)	47	0,4	30,2	273	313	Jaeschke	91-01	RG	BUR
B25	2	N2-H2(.1497)	230	0,4	28,5	273	353	Jaeschke	91-01	RG	OPT
B25	3	N2-H2(.2497)	188	0,5	28,5	270	350	Jaeschke	91-01	RG	OPT
B25	4	N2-H2(.5002)	79	0,3	26,1	275	350	Jaeschke	91-01	RG	BUR
B25	5	N2-H2(.5002)	185	0,5	28,9	270	350	Jaeschke	91-01	RG	OPT
B25	6	N2-H2(.7498)	71	0,5	26,2	275	350	Jaeschke	91-01	RG	BUR
B25	7	N2-H2(.7498)	199	0,5	29,1	270	350	Jaeschke	91-01	RG	OPT
B25	8	N2-H2(.7520)	37	1,9	9,1	273	323	Michels	49-05	MI	PZO
B26	1	N2-C3H8(.0510)	43	3,8	6,3	293	308	Gasunie	90-04	GU	DEH
B26	2	N2-C3H8(.0702)	22	0,9	18,6	313	353	Ruhrgas	90-02	RG	BUR
B26	3	N2-C3H8(.0702)	223	0,3	28,6	270	353	Ruhrgas	90-03	RG	OPT
B27	1	N2-CO(.0301)	56	0,4	30,1	273	353	Ruhrgas	90-02	RG	BUR
B27	2	N2-CO(.0301)	287	0,3	28,7	273	353	Ruhrgas	90-03	RG	OPT
B28	1	N2-C4H10(.0150)	22	0,4	18,4	313	353	Ruhrgas	90-02	RG	BUR
B28	2	N2-C4H10(.0150)	222	0,2	28,4	270	353	Ruhrgas	90-03	RG	OPT
B29	1	N2-He(.2496)	26	0,5	26,7	298	298	Zhang	92-03	RG	BUR
B29	2	N2-He(.2496)	337	0,5	28,0	270	350	Zhang	92-03	RG	OPT
B29	3	N2-He(.4996)	30	0,5	26,2	290	310	Zhang	92-03	RG	BUR

Table C.2 Listing of Data Sets and Compositions (By Mole Fraction of the Second Component) for Binary Mixtures (continued)
* GERG round-robin gas

GERG-Code		Gas	n	p/MPa min	p/MPa max	T/K min	T/K max	Reference		In	App
B29	4	N2-He(.4996)	274	0,4	27,2	270	350	Zhang	92-03	RG	OPT
B29	5	N2-He(.7491)	22	0,7	26,3	298	298	Zhang	92-03	RG	BUR
B29	6	N2-He(.7491)	337	0,2	28,0	270	350	Zhang	92-03	RG	OPT
B34	1	CO2-C2H6(.7155)	80	0,2	3,8	273	353	Ruhrgas	90-03	RG	OPT
B34	2	CO2-C2H6(.2267)	98	0,3	4,0	273	353	Ruhrgas	90-03	RG	OPT
B34	3	CO2-C2H6(.4569)	102	0,2	3,9	273	353	Ruhrgas	90-03	RG	OPT
B34	4	CO2-C2H6(.6992)	104	0,1	5,8	260	360	Ruhrgas	90-03	RG	OPT
B34	5	CO2-C2H6(.8995)	46	0,1	4,7	300	320	Lemming	89-03	AM	BUR
B34	6	CO2-C2H6(.7483)	55	0,0	6,1	300	320	Lemming	89-03	AM	BUR
B34	7	CO2-C2H6(.5075)	44	0,0	6,8	300	320	Lemming	89-03	AM	BUR
B34	8	CO2-C2H6(.2602)	55	0,0	6,7	300	320	Lemming	89-03	AM	BUR
B34	9	CO2-C2H6(.0963)	54	0,0	6,7	300	320	Lemming	89-03	AM	BUR
B34	10	CO2-C2H6(.0100)	83	3,2	34,8	270	400	Sherman	89-11	NI	BUR
B34	11	CO2-C2H6(.2602)	102	0,3	12,2	293	320	Weber	92-08	NG	BUR
B34	12	CO2-C2H6(.5075)	81	0,1	10,2	290	320	Weber	92-08	NG	BUR
B34	13	CO2-C2H6(.7483)	70	0,3	9,6	295	320	Weber	92-08	NG	BUR
B35	1	CO2-H2(.5005)	128	0,2	12,2	275	350	Ruhrgas	90-02	RG	BUR
B35	2	CO2-H2(.7490)	136	0,3	26,3	275	350	Ruhrgas	90-02	RG	BUR
B45	1	C2H6-H2(.5027)	49	0,3	26,1	330	330	Ruhrgas	90-02	RG	BUR
B45	2	C2H6-H2(.7516)	144	0,2	26,2	275	350	Ruhrgas	90-02	RG	BUR
B110	1	CH4-C5H12(.0027)	21	3,8	6,3	293	308	Gasunie	90-04	GU	DEH
B110	2	CH4-C5H12(.0029)	131	0,5	17,8	270	350	Ruhrgas	90-03	RG	OPT
B111	1	CH4-C6H14(.0009)	158	0,5	12,8	270	350	Ruhrgas	90-03	RG	OPT

