George T. Armstrong

NBSIR 75-763

Thermodynamic and Transport Properties of Ethylene and Propylene

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U.S. DEPARTMENT OF COMMERCE, Rogers C.B. Morton, ***Secretary***
James A. Baker, III, ***Under Secretary***
Dr. Betsy Ancker-Johnson, ***Assistant Secretary for Science and Technology***

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Acting Director***

Foreword

The thermophysical properties of ethylene and proplylene are of considerable interest because of the widespread use of these compounds as starting materials in chemical syntheses. The Office of Standard Reference Data of the National Bureau of Standards, with support from a number of industrial firms, has undertaken a program to establish definitive values for the equation of state and thermodynamic properties of ethylene. As one of inputs to this program, the book, "Thermodynamic and Transport Properties of Ethylene and Propylene," has been translated from the Russian. This translation is being made available to interested parties by issuing it as an NBS Internal Report.

For further information on the ethylene program, please contact:

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THERMODYNAMIC AND TRANSPORT PROPERTIES OF ETHYLENE AND PROPYLENE

[Book; Moscow, Termodinamicheskiye i Transportnyye Svoystva Etilena i Propilena, Russian, 1971, Standards Publishing House, signed to press 23 June 1971, 182 pages]

Table of Contents

UDC 536.7:547.313.2/.3

ANNOTATION

This reference monograph contains tables of density, enthalpy, entropy, isobaric heat capacity, heat capacity ratios, velocity of sound, index of adiabatics, viscosity and thermal conductivity of ethylene and propylene in the temperature and pressure ranges encompassed by the experiment. The tables are preceded by a review and analysis of experimental data appearing in the literature.

The book is intended for a large community of engineers, working on problems of calculation, planning and operation of petrochemical industries. It may also be of use to scientists investigating the thermophysical properties of compounds and allied problems.

The monograph contains 76 tables, 227 bibliographic references and 23 illustrations.

Staff of authors: D. M. Vashchenko, Yu. F. Voynov, B. V. Voytyuk, E. K. Dregulyas, A. Ya. Kolomiyets, S. D. Labinov, A. A. Morozov, I. A. Neduzhiy (supervisor of the author staff), V. P. Provotar, Yu. A. Soldatenko, Ye. I. Storozhenko, and Yu. I. Khmara.

PREFACE

This book is dedicated to the founder of the problem laboratory of engineering thermophysics of KTILP [Kiyevskiy tekhnologicheskiy institut legkoy promyshlennosti; Kiev Technological Institute of Light Industry] professor N. V. Pavlovich.

The use of ethylene and propylene in the organic synthesis industry and the high rates of expansion of the capacities of planned mass production gas fractionation plants for ethylene and propylene production stimulated a need for the development of detailed tables of the thermodynamic and transport properties of these compounds, essential for technological calculations in the planning of equipment and apparatus.

Previously published manuals contained thermodynamically contradictory data on the various properties of ethylene and propylene for a narrow range of temperatures and pressures, and often in a form unsuitable for use in engineering practice.

An attempt is made in this work to systematize existing experimental data on the thermodynamic and transport properties of ethylene and propylene and to create thermodynamically concordant tables of these properties in the temperature and pressure ranges that are of interest in technological applications. The solution of this problem required the organization of additional experimental and theoretical investigations of the properties of ethylene and propylene, which were carried out by the authors in the problems laboratory of engineering thermophysics of the Kiev Technological Institute of Light Industry from 1963-1968.

The properties measured included the density of the liquid phase, density of the vapor and of the liquid on the saturation line, isobaric heat capacity of the liquid, velocity of sound in gaseous ethylene and propylene, viscosity and thermal conductivity of ethylene and propylene, and thermal equations of state of gaseous ethylene and propylene were derived on the basis of more reliable data on compressibility.

Part One of the book contains a review and analysis of existing data on thermodynamic and transport properties of ethylene and propylene, as well as the results of investigations performed by the authors; the method of processing data on the various properties and the method by which the tables were compiled[1] are described in detail.

Part Two contains tables of the thermophysical properties of ethylene and propylene. The tables of the thermodynamic properties contain: properties on the liquid-vapor equilibrium line in the temperature range from 160°K to the critical point; specific volume, enthalpy, entropy and isobaric heat capacity of the liquid at pressures up to 60 bar, of the heated vapor up to 2,000 bar and 450°K; data on the density of liquid propylene at pressures of 65-600 bar and at temperatures of 270-360°K; data on the density of liquid ethylene at pressures of 70-500 bar and at temperatures of 180-270°K.

Tables of speed of sound, heat capacity ratio and adiabatics index are given for gaseous ethylene and propylene in the 210-470°K temperature range at pressures up to 100 bar.

The tables of the transfer coefficients contain: data on viscosity and thermal conductivity of ethylene in the 170-450°K temperature range at pressures up to 1,000 bar (viscosity) and 3,000 bar (thermal conductivity); data on viscosity and thermal conductivity of propylene at 270-450°K at pressures up to 1,000 bar (viscosity) and 50 bar (thermal conductivity), and also data on these properties of ethylene and propylene on the liquid-vapor equilibrium line.

Chapter I was written by V. P. Provotar, S. D. Labinov and Ye. I. Storozhenko; section I.5 of this chapter was written by Yu. A. Soldatenko and E. K. Dregulyas; Chapter II was written by B. V. Voytyuk and S. D. Labinov; Chapter III by Yu. F. Voynov and S. D. Labinov; Chapters IV-VI by Yu. A. Soldatenko, A. A. Morozov, E. K. Dregulyas and D. M. Vashchenko; Chapter VII by I. A. Neduzhiy and Yu. I. Khmara, and Chapter VIII by I. A. Neduzhiy and A. Ya. Kolomiyets.

Yu. I. Khmara and Yu. A. Soldatenko contributed greatly to the preparation of the manuscript.

The authors gratefully acknowledge N. A. Khanmurzinaya, M. E. Aerov and V. A. Kulikova for their cooperation in the investigations and also doctor of technical sciences professor V. A. Zagoruchenko for his review and esteemed advice.

The authors invite the critical comments and requests pertaining to the material in the monograph, and request that they be mailed to: Moscow, K-1, ul. Shchuseva, d. 4, Standards Publishing House.

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[1] The authors used literature data published prior to 1969.

SYMBOLS EMPLOYED IN MANUAL

$B(T)$ -- second Virial coefficient in expansion in terms of density;

C_p, C_v -- isobaric and isochoric heat capacities;

f -- vibration frequency;

$H^\circ_T - H^\circ_0$ -- change of enthalpy of compound in standard state from 0 to T °K;

i -- enthalpy;

i°_T -- enthalpy in perfect-gas state at temperature T, measured from the crystalline state at 0°K;

I -- electric current;

k -- Boltzmann constant;

k_v -- adiabatics index of real gas in equation;

M -- molecular weight;

p -- pressure;

Q, q -- heat;

R -- gas constant;

R_μ -- universal gas constant, equal to 8.3143 kJ/(kmole•deg);

r -- heat of vaporization, linear distances;

S -- entropy;

S°_T -- entropy in perfect-gas state at temperature T °K;

T -- absolute temperature, °K;

$T^* = \frac{kT}{\varepsilon}$ -- reduced temperature;

t -- temperature on Celcius scale;

U -- voltage of electric current;

V, v -- mole and specific volumes;

w -- speed of sound;

$Z = \frac{pv}{RT}$ -- compressibility coefficient;

Δ -- finite change of property, absolute error;

δ -- relative error;

ε -- depth of potential well;

η -- dynamic viscosity coefficient;

σ -- effective diameter of molecular interaction;

λ -- thermal conductivity coefficient, heat of fusion;

$\pi = \frac{p}{p_k}$ -- reduced pressure;

ρ -- density;

$\tau = \frac{T}{T_k}$ -- reduced temperature;

τ -- time;

$\phi(r)$ -- potential function of molecular interaction;

$\kappa = \frac{C_p}{C_v}$ -- heat capacity ratio;

$\omega = \frac{\rho}{\rho_k}$ -- reduced density.

PART I. REVIEW AND ANALYSIS OF EXISTING DATA ON THERMOPHYSICAL PROPERTIES OF ETHYLENE AND PROPYLENE

CHAPTER I. THERMAL PROPERTIES OF GASEOUS ETHYLENE AND PROPYLENE

Review of Experimental Data on Density of Gaseous Ethylene and Propylene

The works cited in Table 1 pertain to experimental analysis of p, v, T-dependence of gaseous ethylene.

Systematic analysis of the density of ethylene was first done by Amagat [1]. His work is now of historical importance only, despite the rather high accuracy of 0.2-0.3% of the results, since more recent data are now available [4, 5], distinguished by the maximum accuracy for the contemporary level of investigations.

The experimental results [2, 3, 6, 12, 13] are fragmentary. The most noteworthy among them are the data of Walters and coworkers [6]. Agreement of the data of Walters and Michels falls within the range of error of 0.5-0.3%, as stated in [6].

Data on the density of gaseous ethylene and propylene at low pressures are found in [11, 13]. The data of both works coincide, since they were obtained on the same experimental apparatus. These works are of importance in determining the second Virial coefficient.

In [7, 8, 9, 10] are found p, v, T-data obtained by means of grapho-analytical processing of experimental data. Dick and Hedley [8] did correct smoothing of Michels' data [5].

Presented in Table 2 is a list and brief description of investigations of the p, v, T-properties of propylene.

The compressibility of propylene was first subjected to systematic analysis by Vaughan and Graves [17].

The pressure range was expanded to 700 bar by Farrington and Sage [18]. The accuracy of the experiment, according to the authors, is 0.3%. Data of

Table 1. List of Works Containing Data on the p, v, T-Function of Ethylene

1) Авторы	2) Год	3) Диапазон температур T, °C	4) Диапазон давлений p, бар	5) Метод	6) Погрешность	7) Чистота исследованного газа, %
Амага [1]	1893	0—190	1—100	[1]	—	—
Мессон и Долли [2]	1926	24,95	5—125	[2]	—	—
Даниель и Стольценберг [3]	1929	15—45	21—202	[3]	$\Delta T = 0,1°$ C $\Delta v = 0,5\%$ $\Delta p = 0,1$ бар	97,8
Михельс и Нисен [4]	1936	0—150	20—70	[14]	0,01%	—
Михельс и Гелдерманс [5]	1942	0—150	16—3000	[14]	0,01%	—
Вальтерс и др. [6]	1954	(—7)—(+35)	3—40	[6]	0,5%	11) N_2—0,2; другие газы 0,2
Крамер [7]	1955			8) Обработка данных	—	—
Дик и Хедли [8]	1956	0—150	1—2500	9) То же	—	—
Загорученко [9, 10]	1959	(—100) — (+300)	0,5—2000	10) Расчет по уравнению состояния	—	—
Турлингтон, Маккетта [11]	1961	(—30)— (+30)	0,5—1,5	[15]	0,1%	—
Томас и Цандер [12]	1966	0—50	0—21	[16]	1%	—
Пфенниг, Маккетта [13]	1957	32,2; 48,8; 68,9	1—2	[15]	0,1%	99,9

KEY: 1. Authors
Amagat [1]
Masson and Dolly [2]
Dannell and Stolzenberg [3]
Michels and Niesen [4]
Michels and Geldermans [5]
Walters, et al [6]
Cramer [7]
Dick and Hedley [8]
Zagoruchenko [9, 10]
Turlington and McKetta [11]
Thomas and Zander [12]
Pfennig and McKetta [13]

2. Year
3. Temperature range T, °C
4. Pressure range p, bar
5. Method
6. Error
7. Purity of investigated gas, %
8. Data processing
9. Same
10. Calculation by equation of state
11. N_2 -- 0.2; other gases 0.2

Marchman, Prengle and Motard [19] coincide with an accuracy of 0.3% with data of Farrington and Sage. Results of Vaughn and Graves for low pressures agree satisfactorily with Marchman's data. At high pressures, however, deviations reach 1-2.7%.

Michels and coworkers [21] published data in the 0-150°C temperature range and 6-2,800 bar pressure range. The error is 0.03%. They investigated high-purity propylene.

Data [17, 18, 19] at pressures to 20-30 bar coincide with Michels' results within 0.3-0.5%. At higher pressures the discrepancies reach 3-3.5%.

Table 2. List of Works Containing Data on the p, v, T-Function of Propylene

1) Авторы	2) Год опубликования	3) Диапазон температур T, °C	4) Диапазон давлений p, бар	5) Метод эксперимента	6) Погрешность, %	7) Чистота исследованного газа, %
Воуген и Гревс [17]	1940	0—300	2—80	[17]	1	10) —
Фаррингтон и Сейдж [18]	1949	4—282	1—689	[18]	0,3	Примесей 0,11
Марчман, Пренгль, Мотард [19]	1949	30—250	0—215	[24]	0,25	99,7
Каньяр, Голдман, Марчман [20]	1951	(—40) — (+200)	1—200	8) Расчет по уравнению состояния	—	—
Михельс и сотрудники [21]	1953	5—150	6—2830	[15]	0,03	—
Пфенниг, Маккетта [13]	1957	32,2; 48,8; 69,9	1—2	[23]	0,1	99,7
Каньяр и сотрудники [22]	1963	—	—	9) Обработка данных	—	—
Дитмар и Шульц	1962	100, 110, 120, 130, 140	60—1000	—	—	—

KEY:

1. Authors	2. Year published
Vaughan and Graves [17]	3. Temperature range T, °C
Farrington and Sage [18]	4. Pressure range p, bar
Marchman, Prengle, Motard [19]	5. Experimental method
Michels, et al [21]	6. Error, %
Pfennig and McKetta [13]	7. Purity of investigated gas, %
Canjar, et al [22]	8. Calculation by equation of state
Ditmar and Schultz	9. Data processing
	10. Impurities

Published in [20] are data obtained by calculation according to the Benedict-Webb-Rubin equation, the constants of which were determined by Marchman on the basis of experimental data.

It follows from the above review that highly accurate experimental data exist for gaseous ethylene and propylene in a rather wide pressure range, but in a narrow temperature range of 0-150°C. Experimental data [6, 11, 13] for ethylene can also be recommended as reference material. The range of the gas adjacent to the right boundary of the curve is not experimentally investigated.

Analysis of Thermal Equations of State for Gaseous Ethylene and Propylene

Numerous equations of state, derived on the basis of existing experimental p, v, T-data for ethylene and propylene, have been published in Soviet and foreign literature.

The constants of the Benedict-Webb-Rubin (B-W-R) equation are given in [23, 25, 26]. In addition, Michels' equations of experimental isotherms are given in [5, 21]. Most recent are V. A. Zagoruchenko's equations of state [9, 27] and those of Ya. Z. Kazavchinskiy and V. A. Zagoruchenko [28]. The Martin-Hou [29] and Bentzler [30] equations are used to a lesser extent.

The equations of state describe the p, v, T-surface of ethylene and propylene with various accuracy, depending on the pressures and temperatures. Tables of reference data were compiled on the basis of the experimental data of Michels [5, 21] and Walters [6] for analysis of these equations, and were later used for checking the equations with the computer. Calculation results are presented in the form of nomograms in Figure 1.

The region encompassed by the experiment is cross hatched in the nomograms. The area of the nomograms is divided into regions by pressures, in which they are given with a constant step. The mean and maximum deviations of the experimental and calculated data are stated on the isotherms for each region, as are the average deviations for the entire region. The measure of deviation is the relation

$$\delta = \frac{p_{exp} - p_{calc}}{p_{exp}} \cdot 100\%.$$

The B-W-R equation (Figure 1a) can be used with confidence with a mean error not exceeding 0.1% for interpolation of the p, v, T-properties of ethylene to a pressure of the order of 20 bar at temperatures of 270-440°K. Here the maximum deviation does not exceed 0.2%. The maximum deviations occur in the region next to the saturation line.

The B-W-R equation describes the p, v, T-properties of propylene (Figure 1b) with lesser accuracy, but at pressures up to 10 bar the maximum deviations are 0.3-0.4% and the mean deviation for the given region of parameters is 0.19%. In the 10-100 bar pressure range the accuracy decreases; the mean deviation for the given region is 0.74%, whereas the maximum deviation near the saturation line is 5.5%.

Zagoruchenko's equation [9] for ethylene quite accurately describes the p, v, T-data (Figure 1c) in the 1-200 bar pressure range and 270-400°K temperature range, where the mean error does not exceed 0.2%. Here the maximum deviations up to a pressure of 20 bar fall within the limits of 0.2%. At higher pressures (300-1,800 and 1,500-3,000 bar) the mean deviation for the region is 2-3%, i.e., substantially exceeds the experimental error. The equation may be used for calculations in the 1-200 bar pressure range and 270-400°K temperature range.

The Kazavchinskiy-Zagoruchenko equation [28] (Figure 1d) should be considered unsuitable for describing the p, v, T-function of propylene, since it gives deviations exceeding the error of experimental determination of the p, v, T-data in the entire range of parameters (p = 1-3,000 bar and T = 270-440°K).

KEY: 1) Mean deviation
2) Maximum deviation

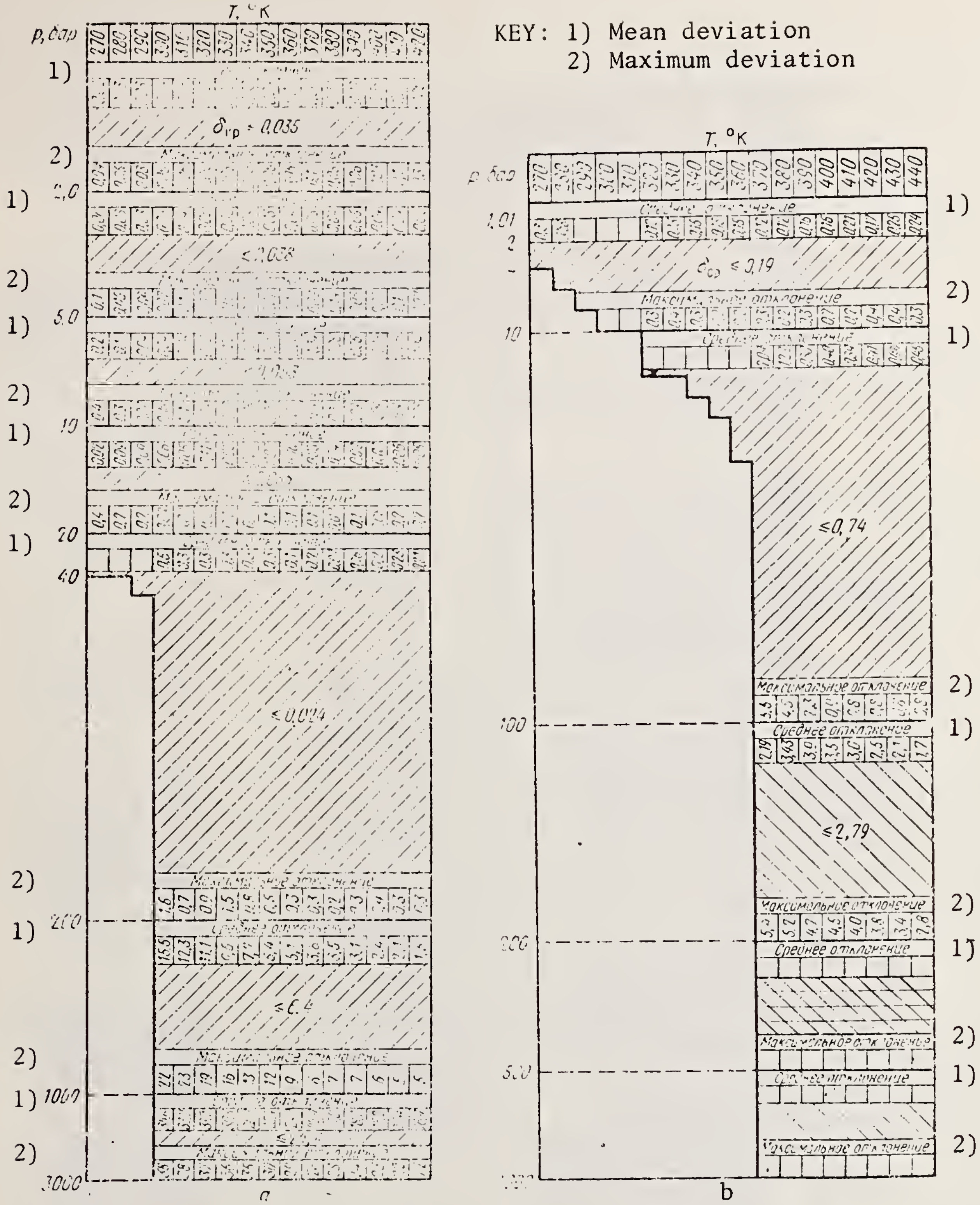
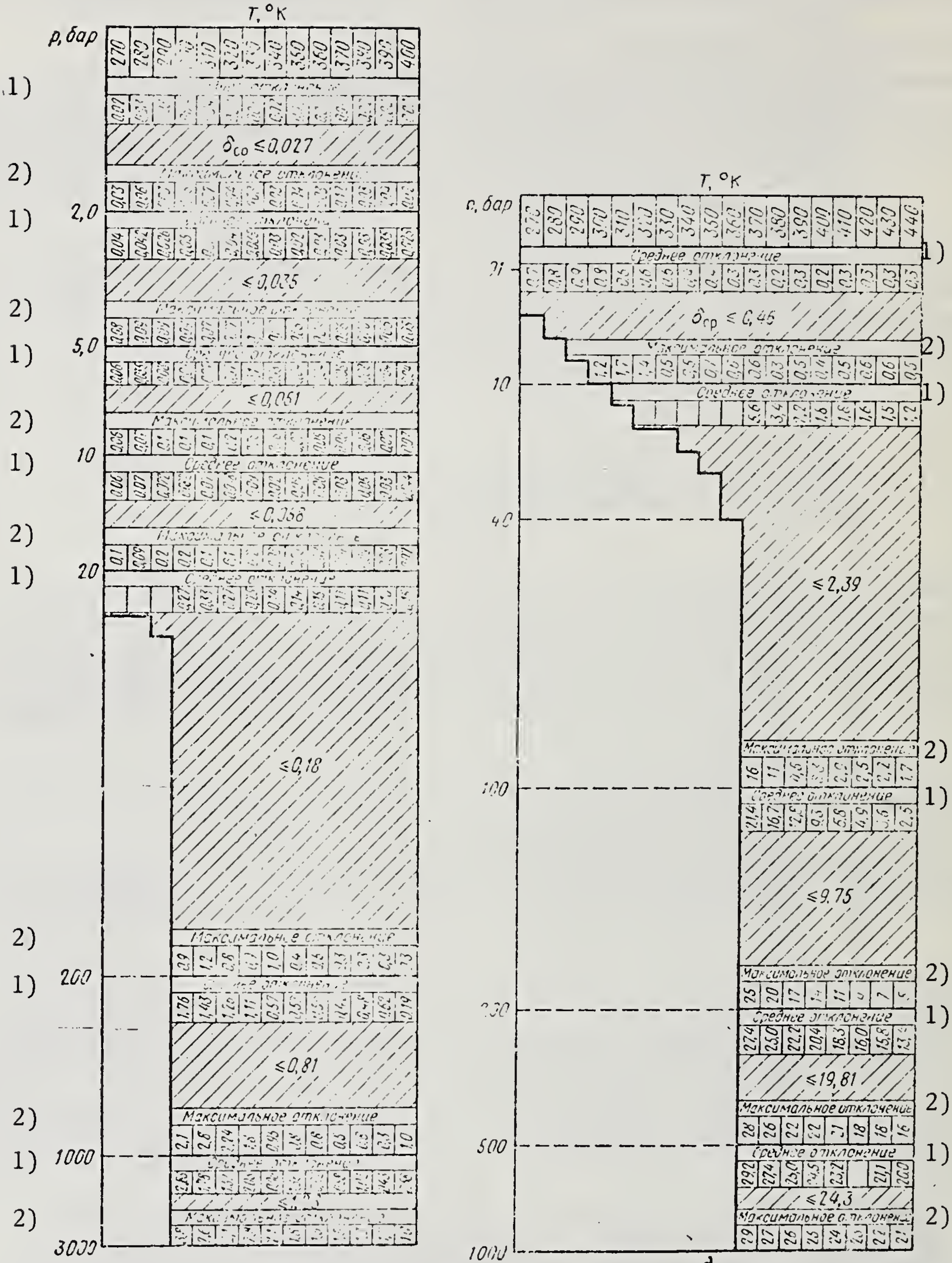


Figure 1. Field of errors of thermal equations of state for ethylene and propylene: a -- field of errors of the Benedict-Webb-Rubin equation for ethylene [23, 25, 26]; b -- field of errors of Benedict-Webb-Rubin equation for propylene [23, 25, 26]; c -- field of errors of Zagoruchenko's equation for ethylene [9]; d -- field of errors of the Kazavchinskiy-Zagoruchenko equation for propylene [28]; e -- field of errors of Zagoruchenko's equation for propylene [27]; f -- field of errors of Zagoruchenko's equation for liquid propylene [27]; density and equation of state of gaseous phase. [Continued on next page].

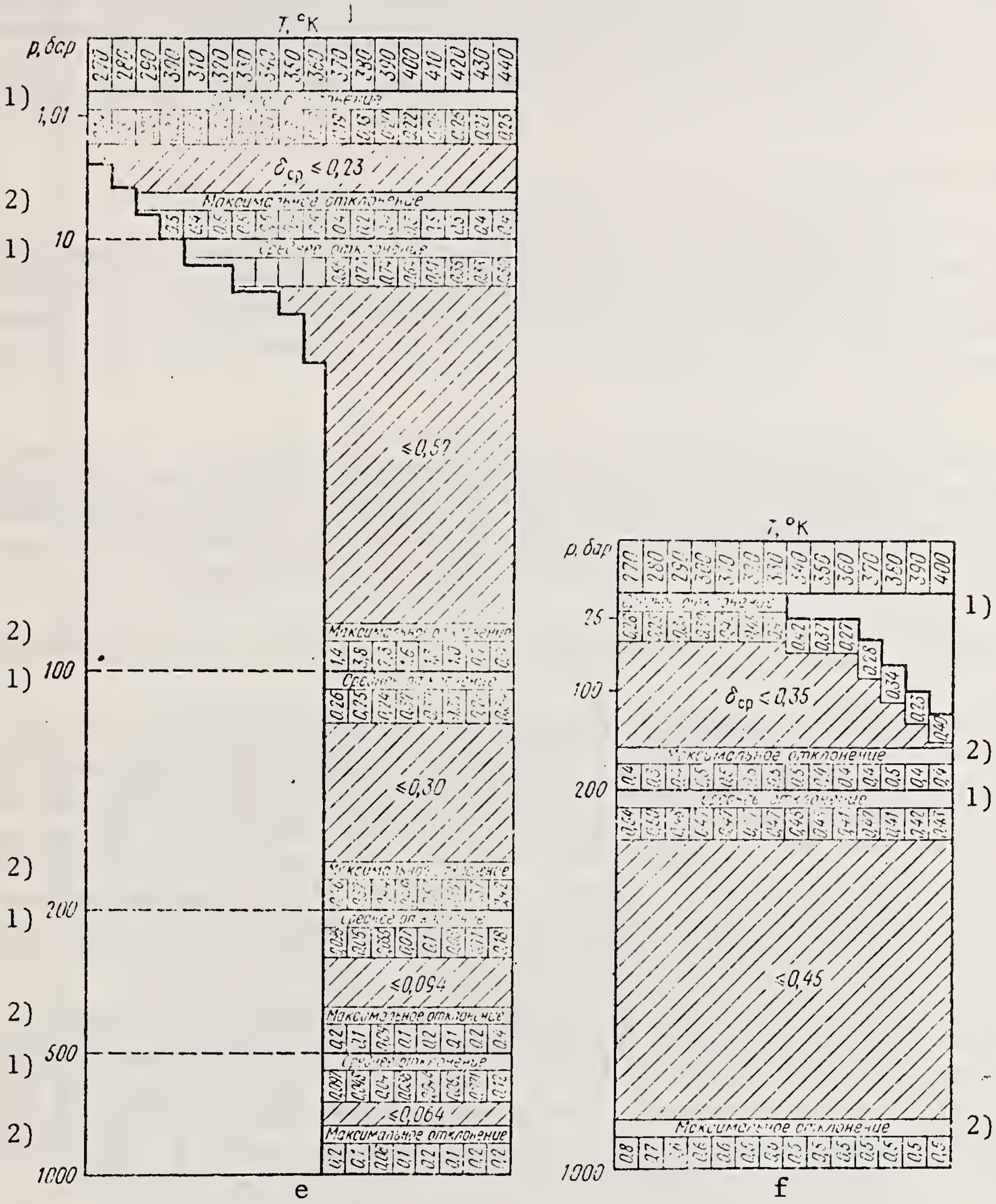


c

d

Figure 1.

[Continued on next page]



e f

Figure 1.

The Zagoruchenko equation [27] (Figure 1e) should be considered most accurate for propylene. Its maximum deviation in the near-critical region, however, reaches 3.8%. Here the path of the isotherm in p, v-coordinates does not correspond to the path of the experimental isotherms in the supercritical region. Equation [27] describes the range of the liquid state of propylene (Figure 1f).

It can be concluded on the basis of analysis of the existing equations of state of ethylene and propylene that none of the examined equations describes the experimental data in the entire, rather wide pressure range. The authors of this reference manual, therefore, attempted to derive equations of state for the entire gaseous range, for which experimental information exists for the p, v, T-data of ethylene and propylene.

Thermal Equations of State of Gaseous Ethylene and Propylene

Several methods are now being used [31, 32, 33] for formulating the equation of state on the basis of experimental data using polynomial theories. Approximation of the p, v, T-plane with the aid of orthogonal polynomials, as shown in the work of Pings and Sage [31], has certain advantages over other methods.

In the usual method of least squares the matrix of the linear equation system is usually poorly defined. The situation gets worse as the degree of approximation of the polynomial and the number of experimental points used for the approximation increase. In view of this the matrix inversion operation leads to considerable difficulties in the calculations.

When orthogonal polynomials are used the matrix becomes diagonal and the inversion operation is obviated.

The use of orthogonal polynomials increases the power of the approximating polynomial without repeated calculation of the coefficients, which were determined earlier for a lower power. However, the use of first and second order Chebyshev polynomials [31] for the given problem involves certain inconveniences. Specifically, the experimental data must be represented as a special matrix, where the roots of the stated polynomials are taken as the nodes of approximation, and this entails graphic processing of the data, which inevitably leads to loss of accuracy.

The essence of the proposed method of approximation consists in application of the Forsythe algorithm [34] to the case of the function of two variables. The advantage here is that it is not necessary to use a special lattice for representing the experimental data. If f(x, y) is integrable with weight R(x, y) in rectangle $a \leq x \leq b$, $c \leq y \leq d$, then to it can be compared the Fourier series

$$f(x, y) = \sum_{i,k} C_{ik}\omega_{ik}(x, y), \tag{1}$$

where

$$\omega_{ik}(x, y) = \varphi_i(x)\psi_k(y), \tag{2}$$

and $\phi_i(x)$, $\psi_k(y)$ are the orthogonals in the intervals $a \leq x \leq b$ and $c \leq y \leq d$, respectively.

Table 3. Experimental Data on Ethylene, Obtained by Michels [5]

ρ, кг/м³	T, °K					
	298,15	323,15	348,15	373,15	398,15	423,15
24,0011	—0,004773002	—0,003999019	—0,003372144	—0,002861105	—0,002430700	—0,002070435
30,0331	—0,004718516	—0,003950185	—0,003338368	—0,002824758	—0.002395936	—0,002035571
36,0723	—0,001660129	—0,003899881	—0.003286574	—0,002783019	—0,002360343	—0,001998264
41,3727	—0,004602637	—0,003849014	—0,003240539	—0,002742185	—0.002323290	—0,001964493
48,1758	—0,004542613	—0,003797906	—0,003194470	—0,002698760	—0.002283770	—0,001925877
54,3233	—0,001483302	—0,003744651	—0,003147510	—0,002657213	—0,002244337	—0,001889199
57,5087	—0,001453010	—0,003716992	—0,003124699	—0,002635797	—0,002223760	—0,001869550
60,3473	—0,004423645	—0.003692338	—0,003102637	—0,002616314	—0,002201391	—0,001852689
66,4886	—0,004361518	—0,003640761	—0,003056189	—0,002572466	—0,002164810	—0,001817314
86,9052	—0.004167517	—0,003467834	—0,002902234	—0,002432990	—0,002036316	—0,001694513
114,5069	—0,003897654	—0.003233581	—0,002695210	—0,002245092	—0,001862390	—0,001531020
140,9879	—0,003639934	—0,003013424	—0,002499258	—0.002065639	—0,001694252	—0,001370985
167,7538	—0,003385570	—0.002797355	—0,002304437	—0,001884025	—0,001521797	—0,001206184
193,2995	—0,003155591	—0,002596314	—0,002119352	—0,001709880	—0,001354258	—0,001042572
214,2292	—0,002975157	—0,002434611	—0,001966937	—0,001562670	—0,001210986	—0,000961264
234,4580	—0,002807599	—0,002278774	—0,001817294	—0,001416687	—0,001066450	—0,000757937
236,9904	—0,002786952	—0,002259169	—0,001798203	—0,001397932	—0,001047842	—0,000739038
248,9288	—0,002690233	—0,002166289	—0,001706863	—0,001307243	—0,000957562	—0,000649335
259,5158	—0,002601593	—0,002082638	—0,001623818	—0,001224347	—0,000874413	—0,005665592
261,6209	—0,002587632	—0,002065818	—0,001517961	—0.001207691	—0,000857618	—0,000549352
271,2261	—0,002509878	—0,001988107	—0,001528716	—0,001129265	—0,000778685	—0,000469957
279.1800	—0,002448470	—0.001922270	—0,001462689	—0,001062008	—0,000710962	—0,000401799
286,6927	—0,002382847	—0.001858816	—0,001398092	—0,0009966674	—0,000644989	—0,000335472
293,2096	—0,002328087	—0,001802365	—0,001340561	—0,0009381618	—0,000585782	—0,000273940
299,1088	—0,002277703	—0.001749958	—0,001286860	—0.0008835567	—0,000530560	—0,000220143
300,7601	—0,002263350	—0,001735188	—0,001271382	—0,000867738	—0,000514946	—0,000204486
304,6046	—0,002229619	—0,001699899	—0,001235314	—0,000831214	—0,000477789	—0,000166777
309,7728	—0,002184026	—0,001650108	—0,001186420	—0,000781433	—0,000427526	—0,000115966
319,3401	—0,002096379	—0,001560108	—0,001091393	—0,000679552	—0,000317555	—0,000091376
335,6134	—0,001937503	—0,001392761	—0,000919013	—0,000509027	—0,000151920	0,000159639

[Continued on next page]

Table 3 (Continued)

ρ, кг/м³	T, °K					
	298,15	323,15	348,15	373,15	398,15	423,15
347,9665	—0,001806622	—0,001255015	—0,000777278	—0,000359948	0,000025316	0,000315778
258,1768	—0,001690276	—0,001132893	—0,000651925	—0,000232823	0,000133398	0,000444389
367,8197	—0,001573200	—0,001010577	—0,000526682	—0,000112843	0,000249328	0,000563664
376,1896	—0,001464782	—0,000897785	—0,000411637	0,000010845	0,000378319	0,000689572
383,7905	—0,001360167	—0,000789801	—0,000301710	0,000121837	0,000189537	0,000800618
390,8620	—0,001258028	—0,000684228	—0,000191482	0,000223859	0,000584960	0,000897825
396,8979	—0,001166578	—0,000590260	—0,000099654	0,000318911	0,000679312	0,000992166
397,4921	—0,001157402	—0,000580872	—0,000090041	0,000328169	0,000689149	0,001002120
400,3914	—0,001106180	—0,000527800	—0,000037066	0,000382175	0,000750090	0,001060010
422,1103	—0,000736190	—0,000152745	0,000340980	0,000757380	0,001115547	0,001426558
425,7784	—0,000661645	—0,000075194	0,000420118	0,000834754	0,001199780	0,001505500
435,8248	—0,000467302	0,000117665	0,000610084	0,001033370	0,001397120	0,001699440
418,0266	—0,000291560	0,000380381	0,000870100	0,001281850	0,001633039	0,001936289
451,8712	—0,000109556	0,000476021	0,000968140	0,001375790	0,001734280	0,002031600
463,5688	—0,000155100	0,000746139	0,001235172	0,001615990	0,001999980	0,002291950
473,0732	0,000110465	0,000988117	0,001468413	0,001868763	0,002208180	0,002499004
477,0561	0,000524383	0,001101080	0,001586250	0,001981500	0,002327740	0,002612210
482,1522	0,000952152	0,001518366	0,001986781	0,002384680	0,002722640	0,002996700
498,1953	0,001139109	0,001700467	0,002161417	0,002544766	0,002868046	0,003143222
502,3172	0,001277400	0,001839020	0,002303070	0,002676560	0,003007020	0,003272790
519,7628	0,001862619	0,002401222	0,002812571	0,003214140	0,003534650	0,003778260
524,2121	0,002023614	0,002557382	0,002992662	0,003316608	0,003645321	0,003896890
528,1604	0,002192240	0,002722270	0,003157080	0,003500410	0,003806100	0,004045760
547,5573	0,002938323	0,003435089	0,003838223	0,004172990	0,004455210	0,004671080
550,8851	0,003079053	0,003569480	0,003965464	0,004282258	0,004546541	0,004767724
555,2464	0,003281660	0,003765360	0,004158540	0,004461250	0,004704280	0,004937560
556,2423	0,003325350	0,003807140	0,004198510	0,004499430	0,004769180	0,004972870
575,8686	0,004213080	0,004649751	0,004997600	0,005218075	0,005491882	0,005674577
576,4232	0,004239797	0,004675978	0,005021399	0,005300921	0,005546190	0,005717830
530,3182	0,004419580	0,004876930	0,00521945	0,005474120	0,00570394	0,005868842
592,2931	0,005059340	0,005455920	0,00576961	0,005997890	0,00620141	0,00634730
606,1336	0,005782717	0,006137675	0,006411056	0,006636720	0,00681328	0,00692838
629,7810	0,007065440	0,007469990	0,00767857	0,007811140	0,00792872	0,00799078
633,9533	0,007422066	0,007713540	0,00790844	0,008029520	0,00813538	0,00818753

The system of orthogonal functions $\phi_i(x)$ is constructed in the examined range of change of the argument by means of orthogonalization of the system of power functions 1, x, ..., x^n, ... with unit weight.

The polynomials $\phi_i(x)$ satisfy the recurrent relations

$$\begin{aligned} \varphi_0 &= 1 \\ \varphi_1 &= x + a_1^0 \\ \varphi_2 &= (x + a_2^1)\varphi_1 + a_2^0\varphi_0 \\ \varphi_3 &= (x + a_3^1)\varphi_2 + a_3^0\varphi_1 \\ &\cdots\cdots\cdots\cdots \\ \varphi_{n+1} &= (x + a'_{n+1})\varphi_n + a_{n+1}\varphi_{n-1}, \end{aligned} \tag{3}$$

where the coefficients a'_n and a°_n are determined from the conditions of orthogonality

$$(\phi_i, \phi_j) = 0, \text{ if } i \neq j. \tag{4}$$

The condition of orthogonality of polynomials ϕ_i is determined on the discrete set of values of the argument x. Such a set, in particular, may be temperatures at which the experimental investigations were conducted.

The coefficients a'_n and a°_n of the polynomials $\phi_i(x)$ and $\psi_k(y)$ are thus defined by the equations:

$$a'_n = \frac{(\varphi_n, x\varphi_n)}{(\varphi_n, \varphi_n)} = \frac{\sum\limits_{i=1}^{N} x_i\varphi_n^2(x_i)}{\sum\limits_{i=1}^{N} \varphi_n^2(x_i)}; \tag{5}$$

$$a^\circ_n = \frac{(x\varphi_{n-1}, \varphi_n)}{(\varphi_{n-1}, \varphi_{n-1})} = \frac{\sum\limits_{i=1}^{N} x_i\varphi_{n-1}(x_i)\varphi_n(x_i)}{\sum\limits_{i=1}^{N} \varphi_{n-1}^2(x_i)}. \tag{6}$$

The coefficients C_{ik} in equation (1) are determined from the condition of the minimum mean square deviation of series (1) from the function f(x, y):

$$\sum_{\alpha,\beta}^{M,N} \delta^2_{\alpha,\beta} = \min, \tag{7}$$

where $\delta_{\alpha,\beta} = f(x_\alpha, y_\beta) - \sum\limits_{i,k}^{m,n} C_{ik}\omega_{ik}(x_\alpha, y_\beta)$; m, n are the maximum powers of the expansions in terms of the variables x and y, respectively; M, N are the numbers of values of the arguments x and y, respectively, according to which the orthogonal functions $\phi_i(x)$ and $\psi_k(y)$ are constructed.

$$-2\sum_{\alpha,\beta}^{M,N}\Big[f(x_\alpha, y_\beta)-\sum_{j,l=1}^{m,n}C_{jl}\omega_{jl}(x_\alpha, y_\beta)\Big]\omega_{ik}(x_\alpha, y_\beta)=0;$$

$$\sum_{\alpha,\beta}^{M,N}f(x_\alpha, y_\beta)\,\omega_{ik}(x_\alpha, y_\beta)-C_{ik}\sum_{\alpha,\beta}^{M,N}\omega_{ik}^2(x_\alpha, y_\beta)=0;$$

$$C_{ik}=\frac{\sum\limits_{\alpha,\beta}^{M,N}f(x_\alpha, y_\beta)\,\omega_{ik}(x_\alpha, y_\beta)}{\sum\limits_{\alpha,\beta}^{M,N}\omega_{ik}^2(x_\alpha, y_\beta)}. \qquad (8)$$

In our work the variables were selected as follows:

$$x=\frac{1}{v};\quad y=\frac{1}{T},\quad f(x, y)=\left(\frac{pv}{RT}-1\right)v. \qquad (9)$$

The program that executed the described algorithm was written in the command system of the BESM-3M computer[1].

To calculate the coefficients of the polynomials ϕ_i, ψ_k and C_{ik} we used experimental data of Michels [5, 21], presented in Tables 3 and 4.

Table 4. Michels' [21] Experimental Data on Propylene

$$f(x, y)=\left(\frac{pv}{RT}-1\right)v;\ [\rho]=\frac{кг}{м^3};\ [T]={}^\circ K$$

ρ, кг/м³	Date for T, °K			
	298,15	318,15	323,15	348,15
12,4233	—0,008142940	—0,007059020	—0,006824940	—0,005787110
15,9476	—0,008114905	—0,007031900	—0,006795350	—0,005761340
19,4701	—0,008087200	—0,007000590	—0,006762940	—0,005733210
23,1491	—0,008057070	—0,006968650	—0,006727450	—0,005698640
27,5319	—0,008022750	—0,006929450	—0,006683050	—0,005657940
31,0289	—0,007987100	—0,006890240	—0,006638430	—0,005616470
35,0957	—0,007954700	—0,007852010	—0,006612500	—0,005585090
37,3027	—0,007943500	—0,006842220	—0,006581440	—0,005561000
43,9904	—0,007888800	—0,006782570	—0,006524020	—0,005492450

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[1] The authors gratefully acknowledge the cooperation of S. A. Mednikova of the NIIASS [Nauchno-issledovatel'skiy institut avtomatizatsii sistem planirovaniya i upravleniya stroitel'stvom; Scientific-Research Institute of Automation of Construction Planning and Control Systems], Gosstroy [Gosudarstvennyy komitet po delam stroitel'stva; State Committee for Construction] Ukrainian SSR in the writing of the program.

Table 4 (Continued)

ρ, кг/м³	Data for T, °K		
	373,15	398,15	423,15
12,4233	—0,004962120	—0,004290550	—0,003732490
15,9476	—0,004940160	—0,004270200	—0,003711970
19,4701	—0,004915570	—0,004247620	—0,003688400
23,1491	—0,004885230	—0,004220770	—0,003663540
27,5319	—0,004847360	—0,004186510	—0,003632940
31,0289	—0,004809250	—0,004154600	—0,003600700
35,0957	—0,004779940	—0,004124790	—0,003574840
37,3027	—0,004760250	—0,004106960	—0,003558860
43,9904	—0,004694800	—0,004047790	—0,003506590
52,8926	—0,004610220	—0,003971950	—0,003438198
61,5480	—0,004527430	—0,003898150	—0,003371820
70,6220	—0,004439900	—0,003819860	—0,003302120
79,6525	—0,004353160	—0,003743200	—0,003233700
81,0886	—0,004339190	—0,003730270	—0,003223200
88,3320	—0,004269306	—0,003669145	—0,003167406
90,4661	—0,004248370	—0,003650646	—0,003152033
97,4213	—0,004180899	—0,003591424	—0,003098313
100,6545	—0,004149677	—0,003563372	—0,003074903
110,4019	—0,004055528	—0,003480733	—0,003013851
120,8869	—0,003954789	—0,003392546	—0,002923342
126,7396	—0,003898867	—0,003344120	—0,002879851
130,4939	—0,003863234	—0,003313040	—0,002852312
140,6368	—0,003767124	—0,003230031	—0,002778148
141,3968	—0,003759930	—0,003223810	—0,002772800
150,8833	—0,003671041	—0,003147013	—0,002704459
157,3202	—0,003611516	—0.003095750	—0,002658556
172,5556	—0,003472976	—0.002976295	—0,002551512
183,1000	—0,003379121	—0,002895448	—0,002478264
188,9419	—0,003327957	—0,002851226	—0,002437862
203,9584	—0,003199102	—0,002739256	—0,002335080
204,2748	—0,003196466	—0,002736923	—0,002332858
219,8116	—0,003068101	—0,002623556	—0,002274196
227,2808	—0,003000793	—0,002569638	—0,002176840
235,8269	—0,002940571	—0,002508671	—0,002119053
249,2921	—0,002837236	—0,002413168	—0,002027679
272,9678	—0,002662616	—0,002246414	—0,001864452
277,1274	—0,002632549	—0,002217066	—0,001835143
294,6654	—0,002507271	—0,002091436	—0,001708965
309,1809	—0,002402842	—0,001981736	—0,001599899
311,3877	—0,002386988	—0,001968078	—0,001583050
317,5738	—0,002341959	—0,001920800	—0,001534271
340,7207	—0,002166257	—0,001734836	—0,001341329
344,0120	—0,002139894	—0,001707144	—0,001312372
347,4115	—0,002112652	—0,001677987	—0,001281994
377,3512	—0,001847991	—0,001395206	—0,000986096
386,5670	—0,001756669	—0,001297730	—0,000885584
402,2806	—0,001586016	—0.001117288	—0,000698908
413,2332	—0,001455716	—0.000980292	—0,000556661
424,0634	—0,001316276	—0,000834272	—0,000407116
446,1533	—0,000993027	—0,000499693	—0,000064850
448,9080	—0,000949140	—0,000454476	—0,000196579
464,4563	—0.000682212	—0,000181321	—0,000257318
480,9735	—0,000363010	—0.000142303	—0,000583351
499,7097	—0,000048175	—0,000555590	—0,000998587
501,5707	—0,000092114	—0.000599570	—0,001041855
516,2530	—0.000459127	—0,000965308	—0,001404222
540,9137	—0,001181318	—0.001661405	—0,002031397
548,5700	—0,001403807	—0 001898789	—0,002324141
580,9129	—0,002558346	—0,003027422	—0,003427535
601,5930	—0,003418701	—0,003863837	—0,004238065
650,9040	—0,005905562	—0,006264682	—0,006556777

The equation of state is written in the form

$$\left(\frac{pv}{RT}-1\right)v=\sum_{i,k=1}^{m,n} C_{ik}\varphi_i\left(\frac{1}{v}\right)\psi_k\left(\frac{1}{T}\right), \qquad (10)$$

from which it is easy to convert to the Virial form by reduction of like terms.

The conversion to the Virial form is provided for by the program and is executed after calculation of the coefficients of the polynomials ϕ_i, ψ_k and coefficients C_{ik}.

In the theory of approximation of the functions of two variables there is no explicit criterion for determining the optimum number of powers of the expansion with respect to each of the variables. Therefore the optimum power of the expansion in terms of 1/v and 1/T was found as a set of powers. Here the deviations at the points and the minimum sum of squares of deviations were the criterion.

Equation (10) is written in Virial form as

$$\frac{pv}{RT}=1+\sum_{i=1}^{m}\frac{1}{v^i}\sum_{k=0}^{n}C'_{ik}\left(\frac{1}{T}\right)^k. \qquad (11)$$

This method requires a rectangular network of experimental data. For this reason the field of p, v, T-data of propylene is broken down into two regions, for each of which is constructed an equation of the form (11).

The constants determined by the above-described method for the equations are presented below.

Ethylene ($p = 1 - 3000$ bar, $T = 250 - 450°$ K)

$C_{01} = +0{,}760072429$ $\qquad C_{02} = -0{,}548705429 \cdot 10^{-1}$

$C_{11} = -0{,}134563848 \cdot 10^{4}$ $\qquad C_{12} = +0{,}972058755 \cdot 10^{2}$

$C_{21} = +0{,}950060646 \cdot 10^{6}$ $\qquad C_{22} = -0{,}686258650 \cdot 10^{5}$

$C_{31} = -0{,}334667515 \cdot 10^{9}$ $\qquad C_{32} = +0{,}241393035 \cdot 10^{8}$

$C_{41} = +0{,}587269730 \cdot 10^{11}$ $\qquad C_{42} = -0{,}423108315 \cdot 10^{10}$

$C_{51} = -0{,}410898360 \cdot 10^{13}$ $\qquad C_{52} = +0{,}295678870 \cdot 10^{12}$

$C_{03} = +0{,}132142978 \cdot 10^{-2}$ $\qquad C_{04} = -0{,}144380734 \cdot 10^{-4}$

$C_{13} = -0{,}233803377 \cdot 10^{1}$ $\qquad C_{14} = +0{,}255267906 \cdot 10^{-1}$

$C_{23} = +0{,}164875060 \cdot 10^{4}$ $\qquad C_{24} = -0{,}179881158 \cdot 10^{2}$

$C_{33} = -0{,}579326847 \cdot 10^{6}$ $\qquad C_{34} = +0{,}631603632 \cdot 10^{4}$

[Continued on next page]

$C_{43} = +0{,}101441262 \cdot 10^{9}$ $\quad C_{44} = -0{,}110517516 \cdot 10^{7}$

$C_{53} = -0{,}708228885 \cdot 10^{10}$ $\quad C_{54} = +0{,}771067345 \cdot 10^{8}$

$C_{05} = +0{,}831940857 \cdot 10^{-7}$ $\quad C_{06} = -0{,}269842664 \cdot 10^{-9}$

$C_{15} = -0{,}147018406 \cdot 10^{-3}$ $\quad C_{16} = +0{,}476717255 \cdot 10^{-6}$

$C_{25} = +0{,}103550508$ $\quad C_{26} = -0{,}335666604 \cdot 10^{-3}$

$C_{35} = -0{,}363412433 \cdot 10^{2}$ $\quad C_{36} = +0{,}117765335$

$C_{45} = +0{,}635581200 \cdot 10^{4}$ $\quad C_{46} = -0{,}2055894276 \cdot 10^{2}$

$C_{55} = -0{,}443212965 \cdot 10^{6}$ $\quad C_{56} = +0{,}143526876 \cdot 10^{4}$

$C_{07} = +0{,}494436598 \cdot 10^{-12}$ $\quad C_{08} = -0{,}476946020 \cdot 10^{-15}$

$C_{17} = -0{,}873357290 \cdot 10^{-9}$ $\quad C_{18} = +0{,}842422128 \cdot 10^{-12}$

$C_{27} = +0{,}614844932 \cdot 10^{-6}$ $\quad C_{28} = -0{,}593032017 \cdot 10^{-9}$

$C_{37} = -0{,}215673041 \cdot 10^{-3}$ $\quad C_{38} = +0{,}208007008 \cdot 10^{-6}$

$C_{47} = +0{,}376996322 \cdot 10^{-1}$ $\quad C_{48} = -0{,}363565579 \cdot 10^{-4}$

$C_{57} = -0{,}262743658 \cdot 10^{1}$ $\quad C_{58} = +0{,}253357565 \cdot 10^{-2}$

$C_{09} = +0{,}188031735 \cdot 10^{-18}$

$C_{19} = -0{,}332130351 \cdot 10^{-15}$

$C_{29} = +0{,}233813590 \cdot 10^{-12}$

$C_{39} = -0{,}820120622 \cdot 10^{-10}$

$C_{40} = +0{,}143345912 \cdot 10^{-7}$

$C_{59} = -0{,}998924485 \cdot 10^{-6}$

Propylene. ($T = 270 - 450°\,\mathrm{K}$, $\quad p = 1 - 30$ bar)

$C_{01} = -0{,}396637152 \cdot 10^{1}$ $\quad C_{02} = +0{,}860745715$

$C_{11} = +0{,}678436327 \cdot 10^{4}$ $\quad C_{12} = -0{,}147721665 \cdot 10^{4}$

$C_{21} = -0{,}463021591 \cdot 10^{7}$ $\quad C_{22} = +0{,}101148055 \cdot 10^{7}$

$C_{31} = +0{,}157557275 \cdot 10^{10}$ $\quad C_{32} = -0{,}345410258 \cdot 10^{9}$

$C_{41} = -0{,}267451170 \cdot 10^{12}$ $\quad C_{43} = +0{,}588277177 \cdot 10^{11}$

$C_{51} = +0{,}181147750 \cdot 10^{14}$ $\quad C_{52} = -0{,}399749543 \cdot 10^{13}$

$C_{03} = -0{,}634256919 \cdot 10^{-1}$ $\quad C_{04} = +0{,}189023628 \cdot 10^{-2}$

$C_{13} = +0{,}109085668 \cdot 10^{3}$ $\quad C_{14} = -0{,}325404985 \cdot 10^{1}$

$C_{23} = -0{,}748515689 \cdot 10^{5}$ $\quad C_{24} = +0{,}223489403 \cdot 10^{4}$

$C_{33} = +0{,}256142088 \cdot 10^{8}$ $\quad C_{34} = -0{,}765471148 \cdot 10^{6}$

[Continued on next page]

$$C_{43} = -0{,}437127355 \cdot 10^{10} \qquad C_{44} = +0{,}130749631 \cdot 10^{9}$$

$$C_{53} = +0{,}297625345 \cdot 10^{12} \qquad C_{54} = -0{,}891006876 \cdot 10^{10}$$

$$C_{05} = -0{,}1\text{[illegible]} \cdot 10^{\text{[illegible]}}$$

$$C_{15} = +0{,}334256852 \cdot 10^{-1}$$

$$C_{25} = -0{,}229744935 \cdot 10^{2}$$

$$C_{35} = +0{,}787500243 \cdot 10^{4}$$

$$C_{45} = -0{,}134615528 \cdot 10^{7}$$

$$C_{55} = +0{,}918055308 \cdot 10^{8}$$

Propylene ($T = 370 - 450°$ K, $p = 1 - 3000$ bar)

$$C_{01} = 0{,}65985925 \cdot 10^{-3} \qquad C_{02} = +0{,}446437162 \cdot 10^{-4}$$

$$C_{11} = -0{,}107675927 \qquad C_{12} = -0{,}343637737 \cdot 10^{-1}$$

$$C_{21} = -0{,}761754943 \cdot 10^{3} \qquad C_{22} = +0{,}758758270 \cdot 10^{1}$$

$$C_{03} = -0{,}707839462 \cdot 10^{-6} \qquad C_{04} = +0{,}199772917 \cdot 10^{-8}$$

$$C_{13} = +0{,}586824620 \cdot 10^{-3} \qquad C_{14} = -0{,}202807342 \cdot 10^{-5}$$

$$C_{23} = -0{,}114654261 \qquad C_{24} = +0{,}433482162 \cdot 10^{-3}$$

$$C_{05} = +0{,}238533263 \cdot 10^{-10} \qquad C_{06} = -0{,}169756637 \cdot 10^{-12}$$

$$C_{15} = -0{,}166153171 \cdot 10^{-7} \qquad C_{16} = +0{,}129786612 \cdot 10^{-9}$$

$$C_{25} = +0{,}309699415 \cdot 10^{-5} \qquad C_{26} = -0{,}255484795 \cdot 10^{-7}$$

$$C_{07} = +0{,}434039867 \cdot 10^{-15} \qquad C_{08} = -0{,}500738055 \cdot 10^{-18}$$

$$C_{17} = -0{,}340026491 \cdot 10^{-12} \qquad C_{18} = +0{,}396632938 \cdot 10^{-15}$$

$$C_{27} = +0{,}680235451 \cdot 10^{-10} \qquad C_{28} = -0{,}799576203 \cdot 10^{-13}$$

$$C_{09} = +0{,}218934207 \cdot 10^{-21}$$

$$C_{09} = -0{,}174502194 \cdot 10^{-18}$$

$$C_{29} = +0{,}353268277 \cdot 10^{-16}$$

The deviations at the points, i.e., the differences between the experimental values of f(x, y) and those calculated according to the equations, are listed in Tables 5 and 6.