Table C.3 Listing of Data Sets for Ternary Mixtures
* GERG round-robin gas

GERG-Code		Gas	n	p/MPa min	p/MPa max	T/K min	T/K max	Reference		In	App
C123	1	CH4-N2-CO2	33	3,7	6,3	279	308	Gasunie	90-04	GU	DEH
C124	1	CH4-N2-C2H6	22	3,8	6,3	280	308	Gasunie	90-04	GU	DEH
C124	2	CH4-N2-C2H6	99	0,2	58,8	275	345	Staby	91-04	MO	BUR
C134	1	CH4-CO2-C2H6	22	3,7	6,4	279	308	Gasunie	90-04	GU	DEH
C134	2	CH4-CO2-C2H6	33	3,8	6,2	293	308	Gasunie	90-04	GU	DEH
C136	1	CH4-CO2-C3H8	21	3,8	6,1	293	308	Gasunie	90-04	GU	DEH
C146	1	CH4-C2H6-C3H8	32	3,8	6,6	293	308	Gasunie	90-04	GU	DEH
C146	2*	CH4-C2H6-C3H8	29	0,3	11,9	320	320	Jaeschke	89-01	RG	BUR
C146	3*	CH4-C2H6-C3H8	347	0,2	29,1	270	350	Jaeschke	89-01	RG	OPT
C146	4*	CH4-C2H6-C3H8	14	1,0	7,0	290	300	Fauveau	89-01	GF	DEH
C146	5*	CH4-C2H6-C3H8	17	3,1	7,7	283	293	v.Caneghem	89-01	DI	DEH
C146	6*	CH4-C2H6-C3H8	9	2,0	6,0	294	313	Humphreys	89-01	BG	DEH
C146	7*	CH4-C2H6-C3H8	22	2,9	7,3	290	313	Janssen	89-01	GU	DEH
C146	8*	CH4-C2H6-C3H8	24	2,0	7,0	280	310	Jaeschke	89-01	RG	ADH
C146	9*	CH4-C2H6-C3H8	12	2,1	7,1	289	300	Pellei	89-01	SN	DEH
C146	10*	CH4-C2H6-C3H8	40	0,2	10,7	290	320	Hall	89-01	AM	BUR
C146	11*	CH4-C2H6-C3H8	30	2,0	7,0	280	310	Jaeschke	89-01	RG	ADH
C146	12*	CH4-C2H6-C3H8	11	2,9	6,8	290	290	Janssen	89-01	GU	DEH
C146	13*	CH4-C2H6-C3H8	108	0,6	13,1	280	313	Jaeschke	89-01	RG	OPT

Table C.4 Listing of Data Sets for Quaternary Mixtures and Synthetic Gas Mixtures
* GRI round-robin gas

GERG-Code	Gas	n	p/MPa min	p/MPa max	T/K min	T/K max	Reference		In	App
D 1	CH4-N2-C2H6-O2	24	0,3	9,9	219	273	Roe	72-01	BG	BUR
D 2	CH4-N2-C2H6-C3H8	5	3,0	7,0	283	293	GazdeFrance	90-05	GF	DEH
D 3	CH4-N2-C2H6-C3H8	6	3,0	7,0	283	293	GazdeFrance	90-05	GF	DEH
D 4	CH4-N2-C2H6-C3H8	6	3,0	7,0	283	293	GazdeFrance	90-05	GF	DEH
D 5	CH4-N2-C2H6-C3H8	6	3,0	7,0	283	293	GazdeFrance	90-05	GF	DEH
D 6	CH4-N2-C2H6-C3H8	6	3,0	7,0	283	293	GazdeFrance	90-05	GF	DEH
D 7	CH4-N2-C2H6-C3H8	6	3,0	7,0	284	294	GazdeFrance	90-05	GF	DEH
D 8	CH4-N2-C2H6-C3H8	6	3,0	7,0	284	293	GazdeFrance	90-05	GF	DEH
D 9	CH4-N2-C2H6-C3H8	6	3,0	7,0	283	293	GazdeFrance	90-05	GF	DEH
D 10	CH4-N2-C2H6-H2	7	3,0	7,0	283	293	GazdeFrance	90-05	GF	DEH
D 11	CH4-N2-C2H6-C3H8	6	3,0	7,0	283	293	GazdeFrance	90-05	GF	DEH
D 12	CH4-N2-C2H6-C3H8	6	3,0	7,0	283	293	GazdeFrance	90-05	GF	DEH
D 13	CH4-N2-C2H6-C3H8	6	3,0	7,0	283	293	GazdeFrance	90-05	GF	DEH
D 14	CH4-N2-CO2-C2H6	22	3,8	6,4	280	308	Gasunie	90-04	GU	DEH
D 15	CH4-N2-C2H6-C3H8	18	2,0	7,0	273	293	Jaeschke	84-01	RG	DEH
D 16	CH4-CO2-C2H6-C3H8	49	0,4	30,2	273	313	Ruhrgas	90-02	RG	BUR
D 17	CH4-CO2-C2H6-C3H8	168	0,4	28,2	273	313	Ruhrgas	90-03	RG	OPT
D 18	CH4-N2-CO2-C2H6	274	0,4	28,4	270	350	Ruhrgas	90-03	RG	OPT
D 19	CH4-N2-C2H6-C3H8	284	0,3	28,4	275	350	Ruhrgas	90-03	RG	OPT
D 20	CH4-N2-C2H6-C3H8	153	0,4	27,4	290	350	Ruhrgas	90-03	RG	OPT
D 21	CH4-N2-CO2-C2H6	228	0,5	28,4	280	330	Ruhrgas	94-05	RG	OPT
D 22*	GU1	279	0,5	28,0	275	350	Jaeschke	93-05	RG	OPT
D 23*	GU1	13	0,5	5,0	300	300	Jaeschke	93-05	RG	GDM
D 24*	GU1	78	0,2	10,4	250	325	Holste	93-05	AM	BUR
D 25*	GU1	91	3,5	60,0	225	350	Holste	93-05	AM	PYC
D 26*	GU1	65	2,0	34,7	225	350	Bruno	93-05	NI	BUR
D 27*	GU1	155	0,2	33,9	273	323	Schouten	93-05	VW	BUR
D 28*	GU1	64	0,6	4,1	242	273	Schouten	93-05	VW	IBU
D 29*	GU2	271	0,5	27,7	275	350	Jaeschke	93-05	RG	OPT
D 30*	GU2	13	0,5	8,0	300	300	Jaeschke	93-05	RG	GDM
D 31*	GU2	85	0,2	11,2	250	325	Holste	93-05	AM	BUR
D 32*	GU2	89	3,4	60,0	225	350	Holste	93-05	AM	PYC
D 33*	GU2	70	1,7	33,1	225	350	Bruno	93-05	NI	BUR
D 34*	GU2	119	0,3	35,9	273	323	Schouten	93-05	VW	BUR
D 35*	RG2	18	0,3	22,1	300	300	Jaeschke	93-05	RG	BUR
D 36*	RG2	275	0,5	27,9	275	350	Jaeschke	93-05	RG	OPT

Table C.4 Listing of Data Sets for Quaternary Mixtures and Synthetic Gas Mixtures (continued)
* GRI round-robin gas

GERG-Code	Gas	n	p/MPa min	p/MPa max	T/K min	T/K max	Reference		In	App
D 37*	RG2	9	0,5	6,0	300	300	Jaeschke	93-05	RG	GDM
D 38*	RG2	61	0,2	10,2	275	325	Holste	93-05	AM	BUR
D 39*	RG2	87	2,8	59,6	225	350	Holste	93-05	AM	PYC
D 40*	RG2	65	1,9	33,0	225	350	Bruno	93-05	NI	BUR
D 41*	NIST1	280	0,5	27,6	275	350	Jaeschke	93-05	RG	OPT
D 42*	NIST1	15	0,5	8,0	300	300	Jaeschke	93-05	RG	GDM
D 43*	NIST1	77	0,2	10,3	250	325	Holste	93-05	AM	BUR
D 44*	NIST1	82	3,5	56,8	225	350	Holste	93-05	AM	PYC
D 45*	NIST1	66	2,0	34,3	225	350	Bruno	93-05	NI	BUR
D 46*	NIST1	64	0,5	4,1	243	273	Schouten	93-05	VW	IBU
D 47*	NIST2	278	0,5	28,0	275	350	Jaeschke	93-05	RG	OPT
D 48*	NIST2	11	0,5	3,8	300	300	Jaeschke	93-05	RG	GDM
D 49*	NIST2	78	0,2	9,6	250	325	Holste	93-05	AM	BUR
D 50*	NIST2	66	3,4	58,7	225	350	Holste	93-05	AM	PYC
D 51*	NIST2	67	1,9	34,5	225	350	Bruno	93-05	NI	BUR
D 52*	NIST2	135	0,1	39,0	273	323	Schouten	93-05	VW	BUR
D 53*	NIST2	40	1,1	4,1	243	273	Schouten	93-05	VW	IBU
D 54	SHELL A	33	0,1	15,0	298	323	Biswas	90-13	VW	BUR
D 55	SHELL B	35	0,1	16,1	290	323	Biswas	90-13	VW	BUR
D 56	CH4-N2-C2H6-C3H8	133	0,1	54,5	255	315	Mollerup	85-03	MO	BUR
D 57	CH4-N2-C2H6-C3H8	47	0,2	52,3	340	340	Mollerup	85-03	MO	BUR
D 58	GULF COAST	13	1,1	5,3	300	300	Ellington	86-05	OK	DEH
D 59	AMARILLO	32	1,1	6,3	289	300	Ellington	86-05	OK	DEH

Table C.5 Listing of Data Sets for Natural Gases

GERG-Code	Gas	n	p/MPa min	p/MPa max	T/K min	T/K max	Reference		In	App
N 1	EKOFISK-H	18	2,0	7,0	273	293	Jaeschke	84-01	RG	DEH
N 2	UDSSR-H	18	2,0	7,0	273	293	Jaeschke	84-01	RG	DEH
N 3	TENP-H	18	2,0	7,0	273	293	Jaeschke	84-01	RG	DEH
N 4	EPE-H	18	2,0	7,0	273	293	Jaeschke	84-01	RG	DEH
N 5	MIXTURE+H2-H	24	2,0	7,0	273	303	Jaeschke	84-01	RG	DEH
N 6	MIXTURE+H2-H	24	2,0	7,0	273	303	Jaeschke	84-01	RG	DEH
N 7	MIXTURE+H2-L	24	2,0	7,0	273	303	Jaeschke	84-01	RG	DEH
N 8	MIXTURE+H2-L	23	2,0	7,0	273	303	Jaeschke	84-01	RG	DEH
N 9	UDSSR-H	67	0,2	8,6	273	293	Achtermann	82-02	TH	BUR
N 10	EKOFISK-H	68	0,2	8,7	273	293	Achtermann	82-02	TH	BUR
N 11	TENP-H	69	0,2	8,6	273	293	Achtermann	82-02	TH	BUR
N 12	EPE-H	69	0,2	8,6	273	293	Achtermann	82-02	TH	BUR
N 13	UDSSR-H	74	0,1	7,7	273	293	Achtermann	82-01	TH	OPT
N 14	EKOFISK-H	74	0,1	7,8	273	293	Achtermann	82-01	TH	OPT
N 15	TENP-H	73	0,1	7,7	273	293	Achtermann	82-01	TH	OPT
N 16	EPE-H	74	0,1	7,7	273	293	Achtermann	82-01	TH	OPT
N 17	UDSSR-H	76	0,1	7,8	273	293	Achtermann	82-01	TH	OPT
N 18	EKOFISK-H	68	0,1	7,9	273	293	Achtermann	82-01	TH	OPT
N 19	TENP-H	73	0,1	7,7	273	293	Achtermann	82-01	TH	OPT
N 20	EPE-H	77	0,1	7,9	273	293	Achtermann	82-01	TH	OPT
N 21	SOUTH.N.SEA-H	12	0,4	7,0	274	291	Roe	72-01	BG	BUR
N 22	BACTON-H	15	0,2	10,2	273	294	Roe	72-01	BG	BUR
N 23	GRONINGEN-L	18	2,0	7,0	279	298	GazdeFrance	90-05	GF	DEH
N 24	LACQ-H	12	2,0	7,0	278	298	GazdeFrance	90-05	GF	DEH
N 25	EKOFISK-H	10	1,0	4,5	288	293	GazdeFrance	90-05	GF	DEH
N 26	EKOFISK-H	5	1,0	4,5	284	284	GazdeFrance	90-05	GF	DEH
N 27	EKOFISK-H	5	1,0	4,5	279	279	GazdeFrance	90-05	GF	DEH
N 28	STATENZIJL-H	64	3,8	6,4	280	300	Gasunie	90-04	GU	DEH
N 29	URETERP-L	53	3,7	6,4	281	300	Gasunie	90-04	GU	DEH
N 30	AMBACHT-H	52	3,7	6,4	281	300	Gasunie	90-04	GU	DEH
N 31	PLACID-H	53	3,7	6,4	280	300	Gasunie	90-04	GU	DEH
N 32	MIDDENM.-H	54	3,7	6,5	280	300	Gasunie	90-04	GU	DEH
N 33	MID.MIX-L	64	3,7	6,5	279	300	Gasunie	90-04	GU	DEH
N 34	MID.ZECH.-L	52	3,7	6,4	281	300	Gasunie	90-04	GU	DEH
N 35	MID.ROTL.-M	55	3,8	6,4	281	300	Gasunie	90-04	GU	DEH
N 36	BOCHOLTZ-H	55	3,8	6,5	281	300	Gasunie	90-04	GU	DEH
N 37	EKOFISK-H	64	3,7	6,5	280	300	Gasunie	90-04	GU	DEH
N 38	GARYP-L	65	3,7	6,6	280	300	Gasunie	90-04	GU	DEH
N 39	GRAVENV.-H	55	3,7	6,5	280	300	Gasunie	90-04	GU	DEH
N 40	TIETJERK-L	54	3,7	6,5	281	300	Gasunie	90-04	GU	DEH