The mean pressure deviations on the isotherm

$$\delta = \frac{p_{exp} - p_{calc}}{p_{exp}} \cdot 100\%$$

in the entire region of states covered by the experiment on ethylene [5] and propylene [21], are found within the limits of 0.1-0.2%.

The proposed method of writing the interpolation equations of state is suitable for the description of the p, v, T-data in wide temperature and

Table 5. Field of Errors of Equations of State of Ethylene

$$\Delta = f(x, y)_{exp} - f(x, y)_{theo}$$

ρ, кг/м³	Δ at T, °K					
	298,15	323,15	348,15	373.15	398.15	423,15
24,0012	$+0{,}2924\cdot10^{-5}$	$+0{,}6747\cdot10^{-6}$	$+0{,}3936\cdot10^{-5}$	$+0{,}2158\cdot10^{-6}$	$+0{,}4282\cdot10^{-5}$	$+0{,}7308\cdot10^{-5}$
30,0331	$-0{,}1699\cdot10^{-5}$	$-0{,}6963\cdot10^{-6}$	$-0{,}6841\cdot10^{-5}$	$-0{,}1965\cdot10^{-5}$	$+0{,}1336\cdot10^{-5}$	$-0{,}6999\cdot10^{-5}$
36,0723	$-0{,}2121\cdot10^{-5}$	$-0{,}9630\cdot10^{-6}$	$-0{,}1244\cdot10^{-6}$	$-0{,}1060\cdot10^{-5}$	$-0{,}2751\cdot10^{-5}$	$+0{,}3237\cdot10^{-5}$
41,9728	$-0{,}1099\cdot10^{-5}$	$+0{,}2434\cdot10^{-6}$	$+0{,}1589\cdot10^{-5}$	$+0{,}3588\cdot10^{-6}$	$-0{,}2956\cdot10^{-5}$	$-0{,}1302\cdot10^{-6}$
48,1758	$-0{,}4196\cdot10^{-6}$	$-0{,}1841\cdot10^{-6}$	$+0{,}8427\cdot10^{-6}$	$+0{,}6818\cdot10^{-6}$	$-0{,}2367\cdot10^{-5}$	$-0{,}1574\cdot10^{-6}$
54,3234	$-0{,}1413\cdot10^{-6}$	$+0{,}1357\cdot10^{-7}$	$+0{,}1249\cdot10^{-5}$	$-0{,}8962\cdot10^{-7}$	$-0{,}1375\cdot10^{-5}$	$-0{,}6527\cdot10^{-7}$
57,5087	$-0{,}4270\cdot10^{-6}$	$+0{,}5883\cdot10^{-6}$	$-0{,}1011\cdot10^{-6}$	$-0{,}3653\cdot10^{-6}$	$-0{,}6881\cdot10^{-6}$	$-0{,}6815\cdot10^{-6}$
60,3474	$+0{,}1713\cdot10^{-5}$	$+0{,}1078\cdot10^{-5}$	$+0{,}4132\cdot10^{-6}$	$-0{,}3578\cdot10^{-6}$	$+0{,}9625\cdot10^{-6}$	$+0{,}5916\cdot10^{-6}$
66.4886	$+0{,}1745\cdot10^{-5}$	$+0{,}3111\cdot10^{-6}$	$+0{,}2205\cdot10^{-6}$	$+0{,}1233\cdot10^{-5}$	$+0{,}2208\cdot10^{-5}$	$-0{,}6743\cdot10^{-6}$
86,9053	$+0{,}6238\cdot10^{-6}$	$-0{,}9335\cdot10^{-6}$	$-0{,}6416\cdot10^{-6}$	$+0{,}4032\cdot10^{-6}$	$+0{,}2820\cdot10^{-5}$	$+0{,}5165\cdot10^{-6}$
114.507	$-0{,}3359\cdot10^{-6}$	$-0{,}4102\cdot10^{-6}$	$-0{,}8343\cdot10^{-6}$	$-0{,}2662\cdot10^{-6}$	$+0{,}2073\cdot10^{-5}$	$-0{,}5468\cdot10^{-6}$
140.988	$-0{,}9027\cdot10^{-6}$	$-0{,}4054\cdot10^{-7}$	$-0{,}3995\cdot10^{-6}$	$-0{,}2818\cdot10^{-6}$	$+0{,}6400\cdot10^{-6}$	$+0{,}4049\cdot10^{-7}$
167,754	$+0{,}6385\cdot10^{-7}$	$-0{,}1322\cdot10^{-6}$	$-0{,}2192\cdot10^{-6}$	$+0{,}2941\cdot10^{-6}$	$-0{,}4884\cdot10^{-6}$	$-0{,}3967\cdot10^{-7}$
193.299	$-0{,}5980\cdot10^{-6}$	$+0{,}1219\cdot10^{-6}$	$+0{,}3476\cdot10^{-6}$	$-0{,}1309\cdot10^{-6}$	$-0{,}2038\cdot10^{-5}$	$-0{,}7316\cdot10^{-7}$
214,229	$-0{,}2042\cdot10^{-6}$	$+0{,}1759\cdot10^{-6}$	$+0{,}6143\cdot10^{-6}$	$+0{,}6190\cdot10^{-6}$	$-0{,}1742\cdot10^{-5}$	$+0{,}7697\cdot10^{-5}$
234,458	$-0{,}1567\cdot10^{-6}$	$+0{,}2358\cdot10^{-6}$	$+0{,}2576\cdot10^{-6}$	$-0{,}9505\cdot10^{-7}$	$-0{,}1485\cdot10^{-5}$	$+0{,}2187\cdot10^{-6}$
236,990	$-0{,}1508\cdot10^{-6}$	$+0{,}2528\cdot10^{-6}$	$+0{,}2477\cdot10^{-6}$	$-0{,}1781\cdot10^{-6}$	$-0{,}1487\cdot10^{-5}$	$+0{,}4614\cdot10^{-6}$
248,929	$-0{,}4066\cdot10^{-7}$	$+0{,}1823\cdot10^{-6}$	$+0{,}2466\cdot10^{-6}$	$-0{,}3013\cdot10^{-7}$	$-0{,}9275\cdot10^{-6}$	$-0{,}1742\cdot10^{-7}$
259,516	$+0{,}3451\cdot10^{-6}$	$+0{,}1671\cdot10^{-6}$	$+0{,}1398\cdot10^{-6}$	$-0{,}1612\cdot10^{-6}$	$-0{,}4476\cdot10^{-6}$	$-0{,}5956\cdot10^{-6}$
261,621	$+0{,}3465\cdot10^{-6}$	$+0{,}1352\cdot10^{-6}$	$+0{,}4237\cdot10^{-6}$	$-0{,}3501\cdot10^{-6}$	$-0{,}4802\cdot10^{-6}$	$-0{,}3759\cdot10^{-6}$
271,226	$+0{,}4478\cdot10^{-6}$	$+0{,}1430\cdot10^{-6}$	$+0{,}9391\cdot10^{-6}$	$-0{,}4562\cdot10^{-6}$	$-0{,}1341\cdot10^{-6}$	$-0{,}3607\cdot10^{-6}$
279,180	$+0{,}5617\cdot10^{-6}$	$+0{,}1674\cdot10^{-6}$	$-0{,}2178\cdot10^{-6}$	$-0{,}4118\cdot10^{-6}$	$+0{,}8392\cdot10^{-7}$	$-0{,}4074\cdot10^{-6}$
286,963	$+0{,}4185\cdot10^{-6}$	$+0{,}2833\cdot10^{-8}$	$-0{,}2998\cdot10^{-6}$	$-0{,}5793\cdot10^{-6}$	$+0{,}7346\cdot10^{-7}$	$-0{,}7500\cdot10^{-6}$
293,210	$+0{,}3893\cdot10^{-6}$	$-0{,}6524\cdot10^{-7}$	$-0{,}4543\cdot10^{-6}$	$-0{,}6368\cdot10^{-6}$	$+0{,}1522\cdot10^{-6}$	$-0{,}9201\cdot10^{-6}$
299,109	$+0{,}2929\cdot10^{-6}$	$-0{,}3028\cdot10^{-7}$	$-0{,}3596\cdot10^{-6}$	$-0{,}5458\cdot10^{-6}$	$+0{,}2316\cdot10^{-6}$	$-0{,}7580\cdot10^{-6}$
300,760	$+0{,}3430\cdot10^{-6}$	$-0{,}1438\cdot10^{-6}$	$-0{,}1386\cdot10^{-6}$	$-0{,}2562\cdot10^{-6}$	$+0{,}1220\cdot10^{-6}$	$-0{,}9567\cdot10^{-6}$
304,605	$+0{,}4513\cdot10^{-6}$	$+0{,}8993\cdot10^{-7}$	$-0{,}3911\cdot10^{-6}$	$-0{,}3601\cdot10^{-6}$	$+0{,}1647\cdot10^{-6}$	$-0{,}6552\cdot10^{-6}$
309,773	$+0{,}6749\cdot10^{-7}$	$-0{,}2777\cdot10^{-6}$	$-0{,}5298\cdot10^{-6}$	$-0{,}9064\cdot10^{-6}$	$-0{,}6171\cdot10^{-6}$	$-0{,}1250\cdot10^{-5}$
319,340	$-0{,}1014\cdot10^{-6}$	$-0{,}3047\cdot10^{-6}$	$-0{,}2897\cdot10^{-6}$	$+0{,}4306\cdot10^{-5}$	$+0{,}1118\cdot10^{-4}$	$-0{,}6850\cdot10^{-5}$
339,613	$-0{,}4649\cdot10^{-6}$	$-0{,}4617\cdot10^{-6}$	$-0{,}4348\cdot10^{-6}$	$-0{,}1143\cdot10^{-5}$	$-0{,}2100\cdot10^{-5}$	$-0{,}3807\cdot10^{-5}$
347,967	$-0{,}6951\cdot10^{-6}$	$-0{,}5443\cdot10^{-6}$	$-0{,}5229\cdot10^{-6}$	$+0{,}3461\cdot10^{-5}$	$-0{,}8272\cdot10^{-5}$	$-0{,}3505\cdot10^{-5}$

[Continued on next page]

Table 5 (Continued)

ρ, кг/м³	Δ at T, °K					
	298,15	323,15	348,15	373,15	398,15	423,15
358,177	$-0{,}6971\cdot10^{-6}$	$-0{,}3830\cdot10^{-6}$	$-0{,}3094\cdot10^{-6}$	$+0{,}3271\cdot10^{-5}$	$+0{,}7127\cdot10^{-5}$	$+0{,}5199\cdot10^{-5}$
367,820	$-0{,}1055\cdot10^{-5}$	$-0{,}7003\cdot10^{-6}$	$-0{,}7420\cdot10^{-6}$	$-0{,}4126\cdot10^{-5}$	$-0{,}5984\cdot10^{-5}$	$-0{,}4010\cdot10^{-5}$
376,190	$-0{,}1157\cdot10^{-5}$	$-0{,}7588\cdot10^{-6}$	$-0{,}9328\cdot10^{-6}$	$+0{,}2979\cdot10^{-5}$	$+0{,}5180\cdot10^{-5}$	$+0{,}4753\cdot10^{-5}$
383,791	$-0{,}1167\cdot10^{-5}$	$-0{,}8149\cdot10^{-6}$	$-0{,}1041\cdot10^{-5}$	$+0{,}2956\cdot10^{-5}$	$+0{,}4478\cdot10^{-5}$	$+0{,}4659\cdot10^{-5}$
390,862	$-0{,}1083\cdot10^{-5}$	$-0{,}8130\cdot10^{-6}$	$-0{,}9746\cdot10^{-6}$	$+0{,}2929\cdot10^{-5}$	$-0{,}8606\cdot10^{-5}$	$-0{,}5781\cdot10^{-5}$
396,900	$-0{,}1313\cdot10^{-5}$	$-0{,}1054\cdot10^{-5}$	$-0{,}1549\cdot10^{-5}$	$-0{,}5697\cdot10^{-5}$	$-0{,}1037\cdot10^{-4}$	$-0{,}6721\cdot10^{-5}$
397,492	$-0{,}1356\cdot10^{-5}$	$-0{,}1121\cdot10^{-5}$	$-0{,}1197\cdot10^{-5}$	$-0{,}5729\cdot10^{-5}$	$-0{,}9842\cdot10^{-5}$	$-0{,}6289\cdot10^{-5}$
400,592	$+0{,}4181\cdot10^{-5}$	$+0{,}5145\cdot10^{-5}$	$+0{,}7170\cdot10^{-6}$	$+0{,}2855\cdot10^{-5}$	$+0{,}5325\cdot10^{-5}$	$+0{,}4596\cdot10^{-5}$
422,110	$-0{,}1208\cdot10^{-5}$	$-0{,}1276\cdot10^{-5}$	$-0{,}2146\cdot10^{-5}$	$-0{,}4675\cdot10^{-5}$	$-0{,}1229\cdot10^{-4}$	$-0{,}5979\cdot10^{-5}$
425,778	$+0{,}4186\cdot10^{-5}$	$+0{,}5846\cdot10^{-5}$	$+0{,}7797\cdot10^{-5}$	$+0{,}2858\cdot10^{-5}$	$+0{,}2951\cdot10^{-5}$	$+0{,}4767\cdot10^{-5}$
435,825	$-0{,}1425\cdot10^{-5}$	$-0{,}2106\cdot10^{-5}$	$-0{,}2781\cdot10^{-5}$	$+0{,}2850\cdot10^{-5}$	$+0{,}4096\cdot10^{-5}$	$+0{,}4895\cdot10^{-5}$
448,027	$-0{,}1520\cdot10^{-5}$	$-0{,}2329\cdot10^{-5}$	$-0{,}3718\cdot10^{-5}$	$-0{,}3658\cdot10^{-5}$	$-0{,}1310\cdot10^{-4}$	$-0{,}8043\cdot10^{-5}$
451,871	$+0{,}5794\cdot10^{-5}$	$+0{,}6024\cdot10^{-5}$	$+0{,}8274\cdot10^{-5}$	$+0{,}2956\cdot10^{-5}$	$+0{,}4876\cdot10^{-5}$	$+0{,}5172\cdot10^{-5}$
463,569	$-0{,}1421\cdot10^{-5}$	$-0{,}3094\cdot10^{-5}$	$-0{,}3829\cdot10^{-5}$	$+0{,}3058\cdot10^{-5}$	$+0{,}6505\cdot10^{-5}$	$+0{,}5394\cdot10^{-5}$
473,073	$-0{,}2065\cdot10^{-5}$	$-0{,}3413\cdot10^{-5}$	$-0{,}5442\cdot10^{-5}$	$-0{,}7010\cdot10^{-5}$	$-0{,}1219\cdot10^{-4}$	$-0{,}9865\cdot10^{-5}$
477,056	$+0{,}4005\cdot10^{-5}$	$+0{,}6241\cdot10^{-5}$	$+0{,}8621\cdot10^{-5}$	$+0{,}3411\cdot10^{-5}$	$+0{,}8857\cdot10^{-5}$	$+0{,}5648\cdot10^{-5}$
492,182	$-0{,}2829\cdot10^{-5}$	$-0{,}4764\cdot10^{-5}$	$-0{,}6272\cdot10^{-5}$	$+0{,}3833\cdot10^{-5}$	$+0{,}1198\cdot10^{-4}$	$+0{,}5854\cdot10^{-5}$
493,195	$-0{,}2835\cdot10^{-5}$	$-0{,}4768\cdot10^{-5}$	$-0{,}5345\cdot10^{-5}$	$-0{,}7823\cdot10^{-5}$	$-0{,}8915\cdot10^{-5}$	$-0{,}1038\cdot10^{-5}$
502,317	$+0{,}4241\cdot10^{-5}$	$+0{,}6255\cdot10^{-5}$	$+0{,}8909\cdot10^{-5}$	$+0{,}4064\cdot10^{-5}$	$+0{,}1404\cdot10^{-4}$	$+0{,}5776\cdot10^{-5}$
519,763	$-0{,}3872\cdot10^{-5}$	$-0{,}5693\cdot10^{-5}$	$-0{,}7558\cdot10^{-5}$	$+0{,}5145\cdot10^{-5}$	$+0{,}2319\cdot10^{-4}$	$+0{,}5927\cdot10^{-5}$
519,763	$-0{,}3872\cdot10^{-5}$	$-0{,}5693\cdot10^{-5}$	$-0{,}7558\cdot10^{-5}$	$+0{,}5145\cdot10^{-5}$	$+0{,}2319\cdot10^{-4}$	$+0{,}5927\cdot10^{-5}$
524,212	$-0{,}4336\cdot10^{-5}$	$-0{,}5109\cdot10^{-5}$	$-0{,}7593\cdot10^{-5}$	$-0{,}6921\cdot10^{-5}$	$-0{,}5707\cdot10^{-5}$	$-0{,}1103\cdot10^{-4}$
528,460	$-0{,}6206\cdot10^{-5}$	$+0{,}7703\cdot10^{-5}$	$+0{,}1621\cdot10^{-4}$	$+0{,}5934\cdot10^{-5}$	$+0{,}1896\cdot10^{-4}$	$+0{,}5795\cdot10^{-5}$
547,557	$-0{,}6802\cdot10^{-5}$	$-0{,}7066\cdot10^{-5}$	$-0{,}7827\cdot10^{-5}$	$+0{,}7765\cdot10^{-5}$	$+0{,}2063\cdot10^{-4}$	$+0{,}5561\cdot10^{-5}$
550,885	$-0{,}6634\cdot10^{-5}$	$-0{,}6900\cdot10^{-5}$	$-0{,}9288\cdot10^{-5}$	$-0{,}6172\cdot10^{-5}$	$-0{,}6966\cdot10^{-5}$	$-0{,}1224\cdot10^{-4}$
555,245	$+0{,}7968\cdot10^{-5}$	$+0{,}9544\cdot10^{-5}$	$+0{,}1196\cdot10^{-4}$	$+0{,}8140\cdot10^{-5}$	$-0{,}1073\cdot10^{-3}$	$+0{,}5106\cdot10^{-5}$
556,212	$+0{,}8122\cdot10^{-5}$	$+0{,}9798\cdot10^{-5}$	$+0{,}1219\cdot10^{-4}$	$+0{,}8618\cdot10^{-5}$	$+0{,}2033\cdot10^{-4}$	$+0{,}5198\cdot10^{-5}$
575,869	$-0{,}8584\cdot10^{-5}$	$-0{,}8632\cdot10^{-5}$	$-0{,}1090\cdot10^{-4}$	$-0{,}5775\cdot10^{-4}$	$-0{,}1448\cdot10^{-4}$	$-0{,}1767\cdot10^{-4}$
576,423	$-0{,}8729\cdot10^{-5}$	$-0{,}7935\cdot10^{-5}$	$-0{,}8132\cdot10^{-5}$	$+0{,}1018\cdot10^{-4}$	$+0{,}1744\cdot10^{-4}$	$+0{,}4247\cdot10^{-5}$
580,318	$+0{,}1044\cdot10^{-4}$	$+0{,}1181\cdot10^{-4}$	$+0{,}1400\cdot10^{-4}$	$+0{,}1055\cdot10^{-4}$	$+0{,}1654\cdot10^{-4}$	$+0{,}4129\cdot10^{-5}$
592,293	$+0{,}1200\cdot10^{-4}$	$+0{,}1212\cdot10^{-4}$	$+0{,}1423\cdot10^{-4}$	$+0{,}1056\cdot10^{-4}$	$+0{,}1259\cdot10^{-4}$	$+0{,}3208\cdot10^{-5}$
606,133	$-0{,}9226\cdot10^{-5}$	$-0{,}1409\cdot10^{-4}$	$-0{,}1720\cdot10^{-4}$	$+0{,}9447\cdot10^{-5}$	$+0{,}7193\cdot10^{-5}$	$+0{,}2229\cdot10^{-5}$
629,781	$-0{,}1757\cdot10^{-6}$	$+0{,}2862\cdot10^{-5}$	$+0{,}3559\cdot10^{-5}$	$-0{,}2181\cdot10^{-7}$	$-0{,}2314\cdot10^{-5}$	$-0{,}2361\cdot10^{-6}$
633,953	$+0{,}1224\cdot10^{-5}$	$+0{,}7114\cdot10^{-7}$	$+0{,}9993\cdot10^{-7}$	$-0{,}2951\cdot10^{-5}$	$-0{,}3516\cdot10^{-5}$	$-0{,}6588\cdot10^{-6}$

Table 6. Field of Errors of Equations of State of Propylene

$$\Delta = f(x, y)_{exp} - f(x, y)_{theo}$$

ρ, кг/м³	Field of errors at T°K			
	298,15	318,15	323,15	348,15
12,4233	$-0,1228 \cdot 10^{-6}$	$0,1646 \cdot 10^{-5}$	$-0,1639 \cdot 10^{-5}$	$0,1639 \cdot 10^{-5}$
15,9476	$-0,2798 \cdot 10^{-8}$	$-0,3097 \cdot 10^{-6}$	$-0,8453 \cdot 10^{-6}$	$-0,1853 \cdot 10^{-5}$
19,4701	$-0,1861 \cdot 10^{-6}$	$-0,5650 \cdot 10^{-6}$	$0,1120 \cdot 10^{-6}$	$0,9076 \cdot 10^{-6}$
23,1491	$-0,2773 \cdot 10^{-6}$	$-0,8692 \cdot 10^{-6}$	$0,8404 \cdot 10^{-6}$	$0,7853 \cdot 10^{-6}$
27,5319	$-0,6765 \cdot 10^{-6}$	$-0,2363 \cdot 10^{-5}$	$0,3370 \cdot 10^{-5}$	$-0,1737 \cdot 10^{-5}$
31,8333	$-0,8757 \cdot 10^{-6}$	$-0,3182 \cdot 10^{-5}$	$0,7404 \cdot 10^{-5}$	$-0,3007 \cdot 10^{-5}$
35,0957	$-0,4306 \cdot 10^{-5}$	$-0,5021 \cdot 10^{-5}$	$-0,3086 \cdot 10^{-5}$	$-0,3934 \cdot 10^{-5}$
37,3027	$-0,2665 \cdot 10^{-5}$	$-0,5360 \cdot 10^{-5}$	$-0,1336 \cdot 10^{-4}$	$-0,1790 \cdot 10^{-5}$
43,9904	$-0,4020 \cdot 10^{-6}$	$-0,4503 \cdot 10^{-5}$	$0,5282 \cdot 10^{-5}$	$-0,3010 \cdot 10^{-5}$

ρ, кг/м³	Field of errors at T°K		
	373,15	398,15	423,15
12,4233	$0,7911 \cdot 10^{-5}$	$0,6272 \cdot 10^{-5}$	$0,2813 \cdot 10^{-5}$
15,9476	$0,1294 \cdot 10^{-5}$	$0,9871 \cdot 10^{-6}$	$-0,4811 \cdot 10^{-6}$
19,4701	$-0,2884 \cdot 10^{-5}$	$-0,2307 \cdot 10^{-5}$	$-0,8876 \cdot 10^{-5}$
23,1491	$-0,3525 \cdot 10^{-5}$	$-0,3374 \cdot 10^{-5}$	$-0,1828 \cdot 10^{-5}$
27,5319	$-0,3401 \cdot 10^{-5}$	$-0,3160 \cdot 10^{-5}$	$-0,2598 \cdot 10^{-5}$
31,8333	$-0,3070 \cdot 10^{-5}$	$-0,2392 \cdot 10^{-5}$	$-0,1714 \cdot 10^{-5}$
35,0957	$-0,2886 \cdot 10^{-5}$	$-0,1900 \cdot 10^{-5}$	$0,4553 \cdot 10^{-7}$
37,3027	$-0,3101 \cdot 10^{-5}$	$-0,2057 \cdot 10^{-5}$	$-0,4118 \cdot 10^{-6}$
43,9904	$0,1126 \cdot 10^{-5}$	$0,1826 \cdot 10^{-5}$	$0,4506 \cdot 10^{-5}$
52,8926	$0,2479 \cdot 10^{-5}$	$0,2643 \cdot 10^{-5}$	$0,1963 \cdot 10^{-5}$
61,5480	$0,2901 \cdot 10^{-5}$	$0,2433 \cdot 10^{-5}$	$0,1737 \cdot 10^{-5}$
70,6220	$0,2996 \cdot 10^{-5}$	$0,2490 \cdot 10^{-5}$	$0,1434 \cdot 10^{-5}$
79,6525	$0,2006 \cdot 10^{-5}$	$0.1041 \cdot 10^{-5}$	$0,3246 \cdot 10^{-6}$
81,0886	$0,1982 \cdot 10^{-5}$	$0\;1549 \cdot 10^{-5}$	$-0.2028 \cdot 10^{-6}$
88,3320	$0,1082 \cdot 10^{-5}$	$0,9312 \cdot 10^{-7}$	$0,1435 \cdot 10^{-6}$
90,4661	$0,1274 \cdot 10^{-5}$	$0,1894 \cdot 10^{-6}$	$-0,7566 \cdot 10^{-6}$
97,4213	$0,8191 \cdot 10^{-6}$	$-0,3986 \cdot 10^{-6}$	$0,1583 \cdot 10^{-6}$
100,6545	$0,4894 \cdot 10^{-6}$	$-0,4531 \cdot 10^{-7}$	$-0,8486 \cdot 10^{-6}$
110,4019	$-0,2582 \cdot 10^{-6}$	$-0.1114 \cdot 10^{-6}$	$-0,1286 \cdot 10^{-4}$
120,8863	$-0,9827 \cdot 10^{-6}$	$-0,5099 \cdot 10^{-6}$	$-0,1370 \cdot 10^{-7}$
126,7396	$-0,1326 \cdot 10^{-5}$	$-0,8635 \cdot 10^{-6}$	$-0,6101 \cdot 10^{-6}$
130,4938	$-0,1609 \cdot 10^{-5}$	$-0,8629 \cdot 10^{-6}$	$-0,8057 \cdot 10^{-6}$
140,6366	$-0,1764 \cdot 10^{-5}$	$-0,9755 \cdot 10^{-6}$	$-0,1737 \cdot 10^{-5}$
141,3965	$-0,1733 \cdot 10^{-5}$	$-0,9309 \cdot 10^{-6}$	$0,1655 \cdot 10^{-5}$

[Continued on next page]

Table 6 (Continued)

ρ, кг/м³	Field of errors at T, °K		
	373,15	398,15	423,15
150,8831	$-0,1626 \cdot 10^{-5}$	$-0,6253 \cdot 10^{-6}$	$0,2362 \cdot 10^{-5}$
157,3202	$-0,1619 \cdot 10^{-5}$	$-0,6089 \cdot 10^{-6}$	$0,2805 \cdot 10^{-5}$
172,5556	$-0,1349 \cdot 10^{-5}$	$-0,3209 \cdot 10^{-6}$	$0,3470 \cdot 10^{-5}$
183,1002	$-0,8668 \cdot 10^{-6}$	$-0,2301 \cdot 10^{-6}$	$0,3958 \cdot 10^{-5}$
188,9419	$-0,5638 \cdot 10^{-6}$	$-0,1658 \cdot 10^{-6}$	$0,4299 \cdot 10^{-5}$
203,9584	$0,5072 \cdot 10^{-6}$	$0,8876 \cdot 10^{-7}$	$0,4730 \cdot 10^{-5}$
204,2748	$0,4972 \cdot 10^{-6}$	$0,9408 \cdot 10^{-7}$	$0,4802 \cdot 10^{-5}$
219,8114	$0,1289 \cdot 10^{-5}$	$0,3447 \cdot 10^{-6}$	$0,4187 \cdot 10^{-4}$
227,2805	$0,1687 \cdot 10^{-5}$	$0,6131 \cdot 10^{-6}$	$0,4869 \cdot 10^{-5}$
235,8269	$0,2062 \cdot 10^{-5}$	$0,6905 \cdot 10^{-6}$	$0,4675 \cdot 10^{-5}$
249,2924	$0,2144 \cdot 10^{-5}$	$0.8749 \cdot 10^{-6}$	$0,4100 \cdot 10^{-5}$
272,9678	$0,1299 \cdot 10^{-5}$	$0,5577 \cdot 10^{-6}$	$0,2676 \cdot 10^{-5}$
277,1274	$0,1104 \cdot 10^{-5}$	$0,3748 \cdot 10^{-6}$	$0,2441 \cdot 10^{-5}$
294,6654	$0,3954 \cdot 10^{-5}$	$0,4310 \cdot 10^{-5}$	$0,5622 \cdot 10^{-5}$
309,1809	$-0,1140 \cdot 10^{-5}$	$-0,7622 \cdot 10^{-6}$	$0,2071 \cdot 10^{-6}$
311,3877	$-0,1411 \cdot 10^{-5}$	$-0,7704 \cdot 10^{-6}$	$-0,1153 \cdot 10^{-6}$
317,5738	$-0,1860 \cdot 10^{-5}$	$-0,7828 \cdot 10^{-6}$	$-0,1796 \cdot 10^{-6}$
340,7204	$-0,2633 \cdot 10^{-5}$	$-0,1147 \cdot 10^{-5}$	$-0,9285 \cdot 10^{-6}$
344,0120	$-0,2485 \cdot 10^{-5}$	$-0,1423 \cdot 10^{-5}$	$-0,1152 \cdot 10^{-5}$
347,4115	$-0,2695 \cdot 10^{-5}$	$-0,1604 \cdot 10^{-5}$	$-0,1400 \cdot 10^{-5}$
377,3512	$-0,1209 \cdot 10^{-5}$	$-0,1014 \cdot 10^{-5}$	$-0,9384 \cdot 10^{-6}$
386,5670	$-0,7799 \cdot 10^{-5}$	$-0,7607 \cdot 10^{-6}$	$-0,8559 \cdot 10^{-6}$
402,2806	$-0,1006 \cdot 10^{-5}$	$0,8763 \cdot 10^{-7}$	$-0,5612 \cdot 10^{-6}$
413,2332	$0,1670 \cdot 10^{-5}$	$0,3783 \cdot 10^{-6}$	$0,2490 \cdot 10^{-5}$
421,0634	$0,1943 \cdot 10^{-5}$	$0,5329 \cdot 10^{-6}$	$-0,9983 \cdot 10^{-7}$
446,1533	$0,2698 \cdot 10^{-5}$	$0,1291 \cdot 10^{-5}$	$0,9934 \cdot 10^{-6}$
148,9080	$0,2373 \cdot 10^{-5}$	$0,1132 \cdot 10^{-5}$	$0,4231 \cdot 10^{-7}$
464,4563	$0,1504 \cdot 10^{-5}$	$0,1133 \cdot 10^{-5}$	$0,3018 \cdot 10^{-6}$
480,9735	$-0,2317 \cdot 10^{-6}$	$0,5790 \cdot 10^{-6}$	$0,3882 \cdot 10^{-7}$
499,7094	$-0,2829 \cdot 10^{-5}$	$-0,3955 \cdot 10^{-6}$	$0,1190 \cdot 10^{-5}$
501,5701	$-0,3039 \cdot 10^{-5}$	$-0,3187 \cdot 10^{-6}$	$0,6349 \cdot 10^{-6}$
516,2524	$-0,4719 \cdot 10^{-5}$	$-0,8223 \cdot 10^{-6}$	$-0,7662 \cdot 10^{-6}$
540,9127	$-0,1281 \cdot 10^{-4}$	$-0,5311 \cdot 10^{-6}$	$-0,2803 \cdot 10^{-6}$
548,5700	$-0,6549 \cdot 10^{-5}$	$-0,1034 \cdot 10^{-5}$	$-0,1196 \cdot 10^{-5}$
580,9129	$-0,2958 \cdot 10^{-5}$	$-0,5599 \cdot 10^{-5}$	$0,5977 \cdot 10^{-7}$
601,5949	$0,2528 \cdot 10^{-5}$	$0,1679 \cdot 10^{-5}$	$0,5804 \cdot 10^{-6}$
650,9030	$-0,3294 \cdot 10^{-6}$	$-0,3094 \cdot 10^{-5}$	$-0,9953 \cdot 10^{-7}$

pressure ranges with an accuracy close to the error of the experimental data, and can be used for the construction of tables of the thermodynamic properties.

The high accuracy of description of these data by the equations derived ensures the required accuracy of calculated caloric values.

Review of Data on Second Virial Coefficient

The Virial form of equation of state is now considered theoretically founded. Despite the difficulties encountered in the extraction of the Virial coefficients of the equation of state from various types of experimental data, several methods have been worked out in recent years for derivation of the equation of state in Virial form.

Data on the second Virial coefficient of ethylene, published by various investigators, are presented in Table 7 and Figure 2. As seen in Figure 2, the existing data display considerable scattering. Data of Roper [35], Turlington and McKetta [11], Pfennig [13], Ratzsh and Bittrich [36], were obtained from measurements of compressibility at low pressures (to 2 bar).

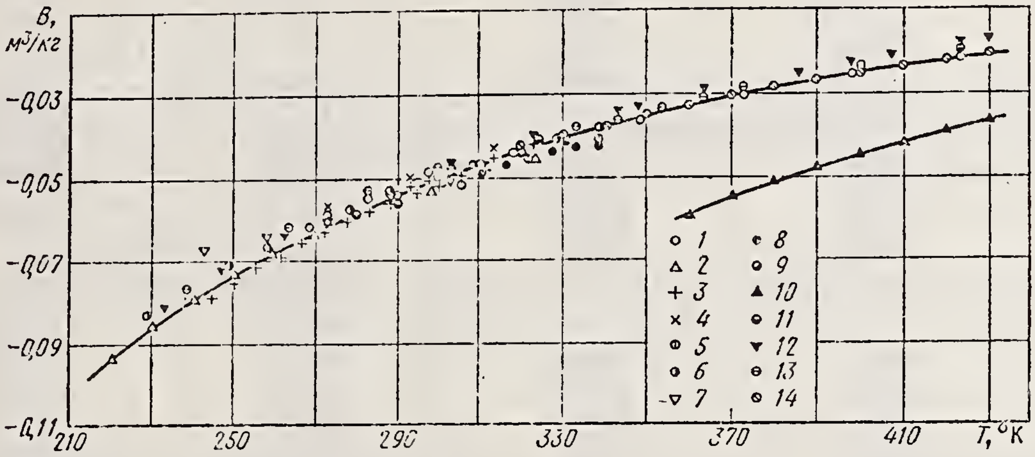

Figure 2. Second Virial coefficient of ethylene according to the following data: 1 -- authors of present book (from data on compressibility) and of Michels [5]; 2 -- Roper [35]; 3 -- Walters and coworkers [6]; 4 -- Thomas and Zander [12]; 5 -- Pfennig and McKetta [13]; 6 -- calculated according to the Leonard-Jones potential [25]; 7 -- Turlington and McKetta [11]; 8 -- Pfennig [13]; 9 -- Ratzsh and Bittrich [36]; 10 -- calculated according to the Corner potential [38]; 11 -- David and Hamman [39]; 12 -- authors of present work (from data on speed of sound); 13 -- Butcher and Dadson [37]; 14 -- calculated by equation [33].

Table 7. Second Virial Coefficient of Ethylene According to Various Data

$T°$,K	$-B\cdot10^2$, м^3/кг	$T°$,K	$-B\cdot10^2$, м^3/кг
1) Ропер [35]		6) Дэвид и Хеммен [39]	
200,00	1,10029	250,00	0,5846
210,00	1,00752	290,00	0,5490
220,00	0,925809	300,00	0,5098
230,00	0,853511	310,00	0,4741
240,00	0,789237	320,00	0,4420
250,00	0,731862	330,00	0,4099
260,00	0,680143	340,00	0,3779
270,00	0,634182	350,00	0,3518
298,15	0,526397	400,00	0,2524
323,15	0,451925	7) Михельс [5]	
2) Турлингтон и Маккетта [11]		273,15	0,5985
243,15	0,6672	298,15	0,5004
258,15	0,6358	323,15	0,4207
273,15	0,5984	348,15	0,3557
288,15	0,5019	373,15	0,3028
303,15	0,5019	398,15	0,2579
3) Пфенниг [13]		423,15	0,2221
305,35	0,5002	8) Пфенниг и Маккетта [13]	
310,95	0,4775	305,37	0,50201
316,55	0,4630	322,04	0,45028
321,95	0,4473	338,71	0,40820
327,55	0,4312	9) Томас и Цандер [13]	
333,15	0,4190	273,15	0,575744
338,65	0,4081	283,15	0,533836
4) Ретш и Биттрих [36]		293,15	0,503694
		303,15	0,473599
293,15	0,5205	313,15	0,444738
303,15	0,4812	323,15	0,418603
313,15	0,4492	10) Батчер и Дадсон [37]	
323,15	0,4070	263,15	0,615999
		273,15	0,575360
5) Вальтерс и др. [6]		283,15	0,537930
244,26	0,7839	299,10	0,480536
249,82	0,7481	313,15	0,439341
255,37	0,7148	323,15	0,410309
260,93	0,6836	333,15	0,384999
266,48	0,6540	343,15	0,360758
272,01	0,6269	353,15	0,338657
277,59	0,6013	363,15	0,315842
283,15	0,5770	373,15	0,296592
		423,15	0,213176
		473,15	0,152930

KEY:		
1. Roper [35]		6. David and Hamman [39]
2. Turlington and McKetta [11]		7. Michels [5]
3. Pfennig [13]		8. Pfennig and McKetta [13]
4. Ratzsh and Bittrich [36]		9. Thomas and Zander [12]
5. Walters, et al [6]		10. Butcher and Dadson [37]

The data of Turlington and McKetta agree with those of Pfennig, but the temperature dependence B given in these works differs from the temperature dependence according to other authors. The data of Thomas and Zander [12], and those of Butcher and Dadson [37], were obtained from measurements of compressibility by the Burnett method in the pressure range up to 20 bar. Their values of B agree, but are somewhat higher than the values of B obtained by other authors. The data of Roper [35], Ratzsh and Bittrich [36] and Michels and Geldermans [5], who obtained values of B by expanding the compressibility at low densities into a series by powers of 1/v, the coefficients of which were determined by the method of least squares, agree quite satisfactorily.

David and Hamman [39] found that the values of B for many compounds can be described by a third-power polynomial in terms of reduced temperature

$$B^* = \alpha + \frac{\beta}{\tau} + \frac{\gamma}{\tau^2} + \frac{\delta}{\tau^3}, \tag{12}$$

where

[kp=cr]

$$B^* = \frac{B}{v_{\text{кр}}}; \quad \tau = \frac{T}{T_{\text{кр}}};$$

v_{cr} = 129 cm^3/mole; T_{cr} = 282.4°K is the critical temperature.

The constants for ethylene have the following values: α = -4.912, β = 18.575, γ = -23.892, δ = 8.975.

Walters and coworkers [6] represented the results of their experimental investigations at low pressures up to 45 bar as polynomials by powers of 1/v. The values of the coefficients for 1/v are somewhat lower than the data of Roper and Michels.

It is noteworthy that when compressibility is expanded into the series

$$Z = 1 + \sum_{i=1} \frac{A_i(T)}{v^i}, \tag{13}$$

the coefficient for 1/v can be equated to the second Virial coefficient under completely determined conditions, as shown in [40].

Roper's values [35] of the second Virial coefficient for ethylene are described by a polynomial of the third power of the inverse temperature in the 199-343°K range

$$B = \frac{16.036}{T}\left[72 - \frac{953,58 \cdot 10^3}{T} - \frac{3,3855 \cdot 10^7}{T^2}\right] \text{см}^3/\text{моль}. \tag{14}$$

Roper's data for temperatures below 270°K fall on a smooth continuation of the curve plotted according to the data of Michels, Ratzsh and Bittrich. At temperatures above 270°K the deviation of Roper's data increases with temperature. This is apparently caused by the fact that the error of Roper's determination of the specific volume of ethylene increases as the temperature increases.

Table 8. Second Virial Coefficient of Propylene According to Data of Different Investigators

$T°$, K	$-B \cdot 10^2$, $м^3/кг$	$T°$, K	$-B \cdot 10^2$, $м^3/кг$	$T°$, K	$-B \cdot 10^2$, $м^3/кг$	$T°$, K	$-B \cdot 10^2$, $м^3/кг$
1) Ропер [35]		298,15	0,825304	320	0,7163	323,15	0,6942
		318,15	0,721790	330	0,6702	348,15	0,5887
220	1,63117	323,15	0,699533	340	0,6274	373,15	0,5055
230	1,4687	348,15	0,603462	350	0,5894	398,15	0,4374
240	1,33050	2) Дэвид и Хеммен [39]		400	0,4349	423,15	0,3811
250	1,212031	280	0,9240	450	0,3280	4) Пфенниг и Маккетта [13]	
260	1,070198	290	0,8722	3) Михельс и др. [21]			
270	1,020919	300	0,8270	298,15	0,8241	305,37	0,76819
280	1,943270	310	0,7629	318,15	0,7175	322,04	0,674490
						338,71	0,599090

KEY:
1. Roper [35]
2. David and Hamman [39]
3. Michels, et al
4. Pfennig and McKetta [13]

The values of B calculated according to the Leonard-Jones potential [6-12] with the parameters: $\varepsilon/k = 199.2°K$, $b_0 = 116.7\ cm^3/mole$ [25] and according to the Corner potential for long molecules [38] with the parameters: $l/\sigma_c = 0.21$, $\varepsilon = 192°K$, $\sigma_c = 4.1\ Å$, are presented in Figure 2.

The values of B calculated by the Leonard-Jones potential agree with Michels' data. Such agreement is quite understandable, considering that the stated constants were determined from values of B obtained in Michels' work [5]. The Corner potential with the stated parameters, which he himself obtained [38], does not yield the correct values for the second Virial coefficient of ethylene.

Published data on the second Virial coefficient of propylene are presented in Table 8 and Figure 3.

It is clear from the table and figure that there is good agreement of data obtained by the various authors. The exceptions are the data of Pfennig and McKetta [13], which are higher than the others.

Roper [35] proposes a polynomial that describes the dependence of B of propylene on temperature:

$$B = \frac{16{,}036}{T}\left[-2906 - \frac{6{,}81 \cdot 10^3}{T} - \frac{31{,}36 \cdot 10^7}{T^2}\right]\ см^3/моль. \qquad (15)$$

The deviations of Roper's data from those of the other authors are analogous to the deviations in the case of ethylene.

Presented in Figure 3 are the values of B calculated according to the Leonard-Jones potential. The parameters of the potential are determined from the critical data are: $\varepsilon/k = 0.77 \cdot T_{cr} = 281°K$;

$b_0 = 18.4$, $T_{cr}/p_{cr} = 147.95\ \mathrm{cm^3/mole}$ and for the Corner potential they are: $l/\sigma_c = 0.26$, $\bar{\varepsilon} = 220°\mathrm{K}$; $\sigma_c = 4.9\ \mathring{A}$.

The values of B determined according to the Corner potential are considerably closer to the actual values than in the case of ethylene. The Corner potential model is apparently more valid for propylene than it is for ethylene.

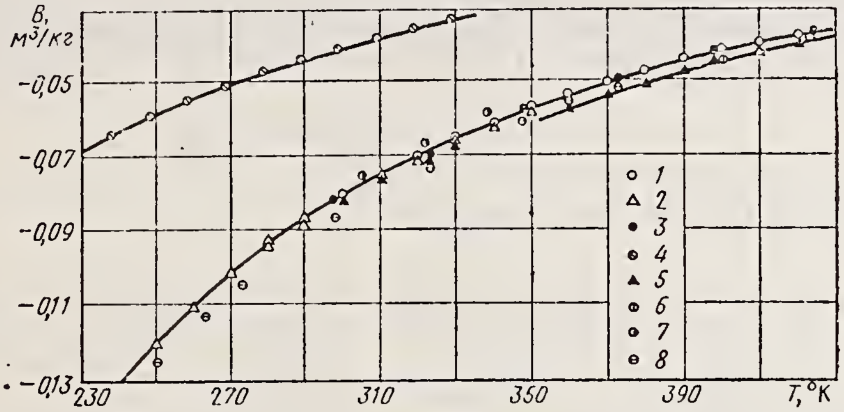

Figure 3. Second Virial coefficient of propylene according to the following data: 1 -- authors of present book (from results on compressibility); 2 -- David and Hamman [39]; 3 -- Michels [21]; 4 -- calculated according to the Leonard-Jones potential (6-12). σ and ε/k determined by critical parameters; 5 -- Roper [35]; 6 -- calculated according to the Corner potential [38]; 7 -- Pfennig and McKetta [13]; 8 -- authors of present book (from data on speed of sound).

Determination of Second Virial Coefficients of Ethylene and Propylene According to Experimental Data on the Speed of Sound

In the range of low pressures, in which the volumetric behavior of gas is described with sufficient accuracy by the equation of state with the second Virial coefficient

$$pv = RT\,[1 + B(T)\,\rho], \tag{16}$$

the thermodynamic speed of sound is determined through the equation

$$w^2 = \varkappa_0 RT\left[1 + 2\rho\left\{B + (\varkappa_0 - 1)\,T\,\frac{dB}{dT} + \frac{(\varkappa_0 - 1)^2}{2\varkappa_0}\,T^2\,\frac{d^2B}{dT^2}\right\}\right]. \tag{17}$$

It follows from this equation that the isotherms of the square of the speed of sound in coordinates w^2 - ρ are straight lines in the above-mentioned range of states, and the angle of inclination of these lines is determined by the second Virial coefficient and its temperature derivatives. Differentiation with respect to pressure and passage to the limit for $p \to 0$ gives equation (17) the form

$$\left[\frac{\partial}{\partial p}\left(\frac{w^2}{\varkappa_0 RT}\right)\right]_{T,\,p\to 0} = \frac{2}{RT}\left[B + (\varkappa_0 - 1)\,T\frac{dB}{dT} + \frac{(\varkappa_0 - 1)^2}{2\varkappa_0}\,T^2\frac{d^2B}{dT^2}\right]. \tag{18}$$

The analogous equations are described in the literature and are used for calculating the second Virial coefficients of gases according to acoustical data.

The dependence of the second Virial coefficient is quite well transmitted in a sufficiently broad temperature range by an equation of the type

$$B = A_1 + A_2\frac{1}{T} + A_3\frac{1}{T^3}. \tag{19}$$

From expressions (18) and (19) we have

$$Y \equiv RT\left[\frac{\partial}{\partial p}\left(\frac{w^2}{\varkappa_0 RT}\right)\right]_{T,\,p\to 0} = 2A_1 + \frac{A^2}{\varkappa_0 T} + \frac{A^3}{T^3}\left(3\varkappa_0 - 8 + \frac{6}{\varkappa_0}\right). \tag{20}$$

For a given slope of the isotherm of the square of the speed of sound equation (20) contains the unknowns A_1, A_2, A_3.

The accuracy of calculation of the second Virial coefficient by the examined method depends on the accuracy of determination of the angle of inclination of the isotherms of the square of the speed of sound and on the number of experimental isotherms in the investigated temperature range.

The accuracy of determination of the angle of inclination, in turn, depends on the accuracy of the initial experimental data on the speed of sound, number of experimental points on each isotherm of the investigated pressure range and method of determining the angle of inclination of the isotherms on the basis of experimental data.

The analytical method in which the isotherms of the speed of sound are approximated, yields the best accuracy in determination of the angle of inclination of the isotherms. Used for calculating the second Virial coefficients is an approximating function of the form

$$w^2 = w_0^2 + ap + bp^3, \tag{21}$$

where $w_0 = \sqrt{RT\kappa_0}$ is the perfect-gas speed of sound.

As indicated by analysis of experimental data, function (21) is most suitable for approximating the speed of sound in a rather broad pressure range.

The essence of the method used for calculating the second Virial coefficient on the basis of acoustical data consists in the following. The experimental isotherms for the speed of sound in gas are approximated by the method of least squares by polynomials (21), with the result that the slope is determined for each isotherm:

$$\left[\frac{\partial}{\partial p}\left(\frac{w^2}{RT\varkappa_0}\right)\right]_{T,\, p\to 0} = \frac{a}{\varkappa_0 RT},$$

where a is the coefficient of polynomial (24) at the pressure in the first power.

The unknowns A_1, A_2, A_3 are found from the condition of the minimum sum of squares of relative deviations of the experimentally determined angles of inclination of the isotherms from the calculated according to the equation

$$\sum_1^m \left(\frac{\varepsilon_i}{Y_i}\right)^2 = \min,$$

where

$$\varepsilon_i = \left\{A_1 + A_2 \frac{1}{\varkappa_{0i} T_i} + A_3 \left[\frac{1}{T_i^3}\left(3\varkappa_{0i} - 8 + \frac{6}{\varkappa_{0i}}\right)\right]^2 - Y_i\right\} \tag{22}$$

is the absolute error of set Y_i.

Data on the speed of sound, obtained by Yu. A. Soldatenko and E. I. Dregulyas (see Chapter V) in the 190-480°K temperature range on 18 isotherms by acoustical interferometry, the accuracy of which is characterized by the maximum possible error of ±0.15%, were used for calculating the second Virial coefficient for ethylene and propylene. The pressure range for each isotherm, in which the experimental data are described within the limits of accuracy of the experiment by a polynomial of type (21), were determined by trial and error.

Data (Chapter IV) on the perfect-gas heat capacities of ethylene and propylene, and values of w_0 determined on the basis of measurements of the speed of sound, were used in the calculations.

The following analytical dependences B(T) were obtained for ethylene in the 230-470°K temperature range:

$$B = 0{,}004003 - \frac{2{,}460}{T} + \frac{38{,}172}{T^2} - \frac{2{,}861 \cdot 10^4}{T^3}; \tag{23}$$

for propylene in the 190-170°K range:

$$B = 0{,}003256 - \frac{2{,}519}{T} - \frac{9{,}266 \cdot 10^4}{T^3}. \tag{24}$$

The scattering of the angles of inclination of the isotherms of the square of the speed of sound relative to the smooth curves, calculated according to formula (20) using expressions (22) and (24), does not exceed ±3.5%. This indicates that the dependence of the second Virial coefficient of ethylene and propylene is satisfactorily transmitted in the investigated temperature range by these equations. The theoretical values of the second Virial coefficient of ethylene and propylene agree with most of the published values within the limits of 0.0005 m^3/kg.

Determination of Second Virial Coefficients of Ethylene and Propylene According to Compressibility Data. Recommended Values

There are several methods of finding the Virial coefficients from experimental compressibility data.

The method most commonly used is calculation of the Virial coefficients according to low pressure data. Since

$$(Z-1)v = B + \frac{C}{v} + \cdots, \tag{25}$$

the second Virial coefficient can be determined by means of limit transition

$$\lim_{1/v \to 0} (Z-1)v = B. \tag{26}$$

The contribution of the third and subsequent Virial coefficients to the compressibility of a gas is presumably negligible at low pressures up to 2-3 bar, since at low pressures $Z \to 1$, the small error in the experimental determination of Z leads to large errors in the determination of B. Limit (26) is usually found graphically in coordinates $(Z - 1)v$, $1/v$. This method is discussed in detail in [25] and [41]. The Virial coefficients are found, as a rule, to be somewhat higher than in the case of other methods (see Figures 2 and 3).

Methods of extracting the Virial coefficients from experimental data on compressibility in a wide range of densities [40, 42, 43] have been worked out in recent years. A method is proposed in [42] based on representation of compressibility as a series by powers of 1/v or p. The coefficients of this series are calculated by the method of least squares using the experimental data at moderate pressures. Since the solution obtained by the method of least squares is not unique, the authors examined such polynomials, the slope $(\frac{\partial Z}{\partial p}$ or $\frac{\partial Z}{\partial (1/v)})$ and curvature $(\frac{\partial^2 Z}{\partial p^2}$ or $\frac{\partial^2 Z}{\partial (1/v)^2})$ of which correspond to the slope and curvature of the compressibility isotherms in the corresponding coordinates. The coefficients of such a polynomial are taken as the Virial coefficients. The stated conditions are by no means sufficient. This is convincingly shown in the works of Michels and coworkers [40], Hall and Canfield [43].

Michels, Abels and Ten Seldam [40] studied in detail the feasibility of extracting the Virial coefficients from the experimental data p, v, T in a wide density range. The essence of the method of Michels and coworkers consists in the following. The compressibility factor Z is represented as a polynomial by powers of density. The investigated density range is broken down into subranges, for each of which is found, by the method of least squares, a polynomial that approximates the experimental data. It is shown that some of the first coefficients of the polynomials constructed for the various subranges with the corresponding density powers, coincide within the limits of accuracy of their determination, which is, in turn, a function of the experimental error. This confirms the feasibility of unique representation of Z as a series by powers of density.

Suppose the experimental data contain an error, which is random in character and obeys the Gauss distribution. This means that the set of experimental points obtained is one of a number of possible sets, for each of which can be found an approximating polynomial by the method of least squares. The coefficients of the polynomials thus obtained display scattering, which is a function of the error of the experiment. It is further shown that the coefficients of the polynomial (of the model function) will be close to the coefficients of the true Virial series.

For the proof a criterion is introduced, the essence of which consists in the fact that if the sum of squares of deviations [40] is small compared with the experimental error, the deviations of the polynomial coefficients from the coefficients of the true series will be small compared with the scattering of polynomial coefficients.

In the work are presented relations that permit the relation between the error of the experimental data and errors of the "model" polynomial coefficients to be established.

The proposed method [40] is suitable for calculating several of the first Virial coefficients of carbon dioxide on the 49.712°C isotherm. It can be concluded from the results obtained that this method makes it possible to calculate with acceptable accuracy only the second and third Virial coefficients. The error in the calculation of the fourth coefficient is comparable with the magnitude of the coefficient itself. It is noteworthy here that the Virial coefficients obtained by means of the above-described very complex and laborious computational procedure are close to the coefficients presented in [44]. The Virial coefficients were calculated in the cited work for carbon dioxide in a narrow density range by the method of least squares.

Hall and Canfield [43] proposed a somewhat different approach to the problem of determining the Virial coefficients on the basis of compressibility data.

Hall and Canfield used the method of least squares for calculating the coefficients of the polynomials. This method employs orthogonal systems of functions and has considerable advantages over the method of least squares in the usual form.

A more stringent criterion was developed for identification of the coefficients of the approximating polynomial with the true Virial coefficients. They call it the series cut-off criterion, which takes into account the fact that an infinite Virial series is approximated by a finite polynomial.

The method of optimal determination of the Virial coefficients is illustrated by Hall and Canfield in two examples. As the first example they calculate the coefficients of some function, selected as an infinite series with known coefficients. Using this function they simulate the path of compressibility isotherms. The computed coefficients of the polynomial, approximating the selected function, are found to agree satisfactorily with the true coefficients.

Also, the Virial coefficients of carbon dioxide were calculated [43] on the 49.712°C isotherm, for which there are the coefficients computed by Michels and coworkers.

The Virial coefficients and their errors, obtained by Hall and Canfield and by Michels, practically coincide. This is evidence of equal effectiveness of both methods.

The Hall-Canfield method requires considerably fewer computational operations.

The method of extracting the second Virial coefficients employed by the authors of the present work is a compromise between Michels and the Hall-Canfield methods in the sense that the coefficients of the approximating polynomial were calculated using orthogonal polynomials, and the errors of the calculated coefficients are determined by a method which is somewhat similar to the proposed by Michels.