Table C.5 Listing of Data Sets for Natural Gases (continued)

GERG-Code	Gas	n	p/MPa min	p/MPa max	T/K min	T/K max	Reference		In	App
N 41	SLOCHTEREN-L	16	3,8	5,5	279	294	Gasunie	90-04	GU	DEH
N 42	SLOCHTEREN-L	44	3,8	6,5	280	300	Gasunie	90-04	GU	DEH
N 43	BALGZAND-H	66	3,7	6,5	280	300	Gasunie	90-04	GU	DEH
N 44	AMOCO-H	66	3,8	6,5	280	300	Gasunie	90-04	GU	DEH
N 45	ANNERVEEN-H	66	3,7	6,4	280	300	Gasunie	90-04	GU	DEH
N 46	ROSWINKEL-L	65	3,7	6,5	280	300	Gasunie	90-04	GU	DEH
N 47	SLEEN-ROSW.-M	65	3,7	6,4	280	300	Gasunie	90-04	GU	DEH
N 48	SLEEN-M	65	3,7	6,5	280	300	Gasunie	90-04	GU	DEH
N 49	STATENZIJL-H	33	3,8	6,4	280	286	Gasunie	90-04	GU	DEH
N 50	GRONINGEN-L	22	3,7	6,4	280	283	Gasunie	90-04	GU	DEH
N 51	EPE-H	31	0,6	30,1	273	313	Ruhrgas	90-02	RG	BUR
N 52	EPE-H	54	0,3	27,0	313	313	Ruhrgas	90-03	RG	OPT
N 53	EPE-H	47	0,4	30,2	273	353	Ruhrgas	90-02	RG	BUR
N 54	EPE-H	113	0,3	28,2	273	353	Ruhrgas	90-03	RG	OPT
N 55	EPE-H	98	0,3	27,3	275	330	Ruhrgas	90-02	RG	BUR
N 56	EPE-H	175	0,4	29,6	270	330	Ruhrgas	90-03	RG	OPT
N 57	UDSSR/NAM-H	30	0,4	25,1	290	290	Ruhrgas	90-02	RG	BUR
N 58	UDSSR/NAM-H	116	0,5	29,0	280	290	Ruhrgas	90-03	RG	OPT
N 59	NAM-L	34	0,3	26,0	310	310	Ruhrgas	90-02	RG	BUR
N 60	NAM-L	342	0,4	29,4	270	350	Ruhrgas	90-03	RG	OPT
N 61	UDSSR-H	36	0,2	26,0	310	310	Ruhrgas	90-02	RG	BUR
N 62	UDSSR-H	311	0,4	28,8	270	350	Ruhrgas	90-03	RG	OPT
N 63	DROHNE-L	62	0,3	26,8	310	330	Ruhrgas	90-02	RG	BUR
N 64	DROHNE-L	336	0,5	28,0	270	350	Ruhrgas	90-03	RG	OPT
N 65	EKOFISK-H	60	0,4	26,8	275	280	Ruhrgas	90-02	RG	BUR
N 66	EKOFISK-H	333	0,3	28,1	270	350	Ruhrgas	90-03	RG	OPT
N 67	MIXTURE+H2-H	68	0,4	9,2	273	303	Ruhrgas	90-02	RG	BUR
N 68	MIXTURE+H2-H	69	0,4	9,2	273	303	Ruhrgas	90-02	RG	BUR
N 69	MIXTURE+H2-L	70	0,4	9,2	273	303	Ruhrgas	90-02	RG	BUR
N 70	MIXTURE+H2-L	68	0,4	9,2	273	303	Ruhrgas	90-02	RG	BUR
N 71	MIXTURE+H2-H	70	0,4	9,2	273	303	Ruhrgas	90-02	RG	BUR
N 72	MIXTURE+H2-L	67	0,4	9,2	273	303	Ruhrgas	90-02	RG	BUR
N 73	MIXTURE+H2-L	31	0,5	26,1	310	310	Ruhrgas	90-02	RG	BUR
N 74	MIXTURE+H2-L	342	0,4	28,5	270	350	Ruhrgas	90-03	RG	OPT
N 75	EKOFISK-H	331	0,4	28,3	270	350	Ruhrgas	90-03	RG	OPT
N 76	EKOFISK-H	135	0,1	8,0	273	323	Duschek	89-06	BO	DMA
N 77	SLOCHTEREN-L	11	3,7	7,2	296	297	Gasunie	90-04	GU	DEH
N 78	STATENZIJL-H	19	3,6	6,5	295	297	Gasunie	90-04	GU	DEH
N 79	EKOFISK-H	21	3,0	5,4	296	297	Gasunie	90-04	GU	DEH
N 80	MID.ROTL.-M	44	3,7	6,4	280	294	Gasunie	90-04	GU	DEH

Table C.5 Listing of Data Sets for Natural Gases (continued)

GERG-Code	Gas	n	p/MPa min	p/MPa max	T/K min	T/K max	Reference		In	App
N 81	MID.ZECH.-L	42	3,8	6,4	280	294	Gasunie	90-04	GU	DEH
N 82	TENP-H	57	0,6	26,2	310	330	Ruhrgas	90-02	RG	BUR
N 83	TENP-H	353	0,3	28,8	270	350	Ruhrgas	90-03	RG	OPT
N 84	BACTON+H2-H	37	1,0	8,0	283	313	Cowan	88-08	BG	DEH
N 85	EKOFISK-H	48	2,9	7,4	280	298	Gasunie	90-04	GU	DEH
N 86	STATOIL-H	10	1,0	15,0	303	303	Hannisdal	87-03	HD	EXP
N 87	GULF COAST-H	7	4,9	5,3	289	289	Ellington	86-02	OK	DEH
N 88	LEMAN BANK-H	40	1,0	6,0	283	313	British Gas	90-06	BG	DEH
N 89	HAMILTON-L	42	1,5	6,6	284	313	British Gas	90-06	BG	DEH
N 90	ARCO(THAMES)-H	35	1,5	5,5	284	313	British Gas	90-06	BG	DEH
N 91	S.MORECAMBE-L	32	1,0	5,1	283	313	British Gas	90-06	BG	DEH
N 92	FRIGG-H	26	1,0	4,0	283	313	British Gas	90-06	BG	DEH
N 93	BRENT-H	8	1,0	5,2	303	303	British Gas	90-06	BG	DEH
N 94	EKOFISK-H	26	3,0	7,8	286	286	Gasunie	90-04	GU	DEH
N 95	EKOFISK+C7-H	44	2,9	7,2	280	298	Gasunie	90-04	GU	DEH
N 96	ROSWINKEL-L	48	2,8	7,7	280	298	Gasunie	90-04	GU	DEH
N 97	EPE-H+N2+CO2+C2H6	33	0,4	25,7	310	310	Ruhrgas	94-04	RG	BUR
N 98	EPE-H+N2+CO2+C2H6	306	0,5	28,4	270	350	Ruhrgas	94-05	RG	OPT
N 99	GESCHER-L +N2	15	0,6	26,9	290	290	Ruhrgas	94-04	RG	BUR
N100	GESCHER-L +N2	285	0,4	28,0	270	350	Ruhrgas	94-05	RG	OPT
N101	GESCHER-L +N2	338	0,5	28,5	270	350	Ruhrgas	94-05	RG	OPT
N102	EKOFISK-H +C2H6	33	0,4	26,1	290	290	Ruhrgas	94-04	RG	BUR
N103	EKOFISK-H +C2H6	336	0,5	28,6	270	350	Ruhrgas	94-05	RG	OPT
N104	EKOFISK-H +C2H6	223	0,5	28,0	270	350	Ruhrgas	94-05	RG	OPT
N105	TENP-H +CO2	33	0,4	26,3	330	330	Ruhrgas	94-04	RG	BUR
N106	TENP-H +CO2	220	0,5	28,6	270	350	Ruhrgas	94-05	RG	OPT
N107	EMSBÜREN +N2	460	0,5	29,3	265	350	Ruhrgas	94-05	RG	OPT
N108	EKOFISK-H +C2H6	187	0,5	20,0	270	350	Ruhrgas	94-05	RG	OPT
N109	MIXTURE +CO2	322	0,5	30,0	265	350	Ruhrgas	94-05	RG	OPT
N110	MIXTURE+N2+H2+CO	360	0,5	30,0	270	350	Ruhrgas	94-05	RG	OPT
N111	MIXTURE +C3H8	90	0,4	4,9	270	350	Ruhrgas	94-05	RG	OPT
N112	GESCHER-L +C4H10	100	0,4	6,8	270	350	Ruhrgas	94-05	RG	OPT
N113	GESCHER-L +C3H8	173	0,4	14,0	270	350	Ruhrgas	94-05	RG	OPT
N114	GESCHER-L +C3H8	125	0,4	8,5	270	350	Ruhrgas	94-05	RG	OPT
N115	GESCHER-L +O2	342	0,5	28,4	270	350	Ruhrgas	94-05	RG	OPT
N116	MIXTURE +N2+H2+CO	348	0,4	28,5	270	350	Ruhrgas	94-05	RG	OPT

Table C.6 Listing of Approximate Compositions (by Mole Percent) for Ternary Mixtures

GERG-Code		Gas No.	CH4 %	N2 %	CO2 %	C2H6 %	C3H8 %	N-C4 %	I-C4 %	H2 %	CO %	REST %
C123	1	299	50,21	24,97	24,82							
C124	1	297	49,97	24,90		25,13						
C124	2	167	62,65	12,09		25,26						
C134	1	300	50,39		24,77	24,84						
C134	2	302	59,60		20,27	20,14						
C136	1	304	74,73		20,19		5,08					
C146	1	311	74,70			20,12	5,18					
C146	2	213	81,20			16,54	2,26					
C146	3	213	81,20			16,54	2,26					
C146	4	230	81,15			16,59	2,26					
C146	5	228	81,19			16,55	2,26					
C146	6	282	81,32			16,24	2,44					
C146	7	280	81,36			16,20	2,44					
C146	8	284	81,37			16,19	2,44					
C146	9	281	81,34			16,22	2,44					
C146	10	271	81,18			16,56	2,26					
C146	11	213	81,20			16,54	2,26					
C146	12	260	81,13			16,62	2,25					
C146	13	285	81,40			16,16	2,44					

Table C.7 Listing of Approximate Compositions (by Mole Percent) for Quaternary Mixtures and Synthetic Gas Mixtures