The Forsythe algorithm [34] is used for approximation of the isotherms for the case of one variable. The function $f = (\frac{pv}{RT} - 1)v$ was approximated as a function of density $\rho = \frac{1}{v}$.

The Virial form of the isotherm equation was found by reducing similar terms for identical powers of $\frac{1}{v}$.

The program for approximation was written in the command system of the BESM-3M computer.

The program finds 10 powers of the expansion. The deviations at points δ_i, sum of squares of deviations $\Sigma\delta_i^2$ and coefficients of the Virial form of the isotherm equation are read out on the printout system of the computer.

The program was written as a standard program that can be used for approximating any tabulated function.

Table 9. Values of Second Virial Coefficient B, Calculated for Various Density Ranges and Various Expansion Powers on 348.15°K Isotherm of Ethylene

m	$-B \cdot 10^2$, m^3/kg for n, equal to				
	12	24	36	48	64
0	0,3079	0,2397	0,1872	0,1026	—
1	0,3555	0,3557	0,3630	0,4174	0,4609
2	0,3555	0,3543	0.3452	0,3130	0,2941
3	0,3547 *	0,3565	0,3625	0,3763	0,3802
4	0,3555 *	0,3564 *	0,3534	0,3574	0,3613
5	0,3510	0,3562 *	0,3555 *	0,3519	0,3513
6	0,3430	0,3563 *	0,3559 *	0,3546 *	0,3536 *
7	0,3328	0.3620	0,3503	0,3594 *	0,3585 *
8	0,3221	0,3671	0,3445	0,3639	0,3630
9	0,3113	0,3720	0,3385	0,3683	0,3673
10	0,3001	0,3769	0,3324	0,3725	0,3714

*The asterisk denotes the region in which B acquires approximately constant values and is shifted toward higher powers as the number of experimental points used for the approximation is increased.

The coefficients of a series for the experimental isotherms of ethylene and propylene were computed with the program for various density ranges.

Listed in Table 9 by way of example are the calculations of the second Virial coefficient of ethylene on the 348.15°K isotherm. The number denotes the number of experimental points, read from the beginning of the isotherm. The initial experimental data for ethylene and propylene are presented in Tables 3 and 4.

As seen in the table, the second Virial coefficient, starting at some power, does not depend on the number of expansion powers m.

For the purpose of identifying the values of B obtained for the various powers of the expansion and various density ranges with "true" values, the results obtained were statistically processed to enable evaluation of the error (confidence interval) of the calculated second Virial coefficients.

Using Michels' experimental data they calculated the error

$$\sigma = \frac{\sum_{i=1}^{N} \eta}{N} \cdot \frac{1}{N - m - 1}, \qquad (27)$$

where

$$\eta_i = f_{exp} - f_{calc}; \qquad (28)$$

m is the power of the approximating polynomial; N is the number of experimental points.

Twelve samplings were made with the aid of random numbers tables and in consideration of the values of σ obtained, for each isotherm, each of which, within the limits of error, is an experimental set of data. The approximating polynomial was formulated for each sampling. The final values of the coefficient were obtained as the most probable values on the stability segment. The values of B and ΔB, given in Table 10, were obtained by statistical evaluation of the parameters of the normal law (confidence interval)

$$\Delta B = 1{,}038\, S_{\bar{B}}; \quad S_{\bar{B}} = \sqrt{\frac{\Sigma\,(B - \bar{B})^2}{n - 1}}, \tag{29}$$

where n is the number of samplings.

The significance of the band ΔB is that the probability of the calculated ΔB falling within this band is 70%.

Table 10. Virial Coefficients of Ethylene and Propylene According to Data of the Authors

T, °K	B, м³/кг	ΔB, м³/кг	T, °K	B, м³/кг	ΔB, м³/кг
Ethylene			Propylene		
298,15	—0,005014	±0,000023	298,15	—0,008242	±0,000010
323,15	—0,004207	±0,000054	318,15	—0,007183	±0,000091
348,15	—0,003551	±0,000012	323,15	—0,006903	±0,000052
373,15	—0,003032	±0,000018	348,15	—0,005901	±0,000074
398,15	—0,002584	±0,000021	375,15	—0,005027	±0,000095
423,15	—0,002224	±0,000037	398,15	—0,004328	±0.000083
—	—	—	423,15	—0,003829	±0,000093

On the basis of the above review of analysis of published data and of calculations done by the authors on compressibility and the speed of sound, the most reliable data were selected, and were then approximated by the polynomials:

$$B(T) = 0{,}02084681 - 0{,}3325466\,\frac{10^2}{T} + 0{,}2079736\,\frac{10^5}{T^2} - 0{,}6639566\,\frac{10^7}{T^3} +$$

$$+ 0{,}1003753\,\frac{10^{10}}{T^4} - 0{,}5853397\,\frac{10^{11}}{T^5} \text{ (for ethylene)}; \tag{30}$$

$$B(T) = -0{,}08480803 + 0{,}128806\,\frac{10^3}{T} - 0{,}7710073\,\frac{10^5}{T^2} +$$

$$+ 0{,}2215192\,\frac{10^8}{T^3} - 0{,}3142363\,\frac{10^{10}}{T^4} + 0{,}17366099\,\frac{10^{12}}{T^5} \tag{31}$$

(for propylene).

The recommended second Virial coefficients and their first derivatives, calculated on the basis of polynomials (30) and (31), are listed in Table 11.

Table 11. Recommended Values of Second Virial Coefficients and Their First Derivatives for Ethylene and Propylene

T, °K	— B, м³/кг	dB/dT	T, °K	— B, м³/кг	dB/dT
	Ethylene			Propylene	
200	0,011011	0,0037776	200	0,020519	0,0219912
210	0,010054	0,0031971	210	0,018292	0,0168845
220	0,009256	0,0030431	220	0,016321	0,0130191
230	0,008568	0,0023545	230	0,014639	0,0102085
240	0,007927	0,0020177	240	0,013224	0.0080745
250	0,007325	0,0017956	250	0,012031	0,0064572
260	0,006789	0,0015869	260	0,011018	0,0052110
270	0,006284	0,0014125	270	0,010147	0,0042432
280	0,005819	0,001265	280	0,009389	0,0034826
290	0,005393	0,0011411	290	0,008720	0,0028798
300	0,005003	0,0010345	300	0,008120	0,0023982
310	0,004646	0,0009607	310	0,007577	0,0020104
320	0,004321	0,0008632	320	0,007082	0,0016956
330	0,003974	0,0007937	330	0,006626	0,0014383
340	0,003704	0,0007330	340	0,006364	0,0012266
350	0,003509	0,0006788	350	0,005819	0,0010512
360	0,003284	0,0006309	360	0,005461	0,0009051
370	0,003079	0,0005881	370	0,005132	0,000782
380	0,002891	0,0005498	380	0,004829	0,0006730
390	0,002718	0,0005153	390	0,004552	0,0005918
400	0,001558	0.0004840	400	0,004302	0,000517
410	0,002409	0,0004557	410	0,004076	0,0004535
420	0,002271	0,0004299	420	0,003874	0,0003961
430	0,002142	0,0004062	430	0,003697	0,000351
440	0,002020	0,0003841	440	0,003542	0,0002809
450	0,001906	0,0003646	450	0,003411	0,0002743
460	0,001797	0,0003462	460	0,003302	0,0002441
470	0,001693	0,0003292	470	0,003214	0,0002156
480	0,001593	0,0003135	480	0,003148	0,0001914
490	0,001496	0,0002908	490	0,003102	0,0001701
500	0,001403	0.0002852	500	0,003075	0,0001511

Recommended Values of Specific Volume, Enthalpy, Entropy, Isobaric Heat Capacity of Gaseous Ethylene and Propylene

The recommended specific volumes of ethylene and propylene were calculated using equations of state of the form (11), the coefficients of which are given on page 18. The roots of the equation were determined by methods of iterations and half division using the BESM-3M computer[1].

The specific volumes in the 200-270°K temperature range and 0.5-20 bar pressure range were computed by an equation with the true second Virial coefficient:

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[1] The authors gratefully acknowledge the cooperation of N. S. Levchuk and K. A. Lensyurovskaya of NIIASS Gosstroy Ukrainian SSR in the writing of the programs and execution of the calculations in the computer.

$$\frac{pv}{RT} = 1 + \frac{B(T)}{v}. \tag{32}$$

The second Virial coefficients of ethylene and propylene are listed in Table 11.

The enthalpy, entropy and heat capacity C_p were calculated on the same computer in accordance with equations derived on the basis of thermal equations of state. The enthalpy was measured from the 0°K crystalline state:

$$i = i_T^0 + \Delta i;$$

$$\Delta i = RT\left[Z - 1 - \sum_i \frac{\rho^i}{i} T \frac{dA_i}{dT}\right];$$

$$S = S_T^0 - \Delta S;$$

$$\Delta S = R\left[\ln \frac{p}{1{,}01325} - \ln Z + \sum \frac{\rho^i}{i}\left(A_i + T\frac{dA_i}{dT}\right)\right];$$

$$C_p = C_v + R\left[1 + \sum_i \left(A_i + T\frac{dA_i}{dT}\right)\rho^i\right]^2 \left[1 + \sum_i (i+1) A_i \rho^i\right]^{-1};$$

$$C_v = C_v^0 - R\left[\sum_i \frac{\rho^i}{i}\left(2T\frac{dA_i}{dT} + T^2 \frac{d^2A_i}{dT^2}\right)\right].$$

In these equations A_i are the "Virial coefficients" of the equations of state of ethylene and propylene.

$$A_i = \sum_{k=0} C'_{ik} \frac{1}{T^k};$$

$$\frac{dA_i}{dT} = -\sum_{k=1} C'_{ik} \frac{k}{T^{k+1}},$$

$$\frac{d^2A_i}{dT^2} = \sum_{k=1} C'_{ik} \frac{k(k+1)}{T^{k+2}}.$$

Given in Tables II and VI are the isobaric heat capacities C_p of ethylene and propylene, calculated by the above-mentioned method, for pressures above 100 bar. The isobaric heat capacities in the range of parameters of state near the saturation curve and in the supercritical region to a pressure of 100 bar were calculated on the basis of experimental data on the speed of sound. These data agree well (deviation up to 3% in the region of peak heat capacity C_p) with data calculated by the equations of state. This fact and the high accuracy of description of the p, V, T-data confirm the reliability of the computed caloric properties of gaseous ethylene and propylene with the aid of the thermal equations of state offered on pp. 18-20.

CHAPTER II. SPECIFIC VOLUME OF LIQUID ETHYLENE AND PROPYLENE

Review of Experimental Data

Three works have been published to date on experimental determination of the specific volume of liquid ethylene. Michels and Gelderman [1] did investigations on the 273.15°K isotherm at pressures up to 2,696 bar. The accuracy of these data is 0.01%. The specific volumes obtained in [1] are listed below:

p, bar	v, см^3/г	p, bar	v, см^3/г
43,37	2,8738	330,81	2,1138
48,25	2,7919	353,11	2,0961
54,52	2,7187	494,72	2,0072
61,52	2,6582	527,24	1,9308
69,27	2,6055	729,04	1,9076
77,86	2,5584	774,79	1,8922
86,33	2,5195	1053,43	1,8152
87,24	2,5157	1116,12	1,8010
91,78	2,4975	1130,42	1,7977
135,57	2,3690	1450,80	1,7365
144,82	2,3486	1532,15	1,7231
215,57	2,2320	1769,72	1,6883
230,53	2,2130	2695,80	1,5878

N. V. Boyko and B. V. Voytyuk [2] investigated the specific volume of liquid ethylene at temperatures from 180 to 273°K and pressures up to 60 bar by the method of hydrostatic weighing using strain gauges. The error of the data, according to the authors, was 0.5%. Considering the low purity of the investigated compound (99.7%), these data should be considered preliminary. Later on, after improvement of experimental method, the specific volume of liquid ethylene with the same parameters was investigated by B. V. Voytyuk for a specimen containing 99.99% ethylene. The data obtained, the accuracy of which is 0.15%, are presented in Table 12.

The main procedural element of this work is consideration of the correction for heat transfer in the weighing head. Since high-density current (55 A/mm^2) passes through the strain gauge, the latter is a heating element. The conditions of heat exchange between the strain gauge and the investigated gas are governed, assuming other conditions to be equal, by the nature and density of the gas, which varies as the pressure in the system changes.

Table 12. Experimental Data on Specific Volume of Liquid Ethylene (Ethylene -- 99.99% by Volume, Ethane -- 0.01% by Volume)

p, кгс/см^2	v, cm^3/g at t, °C									
	0	—5	—10	—20	—30	—45	—60	—70	—80	—90
5	—	—	—	—	—	—	—	—	1,882	1,830
10	—	—	—	—	—	—	2,005	1,938	1,879	1,828
15	—	—	—	—	—	2,124	2,001	—	—	—
20	—	—	—	—	2,285	2,116	1,997	1,931	1,874	1,824
25	—	—	—	—	2,273	2,109	—	—	—	—
30	—	—	—	2,406	2,260	2,103	1,989	1,925	1,869	1,820
35	—	—	2,595	2,388	2,250	2,096	—	—	—	—
39	—	2,731	—	—	—	—	—	—	—	—
40	—	—	2,561	2,371	2,239	2,091	1,982	1,920	1,864	1,816
42	2,921	2,699	—	—	—	—	—	—	—	—
45	2,863	2,670	2,531	2,357	2,230	2,086	—	—	—	—
48	2,813	2,643	—	—	—	—	—	—	—	—
50	—	—	2,506	2,343	2,221	2,080	1,975	1,914	1,860	1,813
51	2,771	2,619	—	—	—	—	—	—	—	—
54	2,733	2,597	—	—	—	—	—	—	—	—
55	—	—	2,483	2,329	2,212	2,076	—	—	—	—
57	2,701	2,577	—	—	—	—	—	—	—	—
60	2,675	2,558	2,462	2,315	2,204	2,071	1,969	1,909	1,855	1,810

The required correction for fluctuation of heat transfer conditions was determined by finding the dependence of the readings of the strain gauge, installed on the top and bottom locking devices, on the pressure at a strictly fixed weighing unit temperature.

Both dependences, as it turned out, coincide for the same compound, and this is reason to consider them uniquely when the strain gauge is operating normally. The correction for heat transfer is 2% of the measured specific volume, and the error of determination of the correction does not exceed 2.5%.

During determination of the density of liquid ethylene the pressure in the system was created by the gas of the investigated compound, since the temperature of the weighing head was maintained at 323.15°K. The critical temperature of ethylene is 283.05°K.

Data on the specific volume of liquid ethylene on the saturation curve at temperatures of 183.15-273.15°K were obtained by extrapolating the experimental isotherms to saturation pressure [3]. Analysis of these data (see Chapter III) confirms their high accuracy.

The specific volume of liquid ethylene was investigated by Ye. A. Golovskiy, V. A. Yelema, V. A. Zagoruchenko and V. A. Tsymarnyy [4] (Table 13) by constant quantity piezometry in the temperature range from 202°K to the critical point at pressures up to 600 bar. The authors give the following measurement errors: $\Delta p = 0.04\text{-}0.16$ bar, $\delta V = 0.06\%$, $\delta G = 0.009\%$ and $\Delta T = 0.08$ deg.

Noteworthy is the work of Dick and Hedley [5], in which Michels' data [1] are smoothed for rounded off pressures.

Table 13. Experimental Data of Golovskiy, Yelema, Zagoruchenko and Tsymarnyy [4] on Density of Liquid Ethylene (Ethylene -- 99.66%, Ethane -- 0.34%)

T°, K	p, кгс/см^2	ρ, г/см^3	T°, K	p, кгс/см^2	ρ, г/см^3
235,62	51,05	0,4668	259,37	113,52	0,4400
240,00	80,63	0,4667	263,77	138,08	0,4400
245,28	115,63	0,4666	270,34	174.29	0,4398
249,61	144,69	0,4665	276,31	207,17	0,4396
255,86	185,95	0,4663	281,05	233,35	0,4395
263,22	234,23	0,4661	278,64	220.14	0,4396
270,61	282,55	0,4659	286,25	261,82	0,4394
270,48	282,39	0,4659	290,87	287,28	0,4393
278,79	331,21	0,4657	296,55	318,06	0,4391
285,09	371,41	0,4655	301,52	348,14	0,4390
291,97	415,21	0,4653	254.43	37,66	0,4171
299,29	461,95	0,4651	260,08	64,76	0,4170
306,83	508,85	0,4650	265,79	91,70	0,4169
202,57	298,33	0,5542	270,05	111,90	0,4168
207,62	357,33	0,5540	272,54	121,82	0,4167
212,80	417,53	0,5538	278,88	151,86	0,4166
218,21	479,73	0,5536	284,87	180,11	0,4164
223,39	538,53	0,5534	290,44	206,63	0,4163
228,99	599,97	0,5532	295,83	231.83	0,4162
218,57	13,79	0,4900	202,02	512,44	0,4160
221,18	34,18	0,4899	202,11	513,24	0,5723
228,93	94,82	0,4897	305,24	276,43	0,5723
234,00	134,48	0,4895	305,51	277,63	0,4160
241,10	189,96	0,4893	265,27	42,75	0,3354
246,23	229,15	0,4891	268,11	53,33	0,3852
250,79	264,08	0,4890	271,48	67,35	0,3852
254,36	291,24	0,4889	276,39	82,81	0,3851
262,07	348.84	0,4887	282,28	105,03	0,3850
266,52	382,36	0,4885	287,36	124,25	0,3849
270,41	411,29	0,4884	293.87	149,23	0,3848
278,60	471,89	0,4882	300,01	172,53	0,3846
286,25	527,92	0,4880	304,86	191,27	0,3845
293,93	583,36	0,4877	304,89	191,39	0,3845
207,86	26,87	0,5121	200,69	390,53	0,5642
211,43	59,55	0,5120	206,45	460,81	0,5640
217,42	114,17	0,5118	211,47	521,84	0,5638
223,33	167,10	0,5116	218,63	605,13	0,5635
228,19	210,40	0,5114	218,52	606,33	0,5635
228,34	211,72	0,5114	200,28	200,70	0,5460
236,15	280,78	0,5112	206.30	256,82	0,5458
242,13	332,96	0,5110	211,56	315,96	0,5456
245,99	366,24	0,5109	216,97	375,52	0,5454
207,36	581,44	0,5722	222,57	436,36	0,5452
209,15	604,08	0,5721	227,37	486,71	0,5450
242,79	21,87	0,4105	232,60	542,18	0,5448
247,45	48,32	0,4404	238,06	599,27	0,5447
253,63	82,92	0,4402			

A list of experimental works pertaining to investigation of the density of liquid propylene is given in Table 14.

Vanghan and Graves [6] investigated density by constant quantity piezometry with an accuracy of ±1%. Their data are presented in Table 15.

Farrington and Sage, using a method described in [7], measured the specific volume of liquid propylene with an accuracy of 0.3%. Their data are given in Table 16.

Table 14. List of Experimental Works on Density of Liquid Propylene

1) Авторы	2) Год	3) Интервал температур, °С	4) Интервал давления, *бар*
Воуген и Гревс [6]	1940	0—91,4	6,9—82,8
Фаррингтон и Сейдж [7]	1949	4,44—87,78	6,9—689,5
Михельс и сотрудники [8]	1953	66,3—88,2	36,26—2192,86
Дитмар, Шульц и Штрессе [9]	1962	(0) — (+90)	19,6—1028,7
Войтюк	1967	(—90) — (+39,3)	5—60

KEY: 1. Authors
Vanghan and Graves [6]
Farrington and Sage [7]
Michels, et al [8]
Dittmar, Schulz and Stresse [9]
Voytyuk

2. Year
3. Temperature range, °C
4. Pressure range, bar

Table 15. Compressibility Factor Z for Liquid Propylene According to Vanghan and Graves [6] for P_{cr} = 45.4 atm, t_{cr} = 91.4°C, ρ_{cr} = 0.233 g/cm^3

π	*p*, *бар*	*z* at *t*, °C				
		0	25	50	75	91,4
0,15	6,90	0,022	—	—	—	—
0,20	9,20	0,028	—	—	—	—
0,25	11,50	0,035	—	—	—	—
0,30	15,64	0,042	0,043	—	—	—
0,40	18,40	0,055	0,057	—	—	—
0,50	23,00	0,069	0,071	0,075	—	—
0,60	27,60	0,083	0,085	0,090	—	—
0,70	32,20	0,097	0.099	0,104	—	—
0,80	36,80	0,109	0,113	0,119	0,131	—
0,90	41,40	0,124	0,127	0,133	0,144	—
1,00	46,00	0,138	0,141	0,147	0,157	0,273
1,02	46,92	—	—	—	—	0,210
1,10	50,60	1,151	0,155	0,161	0,171	0,202
1,20	55,20	0,165	0,169	0,175	0,184	0,209
1,30	59,80	0,179	0,183	0,188	0,197	0,219
1,40	64,40	—	—	—	0,211	0,230
1,50	69,00	—	—	—	—	0,242
1,60	73,60	—	—	—	—	0,254
1,70	78,20	—	—	—	—	0,266
1,80	82,80	—	—	—	—	0,278

The results of experimental investigation of Michels and coworkers [8] on the 66.3, 74.8, 82.8 and 88.2°C isotherms at pressures up to 2,000 atm, were published in 1953. The error of the data was estimated by the authors to be 0.03%. The results of studies [8] are presented in Table 17.

A rather detailed investigation of the specific volume of liquid propylene by means of a constant volume piezometer relieved of pressure was done by Dittmar, Schulz and Stresse [9]. The authors do not give a conclusive evaluation of the accuracy of their data, but state only the errors of measurement of temperature (0.01°C), pressure (0.06%) and volume of the measurement bomb (0.1%). The experimental data [9] are presented in Table 18.

Table 16. Experimental Data of Farrington and Sage [7] on Specific Volume of Liquid Propylene

p, бар	v, см³/г при t, °C						
	4,44	21,11	37,78	54,14	71,11	82,22	87,78
6,895	1,8529	—	—	—	—	—	—
8,619	1,8516	—	—	—	—	—	—
10,343	1,8510	—	—	—	—	—	—
13,790	1,8479	1,9447	—	—	—	—	—
20,685	1,8429	1,9365	2,0620	—	—	—	—
27,580	1,8379	1,9290	2,0501	2,2181	—	—	—
34,475	1,8329	1,9215	2,0383	2,1981	2,4659	—	—
41,370	1,8279	1,9147	2,0277	2,1794	2,4116	2,7250	—
55,160	1,8192	1,9016	2,0077	2,1457	2,3348	2,5302	2,6763
68,950	1,8104	1,8891	1,9890	2,1169	2,2786	2,4322	2,5283
86,188	1,7992	1,8735	1,9684	2,0832	2,2237	2,3442	2,4160
103,425	1,7892	1,8601	1,9490	2,0545	2,1800	2,2817	2,3410
120,663	1,7792	1,8485	1,9315	2,0295	2,1444	2,2343	2,2855
137,900	1,7705	1,8373	1,9159	2,0077	2,1126	2,1975	2,2443
155,138	1,7617	1,8273	1,9022	1,9883	2,0895	2,1663	2,2068
172,375	1,7536	1,8179	1,8891	1,9709	2,0664	2,1400	2,1762
189,613	1,7455	1,8085	1,8772	1,9552	2,0451	2,1138	2,1481
206,850	1,7380	1,7998	1,8666	1,9403	2,0258	2,0913	2,1232
241,325	1,7243	1,7829	1,8472	1,9147	1,9915	2,0526	2,0795
275,800	1,7118	1,7680	1,8298	1,8922	1,9621	2,0189	2,0420
310,275	1,7005	1,7542	1,8142	1,8728	1,9365	1,9890	2,0102
344,750	1,6899	1,7417	1,8010	1,8547	1,9140	1,9634	1,9821
413,700	1,6712	1,7199	1,7730	1,8241	1,8766	1,9203	1,9353
482,650	1,6556	1,7012	1,7486	1,7967	1,8441	1,8803	1,8953
551,600	1,6418	1,6850	1,7268	1,7705	1,8160	1,8479	1,8616
620,55	1,6294	1,6668	1,7068	1,7474	1,7910	1,8192	1,8316
689,500	1,6175	1,6512	1,6862	1,7249	1,7667	1,7936	1,8073

Table 17. Experimental Data of Michels and Coworkers on Specific Volume of Liquid Propylene

v, см³/г	p, bar at t, °C			
	66,3	74,8	82,8	88,2
3,1461	—	—	—	43,504
2,9326	—	—	—	46,212
2,6477	—	—	46,967	—
2,4834	—	42,034	62,610	76,777
2,4176	—	50,788	73,114	—
2,2555	56,256	—	—	—
2,2390	64,142	94,319	122,745	—
2,2253	68,692	99,404	128,486	148,278
2,0772	142,769	181,395	217,317	—
1,9989	209,522	293,405	321,030	—
1,9347	285,783	333,883	379,081	—
1,8468	435,967	—	—	—
1,8212	492,742	550,942	605,445	642,023
1,7203	798,796	—	—	—
1,6615	1059,397	1136,362	1208,575	1256,802
1,5363	1940,154	2039,289	2131,009	2192,857

Table 18. Experimental Data of Dittmar, Schulz and Stresse [9] on Specific Volume of Liquid Propylene

v, см^3/г	p, bar at t, °C									
	0	10	20	30	40	50	60	70	80	90
1,5873	757,1	868,9	977,7	—	—	—	—	—	—	—
1,6129	620,8	725,7	828,7	929,7	1028,7	—	—	—	—	—
1,6393	497,2	599,2	699,2	798,3	894,4	988,5	—	—	—	—
1,6666	388,3	484,4	579,6	672,7	764,9	856,1	945,5	—	—	—
1,6949	291,3	382,5	472,7	561,9	649,2	735,5	820,8	905,2	989,5	—
1,7241	205,9	292,2	377,6	461,9	545,2	628,6	711,0	792,4	874,8	956,1
1,7543	134,4	214,8	295,2	374,6	454,0	532,5	611,0	684,4	766,9	843,4
1,7857	73,5	148,1	222,6	297,1	371,7	445,2	518,8	591,3	662,9	734,5
1,8181	19,6	90,2	160,8	220,6	300,1	369,7	438,4	507,0	575,7	643,3
1,8518	—	41,2	106,9	172,6	237,3	302,0	366,8	431,5	496,2	560,0
1,8867	—	—	61,8	123,6	184,4	245,2	306,9	367,7	428,6	488,4
1,9230	—	—	26,5	83,4	140,2	196,1	253,0	309,9	366,8	423,6
1,9607	—	—	—	48,1	101,0	154,0	207,9	261,8	314,8	367,7
1,9999	—	—	—	19,6	69,6	119,6	169,7	219,7	269,7	319,7
2,0833	—	—	—	—	19,6	63,7	107,9	152,0	196,1	240,3
2,1739	—	—	—	—	—	23,5	62,8	102,0	140,2	178,5
2,2727	—	—	—	—	—	—	23,5	66,7	101,0	135,3
2,3809	—	—	—	—	—	—	—	44,1	73,5	103,0
2,4999	—	—	—	—	—	—	—	—	55,9	81,4
2,6315	—	—	—	—	—	—	—	—	44,1	66,7
2,7777	—	—	—	—	—	—	—	—	—	56,9
2,9411	—	—	—	—	—	—	—	—	—	50,0

The experimental data are generalized in Lehman's review [10]. The tables which he compiled are based on the results of Vanghan and Graves [6], Farrington and Sage [7] and the data of Poll and Maas [11], Hanson [12], Lu, Newitt and Ruhemann [13] on the specific volume of the liquid on the saturation curve.

Table 19. Experimental Data of Authors on Specific Volume of Liquid Propylene (Propylene -- 99.80% by Volume, Propane -- 0.15% by Volume, Ethane -- 0.01% by Volume, Ethylene -- 0.04% by Volume)

t, °C	v, cm^3/g at p, kg/cm^2						
	5	10	20	30	40	50	60
—90	1,515	1,514	1,513	1,512	1,511	1,510	1,509
—80	1,543	1,542	1,540	1,539	1,538	1,537	1,535
—70	1,572	1,571	1,568	1,566	1,564	1,562	1,560
—60	1,602	1,601	1,598	1,596	1,593	1,591	1,589
—50	1,634	1,632	1,629	1,626	1,624	1,621	1,619
—40	1,666	1,664	1,660	1,657	1,654	1,651	1,649
—30	1,701	1,699	1,695	1,692	1,688	1,685	1,682
—20	1,741	1,739	1,735	1,730	1,726	1,722	1,718
—10	1,790	1,787	1,780	1,774	1,768	1,762	1,757
0	—	1,837	1,828	1,820	1,813	1,806	1,800
14,27	—	1,913	1,903	1,894	1,886	1,877	1,869
16,58	—	1,926	1,916	1,907	1,899	1,891	1,883
25,83	—	—	1,976	1,964	1,953	1,942	1,931
32,23	—	—	2,027	2,013	1,999	1,986	1,973
39,31	—	—	2,086	2,067	2,050	2,034	2,020

B. V. Voytyuk, using a method described in [2], did experimental investigations of the specific volume of liquid propylene at temperatures from +40°C to -90°C and at pressures up to 60 atm. Pressure in the system was created by nitrogen, since the critical point of propylene is 365.05°K. In this case nitrogen and liquid propylene came into contact in a connective tube 10 mm in diameter, which minimized the dissolving of nitrogen in the investigated liquid. An experiment was done at -45°C for liquid ethylene to determine the possible solubility of nitrogen in hydrocarbons. The pressure in the system was created first with gaseous ethylene and then with nitrogen. The scattering of experimental data did not exceed 0.15%. Analysis of the composition of the investigated liquid in a KhL-4 chromatograph revealed no notable concentration of nitrogen. The accuracy of data on the specific volume of propylene is 0.15%. The data are listed in Table 19.

Recommended Specific Volumes of Liquid Ethylene and Propylene

The recommended specific volumes of liquid ethylene were found on the basis of experimental data [1, 4] and of the authors' present work.

Results [4] agree quite well with Michels' data [1] on the 273.15°K isotherm. The data in the present work agree with the data in [1] with an accuracy of 0.15%.

In view of the fact that data [4] are limited to comparatively high pressures it is difficult to check their concordance with the authors' data (see Table 12) by direct comparison.

V. A. Zagoruchenko and V. A. Tsymarnyy reported at the Third Thermophysical Conference on the High-Temperature Properties of Matter (Baku, 1968) about the thermal equation of state of liquid ethylene, formulated on the basis of data [4]. The equation is

$$pV = A(T) + B(T)\rho^3 + C(T)\rho^4, \qquad (36)$$

where $A(T) = 427\,505 - 969\,968 \cdot 10^2 \cdot T^{-1} + 826\,658 \cdot 10^4 T^{-2} - 84\,221 \times 10^{-2} T + 6447{,}5 \cdot 10^{-4} T^2$; $B(T) = -37{,}4967 + 132{,}707 \cdot 10^2 T^{-1} - 166{,}370 \cdot 10^4 T^{-2} + 3{,}308 \cdot 10^{-2} T$; $C(T) = 0{,}5739 - 2{,}8167 \times 10^2 T^{-1} + 4{,}4402 \cdot 10^4 T^{-2}$; $[\rho] =$ kmole/m^3; [pV] = kJ/kmole.

The agreement of data [4] with the data presented in this monograph was checked with the aid of this equation. The discrepancy increases monotonically on the 60 bar isobar from 0 at 180 to 0.25% at 270°K. Near the saturation curve the data calculated on the basis of specific volume are overstated by up to 0.6% compared with the data of the authors, and the deviations decrease as the temperature drops. Thus, in the range of parameters of state where equation (36) is interpolated, satisfactory agreement of the results obtained by the authors of the present monograph and of results [4] is confirmed.

The specific volumes of liquid ethylene at pressures below 60 bar, found by graphic processing of experimental data of the authors of the present book, are presented in Table II. The values at pressures from 70 to 500 bar (see Table III) were calculated according to thermal equation of state (36).

Comparison and analysis of the experimental data on the basis of the specific volume of liquid propylene revealed that the data of Dittmar, Schulz and Stresse [9] in overlapping temperature and pressure ranges deviate from the data of Michels and coworkers [8] by 0.5-0.6%. Only on the 50 bar isobar at temperatures above 350°K do the deviations exceed 0.6, and reach 3.6% near the critical point.

The deviations of the data of Farrington and Sage [7] from the data of Michels and coworkers is 0.3% on the 700 bar isobar and drops considerably as pressure decreases. Near the critical point, however, the deviations reach 1%.

The data of Vanghan and Graves [6] are considerably inferior in terms of accuracy to the data in [7, 8, 9]. In the overlapping temperature range of 280-310°K the experimental results of the authors of this work agree with the results of Farrington and Sage within the limits of 0.3-0.40%, and the deviations decrease as temperature drops. Deviations from the data of Dittmar, Schulz and Stresse in the same temperature range amount to 0.5-0.6%.

There is good agreement between the experimental data of Farrington and Sage and test data on the saturation curve [11, 12, 13] in Lehman's review [10]. By extrapolating the experimental isotherms to the saturation pressures [10] the authors obtained data on the specific volume of liquid propylene at temperatures from 183.15 to 313.15°K. Analysis of these data (see Chapter III) confirm their high accuracy.

The data of Michels and coworkers [8], Farrington and Sage [7], and of the authors of this book were used on the basis of what has been stated above for compilation of Table VII of recommended specific volumes of liquid propylene. The accuracy of the data is 0.15% for pressures below 60 bar, 0.3-0.5% for pressures above 60 bar.

CHAPTER III. PROPERTIES OF ETHYLENE AND PROPYLENE ON SATURATION CURVE

Pressure and Density of Saturated Vapor and Liquid

Experimental investigation of the thermal properties of ethylene and propylene on the liquid-vapor equilibrium curve is the subject of a series of works, enumerated in Table 20.

The data presented in the cited works are given in Tables 21 and 22.

Experimental data on the pressure of saturated vapor of ethylene, found in the works of Michels and Wassenaar [8], Mathias, et al [5], Henning and Stock [1], agree satisfactorily. The average divergence between them does not exceed 0.2%. The data of Egan and Kemp [6] are understated relative to the data of Michels by an average of 0.5%, and the data of Crommelin and Watts [3] are 0.9% higher than the data of Michels. The specific volume of saturated liquid ethylene was determined by Maass, Wrigt [2] and Mathias and coworkers [4]. Their data practically coincide at a temperature of 165°K. In the 170-200°K temperature interval, however, interpolation of Mathias' data yields specific volumes of the liquid up to 0.4% overstated in comparison with Maass' data. The specific volume of saturated ethylene vapor was investigated by Mathias and coworkers [4]. Deviations of the experimental points obtained in this work from the smooth curve amount to an average of 2%. It is noteworthy that not all thermal parameters were determined in [1-8] on the saturation curve. The data of B. V. Voytyuk on the specific volume of the liquid were obtained by extrapolating the experimental isotherms of compressibility (see Chapter II) to the saturation pressures of the vapors. The experimental data of Yu. F. Voynov, N. V. Pavlovich, D. L. Timrot [17] were obtained by direct measurement of the pressure of saturated vapors and specific volumes of equilibrium liquid and vapor. The specific volumes of the liquid and vapor were determined by hydrostatic weighing with the aid of double strain gauges. In this case the difference method of weighing was employed (quartz float and calibrated weight, placed in the investigated phase, were weighed), which excluded the effect of changing conditions of heat exchange in the weighing head. The limit relative error of determination of the specific volume of the vapor, attributed to errors in weighing and determination of the volume of the float, is 0.02-0.12%, and the limiting error of determination of the specific volume of the liquid is 0.06-0.7%. The maximum errors correspond to minimum densities.

Table 20. List of Works Pertaining to Experimental Investigation of Thermal Properties of Ethylene and Propylene on Saturation Curve

1) Авторы	2) Год	3) Измеряемая величина	4) Температура, °К
	5) Этилен		
7) Хеннинг, Шток [1]	1921	p	131—162
Маасс, Райт [2]	1921	v'	164—203
Кроммелинг, Уотс [3]	1927	p	208—276
		v', v''	209—282
Матиас, Кроммелинг, Уотс [4]	1927	v'	128—170
Матиас, Кроммелинг, Уотс [5]	1929	p	203—281
Эган, Кемп [6]	1937	p	123—170
Ламб, Ропер [7]	1940	p	147—173
Михельс и др. [8]	1950	p	149—280
Войтюк	1967	v'	183—273
Войнов и др.	1965—1967	p, v', v''	163—280
	6) Пропилен		
8) Маас, Райт [2]	1921	p	235—283
		v'	194—292
Пауелл, Джайок [9]	1939	p	165—225
Воуген, Гревс [10]	1940	p, v', v''	273—364
Ламб, Ропер [7]	1940	p	151—235
Лу, Ньюит, Рухман [11]	1941	p, v', v''	243—365
Технический Комитет NGAA [12]	1942	v'	260—283
Марчман и др. [13]	1949	p, v'	303—348
Фаррингтон, Сейдж [14]	1949	p, v', v''	277—360
Михельс и др. [15]	1953	p	297—363
Морекрофт [16]	1958	v'	273—348
Войтюк	1967	v'	183—313
Войнов и др. [17]	1965—1967	p, v', v''	173—362

KEY: 1. Authors
2. Year
3. Measured parameter
4. Temperature, °K
5. Ethylene
6. Propylene
7. Henning, Stock [1]
Maass, Wrigt [2]
Crommelin, Watts, [3]
Mathias, Crommelin, Watts [4]
Mathias, Crommelin, Watts [5]
Egan, Kemp [6]
Lamb, Roper [7]
Michels, et al [8]
Voytyuk
Voynov, et al

8. Maass, Wrigt [2]
Powell, Giaque [9]
Voughan, Graves [10]
Lamb, Roper [7]
Lu, Newitt, Ruheman [11]
Technical Committee NGAA [12]
Marchman, et al [13]
Farrington, Sage [14]
Michels, et al [15]
Morecroft [16]
Voytyuk
Voynov, et al [17]

The recommended thermal parameters of ethylene and propylene on the saturation curve (Tables I, V) were found by graphic analysis of the experimental data listed in Tables 21 and 22. The data on the pressure of the saturation vapors of ethylene thus obtained coincide with an accuracy of 0.2% with the experimental data of Michels [8], Mathias [5], Henning and Stock [1] and of the authors of the present work. The data of Crommelin and Watts [3] are 1% overstated compared with the recommended values, and the data of Egan and Kemp [6] are 0.6% understated.

Deviations of the recommended specific volumes of liquid ethylene from the experimental data of Maass [2], Mathias [4] and the authors of the present work, fall within the limits of 0.5%. The data of B. V. Voytyuk and Yu. F. Voynov, et al, agree, also within the limits of 0.5%.

Table 21. Experimental Data of Various Authors on Properties of Ethylene on Saturation Curve

1) Авторы	2) Год	T, °K	p, бар	v', м³/кг	v'', м³/кг
3) Хеннинг, Шток [1]	1921	131,69	0,05235	—	—
		143,09	0,1553	—	—
		152,13	0,3217	—	—
		162,82	0.6775	—	—
4) Маасс, Райт [2]	1921	164,45	—	0,001735	—
		168,45	—	0,001756	—
		174,10	—	0,001776	—
		178,85	—	0,001799	—
		183,75	—	0,001824	—
		189,10	—	0,001852	—
		198,95	—	0,001906	—
		203,70	—	0,001933	—
5) Кроммелинг, Уотс [3]	1927	208,11	6,314	—	—
		216,65	8,602	—	—
		226,60	11,997	—	—
		237,38	16,597	—	—
		247,88	22,17	—	—
		258,14	28,82	—	—
		264,37	33,39	—	—
		269,38	38,45	—	—
		276,60	41,80	—	—
6) Матиас, Кроммелинг, Уотс [4]	1927	128,08	—	0,001601	—
		153,25	—	0,001654	—

[Continued on next page]

KEY: 1. Authors
2. Year
3. Henning, Stock [1]
4. Maass, Wrigt [2]
5. Crommelin, Watts [3]
6. Mathias, Crommelin, Watts [4]
7. Mathias, Crommelin, Watts [4]
8. Mathias, Crommelin, Watts [5]
9. Lamb, Roper [7]
10. Egan, Kemp [6]
11. Michels, Wassenaar, Louwerse [8]
12. Michels, Wassenaar, Louwerse [8]
13. Voytyuk
14. Voynov, Pavlovich, Timrot

Table 21 (Continued)

1) Авторы	2) Год	T, °K	p, бар	v', м³/кг	v'', м³/кг
7) Матнас, Кроммелинг, Уотс [4]	1927	158,46	—	0,001713	—
		170,14	—	0,001762	—
		209,74	—	0,001977	0,07946
		225,00	—	0,002091	0,04899
		236,02	—	0,002192	0,03394
		248,82	—	0,002344	0,02389
		253,95	—	0,002421	0,01955
		258,97	—	0,002509	0,01668
		262,23	—	0,002576	0,01488
		265,45	—	0,002651	0,01315
		278,99	—	0,003242	0,007538
		279,65	—	0,003296	0,007291
		281,13	—	0,003481	0,006550
		282,65	—	0,004630	0,004630
8) Матнас, Кроммелинг, Уотс [5]	1929	203,88	5,329	—	—
		212,25	7,301	—	—
		221,06	9,903	—	—
		232,14	14,091	—	—
		242.62	19,101	—	—
		253,14	25,235	—	—
		263.14	32,395	—	—
		265,61	34,372	—	—
		273,15	40,810	—	—
		281.05	48,800	—	—
9) Ламб, Ропер [7]	1940	147,88	0,2318	—	—
		154,91	0,3946	—	—
		163,12	0,6973	—	—
		168,30	0,9517	—	—
		170,16	1,0587	—	—
		173.24	1,2640	—	—
10) Эган, Кемп [6]	1937	123,51	0.02102	—	—
		128,59	0,03781	—	—
		135,96	0,06082	—	—
		140,98	0,12864	—	—
		145,59	0,1914	—	—
		151,05	0,2954	—	—
		156,21	0,4313	—	—
		161,67	0,6253	—	—
		165,15	0,7812	—	—
		167,80	0,9179	—	—
		170.40	1,0702	—	—
11) Михельс, Вессенар, Лоуверзе [8]	1950	149,36	0,26030	—	—
		156,11	0,43040	—	—
		159,74	0,55264	—	—
		163,60	0,71116	—	—
		166,61	0,85894	—	—
		169,03	0,99358	—	—
		169,03	0,99368	—	—
		169.04	0,99377	—	—
		169,71	1,0338	—	—
		169,70	1,0338	—	—
		169,70	1,0339	—	—
		172,44	1,2101	—	—
		179,77	1,7983	—	—
		183,96	2,2196	—	—
		188,56	2,7661	—	—
		196,60	3,9575	—	—
		204,23	5,4086	—	—
		213,61	7,6782	—	—
		223,33	10,688	—	—
		233,10	14,501	—	—
		243,07	19,314	—	—

[Continued on next page]

Table 21 (Continued)

Авторы 1)	Год 2)	T, °K	p, бар	v', м³/кг	v", м³/кг
12) Михельс, Вассенар, Лоуверзе [8]	1950	249,67	23,087	—	—
		255,26	26,677	—	—
		261,89	31,438	—	—
		267,84	36,231	—	—
		273,59	41,354	—	—
		277,30	44,946	—	—
		279,61	47,306	—	—
		280,54	48,279	—	—
13) Войтюк	1967	183,15		0,001831	—
		193,15		0,001883	—
		203,15	—	0,001941	—
		213,15	—	0,002007	—
		223,15	—	0,002084	—
		233,15	—	0,002175	—
		243,15	—	0,002286	—
		253,15	—	0,002422	—
		263,15	—	0,002610	—
		268,15	—	0,002752	—
		273,15	—	0,002934	—
14) Бойнов, Павлович, Тимрот	1965	163,3	—	0,001732	0,6757
	1967	173,15	1,265	0,001785	0,3891
		178,15	1,659	0,001808	0,3023
	1965	183,1	—	0,001824	0,2357
	1967	183,15	2,137	0,001832	0,2381
		188,15	—	0,001856	0,1899
	1966	193.15	3,409	0,001873	0,1541
	1967	193,15	3,409	0,001883	0,1531
		198,15	4,224	0,001911	0,1250
		203,15	5,178	0,001941	0,1028
		208,15	6,273	0,001972	0,08554
		213,15	7,518	0,002006	0,07179
		218,15	8,973	0,002042	0,06064
		223,15	10,61	0,002081	0,05171
		228,15	12,46	0,002123	0,04427
	1966	233,15	11,52	0,002163	0,03755
	1967	233,15	14,49	0,002158	0,03788
		238,15	16,78	0,002221	0,03239
	1966	243,15	19,35	0,002272	0,02754
	1967	243,15	19,34	0,002279	0,02775
	1965	247,4	21,73	0,002317	0,02424
	1967	248,15	22,12	0,002345	0,02375
	1965	252,8	25,06	0,002401	0,02056
	1966	253,15	25,28	0,002412	0,02029
	1967	253,15	25,25	0,002420	0,02025
	1965	257,2	27,99	0,002475	0,01799
	1967	258,15	28,67	0,002510	0,01726
	1965	261,8	31,33	0,002562	0,01554
	1966	263,15	32,45	0,002607	0,01485
	1967	263.15	32,35	0,002622	0,01466
	1965	264,7	33,65	0,002628	0,01411
		267,2	35,64	0,002688	0,01279
	1966	268,15	36,53	0,002738	0,01264
	1967	268,15	36,51	0,002771	—
	1965	269,8	37,84	0,002764	0,01191
	1965	272,2	39,99	0,002842	0,01090
	1967	273,15	40,89	0,002965	—
	1965	274,4	—	0,002924	0,00992
	1965	276.1	43,75	0.003009	0.00912
	1965	277.8	45,39	0.003111	0.00834
	1965	280,9	48,64	0,003455	0,00666

Table 22. Experimental Data of Various Authors on Properties of Propylene on Saturation Curve

1) Авторы	2) Год	T, °K	p, бар	v', м³/кг	v'', м³/кг
3) Маасс, Райт [2]	1921	235,70	1,480	—	—
		238,75	1,742	—	—
		246,10	2,228	—	—
		257,50	3,426	—	—
		273,25	5,679	—	—
		278,90	6.986	—	—
		280,65	7,359	—	—
		283,15	7.919	—	—
		194,95	—	0,001542	—
		214,65	—	0,001601	—
		224,65	—	0,001637	—
		235,70	—	0,001674	—
		238,75	—	0,001684	—
		245,50	—	0,001708	—
		257,50	—	0,001752	—
		273,15	—	0,001827	—
		292,15	—	0,001929	—
4) Пауелл, Джайок [9]	1939	165.81	0,02130	—	—
		172,77	0,03921	—	—
		176,52	0,05322	—	—
		180,00	0,06975	—	—
		184,54	0,09768	—	—
		189,50	0,1380	—	—
		195,63	0,2060	—	—
		202,72	0,3164	—	—
		207,45	0,4132	—	—
		213,39	0,5672	—	—
		220,28	0.7977	—	—
		225,98	1,0398	—	—
5) Воуген, Гревс [10]	1940	273.15	5,83	0,001695	0,08130
		298,15	11,53	0,001862	0,04065
		323.15	20,55	0,002092	0,02183
		348,15	33,94	0.002519	0,01124
		363.15	44,76	0,003401	0,005747
		364.15	45.68	0.003610	0,005291
		364.55	46.00	0,004292	0.004292
6) Ламб, Ропер [7]	1940	151,72	0.005159	—	—
		185,08	0.1010	—	—
		198,47	0,2445	—	—
		212,51	0,5394	—	—
		222,52	0,8836	—	—
		227,58	1,1122	—	—
		235.42	1,5521	—	—
7) Лу, Ньюнт, Рухман [11]	1941	243,15	2,097	0.001703	—
		253,17	3,040	0.001742	0,1462
		263,15	4,306	0.001779	0,1096
		273,15	5,867	0,001831	0.08130
		283,15	7,731	0,001883	0,06211
		293,15	10,26	0,001938	0,04717
		303.15	13.19	0,002020	0,03610
		313,15	16,54	0,002101	0,02833
		323,15	20.66	0,002183	0,02188
		333,15	25.20	0.002288	0,01683
		343,15	30,40	0,002451	0,01312
		353,15	36,73	0,002703	0.01000
		363,15	44,60	—	0,007299
		365.25	46.00	0,004167	0,004167
8) Технический комитет NGAA [12]	1942	260.92	—	0,001775	—
		266.48	—	0,001801	—
		277,59	—	0,001856	—
		283,15	—	0,001886	—

[Continued on next page; key on page 54]

Table 22 (Continued)

1) Авторы	2) Год	T, °K	p, бар	v', м³/кг	v'', м³/кг
9) Марчман, Пренгль, Мотард [13]	1949	303,15	13,06	—	0,03604
		323,15	20,56	—	0,02182
		348,15	33,92	—	0,01122
10) Фаррингтон, Сейдж [14]	1949	277,59	6,722	0,001853	0,07009
		291,26	10,49	0,001948	0,04499
		310,93	15,67	0,002071	0,02945
		327,59	22,55	0,002230	0,01941
		344,26	31,48	0,002486	0,01250
		355,37	38,75	0.002810	0,008765
		360,93	42,89	0,003121	0,006792
11) Михельс, Вессенар, Лоуверзе [15]	1953	297,93	11,494	—	—
		317,28	18,103	—	—
		339,48	28,735	—	—
		347,91	33,755	—	—
		355,93	39,139	—	—
		361,02	42,910	—	—
		361,43	43,274	—	—
		361,56	43,368	—	—
		362,13	44,626	—	—
12) Морекрофт [16]	1958	273,15	—	0,001825	—
		286,25	—	0,001896	—
		298,15	—	0,001975	—
		313,15	—	0,002090	—
		323,15	—	0,002178	—
		333,15	—	0,002360	—
		343,15	—	0,002479	—
		348,15	—	0,002598	—
13) Войтюк	1967	183,15	—	0,001506	—
		193,15	—	0,001533	—
		203,15	—	0,001562	—
		213,15	—	0,001593	—
		223,15	—	0,001626	—
		233,15	—	0,001661	—
		243,15	—	0,001698	—
		253,15	—	0,001739	—
		263,15	—	0,001783	—
		273,15	—	0,001832	—
		283,15	—	0,001886	—
		293,15	—	0,001946	—
		303,15	—	0,002014	—
		313,15	—	0,002094	—
14) Войнов, Павлович, Тимрот	1965	173,2	—	0,001498	—
		173,2	—	0,001479	8,382
		203,2	—	0,001572	—
	1967	213,15	0,5591	0,001596	0,7337
		218,15	0,7190	0,001612	0,5787
		223,15	0.9131	0,001629	0,4632
		228,15	1,146	0,001646	0,3781
		233,15	1,420	0,001664	0,3094
		238,15	1,744	0,001683	0,2560
		243,15	2,122	0,001701	0,2136
	1965	243,2	—	0,001702	0,2141
	1967	248,15	2,557	0,001720	0,1790
		253,15	3,059	0,001711	0,1509
		258,15	3,629	0,001761	0,1284
		263,15	4,275	0,001781	0,1097
		268,15	5,009	0,001808	0,09434
		273,15	5,831	0,001831	0,08137
	1965	273,2	—	0,001829	0,08038
	1967	278,15	6,757	0,001858	0,07042
	1966	283,15	7,783	0,001884	0,06109
		285,00	8,22	0,001888	0,05767

[Continued on next page]

Table 22 (Continued)

1) Авторы	2) Год	T °K	p, бар	v', м³/кг	v'', м³/кг
15) Войнов, Павлович, Тимрот	1967	288,15	8,913	0,001914	0,05319
	1966	290,00	9,39	0,001928	—
	1967	293,15	10,17	0,001943	0,04651
	1966	295,00	10,69	0,001954	0,04427
	1967	298,15	11,56	0,001978	0,04080
	1966	300,00	12,11	—	0,03889
	1967	303,15	13,08	0,002011	0,03597
	1965	303,5	—	0,002014	0,03592
	1966	305,00	13,65	0,002018	0,03436
	1967	308,15	14,72	0,002051	0,03172
	1965	309,6	—	0,002054	0,03050
	1966	310,00	15,35	0,002061	0,03027
	1967	313,15	16,51	0,002091	0,02803
	1966	315,00	17,18	0,002094	0,02679
	1965	315,6	—	0,002109	0,02603
	1967	318,15	18,45	0,002135	0,02482
	1966	320,00	19,19	—	0,02366
	1965	322,0	—	0,002169	0,02233
	1967	323,15	20,55	0,002185	0,02195
	1966	325,00	21,33	0,002193	0,02084
	1967	328,15	22,82	0,002239	0,01935
	1965	328,5	—	0,002239	0,01904
	1966	330,00	23,77	0,002254	—
	1967	333,15	25,30	0,002305	0,01708
	1965	334,4	—	0,002323	0,01624
	1966	335,00	26,24	0,002333	0,01629
	1967	338,15	27,95	0,002374	0,01491
	1966	340,00	28,97	0,002415	0,01422
	1965	340,7	—	0,002424	0,01371
	1967	343,15	30,80	0,002460	0,01297
	1966	345,00	31,84	0,002518	0,01236
	1965	347,0	—	0,002547	0,01155
	1967	348,15	33,86	0,002574	0,01112
	1966	350,00	35,08	0,002630	0,01054
	1965	353,1	—	0,002722	0,009515
	1967	353,15	37,18	0,002734	0,009311
	1966	355,00	38,55	0,002780	0,008787
	1965	355,6	—	0,002815	0,008680
		358,0	—	0,002936	0,007825
		359,2	—	0,003006	0,007423
		360,4	—	0,003101	0,006973
		361,5	—	0,003210	0,006506
		362,8	—	0,003389	0,005977

KEY: 1. Authors
2. Year
3. Maass, Wrigt [2]
4. Powell, Giaque [9]
5. Voughan, Graves [10]
6. Lamb, Roper [7]
7. Lu, Newitt, Ruheman [11]
8. Technical Committee NGAA [12]
9. Marchman, Prengle, Motard [13]
10. Farrington, Sage [14]
11. Michels, Wassenaar, Louwerse [15]
12. Morecroft [16]
13. Voytyuk
14. Voynov, Pavlovich, Timrot
15. Voynov, Pavlovich, Timrot

The recommended specific volumes of ethylene vapor coincide to 0.6% with the experimental data of the authors of the present book and diverge up to 3% from Mathias' data [4]. All thermal parameters on the saturation curve of propylene were investigated in [10, 11, 13, 14]. The other works pertain to investigation of the thermal dependences of the saturation pressure of the vapors and specific volume of the liquid. Data on the saturation vapor pressure, obtained by Michels and coworkers [15], Voughan and Graves [10], Farrington and Sage [14] and Marchman and coworkers [13], agree satisfactorily. The average scattering among them does not exceed 0.2%. The data of Lu, Newitt, Ruheman [11] differ by up to 1% from the data in [10, 13, 14, 15], and the data of Maass and Wrigt [2], by more than 2%. The data of Powell and Giaque [9] agree with the data of Lamb and Roper [7] with an accuracy of 0.5%. The discrepancies between the individual volumes of the liquid, obtained in the works of Maass and Wrigt [2], NGAA Technical Committee [12], Farrington and Sage [14], Morecroft [16], do not exceed 0.2% on the average. The data of Lu, Newitt and Ruheman [11] far from the critical point agree satisfactorily with the data in [10, 13, 14, 15]. The scattering does not exceed 0.5%. Near the critical point, however, the discrepancies between the data of Farrington and Sage reach 0.8%, and Morecroft's data more than 1%. The data of Voughan and Graves [10] on the specific volumes of the saturated liquid are strongly understated and deviations of the relative data of Farrington and Sage [14] and of the authors of [11, 12, 13, 16] reach up to 7%. The disagreement of the specific volumes of the saturated vapor obtained in [13, 14, 10] averages 0.5% with maximum deviations up to 2%. In terms of the pressure of saturated propylene vapors the recommended values coincide to 0.2% with the data of Marchman [13], Farrington [14], Michels [15], and the authors of this book. Disagreement with the data of Maass [2] reaches 6%, with the data of Voughan and Graves [10] and data of Powell [9], 0.4%.

In terms of the specific volume of liquid propylene the data of Voughan and Graves [10] are up to 7% lower than recommended and the data of the other authors coincide with the recommended values with an accuracy of 0.5%. The data of B. V. Voytyuk, Yu. F. Voynov, et al [17] coincide within the same limits. In terms of the specific volumes of propylene vapor the recommended values coincide to 0.6% with the experimental data of Voughan and Graves [10], Farrington [14], Marchman [13] and the authors of this book.

Heat of Evaporation

Experimental works on the heat of evaporation of ethylene and propylene are listed in Table 23.

Experimental data on the heat of evaporation near the normal boiling point were found by Egan and Kemp [6] ($r = 483.1 \pm 0.4$ kJ/kg at $T = 169.45°K$) and for propylene by Powell and Giaque [9] ($r = 438.0 \pm 0.3$ kJ/kg at $T = 225.40°K$). The heats of evaporation of ethylene and propylene were measured by Clusius and Konnertz [18]. The other works listed in Table 23 contain theoretical data. The discrepancies among the various authors reach 3%.

Our heat of evaporation (Table I) was calculated according to the Clapeirone-Clusius equation using the recommended p, v, T-data on the saturation curve. To determine the pressure derivative in terms of temperature for ethylene we used the equation

$$\lg p = 30{,}47713 + 0{,}01102067 \cdot T - 11{,}213925 \cdot \lg T - \frac{1243{,}765}{T}, \tag{34}$$

which describes our experimental data on the pressure of the saturated vapors with an accuracy of 0.2%. The pressure derivative in terms of temperature was determined for propylene by the graphoanalytic method. For the 160-250°K temperature range we used the equation

$$\lg p = 3{,}94460 - \frac{785}{T - 26{,}15} + \Delta_1 (T); \tag{35}$$

for temperatures above 250°K we used the equation

$$\lg p = 11{,}53678 + 0{,}00208316 \cdot T - 2{,}90052 \cdot \lg T - \frac{1167{,}816}{T} + \Delta_2 (T), \tag{36}$$

where p is pressure, bar; T is temperature, °K.

Table 23. List of Works Containing Data on the Heats of Evaporation of Ethylene and Propylene

Authors	Year	Temperature range, °K
	Ethylene	
1)		
Матиас и др. [5]	1929	128—281
Эган, Кемп [6]	1937	169
Клузиус, Конертц, [18]	1946	143—254
Тиличеев [19]	1951	113—273
Крамер [20]	1955	123—281
Загорученко [21]	1959	153—282
	Propylene	
2)		
Пауелл, Джайок [9]	1939	225
Воуген, Гревс [10]	1940	273—364
Клузиус, Конертц [18]	1946	193—288
Фаррингтон, Сейдж [14]	1949	277—361
Каньяр и др. [22]	1951	225—361
Тиличеев [19]	1951	93—363
Леман [23]	1962	163—363

KEY:

1. Mathias, et al [5]
   Egan, Kemp [6]
   Clusius, Konnertz [18]
   Tilicheyev [19]
   Cramer [20]
   Zagoruchenko [21]
2. Powell, Giaque [9]
   Voughan, Graves [10]
   Clusius, Konnertz [18]
   Farrington, Sage [14]
   Canjar, et al [22]
   Tilicheyev [19]
   Lehman [23]

The functions $\Delta_1(T)$ and $\Delta_2(T)$ were determined from the recommended saturation pressures according to Table V. The derivatives of the functions $\Delta_1(T)$ and $\Delta_2(T)$ were found graphically. Near the normal boiling point of ethylene for T = 169.45°K interpolation of our data yields a heat of evaporation of ethylene r = 481.3 kJ/kg, which coincides with an accuracy of 0.4% with the r obtained experimentally by Egan and Kemp [6]. The experimental data of Clusius and Konnertz [18] coincide with the recommended data at temperatures of 177 and 226°K. At 210°K data [18] exceed the recommended values by 2%. At temperatures above 226°K the deviations change sign and reach 3-4% near the critical point.

Our data coincide with an accuracy up to 1% with Zagoruchenko's data [21] in the entire investigated temperature range. The deviation of the data of M. D. Tilicheyev [19] and Cramer [20] is analogous to those of Clusius and Konnertz [18]. Mathias' data [5] are lower than the recommended, the deviations do not exceed 2-3% and the mean deviation is 1.5%. Near the normal boiling point of propylene for T = 225.40°K interpolation of our data yields a heat of evaporation of propylene r = 437.2 kJ/kg, which coincides with an accuracy of 0.2% with the r obtained experimentally by Powell and Giaque [9]. The experimental data of Clusius and Konnertz [18] are 0.5-1.5% higher than the recommended. In the 210-320°K temperature range the discrepancies between the recommended data and the data of Voughan, Graves [10], M. D. Tilicheyev [19] and Canjar [22] do not exceed 1%. At 350°K our data coincide with the data of Farrington and Sage [14]; Lehman's data [23] fall 1.5% below, and Voughan and Graves' data [10] and those of M. D. Tilicheyev [19], 1.5% above our data.

Analysis of the method of calculating our heats of evaporation of ethylene and propylene and the character of the difference of these data from the data of other authors made it possible to evaluate the accuracy of the recommended heats of evaporation of ethylene and propylene as not worse than ±1% in the temperature range from 160°K to the critical point.

Critical Parameters

The critical parameters of ethylene and propylene were determined in the works listed in Tables 24 and 25. The specific difficulties of experimental analysis of the critical parameters are the cause of considerable difference among the results obtained by the various authors. Detailed analysis of the methods and results of investigation of the critical parameters of ethylene and propylene is done in the work of Kobe and Lynn [38].

The critical pressure and temperature can be measured directly. The critical specific volume, however, because of the infinite compressibility of the compound in the critical state and difficulty of reaching thermodynamic equilibrium, is determined experimentally with great errors. Various empirical principles [28, 47, 48] yield more accurate results.

Table 24. Critical Parameters of Ethylene According to Various Authors

Authors	Year	T, °K	p, бар	v, м³/кг
1) Ван дер Ваальс [24]	1880	282,35	58,77	0,00278
Сарpау [25]	1882	274,65	44,08	0,00676
Кальетет [26]	1882	286,15	—	—
Дьюар [27]	1881	283,25	51,67	—
Кальетет, Матиас [28]	1886	285,65	—	0,004762
Ольшевский [29]	1895	283,15	51,67	—
Виллард [30]	1897	283,15	—	—
Кардозо, Арни [31]	1912	282,65	51,32	—
Маасс, Геддес [32]	1937	282,65	50,64	0,004212
Маасс, Райт [2]	1921	283,05	—	—
Мак Интош, Маасс [33]	1938	282,65	—	—
Мак Интош и др. [34]	1939	283,05	51.17	0,00440
Нальдрет, Маасс [35]	1940	282,36	—	—
Кей [36]	1948	282,40	50,71	—
Перри [37]	1950	282.85	51,57	0.004545
Кобе, Линн [38]	1952	283.05	51,17	0,004405
Дин [39]	1956	282.65	50,64	0,004550
Стил, Тодос [40]	1961	282,4	50,66	—
Флинн, Тодос [41]	1962	283,1	—	0,004406
Варгафтик [42]	1963	283,05	50,97	0,004739
Катц и др. [43]	1965	283.05	51,17	0,004402
Принятые значения	—	283.05	51,0	0,00469

KEY: 1. Van der Waals [24]
Sarrau [25]
Cailletet [26]
Dewar [27]
Cailletet, Mathias [28]
Olszewski [29]
Villard [30]
Cardoso, Arni [31]
Maass, Geddes [32]
Maass, Wrigt [2]
McIntosh, Maass [33]
McIntosh, et al [34]
Naldrett, Maass [35]
Kay [36]
Perry [37]
Kobe, Lynn [38]
Din [39]
Stiel, Thodos [40]
Flynn, Thodos [41]
Vargaftik [42]
Katts, et al [43]
Accepted values

The p, v, T-data of ethylene and propylene on the saturation curve which we recommend agree satisfactorily with the following critical parameters: for ethylene T_f = 283.05°K, p_f = 51.0 bar, v_f = 0.00469 m^3/kg; for propylene T_f = 365.05°K, p_f = 46.4 bar, v_f = 0.00434 m^3/kg.

These data were obtained in the following manner. The critical temperatures were taken from [42]. The critical pressures were found by graphic extrapolation to T_f of the recommended data in terms of the saturation pressure of the vapors. The critical volumes were determined according to the empirical law of averages. According to this rule the graphs of the functions

$$\lg \frac{\rho' + \rho''}{2} = f\left(\lg \sqrt{\rho' \cdot \rho''}\right),$$

$$\left|\lg \frac{v' + v''}{2}\right| = f\left(\lg \sqrt{\rho' \cdot \rho''}\right)$$

in the range of temperatures from critical to a temperature 50°K below critical are linear to 0.5%, and the point of intersection of these curves with $\log \frac{\rho' + \rho''}{2} = \log \sqrt{\rho' \cdot \rho''}$ corresponds to the logarithm of the critical density (Figure 4).

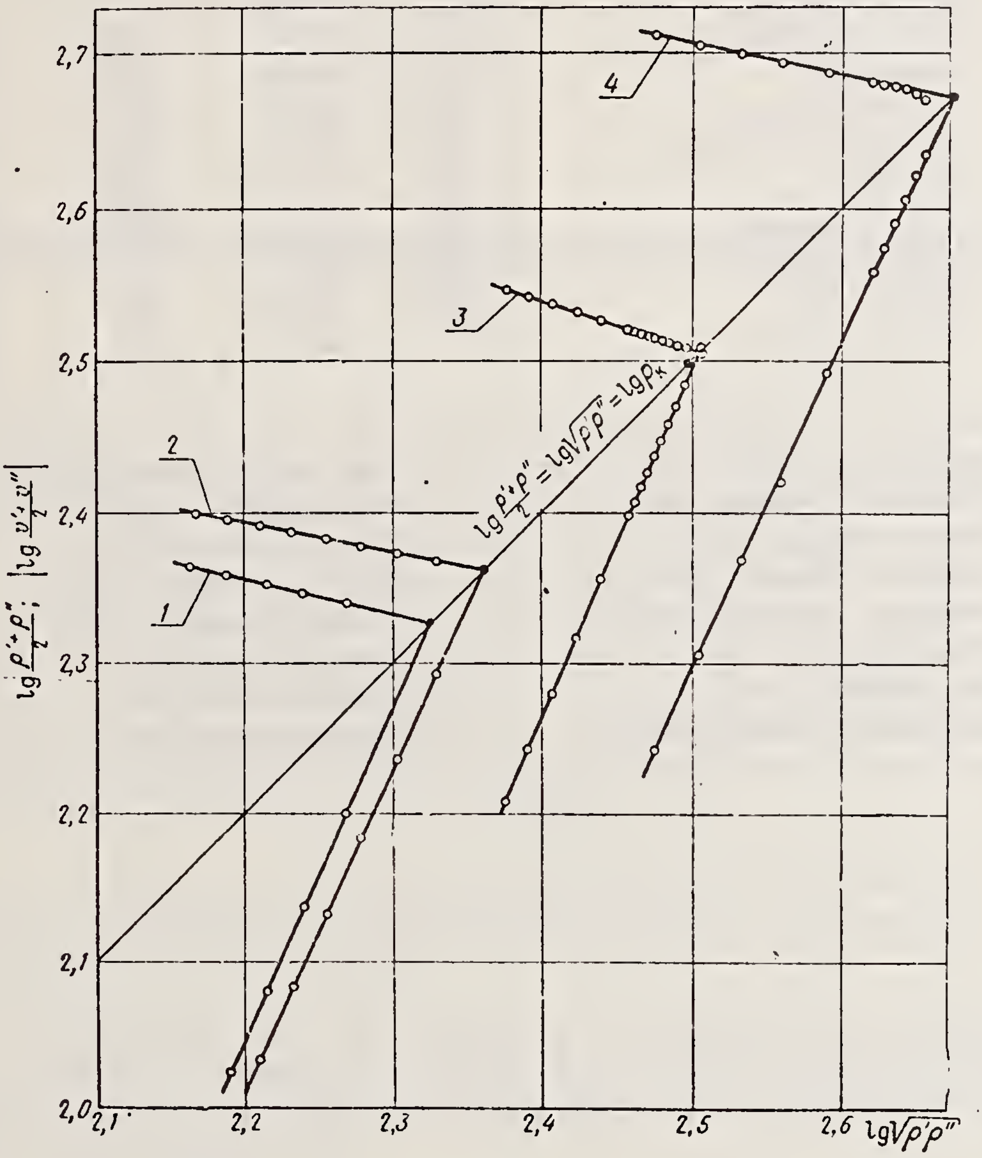

Figure 4. Critical volumes: 1 -- ethylene; 2 -- propylene; 3 -- water; 4 -- carbon dioxide gas.

The mean deviations between the data which we recommend and the data of other authors are: for pressure for ethylene 0.2, for propylene 0.9%, for specific volumes for ethylene 3.8, and for propylene 0.07%.

Table 25. Critical Parameters of Propylene According to Various Authors

Authors	Year	T, °K	p, бар	v, м^3/кг
1)				
Надеждин [44]	1883	370,15	—	—
Зиберт, Буррель [45]	1915	365,75	45,94	—
Маасс, Райт [2]	1921	365,25	—	—
Винклер, Маасс [46]	1933	365,15	—	—
Воуген, Гревс [10]	1940	364,55	46,00	0,004292
Зайдерс [10]	1940	365,05	45,19	0,004273
Лу, Невит [11]	1941	365,25	46,00	—
Марчман и др. [13]	1949	364,91	46,21	0,004539
Фаррингтон, Сейдж [14]	1949	364,82	46,06	0,004335
Перри [37]	1950	365,45	45,60	—
Кобе, Линн [38]	1953	364,95	46,20	0,004292
Стил, Тодос [40]	1961	365,1	46,00	—
Флинн, Тодос [41]	1962	366,0	—	0,004292
Варгафтик [42]	1963	365,05	46,00	0,004292
Катц и др. [43]	1965	365,03	45,99	0,004430
Принятые значения	—	365,05	46,4	0.00434

KEY: 1. Nadeydine [44]
Siebert, Burell [45]
Maass, Wrigt [2]
Winkler, Maass [46]
Voughan, Graves [10]
Zayders [10]
Lu, Newitt [11]
Marchman, et al [13]
Farrington, Sage [14]
Perry [37]
Kobe, Lynn [38]
Stiel, Thodos [40]
Flynn, Thodos [41]
Vargaftik [42]
Katts, et al [43]
Accepted values

CHAPTER IV. THERMODYNAMIC FUNCTIONS OF ETHYLENE AND PROPYLENE IN PERFECT-GAS STATE

Review of Data

The perfect-gas functions of ethylene and propylene presented in various sources were obtained on the basis of experimental measurements of the heat capacity of these compounds at atmospheric pressure or by means of calculation on the basis of spectroscopic data. The primary sources, which contain either experimental data on heat capacity or the results of original calculation of the perfect-gas functions according to spectroscopic data for ethylene and propylene, are listed in Table 26. In the range of temperatures above 273°K the most reliable are considered the functions derived on the basis of spectroscopic data. At lower temperatures the only source of information concerning the perfect-gas functions of ethylene and propylene are experimental data on heat capacity.

The works of Heuse [1], Eucken and Parts [2], Burcik and coauthors [3], Egan and Kemp [4] pertain to experimental analysis of the heat capacity of ethylene at low pressures.

Heuse [1] determined the heat capacity of ethylene at atmospheric pressure in the 182-291°K temperature range by the flow method. The data of Eucken and Parts [2] were obtained by adiabatic expansion in accordance with the Lummer-Pringsteim method.

Burcik and coworkers [3] determined the heat capacity C_p^0 of ethylene at temperatures of 270.7, 300.0 and 320.7°K by the same method. The essence of the method consists in determination of the change of temperature and pressure during adiabatic expansion of the gas. The heat capacity in the perfect-gas state is calculated according to the measured values using the known thermodynamic relations according to the equation

[H=in; k=f;
kp=cr]

$$C_p^0 = \frac{R \ln \frac{p_\text{н}}{p_\text{к}}}{\ln \frac{T_\text{н}}{T_\text{к}}} + \frac{\Delta p \frac{dB_0}{dT}}{\ln \frac{T_\text{н}}{T_\text{к}}} + T_\text{кр} p_\text{кр} \frac{d^2 B_0}{dT^2}, \tag{37}$$

where p_{in}, T_{in} are the initial pressure and temperature; p_f, T_f are the final pressure and temperature; B_0 is the second Virial coefficient according to Keyes [17].

Burcik and coworkers [3] analyzed and compared the results of all the listed works. Approximation of the experimental data is done in the very same work. The deviation of the experimental data from the dependence expressed by the equation

$$C_p^0 = 9{,}638 - 3{,}109 \cdot 10^{-2} T + 1{,}551 \cdot 10^{-4} T^2 - 1{,}426 \cdot 10^{-7} T^3, \tag{38}$$

where T is temperature in °K, C_p° is heat capacity in cal/(mole•deg) in the 200-300°K temperature range, does not exceed 1%.

Eucken and Parts [2] determined the heat capacities at T equal to 178.6, 192.8, 210.8, 231.4, 250.9, 272.1, 293.5 and 464.0°K, equal respectively to 8.293, 8.450, 8.860, 9.001, 9.332, 9.809, 10.257 and 14.161 cal/(mole•deg). Burcik and coworkers [3] determined the heat capacities for T equal to 270.7, 300.0 and 320.7°K, equal respectively to 9.74, 10.39 and 10.99 cal/(mole•deg) and Heuse [1] determined the heat capacities for T equal to 182.2, 205.2, 237.2 and 291.2, equal respectively to 8.28, 8.54, 9.02 and 10.14.

One of the first studies on calculation of the thermodynamic functions according to spectroscopic data was Kassel's work [9], in which is described a method of calculating the entropy for multiatomic gases, and also the free energy of ethylene in the 300-3,000°K temperature range. The spectroscopic data of Mecke [18] were analyzed in the work.

The entropy of ethylene at the critical point T = 169.40°K was calculated by Egan and Kemp [4] on the basis of calorimetric measurements and was found to be $S^\circ_{169.10}$ = 47.36 cal/(mole•deg). The entropies at the two temperatures were also calculated in this work on the basis of vibration frequencies: S° = 47.35 and $S^\circ_{198.10}$ = 52.47 cal/(mole•deg).

Later on Thompson [10], using the data of Conn and Sutherland [20], determined the heat capacity, entropy and enthalpy change of ethylene in the perfect-gas state. These data were subsequently refined by Kilpatrick and Pitzer [13].

The thermodynamic functions of ethylene and propylene, calculated on the basis of spectroscopic data of Gallaway and Barker [21], are given in [13]. The heat capacity, entropy and enthalpy change determined by Kilpatrick and Pitzer [13] were used as the basis of tables on the caloric properties of ethylene and propylene presented in [22].

Later on L. V. Gurvich and coworkers [12] determined the new entropy and enthalpy change of ethylene in connection with more accurate spectroscopic data, presented in [23, 24, 25].

Table 26

1) Авторы	2) Год опубликования	3) Термодинамические функции		6) Интервал температур T, °K
		4) этилена	5) пропилена	
Хейзе [1]	1919	C_p° 7) (эксперимент)	—	182—291
Эйкен и Партс [2]	1933	То же 8)	—	178—464
Бурсик и соавторы [3]	1941		—	270—321
Эган и Кэмп [4]	1937	$S^\circ_{169,4}$, $S^\circ_{298,1}$ 9) (эксперимент, расчет)	—	169,4—298,1
Кистяковский, Райс [5]	1940	—	C_p° 7) (эксперимент)	272—366
Кистяковский, Лахар, Ранзом [6]	1940	—	То же 8)	148—259
Тельфер [7]	1942	—		270—510
Пауэлл и Джайок [8]	1939	—	S° 9) (эксперимент и расчет)	225—298
Кассель [9]	1933	10) Расчет изменения внутренней энергии	—	300—3000
Томпсон [10]	1941	C_p°; S°; $H^\circ_m - H^\circ_0$ (расчет) 11)	—	291—1500
Гравфорд [11]	1939	—	S° (расчет) 11)	298,15
Гурвич и соавторы [12]	1962	C_p°; S°; $H^\circ_m - H^\circ_0$ (расчет) 11)	—	293—6000
Килпатрик, Питцер [13]	1946	C_p°; S°; $H^\circ_m - H^\circ_0$ (расчет) 11)	Расчет 11)	298—1500
Станл и Майфилд [14]	1943	C_p° (расчет) 11)	То же 8)	250—1500
Спенсер [15]	1948	12) Эмпирическое уравнение для C_p°	Эмпирическое 12) уравнение для C_p°	298—1500
Вукалович и соавторы [16]	1953	C_p°; S°; $H^\circ_m - H^\circ_0$ (расчет) 11)	C_p°; S°; $H^\circ_m - H^\circ_0$ (расчет) 11)	273—1473

KEY:
1. Authors
   Heuse [1]
   Eucken and Parts [2]
   Burcik, et al [3]
   Egan and Kemp [4]
   Kistiakowsky and Rice [5]
   Kistiakowsky, et al [6]
   Telfair [7]
   Powell and Giaque [8]
   Kassel [9]
   Thompson [10]
   Grawford [11]
   Gurvich, et al [12]
   Kilpatzick, Pitzer [13]
   Stull, Mayfield [14]
   Spenser [15]
   Vukalovich, et al [16]
2. Year of publication
3. Thermodynamic functions
4. Ethylene
5. Propylene
6. Temperature range T, °K
7. C_p° (experiment)
8. Same
9. (experiment, calculation)
10. Calculation of change of internal energy
11. (calculation)
12. Empirical equation for

Deviations of the data from the values presented in [13] do not exceed 0.4%. Interpolation equations are also presented in [12] for determining the entropy and enthalpy change in the 293-1,600°K temperature range. The perfect-gas functions of ethylene, calculated on the basis of spectroscopic data, are presented in Tables 27, 28, and 29.

Experimental data on the caloric properties of propylene are found in works by Kistiakowsky and Rice [5], Powell and Giaque [8], Kistiakowsky, Lachar and Ransom [6], and Telfair [7].

Kistiakowsky and Rice [5] analyzed the heat capacity of propylene at 272-367°K by the Lummer-Pringsteim method. Kistiakowskiy, et al [6] determined the heat capacity of propylene at temperatures below 273°K by the relative heated wire method.

The heat capacity of propylene according to Telfair [7] was calculated on the basis of data on the speed of sound in propylene.

Telfair's data agree satisfactorily with the experimental heat capacity values determined by Kistiakowsky, et al [5, 6]. The deviations of the experimental data from the smooth curve do not exceed 0.5%.

Table 27. Heat Capacity of Ethylene and Propylene According to Various Authors

T, °K	1) c_p^0, кал/(моль·град) по данным				
	2) Килпатрика, Питцера [13] и Россини [22]		3) Сталла, Майфилда [14], Томпсона [10]		
	4) Этилен	5) Пропилен	4) Этилен	5) Пропилен	4) Этилен
250	—	—	9,53	13,76	—
291,16	—	—	—	—	10,28
298,16	10,41	15,27	—	—	10,45
300	10,45	15,34	10,48	15,43	10,50
350	—	—	11,56	17,24	11,67
400	12,90	19,10	12,69	19,11	12,95
450	—	—	13,81	20,93	14,11
500	15,16	22,62	14,89	22,68	15,21
550	—	—	—	—	16,22
600	17,10	25,70	16,87	25,83	17,15
650	—	—	—	—	18,01
700	18,76	28,37	18,61	28,55	18,30
800	20,20	30,58	19,96	30,92	20,20
900	21,46	32,70	21,45	32,97	21,50
1000	22,57	34,46	22,62	34,75	22,60
1100	23,54	35,99	23,63	36,29	23,60
1200	24,39	37,32	24,51	37,63	24,40
1300	25,14	38,49	25,26	38,79	25,20
1400	25,79	39,51	25,92	39,79	25,80
1500	26,36	40,39	26,50	40,66	26,40

KEY:
1. C_p^0, cal/(mole·deg) according to data
2. Kilpatrick, Pitzer [13] and Rossini [22]
3. Stull, Mayfield [14], Thompson [10]
4. Ethylene
5. Propylene

Table 28. Entropy of Ethylene and Propylene in Perfect-Gas State According to Various Authors

T, °K	1) S°, кал/(моль·град) по данным			
	2) Килпатрика, Питцера [13] и Россини [22]		3) Томпсона [10], Гурвича и соавторов [12]	
	4) Этилен	5) Пропилен	4) Этилен	
291,16	—	—	52,22	—
293,16	—	—	—	52,239
298,16	52,45	63,80	52,47	52,412
300	52,51	63,90	52,53	—
350	—	—	54,23	—
400	55,89	68,86	55,89	55,765
450	—	—	57,48	—
500	58,98	73,47	59,05	58,841
550	—	—	60,52	—
600	61,92	77,82	61,97	61,740
650	—	—	63,38	—
700	64,68	82,04	64,75	64,473
800	67,28	85,98	67,35	67,050
900	69,74	89,72	69,71	69,487
1000	72,06	93,26	72,13	71,792
1100	74,26	96,61	74,34	73,978
1200	76,34	99,80	76,33	76.054
1300	78,32	102,84	78,40	78,028
1400	80,21	105,98	80,30	79,908
1500	82,01	108,48	82,11	81,702

KEY: 1. S°, cal/(mole·deg) according to data
2. Kilpatrick, Pitzer [13], Rossini [22]
3. Thompson [10], Gurvich, et al [12]
4. Ethylene
5. Propylene

Table 29. Enthalpy of Ethylene and Propylene in Perfect-Gas State According to Various Authors

T, °K	1) $H^\circ_T - H^\circ_0$, кал/моль по данным			
	2) Килпатрика, Питцера [13] и Россини [22]		3) Томпсона [10], Гурвича и соавторов [12]	
	4) Этилен	5) Пропилен	4) Этилен	
291,16	—	—	2456	—
293,16	—	—	—	2465
298,16	2525	3237	2527	2516
300	2544	3265	2548	—
350	—	—	3100	—
400	3711	4990	3720	3684
450	—	—	4100	—
500	5117	7076	5130	5067
550	—	—	5920	—
600	6732	9492	6750	6661
650	—	—	7630	—
700	8527	12200	8550	8436
800	10480	15150	10500	10367
900	12560	18320	12500	12438
1000	14760	21690	14800	14626
1100	17070	25210	17110	16920
1200	19470	28880	19450	19306
1300	21950	32760	21970	21774
1400	24490	30570	24320	24311
1500	27100	40570	27160	26912

KEY: 1. $H^\circ_T - H^\circ_0$ cal/mole according to data 2-5. Same as Table 28

Tables of the heat capacity of propylene, tabulated on the basis of processing of experimental and theoretical data, are also presented in Lehman's work [26] for the 220-1,270°K temperature range. Experimental data on the heat capacity of propylene in the perfect-gas state are given in Table 30.

Table 30. Experimental Data on Heat Capacity of Propylene in Perfect-Gas State

T, °K	C_v°, кал/(моль × × град) 1)	T, °K	C_p°, кал/(моль × × град) 1)	T, °K	C_p°, кал/(моль × × град) 1)
2) Тельфер [7]		3) Кистяковский, Лахар, Ранзом [6]		4) Райс [5]	
270	12,30	148,1	10,63	272,29	14,36
280	12,70	148,3	10,64	299,33	15,47
290	13,09	157,3	10,86	333,86	16,74
300	13,48	157,6	10,86	367,11	17,93
310	13,86	158,0	10,87	—	—
320	14,34	212,3	12,46	—	—
330	14,62	212,9	12,50	—	—
340	14,99	219,9	12,68	—	—
350	15,36	220,2	12,70	—	—
360	15,73	223,4	12,82	—	—
380	16,45	256,4	13,90	—	—
390	16,81	258,3	13,97	—	—
400	17,17	258,4	13,98	—	—
410	17,53	259,0	14,04	—	—
420	17,89	291,1	15,16	—	—
430	18,24	—	—	—	—
440	18,59	—	—	—	—
450	18,94	—	—	—	—
460	19,29	—	—	—	—
470	19,63	—	—	—	—
480	19,98	—	—	—	—
490	20,32	—	—	—	—
500	20,32	—	—	—	—
510	21,00	—	—	—	—

KEY: 1. cal/(mole·deg)
2. Telfair [7]
3. Kistiakowsky, Lachar, Ransom [6]
4. Rice [5]

The entropy of propylene at the boiling point T = 225.39°K was determined directly by caloric measurements by Powell and Giaque [8] and was found to be 59.93 cal/(mole•deg). This same researcher calculated the entropy of propylene on the basis of spectroscopic data for two temperatures: $S^\circ_{225.35} = 61.0 \pm 0.3$ and $S^\circ_{298} = 64.10$ cal/(mole•deg). Grawford and coworkers [11], using the corrected vibration frequencies, obtained the following entropy for propylene at the boiling point: $S^\circ_{225.35} = 59.87$ cal/(mole•deg).

Of great importance in addition to the cited works are calculations on the basis of spectroscopic data by M. P. Vukalovich and coworkers [16], Stull and Mayfield [14], in which the thermodynamic functions of a large number of gases, including ethylene and propylene, are determined. The comparisons of the results with existing literature data on the perfect-gas temperature of ethylene [2, 3, 10] made by Stull and Mayfield revealed that the maximum deviations are, respectively, 0.7, 0.9 and 2.1%. The theoretical heat capacities of propylene were compared with the data in [5, 7]. The maximum deviations here are, respectively, 0.8 and 0.3%.

M. P. Vukalovich and coworkers [16] give the perfect-gas heat capacities, enthalpies and entropies of ethylene and propylene at 273-1,473°K. The perfect-gas functions of ethylene and propylene, determined by various authors on the basis of spectroscopic data, are presented in Tables 27, 28, 29.

Recommended Isobaric Heat Capacity, Entropy and Enthalpy of Ethylene and Propylene in Perfect-Gas State

At the present time the most reliable data on the entropy and enthalpy change of ethylene in the perfect-gas state are those of L. V. Gurvich and coworkers [12]. The entropy and enthalpy change of ethylene were calculated in the same work using current data on the ground frequencies and rotation constants of the ethylene molecule. Also given there are interpolation equations for calculating the entropy and enthalpy change of ethylene in the 293-6,000°K temperature range.

If the heat capacity of ethylene is calculated by converting the interpolation equation for entropy, the results obtained at temperatures above 700°K agree satisfactorily with M. P. Vukalovich's data [16] and those of Kilpatrick [13]. The discrepancy does not exceed 0.5%. At temperatures of 298-500°K, however, the heat capacity of ethylene, calculated according to the converted equation, differs from the heat capacity given in [13, 16] by more than 5%.

Considering that the heat capacities of ethylene were computed directly in [13, 16] on the basis of spectroscopic data, these data were preferred for tabulation of the perfect-gas heat capacities in the 280-500°K temperature range (Tables II, VI). Data [13, 16] at these temperatures are quite satisfactorily transmitted (±0.4%) by the Spenser interpolation equation [15] presented below:

$$C_p^{\circ} = a + bT + cT^2 + dT^3, \qquad (39)$$

where $a = 1.003$, $b = 36.948 \cdot 10^{-3}$, $c = -193.81 \cdot 10^{-7}$, $d = 4.019 \cdot 10^{-9}$.

Using the known thermodynamic relations we find from equation (39) the expressions for the entropy of ethylene and for enthalpy change in the perfect-gas state:

$$S_T^{\circ} = a \ln T + bT + \frac{cT^2}{2} + \frac{dT^3}{3} - \left[a \ln T_0 + bT_0 + \frac{cT_0^2}{2} + \frac{dT_0^3}{3}\right] + S_{T_0}^{\circ}, \qquad (40)$$

$$H_T^{\circ} - H_0^{\circ} = aT + \frac{bT^2}{2} + \frac{cT^3}{3} + \frac{dT^4}{4} - \left[aT_0 + \frac{bT_0^2}{2} + \frac{cT_0^3}{3} + \frac{dT_0^4}{4}\right] + i'_{T_0}. \qquad (41)$$

The thermodynamic functions of ethylene, computed through equations (40) and (41) for the 280-500°K temperatures, differ from the data of L. V. Gurvich [12] in the case of entropy by 0.4%, and in the case of enthalpy by 0.7% (see Tables 28 and 29).

The most recent works in which the thermodynamic functions of propylene are analyzed are those of M. P. Vukalovich and coworkers [16] and of Kilpatrick [13]. The heat capacity of propylene, computed from an equation of the type (39) in the 280-500°K temperature range for $a = 0.790$, $b = 56.372$, $c = -281.07 \cdot 10^{-7}$, $d = 3.427 \cdot 10^{-9}$, differs from the data of M. P. Vukalovich, et al [16] by not more than 0.5%. The entropy and enthalpy change obtained from equations of the type (40) and (41), also agree satisfactorily with the data of M. P. Vukalovich and coworkers [16]. The deviations do not exceed 0.4%.

The thermodynamic functions in the perfect-gas state, calculated according to equations (39), (40) and (41), were used by us for compiling Tables II and VI of the thermodynamic properties of ethylene and propylene at temperatures of 280-500°K.

Spectroscopic data do not exist for temperatures below 273°K, and the only source of information about the perfect-gas functions of ethylene and propylene are the results of experimental measurements of the heat capacity or speed of sound in these gases at small pressures. The accuracy of such data is considerably less than that of the data calculated on the basis of spectroscopic data. In the 200-280°K range equation (41) of Burcik and coworkers [3] is recommended; for propylene ($T = 148\text{-}291$°K) the experimental data of Kistiakowsky and coworkers [6], presented in Table 30, are recommended.

CHAPTER V. SPEED OF SOUND AND HEAT CAPACITIES OF GASEOUS ETHYLENE AND PROPYLENE

Review of Data on Heat Capacities of Gaseous Ethylene and Propylene

The isochoric heat capacity of ethylene and propylene in a comparatively narrow temperature range and pressure range was measured by Nevers and Martin [1], Pall, Broughton and Maass [2].

Nevers and Martin [1] did their study in the 340-420°K temperature range for reduced densities ω equal to 0.218-0.726, in order to check the suitability of the Benedict-Webb-Rubin [3] and Martin-Hou [4] equations of state for calculating the isochoric heat capacity of propylene in the stated range of states. The investigated specimen of propylene was 99.0 mole % pure; the heat capacity was measured in a constant-volume adiabatic calorimeter of original design with a blower (mixer), resistance heater and thermometer installed inside the calorimeter. The calorimeter was calibrated for filling with propylene at low pressure. The perfect-gas heat capacity of propylene C_{v_0} was determined by the Kilpatrick-Pitzer method, and the small pressure correction factor was calculated on the basis of the Martin-Hou thermal equation of state. The heat capacity of propylene was 7% of the total heat capacity of the reactor and contents; the pressure correction factor ΔC_{v_0} was 0.1% of this value. The error in determination of the calorimeter constant, according to the authors, did not exceed ±0.8%, and the scattering of individual measurements did not exceed ±0.4%. The calorimeter was filled from a light-weight steel container, which was weighed before and after filling of the apparatus. The density of the investigated compound in the calorimeter was determined with an error not exceeding ±0.3%. The temperature drift of the calorimeter, occurring during operation of the mixture and with the resistance thermometer turned on, a value of ~0.002 deg/min, was taken into account in the processing of the results of the calorimetric experiment. The error of the isochoric heat capacity obtained for propylene as a function of the density of the investigated compound was ±1.1-3.2%. The experimental data obtained in [1] are presented in Table 31.

The authors found [1] as a result of comparing the experimental data on isochoric heat capacity with the theoretical according to the above-described equations that the discrepancy in the investigated range of the compounds does not exceed 6.7% of the pressure correction factor ΔC_v for the perfect-gas heat capacity, but the isotherms of heat capacity in heat capacity-density coordinates have a varying qualitative path. The isotherms plotted on the basis of experimental data have a positive second pressure derivative in the low pressure range and in the entire density range.

Table 31. Experimental Data [1]

ρ, г/см³	t, °G	1) c_v, кал/(г·град)	ρ, г/см³	t, °C	1) c_v, кал/(г·град)	ρ, г/см³	t, °C	1) c_v, кал/(г·град)
0,04814	67,15	0,3903	0,09228	84,64	0,4380	0,1404	93,17	0,4842
	82,14	0,3952		92,91	0,4337		99,58	0,4710
	98,45	0,4047		103,71	0,4341		106,68	0,4659
	111,62	0,4159		115,36	0,4385		112,47	0,4638
	123,90	0,4226		125,32	0.4439			
	140,21	0,4357						
0,07219	75,09	0,4160	0,1102	90,71	0,4486	0,1609	94,92	0,4991
	85,21	0,4163		95,75	0,4460		99,51	0,4840
	99,93	0,4208		101,28	0,4438		104,51	0,4761
	117,06	0,4305		107.59	0,4439		103,74	0,4768
	133,72	0,4412		113,37	0,4438		108,41	0,4704
	145,92	0,4485						

KEY: 1. C_v, cal/(g·deg)

The theoretical data on the caloric properties and thermodynamic diagrams of ethylene and propylene at high pressures, presented in [5-9], were obtained on the basis of experimental p, v, T-data of Michels and coworkers [10, 11], or on the basis of thermal equations of state whose derivation was based on these p, v, T-data.

Calculation of the isobaric and isochoric heat capacities and their ratio on the basis of the results of analysis of thermal properties necessitates, as we know, determination of the second derivatives of the thermal functions, which leads to considerable loss of accuracy, particularly in the near-critical and supercritical regions of state. As a rule, the errors of such calculations exceed by more than one order of magnitude the errors of the initial thermal data. In the range of state parameters where the heat capacities peak, the various equations of state, which describe the experimental p, v, T-data with the same accuracy, lead to heat capacities that differ by 30-60%. Calculation using the experimental data on the speed of sound occupies a special place, among the indirect methods of determining the heat capacity of gases.

The use of p, v, T-data and the speed of sound, which are presently the most accurate measured properties of matter, in calculations of heat capacities C_p and C_v, their ratio κ and adiabatics index k_v, makes it possible to find the stated parameters with an accuracy much better than that of calculation simply on the basis of p, v, T-data.

Review of Experimental Data on Speed of Sound in Gaseous Ethylene and Propylene

Works pertaining to experimental analysis of the speed of sound in gaseous ethylene and propylene are listed in Table 32.

Herget measured the speed of sound by acoustical interferometry on the frequencies 274.1 and 598 kHz at pressures of 35-70 bar on the 9.7, 18.7 and 23°C isotherms. The investigated ethylene was 99.7% pure. The pressure was measured with a class 0.5 piston manometer. The results of the measurements are presented in Table 33.

The experimental data, in Herget's opinion, have an accuracy of ±0.05% in the entire range of investigation, with the exception of range of minimum speed of sound on the 9.7°C isotherm, where the error of the data is estimated at ±3.5%. The information in the work is not enough for analysis of the accuracy of the speeds of sound presented. Graphic processing of the measurement results, however, shows that the scattering of the experimental points exceeds the stated error and averages ±0.2%.

Table 32

1) Авторы	2) Интервал исследованных температур и давлений	3) Форма представления результатов исследования
	4) Этилен	
Херrет [12]	t = 9,7—23° C; p = 35—70 *бар*	6) Таблицы экспериментальных значений
Парбрук и Ричардсон [13]	t = 7—18,7° C p = 1—100 *бар*	7) Малоформатный график
М'Хирси и Нури [14]	t = 25—50° C p = 30—1000 *бар*	7) То же
Солдатенко, Дрегуляс [15, 16]	T = 190—470° K p = 1—100 *бар*	6) Таблицы экспериментальных значений
	5) Пропилен	
Тельфейр [17]	t = 0—217° C; p = 1 *бар*	8) Таблицы теплоемкости, рассчитанные по скорости звука
Солдатенко, Дрегуляс [15, 18]	T = 190—470° K; p = 0,1—100 *бар*	6) Таблицы экспериментальных значений

KEY: 1. Authors
Herget [12]
Parbrook, Richardson [13]
McHirsi, Houry [14]
Soldatenko, Dregulyas [15, 16]
Telfair [17]
Soldatenko, Dregulyas [15, 18]
2. Range of investigated temperatures and pressures
3. Form of presentation of results
4. Ethylene
5. Propylene
6. Tables of experimental values
7. Small-scale graphs
8. Tables of heat capacity, calculated by speed of sound

Table 33

p, бар	w, м/сек	p, бар	w, м/сек	p, бар	w, м/сек
$t = 9{,}7$° C		$t = 18{,}7$° C		$t = 23{,}0$° C	
35,73	265,3	36,15	276,8	36,21	281,6
43,03	247,6	44,23	261,5	38,17	278,6
45,81	239,1	51,38	247,2	39,71	276,1
49,81	222.0	55,73	236,8	41,11	273,6
51,32	202,8	58,96	230.6	41,88	272,1
51,43	193,0	59,59	229,6	42,47	271,1
51,65	160.0	60,41	228,7	45,19	266,4
51,73	162,0	61,16	229,3	48,06	261,5
51,73	165,0	61,94	232,4	48,21	261,1
51,94	196.2	62 25	234,1	50,34	257,4
52,35	225,0	63 04	240,4	52,52	253,1
53,65	263,0	63,73	246,5	53,50	256,1
54,11	280,8	64,46	254,8	54,90	249,0
54,68	290,0	66,48	275,5	57,73	244,2
55,31	298,6	68,68	300,3	60,28	240,7
56,03	309,0	69,38	306,5	61,86	238,4
57,72	318,0	70,10	311,5	62,48	237,2
59,25	348,5	71,31	322,8	63,71	237,7
—	—	71,48	325,6	65,23	240,3
—	—	72,72	335,4	65,86	242,1
—	—	—	—	67,05	246,3
—	—	—	—	67,66	249,9

Parbrook and Richardson [13] studied the speed of sound in ethylene by means of interferometry with a mobile reflector on frequencies 0.5 and 2 MHz. The measurements were done at 7°C in the 25-50 bar pressure range and at pressures from atmospheric to 100 bar on 18.7°C isotherm, on which the dispersion at atmospheric pressure was observed. The accuracy of the data obtained by the authors is not stated, and the published data do not permit evaluation of the possible error.

McHirsi and Noury [14] measured the speed of sound in the 30 to 1,000 bar pressure range at 25 and 50°C by the light diffraction method on an ultrasonic network at 865, 2,590 and 4,320 kHz. According to the authors there was no dispersion of the speed of sound and the maximum measurement error was ±1%.

The results of the investigations [13, 14] are presented in the form of small-scale graphs, which hampers their use in the calculation of the thermodynamic functions.

Yu. A. Soldatenko and E. K. Dregulyas [15, 16, 18] measured the speed of sound in ethylene and propylene by acoustic interferometry with variable emitter-reflector distance, ensuring high accuracy of measurements in the investigated range of state parameters.

Table 34. Speed of Sound in Ethylene According to Data of Yu. A. Soldatenko and E. K. Dregulyas

p, бар	w, м/сек
T = 193,15° K	
0,61	274,8
0,88	274,0
1,01	273,3
1,75	269,0
1,95	267,8
2,76	264,4
2,97	262,8
3,35	262,3
3,40	261,1
T = 213,15° K	
1,49	284,2
5,22	273,4
6,30	270,3
T = 233,15° K	
1,48	295,0
2,40	291,8
5,22	285,8
9,73	275,7
13,06	265,0
T = 247,48° K	
0,80	307,6
3,35	301,4
10,61	284,9
17,87	264,8
21,59	252,5
T = 263,15° K	
0,59	315,4
3,35	309,3
7,28	302,8
11,74	294,4
19,83	277,2
27,09	257,6
31,40	240,8
32,38	236,3
T = 273,15° K	
0,84	322,2
1,57	319,9
2,97	316,1
5,41	311,3
11,05	302,5
18,16	290,0
24,63	276,6
25,22	275,4
31,30	260,6
32,53	257,3
34,83	250,8
37,19	243,1
39,34	234,8
39,50	231,1
39,93	232,0
40,91	224,8
T = 283,32° K	
0,72	327,2
1,00	328,1
1,04	326,4
3,95	319,3
4,68	317,9
10,59	309,5
10,82	308,9
12,88	306,2
16,31	300,5
23,06	289,2
29,35	278,4
35,03	267,5
39,05	257,8
39,32	258,4
43,22	248,7
46,11	239,6
47,49	235,1
49,44	226,5
49,85	223,2
50,44	219,8
50,50	217,9
51,61	205,6
52,00	189,4
52,12	188,5
52,33	203,3
52,59	211,8
52,88	228,1
52,89	231,5
53,38	241,1
54,53	271,2
54,93	283,7
55,03	282,2
57,94	326,6
59,33	339,8
59,84	346,4
60,78	355,1
65,13	388,7
69,93	422,4
76,06	454,9
76,11	456,3
89,47	512,0
99,37	547,5
T = 292,89° K	
1,01	331,4
1,83	328,2
1,99	327,3
3,95	323,5
4,68	322,6
6,97	319,4
13,36	311,6
19,82	302,7
26,07	293,1
29,53	287,9
36,05	277,1
40,83	268,8
46,09	253,8
50,52	249,6
51,50	248,3
53,47	244,5
54,53	241,5
56,11	238,5
57,17	235,5
T = 292,89° K	
58,57	233,3
59,64	232,3
60,82	230,7
61,16	230,9
61,56	231,4
62,53	233,4
63,57	238,1
63,65	240,0
65,76	258,3
68,57	286,2
70,71	307,4
73,36	329,0
79,63	371,4
90,24	427,2
99,39	469,2
T = 303,15° K	
1,66	333,4
2,76	331,9
4,91	328,0
8,84	323,4
12,77	319,7
15,22	316,6
19,63	310,7
29,87	297,3
39,34	283,8
46,80	272,5
47,48	271,8
51,41	266,3
55,43	260,5
59,45	255,2
63,22	251,2
64,64	250,2
66,70	249,0
67,24	249,5
68,76	250,3
69,65	250,5
71,21	253,3
74,55	263,6
82,10	301,3
91,91	353,7
92,00	353,3
99,66	389,7
T = 308,67° K	
3,45	333,5
10,00	325,4
25,52	306,7
29,44	302,0
36,89	291,5
47,48	278,3
59,94	263,2
67,88	258,2
69,22	258,0
73,08	258,0
74,53	259,2
77,39	263,5
79,40	269,4
80,29	273,2
81,32	276,3

[Continued on next page]

Table 34 (Continued)

p, бар	w, м/сек
$T = 308,67°$ K	
82,83	282,8
86,37	300,0
90,53	326,0
95,24	343,0
$T = 343,15°$ K	
1,80	351.6
3,45	349.6
3,65	348,9
5,40	347,6
8,84	345,2
9,82	344,7
23,95	332,6
39,74	320,4
54,35	309,1
69,64	301,2
80,29	298,9
88,33	300.4
98,33	305,7
$T = 363,15°$ K	
1,03	362,5
1,98	359,5
2,86	357,9
4,63	356,5
6,88	355,9
12,77	352,0
18,35	349,4
27,37	343,8
44,44	333,0

p, бар	w, м/сек
$T = 363,15°$ K	
64,55	322,1
81,90	316,8
99,21	317,8
$T = 385,84°$ K	
1,00	370,5
3,84	366,9
6,59	366,1
13,32	362,7
23.75	358,0
41,60	349,5
57,98	342,6
79,99	337,7
87,54	336.6
93,77	336,8
99,12	338,2
$T = 407.54°$ K	
0,73	380,0
1,20	378,2
4,33	376,3
11,49	373,3
26,99	368,0
43,46	362,0
63,57	356,5
84,06	353,4
98,28	352,9
$T = 429,53°$ K	
0,96	385,6
1,52	385,6
8,61	384.0

p, бар	w, м/сек
$T = 429,53°$ K	
19,73	381,1
34,83	375,9
59,45	370,5
78,86	368,6
95,73	368,1
$T = 448,62°$ K	
4,25	392,9
10,71	391,2
15,81	389,5
24,54	388,3
37,48	385,4
50,43	383,8
59,74	381,9
75,68	380,3
76,90	379,5
83,67	378,9
88,97	379,3
98,02	378,9
$T = 473,15°$ K	
1,21	403,0
1,79	403,5
16.41	400,6
27,30	399,1
39,84	397,3
52,97	395,5
68,38	394,3
84.72	393,7
94,07	393,5
98,09	393,7

The purity of the investigated compounds was determined by chromatographic analysis. The ethylene specimen contained 99.97% of the basic component and 0.03% ethane; the propylene was 99.50% pure and the propane and ethane impurities amounted to 0.3 and 0.2%, respectively. The compound was not subjected to additional purification.

The experimental investigations of the speed of sound in ethylene encompass the 193 to 473°K temperature and 1 to 100 bar pressure ranges. In this range of parameters, including the subcritical, near-critical and supercritical states of ethylene, 273 experimental points were obtained, measured on 18 isotherms and the liquid-vapor phase equilibrium line.

The subcritical region of state was investigated on the saturation line and six isotherms, on which the speed of sound was measured at temperatures of 193.15-273.15°K and from atmospheric pressure to the vapor saturation pressure at the experimental temperature.

The near-critical and supercritical regions of state were investigated on 12 isotherms in the 1-100 bar pressure range. The rather large number of points on each isotherm and the use of the variable pressure step for the measurement made it possible to determine reliably the coordinates of the characteristic points of the speed of sound isotherms (the position of the minimum and points of inflection).

The results of the measurements of the speed of sound on the isotherms are presented in Table 34 and Figure 5. The maximum scattering of the experimental points relative to the smooth curve does not exceed ±0.4 m/sec. Usually not more than 1-2 points with such scattering appeared on an isotherm. The mean scattering of the points is ±0.2 m/sec.

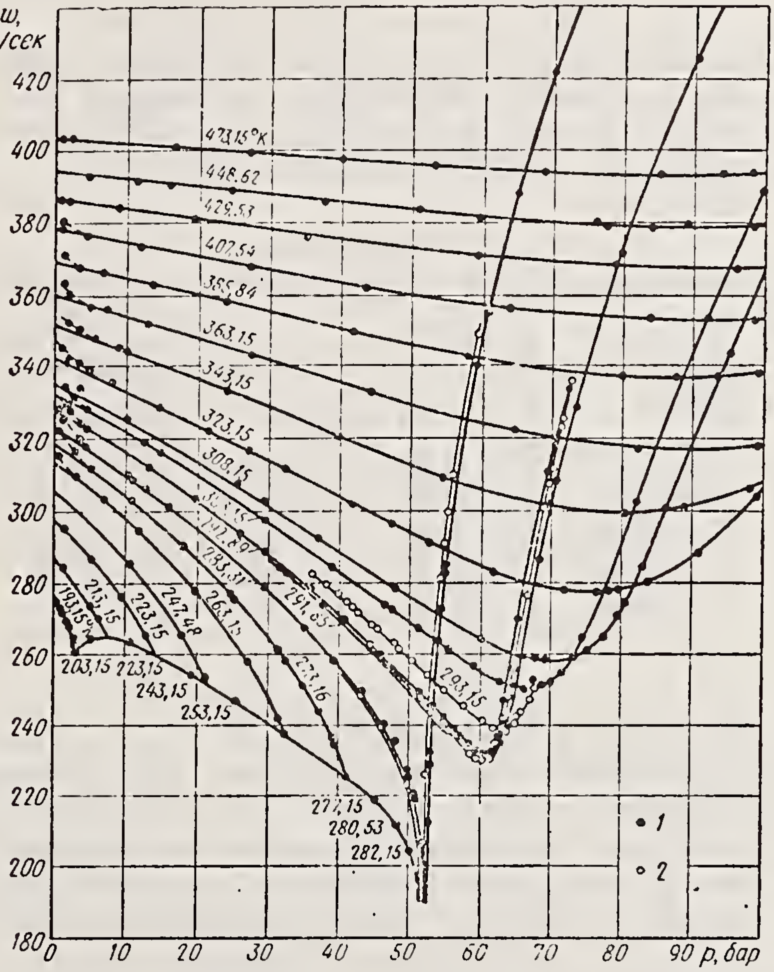

Figure 5. Speed of sound in ethylene as function of temperature and pressure according to data: 1 -- authors of present book; 2 -- Herget [12].

The speed of sound on the liquid-vapor phase equilibrium line was investigated at 10 experimental points from temperatures of 193.15 to 282.15°K.

The results of the measurements on the liquid-vapor phase equilibrium line are presented in Figure 5 and in Table 35.

Table 35. Experimental Speeds of Sound in Ethylene on Saturation Curve According to Soldatenko and Dregulyas

T, °K	p, бар	w, м/сек	T, °K	p, бар	w, м/сек
193,15	3,40	261,1	263,15	32,38	263,3
203,15	5,12	264,2	273,15	40,91	224,8
223,15	10,61	262,7	277,29	44,98	218,0
243,15	19,29	254,0	280,53	48,22	210,5
253,15	25,30	246,4	282,15	50,13	203,2

Yu. A. Soldatenko and E. K. Dregulyas measured speed of sound at several points of the isotherms investigated by Herget for the purpose of direct comparison of the measurement results with Herget's data [12]. The results of the measurements are presented in Table 36.

Table 36

p, бар	w, м/сек	p, бар	w, м/сек	p, бар	w, м/сек
$t = 9{,}7^\circ$ C		$t = 18{,}7^\circ$ C		$t = 23^\circ$ C	
51,21	200,2	60,28	229,6	44,64	266,9
$t = 18{,}7^\circ$ C		62,28	235,9	52.92	252,0
31,79	283,4	63.42	246,0	65,18	241,3
37,77	273,0	65,63	269,9	65,63	241,9
43,66	262,2	69,55	310,2	67,77	251,1
55,36	237,0	72,52	334,3	—	—

Considering that the compared measurements were done in the ranges of temperatures and pressures close to critical, the discrepancies can be attributed to the different purities of the investigated specimens of ethylene or to the presence of systematic error in temperature measurements. This is confirmed by the fact that the least deviations take place at the point on the 23°C isotherm farthest from the critical point, and the discrepancies on the 18.7°C isotherm reach maximum values (1%) in the vicinity of the minimum speed of sound as pressure increases, and diminish with a further increase of pressure. Such character of deviations can be explained by the different purities of the compounds used for the experiments.

The results of measurements [13, 14] coincide within the limits of accuracy of their graphic representation with the data of Yu. A. Soldatenko and E. K. Dregulyas [15, 16].

Telfair [17] measured the speed of sound in gaseous propylene at atmospheric pressure and at temperatures of 273-490°K. The experimental speeds of sound were not given in the publication.

Yu. A. Soldatenko and E. K. Dregulyas also did measurements in propylene [15, 18] in the 193-473°K temperature and 0.1-100 bar pressure ranges.

The speed of sound was measured on 19 isotherms and on the liquid-vapor phase equilibrium curve. The results of the measurements are shown in Figure 6 and in Tables 37 and 38. The experimental points have a scattering relative to the smooth curves of ±0.2 m/sec.