GERG-Code	Gas No.	CH4 %	N2 %	CO2 %	C2H6 %	C3H8 %	N-C4 %	I-C4 %	H2 %	CO %	REST %
D 1	40	76,80	15,60		7,20						0,40
D 2	24	92,93	3,01		3,01	1,05					
D 3	25	89,71	3,12		6,16	1,02					
D 4	26	86,80	3,04		9,12	1,04					
D 5	27	83,72	3,15		12,09	1,04					
D 6	28	88,84	2,94		6,10	2,12					
D 7	29	84,77	2,85		9,25	3,13					
D 8	32	81,32	2,95		11,83	3,90					
D 9	51	66,93	17,87		11,46	3,74					
D 10	52	90,10	1,00		6,00				2,90		
D 11	53	61,80	22,60		11,70	3,90					
D 12	54	81,90	13,70		3,30	1,10					
D 13	55	73,90	22,00		3,10	1,00					
D 14	276	25,18	25,00	25,16	24,66						
D 15	72	95,44	1,86		1,91	0,79					
D 16	105	84,78		2,01	8,92	3,05	1,24				
D 17	105	84,78		2,01	8,92	3,05	1,24				
D 18	267	61,77	12,66	12,60	12,97						
D 19	265	88,60	0,65		8,69	1,51	0,30	0,19			0,06
D 20	264	88,65	0,60		8,70	1,52	0,30	0,19			0,05
D 21	287	66,09	13,13	11,06	9,71						0,01
D 22	336	81,44	13,47	0,99	3,30	0,61	0,10	0,10			
D 23	336	81,44	13,47	0,99	3,30	0,61	0,10	0,10			
D 24	358	81,30	13,58	0,99	3,29	0,64	0,10	0,10			
D 25	358	81,30	13,58	0,99	3,29	0,64	0,10	0,10			
D 26	358	81,30	13,58	0,99	3,29	0,64	0,10	0,10			
D 27	336	81,44	13,47	0,99	3,30	0,61	0,10	0,10			
D 28	336	81,44	13,47	0,99	3,30	0,61	0,10	0,10			
D 29	316	81,21	5,70	7,59	4,30	0,90	0,15	0,15			
D 30	316	81,21	5,70	7,59	4,30	0,90	0,15	0,15			
D 31	359	81,20	5,70	7,59	4,31	0,89	0,16	0,15			
D 32	359	81,20	5,70	7,59	4,31	0,89	0,16	0,15			
D 33	359	81,20	5,70	7,59	4,31	0,89	0,16	0,15			
D 34	316	81,21	5,70	7,59	4,30	0,90	0,15	0,15			
D 35	318	85,91	1,01	1,50	8,49	2,30	0,35	0,35			0,10
D 36	318	85,91	1,01	1,50	8,49	2,30	0,35	0,35			0,10
D 37	318	85,91	1,01	1,50	8,49	2,30	0,35	0,35			0,10
D 38	360	85,90	1,01	1,50	8,50	2,30	0,35	0,35			0,10
D 39	360	85,90	1,01	1,50	8,50	2,30	0,35	0,35			0,10
D 40	360	85,90	1,01	1,50	8,50	2,30	0,35	0,35			0,10

Table C.7 Listing of Approximate Compositions (by Mole Percent)
for Quaternary Mixtures and Synthetic Gas Mixtures (cont.)

GERG-Code	Gas No.	CH4 %	N2 %	CO2 %	C2H6 %	C3H8 %	N-C4 %	I-C4 %	H2 %	CO %	REST %
D 41	317	96,52	0,26	0,60	1,82	0,46	0,10	0,10			0,15
D 42	317	96,52	0,26	0,60	1,82	0,46	0,10	0,10			0,15
D 43	361	96,58	0,27	0,59	1,82	0,41	0,10	0,10			0,14
D 44	361	96,58	0,27	0,59	1,82	0,41	0,10	0,10			0,14
D 45	361	96,58	0,27	0,59	1,82	0,41	0,10	0,10			0,14
D 46	317	96,52	0,26	0,60	1,82	0,46	0,10	0,10			0,15
D 47	319	90,67	3,13	0,47	4,53	0,83	0,16	0,10			0,12
D 48	319	90,67	3,13	0,47	4,53	0,83	0,16	0,10			0,12
D 49	362	90,64	3,13	0,47	4,55	0,83	0,16	0,10			0,12
D 50	362	90,64	3,13	0,47	4,55	0,83	0,16	0,10			0,12
D 51	362	90,64	3,13	0,47	4,55	0,83	0,16	0,10			0,12
D 52	319	90,67	3,13	0,47	4,53	0,83	0,16	0,10			0,12
D 53	319	90,67	3,13	0,47	4,53	0,83	0,16	0,10			0,12
D 54	291	88,27	2,69	0,94	6,12	1,00	0,99				
D 55	292	80,08			11,64	6,53	1,75				
D 56	268	89,92	2,20		6,28	1,60					
D 57	270	90,35	2,15		4,97	2,53					
D 58	205	96,50	0,25	0,60	1,75	0,40	0,10	0,10			0,30
D 59	208	90,66	3,22	0,42	4,59	0,78	0,14	0,10			0,09

Table C.8 Listing of Approximate Compositions (by Mole Percent) for Natural Gases