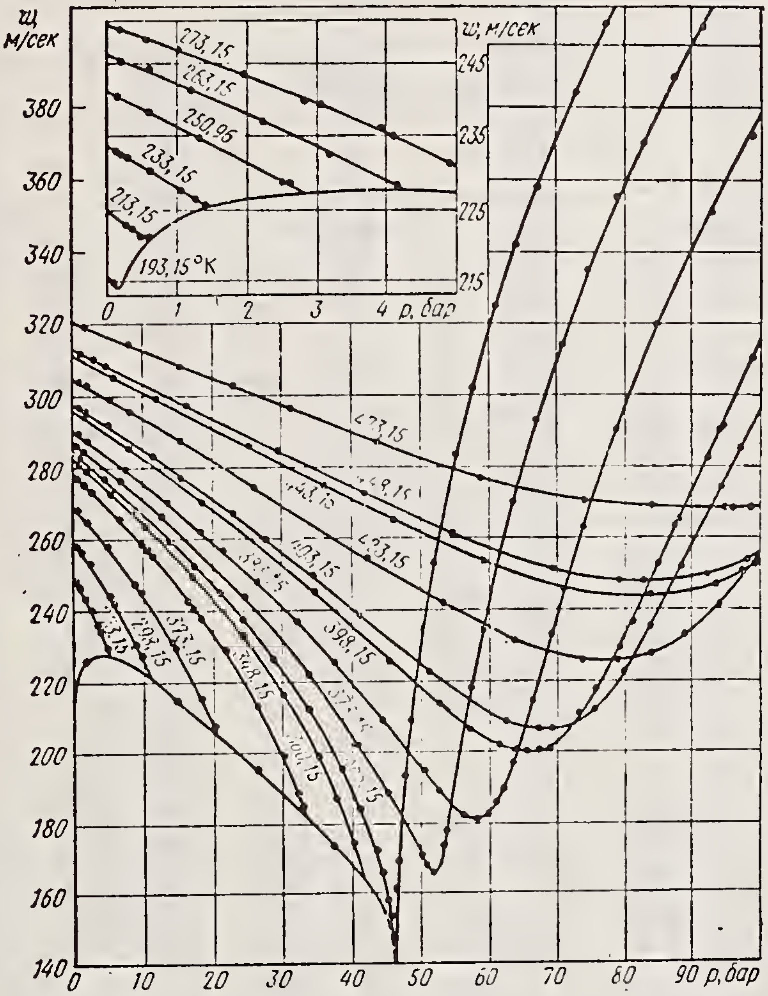

Figure 6. Speed of sound in propylene as function of temperature and pressure according to Soldatenko and Dregulyas.

Table 37. Speed of Sound in Propylene on Saturation Curve According to Soldatenko and Dregulyas

T, °K	p, бар	w, м/сек	T, °K	p, бар	w, м/сек
193,15	0,164	214,1	353,15	37,47	172,9
233,15	1,41	225,3	360,15	42,42	161,8
313,15	16,46	212,4	363,15	44,84	153,4
333,15	25,38	196,4	363,15	44,88	153,1

The maximum absolute error of measurement of the speed of sound in ethylene and propylene, calculated by the generally accepted method from the theoretical equation, is ±0.5 m/sec.

The speeds of sound, as we know, can be used for calculating the thermodynamic functions only if they do not depend on frequency. In this connection discussion of the measurement results must start with definition of the boundaries of the region of dispersion of the speed of sound in the investigated compound.

Table 38. Speed of Sound in Propylene According to Soldatenko and Dregulyas

p, бар	ω, м/сек
$T = 193,15°$ K	
0,081	215,0
0,092	214,8
0,164	214,4
$T = 213,15°$ K	
0,237	223,1
0,288	222,8
0,445	221,4
0,537	221,1
$T = 233,15°$ K	
0,118	232,8
0,152	232,6
0,236	232,1
0,553	230,4
1,00	227,6
1,23	226,3
1,41	225,3
$T = 250,97°$ K	
0,102	240,5
0,547	238,6
1,244	235,0
1,97	231,4
2,46	228,8
2,53	229,1
$T = 263,15°$ K	
0,171	245,3
0,570	244,2
1,144	241,2
2,17	237,3
3,14	233,0
3,69	230,6
4,13	228,7
$T = 273,15°$ K	
0,141	250,0
0,501	248,4
0,991	247,2
1,902	243,8
2,77	240,3
3,00	239,6
3,92	236,2
4,10	235,0
4,90	231,9
5,35	229,8
5,59	227,7
$T = 298,15°$ K	
1,00	257,5
1,39	256,3
2,37	253,2
5,71	243,8
6,00	242,2
9,24	230,7
9,97	227,9
$T = 323,15°$ K	
1,00	267,8
2,37	264,4
5,17	258,1
9,09	247,4
10,22	245,1
14,73	231,1
14,93	230,1
18,65	215,6
20,09	207,3
$T = 348,15°$ K	
1,01	277,1
1,98	275,3
2,86	273,1
3,26	273,0
6,79	265,3
6,79	265,7
10,22	258,4
11,05	256,2
11,54	255,3
16,89	241,9
17,38	240,2
18,55	237,4
21,84	228,9
26,50	213,7
30,16	199,1
32,44	188,5
33,17	184,2
$T = 360,15°$ K	
1,00	281,6
1,98	279,7
5,71	272,6
10,32	264,0
17,48	249,7
24,29	233,3
30,08	217,2
35,62	198,6
40,72	174,0
42,42	162,1
$T = 365,15°$ K	
1,01	283,4
2,48	280,5
4,68	276,7
13,86	259,4
26,80	231,7
33,67	212,7
40,14	189,8
42,29	179,8
43,87	171,8
44,65	165,6
45,63	157,5
45,63	158,3
46,02	153,2
46,34	144,6
46,61	160,6
46,86	168,4
47,79	192,9
48,62	209,1
50,04	227,2
55,28	284,8
60,78	325,9
69,61	372,1
79,02	412,0
91,48	455,0
95,89	466,8
98,78	474,5
$T = 373,15°$ K	
1,01	286,3
1,99	285,2
6,80	276,6
12,68	266,4
24,45	243,8
33,67	227,6
41,02	202,4
46,12	186,0
47,94	178,7
48,17	178,6
50,53	170,0
50,73	169,5
51,52	166,4
52,00	164,1
52,69	164,5
53,48	173,3
53,97	177,4
57,30	217,3
58,97	233,7
70,34	313,2

[Continued on next page]

Table 38 (Continued)

p. бар	ω. м/сек
$T = 373{,}15°$ K	
81,43	368,7
90,96	403,3
96,82	423,1
98,34	428,0
$T = 383{,}15°$ K	
1,00	289,6
1,59	288,7
2,47	287,8
7,78	279,2
19,83	259,5
32,14	236,3
40,52	218,5
51,01	193,8
56,89	181,0
58,76	180,6
60,14	182,4
61,12	184,7
62,05	188,1
67,74	223,6
75,95	276,0
84,30	318,1
92,20	350,8
97,84	372,1
$T = 398{,}15°$ K	
1,72	294,0
8,27	285,4
18,76	270,1
34,26	245,4
49,65	218,9
57,10	206,8
61,21	202,0
63,57	199,8
65,34	199,4
67,74	200,6
70,25	203,1
73,48	210,2
79,41	230,1
87,70	263,7
$T = 398{,}15°$ K	
88,05	264,6
94,86	291,8
98,98	311,6
$T = 403{,}15°$ K	
0,41	297,3
0,74	296,6
0,93	297,3
1,56	296,3
5,17	291,7
15,81	277,1
28,07	259,5
41,50	238,0
51,80	222,0
62,05	208,5
67,70	205,8
69,35	206,1
73,27	208,2
80,53	223,4
91,07	261,5
97,30	284,1
$T = 423{,}15°$ K	
0,226	304,6
0,333	304,5
0,549	304,4
0,902	303,9
1,57	303,4
5,18	299,2
7,97	296,0
15,23	287,4
25,76	274,3
42,10	254,2
53,48	241,5
64,07	231,5
74,07	226,0
79,41	226,0
83,78	227,9
89,66	233,5
95,06	242,6
98,88	252,0
$T = 443{,}04°$ K	
5,28	305,8
11,94	292,2
25,04	286,5
36,02	274,9
46,22	264,9
59,16	254,0
71,13	245,8
83,68	243,9
93,58	247,0
98,34	251,3
$T = 448{,}15°$ K	
1,11	311,8
2,86	310,4
4,78	308,3
16,40	297,6
29,44	284,5
41,80	272,7
54,45	261,4
69,35	252,2
79,40	248,3
83,29	248,3
92,84	250,1
98,87	254,2
$T = 473{,}15°$ K	
1,01	319,9
1,60	319,3
7,97	314,6
15,23	308,5
22,98	303,1
30,92	296,7
43,57	287,0
58,67	277,6
74,51	270,4
83,68	269,0
95,25	269,1
95,76	269,0
98,69	268,8

Analysis of the results of measurements in ethylene reveals that experimental points of the isotherms fall above the smooth curves, which pass through the speed of sound values corresponding to the perfect-gas state, in the investigated temperature range at pressures less than 3-4 bar (see Figure 5). Deviations increase nonlinearly as pressure decreases and at 1 bar they amount to 2-3 m/sec. Such a form of dependence of the speed of sound on pressure, as we know, indicates that there is dispersion of the speed of sound in the range of pressures below 4 bar, and the lower boundary of the dispersion region, corresponding to "freezing" of vibration degrees of freedom of only part of the molecules, takes place for f/p 175 kHz/bar.

These data agree satisfactorily with the results of experimental investigations of the speed of sound in ethylene, carried out by the acoustical interferometry method by Namoto and coworkers [19] and by Richardson and Reid [20]. According to the data of these works, the dispersion caused by relaxation of the vibration degrees of freedom, occurs in the range of values of f/p from 180 to 5,000 kHz/bar. The time of vibration relaxation at atmospheric pressure is 2.15×10^{-7} sec at 27°C according to [19] and 2.38×10^{-7} sec at 30°C according to [20]. The measured speed of sound in ethylene is thermodynamic, with the exception of that measured at pressures below 4 bar.

The dispersion of the speed of sound in propylene was investigated by Pusat and coworkers [21]. The experimentally determined region of dispersion is bounded by values of f/p equal to 10-148 MHz/bar. The time of vibration relaxation at 30°C and at atmospheric pressure is $1.48 \times$ $\times 10^{-8}$ sec.

Investigations [15, 18] indicate the absence of dispersion at 690 kHz in the investigated range of pressures, which agrees completely with the conclusions of [21].

Recommended Thermodynamic Speeds of Sound, Adiabatics Index, Heat Capacity Ratios and Isobaric Heat Capacity of Gaseous Ethylene and Propylene

Determination of the heat capacity ratio and adiabatics index on the basis of the speed of sound is most accurate of the known methods. Calculation of κ and k_V is based on the Laplace equation for the speed of sound:

$$w^2 = \left(\frac{\partial p}{\partial \rho}\right)_s. \tag{42}$$

Using the known thermodynamic relations $(\frac{\partial p}{\partial \rho})_s = \kappa(\frac{\partial p}{\partial \rho})_T$ and the equation of the adiabatics of a real gas in the form pv = const, it is possible to derive calculation equations for determination of κ and k_V on the basis of experimentally measured speeds of sound and p, v, T-data or using the thermal equation of state:

$$\varkappa = \frac{w^2}{\left(\frac{\partial p}{\partial \rho}\right)_T}; \tag{43}$$

$$k_v = \frac{w^2}{pv}. \tag{44}$$

It is obvious from (43) and (44) that the speed of sound, density and the first derivatives of the temperature functions must be known in order to do the calculation.

Equation (43), together with the known thermodynamic relation

$$C_p - C_v = -T \frac{\left(\frac{\partial p}{\partial T}\right)_v^2}{\left(\frac{\partial p}{\partial v}\right)_T} \tag{45}$$

gives expressions for calculating heat capacities:

$$C_p = \frac{R^2 T Y^2 w^2}{\left(\frac{\partial p}{\partial \rho}\right)_T \left[w^2 - \left(\frac{\partial p}{\partial \rho}\right)_T\right]}\,; \tag{46}$$

$$C_v = \frac{R^2 T Y^2}{w^2 - \left(\frac{\partial p}{\partial \rho}\right)_T}\,, \tag{47}$$

where R is universal gas constant; $Y = \frac{\left(\frac{\partial \rho}{\partial T}\right)_\rho}{R\rho}$ is a dimensionless value.

In order to calculate the heat capacities, as follows from equations (46) and (47), it is essential to have data on the speed of sound and the first derivatives of the thermal functions.

The method of calculation set forth herein makes it possible to determine the heat capacities with a higher accuracy than C_p and C_v calculated with the aid of the p, v, T-data and heat capacities in the perfect-gas state. Moreover, as follows from expressions (46) and (47), the contribution of the measurement error of the speed of sound to the overall error of determination of the heat capacities decreases by measure of approach to the region of their maximums. The accuracy of the values C_p and C_v in this region is limited basically by errors of determination of the derivative and complex Y.

The recommended adiabatics indices, heat capacity ratios and isobaric heat capacity (Tables II, IV, VI, VIII), computed according to data on the speed of sound, were obtained by Yu. A. Soldatenko and E. K. Dregulyas. The thermal functions and their first derivatives, required for the calculation, were taken from the works of Michels and coworkers [10, 11] and were calculated according to the thermal equations of state.

Comparison of the isochoric heat capacity of propylene with the heat capacities found by Nevers and Martin [1] revealed that they agree in overlapping temperature and pressure ranges within the limits of experimental error.

The isobaric heat capacity and heat capacity ratio calculated according to p, v, T-data of Michels and coworkers [10, 11] are presented in [4, 7].

As seen in Figures 7, 8, 9, 10, these data agree with the values calculated on the basis of the speed of sound within the limits of a few percent. Maximum discrepancies occur in the region of extremal change of the compared values. The heat capacities at pressures above 100 bar in Tables II and VI were calculated from the thermal equations of state used in Chapter I.

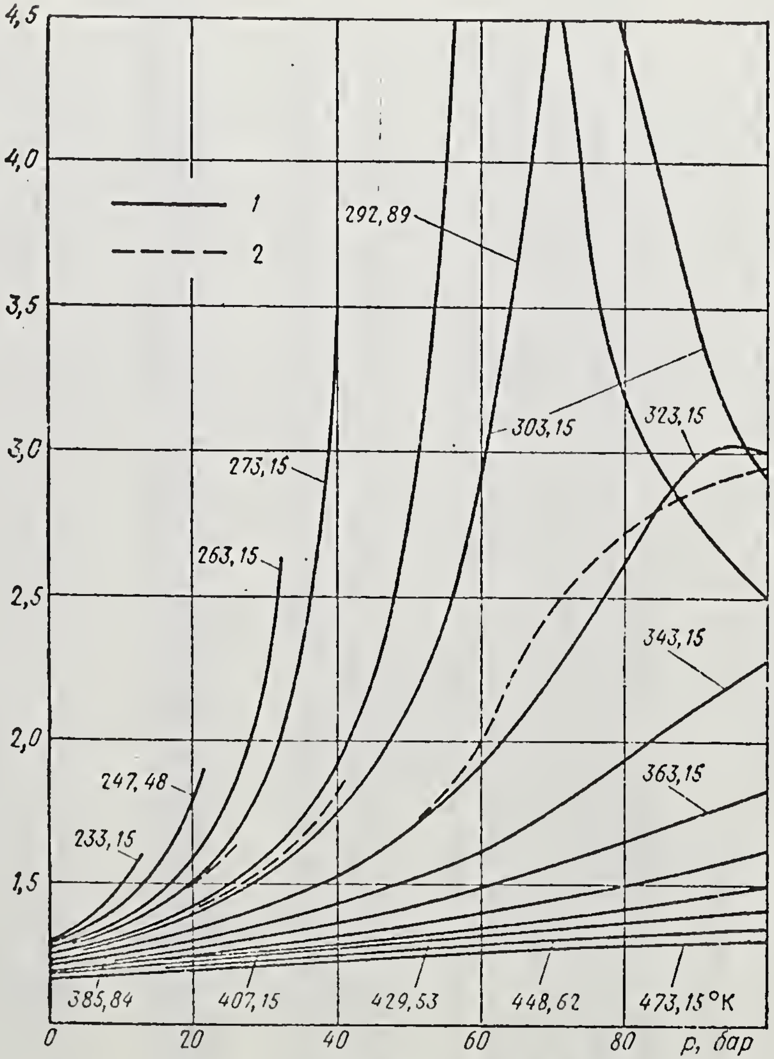

Figure 7. Isotherms of the heat capacity ratio of ethylene. Results of calculations according to: 1 -- authors of present work; 2 -- Dick and Hedley [4].

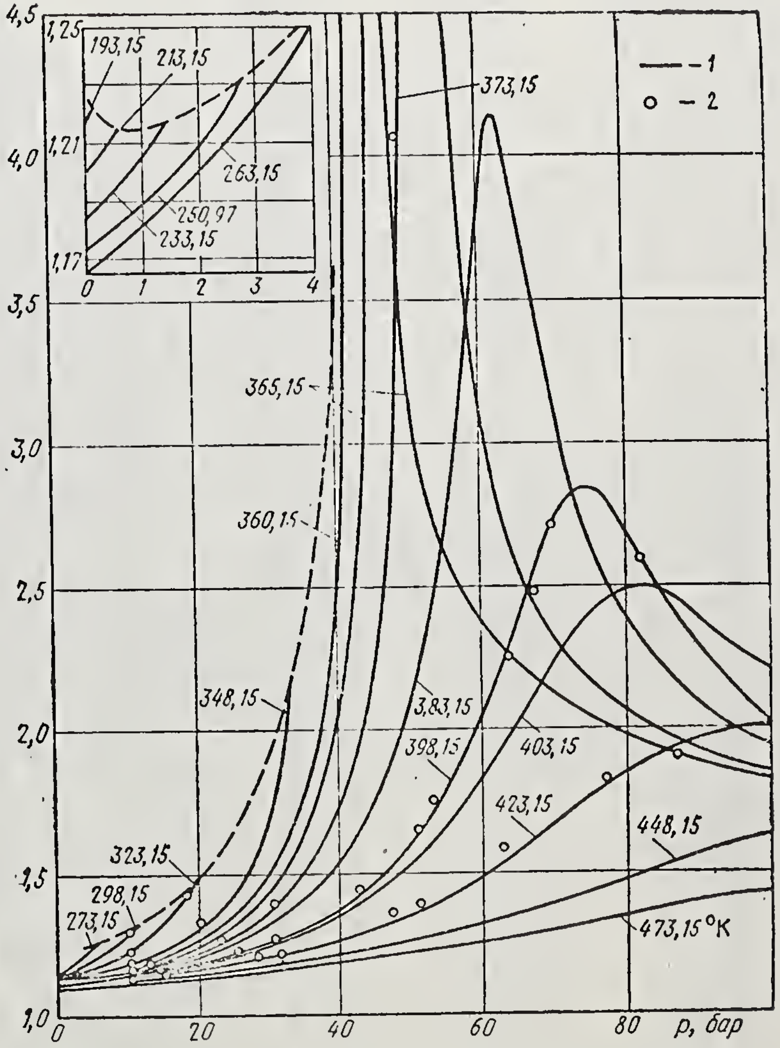

Figure 8. Heat capacity ratio of propylene as function of temperature and pressure. Results of calculations according to: 1 -- authors of present work; 2 -- Michels [10, 11].

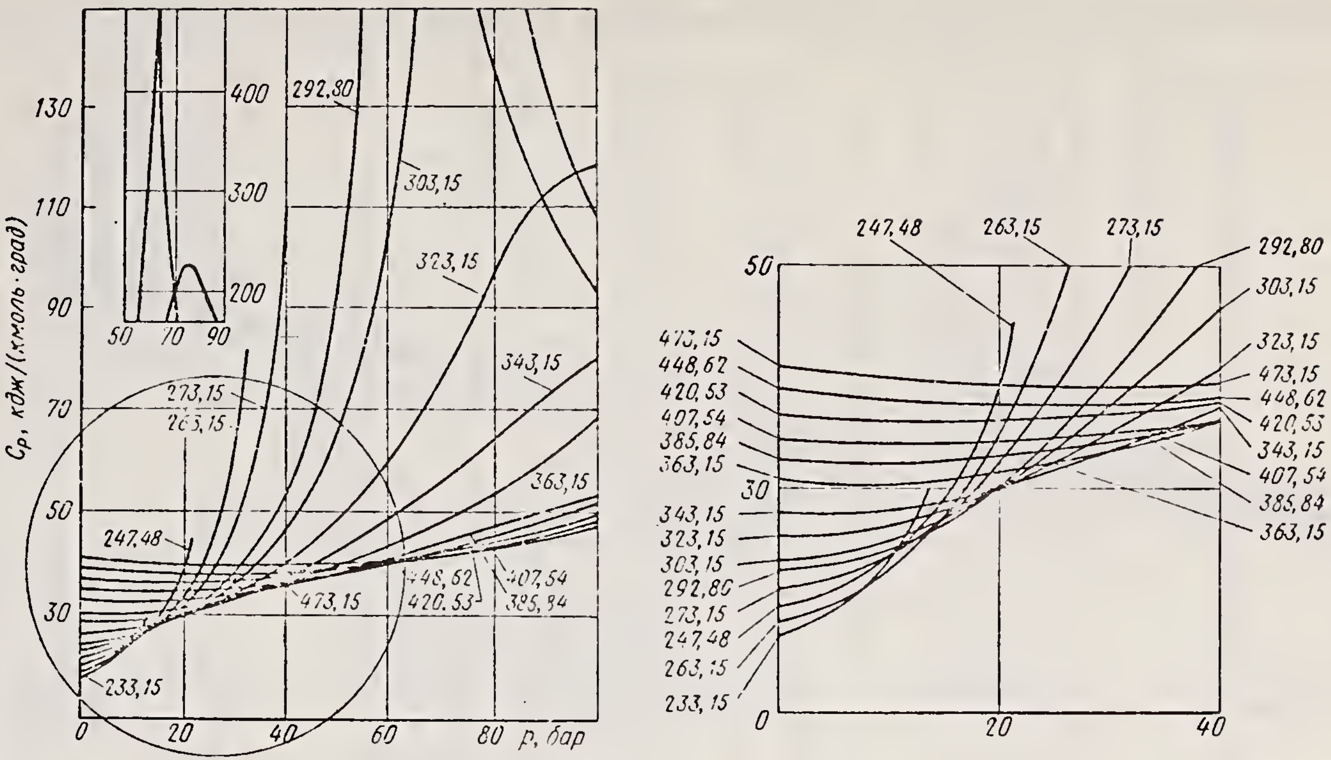

Figure 9. Isotherms of isobaric heat capacity of ethylene. Results of authors of present book.

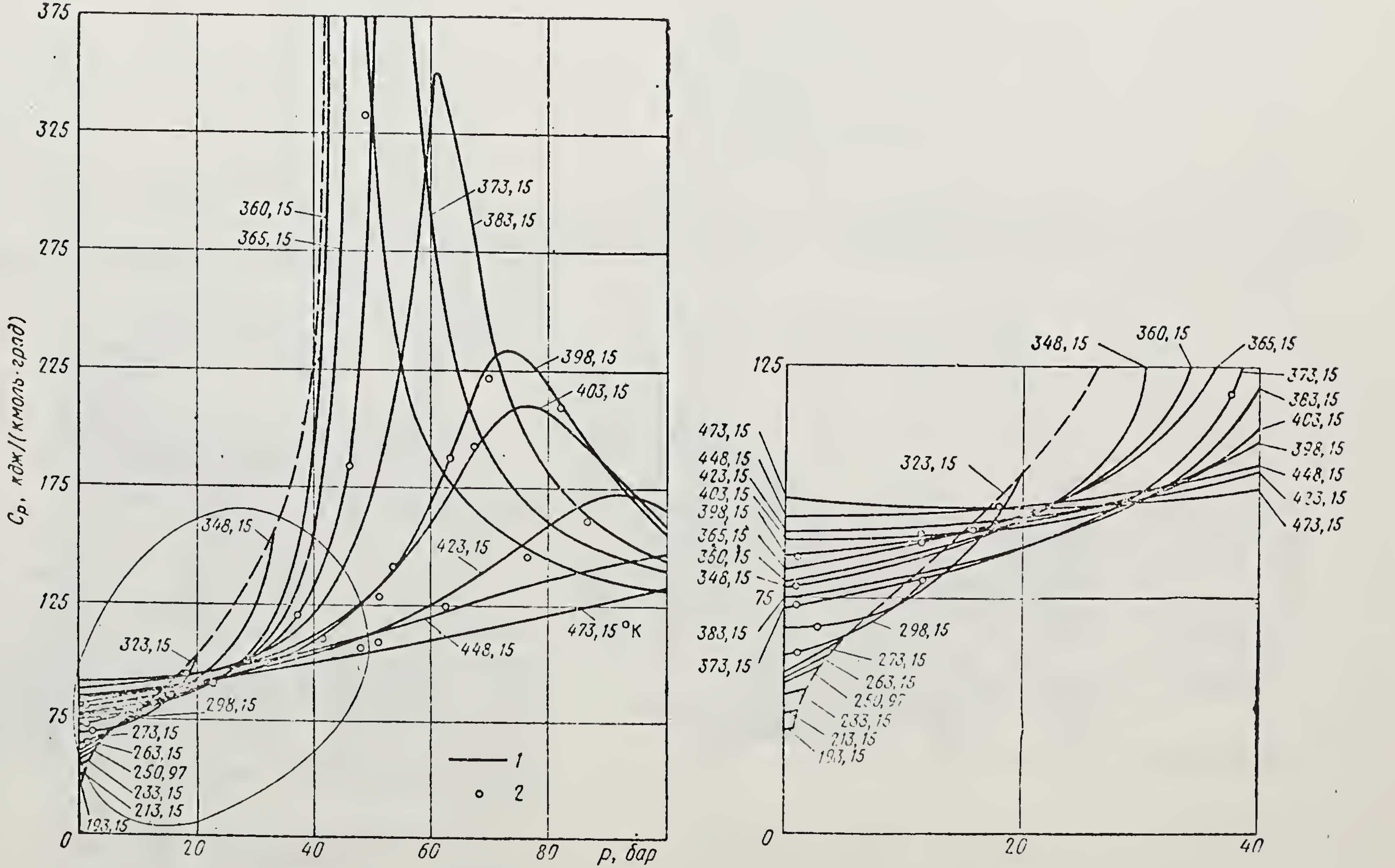

Figure 10. Isobaric heat capacity of propylene as function of temperature and pressure. Results of: 1 -- authors of present book; 2 -- Michels [11].

CHAPTER VI. CALORIC PROPERTIES OF ETHYLENE AND PROPYLENE IN CONDENSED STATE

Review of Experimental Data

The experimental measurements of the isobaric heat capacity of ethylene and propylene and the heats of phase transitions are based on the determination of the caloric properties of these compounds in the solid and liquid states. The works containing the results of such analyses are listed in Table 39.

Table 39. Caloric Properties of Solid and Liquid Ethylene and Propylene

1) Авторы	2) Год	3) Интервал исследованных температур, °K	4) Вещество и его измеренные свойства
Эйкен и Гаук [1]	1928	80—170	5) Этилен, изобарная теплоемкость и теплота плавления
Эган и Кемп [2]	1937	16—169	6) Этилен, изобарная теплоемкость, теплота плавления и парообразования
Кострюков с сотрудниками [3]	1954	35—115	7) Этилен, изобарная теплоемкость
Гуфман и Паркс [4]	1931	68—210	8) Пропилен, изобарная теплоемкость и теплота плавления
Пауелл и Джайок [5]	1939	14—225	9) Пропилен, изобарная теплоемкость, теплота плавления и парообразования
Ауербах, Сейдж и Леси [6]	1950	300—330	10) Пропилен, изобарная теплоемкость

KEY: 1. Authors
Eucken and Hauck [1]
Egan and Kemp [2]
Kostryukov, et al [3]
Huffman and Parks [4]
Powell and Giaque [5]
Auerbach, Sage, Laccey [6]
2. Year
3. Range of investigated temperatures, °K
4. Compound and its measured properties
5. Ethylene, isobaric heat capacity and heat of fusion
6. Ethylene, isobaric heat capacity, heat of fusion and heat of evaporation
7. Ethylene, isobaric heat capacity
8. Propylene, isobaric heat capacity and heat of fusion
9. Propylene, isobaric heat capacity, heat of fusion and heat of evaporation
10. Propylene, isobaric heat capacity

All the works listed in the table were carried out by direct heating of the investigated compound in a constant-volume adiabatic calorimeter with a free interface between the gas and condensed phases in the calorimetric vessel. The ratio of the heats applied to the investigated compound to the rise of temperature, measured in such tests, as we know, is related to the thermodynamic functions of the compound by the expression

[ж=li;
п=v]

$$\frac{q}{\Delta T} = m_{ж} C_s' + m_{п} C_s'' + \frac{dm_{ж}}{dT} r, \tag{48}$$

where C_s' is the heat capacity of the liquid on the saturation curve; C_s'' is the heat capacity of the vapor on the saturation curve; r is the heat of evaporation; m_{li}, m_v are the masses of the liquid and vapor phases, respectively, of the investigated compound.

The desired isobaric heat capacity of the liquid is calculated by one of equations (48) of heat capacity on the saturation curve using the known thermodynamic relation

$$C_{p_{ж}} = C_s' + T\left(\frac{dv_{ж}}{dT}\right)_p \cdot \frac{dp_s}{dT}, \tag{49}$$

where v_{li} is the specific volume of the liquid.

In the region of states far from critical all correction factors which, according to equations (48) and (49), must be reduced to the values measured in the experiment for determination of Cp_{li}, are negligibly small. At temperatures exceeding the normal boiling point, however, exact calculation of the isobaric heat capacity according to these relations requires extremely reliable data on the thermal properties of the investigated liquid, its vapor and heat of evaporation.

The heat capacity of ethylene in the condensed phase is measured by Eucken and Hauck [1], Egan and Kemp [2] at temperatures from 16°K to the normal boiling point 170.4°K. The results of these investigations vary substantially both in the solid (up to 28%) and in the liquid (up to 17%) states and give a different temperature curve for the heat capacity of ethylene in the liquid state (Figure 11). Eucken and Hauck obtained four experimental points for the heat capacity of solid ethylene and 11 points for the liquid. They are all presented in [1] in the form of a small graph. The smooth values of heat capacity obtained in this work are: for solid ethylene 14.80, 15.35 and 16.00 cal/(mole·deg) at 80, 90 and 100°K, respectively; for liquid ethylene 17.40, 17.80, 18.17, 18.50, 18.80 and 18.80 cal/(mole·deg) at 110, 120, 130, 140, 150, 160 and 170°K, respectively

The authors [1] estimate the accuracy of their data as ±1%.

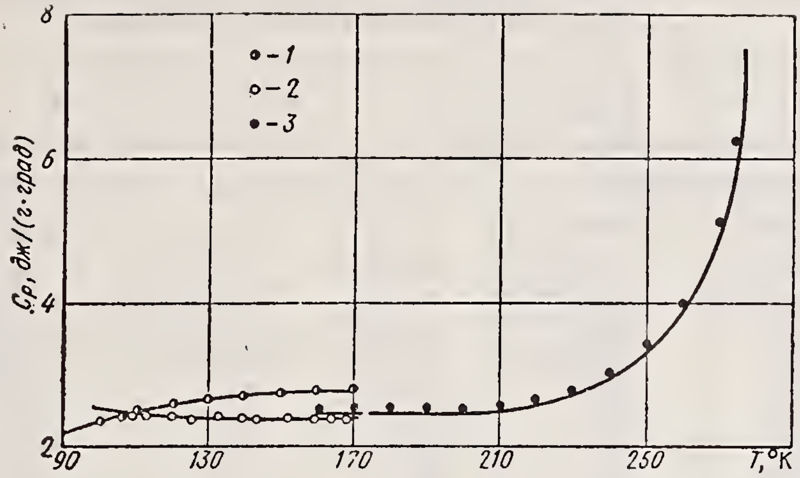

Figure 11. Isobaric heat capacity of ethylene on saturation curve according to: 1 -- Eucken and Hauck [1]; 2 -- Egan and Kemp [2]; 3 -- Soldatenko and Vashchenko [10].

Direct measurements are not given in [1], in which connection it is impossible to establish the possible error or systematic error in the measurements and in the processing of the experimental data. Another important deficiency of the cited work is the absence of chemical analysis of the ethylene employed in the tests.

Egan and Kemp [2] used 99.5% pure ethylene. They further purified it by drying over phosphorous pentoxide and distillation at low pressure (100-200 mm Hg) and pumping of the vapors over the solid phase, before filling the apparatus with it. The purity of the thus prepared specimen was determined cryoscopically on the basis of residual impurities, amounting to not more than 0.001 mole %.

The experimental data [2] on the isobaric heat capacity of ethylene are presented in Table 40.

The same values are used as recommended values for technical calculations in many manuals, [7, 8] for instance. The heat of fusion of ethylene (λ = 800.8 ± 0.8 cal/mole) and heat of evaporation (r = 3,237 ± ± 3 cal/mole) at normal pressure of 760 mm Hg, measured calorimetrically, are also given in [2].

The heats of evaporation stated above agree satisfactorily with those calculated by the authors (r = 3,222 cal/mole) according to the saturation pressure of the vapors.

Egan and Kemp, on the basis of caloric data, calculated the entropy of ethylene in the perfect-gas state at the normal boiling point $S^{\circ}_{169.40}$. It is 47.36 ± 0.10 cal/(mole•deg) and agrees very well with the results of later calculations on the basis of spectroscopic data. The entropy of ethylene in this state, according to [2], is 47.354 cal/(mole•deg). The

Table 40. Experimental Data of Egan and Kemp [2] on Isobaric Heat Capacity of Ethylene

T° K	C_p, кал/(моль × × град)	T° K	C_p, кал/(моль × × град)	T° K	C_p, кал/(моль × × град)
1) Твердое состояние		1) Твердое состояние		1) Твердое состояние	
16,00	0,803	80,79	11,70	103,81	34,96
18,81	1,299	86,77	12,65	2) Жидкое состояние	
21,91	1,921	92,11	13,83	106,69	16,51
25,17	2,556	94,46	74,56	108,58	16,49
29,10	3,362	95,48	14,94	112,28	16,43
33,16	4,288	98,10	16,03	119,03	16,33
37,35	5,187	98,99	16,44	125,90	16.28
43,08	6,045	100,94	17,65	132,60	16,21
47,29	6,932	101,39	17,97	139,08	16,11
52,52	7,809	101,90	18,48	145,38	16,09
57,60	8,598	102,28	18,59	151,88	16.08
62,80	9,279	103,03	19,32	158,55	16,03
68,41	9,980	103,36	20,77	164,23	16,04
74,70	10,79	103,59	20,58	168,71	16,09

KEY: 1. Solid state 2. Liquid state

coincidence of the stated entropy values is indirect proof of the reliability of the experimental data on the calorimetric properties of ethylene presented in [2].

Some experimental points on the thermal capacity of ethylene are given by V. N. Kostryukov, et al [3] in graphic form. These values were obtained at the request of the authors during trial measurements, in which the operation of the experimental apparatus was checked. The data obtained practically coincide with the data of Egan and Kemp [2], with the exception of the region very close to the melting point, where the authors [3] observed a very sharp (4-5-fold) increase in the heat capacity. The authors [3] attribute the increase in heat capacity to the insufficient purity of the investigated ethylene specimen.

The isobaric heat capacity of propylene in the condensed state was measured to the normal boiling point by Huffman, Parks, Barmore [4] and Powell and Giaque [5]. The purity of the investigated specimen of propylene in [4] was characterized by the presence of 0.1 mole % impurities, and in [5] the purity of the main component was 99.98%.

The experimental data obtained on isobaric heat capacity of propylene agree within the limits of the accuracy of experimental measurements of ±1%, as requested by the authors, and the data in [4] are understated in relation to the data in [5] within the limits of systematic error in the liquid state. The experimental data derived from these investigations are listed in Tables 41 and 42.

The data on the heat of fusion of propylene, measured in the cited works, diverge to a somewhat greater extent.

Table 41. Experimental Data of Huffman, Parks and Barmore [4] on Isobaric Heat Capacity of Propylene

T°, K	C_p, кал/(г·град)	T°, K	C_p, кал/(г·град)	T°, K	C_p, кал/(г·град)
1) Твердый этилен		2) Жидкий этилен			
68,9	0,273	93,1	0,523	153,9	0,490
72,0	0,280	93,5	0,522	165,3	0,492
73,5	0,286	98,6	0,516	189,5	0,502
76,5	0,296	108,7	0,504	210,3	0,512
76,7	0,295	125,2	0,494		
81,6	0,317	144,8	0,490		

KEY: 1. Solid ethylene 2. Liquid ethylene

Table 42. Isobaric Heat Capacity of Propylene, Experimental Data of Powell and Giaque [5]

T°, K	C_p, кал/(г·град)	T°, K	C_p, кал/(г·град)	T°, K	C_p, кал/(г·град)
1) Твердый пропилен		61,25	0,2438	115,64	0,5024
		66,61	0,2609	128,09	0,4988
14,18	0,0271	71,46	0,2759	134,56	0,4974
16,66	0,0377	76,49	0,2920	141,21	0,4945
19,63	0,0523	76,59	0,2949	154,97	0,4950
22,81	0,0726	81,69	0,3184	161,88	0,4948
26,23	0,0924	84,37	0,3374	169,01	0,4960
29,87	0,1113	86,17	0,3826	176,71	0,4986
33,62	0,1332	2) Жидкий пропилен		187,77	0,5005
37,46	0,1537			194,66	0,5036
41,29	0,1705	93,91	0,5235	201,77	0,5090
45,53	0,1865	98,66	0,5171	209,18	0,5121
50,66	0,2069	104,18	0,5107	216,41	0,5136
55,96	0,2243	109,98	0,5073	223,40	0,5195

KEY: 1. Solid Propylene 2. Liquid propylene

According to measurements [4] the heat of fusion is 701.4 cal/mole, and in [5] it is 717.6 cal/mole. The 2% discrepancy in the heat of fusion is obviously related to the purity of the investigated specimens, as well as to the fact that the sharp increase in heat capacity of the solid propylene near the melting point, observed in [5] at temperatures from 82°K to the melting point (87.70°K) was taken into account in [4] during processing of the experimental data on the heat of fusion. The last experimental point in [4] in the region of the solid state was determined at T = 81.6°K. Thus, the heat of fusion of propylene λ = 717.6 cal/mole, obtained in [5], should be considered more reliable.

The heat of evaporation (r) of propylene at normal pressure was measured in [5] by the calorimetric method and is equal to 4,402 ± 3 cal/mole.

The isobaric heat capacity of liquid propylene on the saturation curve at temperatures above the normal boiling point were measured in a narrow temperature range by Auerbach, Sage and Laccey [6] in a constant-volume adiabatic calorimeter with the presence of a free interface between the liquid and gaseous phases. The isobaric heat capacity was calculated on the basis of two series of calorimetric measurements, taken with different concentrations of the investigated compound in the calorimetric vessel at 308-339°K.

The basic calculation equation is

$$C_{p_{\text{ж}}} = \frac{\frac{q_1}{\Delta T_1} - \frac{q_2}{\Delta T_2}}{m_1 - m_2} \left(\frac{v'' - v'}{v''} \right) + T \left(\frac{\partial v_{\text{ж}}}{\partial T} \right)_p \frac{dp_s}{dT} + T \frac{dp_s}{dT} \left(\frac{v'' \frac{dv'}{dT} - v' \frac{dv''}{dT}}{v''} \right) + \frac{v'}{v''} \left[C_{p_{\text{п}}} - T \left(\frac{\partial v_{\text{п}}}{\partial T} \right)_p \frac{dp_s}{dT} \right], \quad (5)$$

where $(\frac{q_1}{\Delta T_1})$ and $(\frac{q_2}{\Delta T_2})$ are the ratios of the heats applied to the calorimetric system to the temperature rise, measured directly in the first and second series of tests; m_1 and m_2 are the masses of propylene in the calorimeter in the first and second series of tests.

The original propylene was 99.0% pure. It was subjected to additional purification by fractionation at low temperature and at atmospheric pressure in the ratio 40:1 before filling the apparatus, and at the beginning of purification more than 15% of the specimen was discarded, and 20% at the end of the purification process. The specimen used in the test changed temperature by not more than 0.05°K during evaporation at atmospheric pressure.

The difference $(\frac{q_1}{\Delta T_1} - \frac{q_2}{\Delta T_2})$ required for calculating the isobaric heat capacity of the liquid in accordance with equation (50), was determined in accordance with smooth curves plotted in coordinates $q/\Delta T$ - T for both series of tests. During investigation of propylene the scattering of the individual measurements in relation to the smooth curve constituted an extremely large part (±5%) of the above-mentioned difference. A considerable drawback of the examined investigation, inherent to the experimental procedure, is the extremely large correction factor related to the presence of a two-phase system in the calorimeter, which must be reduced to values measured in the test in order to calculate the isobaric heat capacity of the liquid on the saturation curve (see equation (50)).

According to data in [6], the correction factor in the given temperature range is 16-45% of the isobaric heat capacity of the liquid. It is also noteworthy that this correction, due to the insufficient accuracy of the existing data on the thermal and caloric properties of liquid and gaseous propylene, cannot be calculated with sufficient accuracy.

On the basis of what has just been said it can be concluded that the accuracy referred to by the authors of [6] of data on the isobaric heat capacity of liquid propylene on the saturation curve, ±3%, is hardly justified, and the smooth data (see Table 43) are not reliable.

Yu. A. Soldatenko and D. M. Vashchenko [10] investigated in 1964-1968 the isobaric heat capacity of liquid ethylene and propylene at 170-280 and 170-360°K at pressures of 1 to 60 bar. The experimental apparatus used for these purposes accomplishes direct heating of the investigated compound in a calorimeter with an isothermic shell in the variation proposed by A. Ye. Sheyndlin, S. G. Shleyfer and E. E. Shpil'rayn [11]. A characteristic feature of the method is the absence of a free liquid surface in the calorimeter, ensuring the capability of measuring the heat capacity of unsaturated liquids under pressure. The pressure is created in the apparatus by the vapors of the investigated liquid, and its free level extends beyond the limits of the calorimetric vessel into a region of higher temperatures than the temperature existing in the calorimeter. The amount of the investigated compound is determined by the known volume of the calorimetric vessel and the density of the liquid at the test temperature and pressure. The experimental apparatus is described in detail in [10].

Table 43. Isobaric Heat Capacity of Liquid Propylene on Saturation Curve According to Auerbach, Sage and Laccey [6]

t° F	T° K	C_p, кал/(г·град)	t° F	T° K	C_p, кал/(г·град)
80	299,8	0,5615 *	130	327,6	0,6607
90	305,4	0,5747 *	140	333,2	0,6985
100	310,9	0,5917	150	338,7	0,7607
110	316,5	0,6102	160	344,3	0,8608 *
120	322,0	0,6329	—	—	—

*Values extrapolated by the authors [6].

A new method of introducing the correction factor for heat exchange between the calorimeter and the isothermic shell is original in the given study. During calorimetry the temperature of the calorimeter is measured both during the main period of the test, including the operating time of the heater and time interval during which the temperature varies in the calorimeter, and in the final period. Here the time of passage of the "spot" of the galvanometer, hooked into the measurement circuit of a platinum resistance thermometer, through the zero graduation when certain a priori known temperatures are reached in the calorimeter, is recorded with the aid of a two-hand type 51-SD stop watch. The temperature pitch between consecutive measurements was maintained constant.

The curve of change of calorimeter temperature in time, thus obtained, was used for determining the "adiabatic" [13] temperature rise of the calorimeter, which is determined with the expression

$$\Delta t_{ad} = \Delta t' + \delta t, \tag{51}$$

where $\Delta t'$ is the observed temperature rise of the calorimeter on completion of the main period of the test; δt is the correction factor for heat exchange between the calorimeter and the isothermic shell during the main period.

The correction factor for heat exchange is found from the expression

$$\delta t = k \int_0^{\tau_n} (t - t_k)\, d\tau, \tag{52}$$

where k is the rate of cooling of the calorimeter; t is current temperature; t_k is the convergence temperature [12], equal in our case to the initial calorimeter temperature; τ_n is the time of completion of the main test period.

The accuracy of calculation of the correction factor for heat exchange depends principally on the accuracy of determination of the cooling rate k, calculation of which is now done by a new method with high accuracy.

The generally accepted methods of calculating the rate of cooling [11, 12] are based on the assumption of linear change of calorimeter temperature in the final test period, which, as shown by experience, is at best a very rough approximation. Disregarding the nonlinearity of the temperature curve of the calorimeter in the final test period causes notable errors, particularly during testing in the negative temperature range.

A new method is based on the fact that at the end of the test the temperature drop of the calorimeter is governed only by heat losses from the calorimeter to the thermostat and consequently for any time interval $(\tau_{n+1} - \tau_n)$ of the final period the heat exchange correction factor δt, calculated according to equation (52), is equal to the observed temperature drop of the calorimeter:

$$\delta t = k \int_{\tau_n}^{\tau_{n+1}} (t - t_k)\, d\tau = (t_n - t_{n+1}). \tag{53}$$

Writing expression (53) for the entire final period from τ_n to τ_l (time of completion of the test), we obtain

$$(t_n - t_l) = k \int_{\tau_n}^{\tau_l} (t - t_k)\, d\tau. \tag{54}$$

Equation (54) is used for calculating the rate of cooling k. For the adiabatic rise of temperature of the calorimeter in the principal period we have, with consideration of what has been said above,

$$\Delta t_{\text{ад}} = (t_n - t_0) + (t_n - t_l)\frac{\int\limits_0^{\tau_n}(t - t_0)\,d\tau}{\int\limits_{\tau_n}^{\tau_l}(t - t_0)\,d\tau}. \qquad (55)$$

The integrals in equation (55) are calculated by the trapezoid method on the basis of calorimeter temperature measurements in the main and final test periods.

The time of completion of the main period of the calorimetric test is determined quite distinctly within the frameworks of the given method. Actually, with consideration of the constant temperature pitch between consecutive measurements and conditions (53), we may write for any interval of time between consecutive measurements in the final period, the following relation:

$$k\int\limits_{\tau_i}^{\tau_{i+1}}(t - t_0)\,d\tau = (t_i - t_{i+1}) = \text{const.} \qquad (56)$$

Since the rate of cooling is constant for the entire calorimetric test it follows from expression (56) that

$$\int\limits_{\tau_i}^{\tau_{i+1}}(t - t_0)\,d\tau = \text{const}, \qquad (57)$$

for the entire final period, or calculating the integral as the area of a trapezoid, we obtain

$$\frac{t_i + t_{i+1}}{2}\,\Delta\tau_i = \text{const.} \qquad (58)$$

Consequently the point on the curve of change of temperature in time, after which equation (58) is satisfied for all subsequent measurements, may be taken as the completion of the main period. Its shift toward an increase in time does not alter the results of the calculation by the equation

$$\Delta t_{ad} = \Delta t' + \delta t.$$

The isobaric heat capacity of liquid ethylene and propylene was investigated at 170-280°K and 170-360°K at pressures from 1 to 60 bar.

Ethylene and propylene were supplied in metal cylinders. The concentration of the main component according to the data of factory chromatographic analysis in specimens taken from the cylinders is 99.98% for ethylene and 99.7% for propylene. The investigated compounds were not subjected to additional refining.

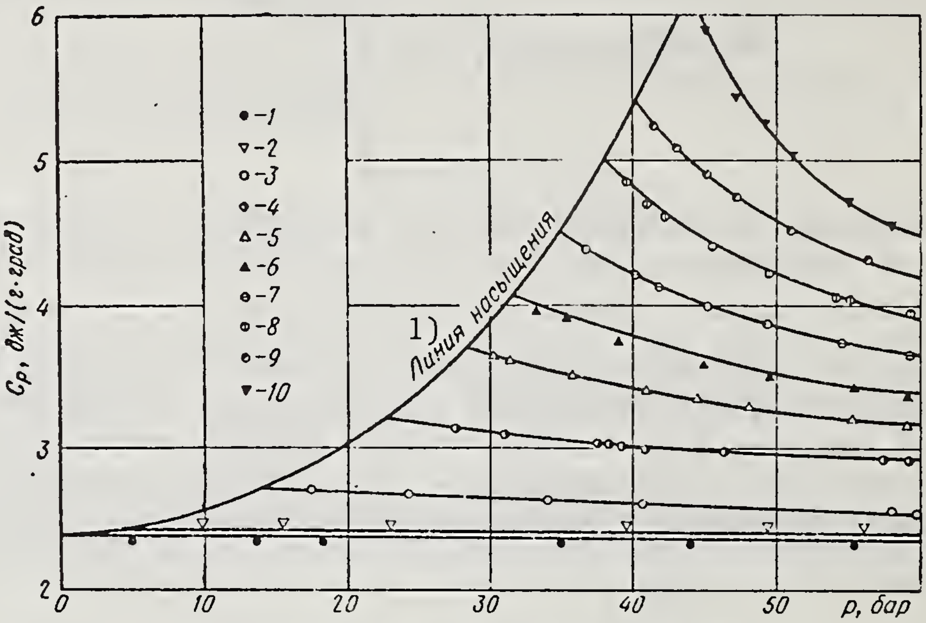

Figure 12. Experimental data on isobaric heat capacity of liquid ethylene at T equal to: 1 -- 168.90; 2 -- 196.65; 3 -- 232.65; 4 -- 249.65; 5 -- 257.25; 6 -- 262.65; 7 -- 266.65; 8 -- 270.35; 9 -- 273.65; 10 -- 277.65°K.
KEY: 1. Saturation curve.

Sixty-nine experimental points were obtained on the basis of the isobaric heat capacity of ethylene. During the calorimetric test the initial temperature of the specimen and the heat supplied were chosen from the consideration that the average temperatures of the series of tests conducted at different pressures be close to each other. Thus, the entire series of measurements was conducted on the same isotherm. The small correction factors that are inevitable in such a case at certain experimental points, for reduction to the temperature on the investigated isotherm, did not exceed 0.3% of the measured isobaric heat capacity. The correction factors were introduced by the successive approximation method during processing of the series of isotherms.

Eleven isotherms were found for ethylene in the stated temperature range, each of which included at least five experimental points. Most of the experimental points were the result of averaging two identical measurements.

The experimental points and the smooth curves (isotherms) are illustrated in Figure 12. Smoothing was done in the coordinates C_p-p on the basis of the isotherms and in the coordinates C_p-T on the basis of the isobars. Deviations of the experimental points from the smooth curves do not exceed ±1%. The isobaric heat capacity on the saturation curve was determined by extrapolating the isotherms to the saturation pressure, which was taken on the basis of the data in [7]. Seventy experimental points on 10 isotherms were obtained in the above-stated temperature and pressure ranges in terms of the isobaric heat capacity of propylene. The deviations of the experimental points from the smooth curves did not exceed ±1%. The experimental points and smooth curves (isotherms) are illustrated in Figure 13.

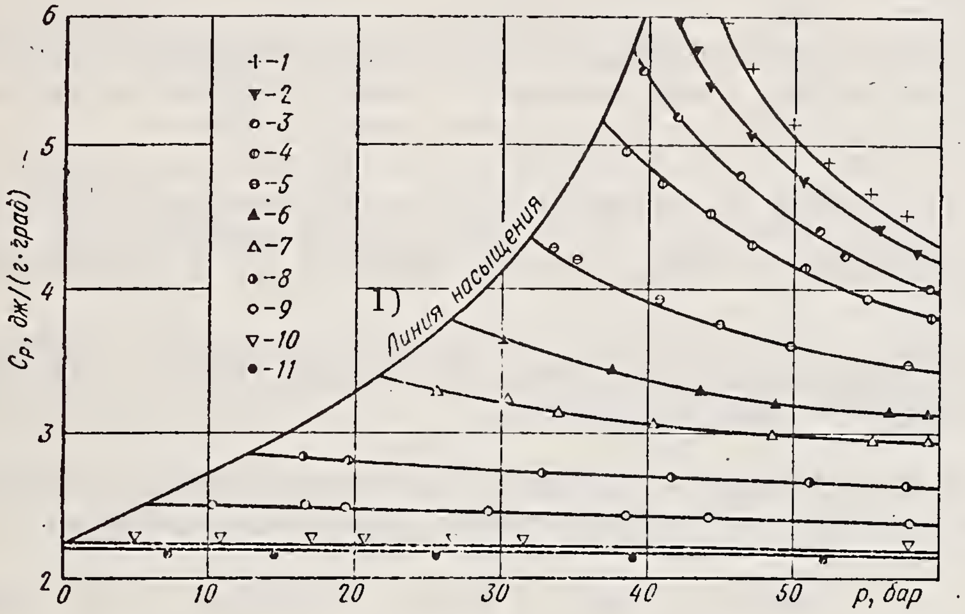

Figure 13. Experimental data on isobaric heat capacity of liquid propylene at T equal to: 1 -- 360.35; 2 -- 358.65; 3 -- 355.15; 4 -- 352.55; 5 -- 344.64; 6 -- 335.15; 7 -- 325.65; 8 -- 301.65; 9 -- 274.57; 10 -- 197.55; 11 -- 164.65°K.
KEY: 1. Saturation curve.

Detailed analysis of the accuracy of experimental determination of the isobaric heat capacity yields a maximum possible error equal to ±1.5%. The accuracy of the extrapolated values of heat capacity on the saturation curve, by our estimate, is ±(2.5-3)% in the high-temperature range.

Recommended Caloric Properties of Ethylene and Propylene in Condensed State

Ethylene

The review and comparison of existing experimental data on the isobaric heat capacity and heat of phase transitions of ethylene, presented in the preceding section, make it possible to recommend the following initial data as the most reliable:

a) Egan and Kemp [2], presented in Table 44, on the isobaric heat capacity in the solid state from 15°K to the melting point (103.95°K) and on the heat capacity of the liquid in the range of temperatures from the melting point to the normal boiling point (169.37°K).

The heats of phase transitions, found by the same authors, for the heat of fusion λ = 119.26 ± 0.41 kJ/kg and heats of evaporation r = 483, 144 ± 0.12 kJ/kg at the normal boiling point for p = 760 mm Hg, are also the most reliable values.

b) Yu. A. Soldatenko and D. M. Vashchenko on the isobaric heat capacity of liquid ethylene in the temperature range above the normal boiling point, the results of which are presented in the preceding section (see Figure 12).

The data of Egan and Kemp were used in the present work for calculating the enthalpy and entropy of liquid ethylene at the normal boiling point, measured from the crystal state at 0°K.

Heat capacity C_p below 15°K was found by extrapolating to 0°K according to the Debye theory [13] and agrees at 15°K with the data of Egan and Kemp.

The enthalpy and entropy were obtained by graphic integration of the data on isobaric heat capacity.

The heat of fusion was found on the basis of data [2]. The results of the values in the most characteristic points are presented in Table 44.

Table 44. Heat of Fusion According to [2]

1) Температура	2) Изменение энтальпии, *кдж/кг*	3) Изменение энтропии, *кдж/(кг·град)*
$0°K - 15°K$	$i_{15°K} - i_{0°K} = 0{,}414$	$S_{15°K} = 0{,}0357$
$15°K - T_{пл}$	$i_{103{,}95°K} - i_{15°K} = 115{,}86$	$S_{T_{пл}} - S_{15°K} = 4{,}178$
$T_{пл}$	$\lambda = 119{,}53$	$\lambda/T_{пл} = 1{,}149$
$T_{пл} - T_{н.к}$	$i_{169{,}37°K} - i_{103{,}95°K} = 158{,}204$	$S_{169{,}37°K} - S_{103{,}95°K} = 1{,}181$
4) Сумма	$i_{169{,}37°K} - i_{0°K} = 394{,}00$	$S_{169{,}37°K} = 4{,}214$

KEY: 1. Temperature
2. Enthalpy change, kJ/kg
3. Entropy change, kJ/(kg·deg)
4. Total
пл = melt.
H.k = normal boiling

The enthalpy of gaseous ethylene, given in Table II, was also measured from the crystal state at 0°K. Conversion of the enthalpy change measured from the gas state at 0°K, to the zero reading employed, was done at the normal boiling point using the value $i_{169.37°K}$ presented above.

It was found that

$$i_T^0 = [(H_T^0 - H_0^0) + 662{,}4], \quad \text{kJ/kg} \tag{59}$$

where i^0_T is the enthalpy at T and p = 0, measured from the crystal state at 0°K; $(H^0_T - H^0_0)$ is the enthalpy of the gas in the same state, measured from the gaseous state at 0°K.

The data of Yu. A. Soldatenko and D. M. Vashchenko were used for tabulating the isobaric heat capacity, enthalpy and entropy of liquid ethylene in the temperature range above the normal boiling point and at pressures of 0.5-60 bar (Table II). The tabulated values of enthalpy and entropy were obtained by graphic integration of the smooth isobaric heat capacities in the temperature range from 169.37°K to the given tabular temperature every 10° (Table II).