GERG-Code	Gas No.	CH4 %	N2 %	CO2 %	C2H6 %	C3H8 %	N-C4 %	I-C4 %	H2 %	CO %	REST %
N 1	49	84,33	0,44	1,93	8,89	3,19	0,65	0,34			0,23
N 2	58	95,53	1,60	0,23	1,88	0,49	0,09	0,06			0,11
N 3	57	85,15	5,68	1,45	5,42	1,60	0,32	0,18			0,20
N 4	56	85,48	0,62	1,86	8,06	2,86	0,57	0,30			0,24
N 5	85	80,20	5,39	1,70	5,50	1,68	0,35	0,20	4,19	0,38	0,41
N 6	86	82,17	5,28	1,71	5,68	1,77	0,36	0,21	2,31	0,20	0,31
N 7	87	73,64	9,91	1,34	3,31	0,75	0,15	0,10	9,39	0,91	0,51
N 8	88	78,71	10,30	1,26	3,59	0,82	0,16	0,11	4,29	0,41	0,35
N 9	71	95,52	1,61	0,23	1,88	0,49	0,09	0,06			0,12
N 10	70	84,47	0,43	1,85	8,86	3,18	0,63	0,34			0,25
N 11	64	85,17	5,68	1,46	5,40	1,59	0,32	0,18			0,20
N 12	65	85,49	0,61	1,86	8,06	2,86	0,57	0,30			0,25
N 13	71	95,52	1,61	0,23	1,88	0,49	0,09	0,06			0,12
N 14	70	84,47	0,43	1,85	8,86	3,18	0,63	0,34			0,25
N 15	64	85,17	5,68	1,46	5,40	1,59	0,32	0,18			0,20
N 16	65	85,49	0,61	1,86	8,06	2,86	0,57	0,30			0,25
N 17	67	95,55	1,60	0,23	1,87	0,49	0,09	0,06			0,11
N 18	69	84,43	0,43	1,86	8,87	3,19	0,63	0,34			0,25
N 19	66	85,18	5,67	1,43	5,42	1,60	0,32	0,18			0,20
N 20	68	85,46	0,61	1,87	8,08	2,86	0,57	0,30			0,25
N 21	37	92,28	2,29	0,04	3,73	0,92	0,25	0,19			0,31
N 22	38	93,04	2,39	0,04	3,12	0,64	0,15	0,13			0,49
N 23	30	81,21	14,38	0,99	2,81	0,38	0,07	0,06			0,10
N 24	31	90,83	2,46	1,53	4,41	0,64	0,06	0,05			0,02
N 25	34	83,95	0,40	1,99	9,14	3,26	0,63	0,36			0,27
N 26	35	83,87	0,41	2,03	9,18	3,28	0,62	0,36			0,27
N 27	36	83,75	0,39	1,97	9,35	3,31	0,61	0,36			0,26
N 28	110	88,97	1,23	1,98	5,46	1,62	0,33	0,18			0,24
N 29	111	75,72	13,75	7,18	2,52	0,41	0,09	0,06			0,28
N 30	112	87,98	4,12	1,57	4,80	0,91	0,17	0,14			0,30
N 31	113	92,72	1,86	1,99	2,80	0,34	0,06	0,05			0,19
N 32	114	88,80	5,05	0,58	4,15	0,86	0,17	0,13			0,26
N 33	115	68,71	2,07	25,44	2,81	0,55	0,12	0,09			0,22
N 34	116	80,88	2,91	11,25	3,77	0,70	0,15	0,09			0,26
N 35	117	65,69	1,86	28,94	2,55	0,54	0,12	0,09			0,22
N 36	118	86,65	4,90	1,60	4,96	1,24	0,25	0,16			0,24
N 37	119	84,01	0,42	2,13	8,78	3,24	0,70	0,38			0,35
N 38	120	79,32	16,81	0,56	2,67	0,41	0,08	0,05			0,11
N 39	121	87,97	2,43	1,78	5,55	1,51	0,31	0,19			0,26
N 40	122	79,61	14,77	1,47	3,04	0,62	0,14	0,10			0,26

Table C.8 Listing of Approximate Compositions (by Mole Percent) for Natural Gases (continued)

GERG-Code	Gas No.	CH4 %	N2 %	CO2 %	C2H6 %	C3H8 %	N-C4 %	I-C4 %	H2 %	CO %	REST %
N 41	123	81,59	13,79	0,98	2,92	0,41	0,08	0,07			0,17
N 42	124	81,48	13,93	0,98	2,90	0,40	0,08	0,07			0,17
N 43	125	86,45	5,46	1,80	4,76	0,91	0,18	0,15			0,30
N 44	126	92,32	2,45	0,98	3,29	0,57	0,11	0,07			0,22
N 45	127	90,44	4,07	0,70	3,51	0,75	0,16	0,13			0,24
N 46	128	75,11	23,73	0,12	0,87	0,06	0,01	0,01			0,10
N 47	129	70,32	28,50	0,11	0,89	0,06	0,01	0,01			0,11
N 48	130	45,24	53,56	0,06	0,95	0,05	0,01				0,14
N 49	274	88,05	1,01	2,04	6,24	1,84	0,30	0,31			0,21
N 50	275	81,55	13,93	0,96	2,86	0,40	0,07	0,07			0,15
N 51	65	85,49	0,61	1,86	8,06	2,86	0,57	0,30			0,25
N 52	65	85,49	0,61	1,86	8,06	2,86	0,57	0,30			0,25
N 53	68	85,46	0,61	1,87	8,08	2,86	0,57	0,30			0,25
N 54	68	85,46	0,61	1,87	8,08	2,86	0,57	0,30			0,25
N 55	212	85,35	0,60	1,91	8,14	2,87	0,59	0,31			0,24
N 56	212	85,35	0,60	1,91	8,14	2,87	0,59	0,31			0,24
N 57	211	94,61	3,76	0,26	1,01	0,21	0,04	0,03			0,08
N 58	211	94,61	3,76	0,26	1,01	0,21	0,04	0,03			0,08
N 59	223	82,52	11,73	1,11	3,46	0,76	0,15	0,10			0,17
N 60	223	82,52	11,73	1,11	3,46	0,76	0,15	0,10			0,17
N 61	210	98,27	0,89	0,07	0,52	0,16	0,03	0,03			0,04
N 62	210	98,27	0,89	0,07	0,52	0,16	0,03	0,03			0,04
N 63	224	89,45	5,37	4,86	0,24	0,02					0,06
N 64	224	89,45	5,37	4,86	0,24	0,02					0,06
N 65	225	85,45	0,43	1,77	8,50	2,74	0,59	0,30			0,22
N 66	225	85,45	0,43	1,77	8,50	2,74	0,59	0,30			0,22
N 67	86	82,17	5,28	1,71	5,68	1,77	0,36	0,21	2,31	0,20	0,31
N 68	85	80,20	5,39	1,70	5,50	1,68	0,35	0,20	4,19	0,38	0,41
N 69	87	73,64	9,91	1,34	3,31	0,75	0,15	0,10	9,39	0,91	0,51
N 70	137	82,24	5,27	1,71	5,69	1,76	0,35	0,21	2,28	0,20	0,31
N 71	241	80,15	5,39	1,70	5,49	1,70	0,35	0,20	4,22	0,39	0,40
N 72	242	73,50	9,93	1,34	3,32	0,75	0,15	0,10	9,49	0,91	0,51
N 73	242	73,50	9,93	1,34	3,32	0,75	0,15	0,10	9,49	0,91	0,51
N 74	242	73,50	9,93	1,34	3,32	0,75	0,15	0,10	9,49	0,91	0,51
N 75	240	85,93	0,96	1,50	8,46	2,30	0,46	0,24			0,15
N 76	278	84,38	0,42	1,92	8,87	3,18	0,66	0,34			0,23
N 77	22	81,31	14,18	0,99	2,83	0,39	0,08	0,07			0,16
N 78	23	88,22	1,17	1,86	6,12	1,88	0,38	0,21			0,17
N 79	16	83,42	0,34	1,88	9,53	3,57	0,66	0,38			0,23
N 80	62	65,70	1,85	28,93	2,55	0,54	0,12	0,09			0,23