The enthalpy and entropy of the saturated liquid were determined by the same method with integration to the saturation temperature on the given isobar. The enthalpy and entropy of the saturated vapor were calculated with consideration of the heat of evaporation at the given pressure.

The enthalpy and entropy at the critical point were determined by extrapolating the top and bottom boundary curves in coordinates T - i and T - S to mutual intersection at T_{cr} and in coordinates p - i and p - S to intersection at p_{cr}. The tie-in of i_{cr} and S_{cr} was checked in coordinates i - S.

Propylene

The data of Powell and Giaque [5], presented in Table 42, are recommended on the basis of the isobaric heat capacity in the solid state from 15°K to the melting point (87.85°K) and on the basis of the heat capacity of the saturated liquid in the temperature range from the melting point to the normal boiling point (225.35°K).

Also considered most reliable are data on the heat of fusion $\lambda =$ $= 71.402$ kJ/kg and heat of evaporation at the normal boiling point at $p =$ $= 760$ mm Hg, $r = 438.00 \pm 0.3$ kJ•kg.

At temperatures above the normal boiling point the isobaric heat capacities obtained by Yu. A. Soldatenko and D. M. Vashchenko are used, both for the saturated and unsaturated liquid.

The recommended values are compared with data in [6] in Figure 14. The comparison can be done only on the saturation curve, since data on the isobaric heat capacity of the liquid under pressure are found only in [10]. The data of [6], as seen in Figure 14, were obtained for 300-345°K, and are 12-18% lower than the data of [7]. Possible reasons for such great discrepancies are discussed in the preceding section.

Powell's results [5] were used in our work for calculating the enthalpy and entropy of liquid propylene at the normal boiling point, measured from the 0°K crystal state.

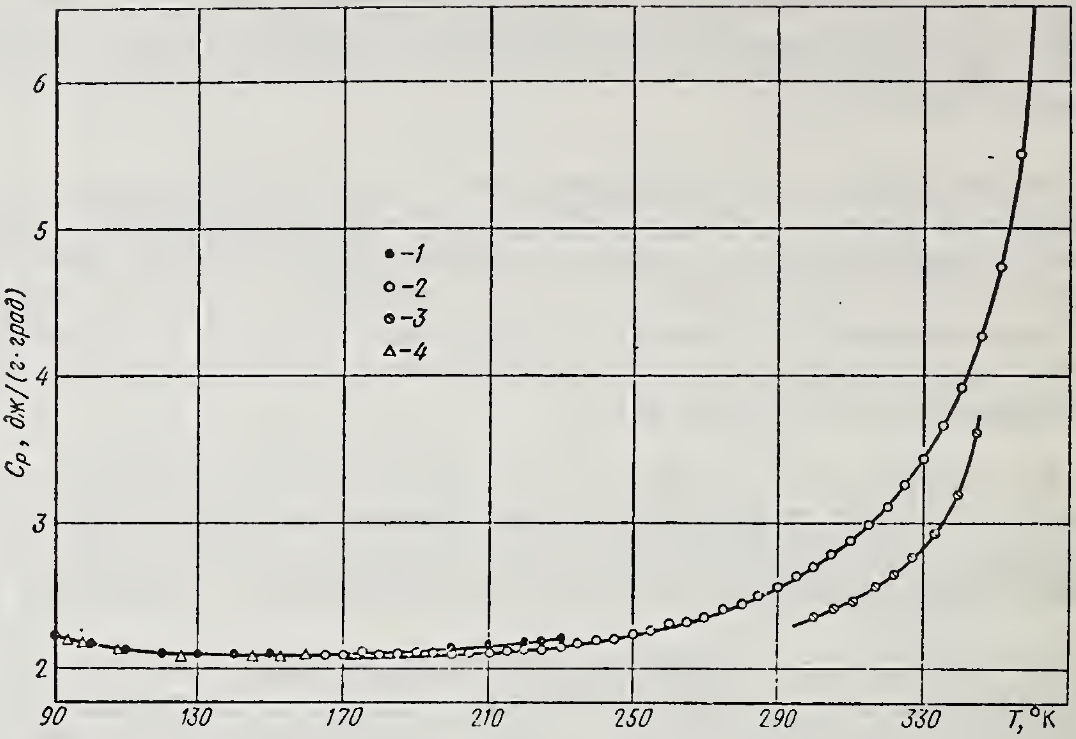

Figure 14. Isobaric heat capacity of propylene on saturation curve according to: 1 -- Powell [5]; 2 -- Huffman, Parks [4]; 3 -- Yu. A. Soldatenko, D. M. Vashchenko [7]; 4 -- Auerbach, Sage, Laccey [6].

Table 45. Heat, Enthalpy and Entropy

1) Температура	2) Изменение энтальпии, *кдж/кг*	3) Изменение энтропии, *кдж/(кг·град)*
0°K — 15°K	$i_{15°K} - i_{0°K} = 0{,}552$	$S_{15°K} = 0{,}049$
15°K — $T_{пл}$	$i_{87{,}90°K} - i_{15°K} = 60{,}958$	$S_{T_{пл}} - S_{15°K} = 1{,}159$
$T_{пл}$	$\lambda = 71{,}402$	$\lambda/T_{пл} = 0{,}812$
$T_{пл} - T_{н.к}$	$i_{225{,}45°K} - i_{87{,}90°K} = 292{,}04$	$S_{225{,}45°K} - S_{87{,}90°K} = 1{,}985$
4) Сумма	$i_{225{,}45°K} - i_{0°K} = 424{,}40$	$S_{225{,}45°K} = 4{,}005$

KEY: 1. Temperature
2. Enthalpy change, kJ/kg
3. Entropy change, kJ/(kg·deg)
4. Total
пл = melt
H.k = normal boiling

The heat, enthalpy and entropy at the most characteristic points are given in Table 45. The enthalpy change in the perfect-gas state was converted to the employed zero according to the equation

$$i_T^0 = [(H_T^0 - H_0^0) + 635{,}3], \text{ kJ/kg}. \qquad (60)$$

All other data in Table VI were calculated by the same methods used for ethylene.

CHAPTER VII. VISCOSITY OF ETHYLENE AND PROPYLENE

Viscosity of Gaseous Ethylene and Propylene at Atmospheric Pressure

The viscosity of gaseous ethylene and propylene at atmospheric pressure has been thoroughly investigated. Studies pertaining to the experimental determination of the dynamic viscosity coefficient of gaseous ethylene and propylene at atmospheric pressure are given in Table 46 and the numerical values of these coefficients are listed in Table 47 and Table 48. Noteworthy are the calculated data of Trautz [17] for ethylene. On the basis of his measurements he calculated the dynamic viscosity coefficients of ethylene at atmospheric pressure at temperatures T = 1,165°K (η = 2917 × × 10^{-8} N•sec/m^2) and T = 1,270°K (η = 3060•10^{-8} N•sec/m^2). The smoothed dynamic viscosity coefficients of gaseous ethylene at atmospheric pressure are presented in I. F. Golubev's review [13] for the 223°K to 773°K temperature range, and are given below:

T, °K	$\eta\cdot10^{-8}$, *н·сек/м*^{2}	T, °K	$\eta\cdot10^{-8}$, *н·сек/м*^{2}
223,15	792	373,15	1260
248,15	864	423,15	1405
273,15	941	473,15	1545
293,15	1010	523,15	1670
298,15	1027	573,15	1810
323,15	1108	673,15	2049
348,15	1180	773,15	2260

These values were found as a result of processing experimental data of Trautz and coworkers [2, 3, 5 and 6] and data published in [1, 4]. The results of Braune and coworkers [18, 19] on the viscosity of gaseous NH_3, H_2O, HCN, I_2, Cl_2, CH_3Cl, CH_2Cl_2, $CHCl_3$, $HgCl_2$, $HgBr_2$, HgI_2, $SnCl_4$, Br_2 and air at atmospheric pressure were used in the calculations. These investigators demonstrated that the experimental data for the above-listed compounds in the 270-900°K temperature range are described with high accuracy (mean deviations of the order of 0.2% with maximum up to 1.5%) by the Sutherland equation [20].

The smoothed dynamic viscosity coefficients of gaseous propylene at atmospheric pressure for the 193.15-1,273.15°K temperature range (see Table 49) are presented in Lehman's review [21]. The author of the review asserts that they were obtained on the basis of numerous existing experimental data, but does not cite the sources.

Table 46. List of Experimental Studies of Dynamic Viscosity Coefficient of Gaseous Ethylene and Propylene at Atmospheric Pressure

1) Авторы	2) Год	3) Температура, °K	4) Количество эксперимен-тальных точек
7) 5) Этилен			
Обермайер [1]	1875	251—326	3
Брейтенбах [1]	1901	251—575	5
Зиммер [1]	1912	197—286	4
Траутц, Нарат [2]	1926	196—286	5
Траутц, Стауф [3]	1929	193—525	13
Титани [4]	1929	295—393	6
Траутц, Мельстер [5]	1930	292—374	3
Траутц, Геберлинг [6]	1931	291—523	10
Ван Клив, Маасс [7]	1935	192—296	11
Комингс, Майланд, Эгли [8]	1944	303—368	5
Гравен, Ламберт [9]	1951	193—523	5
Зенфтлебен [10]	1953	303	1
Голубев, Петров [11]	1953	313	1
Ламберт [12]	1955	308—364	9
Голубев [13]	1959	297—423	4
Мизик [14]	1961	293—523	5
Недужий, Хмара [15]	1967	193—297	6
8) 6) Пропилен			
Титани [4]	1929	293—393	7
Траутц, Хусейни [16]	1934	289—521	10
Ван Клив, Маасс [7]	1935	193—297	13
Гравен, Ламберт [9]	1951	293—523	4
Зенфтлебен [10]	1953	303	1
Ламберт [12]	1955	308—363	9
Голубев [13]	1959	291—523	7
Недужий, Хмара [15]	1967	210—310	6

KEY: 1. Authors
2. Year
3. Temperature, °K
4. Number of experimental points
5. Ethylene
6. Propylene
7. Obermayer [1]
Breitenbach [1]
Zimmer [1]
Trautz, Narath [2]
Trautz, Stauf [3]
Titani [4]
Trautz, Melster [5]
Trautz, Heberling [6]
Van Cleave, Maass [7]
Comings, Mayland, Egly [8]
Graven, Lambert [9]
Senftleben [10]
Golubev, Petrov [11]
Lambert [12]
Golubev [13]
Misic [14]
Neduzhiy, Khmara [15]
8. Titani [4]
Trautz, Husseini [16]
Van Cleave, Maass [7]
Graven, Lambert [9]
Senftleben [10]
Lambert [12]
Golubev [13]
Neduzhiy, Khmara [15]

It is well known that the viscosity of gases at atmospheric pressure in the moderate temperature range (up to $T < 1,000°K$) can be described with sufficient accuracy by means of equations of kinetic theory. At the present time the Girshfel'der equation [22], derived through the solution of the Boltzmann equation by Enskog's method for model of spherically symmetrical molecules with the Leonard-Jones potential (6-12) is considered most rigorous. When describing the viscosity of gases the parameters of the Leonard-Jones potential (6-12) are determined directly from the experimental data and depend on the temperature range due to scattering of the experimental data. For this reason the Girshfel'der equation, like other equations of kinetic theory, can be used only for interpolation and analysis of existing experimental data.

The force constants of the Leonard-Jones potential (6-12), calculated through the Girshfel'der equation, yielded values $\varepsilon/k = 228°K$ and $\sigma = $ $= 4.1385$ Å for ethylene; $\varepsilon/k = 296.0°K$ and $\sigma = 4.5945$ Å for propylene.

The deviations of the dynamic viscosity coefficients of ethylene and propylene at atmospheric pressure from the values obtained as a result of graphoanalytic processing of data [1-17, 21] are presented in Table 50. As seen, the force constants of the Leonard-Jones potential (6-12) can be considered as not depending on temperature and the values recommended for the calculations are presented in Table 50.

The following values were obtained during calculation of the force constants by the Sutherland equation: $i_2(\gamma)$ $\varepsilon/k = 236.0°K$, $\sigma = 3.895$ Å for ethylene; $i(\gamma)$ $\varepsilon/k = 320.0°K$, $\sigma = 4.387$ Å for propylene.

The results of such calculations by the Sutherland equation [20] are presented in Table 51. It is obvious from the table that the force constants of the Sutherland potential also do not depend on temperature, and the Sutherland equation [20] is just as good in terms of the accuracy of description of experimental data as the Girshfel'der equation [22].

On this basis the Sutherland equation was used, being more convenient for the calculations than the Girshfel'der equation, for compiling Table X of recommended dynamic viscosity coefficients of gaseous ethylene and propylene at atmospheric pressure. Scattering of existing data relative to the smooth values is comparatively low. The following results were obtained from comparison of the recommended dynamic viscosity coefficients with the experimental data. The mean deviations of the experimental data [3, 5-8, 10, 13, 14] on the viscosity of gaseous ethylene at atmospheric pressure do not exceed 0.6%. The mean deviations of data [12, 15] do not exceed 0.8%. The mean deviations of data [1, 2, 4, 7, 9, 11] are about 2-2.5%. The maximum deviations are comparatively low. They do not exceed 2-4.5%, with the exception only of one point obtained by Trautz and Narath [2] at 244.6°K, where the deviation is 7.9%.

Table 47. Experimental Data on Viscosity of Gaseous Ethylene at Atmospheric Pressure

T, ° K	$\eta \cdot 10^{-8}$, н·сек/м²
1) Обермайер	
261,65	851
293,75	989
326,65	1096
2) Брейтенбах	
251,95	891
288,15	1016
372,40	1278
455,55	1530
575,75	1826
3) Зиммер	
197,45	699,3
229,07	768,5
234,55	784,5
286,87	954,2
4) Траутц, Нарат	
196,16	697
229,15	766
244,65	782
273,15	903
287,15	950
5) Траутц, Стауф	
193,85	716
235,45	816
271,35	940
287,15	990
289,25	996
291,35	1008
292,25	1007
294,95	1018
324,15	1109
373,75	1266
422,35	1405
470,55	1539
525,45	1687
6) Титани	
295,15	970
313,15	1036
333,15	1108
353,15	1154
373,15	1220
393,15	1279
7) Траутц, Мельстер	
292,75	1008
324,15	1109
374,15	1262
8) Траутц, Геберлинг	
291,75	1003
299,45	1027
323,75	1105
373,05	1256
373,15	1258
423,35	1404
472,35	1539
472,95	1540
523,65	1668
523,85	1667
9) Ван Клив, Маасс	
192,29	652,1
204,63	697,2
212,77	704,2
220,65	752,3
235,15	802,5
250,56	856,0
264,13	900,8
273,08	932,2
284,38	969,6
290,33	990,7
296,50	1010,6
10) Комингс, Мейланд, Эгли	
303,15	1054
323,15	1093
343,15	1172
368,15	1255
11) Гравен, Ламберт	
193,15	714
273,15	945
323,15	1106
423,15	1407
523,15	1680
12) Ламберт	
308,15	1059
323,15	1110
334,75	1157
338,15	1163
339,15	1168
343,65	1187
350,95	1209
353,35	1217
361,35	1251
13) Голубев	
297,15	1023
323,15	1108
373,15	1260
423,15	1405
14) Мизик	
293,15	1008
323,15	1103
373,15	1257
473,15	1541
523,15	1666
15) Недужий, Хмара	
193,15	695
213,15	751
233,15	808
253,15	868
273,15	949
297,15	1023

[Key on next page]

KEY:
1. Obermayer
2. Breitenbach
3. Zimmer
4. Trautz, Narath
5. Trautz, Stauf
6. Titani
7. Trautz, Melster
8. Trautz, Heberling
9. Van Cleave, Maass
10. Comings, Mayland, Egly
11. Graven, Lambert
12. Lambert
13. Golubev
14. Misic
15. Neduzhiy, Khmara

Table 48. Experimental Data on Viscosity of Gaseous Propylene at Atmospheric Pressure

T,° K	$\eta\cdot10^{-8}$, н·сек/м²
1) Титани	
293,15	833
294,65	856
313,15	843
313,15	959
353,15	1023
373,15	1071
393,15	1122
2) Траутц, Хусейни	
289,9	834
293,1	844
296,2	854
323,1	935
329,5	951
373,3	1076
423,1	1211
425,9	1219
472,6	1338
521,7	1464
3) Ван Клив, Маасс	
193,43	561,5
197,45	572,4
202,26	582,6
212,45	611,9
217,52	623,6
234,40	670,4
247,34	709,3
261,36	750,0
273,0	783,9
273,15	784,1
282,51	813,3
291,84	840,6
297,31	858,3
4) Гравен, Ламберт	
293,15	843
323,15	933
423,15	1210
523,15	1467
5) Зенфтлебен	
303,15	898
6) Ламберт	
308,15	922
323,15	954
333,05	991
338,15	986
339,15	1000
344,15	1024
350,95	1023
354,35	1056
363,95	1080
7) Голубев	
291,15	839
326,15	942
358,15	1032
373,15	1075
423,15	1212
473,15	1340
523,15	1468
8) Недужий, Хмара	
210	586
230	640
250	736
270	800
290	828
310	904

KEY:
1. Titani
2. Trautz, Husseini
3. Van Cleave, Maass
4. Graven, Lambert
5. Senftleben
6. Lambert
7. Golubev
8. Neduzhiy, Khmara

Deviations of the experimental data on the viscosity of gaseous propylene at atmospheric pressure from the recommended values are of the same order of magnitude. The experimental data [4, 16, 9, 13, 15] have a mean deviation of 0.4%. The maximum deviations do not exceed 3.6%.

Table 49. Smooth Data on Viscosity of Gaseous Propylene at Atmospheric Pressure, Presented in Lehman's Review [21]

T, ° K	$\eta \cdot 10^{-8}$, н·сек/м²	T, ° K	$\eta \cdot 10^{-8}$, н·сек/м²	T, ° K	$\eta \cdot 10^{-3}$, н·сек/м²
193,15	560	423,15	1220	973,15	2123
223,15	639	473,15	1342	1073,15	2615
253,15	726	523,15	1468	1173,15	2785
273,15	784	573,15	1590	1273,15	2947
293,15	845	673,15	1816	—	—
323,15	933	773,15	1970	—	—
373,15	978	873,15	2235	—	—

Table 50. Calculation of Numerical Constants According to Girshfel'der's Equation

T, ° K	1) $\eta_{граф} \cdot 10^{-8}$, н·сек/м²	δ, %	T, ° K	1) $\eta_{граф} \cdot 10^{-8}$, н·сек/м²	δ, %
2) Этилен $\left(\frac{\varepsilon}{k} = 228{,}0°K;\ \sigma = 4{,}1385\ Å\right)$			3) Пропилен $\left(\frac{\varepsilon}{k} = 296{,}0°K;\ \sigma = 4{,}5945\ Å\right)$		
220	770	—1,61	220	624	—1,21
260	903	—0,2	260	1748	+0,08
300	1033	—0,62	300	863	+0,02
400	1336	—0,29	400	1148	+0,47
500	1622	—0,03	500	1413	+0,52
600	1879	—0,12	600	1652	+0,28
800	2312	—1,36	800	2085	+0,13
—	—	—	1000	2465	—0,35

KEY: 1. $\eta_{graph} \cdot 10^{-8}$, N•sec/m²
2. Ethylene
3. Propylene

Table 51. Calculation of Force Constants by Sutherland Equation

T, ° K	1) $\eta_{граф} \cdot 10^{-8}$, н·сек/м²	δ, %	T, ° K	1) $\eta_{граф} \cdot 10^{-8}$, н·сек/м²	δ, %
2) Этилен ($i_2(\gamma)$ $\varepsilon/k = 236{,}0°$ K, $\sigma = 3{,}895$ Å)			3) Пропилен ($i_2(\gamma)$ $\varepsilon/k = 320{,}0°$ K, $\sigma = 4{,}387$ Å)		
220	270	+0,61	220	624	—0,01
260	903	—0,10	260	747	+0,08
300	1033	—0,38	300	863	—0,31
400	1336	—0,71	400	1148	+0,03
500	1622	—0,18	500	1413	+0,034
600	1879	—0,07	600	1652	+0,14
800	2312	—1,03	800	2085	—0,07
—	—	—	1000	2465	0,38

KEY: 1. $\eta_{graph} \cdot 10^{-8}$, N•sec/m²
2. Ethylene
3. Propylene

The smooth data on the viscosity of gaseous ethylene at atmospheric pressure, presented in I. F. Golubev's review [13], have a mean deviation of 0.3% from the recommended values; the maximum deviation is +2.25%. The smooth data on the viscosity of gaseous propylene at atmospheric pressure according to Lehman [21] deviate by 0.35% on the average if one clearly falling point is excluded from the examination (T = 373.15°K, $\eta = 978 \times \times 10^{-8}$ N•sec/m^2; η = -9.0%); the maximum deviation is 3.6%.

The error of the recommended data (Table X) is 2%.

Viscosity of Gaseous Ethylene and Propylene at High Pressures

The viscosity of ethylene was measured by Comings, Mayland and Egly [8] in the 303.15 to 368.15°K temperature range at pressures up to 173.3 bar. A capillary viscometer of the Renkin design was used for the measurements. Fifty experimental points were obtained (see Table 52); the measurement error did not exceed ±1.3%.

I. F. Golubev and V. A. Petrov [11] and I. F. Golubev [13] investigated the viscosity of ethylene with capillary viscometers of original design. These viscometers, in addition to ease of handling, provide high measurement accuracy. The error is of the order of ±(1-2)%. The authors [11] analyzed experimentally the viscosity of ethylene at 313.15°K at pressures up to 137.1 atm (10 experimental points). Investigations [13] were conducted at 297.15-423.15°K at pressures up to 810.6 bar (76 experimental points). Data [11] for t = 40°C are presented below:

p, атм	$\eta \cdot 10^{-8}$, *н·сек/м²*	*p, атм*	$\eta \cdot 10^{-8}$, *н·сек/м²*
1	1093	67,4	1620
4,4	1101	79,3	2030
28,2	1192	89,5	2500
48,6	1330	103,1	2980
55,5	1410	137,1	3790

Data [13] are listed in Table 53. The viscosity of gaseous ethylene at 297.15°K at pressures up to 1,000 bar was investigated by M. G. Gonikberg and L. F. Vereshchagin [23] (10 experimental points). Measurement was done with an oscillating disc viscometer; the dynamic viscosity coefficient was calculated with the Macwood equations [24]. According to the authors' calculations the measurement error did not exceed ±2%. Their data on the dynamic viscosity coefficient of ethylene are presented below:

p, атм	$\eta \cdot 10^{-8}$, *н·сек/м²*	*p, атм*	$\eta \cdot 10^{-8}$, *н·сек/м²*
100	3800	600	9400
200	5500	700	10 160
300	6810	800	10 940
400	7820	900	11 710
500	8620	1000	12 430

The viscosity of gaseous ethylene at 193.15-297.15°K at pressures up to 39.2 bar was investigated experimentally by I. A. Neduzhiy and Yu. I. Khmara [15] (Table 54). The investigations were done with a capillary viscometer with annular weights of the Timrot design. The measurement error was ±3%.

The experimental data found in the present literature can be used as the basis for comparing tables of the dynamic viscosity coefficients of gaseous ethylene to densities ρ = 490 kg/m^3.

The viscosity of compressed gaseous propylene was investigated experimentally by I. F. Golubev [13] at 291.15-523.15°K and 1-800 atm (96 experimental points). I. A. Neduzhiy and Yu. I. Khmara [15] experimentally found the viscosity of gaseous propylene at 210-310°K at pressures up to 8 atm. The experimental data [13, 15] are presented in Tables 55 and 56. These data can be used as the basis for comparing the dynamic viscosity coefficients of propylene to density ρ = 620 kg/m^3. The results of Enskog's theory [25] were used for explaining the question of reliability of the experimental data.

As pointed out in [26], there are certain dependences of the effective diameters of collisions of molecules on temperature and pressure.

Table 52. Experimental Data of Comings, Mayland and Egly [8] on Viscosity of Ethylene

p, ат	$\eta \cdot 10^{-8}$, *н·сек/м²* при *t*, °C				
	30	40	50	70	95
1,00	1054	1074	1093	1172	1255
5,08	1060	1080	1099	1180	1258
28,2	1131	1150	1192	1243	1295
48,6	1299	1306	1305	1336	1389
55,6	1406	1369	1362	1381	1426
67,3	1775	1592	1505	1474	1498
79,1	2545	2003	1721	1606	1589
89,3	3047	2483	1975	1736	1681
103,1	3592	2997	2396	1919	1818
137,0	4347	—	3203	2558	2265
171,0	—	—	—	—	2773

Table 53. Experimental Data of I. F. Golubev [13] on Viscosity of Ethylene

p, атм	$\eta \cdot 10^{-8}$, *н·сек/м²* при *t*, °C								
	24	50	100	150	*p, атм*	24	50	100	150
1	1023	1108	1260	1405	150	4885	3670	2380	2150
25	1096	1175	1290	1470	200	5524	4380	3027	2600
50	1410	1310	1395	1560	300	6520	5380	4095	3415
60	1813	1400	—	1600	400	7323	6180	4863	4150
70	2820	1560	1500	1640	500	8090	6890	5440	4770
80	3357	1760	1575	1685	600	8820	7560	6147	5330
90	3667	2004	—	1730	700	9440	8140	6713	5860
100	3906	2420	1734	1780	800	9956	8670	7255	6360
125	4420	3010	2040	1950	—	—	—	—	—

Table 54. Experimental Data of I. A. Neduzhiy and Yu. I. Khmara [15] on Viscosity of Ethylene

p, бар	$\eta \cdot 10^{-8}$, н·сек/м² при T, °K					
	193,15	213,15	233,15	253,15	273,15	297,15
0,98	695	751	808	868	949	1023
4,90	—	799	835	898	968	1026
9,81	—	—	869	922	1009	1034
13,73	—	—	889	939	1021	1049
19,61	—	—	—	970	1045	1069
24,52	—	—	—	1018	1074	1096
29,42	—	—	—	—	1099	1128
34,32	—	—	—	—	1175	1172
39,23	—	—	—	—	1273	1231

Table 55. Experimental Data of I. F. Golubev [13] on Viscosity of Propylene

p, атм	$\eta \cdot 10^{-8}$, н·сек/м² при t, °C						
	18	53	85	100	150	200	250
1	839	942	1032	1075	1212	1340	1468
25	10 680	—	—	1192	1312	1423	1530
50	11 160	7780	5140	2805	1550	1547	1660
75	11 620	8280	5880	4970	2400	1853	1820
100	12 050	8700	6400	5500	3405	2294	2060
125	12 480	9080	6570	6030	4100	2782	2350
150	12 880	9440	7280	6470	4600	3280	2695
200	13 660	10 130	8030	7240	5440	4085	3380
300	15 100	11 460	9350	8520	6740	5330	4465
400	16 400	12 700	10 460	9650	7850	6350	5420
500	17 700	13 900	11 500	10 680	8770	7270	6300
600	18 940	15 000	12 300	11 620	9670	8055	7050
700	20 120	16 100	13 460	12 500	10 480	8805	7740
800	21 300	17 100	14 400	13 370	11 250	9500	8450

The calculations were done for ethylene and propylene using the experimental data on viscosity [13] and data on density and thermal pressure, found from the thermal equations of state [27, 28], derived by V. A. Zagoruchenko. It is obvious from Figure 15 that the character of dependence of the effective diameters of collisions σ on temperature is identical for all pressures, and the ratio σ/σ_0 (σ_0 is the effective collision diameter at atmospheric pressure) is constant at pressures above 100 bar. At pressures below 100 bar the ratio diminishes monotonically from unity at atmospheric pressure to 0.92 for ethylene and 0.93 for propylene. The observed scattering of σ/σ_0 is attributed to errors in the experimental data on viscosity and to errors in the determination of the thermal pressure. Since the scattering of points is asymmetric and falls within the limits of possible errors, it can be concluded that the experimental data of I. F. Golubev are reliable and that these data can be used as references for compiling tables of the recommended dynamic viscosity coefficients of compressed gaseous ethylene and propylene. The experimental data of

I. F. Golubev and V. A. Petrov [11] agree with I. F. Golubev's data within the limits of deviations up to 3.5%. The data of M. G. Gonikberg and L. F. Vereshchagin [23] deviate from I. F. Golubev's data [13] by up to 10%. The experimental data of Comings, Mayland and Egly [8] for ethylene are 5-7% understated in comparison with I. F. Golubev's data at 300.15°K, and 5% overstated at 103.1 atm and 368.15°K. The experimental data of I. A. Neduzhiy and Yu. I. Khmara [15] on the 297.1°K isotherm coincide with I. F. Golubev's data [13] to 0.5%. These data confirm the uniqueness of the excess viscosity as a function of density for ethylene at temperatures below critical. The results of the measurements of I. A. Neduzhiy and Yu. I. Khmara [15] for gaseous propylene agree satisfactorily (deviations up to 2% in conversion to the dynamic viscosity coefficient) with I. F. Golubev's data [13] in these coordinates.

Table 56. Experimental Data of Neduzhiy and Khmara [15] on Viscosity of Propylene

р, бар	$\eta \cdot 10^{-8}$, н·сек/м² при T, °K					
	210	230	250	270	290	310
0,98	586	640	736	800	828	904
1,96	—	—	—	808	835	909
3,92	—	—	—	824	846	920
5,88	—	—	—	—	860	931
7,84	—	—	—	—	875	944

Experimental data [13, 15] were used for plotting the analytic dependence of "excess viscosity" of ethylene and propylene on density. The approximating polynomials were found by computer using the method of least squares:

$$\Delta\eta = 2{,}20841 \cdot 10^3\rho + 7.26137 \cdot 10^3\rho^2 + 7{,}63700 \cdot 10^4\rho^3 - 2{,}72752 \cdot 10^5\rho^4 + 4{,}68144 \cdot 10^5\rho^5 - 1{,}25904 \cdot 10^5\rho^6; \quad (61)$$

$$\Delta\eta = 5{,}36654 \cdot 10^3\rho - 4{,}49091 \cdot 10^4\rho^2 + 4{,}41389 \cdot 10^5\rho^3 - 1{,}16544 \cdot 10^6\rho^4 + 1{,}10455 \cdot 10^6\rho^5, \quad (62)$$

where $\Delta\eta = 10^{-8}$ N•sec/m^2; $\rho = 10^3$ kg/m^3.

Polynomial (61) describes experimental data for ethylene in the density range ρ = 0-490 kg/m^3 with an average error of 0.6%. For the calculation 129 points were used.

Polynomial (62) describes the experimental data for propylene in the density range ρ = 0-620 kg/m^3 with an average error of 1.6%. The approximation was done on the basis of 88 points.

Polynomials (61) and (62) were used for compilation of Tables XI and XII of recommended viscosity. The error of the data is 2-3%.

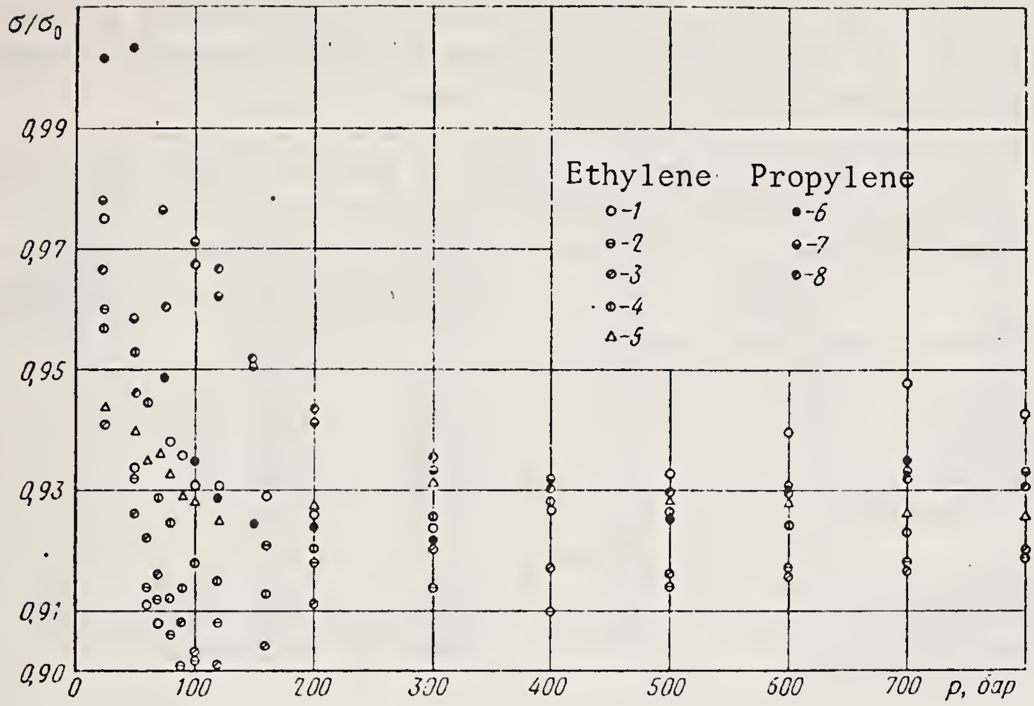

Figure 15. Ratio σ/σ_0 for ethylene and propylene according to I. F. Golubev [13]: 1 -- 293.15; 2 -- 333.15; 3 -- 373.15; 4 -- 410.15; 5 -- 433.15°K (ethylene); 6 -- 370; 7 -- 420; 8 -- 440°K (propylene).

Viscosity of Ethylene and Propylene on Saturation Curve

Experimental works on the viscosity of liquid ethylene and propylene near the saturation curve are listed in Table 57. Studies [29, 31, 34] were done by the capillary method. Studies [30, 32, 33] were done by the oscillating cylinder method. The experimental values of the dynamic viscosity coefficients are summarized in Tables 58 and 59. Data in various source on the viscosity of liquid ethylene and propylene near the saturation line are either repetition of data [29-33], or are the result of smoothing of these data.

It follows from Tables 58 and 59 that ethylene is experimentally investigated in the 105.0-289.9°K temperature range (the melting point of ethylene T_{melt} = 104.0, and the critical point T_{cr} = 283.05°K); propylene is investigated in the T = 88.7-361.95°K temperature range (the melting point of propylene T_{melt} = 87.9 and the critical point T_{cr} = 365.05°K).

Since the existing experimental data are contradictory and are characterized by substantial scattering, the possibility of constructing tables of the dynamic viscosity coefficients without additional information is doubtful at the very least. This situation is not exceptional. As pointed out in [26], the dynamic viscosity coefficients can be determined with sufficient reliability for several n-paraffins if, in addition to viscosity data, data on density of the liquid and saturation vapor tension are used. The correlations obtained in [26] ensure an accuracy of the order of 2-4% in the calculation of the dynamic viscosity coefficients of n-paraffins in the liquid saturation state.

Table 57. List of Experimental Works on the Viscosity Coefficient of Liquid Ethylene and Propylene near Saturation Curve

1) Авторы	2) Год	3) Температура, °К	4) Количество экспериментальных точек
5) Этилен			
7) Руденко [29]	1934	110,6—168,3	9
Руденко [30]	1939	169,3—280,3	6
Герф, Галков [31]	1940	105,0—168,2	9
Галков, Герф [32]	1941	183,8—273,1	5
6) Пропилен			
8) Герф, Галков [31]	1940	88,7—169,6	12
Галков, Герф [33]	1941	119,0—174,8	5
Недужий, Хмара [34]	1967	193,9—362,9	34

KEY:
1. Authors
2. Year
3. Temperature, °K
4. Number of experimental points
5. Ethylene
6. Propylene
7. Rudenko [29]
   Rudenko [30]
   Gerf, Galkov [31]
   Galkov, Gerf [32]
8. Gerf, Galkov [31]
   Galkov, Gerf [33]
   Neduzhiy, Khmara [34]

Table 58. Experimental Data on Viscosity of Liquid Ethylene

T,°K	$\eta \cdot 10^{-6}$, н·сек/м^2	T°, K	$\eta \cdot 10^{-6}$, н·сек/м^2
Руденко		Герф, Галков	
110,5	522	105,0	660
126,0	402	108,0	600
127,2	388	110,4	553
128,1	369	129,8	334
134,1	333	138,4	282
141,2	261	148,8	231
155,0	215	156,8	197
160,0	207	168,2	164
168,3	181	183,8	135
169,3	167	204,6	115
206,1	96	226,4	92,0
233,9	77,5	252,2	72,0
240,9	75	273,1	64,0
273,1	65	—	—
280,9	62,5	—	—

Table 59. Experimental Data on Viscosity of Liquid Propylene

T,° K	η · 10—6, н·сек/м²	T,° K	η · 10—6, н·сек/м²	T,° K	η · 10—6, н·сек/м²
1) Герф, Галков		2) Недужий, Хмара			
88,7	14 660	193,92	278,6	291,57	99,9
89,8	12 730	198,09	264,2	291,94	99,8
90,1	12 400	202,53	238,2	292,19	92,2
94,3	7840	208,92	219,9	294,86	93,7
98,0	5370	213,03	214,0	297,45	91,7
102,6	3580	217,62	208,8	299,33	89,0
111,1	2150	221,50	197,3	301,93	88,4
141,6	700	229,37	179,4	304,3	82,9
141,9	670	233,12	173,4	307,36	82,4
150,0	550	237,68	162,4	311,48	78,7
159,8	450	242,07	155,9	315,43	76,2
169,6	340	246,35	148,0	315,61	74,6
119,0	1550	251,75	143,3	329,07	63,7
123,0	1310	259,14	132,5	340,68	52,4
134,2	900	265,54	123,6	354,23	43,6
173,0	380	281,48	105,1	355,21	42,8
174,8	370	291,57	93,98	362,86	32,7

KEY: 1. Gerf, Galkov 2. Neduzhiy, Khmara

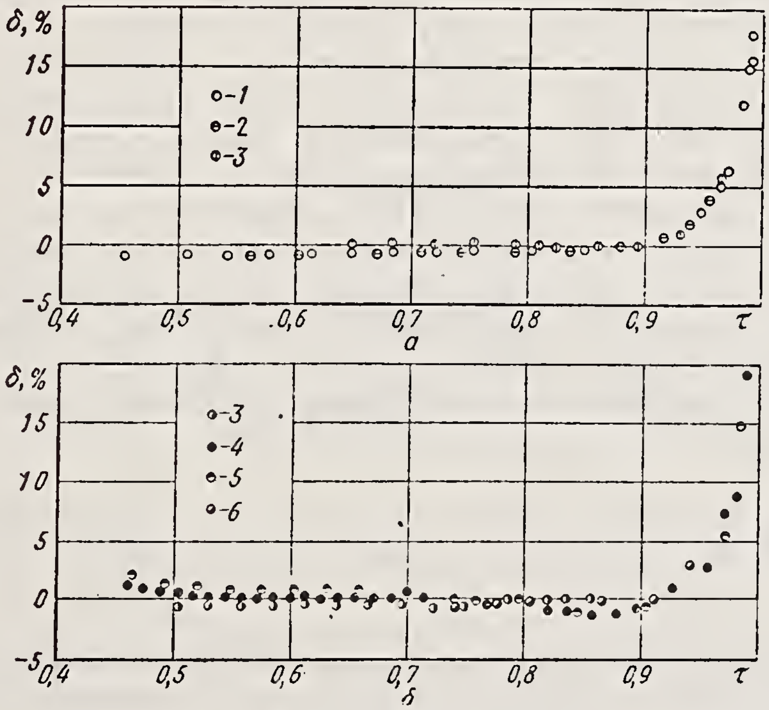

Figure 16. Deviations of experimental data of specific volume of ethylene (a) and propylene (b) from theoretical according to: 1 -- Mathias, Crommelin, Wotts [35]; 2 -- V. A. Zagoruchenko [27, 28]; 3 -- Voytyuk (see Chapters II and III); 4 -- Rossini [37]; 5 -- Lehman [21]; 6 -- Morecroft [38].

As applies to ethylene and propylene, it is essential first of all to check how accurately the experimental data on density agree with the theoretical according to equations [26].

The deviations of the experimental values of specific volume on the saturation curve from the theoretical are shown in Figure 16. As seen, the data of Mathias, Crommelin and Wotts [35] are up to 0.9-0.4% understated in the range of reduced temperatures from τ = 0.45 to τ = 0.80, agree with the theoretical from τ = 0.80 to τ = 0.90 and then increasingly exceed the theoretical. The saturation parameters of ethylene were calculated by V. A. Zagoruchenko [27] and are presented in [36]. As seen in Figure 16, these data have the same deviations from the theoretical as data [35]. B. V. Voytyuk's experimental data (see Figure 16), obtained by extrapolating experimental data on the density of the liquid to the saturation curve, have a 0.2% deviation from the theoretical in the τ = = 0.65 to τ = 0.90 temperature range. At higher temperatures the experimental specific volumes systematically exceed the theoretical.

And so, according to experimental data on the density of liquid ethylene on the saturation curve, calculation using equations [26] is justified within 1-1.5% for reduced temperatures τ < 0.95, i.e., just as in the case of n-paraffins.

The experimental data of Farrington and Sage [40] and the calculated data of Canjar, Goldman and Marchman [41] are generalized in Lehman's review [21]. The specific volumes of liquid propylene presented in this review are 0.05-0.6% overstated in the range of reduced temperatures from τ = 0.45 to τ = 0.71, and the deviations are not systematic; in the reduced temperature range of τ = 0.71 to τ = 0.90 they change sign and amount to 0.25-1.1%. At higher temperatures the data have a certain amount of scattering, but the deviations from the theoretical values are characteristic of n-paraffin. Morecroft's data [38] on the density of propylene are up to 0.35% overstated in the temperature range from τ = = 0.75 to τ = 0.88; at τ = 0.95 the data are 1.3% lower than the theoretical. B. V. Voytyuk's experimental data are an average of 0.5% higher than the theoretical in the range from τ = 0.50 to τ = 0.75, and in the temperature range from τ = 0.75 to τ = 0.85 the deviations amount to +0.2%.

For ethylene β = 0.5414, which is close to β = 0.5129 for ethane; for propylene β = 0.5953, which is close to β = 0.6145 for propane.

These results enable us to proceed to analysis of the existing experimental data on the viscosity of liquid ethylene and propylene on the saturation curve and, in the final analysis, to calculate the dynamic viscosity coefficients. According to [26] the viscosity of liquid n-paraffins on the saturation curve is described by the expressions:

[kp=cr]

$$\frac{\eta}{\dot{\eta}_{\text{кр}}}\left(\frac{v}{v_{\text{кр}}}-\alpha\right)=\beta; \qquad \frac{\lg \pi_s}{\lg \eta/\dot{\eta}_{\text{кр}}}=f(\tau); \tag{63}$$

$$f(\tau)=-9{,}7404+40{,}795\tau-114{,}647\tau^2+194{,}005\tau^3-167{,}925\tau^4+ +57{,}471\tau^5, \tag{64}$$

where α = 0.3026 does not change with temperature; β is a constant in the reduced temperature range from (0.35-0.45) to 0.95; η* is calculated according to the Licht-Stechert equation [39], the applicability of which is demonstrated in [26].

As seen in Figure 17, N. S. Rudenko's data [29, 30] on the viscosity of ethylene are up to 27% overstated in the low temperature range, satisfy the Bachinskiy equation with up to 6% scattering in the 155.0 to 240.9°K temperature range, and are substantially overstated at higher temperatures. The experimental data of S. F. Gerf and G. I. Galkov [31, 32] on the viscosity of ethylene have the same character, with the exception that substantial overstatement of the data compared with the theoretical occurs at a lower temperature (226.4°K). Nevertheless the character of the curve of the constant β as a function of the reduced temperature is noteworthy. Its values are close to 0.541, found from data on density (this value is shown in Figure 17 as a segment of a straight line, denoting the range of temperatures where the Bachinskiy equation is used). The same conclusions concerning the character of experimental data [29-35, 40, 41] can be made on the basis of examination of the results of calculation presented in Figure 18.

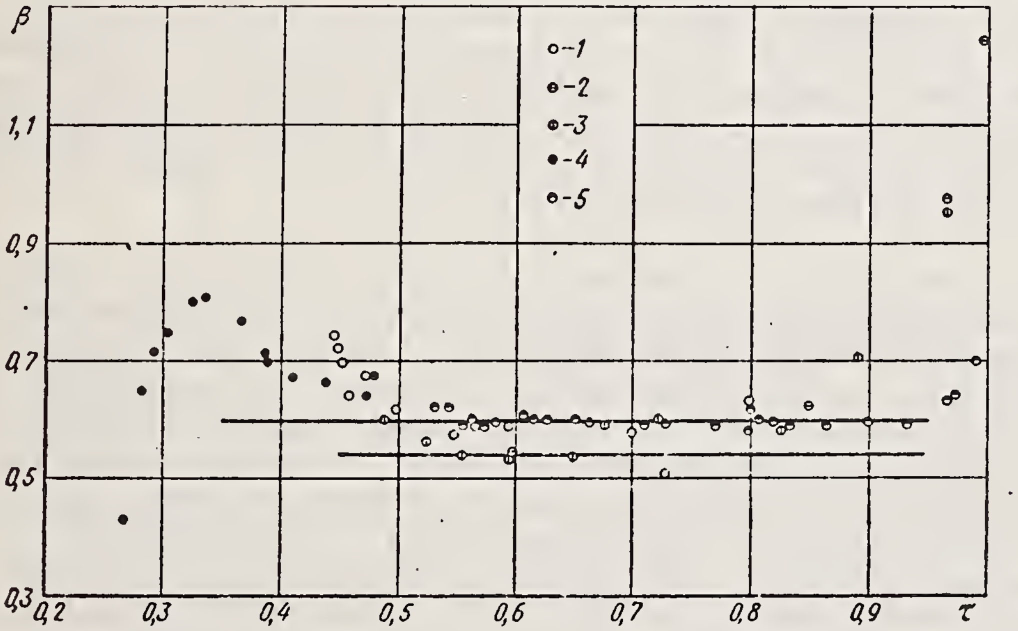

Figure 17. Values of β in expression (63) according to: 1 -- N. S. Rudenko [29]; 2 -- N. S. Rudenko [30]; 3 -- S. F. Gerf and G. I. Galkov [31, 32] (ethylene); 4 -- S. F. Gerf and G. I. Galkov [31, 33]; 5 -- I. A. Neduzhiy and Yu. I. Khmara [34] (propylene).

Experimental data [31, 33] on the viscosity of liquid propylene near the saturation curve are up to 32% overstated at 111.1°K; at lower temperatures a systematic increase of β is observed, characteristic of the region near the solidification point. In the 193.9-363.0°K temperature range the experimental data are given by I. A. Neduzhiy and Yu. I. Khmara [34].

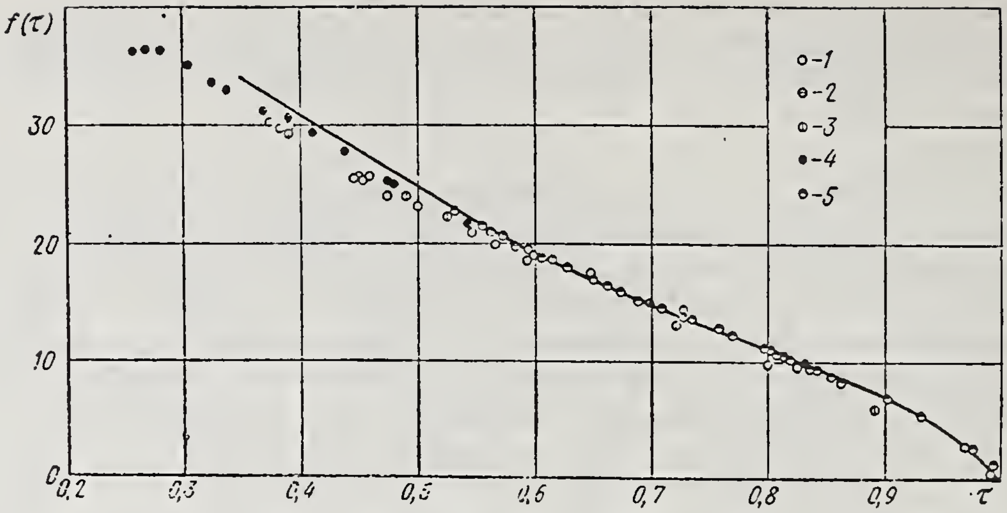

Figure 18. Values of functions f(τ) in expression (64) according to: 1 -- N. S. Rudenko [29]; 2 -- N. S. Rudenko [30]; 3 -- S. F. Gerf and G. I. Galkov [31, 32] (ethylene); 4 -- S. F. Gerf and G. I. Galkov [31, 33]; 5 -- I. A. Neduzhiy and Yu. I. Khmara [34].

As seen in Figures 17 and 18, the data satisfy both equations (63) and the generalized relation (64) with a mean error of 2%. It follows from these data that in order to calculate the viscosity of liquid propylene on the saturation curve it is necessary to take β equal to 0.5953, found from data on density. The data of S. F. Gerf and G. I. Galkov [31, 34] at 141.9-174.8°K also support this conclusion.

Thus, by comparing the experimental data on viscosity of liquid ethylene and propylene near the saturation curve we can conclude that the calculation procedure developed on the basis of analysis of the experimental data for n-paraffins, is also applicable to ethylene and propylene. This conclusion is also verified by the good agreement between the experimental data on the viscosity of ethylene and propylene at high pressures and the theoretical values for the saturation curve, if they are represented in the form of excess viscosity as a function of density. Tables of the recommended dynamic viscosity coefficients of ethylene and propylene in the saturated liquid states have an accuracy of the order of 3-5% and were compiled on the basis of equations (63) and (64). The following critical parameters were assumed [26]: ethylene -- p_{cr} = 50.97 bar, v = 0.00474 m^3/kg, T_{cr} = 283.05°K; propylene -- p_{cr} = 46.41 bar, v = 0.00433 m^3/kg, T_{cr} = = 365.05°K.

In view of the lack of experimental data on the viscosity of gaseous ethylene and propylene on the saturation curve we checked only the agreement with data [15] on the viscosity of compressed gaseous ethylene and propylene at temperatures below critical when we compiled the tables of recommended values. The recommended values were computed according to polynomials (61) and (62). The accuracy of the data is ~3%.

Viscosity of Liquid Ethylene and Propylene at High Pressures

The viscosity of liquid ethylene at high pressures was not investigated. Therefore to compile tables of recommended values we used the fact that in view of the uniqueness of excess viscosity as a function of density it is possible to extrapolate into the high-pressure region on the basis of isochors; here we used the recommended dynamic viscosity coefficients of liquid ethylene on the saturation curve (Table IX) as the reference data. Extrapolation by isochors was done on the basis of thermal equation of state (36) for liquid ethylene, which was reported by V. A. Zagoruchenko and Tsymarnyy at the Third All-Union Conference on Thermophysical Properties of Matter at High Temperatures (Baku, 1968). The results of calculations are presented in Table XI. The accuracy of the data is ~5%.

The viscosity of liquid propylene at high pressures was investigated by I. F. Golubev [13]. The measurement results are given in Table 55. We used these data to construct interpolation polynomial (62), on the basis of which we compiled Table XII of recommended viscosities.

CHAPTER VIII. THERMAL CONDUCTIVITY OF ETHYLENE AND PROPYLENE

Thermal Conductivity of Ethylene and Propylene at Atmospheric Pressure

Experimental works pertaining to investigations of the thermal conductivity of gaseous ethylene and propylene at atmospheric pressure are listed in Table 60. The results of investigations are listed in Table 61.

Eucken [1, 2] measured the thermal conductivity of ethylene by the relative wire heating method in an apparatus consisting of two measurement tubes of different length for compensating the heat losses from the ends. For air, used as the reference gas, $\lambda_0 = 237 \cdot 10^{-4}$ W/(m•deg) at 273.1°K at 1 atm. Eucken's data are the only data available for temperatures below 273°K.

Lambert, et al [7], for determining the thermal conductivity coefficient of several hydrocarbon gases (including ethylene and propylene at 339.15°K) also used the relative (in terms of air) hot wire method, employing, like Eucken, a measurement cell with two wires of different length. The thermal conductivity of air was assumed equal to $289 \cdot 10^{-4}$ W/(m•deg) at 339.15°K. The thermal conductivity coefficient was calculated by two methods on the basis of measurement data, showing agreement within ±0.5%. The deviations of the data from existing data on λ_0 for certain hydrocarbon gases, according to the authors, do not exceed ±(2-3)%.

The thermal conductivity of ethylene and propylene at 70°C was determined by Senftleben and Gladisch [3] on the basis of a relation containing the Nu, Gr and Pr criteria for determining the amount of heat transmitted through a layer of gas between two horizontal coaxial cylinders with different diameters. By altering the procedure somewhat Senftleben [5, 10] determined the thermal conductivity of ethylene and propylene at 20-200°C at nearly atmospheric pressure. Equations of the thermal conductivity coefficients as functions of temperature were derived on the basis of experimental data for ethylene:

$$\lambda_0 = 175 \cdot 10^{-4} + 122{,}7 \cdot 10^{-6}\, t + 147{,}8 \cdot 10^{-9}\, t^2; \tag{65}$$

for propylene:

$$\lambda_0 = 145{,}7 \cdot 10^{-4} + 105{,}9 \cdot 10^{-6}\, t + 180 \cdot 10^{-9}\, t^2, \qquad (66)$$

where t is measured in °C and λ_0 in W/(m•deg).

Table 60. List of Experimental Investigations of Thermal Conductivity Coefficient of Gaseous Ethylene and Propylene at Atmospheric Pressure

1) Авторы	2) Год	3) Температура, °К	4) Количество точек
5) Этилен			
7)			
Эйкен [1]	1913	202—273	3
Эйкен [2]	1940	273	1
Зенфтлебен и Гладиш [3]	1949	343	1
Ленуар и Комингс [4]	1951	314; 340	2
Зенфтлебен [5]	1953	303	1
Кейс [6]	1954	345; 426	2
Ламберт и др. [7]	1955	339	1
Чайкин и Маркевич [8]	1958	293—523	6
Чеунг и др. [9]	1962	591	1
Зенфтлебен [10]	1964	273—673	8
Недужий, Кравец, Коломиец [11]	1967	250—400	16
6) Пропилен			
8)			
Зенфтлебен и Гладиш [3]	1949	343	1
Зенфтлебен [5]	1953	303	1
Ламберт и др. [7]	1955	339	1
Зенфтлебен [10]	1964	273—673	9
Недужий, Кравец, Коломиец [11]	1967	273—400	14

KEY: 1. Authors
2. Year
3. Temperature, °K
4. Number of points
5. Ethylene
6. Propylene
7. Eucken [1]
Eucken [2]
Senftleben, Gladisch [3]
Lenoir, Comings [4]
Senftleben [5]
Keyes [6]
Lambert, et al [7]
Chaykin, Markevich [8]
Cheung [9]
Senftleben [10]
Neduzhiy, Kravets, Kolomiyets [11]
8. Senftleben, Gladisch [3]
Senftleben [5]
Lambert, et al [7]
Senftleben [10]
Neduzhiy, Kravets, Kolomiyets [11]

The values of λ_0 given by equations (65) and (66) were extrapolated to 0, 300 and 400°C. The error of the published data up to 200°C, according to the author, is less than ±1%, and at higher temperatures it may reach 3-4%.

A. M. Chaykin and A. M. Markevich [8] published six values of the thermal conductivity coefficient of ethylene at temperatures of 293.15 to 523.15°K. The accuracy of these data, obtained with the aid of a simplified glass model of the coaxial cylinders method without strict consideration of all required corrections, was estimated by the authors themselves as ±5%.

Table 61. Experimental Data of Various Authors on Thermal Conductivity Coefficient of Ethylene and Propylene at Atmospheric Pressure

Этилен

T, °K	1) $\lambda_0 \cdot 10^4$, вт/(м·град)
2) Эйкен [1]	
202,0	108
235,8	136
273,1	171
2) Эйкен [2]	
273,1	173
3) Ленуар и Комингс [4]	
314,3	221
340,4	256
4) Кейс [6]	
345,4	267
425,7	391
5) Ламберт и др. [7]	
339,15	257
6) Чеунг и др. [9]	
591,15	641
7) Зенфтлебен и Гладиш [3]	
343,15	265
8) Зенфтлебен [5]	
303,15	209
8) Зенфтлебен [10]	
273,15	175
298,15	206
323,15	240
423,15	392
473,15	479
573,15	674
673,15	904

T, °K	1) $\lambda_0 \cdot 10^4$, вт/(м·град)
9) Чайкин, Маркевич [8]	
293,15	197
323,15	247
373,15	310
423,15	368
503,15	477
523,15	515
10) Недужий и др. [11]	
250	148
260	159
270	170
280	181
290	193
300	204
310	217
320	229
330	242
340	255
350	269
360	282
370	296
380	310
390	325
400	340
—	—
—	—
—	—
—	—
—	—

Пропилен

T, °K	1) $\lambda_0 \cdot 10^4$, вт/(м·град)
5) Ламберт и др. [7]	
339,15	219
7) Зенфтлебен и Гладиш [3]	
343,15	220
303,15	178
8) Зенфтлебен [10]	
273,15	146
298,15	173
323,15	203
373,15	270
423,15	345
473,15	431
573,15	624
673,15	854

T, °K	1) $\lambda_0 \cdot 10^4$, вт/(м·град)
10) Недужий и др. [11]	
273,15	150
280	157
290	167
300	178
310	188
320	199
330	210
340	221
350	233
360	245
370	257
380	270
390	282
400	295
—	—

[Key on next page]

KEY: 1. $\lambda_0 \cdot 10^4$, W/(m·deg)
2. Eucken
3. Lenoir, Comings
4. Keyes
5. Lambert, et al
6. Cheung, et al
7. Senftleben and Gladisch
8. Senftleben
9. Chaykin, Markevich [8]
10. Neduzhiy, et al

One experimental value of λ_0 of ethylene at 318°C is presented in the work of Cheung, et al [9], which pertains to investigation of the thermal conductivity of binary and tertiary gaseous mixtures by the coaxial cylinders method.

Experimental data on the thermal conductivity of ethylene and propylene at atmospheric pressure are compared graphically in Figure 19. As follows from the figure, the data of most authors agree within 4%. The exceptions are Eucken's point [1] at 202°K and the values obtained by A. M. Chaykin and A. M. Markevich [8] and by Cheung [9], the deviations of which from the data of the other authors reach 8%.

The limited number of experimental points complicates generalization of data on the λ_0 of ethylene and propylene. For this reason we used the conclusions of Owens and Thodos [12] for the purpose of matching them up and correlating them. Owens and Thodos, by processing a large volume of experimental data on the thermal conductivity of various hydrocarbon gases and their derivatives at atmospheric pressure, discovered that the dependence of the thermal conductivity coefficient in logarithmic coordinates on the reduced temperature is expressed by a straight line with the same slope for all hydrocarbons and their derivatives, excluding cyclic. The authors thereby discovered the identical temperature dependence of λ_0 of these gases at atmospheric pressure (the mean deviation for 414 experimental points is 1.6%).

Here, Owens and Thodos used N. V. Tsederberg's generalized method [13] for representing data on the thermal conductivity of gases at atmospheric pressure in dimensionless coordinates. The critical temperature T_{cr} and thermal conductivity corresponding to it $\lambda_{T_{cr}}$ were used as the reduction parameters. A single common straight line was obtained in logarithmic coordinates for all the gases they investigated, and this line is described by the equation

[kp=cr]

$$\frac{\lambda_0}{\lambda_{T_{кр}}} = \left(\frac{T}{T_{кр}}\right)^n, \tag{67}$$

where n = 1.786.

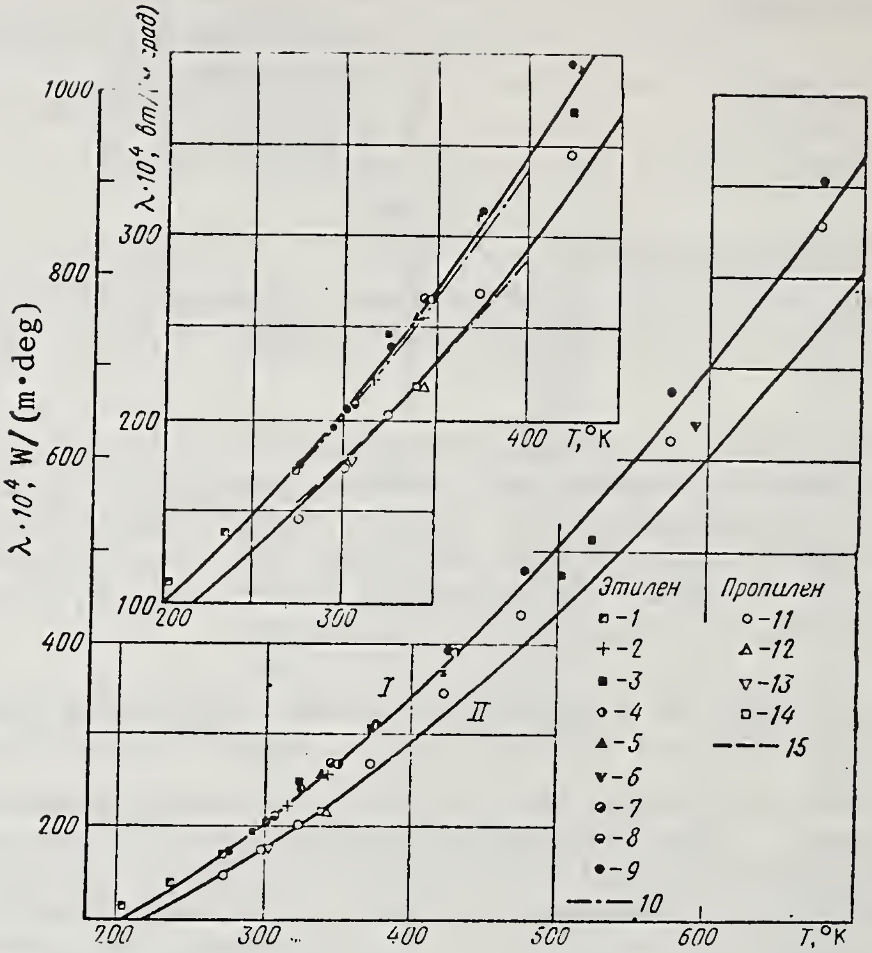

Figure 19. Thermal conductivity coefficients of ethylene (I) and propylene (II) at atmospheric pressure as functions of temperature according to: 1 -- Eucken [1, 2]; 2 -- Lenoir, Comings [4]; 3 -- A. M. Chaykin, A. M. Markevich [8]; 4 -- Keyes [6]; 5 -- Lambert, et al [7]; 6 -- Cheung, et al [9]; 7 -- Senftleben, Gladisch [3]; 8 -- Senftleben [5]; 9 -- Senftleben [10]; 10 -- I. A. Neduzhiy, et al [11] (for ethylene); 11 -- Senftleben [10]; 12 -- Senftleben, Gladisch [3]; 13 -- Senftleben[5]; 14 -- Lambert, et al [7]; 15 -- I. A. Neduzhiy, et al [11] (for propylene).

By converting expression (67) to an equation of the form

[kp=cr]

$$\frac{\lambda_0}{\lambda_{кр}} = \frac{\lambda_{T_{кр}}}{\lambda_{кр}}\left(\frac{T}{T_{кр}}\right)^n \qquad (68)$$

and using $\lambda_{cr} = 504.5 \cdot 10^{-4}$ and $\lambda_{T_{cr}} = 184.2 \cdot 10^{-4}$ W/(m•deg), Owens and Thodos derived a final equation for describing the thermal conductivity of ethylene as a function of temperature at atmospheric pressure:

$$\lambda_{пр} = \frac{\lambda_0}{\lambda_{кр}} = 0{,}364 \cdot \tau^{1{,}786}. \qquad (69)$$

We used equation (67) for processing data on the thermal conductivity of ethylene and propylene at atmospheric pressure, since equation (69) introduces hard-to-determine λ_{cr}.

In equation

$$\lambda_0 = A \cdot T^n \tag{70}$$

the constant $A = \lambda_{T_{cr}}/T^n_{cr}$ is calculated by the method of least squares on the basis of experimental data for ethylene (with the exception of data [8, 9]) and the power index is the same as in [12]. The result is the equation

$$\lambda_0 = 0{,}775 \cdot 10^{-6} \cdot T^{1{,}786}, \tag{71}$$

where λ_0 is measured in W/(m•deg) and T in °K, as recommended for calculating the thermal conductivity coefficient of ethylene at various temperatures and atmospheric pressure.

The deviations of the experimental values of the thermal conductivity coefficient of ethylene from those calculated using equation (71) are shown in Figure 20. The data of all authors coincide only at temperatures close to 273°K. As the temperature rises, the deviations increase. The greatest deviations are found in the data of A. M. Chaykin and A. M. Markevich [8], Cheung [9] and Eucken [1] at 202°K. Here the temperature dependence of these data differ substantially from the most probable, described by equation (71).

The deviations of the data of the other authors from the theoretical do not exceed ±2%. Only the deviation of Senftleben's data of 1964 [10] reaches +3.8% as temperature increases to 673°K, which otherwise coincides with the accuracy specified by the author.

The reference thermal conductivity coefficients of ethylene at atmospheric pressure [14, 15, 16, 17] were also compared.

These data are contradictory and substantially understated: to -12% [14, 15]; from -5.8 to -32.7% at 273-1,073°K [16], and from 3.3 to -23.6% at 223-1,273°K [17].

Thus it can be affirmed that equation (71) describes in the 200-700°K temperature range the dependence of the coefficient of thermal conductivity of ethylene at atmospheric pressure on temperature with a maximum error of 4%. The actual deviations, however, should be considerably lower, since the experimental data of most authors [1-7, 11] agree within ±2%.

When plotting the experimental data on the coefficient of thermal conductivity of propylene at atmospheric pressure on the graph (see Figure 19 and Table 61) what stands out most is the irregular temperature

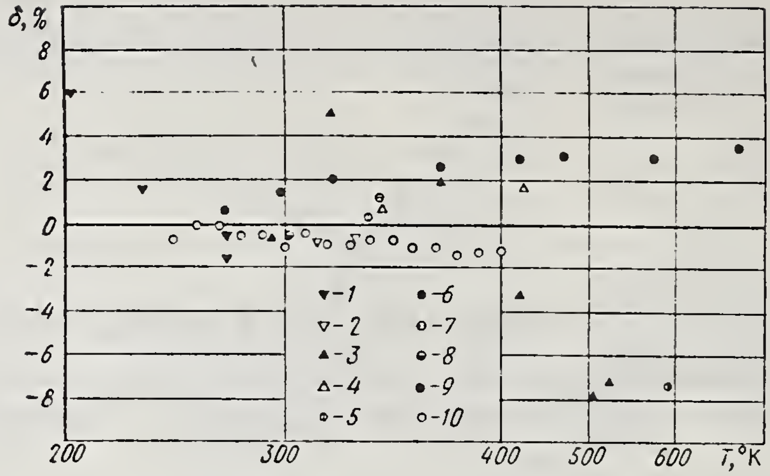

Figure 20. Deviations of $\delta = (\lambda_{exp} - \lambda_{theo})/\lambda_{theo} \cdot 100\%$ of experimental values of thermal conductivity coefficient of ethylene at atmospheric pressure from values computed by equation (71) according to: 1 -- Eucken [1, 2]; 2 -- Lenoir and Comings [4]; 3 -- A. M. Chaykin, A. M. Markevich [8]; 4 -- Keyes [6]; 5 -- Lambert, et al [7]; 6 -- Cheung, et al [9]; 7 -- Senftleben, Gladisch [3]; 8 -- Senftleben [5]; 9 -- Senftleben [10]; 10 -- I. A. Neduzhiy, et al [11].

path of the data of Senftleben of 1964 [10]. This indicates that as the molecular weight of the investigated gas increases, the accuracy of the Senftleben method decreases. Therefore the constant A of equation (70) was calculated for propylene only on the basis of the close experimental data of [3, 5, 11].

The equation which we used for calculating the dependence of the thermal conductivity coefficient of propylene at atmospheric pressure on temperature has the form

$$\lambda_0 = 0{,}667 \cdot 10^{-6} \cdot T^{1.786}. \tag{72}$$

Comparison shows that the experimental point of Lambert, et al [7] at 339.2°K deviates from the theoretical curve by -0.5%. The data of I. A. Neduzhiy, et al [11] deviate from +0.5 to -0.4% as the temperature increases from 273 to 400°K. Senftleben's data of 1964 [10] are 6% overstated even at 400°K, and 14% at 673°K.

The tabular values of the thermal conductivity coefficient of propylene given by Lehman [18] and presented in [17], as for ethylene, are substantially understated.

The divergence of data [18], calculated with the Eucken equation, is (+1.3)-(-10)% when the temperature is changed from 273 to 573°K.

The deviations of the λ_0 data of propylene, published in [17], are (-19.2)-(-13.5)% in the 223-1,273°K range.

The recommended thermal conductivity coefficients of gaseous ethylene and propylene (Tables XI, XII) were calculated through equations (71) and (72). The accuracy of the data is ~4%.

Thermal Conductivity of Ethylene and Propylene at High Pressures

The thermal conductivity of gaseous ethylene at high pressures was investigated by Lenoir and Comings [14]. The investigations were done by the relative coaxial cylinders method on the 314.3°K isotherm at pressures from 1 to 205.1 bar and on the 340.4°K isotherm at pressures from 1 to 230 bar. Nitrogen, methane, carbon dioxide and helium were used as standard gases. To prevent convections the conditions under which the Gr·Pr product was less than 600 in all cases, were maintained in the experiments. The absence of convection was checked by changing the temperature difference in the gas layers. The thermal conductivity coefficients were not changed in the process.

The error of the experimental data is from 1% at low to 3% at high pressures.

The experimental data of Lenoir and Comings [4] are summarized in Table 62.

Table 62. Data of Lenoir and Comings [4] on Thermal Conductivity of Gaseous Ethylene

p, бар	$\lambda \cdot 10^4$, вт/(м·град)	*p*, бар	$\lambda \cdot 10^4$, вт/(м·град)
$T = 314{,}3°$ K		$T = 340{,}4°$ K	
1,01	222	1,01	256
19,6	241	21,7	272
41,9	277	50,5	313
60,2	339	62,7	336
83,6	530	89,3	434
104,4	659	104,7	492
124,7	729	131,3	590
146,9	794	163,1	698
166,3	850	206,0	801
179,2	884	229,0	845
205,7	967	—	—

The thermal conductivity of gaseous ethylene under pressure was also investigated by Keyes [6], but in a considerably narrower pressure range. The data were obtained by the relative vertical coaxial cylinders method at 345.4 and 425.7°K:

$T = 345{,}4°$ K		$T = 425{,}7°$ K	
p, бар	$\lambda \cdot 10^4$, вт/(м·град)	*p*, бар	$\lambda \cdot 10^4$, вт/(м·град)
0	267	0	391
10,5	274	5,0	394
15,7	281	9,0	399

The error of the experimental data was not indicated.

Keyes offers an empirical equation of calculating the thermal conductivity coefficient of ethylene at pressures up to 16 bar, derived on the basis of his own experimental data:

$$\lambda = \lambda_0 \left(1 + 0{,}75 \frac{p}{T} \cdot 9{,}7^{p/T}\right), \tag{73}$$

where p is measured in bar and T in °K.

The thermal conductivity of gaseous ethylene and propylene at 250-400°K and at pressures up to 40 bar was measured by I. A. Neduzhiy, V. A. Kravets and A. Ya. Kolomiyets [11] by the regular method with an apparatus with a spherical bicalorimeter (the diameter of the copper core is 41.50 ± 0.01 mm and the thickness of the gap for the investigated gas is 1.15 ± 0.01 mm). The inner core of the bicalorimeter was centered with the aid of a rigidly attached tube of special construction, made of a heat insulating material, through which differential copper-constantan thermocouple is soldered inside the core. The surfaces bounding the layer of the investigated compound were nickel-plated and carefully polished to minimize heat losses.

The design features of the bicalorimeter, designed for investigation under pressure, necessitated the introduction of a number of correction factors, which are impossible to determine analytically. Therefore the relative method was used to investigate the thermal conductivity coefficient. The apparatus was calibrated on nitrogen using data [19], which made it possible to determine its constant at various temperatures and pressures.

Particular attention was devoted to preventing convection. The tests were conducted under conditions such that the Gr·Pr product would not exceed 1,000. The reproducibility of λ values within 0.5-1% at various temperatures and pressures was also evidence of the lack of convection in the investigated gas. The results of the investigation are summarized in Tables 63 and 64.

Comparison of the thermal conductivity coefficients of ethylene at atmospheric pressure in [11] (see Figure 19) established that the deviation of these data and the data of Lenoir and Comings [4], Lambert, et al [7], Senftleben [5], does not exceed 1.5%. The data of Keyes [6], Senftleben [10] (1964) and especially of A. M. Chaykin and A. M. Markevich [8], Cheung, et al [9], deviate to a much greater extent from the data in [11]. Data [11] on the thermal conductivity of ethylene at high pressures agree satisfactorily (to ±1%) with the data of Lenoir and Comings [4], where they overlap; somewhat less satisfactorily with Keyes' data [6], which are somewhat higher than the data in [4, 11].

Table 63. Thermal Conductivity Coefficient of Gaseous Ethylene According to I. A. Neduzhiy, et al [11]

p, бар	λ · 10⁴, вт/(м·град) при T, °K															
	250	260	270	280	290	300	310	320	330	340	350	360	370	380	390	400
1	148	159	170	181	193	204	217	229	242	255	269	282	296	310	325	340
2	149	160	171	182	194	205	218	230	243	256	270	283	297	311	326	341
4	151	162	173	184	195	207	219	231	244	257	271	284	298	312	327	342
6	154	165	175	186	197	209	220	233	245	258	272	286	300	314	328	343
8	156	166	177	188	199	210	222	234	247	260	273	287	301	315	329	344
10	159	168	179	190	201	212	224	236	248	261	274	288	302	316	330	345
12	162	171	181	192	203	214	226	238	250	263	276	290	304	318	332	346
14	166	174	183	194	205	216	227	239	252	264	277	291	305	319	333	348
16	169	177	186	197	208	218	230	241	253	266	279	292	307	321	335	349
18	173	180	189	199	210	221	232	243	255	268	281	294	308	322	336	351
20	178	184	193	202	213	224	234	246	257	270	283	296	310	324	338	352
22	178	189	196	205	216	226	237	248	260	272	285	298	312	326	340	354
24	—	195	201	208	219	229	240	251	262	274	287	300	314	328	342	355
26	—	202	206	213	223	233	243	253	264	276	289	302	315	329	343	357
28	—	—	213	218	228	237	246	256	267	279	291	304	318	331	345	358
30	—	—	220	223	233	241	250	260	270	281	294	307	320	333	347	360
32	—	—	—	230	238	245	253	263	273	284	296	309	322	336	349	362
34	—	—	—	237	243	249	257	266	276	286	299	312	325	338	351	364
36	—	—	—	245	248	254	261	269	279	290	301	314	327	340	353	366
38	—	—	—	253	254	258	265	273	282	293	304	316	330	342	355	368
40	—	—	—	260	259	262	268	276	285	296	307	319	332	345	358	370

Table 64. Thermal Conductivity Coefficient of Gaseous Propylene According to I. A. Neduzhiy, et al [11]

p, бар	λ · 10⁴; вт/(м·град) при T, °K													
	273.15	280	290	300	310	320	330	340	350	360	370	380	390	400
1	150	157	167	178	188	199	210	221	233	245	257	270	282	295
2	152	159	169	179	189	200	211	223	234	246	259	271	284	297
4	156	163	172	182	192	203	214	226	237	249	262	274	286	299
6	—	167	176	186	196	207	217	229	240	252	264	276	289	302
8	—	—	181	190	200	211	221	232	243	255	267	279	292	304
10	—	—	—	195	205	215	224	235	246	258	270	282	295	307
12	—	—	—	—	210	220	229	239	249	262	273	285	298	310
14	—	—	—	—	216	226	233	243	253	265	277	288	301	313
16	—	—	—	—	—	232	239	248	258	269	280	292	304	316
18	—	—	—	—	—	—	245	254	264	274	285	296	308	320
20	—	—	—	—	—	—	254	261	270	279	290	301	312	323
22	—	—	—	—	—	—	264	270	278	285	296	307	317	327
24	—	—	—	—	—	—	—	281	287	293	302	312	322	332
26	—	—	—	—	—	—	—	292	296	301	309	318	328	336
28	—	—	—	—	—	—	—	—	306	310	317	325	334	341
30	—	—	—	—	—	—	—	—	—	320	325	332	340	346
32	—	—	—	—	—	—	—	—	—	330	333	339	346	352
34	—	—	—	—	—	—	—	—	—	341	312	346	352	358
36	—	—	—	—	—	—	—	—	—	352	351	353	358	364

Comparison of data [11] on the thermal conductivity of propylene at atmospheric pressure shows an error of ±0.5% in relation to the experimental point of Lambert, et al [7]. Data [11] did not support Senftleben's data [10] (1964). Deviations of results of the latter works are +(3-14)%.

At higher pressures, in view of the lack of other experimental data on the thermal conductivity of propylene, we did a comparison with the diagram proposed by Owens and Thodos [12] for ethylene, illustrated in Figure 21. The pseudocritical thermal conductivity of propylene, calculated on the basis of data at atmospheric pressure, is $\lambda^*_{cr} = 690 \times 10^{-4}$ W/(m·deg). The deviation is 0.5-2.5%, which indicates the reliability of the data obtained for the thermal conductivity of propylene.

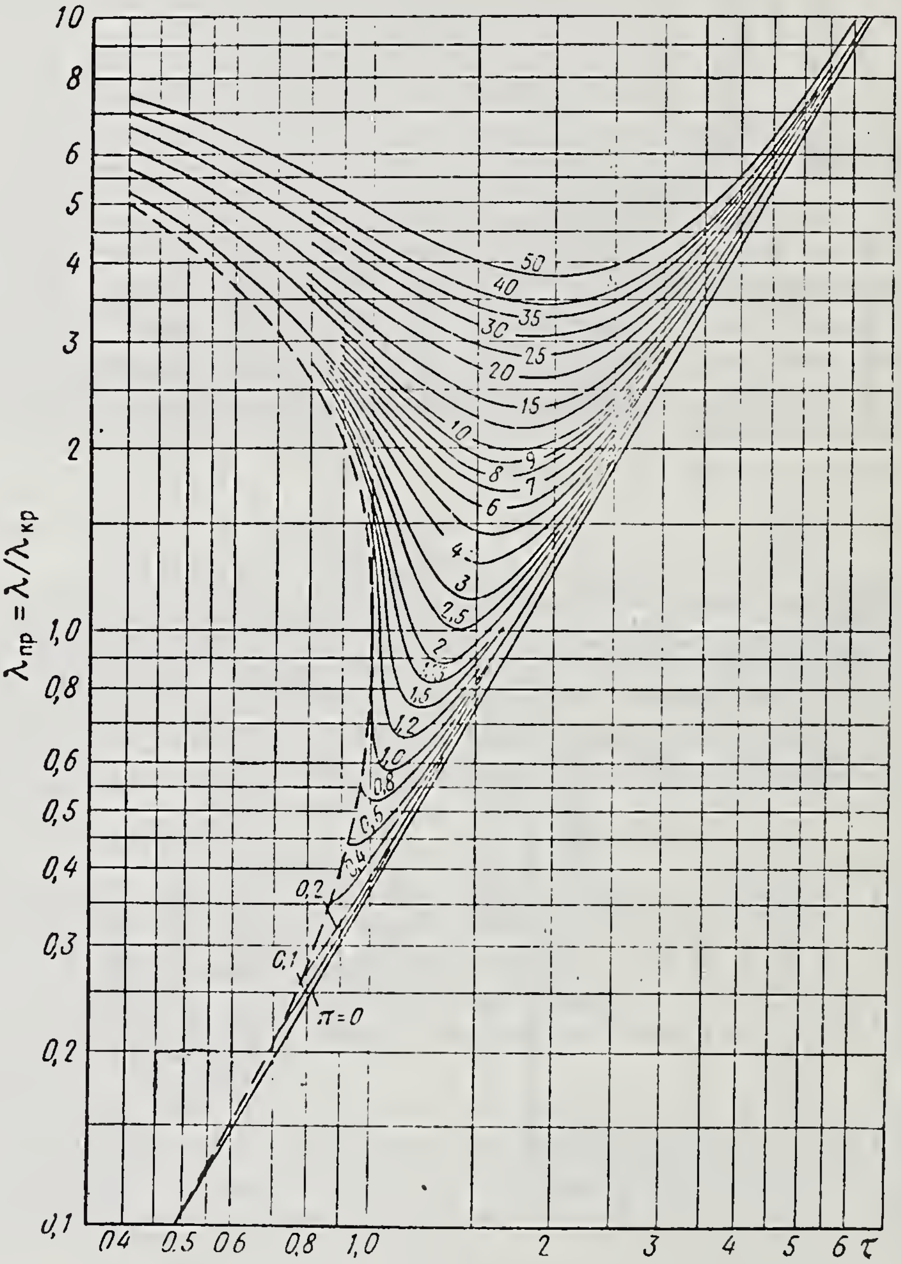

Figure 21. Reduced ethylene thermal conductivity diagram of Owens and Thodos [12]. The authors used the following: $T_{cr} = 282.4°K$, $p_{cr} = 50.66$ bar, $\lambda_{cr} = 504.5 \cdot 10^{-4}$ W/(m·deg).

The limited number of experimental data on the thermal conductivity of ethylene and propylene, encompassing a narrow range of parameters, cannot be used directly for compiling tables of the thermal conductivity coefficients of these compounds without involving calculation methods.

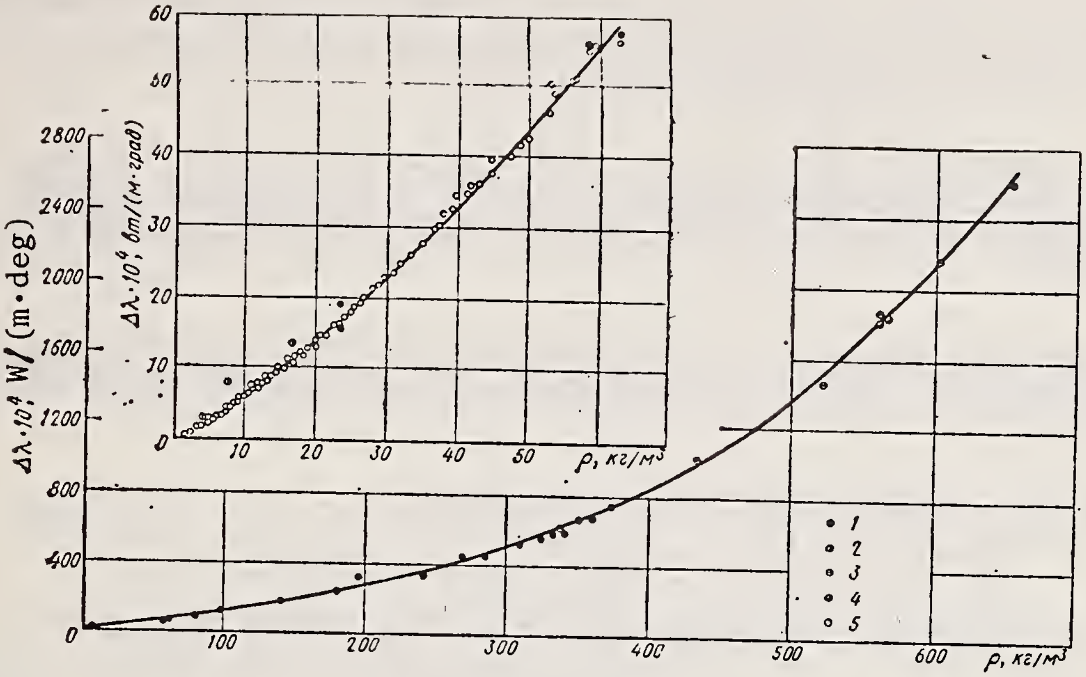

Figure 22. Excess thermal conductivity $\Delta\lambda = \lambda - \lambda_0$ as function of density according to: 1 -- Lenoir and Comings [4]; 2 -- Keyes [6]; 3 -- Ye. Borovik, et al [20]; 4 -- Ye. Borovik [21]; 5 -- I. A. Neduzhiy, et al [11].

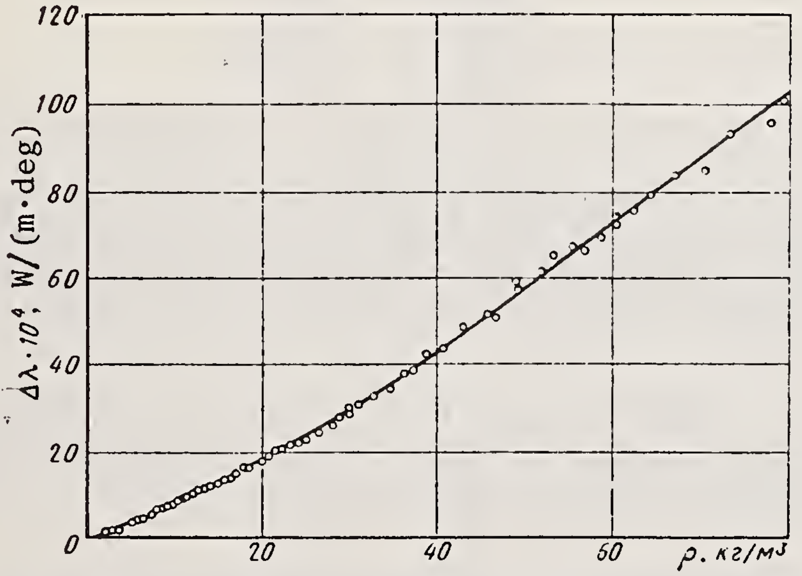

Figure 23. Excess thermal conductivity of propylene as function of density according to I. A. Neduzhiy, et al [11].

When the coordinate system $\Delta\lambda = (\lambda - \lambda_0)$, ρ is used for generalizing the experimental conductivity coefficients, the experimental errors obey the simplest law in the widest range of parameters and are described by a curve that is common to the gaseous and liquid states.

A uniparametric dependence of excess thermal conductivity on density is used in the vast majority of cases, since the question of deviation from it has not yet been answered for thermal conductivity near the critical point and near the saturation curve.

Experimental data [4, 6, 11] for gaseous and [20, 21] liquid ethylene are presented in Figure 22 in the form of excess thermal conductivity as a function of density; data [11] for gaseous propylene are given in Figure 23.

The dependences of excess thermal conductivity on density are approximated by computer by the method of least squares using orthogonal polynomials.

For ethylene is derived the equation

$$\begin{gathered}\Delta\lambda \cdot 10^4 = 0{,}5358 \cdot \rho + 0{,}9365 \cdot 10^{-2}\rho^2 - 0{,}6809 \cdot 10^{-4} \cdot \rho^3 + \\ + 0{,}3635 \cdot 10^{-6} \cdot \rho^4 - 0{,}1056 \cdot 10^{-8} \cdot \rho^5 + 0{,}1550 \cdot 10^{-11} \cdot \rho^6 - \\ - 0{,}8634 \cdot 10^{-15} \cdot \rho^7,\end{gathered} \tag{74}$$

which is valid in the 0-650 kg/m^3 density range; for propylene

$$\begin{gathered}\Delta\lambda \cdot 10^4 = - 0{,}984 + 0{,}8270 \cdot \rho + 0{,}3419 \cdot 10^{-2} \cdot \rho^2 + 0{,}1406 \cdot 10^{-3} \cdot \rho^3 - \\ - 0{,}1374 \cdot 10^{-5} \cdot \rho^4,\end{gathered} \tag{75}$$

which is valid in the 2.5-80 kg/m^3 density range.

The recommended thermal conductivity coefficients of gaseous ethylene, computed using equation (74), are presented in Table XI for T = 180-450°K and p = 1-3,000 bar. Considering the good agreement between the experimental data of various researchers, obtained by various methods (see Figure 22) and the validity of the reference curve $\Delta\lambda = f(\rho)$, it can be assumed that the error of the tabular thermal conductivity coefficients of ethylene is ±2 to ±6%.

Data on the thermal conductivity of gaseous propylene, computed by equation (75), are presented in Table XII and encompass the 300-450°K temperature range and 1-50 bar pressure range.

The reduced diagram of thermal conductivity for ethylene can be used for determining the thermal conductivity of propylene at pressures above 50 bar (see Figure 21). The pseudocritical conductivity of propylene is $\lambda^*_{cr} = 690 \cdot 10^{-4}$ W/(m·deg). Comparison of the data in Table XII with the reduced diagram shows agreement within ±2.5%.

Thermal Conductivity of Liquid Ethylene

Experimental data on the thermal conductivity of liquid ethylene are presented in [20, 21] (no data are available for propylene).

Ye. Borovik, A. Matveyev and Ye. Panina [20] used the hot wire method for studying the thermal conductivity of liquid ethylene. They used two vertical measurement tubes of different length, made of copper, to prevent end losses.

All measurements were done with different temperature drops between a filament and tube wall, not exceeding, however, 0.5-1 deg, to prevent convection.

The pressure of the investigated compounds was maintained a few atmospheres above the saturation vapor pressure at the test temperature.

The thermal conductivity measurements encompass a wide range of temperatures. The extreme measured points are 8.7 and 9.6 deg, respectively, from the melting and critical points.

The experimental data are presented below

T, °K	λ, W/(m•deg)
112,65	0,254
144,15	0,222
172,15	0,184
199,15	0,156
244,35	0,126
273,45	0,080

The errors of the data are ±2.6%.

Borovik [21] measured the thermal conductivity of liquid ethylene at 171.25°K using the parallel plate method, which creates the best conditions for the prevention of convection. The temperature in the instrument was measured with calibrated resistance thermometers. The measurement error was 1% for points far from the critical and up to 3% near the critical point. The temperature drop in the tests was 0.3-3 deg.

The thermal conductivity coefficients of liquid ethylene at 171.25°K and 4.97 and 52.99 bar, were found to be 0.182 and 0.185 W/(m•deg), respectively.

Data [20, 21] on the thermal conductivity of liquid ethylene, obtained by two different methods, agree satisfactorily, which confirms their reliability.

Data [20, 21] were used for derivation of equation (77). Tables IX and XI of the thermal conductivity coefficients of liquid ethylene, including the liquid saturation state, were compiled with the aid of this equation. The accuracy of the data is ±(3-6)%.

PART II

TABLES OF THERMODYNAMIC AND TRANSPORT PROPERTIES OF ETHYLENE AND PROPYLENE

Units of Measurements Used in Tables

Temperature, T, °K;

Pressure, p, bar;

Specific volume, v, m^3/kg;

i, kJ/kg;

r, kJ/kg;

s, kJ/(kg•deg);

Specific heat C_p, kJ/(kg•deg);

Speed of sound, w, m/sec;

Viscosity, η, $N \cdot sec/m^2$;

Thermoconductivity, λ, W/(m•deg).

Table I. Thermodynamic Properties p, v, i, r, s, C_p of Ethylene on Saturation Line as Functions of Temperature

T, °K	p	v'	v''	i'	i''	$-r$	s'	s''	C'_p
160	0,5624	0,001715	0,8281	371,3	868,6	497,3	4,077	7,185	2,395
165	0,7779	0,001738	0,6098	383,5	872,1	488,6	4,153	7,114	2,399
170	1,0526	0,001762	0,4605	395,4	875,7	480,3	4,224	7,049	2,404
175	1,3971	0,001786	0,3538	407,4	879,1	471,7	4,295	6,990	2,407
180	1,8222	0,001811	0,2761	419,6	882,7	463,1	4,362	6,935	2,410
185	2,339	0,001838	0,2185	431,8	885,9	454,1	4,429	6,884	2,415
190	2,959	0,001865	0,1752	443,8	888,9	445,1	4,494	6,837	2,425
195	3,695	0,001893	0,1419	455,6	891,4	435,8	4,557	6,792	2,435
200	4,559	0,001923	0,1162	467,8	894,1	426,3	4,617	6,749	2,450
205	5,564	0,001953	0,09607	480,1	896,8	416,7	4,674	6,707	2,472
210	6,723	0,001986	0,08010	492,6	899,8	407,2	4,731	6,670	2,505
215	8,050	0,002019	0,06736	505,1	902,8	397,7	4,788	6,638	2,538
220	9,560	0,002056	0,05702	518,0	905,7	388,1	4,844	6,608	2,580
225	11,266	0,002095	0,04852	531,1	909,0	377,9	4,900	6,580	2,635
230	13,182	0,002142	0,04148	544,2	911,1	366,9	4,956	6,551	2,706
235	15,324	0,002189	0,03555	557,8	912,5	354,7	5,013	6,522	2,800
240	17,711	0,002243	0,03049	571,5	912,2	340,7	5,070	6,490	2,915
245	20,35	0,002302	0,02616	585,7	910,6	324,9	5,129	6,455	3,072
250	23,28	0,002370	0,02241	600,8	908,1	307,3	5,188	6,417	3,260
255	26,49	0,002447	0,01921	616,3	904,3	288,0	5,251	6,380	3,480
260	30,03	0,002539	0,01644	633,0	900,1	267,1	5,313	6,340	3,775
265	33,89	0,002653	0,01403	652,2	895,9	243,7	5,378	6,298	4,208
270	38.11	0,002798	0,001181	673,2	887,7	214,5	5,459	6,253	4,990
275	42,71	0,002997	0,009638	700,3	874,2	175,3	5,551	6,194	—
283,05	50,97	0,004739	0,004739	799,1	799,1	0	5,903	5,903	—

Table II. Thermodynamic Properties v, i, s, C_p of Ethylene

T, °K	p = 0,5 бар				p = 0,6 бар				p = 0,7 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
200	1,1742	909,4	7,468	1,286 *	0,09767	909,0	7,416	1,288 *	0,8357	908,6	7,370	1,290 *
210	1,2344	920,5	7,530	1,302 *	1,0272	920,1	7,479	1,304 *	0,8790	919,7	7,432	1,306 *
220	1,2995	931,5	7,592	1,321 *	1,0774	931,5	7,540	1,323 *	0,9222	931,1	7,494	1,325 *
230	1,3548	943,6	7,652	1,342	1,1275	943,2	7,600	1,344	0,9652	942,8	7,554	1,346
240	1,4149	955,6	7,711	1,366	1,1776	955,2	7,660	1,367	1,0082	954,9	7,613	1,368
250	1,4746	968,3	7,770	1,392	1,2276	968,0	7,718	1,393	1,0512	967,7	7,672	1,394
260	1,5344	981,7	7,826	1,424	1,2775	981,4	7,774	1,426	1,0941	981,1	7,729	1,427
270	1,5942	995,7	7,882	1,456	1,3275	995,4	7,830	1,458	1,1369	995,1	7,784	1,459
280	1,6537	1010,0	7,936	1,490	1,3770	1009,7	7,883	1,491	1,1794	1009,4	7,838	1,492
290	1,7136	1025,2	7,987	1,526	1,4271	1024,9	7,934	1,527	1,2225	1024,6	7,890	1,528
300	1,7734	1039,9	8,039	1,564	1,4770	1039,7	7,985	1,565	1,2653	1039,5	7,939	1,566
310	1,8330	1055,9	8,092	1,600	1,5268	1055,7	8,037	1,600	1,3080	1055,6	7,991	1,601
320	1.8926	1072,0	8,144	1,635	1,5765	1072,0	8,089	1,636	1,3506	1071,9	8,043	1,637
330	1,9522	1088,8	8,194	1,671	1,6261	1088,6	8,140	1,672	1,3933	1088,5	8,094	1,673
340	2,0117	1105,7	8,245	1,709	1,6758	1105,6	8,191	1,710	1,4359	1105,4	8,145	1,710
350	2,0712	1123,0	8,295	1.743	1,7254	1122,9	8,241	1,744	1,4788	1122,8	8,195	1,744
360	2,1307	1140,8	8,345	1,780	1,7751	1140,7	8,291	1,781	1,5210	1140,5	8,245	1,781
370	2,1902	1158,9	8,395	1,817	1,8247	1158,8	8,341	1,818	1,5636	1158,7	8,295	1,818
380	2,2497	1177,3	8,444	1,852	1,8743	1177,2	8,390	1,853	1,6061	1177,1	8,314	1,853
390	2,3091	1196,1	8,493	1,890	1,9238	1196,1	8,439	1,890	1,6486	1196,0	8,393	1,890
400	2,3600	1215,3	8,541	1,927	1,9734	1215,2	8,487	1,927	1,6911	1215,1	8,441	1,927
410	2,4230	1234,8	8,589	1,962	2,0229	1234,7	8,535	1,962	1,7336	1234,6	8,489	1,963
420	2,4874	1254,7	8,637	1,998	2,0725	1254,6	8,583	1,999	1,7761	1254,5	8,537	1.999
430	2,5469	1274,7 *	8,684 *	2,031 *	2,1220	1274,6 *	8,630 *	2,031 *	1,8186	1274,6 *	8,584 *	2,031 *
440	2,6063	1295,2	8,731	2,061	2,1716	1295,1	8,677	2,061	1,8611	1295,0	8,631	2,065
450	2,6658	1316,0	8,790	2,097	2,2221	1315,9	8,725	2,098	1,9036	1315,8	8,675	2,098
460	2,7253	1334,9 *	8,840 *	2,131 *	2,2708	1334,8	8,775 *	2,131 *	1,9462	1334,7 *	8,725 *	2,132 *
470	2,7848	1355,0 *	8,887 *	2,163 *	2,3200	1355,0 *	8,830 *	2,163 *	1,9889	1354,9 *	8,875 *	2,163 *
480	2,8444	1375,1 *	8,936 *	2,198 *	2,3702	1375,0 *	8,880 *	2,196 *	2,0315	1375,0 *	8,820 *	2,196 *
490	2,9041	1395,0 *	8,981 *	2,227 *	2,4199	1395,0 *	8,912 *	2,227 *	2,0742	1394,9 *	8,864 *	2,227 *
500	2,9637	1414,9 *	9,035 *	2,258 *	2,4697	1414,8 *	8,960 *	2,258 *	2,1169	1414,8 *	8,925 *	2,258 *

[Continued]

[In all tables бap = bar]

Table II (Continued)

T, °K	$p = 0{,}8$ бар				$p = 0{,}9$ бар				$p = 1$ бар			
	v	i	s	c_p	v	i	s	c_p	v	i	s	c_p
200	0,7297	908,2	7,330	1,292	0,6471	907,8	7,289	1,294	0,5815	907,4	7,252	1,296
210	0,7678	919,3	7,393	1,308	0,6814	919,0	7,352	1,310	0,6122	918,6	7,314	1,312
220	0,8057	930,8	7,454	1,327	0,7151	930,5	7,413	1,329	0,6426	930,2	7,375	1,331
230	0,8435	942,4	7,514	1,347	0,7488	942,0	7,474	1,348	0,6730	941,7	7,437	1,350
240	0,8816	954,6	7,574	1,370	0,7825	954,3	7,533	1,321	0,7035	954,0	7,497	1,373
250	0,9188	967,4	7,633	1,395	0,8159	967,1	7,592	1,396	0,7336	966,8	7,556	1,397
260	0,9564	980,8	7,689	1,428	0,8494	980,5	7,649	1,430	0,7638	980,2	7,614	1,431
270	0,9940	994,8	7,745	1,460	0,8828	994,5	7,706	1,461	0,7939	991,2	7,672	1,462
280	1,0312	1009,1	7,798	1,493	0,9160	1008,8	7,760	1,494	0,8238	1008,5	7,727	1,495
290	1,0689	1024,3	7,851	1,529	0,9496	1024,0	7,814	1,530	0,8541	1023,7	7,780	1,531
300	1,1065	1039,3	7,901	1,567	0,9830	1039,2	7,866	1,568	0,8842	1039,0	7,832	1,569
310	1,1439	1055,4	7,951	1,602	1,0163	1055,3	7,916	1,603	0,9142	1055,1	7,883	1,604
320	1,1813	1071,7	8,006	1,638	1,0495	1071,6	7,970	1,638	0,9442	1071,4	7,935	1,639
330	1,2186	1088,4	8,056	1,674	1,0828	1088,2	8,021	1,675	0,9741	1088,1	7,985	1,675
340	1,2559	1105,3	8,108	1,710	1,1160	1105,2	8,073	1,711	1,0040	1106,1	8,036	1,712
350	1,2932	1122,7	8,160	1,745	1,1491	1122,6	8,123	1,745	1,0339	1122,4	8,085	1,746
360	1,3305	1140,4	8,209	1,782	1,1823	1140,3	8,173	1,782	1,0637	1140,2	8,135	1,783
370	1,3677	1158,6	8,258	1,819	1,2154	1158,5	8,224	1,819	1,0936	1158,4	8,185	1,820
380	1,4050	1177,0	8,308	1,853	1,2485	1176,9	8,272	1,854	1,1234	1176,8	8,234	1,855
390	1,4422	1195,9	8,357	1,891	1,2816	1195,8	8,321	1,891	1,1532	1195,7	8,283	1,892
400	1,4794	1215,0	8,405	1,928	1,3147	1214,9	8,369	1,928	1,1830	1214,8	8,331	1,928
410	1,5166	1234,5	8,453	1,963	1,3478	1234,4	8,417	1,963	1,2128	1234,3	8,379	1,964
420	1,5538	1254,4	8,501	1,999	1,3809	1254,3	8,466	1,999	1,2458	1254,2	8,427	2,000
430	1,5910	1274,5	8,547	2,032	1,4140	1274,9	8,511	2,032	1,2724	1274,3	8,474	2,032
440	1,6282	1291,9 *	8,596 *	2,065 *	1,4471	1294,8 *	8,560 *	2,065 *	1,3022	1294,7 *	8,521 *	2,066 *
450	1,6655	1315,7 *	8,645 *	2,098 *	1,4802	1315,7 *	8,605 *	2,098 *	1,3320	1315,5 *	8,568 *	2,099 *
460	1,7028	1334,6 *	8,690 *	2,132 *	1,5134	1334,5 *	8,650 *	2,132 *	1,3619	1334,5 *	8,625 *	2,132 *
470	1,7401	1354,9 *	8,740 *	2,164 *	1,5466	1354,9 *	8,700 *	2,164 *	1,3918	1354,8 *	8,625 *	2,164 *
480	1,7774	1374,9 *	8,796 *	2,197 *	1,5798	1374,8 *	8,751 *	2,197 *	1,4217	1374,7 *	8,710 *	2,197 *
490	1,8148	1394,8 *	8,835 *	2,228 *	1,6131	1394,7 *	8,799 *	2,228 *	1,4517	1394,6 *	8,755 *	2,228 *
500	1,8522	1414,7 *	8,875 *	2,259 *	1,6464	1414,7 *	8,835 *	2,259 *	1,4818	1414,6 *	8,800 *	2,259 *

[Continued]

Table II (Continued)

T, °K	$p = 1{,}1$ бар				$p = 1{,}2$ бар				$p = 1{,}3$ бар			
	v	i	s	c_p	v	i	s	c_p	v	i	s	c_p
200	0,5277	907,0	7,224	1,298	0,4826	906,6	7,203	1,301	0,4448	906,2	7,174	1,304
210	0,5556	918,2	7,286	1,314	0,5084	917,8	7,264	1,316	0,4685	917,4	7,238	1,318
220	0,5834	929,9	7,347	1,333	0,5340	929,6	7,325	1,335	0,4922	929,3	7,299	1,337
230	0,6110	941,4	7,408	1,352	0,5594	941,1	7,384	1,354	0,5157	940,8	7,360	1,356
240	0,6384	953,7	7,463	1,374	0,5847	953,4	7,444	1,376	0,5391	953,1	7,421	1,378
250	0,6668	966,5	7,526	1,398	0,6101	966,2	7,503	1,399	0,5626	965,9	7,480	1,400
260	0,6937	979,9	7,585	1,432	0,6353	979,6	7,560	1,433	0,5859	979,3	7,538	1,434
270	0,7212	993,9	7,642	1,464	0,6605	993,6	7,616	1,465	0,6092	993,3	7,594	1,466
280	0,7483	1008,2	7,697	1,496	0,6854	1007,9	7,670	1,497	0,6322	1007,6	7,648	1,498
290	0,7760	1023,4	7,751	1,532	0,7108	1023,1	7,726	1,533	0,6557	1022,8	7,701	1,534
300	0,8034	1038,8	7,803	1,570	0,7360	1038,7	7,777	1,571	0,6790	1038,5	7,753	1,572
310	0,8307	1055,0	7,856	1,605	0,7611	1054,8	7,830	1,606	0,7022	1054,7	7.806	1,606
320	0,8579	1071,3	7,908	1,640	0,7861	1071,2	7,882	1,641	0,7253	1071,0	7,858	1,642
330	0,8852	1088,0	7,959	1,676	0,8111	1087,9	7,932	1,677	0,7484	1087,7	7,909	1,677
340	0,9124	1140,9	8,010	1,713	0,8360	1104,8	7,984	1,713	0,7714	1104,7	7,960	1,714
350	0,9395	1122,3	8,060	1,746	0,8610	1122,2	8,034	1,747	0,7945	1122,1	8,010	1,747
360	0,9667	1040,1	8,110	1,783	0,8859	1140,0	8,084	1,784	0,8175	1139,9	8,060	1,784
370	0,9939	1158,3	8,161	1,820	0,9108	1158,2	8,135	1,821	0,8405	1158,1	8,111	1,821
380	1,0210	1176,8	8,210	1,855	0,9357	1176,6	8,184	1,855	0,8635	1177,3	8,160	1,855
390	1,0481	1195,6	8,259	1,892	0,9605	1195,5	8,233	1,892	0.8864	1195,4	8,209	1,893
400	1,0752	1214,7	8,307	1,929	0,9857	1214,7	8,281	1,929	0,9094	1214,6	8,257	1,929
410	1,1023	1234,3	8,355	1,964	1,0103	1234,2	8,329	1,964	0,9323	1234,1	8,305	1,964
420	1,1294	1254,1	8,403	2,000	1,0351	1254,0	8,377	2,000	0,9553	1254,0	8,353	2,001
430	1,1565	1274,2	8,450	2,032	1,0599	1274,1	8,424	2,033	0,9783	1274,0	8,400	2,033
440	1,1836	1294,7	8,497	2,066	1,0848	1294,5	8,471	2,066	1,0012	1294,4	8,447	2,066
450	1,2108	1315,5 *	8,543 *	2,099 *	1,1097	1315,3 *	8,517 *	2,100 *	1,0242	1315,1 *	8,493 *	2,100 *
460	1,2379	1334,5 *	8,580 *	2,133 *	1,1347	1334,4 *	8,565 *	2,133 *	1,0473	1334,4 *	8,540 *	2,133 *
470	1,2651	1354,7 *	8,630 *	2,164 *	1,1596	1354,6 *	8,610 *	1,165 *	1,0703	1354,6 *	8,585 *	2,165 *
480	1,2924	1374,6 *	8,680 *	2,197 *	1,1846	1374,5 *	8,660 *	2,198 *	1,0934	1374,4 *	8,635 *	2,198 *
490	1,3197	1394,5 *	8,730 *	2,228 *	1,2096	1394,5 *	8,715 *	2,229 *	1,1165	1394,4 *	8,680 *	2,229 *
500	1,3470	1414,5 *	8,785 *	2,259 *	1,2347	1414,4 *	8,760 *	2,260 *	1,1397	1414,3 *	8,735 *	2,260 *

[Continued]

Table II (Continued)

T, °K	$p = 1{,}4$ бар				$p = 1{,}5$ бар				$p = 1{,}6$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
200	0,4122	905,8	7,152	1,307 *	0,3839	905,4	7,130	1,311 *	0,3590	905,0	7,110	1,315 *
210	0,4343	917,0	7,214	1,320 *	0,4046	916,6	7,194	1,323 *	0,3786	916,2	7,172	1,326 *
220	0,4563	929,0	7,275	1,339 *	0,4252	928,6	7,256	1,341 *	0,3981	928,3	7,234	1,343
230	0,4782	940,5	7,337	1,358	0,4457	940,2	7,317	1,539	0,4173	939,9	7,296	1,360
240	0,5000	952,8	7,398	1,379	0,4662	952,5	7,378	1,380	0,4365	952,2	7,356	1,382
250	0,5218	965,6	7,457	1,402	0.4865	965,3	7,438	1,403	0,4557	965,0	7,416	1,404
260	0,5436	979,0	7,515	1,436	0,5069,	978,7	7,496	1,437	0,4747	978,4	7,474	1,438
270	0,5650	993,0	7,570	1,467	0,5271	992,7	7,554	1,468	0,4938	992,4	7,531	1,470
280	0,5866	1007,3	7,625	1,499	0,5471	1007,0	7,608	1,500	0,5125	1006,8	7,586	1,501
290	0,6085	1022,5	7,678	1,535	0,5676	1022,0	7,660	1,536	0,5318	1022,0	7,640	1,537
300	0,6302	1038,3	7,731	1,573	0,5878	1038,0	7,710	1,577	0,5508	1039,0	7,690	1,575
310	0,6517	1054,5	7,784	1,607	0,6079	1054,4	7,763	1,608	0,5696	1057,0	7,743	1,609
320	0,6732	1070,9	7,836	1,642	0,6280	1070,8	7,815	1,643	0,5885	1070,6	7,796	1,644
330	0,6946	1087,6	7,886	1,678	0,6480	1087,5	7,866	1,679	0,6073	1087,3	7,846	1,680
340	0,7160	1104,6	7,938	1,714	0,6681	1104,5	7,917	1,715	0,6261	1104,3	7,898	1,715
350	0,7375	1123,7	7,988	1,748	0,6881	1123,6	7,957	1,748	0,6448	1121,6	7,948	1,749
360	0,7589	1139,8	8,048	1,785	0,7080	1139,7	8,018	1,785	0,6636	1139,5	7,998	1,786
370	0,7802	1158,0	8,089	1,822	0,7280	1157,9	8,068	1,822	0,6823	1157,8	8,049	1,823
380	0,8016	1176,4	8,138	1,856	0,7480	1176,4	8,117	1,856	0,7010	1176,3	8,098	1,857
390	0,8229	1195,3	8,187	1,893	0,7679	1195,4	8,166	1,893	0,7197	1195,0	8,147	1,894
400	0,8443	1214,5	8,235	1,930	0,7878	1214,4	8,214	1,930	0,7384	1214,3	8,195	1,930
410	0,8656	1234,0	8,283	1,965	0,8077	1233,9	8,263	1,965	0,7571	1233,8	8,243	1,965
420	0,8869	1253,9	8,331	2,001	0,8276	1253,8	8,310	2,001	0,7758	1253,7	8,291	2,001
430	0,9082	1273,9	8,378	2,033	0,8476	1273,8	8,357	2,033	0,7944	1273,7	8,338	2,034
440	0,9296	1294,3	8,425	2,067	0,8675	1294,2	8,404	2,067	0,8131	1294,1	8,385	2,067
450	0,9509	1315,0 *	8,471 *	2,100 *	0,8874	1314,9 *	8,451 *	2,101	0,8319	1314,8	8,431 *	2,101
460	0,9723	1334,3 *	8,520 *	2,133 *	0,9074	1334,3 *	8,500 *	2,133	0,8506	1334,2 *	8,475 *	2,131
470	0,9938	1354,5 *	8,565 *	2,165 *	0,9274	1354,4 *	8,545 *	2,165	0,8694	1354,4 *	8,525 *	2,165
480	1,0152	1374,3 *	8,615 *	1,198 *	0,9475	1374,2 *	8,594 *	2,198 *	0,8882	1374,1 *	8,580 *	2,198 *
490	1,0367	1394,2 *	8,660 *	2,229 *	0,9675	1394,1 *	8,640 *	2,229 *	0,9070	1394,0 *	8,635 *	2,229 *
500	1,0583	1414,3 *	8,714 *	2,260 *	0,9877	1414,2 *	8,693 *	2,260 *	0,9260	1414,1 *	8,680 *	2,260 *

[Continued]

Table II (Continued)