Table C.8 Listing of Approximate Compositions (by Mole Percent) for Natural Gases (continued)

GERG- Code	Gas No.	CH4 %	N2 %	CO2 %	C2H6 %	C3H8 %	N-C4 %	I-C4 %	H2 %	CO %	REST %
N 81	63	80,88	2,91	11,24	3,77	0,70	0,15	0,09			0,27
N 82	243	84,49	6,00	1,40	5,93	1,54	0,33	0,18			0,15
N 83	243	84,49	6,00	1,40	5,93	1,54	0,33	0,18			0,15
N 84	283	57,69	1,28	0,03	1,78	3,20	0,07	0,07	35,63		0,24
N 85	344	85,96	0,64	1,46	8,74	2,39		0,67			0,15
N 86	322	82,71	0,62	0,79	14,70	1,04		0,12			0,02
N 87	323	96,50	0,25	0,60	1,75	0,40		0,20			0,30
N 88	321	95,02	1,12	0,06	2,92	0,49		0,19			0,20
N 89	324	87,43	11,11	0,21	0,91	0,16		0,05			0,12
N 90	325	93,62	2,14	0,32	2,94	0,55		0,21			0,22
N 91	326	85,30	7,75	0,60	4,51	1,06		0,50			0,29
N 92	327	95,62	0,51	0,30	3,48	0,04		0,01			0,04
N 93	315	94,23	1,61	0,85	3,15	0,15					0,01
N 94	345	85,92	0,66	1,44	8,78	2,38		0,66			0,15
N 95	346	85,90	0,59	1,44	8,77	2,39		0,67			0,25
N 96	347	75,20	23,70	0,13	0,78	0,06		0,02			0,11
N 97	279	64,80	10,56	12,37	9,78	1,77	0,37	0,19			0,14
N 98	279	64,80	10,56	12,37	9,78	1,77	0,37	0,19			0,14
N 99	328	59,03	36,21	0,90	2,92	0,60	0,12	0,08			0,14
N100	328	59,03	36,21	0,90	2,92	0,60	0,12	0,08			0,14
N101	329	47,26	48,95	0,71	2,34	0,48	0,10	0,06			0,11
N102	330	82,47	0,57	1,69	11,67	2,57	0,54	0,28			0,21
N103	330	82,47	0,57	1,69	11,67	2,57	0,54	0,28			0,21
N104	334	76,34	0,50	1,40	18,95	2,09	0,40	0,20	0,00		0,13
N105	335	65,85	2,29	26,63	3,94	0,88	0,17	0,11			0,15
N106	335	65,85	2,29	26,63	3,94	0,88	0,17	0,11			0,15
N107	348	79,37	18,97	0,50	0,96	0,09	0,02	0,01			0,08
N108	349	79,95	1,13	1,02	15,96	1,40	0,26	0,13	0,00		0,15
N109	350	80,04	3,04	15,04	1,34	0,30	0,06	0,04			0,14
N110	351	27,93	29,84	3,69	0,19	0,02			36,76	1,03	0,56
N111	352	70,76	13,12	4,94	0,98	9,55	0,10	0,13			0,42
N112	353	81,03	10,51	1,19	3,33	0,61	3,10	0,09			0,16
N113	354	79,57	10,29	1,17	3,28	5,33	0,12	0,08			0,15
N114	355	76,85	9,93	1,10	2,96	8,84	0,10	0,08			0,14
N115	356	81,53	11,81	1,19	2,81	0,62	0,21				1,85
N116	357	28,89	28,00	2,02	0,84	0,16	0,07		26,99	13,00	0,04

Table C.9 Abbreviations for Institutes (In) used in Tables C.1 - C.5

AM	Texas A+M University, U.S.A
BO	Bochum University, Germany
BG	British Gas London Research Station, U.K
CR	Crain (see [66-03])
DI	Distrigaz, Belgium
DO	Douslin (see [64-01],[73-01])
GF	Gaz de France, France
GL	Glowka (see [90-07])
GU	Nederlands Gasunie, Netherlands
HD	Hannisdal (see [87-03])
HO	Hoover (see [65-01])
IC	Imperial College (London), U.K
JI	Jiang (see [90-08])
MI	Michels (see [34-01], [35-04], [41-02], [49-05], [52-01], [54-01], [59-01])
MO	Mollerup (see [85-02], [85-03], [91-04])
NI	National Institute of Standards and Technology (NIST), Boulder, U.S.A
NG	National Institute of Standards and Technology (NIST), Gaithersburg, U.S.A
OK	Oklahoma University, U.S.A
PB	PTB (Braunschweig), Germany
RG	Ruhrgas A.G (Dorsten), Germany
SN	SNAM, Italy
SP	Schamp (see [58-01])
TH	Hannover University, Germany
TS	Thomas (see [82-03])
VW	Van der Waals-Zeeman Laboratory, Netherlands

Table C.10 Abbreviations for Methods of Measurement (App) used in Tables C.1 - C.5

ADH	Automatic Desgranges et Huot Apparatus
BUR	Burnett Apparatus
DEH	Desgranges et Hout Z-Meter
DMA	Two-Sinker Method, Bochum University
EXP	Dantest Expansion Apparatus
GDM	Two-Sinker Method, Ruhrgas A.G
IBU	Isochoric Burnett Apparatus
OPT	Optical Interferometry Method
PZO	Piezometer Method
PYC	Pycnometer Method
SPS	Speed of Sound Measurements