T, °K	$p = 1,7$ бар				$p = 1,8$ бар				$p = 1,9$ бар			
	v	i	s	c_p	v	i	s	c_p	v	i	s	c_p
200	0,3373	904,6	7,088	1,319 *	0,3179	904,2	7,070	1,323 *	0,3006	903,8	7,050	1,329 *
210	0,3558	915,9	7,152	1,329 *	0,3355	915,5	7,133	1,333 *	0,3172	915,1	7,112	1,336 *
220	0,3741	928,0	7,214	1,345 *	0,3528	927,6	7,195	1,347 *	0,3337	927,1	7,174	1,349 *
230	0,3922	939,6	7,277	1,362	0,3699	939,3	7,257	1,364	0,3500	938,9	7,235	1,366
240	0,4102	951,9	7,338	1,384	0,3871	951,6	7,318	1,385	0,3664	951,3	7,296	1,386
250	0,4284	964,7	7,397	1,405	0,4042	964,4	7,379	1,406	0,3825	964,1	7,356	1,407
260	0,4464	978,1	7,456	1,440	0,4212	977,8	7,438	1,441	0,3987	977,5	7,415	1,442
270	0,4644	992,2	7,512	1,471	0,4382	991,0	7,494	1,472	0,4148	991,7	7,473	1,474
280	0,4820	1006,6	7,567	1,502	0,4549	1006,4	7,548	1,503	0,4306	1006,2	7,530	1,504
290	0,5002	1021,8	7,620	1,538	0,4721	1021,6	7,601	1,539	0,4469	1021,4	7,586	1,540
300	0,5181	1037,8	7,672	1,575	0,4890	1037,6	7,655	1,576	0,4630	1037,5	7,638	1,577
310	0,5359	1054,1	7,725	1,610	0,5058	1053,9	7,708	1,610	0,4790	1053,8	7,691	1,611
320	0,5536	1070,5	7,783	1,645	0,5226	1070,3	7,760	1,645	0,4949	1070,2	7,744	1,646
330	0,5713	1087,2	7,828	1,681	0,5394	1087,1	7,811	1,681	0,5108	1086,9	7,794	1,682
340	0,5890	1104,2	7,879	1,716	0,5561	1104,1	7,862	1,716	0,5266	1104,0	7,846	1,717
350	0,6067	1121,6	7,930	1,749	0,5728	1121,5	7,913	1,750	0,5425	—	7,896	1,751
360	0,6244	1139,4	7,980	1,786	0,5895	1139,3	7,963	1,787	0,5583	1139,2	7,947	1,787
370	0,6420	1157,7	8,030	1,823	0,6062	1157,6	8,013	1,824	0,5741	1157,5	7,997	1,824
380	0,6596	1176,2	8,080	1,857	0,6228	1176,1	8,063	1,857	0,5899	1176,0	8,048	1,858
390	0,6772	1195,1	8,129	1,894	0,6394	1195,0	8,112	1,894	0,6056	1194,9	8,096	1,895
400	0,6948	1214,2	8,177	1,931	0,6561	1214,1	8,160	1,931	0,6214	1214,0	8,144	1,932
410	0,7124	1233,4	8,225	1,965	0,6727	1233,7	8,208	1,966	0,6372	1233,6	8,192	1,966
420	0,7300	1253,6	8,273	2,002	0,6893	1253,5	8,256	2,002	0,6529	1253,4	8,240	2,002
430	0,7476	1273,6	8,320	2,034	0,7059	1273,5	8,303	2,034	0,6687	1273,4	8,287	2,034
440	0,7652	1294,0	8,367	2,067	0,7226	1293,9	8,349	2,068	0,6844	1293,8	8,333	2,068
450	0,7828	1314,4	8,413	2,101	0,7392	1314,6	8,396	2,102	0,7002	1314,5	8,380	2,102
460	0,8005	1334,1	8,460	2,134	0,7559	1334,1	8,440	2,134	0,7161	1334,0	8,425	2,134
470	0,8182	1354,4 *	8,510 *	2,166	0,7726	1354,3 *	8,490 *	2,166	0,7319	1354,2 *	8,475 *	2,166
480	0,8359	1374,1 *	8,558 *	2,199 *	0,7894	1374,1 *	8,545 *	2,199 *	0,7478	1374,0 *	8,520 *	2,199 *
490	0,8537	1393,8 *	8,610 *	2,229 *	0,8062	1393,7 *	8,594 *	2,229 *	0,7637	1393,6 *	8,572 *	2,229 *
500	0,8715	1414,0 *	8,662 *	2,260 *	0,8230	1414,0 *	8,645 *	2,260 *	0,7797	1413,9 *	8,624 *	2,260 *

[Continued]

Table II (Continued)

T, °K	$p = 2$ бар				$p = 3$ бар				$p = 4$ бар			
	v	i	s	c_p	v	i	s	c_p	v	i	s	c_p
180	0,001811	419,56	4,363	2,409	0,001811	419,66	4,362	2,402	0,001811	419,75	4,361	2,397
190	0,2691	892,2	6,972	1,324 *	0,001866	443,76	4,492	2,420	0,001866	443,81	4,491	2,411
200	0,2849	903,4	7,032	1,331 *	0,1859	900,0	6,897	1,354 *	0,1362	896,1	6,796	1,384 *
210	0,3008	914,8	7,094	1,340 *	0,1969	912,0	6,959	1,360 *	0,1448	908,4	6,860	1,390 *
220	0,3165	926,6	7,154	1,352 *	0,2077	924,1	7,020	1,371 *	0,1532	921,0	6,923	1,398 *
230	0,3320	938,6	7,216	1,368	0,2185	936,6	7,084	1,385 *	0,1614	933,6	6,986	1,408
240	0,3475	951,0	7,267	1,388	0,2290	949,0	7,145	1,405	0,1714	946,4	7,050	1,422
250	0,3630	963,8	7,337	1,408	0,2394	962,0	7,206	1,410	0,1775	959,6	7,112	1,441
260	0,3784	977,2	7,396	1,444	0,2499	975,6	7,266	1,456	0,1856	973,4	7,173	1,470
270	0,3937	991,5	7,454	1,475	0,2603	990,0	7,326	1,488	0,1936	987,8	7,234	1,500
280	0,4088	1006,0	7,512	1,505	0,2705	1004,6	7,385	1,515	0,2013	1002,5	7,294	1,526
290	0,4243	1021,2	7,569	1,541	0,2810	1019,9	7,442	1,551	0,2094	1018,0	7,353	1,562
300	0,4396	1037,3	7,622	1,578	0,2914	1035,6	7,498	1,587	0,2173	1033,9	7,409	1,596
310	0,4548	1053,6	7,676	1,612	0,3016	1052,1	7,552	1,621	0,2250	1050,7	7,464	1,630
320	0,4699	1070,1	7,729	1,647	0,3118	1068,7	7,605	1,655	0,2328	1067,3	7,517	1,663
330	0,4850	1086,8	7,779	1,682	0,3219	1085,5	7,656	1,689	0,2405	1084,2	7,568	1,696
340	0,5001	1103,8	7,830	1,718	0,3321	1102,6	7,708	1,724	0,2482	1101,3	7,620	1,730
350	0,5152	1121,3	7,881	1,752	0,3423	1120,1	7,758	1,758	0,2558	1118,9	7,661	1,763
360	0,5302	1139,1	7,931	1,788	0,3524	1138,0	7,809	1,793	0,2634	1136,9	7,722	1,798
370	0,5452	1157,4	7,982	1,824	0,3625	1156,3	7,859	1,829	0,2711	1155,3	7,772	1,834
380	0,5602	1175,9	8,031	1,858	0,3725	1174,3	7,909	1,863	0,2787	1173,9	7,822	1,867
390	0,5752	1194,8	8,080	1,895	0,3826	1193,9	7,958	1,898	0,2862	1193,0	7,871	1,902
400	0,5902	1214,0	8,128	1,932	0,3926	1213,1	8,007	1,935	0,2938	1212,2	7,920	1,939
410	0,6052	1233,5	8,176	1,966	0,4026	1232,6	8,055	1,969	0,3014	1231,8	7,968	1,972
420	0,6202	1253,3	8,224	2,002	0,4127	1252,5	8,103	2,005	0,3089	1251,6	8,016	2,008
430	0,6351	1273,4	8,271	2,034	0,4227	1272,4	8,149	2,037	0,3165	1271,5	8,062	2,040
440	0,6501	1293,7	8,318	2,068	0,4328	1292,7	8,196	2,071	0,3241	1291,7	8,109	2,073
450	0,6651	1314,4	8,364	2,102	0,4428	1313,3	8,242	2,104	0,3317	1312,2	8,155	2,107
460	0,6802	1333,9 *	8,410 *	2,134	0,4529	1331,1 *	8,285 *	2,136	0,3393	1330,1 *	8,200 *	2,138
470	0,6952	1354,1 *	8,455 *	2,166	0,4631	1350,6 *	8,330 *	2,168	0,3469	1349,6 *	8,250 *	2,170
480	0,7104	1374,0 *	8,500 *	2,199 *	0,4732	1368,7 *	8,380 *	2,201 *	0,3546	1367,7 *	8,295 *	2,203 *
490	0,7255	1393,5 *	8,545 *	2,229 *	0,4834	1390,5 *	8,425 *	2,231 *	0,3624	1389,5 *	8,340 *	2,233 *
500	0,7407	1413,8 *	8,590 *	2,260 *	0,4937	1402,2 *	8,470 *	2,262 *	0,3701	1401,2 *	8,390 *	2,264 *

[Continued]

Table II (Continued)

T, °K	$p = 5$ бар				$p = 6$ бар				$p = 7$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001811	419,85	4,360	2,395	0,001811	419,94	4,359	2,390	0,001810	420,04	4,358	2,386
190	0,001865	443,86	4,490	2,410	0,001864	443,92	4,489	2,404	0,001864	443,97	4,488	2,400
200	0,001922	468,10	4,615	2,453	0,001921	468,12	4,613	2,440	0,001921	468,14	4,611	2,432
210	0,1135	905,4	6,779	1,420 *	0,0925	902,5	6,714	1,448 *	0,001885	492,68	4,730	2,495
220	0,1204	918,0	6,843	1,424 *	0,0984	915,5	6,780	1,449 *	0,0827	912,8	6,722	1,471 *
230	0,1272	930,8	6,908	1,431	0,1043	928,3	6,848	1,453	0,0879	925,9	6,789	1,474 *
240	0,1338	943,8	6,972	1,442	0,1100	941,3	6,914	1,462	0,0930	939,1	6,856	1,483
250	0,1405	957,2	7,036	1,459	0,1157	954,8	6,979	1,477	0,0979	952,7	6,922	1,488
260	0,1470	971,0	7,099	1,484	0,1212	968,8	7,042	1,500	0,1018	966,6	6,986	1,516
270	0,1594	985,4	7,160	1,513	0,1263	983,5	7,104	1,527	0,1072	981,5	7,050	1,542
280	0,1598	1000,5	7,221	1,538	0,1322	998,6	7,164	1,549	0,1124	996,6	7,112	1,562
290	0,1664	1016,0	7,281	1,573	0,1377	1014,0	7.224	1,583	0,1173	1012,3	7,172	1,594
300	0,1728	1032,2	7,339	1,606	0,1431	1030,4	7,281	1,616	0,1219	1028,7	7,201	1,626
310	0,1791	1049,1	7,394	1,639	0,1484	1047,6	7,337	1,648	0,1266	1046,1	7,288	1,657
320	0,1853	1065,9	7,448	1,671	0,1537	1064,5	7,391	1,680	0,1311	1063,0	7,342	1,688
330	0,1916	1082,9	7,499	1,704	0,1589	1081,5	7,442	1,712	0,1357	1080,2	7,394	1,720
340	0,1978	1100,1	7,551	1,737	0,1642	1098,7	7,494	1,744	0,1402	1097,6	7,446	1,750
350	0,2039	1117,7	7,602	1,769	0,1694	1116,5	7,546	1,775	0,1446	1115,3	7,498	1,781
360	0,2101	1135,8	7,653	1,804	0,1745	1134,5	7,597	1,809	0,1491	1133,5	7,549	1,814
370	0,2162	1154,2	7,705	1,838	0,1797	1153,2	7,648	1,842	0,1536	1152,1	7,600	1,847
380	0,2223	1173,0	7,754	1,872	0,1848	1172,0	7,698	1,876	0,1580	1171,0	7,651	1,880
390	0,2284	1192,0	7,804	1,906	0,1899	1191,1	7,748	1,910	0,1624	1190,2	7,701	1,914
400	0.2345	1211,3	7,852	1,942	0,1950	1210,4	7,797	1,946	0,1668	1209,4	7,749	1,919
410	0,2406	1230,9	7,900	1,976	0,2001	1230,0	7,845	1,978	0,1712	1229,1	7,797	1,982
420	0,2467	1250,6	7,948	2,010	0,2052	1249,8	7,893	2,013	0,1756	1249,0	7,845	2,016
430	0,2528	1270,6	7,995	2,043	0,2103	1269,7	7,939	2,046	0,1800	1268,8	7,892	2,049
440	0,2589	1290,8	8,041	2,076	0,2154	1289,8	7,995	2,079	0,1844	1288,9	7,938	2,082
450	0,2650	1310,5 *	8,085 *	2,109	0,2205	1309,5 *	8,040 *	2,111	0,1888	1308,6 *	7,985 *	2,113
460	0,2711	1331,0 *	8,130 *	2,140	0,2257	1330,1 *	8,085 *	2,142	0,1932	1329,2 *	8,030 *	2,144
470	0,2773	1350,5 *	8,180 *	2,173	0,2308	1349,6 *	8,130 *	2,175	0,1976	1348,7 *	8,075 *	2,177
480	0,2835	1368,5 *	8,225 *	2,206 *	0,2360	1367,6 *	8,180 *	2,208 *	0,2021	1366,7 *	8,120 *	2,210 *
490	0,2897	1390,3 *	8,275 *	2,236 *	0,2413	1389,4 *	8,230 *	2,230 *	0,2066	1388,5 *	8,170 *	2,240 *
500	0,2960	1402,0 *	8,320 *	2,267 *	0,2465	1401,1 *	8,275 *	2,269 *	0,2112	1400,2 *	8,225 *	2,271 *

[Continued]

Table II (Continued)

T, °K	$p = 8$ бар				$p = 9$ бар				$p = 10$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001810	420,13	4,357	2,383	0,001809	420,23	4,356	2,380	0,001808	420,32	4,356	2,377
190	0,001863	444,03	4,487	2,396	0,001863	444,09	4,486	2,393	0,001862	444,16	4,485	2,390
200	0,001920	468,16	4,610	2,428	0,001919	468,19	4,609	2,422	0,001919	468,23	4,608	2,420
210	0,001885	492,68	4,729	2,488	0,001884	492,68	4,728	2,482	0,001983	492,68	4,727	2,477
220	0,0709	910,1	6,674	1,504 *	0,0616	907,6	6,630	1,536 *	0,002055	517,95	4,844	2,576
230	0,0755	923,2	6,743	1,504 *	0,0659	920,9	6,700	1,531 *	0,0581	918,6	6,660	1,564 *
240	0,0801	936,7	6,810	1,516	0,0701	934,4	6,767	1,532	0,0620	932,0	6,728	1,560
250	0,0846	950,3	6,877	1,510	0,0742	948,3	6,834	1,538	0,0658	946,0	6,795	1,563
260	0,0890	964,5	6,942	1,532	0,0782	962,2	6,900	1,550	0,0695	960,1	6,862	1,569
270	0,09299	979,3	7,006	1,557	0,08190	977,2	6,964	1,568	0,07303	975,1	6,926	1,587
280	0,09758	994,6	7,078	1,574	0,08604	992,6	7,027	1,591	0,07681	990,6	6,990	1,603
290	0,1019	1010,2	7,129	1,606	0,08994	1008,5	7,088	1,618	0,08037	1006,6	7,053	1,630
300	0,1061	1027,0	7,187	1,637	0,09369	1025,2	7,148	1,648	0,08379	1023,5	7,113	1,659
310	0,1101	1044,5	7,244	1,667	0,09737	1042,9	7,206	1,677	0,08714	1041,4	7,171	1,687
320	0,1142	1061,6	7,299	1,697	0,1010	1060,2	7,261	1,706	0,09044	1058,7	7,234	1,715
330	0,1182	1078,8	7,351	1,728	0,1046	1077,5	7,314	1,736	0,09371	1076,1	7,279	1,744
340	0,1222	1096,3	7,404	1,756	0,1082	1095,0	7,366	1,764	0,09696	1093,7	7,332	1,772
350	0,1261	1114,1	7,456	1,788	0,1117	1112,9	7,418	1,794	0,1002	1111,7	7,385	1,800
360	0,1301	1132,4	7,507	1,819	0,1152	1131,3	7,470	1,825	0,1034	1130,1	7,437	1,831
370	0,1340	1151,1	7,559	1,852	0,1187	1150,0	7,522	1,857	0,1065	1148,9	7,489	1,862
380	0,1379	1170,0	7,609	1,884	0,1222	1169,0	7,572	1,888	0,1097	1168,0	7,539	1,893
390	0,1418	1189,2	7,659	1,917	0,1257	1188,3	7,623	1,921	0,1129	1187,3	7,590	1,925
400	0,1456	1208,6	7,708	1,952	0,1292	1207,7	7,671	1,955	0,1160	1206,8	7,639	1,958
410	0,1495	1228,3	7,756	1,984	0,1326	1227,4	7,720	1,988	0,1191	1226,5	7,687	1,991
420	0,1539	1248,1	7,804	2,019	0,1361	1247,3	7,767	2,022	0,1222	1246,4	7,735	2,025
430	0,1572	1267,9	7,851	2,052	0,1395	1267,1	7,814	2,054	0,1253	1266,2	7,781	2,057
440	0,1611	1287,9	7,897	2,085	0,1430	1287,0	7,860	2,087	0,1285	1286,1	7,827	2,090
450	0,1649	1307,8 *	7,945 *	2,115	0,1464	1306,9 *	7,910 *	2,117	0,1316	1306,0 *	7,875 *	2,120
460	0,1688	1328,3 *	7,990 *	2,146	0,1499	1327,4 *	7,955 *	2,148	0,1347	1326,5 *	7,920 *	2,150
470	0,1728	1347,8 *	8,035 *	2,179	0,1534	1346,9 *	8,003 *	2,181	0,1379	1346,0 *	7,970 *	2,183
480	0,1767	1365,8 *	8,080 *	2,212 *	0,1569	1364,9 *	8,055 *	2,214 *	0,1411	1364,0 *	8,020 *	2,216 *
490	0,1807	1387,6 *	8,125 *	2,242 *	0,1605	1386,7 *	8,105 *	2,244 *	0,1443	1385,8 *	8,074 *	2,246 *
500	0,1847	1399,3 *	8,175 *	2,273 *	0,1641	1398,4 *	8,150 *	2,275 *	0,1476	1397,5 *	8,125 *	2,277 *

[Continued]

Table II (Continued)

T, °K	p = 11 бар				p = 12 бар				p = 13 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001808	420,42	4,355	2,374	0,001808	420,51	4,355	2,371	0,001808	420,60	4,355	2,368
190	0,001862	444,22	4,484	2,387	0,001861	444,30	4,483	2,384	0,001860	444,38	4,483	2,382
200	0,001918	468,27	4,607	2,415	0,001917	468,32	4,606	2,412	0,001917	468,38	4,605	2,410
210	0,001882	492,69	4,726	2,473	0,001881	492,70	4,725	2,469	0,001881	492,71	4,724	2,465
220	0,002054	517,90	4,844	2,570	0,002054	517,86	4,843	2,564	0,002053	517,82	4,843	2,556
230	0,0517	916,3	6,624	1,620 *	0,0463	914,0	6,589	1,682 *	0,0417	911,9	6,557	2,788 *
240	0,0554	930,0	6,693	1,604 *	0,0499	928,0	6,658	1,653 *	0,0451	925,9	6,628	1,716 *
250	0,0590	943,8	6,760	1,595	0,0532	942,0	6,726	1,632	0,0484	939,8	6,696	1,674
260	0,0624	958,0	6,826	1,595	0,0565	956,3	6,794	1,632	0,0515	954,0	6,764	1,642
270	0,06577	973,0	6,872	1,606	0,05973	971,2	6,860	1,625	0,05460	969,2	6,830	1,644
280	0,06925	988,6	6,956	1,618	0,06295	986,8	6,924	1,635	0,05761	984,9	6,895	1,652
290	0,07253	1004,7	7,019	1,643	0,06600	1003,0	6,988	1,657	0,06047	1001,1	6,960	1,672
300	0,07569	1021,7	7,080	1,670	0,06893	1019,9	7,050	1,683	0,06321	1018,1	7,022	1,696
310	0,07877	1039,8	7,139	1,698	0,07180	1038,2	7,110	1,709	0,06589	1036,5	7,083	1,720
320	0,08181	1057,2	7,196	1,724	0,07461	1055,8	7,166	1,734	0,06852	1054,3	7,139	1,744
330	0,08481	1074,7	7,248	1,752	0,07733	1073,4	7,219	1,761	0,07112	1071,9	7,193	1,770
340	0,08779	1092,4	7,302	1,779	0,08015	1091,1	7,273	1,786	0,07368	1089,8	7,247	1,794
350	0,09074	1110,5	7,354	1,806	0,08288	1109,3	7,326	1,813	0,07622	1108,2	7,299	1,820
360	0,09367	1129,0	7,406	1,836	0,08559	1127,8	7,378	1,842	0,07874	1126,7	7,355	1,848
370	0,09658	1147,9	7,458	1,866	0,08827	1146,8	7,430	1,871	0,08124	1145,7	7,405	1,876
380	0,09918	1167,0	7,509	1,898	0,09094	1166,0	7,482	1,903	0,08372	1165,0	7,456	1,907
390	0,1023	1186,4	7,560	1,929	0,09359	1185,5	7,532	1,933	0,08618	1184,5	7,507	1,937
400	0,1052	1205,9	7,609	1,962	0,09623	1205,0	7,581	1,966	0,08863	1204,1	7,556	1,969
410	0,1081	1225,7	7,657	1,994	0,09886	1224,8	7,630	1,998	0,09107	1223,9	7,605	2,001
420	0,1109	1245,5	7,705	2,028	0,1015	1244,7	7,678	2,031	0,09351	1243,8	7,653	2,034
430	0,1138	1265,3	7,752	2,060	0,1041	1264,4	7,724	2,063	0,09594	1263,6	7,699	2,066
440	0,1166	1285,2	7,797	2,093	0,1067	1284,3	7,770	2,096	0,09837	1282,4	7,745	2,098
450	0,1195	1305,1 *	7,840 *	2,123	0,1094	1304,2 *	7,820 *	2,125	0,1008	1303,3 *	7,790 *	2,128
460	0,1223	1325,6 *	7,890 *	2,152	0,1120	1324,7 *	7,875 *	2,155	0,1032	1323,8 *	7,835 *	2,158
470	0,1252	1345,1 *	7,935 *	2,185	0,1147	1344,2 *	7,910 *	2,187	0,1057	1343,3 *	7,880 *	2,189
480	0,1281	1365,8 *	7,980 *	2,218 *	0,1173	1364,9 *	7,960 *	2,220 *	0,1082	1364,0 *	7,930 *	2,222 *
490	0,1311	1384,9 *	8,030 *	2,248 *	0,1200	1384,0 *	8,005 *	2,250 *	0,1107	1383,1 *	7,975 *	2,262 *
500	0,1340	1396,6 *	8,075 *	2,279 *	0,1228	1395,7 *	8,050 *	2,281 *	0,1132	1394,8 *	8,025 *	2,282 *

[Continued]

Table II (Continued)

T, °K	$p = 14$ бар				$p = 15$ бар				$p = 16$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001807	420,70	4,355	2,366	0,001807	420,80	4,355	2,365	0,001807	420,89	4,355	2,365
190	0,001860	444,46	4,883	2,381	0,001859	444,54	4,483	2,380	0,001859	444,62	4,483	2,379
200	0,001916	468,43	4,605	2,406	0,001915	468,48	4,605	2,404	0,001915	468,54	4,605	2,400
210	0,001880	492,73	4,724	2,460	0,001979	492,76	4,724	2,456	0,001878	492,79	4,724	2,452
220	0,002053	517,78	4,843	2,550	0,002052	517,75	4,843	2,545	0,002051	517,72	4,842	2,540
230	0,002140	544,00	4,961	2,697	0,002139	543,90	4,959	2,685	0,002138	543,79	4,957	2,674
240	0,0410	923,0	6,596	1,789 *	0,0374	920,2	6,567	1,858 *	0,0341	917,7	6,540	1,936 *
250	0,0441	937,0	6,677	1,720	0,0404	934,6	6,638	1,771	0,0372	932,0	6,610	1,820
260	0,0471	951,6	6,735	1,674	0,0433	949,3	6,707	1,707	0,0400	947,0	6,681	1,745
270	0,05021	966,7	6,802	1,666	0,04640	964,7	6,774	1,688	0,04306	962,4	6,750	1,714
280	0,05304	982,6	6,868	1,672	0,04906	980,9	6,841	1,692	0,04558	978,6	6,817	1,712
290	0,05572	999,0	6,933	1,687	0,05160	997,3	6,907	1,704	0,04800	995,4	6,884	1,721
300	0,05831	1016,3	6,996	1,709	0,05405	1014,5	6,971	1,722	0,05033	1012,6	6,948	1,736
310	0,06083	1031,9	7,057	1,732	0,05643	1033,2	7,033	1,744	0,05259	1031,3	7,010	1,757
320	0,06330	1052,8	7,114	1,755	0,05877	1051,2	7,090	1,766	0,05480	1049,7	7,068	1,777
330	0,06573	1070,6	7,168	1,779	0,06107	1069,1	7,144	1,788	0,05698	1067,7	7,122	1,798
340	0,06814	1088,8	7,222	1,802	0,06333	1087,2	7,199	1,811	0,05913	1085,8	7,177	1,819
350	0,07052	1106,8	7,275	1,822	0,06557	1105,6	7,252	1,834	0,06125	1104,3	7,236	1,842
360	0,07238	1125,5	7,328	1,854	0,06779	1124,4	7,305	1,860	0,06334	1123,2	7,284	1,866
370	0,07521	1141,6	7,381	1,881	0,06999	1143,5	7,358	1,887	0,06542	1142,5	7,337	1,892
380	0,07753	1163,9	7,432	1,912	0,07217	1162,9	7,410	1,916	0,06747	1161,9	7,389	1,921
390	0,07983	1183,5	7,483	1,941	0,07433	1182,6	7,461	1,945	0,06951	1181,6	7,440	1,950
400	0,08212	1203,2	7,532	1,973	0,07648	1202,3	7,510	1,976	0,07154	1201,4	7,490	1,980
410	0,08440	1223,0	7,581	2,004	0,07861	1222,1	7,559	2,007	0,07355	1221,3	7,539	2,011
420	0,08667	1242,9	7,629	2,036	0,08074	1242,1	7,607	2,039	0,07556	1241,2	7,587	2,043
430	0,08894	1262,7	7,676	2,068	0,08287	1261,8	7,653	2,071	0,07756	1261,0	7,633	2,073
440	0,09120	1282,6	7,721	2,100	0,08499	1281,7	7,699	2,102	0,07956	1280,8	7,678	2,105
450	0,09348	1302,4 *	7,770 *	2,130	0,08712	1301,6 *	7,750 *	2,132	0,08156	1300,1 *	7,720 *	2,135
460	0,09576	1322,9 *	7,825 *	2,160	0,08926	1321,0 *	7,790 *	2,162	0,08358	1320,3 *	7,770 *	2,165
470	0,09806	1342,4 *	7,860 *	2,191	0,09142	1341,5 *	7,830 *	2,194	0,08560	1340,6 *	7,825 *	2,196
480	0,1004	1363,1 *	7,915 *	2,223 *	0,09358	1362,2 *	7,880 *	2,225 *	0,08764	1361,3 *	7,875 *	2,227 *
490	0,1027	1382,2 *	7,950 *	2,254 *	0,09577	1381,3 *	7,930 *	2,255 *	0,08970	1380,5 *	7,920 *	2,251 *
500	0,1051	1393,9 *	8,002 *	2,284 *	0,09798	1393,0 *	7,975 *	2,285 *	0,09178	1392,1 *	7,960 *	2,287 *

[Continued]

Table II (Continued)

T,° K	p = 17 бар				p = 18 бар				p = 19 бар			
	v	i	s	C_p	v	i	s	G_p	v	i	s	O_p
180	0,001807	420,99	4,355	2,365	0,001806	421,08	4,355	2,365	0,001806	421,18	4,355	2,365
190	0,001858	444,70	4,483	2,378	0,001858	444,81	4,483	2,377	0,001857	444,90	4,483	2,376
200	0,001914	468,61	4,605	2,398	0,001913	468,68	4,605	2,395	0,001913	468,75	4,605	2,394
210	0,001878	492,82	4,723	2,449	0,001877	492,86	4,723	2,445	0,001876	492,91	4,723	2,440
220	0,002050	517,71	4,841	2,533	0,002049	517,70	4,840	2,526	0,002047	517,69	4,839	2,520
230	0,002136	543,69	4,955	2,663	0,002134	543,58	4,953	2,552	0,002132	543,49	4,951	2,541
240	0,0312	914,6	6,510	2,038 *	0,002243	571,35	5,070	2,912	0,002240	571,16	5,070	2,897
250	0,0343	929,4	6.583	1,875	0,0316	926,2	6,555	1,937	0,0292	923,4	6,528	2,005
260	0,0370	944,6	6.654	1,784	0,0344	941,6	6,628	1,827	0,0319	939,2	6.603	1,874
270	0,04011	960,0	6,724	1,741	0,03747	957,2	6,699	1,772	0,03511	955,4	6,675	1,807
280	0,04251	976,4	6,792	1,734	0,03977	973.8	6,670	1,756	0,03731	972.1	6,746	1,783
290	0,04481	993,2	6,860	1,739	0,04198	991,0	6,838	1,758	0,03943	989,4	6,815	1,778
300	0,04703	1010,8	6,925	1,752	0,04411	1008,9	6,904	1,767	0,04148	1007,0	6,883	1,784
310	0,04919	1029,9	6,988	1,770	0,04617	1028,2	6,967	1,784	0,04347	1026,5	6,947	1,798
320	0,05130	1048,1	7,046	1,788	0,04819	1046,6	7,026	1,801	0,04541	1045,0	7,006	1,813
330	0,05338	1066,1	7,101	1,808	0,05017	1064,8	7,081	1,818	0,04730	1063,4	7,062	1,829
340	0,05541	1084,5	7,156	1,828	0,05211	1083,1	7,136	1,836	0,04916	1081,8	7,117	1,846
350	0,05743	1103,1	7,210	1,849	0,05403	1101,8	7,190	1,856	0,05099	1100,5	7,172	1,864
360	0,05942	1122,0	7,263	1,872	0,05592	1120,8	7,244	1,879	0,05280	1119,6	7,226	1,886
370	0,06138	1141,3	7,317	1,898	0,05780	1140,2	7,298	1,904	0,05459	1139,1	7,279	1,910
380	0,06333	1160,9	7,369	1,926	0,05965	1159,8	7,350	1,930	0,05635	1158,8	7,332	1,935
390	0,06526	1180,6	7,420	1,954	0,06148	1179,6	7,401	1,958	0,05810	1178,7	7,384	1,962
400	0,06718	1200,4	7,470	1,984	0,06330	1199,5	7,451	1,988	0,05984	1198,6	—	1,991
410	0,06908	1220,4	7,519	2.015	0,06511	1219,5	7,500	2,018	0,06156	1218,6	7,483	2.021
420	0,07098	1210,4	7,567	2,046	0,06691	1239,5	7,549	2,049	0,06328	1238,6	7,551	2,052
430	0,07287	1260,1	7,614	2,076	0,06871	1259,3	7,595	2,079	0,06498	1258,4	7,578	2,082
440	0,07477	1280,0	7,659	2,108	0,07050	1279,1	7,641	2,111	0,06669	1278,3	7,623	2,113
450	0,07666	1299,9 *	7,700 *	2,138	0,07230	1299,0 *	7,675 *	2,140	0,06840	1298,1 *	7,660 *	2,143
460	0,07856	1319,5 *	7,750 *	2,167	0,07410	1318,6 *	7,725 *	2,170	0,07011	1317,8 *	7,710 *	2,172
470	0,08047	1339,8 *	7,795 *	2,198	0,07591	1339,0 *	7,775 *	2,200	0,07183	1338,2 *	7,750 *	2,203
480	0,08239	1360,4 *	7,840 *	2,229 *	0,07773	1359,5 *	7,820 *	2,231 *	0,07356	1358,7 *	7,800 *	2,233 *
490	0,08434	1379,7 *	7,885 *	2,258 *	0,07957	1378,9 *	7,865 *	2,260 *	0,07530	1378,1 *	7,850 *	2,262 *
500	0,08630	1391,3 *	7,935 *	2,288 *	0,08142	1390,5 *	7,915 *	2,290 *	0,07706	1389,6 *	7,895 *	2,291 *

[Continued]

Table II (Continued)

T, °K	$p = 20$ бар				$p = 25$ бар				$p = 30$ бар			
	v	i	s	c_p	v	i	s	c_p	v	i	s	c_p
180	0,001806	421,27	4,355	2,365	0,001804	421,75	4,355	2,365	0,001803	422,22	4,355	2,365
190	0,001857	445,00	4,483	2,375	0,001855	445,47	4,483	2,373	0,001852	445,94	4,483	2,372
200	0,001912	468,83	4,605	2,390	0,001909	469,22	4,605	2,385	0,001906	469,68	4,605	2,384
210	0,001975	492,96	4,723	2,436	0,001972	493,27	4,722	2,420	0,001968	493,68	4,722	2,418
220	0,002047	517,70	4,839	2,515	0,002042	517,82	4,836	2,488	0,002037	518,11	4,836	2,470
230	0.002130	543,41	4,951	2,630	0,002125	543,18	4,949	2,585	0,002118	543,28	4,948	2,557
240	0.002238	570,98	5,070	2,884	0,002230	570,17	5,064	2,816	0,002220	569,83	5,061	2,755
250	0,0270	920,0	6,501	2,084	0,002365	600,36	5,187	3,224	0,002352	599,24	5,181	3,126
260	0,0297	936,4	6,580	1,926	0,02290	919,1	6,460	2,311	0,01692	900,0	6,340	—
270	0,03298	953,2	6,653	1,848	0,02472	938,0	6,540	2,093	0,01887	923,0	6,436	2,535
280	0.03509	970,1	6,726	1,814	0,02659	957,0	6,621	1,986	0,02076	944,8	6,526	2,235
290	0,03714	987,4	6,796	1,799	0,02838	976,7	6,700	1,926	0,02245	965,6	6,613	2,101
300	0,03912	1005,1	6,864	1,802	0,03010	995,2	6,773	1,901	0,02404	985,7	6,693	2,029
310	0,04103	1021,7	6,928	1,814	0,03175	1015,8	6,841	1,894	0,02552	1006,3	6,769	1,991
320	0,04290	1043,4	6,988	1,826	0,03334	1035,2	6,903	1,897	0,02695	1026,7	6,829	1,978
330	0,04472	1061,9	7,013	1,840	0,03489	1054,4	6,961	1,900	0,02831	1046,5	6,889	1,969
340	0,04650	1080,4	7,099	1,856	0,03639	1073,5	7,018	1,906	0,02963	1066,3	6,919	1,964
350	0,04826	1099,3	7,154	1,873	0,03786	1092,8	7,074	1,915	0.03092	1086,2	7,006	1,963
360	0,04999	1118,5	7,208	1,893	0,03930	1112,4	7,130	1,930	0,03217	1106,3	7,068	1,970
370	0,05170	1138,0	7,262	1,916	0,04072	1132,4	7,185	1,946	0,03340	1126,6	7,119	1,981
380	0,05339	1157,8	7,314	1,940	0,04212	1152,4	7,238	1,967	0,03460	1147,0	7,174	1,997
390	0,05506	1177,7	7,367	1,967	0,04350	1172,7	7,291	1,989	0,03579	1167,6	7,227	2,014
400	0.05672	1197,7	7,417	1,995	0,04487	1192,9	7,342	2,015	0,03697	1188,2	7,279	2,036
410	0,05836	1217,7	7,466	2,025	0,04622	1213,2	7,392	2,043	0,03812	1208,7	7,330	2,062
420	0,06000	1237,8	7,515	2,055	0,04756	1233,5	7,441	2,072	0,03927	1229,2	7,379	2,089
430	0,06163	1257,6	7,561	2,086	0,04889	1253,3	7,487	2,102	0,04040	1249,4	7,426	2,117
440	0,06326	1277,5	7,606	2,116	0,05022	1273,4	7,533	2,131	0,4153	1269,4	7,472	2,145
450	0,06488	1297,3	7,651	2,145	0.05154	1293,4	7,578	2,159	0,04265	1289,2	7,517	2,171
460	0,06652	1315,6 *	7,720 *	2,174	0,05286	1312,0 *	7,625 *	2,187	0,04376	1308,4 *	7,565 *	2,199
470	0,06815	1337,6 *	7,740 *	2,205	0,05419	1334,0 *	7,670 *	2,216	0,04488	1330,4 *	7,610 *	2,228
480	0,06980	1357,0 *	7,790 *	2,234 *	0,05551	1353,5 *	7,715 *	2,244 *	0,04599	1350,0 *	7,55 *	2,256 *
490	0,07146	1376,5 *	7,835 *	2,263 *	0,05685	1373,1 *	7,765 *	2,273 *	0,04581	1350,0 *	7,655 *	2,256 *
500	0,7314	1397,6 *	7,880 *	2,292 *	0,05820	1394,2 *	7,810 *	2,302 *	0,04823	1390,8 *	7,750 *	2,314 *

[Continued]

Table II (Continued)

T, ° K	$p = 35$ бар				$p = 40$ бар				$p = 45$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001302	422,70	4,355	2,365	0,001801	423,16	4,355	2,365	0,001800	423,64	4,355	2,365
190	0,001850	446,10	4,483	2,371	0,001848	446,87	4,483	2,370	0,001846	447,34	4,483	2,370
200	0.001903	470,14	4,605	2,383	0,001901	470,61	4.605	2,382	0,001898	471,08	4,605	2,381
210	0,001965	491,13	4,722	2,416	0.001961	494,60	4,722	2,414	0,001958	495,05	4.722	2,412
220	0,002032	518,51	4,835	2,461	0,002028	518,93	4,835	2,460	0,002023	519.37	4,835	2.457
230	0,002112	543,60	4,917	2,545	0.002106	543,95	4,946	2,539	0,002100	544,34	4,946	2,534
240	0,002211	569,85	5,058	2,714	0,002202	570,09	5,057	2,690	0,002191	570,41	5,057	2,675
250	0,002339	598,78	5,175	3,012	0,002325	598,16	5,173	2,985	0,002312	598,45	5,171	2,955
260	0,002512	631,54	5,305	3,575	0,002187	630,60	5,299	3,442	0,002165	630,10	5,297	3,362
270	0,01102	892,7	6,328	3,395	0,002786	671,93	5,454	4,825	0,002722	669,28	5,444	4,475
280	0,01537	921,0	6.437	2,650	0,01275	906,0	6,334	3,429	0,009215	875,0	6,103	—
290	0,01812	947,6	6,534	2,349	0,01474	933,0	6,450	2,725	0,01194	915,9	6,360	—
300	0,01964	973,2	6.619	2,196	0,01628	960,5	6,546	2,425	0,01360	946,3	6,474	2,744
310	0,02104	996.2	6,694	2,117	0,01761	985.3	6,628	2,276	0,01496	973,6	6,564	2,474
320	0,02236	1017,7	6.768	2.074	0,01889	1008,1	6,701	2,193	0.01617	998,1	6,642	2,336
330	0,02360	1038,4	6.826	2.047	0.02006	1029,9	6,767	2,141	0,01728	1021,0	6,712	2,251
340	0,02480	1058,9	6,887	2,027	0,02116	1051,2	6,831	2,104	0,01833	1043,3	6,779	2,188
350	0,02595	1079,4	6,946	2.017	0,02222	1072,3	6,892	2,080	0,01932	1065,1	6,842	2,144
360	0,02707	1099,9	7,005	2,014	0,02325	1093,5	6,952	2,065	0,02027	1086.9	6,903	2,118
370	0,02817	1120,7	7,062	2,017	0,02424	1114,7	7,011	2,060	0,02119	1108,6	6,963	2,103
380	0,02924	1141,6	7,118	2,026	0,02521	1136,0	7,067	2,063	0,02208	1130,3	7,021	2,098
390	0,03029	1162,5	7,172	2,041	0,02616	1157,2	7,123	2,072	0,02296	1151,9	7,078	2,101
400	0,03133	1183,3	7,225	2,060	0,02710	1178,5	7,176	2,086	0,02381	1173,5	7,132	2,111
410	0,03235	1201,2	7,275	2,083	0,02801	1199,6	7,228	2,105	0,02465	1195,0	7,184	2,128
420	0,03335	1224,9	7,325	2,108	0,02891	1220,5	7,289	2,128	0,02547	1216,2	7,236	2,147
430	0,03434	1245,3	7,374	2,134	0,02980	1241,3	7,327	2,152	0,02627	1237,2	7,285	2,168
440	0,03533	1265.6	7,420	2,160	0,03068	1261.7	7,374	2,177	0,02707	1257,9	7,332	2,191
450	0,03630	1285,5	7,465	2,185	0,03155	1281,9	7,419	2,201	0,02785	1278,3	7,378	2,217
460	0,03727	1304,8 *	7,510 *	2,212	0,03240	1301,2 *	7,465 *	2,226	0,02862	1297,6 *	7,425 *	2,240
470	0,03823	1326,8 *	7,555 *	2,240	0,03325	1323,2 *	7,515 *	2,253	0,02939	1319,6 *	7,475 *	2,266
480	0,03919	1316,5 *	7,605 *	2,268 *	0,03409	1343,0 *	7,560 *	2,281 *	0,03014	1339,5 *	7,520 *	2,293 *
490	0,04015	1366,3 *	7,650 *	2,296 *	0,03493	1362,9 *	7,610 *	2,308 *	0,03089	1359,5 *	7,565 *	2,320 *
500	0,04110	1387,4 *	7,700 *	2,324 *	0,03577	1384,0 *	7,660 *	2,336 *	0,03163	1380,6 *	7,615 *	2,347 *

[Continued]

Table II (Continued)

T, ° K	$p = 50$ бар				$p = 55$ бар				$p = 60$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001799	424,12	4,355	2,365	0,001797	424,59	4,3552	2,355	0,001796	425,06	4,355	2,365
190	0,001844	447,81	4,483	2,370	0,001842	448,28	4,483	2,370	0,001840	448,74	4,483	2,370
200	0,001896	471,55	4,605	2,380	0,001893	472,02	4,605	2,380	0,001891	472,49	4,605	2,380
210	0,001955	495,52	4,722	2,410	0,001951	495,96	4,722	2,408	0,001948	496,42	4,722	2,407
220	0,002019	519,80	4,835	2,454	0,002015	520,25	4,835	2,452	0,002011	520,70	4,835	2,450
230	0,002094	544,74	4,946	2,540	0,002089	545,15	4,946	2,527	0,002084	545,58	4,946	2,525
240	0,002186	570,70	5,056	2,660	0,002178	571,05	5,056	2,656	0,002171	571,44	5,056	2,650
250	0,002300	598,65	5,170	2,935	0,002288	598,96	5,170	2,930	0,002276	599,33	5,170	2,925
260	0,002445	629,94	5,295	3,321	0,002425	630,06	5,293	3,304	0,002406	630,43	5,292	3,300
270	0,002669	667,78	5,435	4,246	0,002628	667,27	5,432	4,120	0,002591	667,13	5,430	4,040
280												
290	0,009472	894,5	6,253		0,007048	879,0	6,106		0,004408	852,0	5,869	
300	0,01137	929,8	6,399	3,215	0,009450	914,1	6,316	3,919	0,007727	888,0	6,222	4,255
310	0,01278	960,9	6,501	2,745	0,01095	946,7	6,435	3,086	0,009382	930,8	6,368	3,523
320	0,01397	987,3	6,585	2,511	0,01216	975,9	6,529	2,727	0,01062	963,5	6,473	2,974
330	0,01505	1011,7	6,659	2,374	0,01322	1001,9	6,608	2,522	0,01168	991,6	6,558	2,692
340	0,01605	1035,0	6,729	2,283	0,01419	1026,5	6,682	2,394	0,01263	1017,6	6,636	2,518
350	0,01699	1057,7	6,795	2,221	0,01509	1050,1	6,750	2,306	0,01350	1042,2	6,707	2,398
360	0,01739	1080,1	6,858	2,180	0,01594	1073,2	6,816	2,249	0,01431	1070,1	6,778	2,320
370	0,01875	1102,3	6,920	2,153	0,01675	1096,0	6,879	2,208	0,01509	1089,6	6,839	2,268
380	0,01958	1124,5	6,977	2,140	0,01754	1118,7	6,939	2,184	0,01583	1112,8	6,901	2,234
390	0,02039	1146,6	7,036	2,135	0,01830	1141,2	6,997	2,174	0,01655	1135,7	6,961	2,215
400	0,02118	1168,5	7,091	2,140	0,01904	1163,5	7,053	2,171	0,01725	1158,3	7,018	2,208
410	0,02195	1190,2	7,145	2,154	0,01976	1185,6	7,108	2,181	0,01793	1180,8	7,073	2,211
420	0,02271	1211,8	7,197	2,170	0,02046	1207,4	7,160	2,196	0,01859	1203,0	7,127	2,220
430	0,02346	1233,1	7,247	2,190	0,02115	1229,0	7,211	2,213	0,01924	1224,9	7,178	2,235
440	0,02418	1254,1	7,294	2,212	0,02183	1250,3	7,260	2,232	0,01987	1246,4	7,227	2,252
450	0,02490	1274,7	7,341	2,233	0,02249	1271,2	7,307	2,253	0,02049	1257,6	7,275	2,270
460	0,02561	1294,0 *	7,390 *	2,255	0,02314	1290,4 *	7,355 *	2,273	0,02110	1286,8 *	7,325 *	2,288
470	0,02630	1316,0 *	7,435 *	2,280	0,02378	1312,4 *	7,410 *	2,293	0,02169	1308,8 *	7,375 *	2,308
480	0,02698	1336,0 *	7,485 *	2,304 *	0,02441	1332,5 *	7,460 *	2,317 *	0,02228	1329,0 *	7,420 *	2,328 *
490	0,02766	1356,1 *	7,530 *	2,329 *	0,02503	1352,7 *	7,506 *	2,340 *	0,02285	1349,3 *	7,470 *	2,350 *
500	0,02832	1377,2 *	7,584 *	2,355 *	0,02564	1373,8 *	7,555 *	2,364 *	0,02341	1370,4 *	7,525 *	2,374 *

[Continued]

Table II (Continued)

T, ° K	p = 65 бар				p = 70 бар				p = 75 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
290	0,003490	743,6	5,737	8,333 *	0,003247	733,4	5,690	6,087 *	0,003111	726,2	5,661	5,129 *
300	0,006147	855,8	6,109	7,945 *	0,004830	821,1	5,984	9,517 *	0,004053	794,2	5,888	8,120 *
310	0,008018	913,0	6,297	4,113	0,006823	892,9	6,220	5,196 *	0,005800	871,0	6,139	6,135 *
320	0,009311	950,3	6,415	3,260	0,008177	936,0	6,358	3,609	0,007193	920,8	6,298	4,013
330	0,01037	980,8	6,509	2,878	0,009218	969,5	6,460	3,091	0,008275	957,5	6,410	3,328
340	0,01130	1008,3	6,591	2,648	0,01017	998,7	6,547	2,790	0,009192	988,9	6,504	2,911
350	0,01215	1034,1	6,666	2,500	0,01100	1025,8	6,626	2,605	0,01001	1017,3	6,586	2,716
360	0,01294	1058,9	6,736	2,402	0,01177	1051,6	6,698	2,486	0,01075	1044,1	6,662	2,574
370	0,01369	1083,1	6,803	2,333	0,01248	1076,4	6,767	2,402	0,01145	1069,8	6,733	2,474
380	0,01440	1100,8	6,866	2,287	0,01317	1100,8	6,832	2,344	0,01210	1094,6	6,799	2,404
390	0,01503	1130,2	6,927	2,261	0,01382	1124,6	6,893	2,308	0,01273	1119,0	6,862	2,358
400	0,01574	1153,2	6,984	2,247	0,01445	1148,0	6,952	2,286	0,01333	1142,9	6,923	2,329
410	0,01638	1176,0	7,040	2,243	0,01506	1171,2	7,009	2,277	0,01392	1166,4	6,980	2,314
420	0,01701	1198,5	7,095	2,248	0,01565	1194,0	7,065	2,277	0,01449	1189,5	7,036	2,307
430	0,01762	1220,7	7,147	2,258	0,01624	1216,5	7,118	2,282	0,01504	1212,2	7,089	2,307
440	0,01822	1242,5	7,197	2,272	0,01680	1238,6	7,168	2,291	0,01558	1234,6	7,141	2,313
450	0,01880	1264,0	7,246	2,288	0,01736	1260,4	7,217	2,305	0,01611	1256,7	7,191	2,324
460	0,01937	1283,2 *	7,295 *	2,305	0,01790	1279,6 *	7,265 *	2,321	0,01663	1276,0 *	7,245 *	2,338
470	0,01993	1305,2 *	7,345 *	2,324	0,01843	1301,6 *	7,320 *	2,340	0,01714	1298,0 *	7,295 *	2,356
480	0,02048	1325,5 *	7,395 *	2,344 *	0,01895	1322,0 *	7,370 *	2,360 *	0,01763	1318,5 *	7,350 *	2,376 *
490	0,02102	1315,9 *	7,445 *	2,364 *	0,01946	1312,5 *	7,425 *	2,381 *	0,01811	1339,1 *	7,400 *	2,397 *
500	0,02154	1367,0 *	7,500 *	2,387 *	0,01995	1363,6 *	7,480 *	2,403 *	0,01858	1360,2 *	7,455 *	2,419 *

1) *Продолжение табл. II*

T, ° K	p = 80 бар				p = 85 бар				p = 90 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
290	0,003016	721,1	5,639	—	0,002944	717,3	5,620	4,172	0,002886	714,3	5,605	3,882
300	0,003665	808,7	5,840	—	0,003440	767,6	5,787	5,640	0,003290	760,1	5,757	5,047
310	0,004989	866,0	6,114	—	0,004411	830,6	5,993	6,503	0,004024	816,2	5,939	5,990
320	0,006349	917,8	6,275	—	0,005641	888,9	6,178	5,003	0,005068	873,6	6,122	5,235

KEY: 1) Table II continued [applies to all following pages]

[Continued]

Table II (Continued)

T, ° K	p = 80 бар				p = 85 бар,				p = 90 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
330	0,007432	956,0	6,389	3,617	0,006703	932,7	6,312	3,853	0,006078	920,2	6,264	4,131
340	0,008342	988,1	6,485	3,098	0,007600	968,4	6,419	3,258	0,006953	958,0	6,378	3,420
350	0,009143	1017,0	6,567	2,831	0,008387	999,8	6,510	2,943	0,007723	991,0	6,474	3,062
360	0,009871	1044,0	6,643	2,668	0,009098	1028,8	6,592	2,769	0,008418	1021,1	6,558	2,863
370	0,01054	1069,6	6,714	2,554	0,009754	1056,2	6,668	2,636	0,009056	1049,3	6,636	2,714
380	0,01118	1094,5	6,780	2,470	0,01037	1082,4	6,737	2,538	0,009652	1076,2	6,708	2,604
390	0,01173	1118,6	6,843	2,414	0,01095	1107,8	6,803	2,468	0,01022	1102,1	6,776	2,526
400	0,01236	1142,2	6,902	2,375	0,01151	1132,5	6,866	2,420	0,01075	1127,2	6,839	2,469
410	0,01292	1165,4	6,959	2,349	0,01205	1156,7	6,925	2,388	0,01127	1151,8	6,899	2,428
420	0,01347	1188,2	7,014	2,335	0,01257	1180,3	6,983	2,368	0,01178	1175,8	6,957	2,401
430	0,01400	1210,7	7,067	2,331	0,01308	1203.7	7,037	2,358	0,01227	1199,3	7,012	2,387
440	0,01452	1232,8	7,117	2,335	0,01358	1226,6	7,089	2,358	0,01275	1222,5	7,065	2,385
450	0,01502	1252,9	7,165	2,344	0,01407	1249,1	7,140	2,365	0,01322	1245,3	7,116	2,390
460	0,01552	1272,4 *	7,215 *	2,358	0,01455	1268,8 *	7,195 *	2,377	0,01368	1265,2 *	7,165 *	2,400
470	0,01601	1294,4 *	7,270 *	2,376	0,01501	1290,8 *	7,245 *	2,395	0,01413	1287,2 *	7,220 *	2,415
480	0,01648	1315,0 *	7,320 *	2,395 *	0,01547	1311,5 *	7,300 *	2,414 *	0,01458	1308,0 *	7,275 *	2,431 *
490	0,01691	1335,7 *	7,370 *	2,416 *	0,01592	1332,3 *	7,350 *	2,434 *	0,01501	1328,9 *	7,325 *	2,452 *
500	0,01739	1356,8 *	7,425 *	2,436 *	0,01635	1353,4 *	7,405 *	2,454 *	0,01543	1350,0 *	7,375 *	2,472 *

Продолжение табл. II

T, ° K	p = 95 бар				p = 100 бар				p = 120 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
290	0,002837	711,9	5,592	3,650 *	0,002794	709,8	5,580	3,454 *	0,002668	704,4	5,513	2,912
300	0,003180	754,5	5,733	4,642 *	0,003094	750,1	5,713	4,346 *	0,002871	738,4	5,654	3,663
310	0,003760	805,3	5,898	5,467 *	0,003572	796,9	5,865	5,040 *	0,003154	776,7	5,777	4,067
320	0,004621	859,9	6,012	5,253 *	0,004281	848,2	6,029	5,110 *	0,003535	818,0	5,910	4,252
330	0,005550	907,9	6,219	4,331 *	0,005111	896,4	6,176	4,453 *	0,004024	860,8	6,041	4,274
340	0,006392	947,6	6,338	3,659 *	0,005907	941,8	6,299	3,803 *	0,004581	902,4	6,165	4,015
350	0,007141	982,1	6,438	3,181	0,006629	973,4	6,403	3,305	0,005152	941,0	6,277	3,663
360	0,007817	1013,4	6,525	2,956	0,007286	1005,7	6,494	3,055	0,005705	976,4	6,377	3,397

[Continued]

Table II (Continued)

T, °K	p = 95 бар				p = 100 бар				p = 120 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
370	0,008439	1042,5	6,606	2,795	0,007890	1035,8	6,577	2,881	0,006229	1009,8	6,469	3,177
380	0,009017	1070,1	6,679	2,675	0,008452	1063,9	6,652	2,751	0,006724	1040,1	6,549	2,990
390	0,009564	1096.5	6,748	2,588	0,008982	1091,0	6,722	2,650	0,007192	1069.2	6,625	2,836
400	0,01008	1122,1	6,813	2,521	0,009486	1117,0	6,788	2,573	0.007637	1096.9	6,695	2,710
410	0,01059	1147,0	6,874	2,470	0,009971	1142,2	6,850	2,513	0,008063	1123,4	6,760	2,601
420	0,01107	1171,2	6,933	2,437	0,01044	1166,7	6.909	2,473	0,008477	1149,4	6,822	2,515
430	0,01155	1195,1	6,988	2,418	0,01090	1190,7	6,965	2,447	0,008881	1173,8	6.880	2,477 *
440	0,01201	1218,4	7,042	2,411	0.01135	1214,3	7,019	2,437	0.009278	1197,9	6,935	2,459 *
450	0,01247	1241,4	7,094	2,412	0.01179	1237,4	7,071	2,437	0,009670	1221,6	6,989	2,453 *
460	0.01291	1261,6 *	7,145 *	2,421	0,01222	1258,0 *	7,125 *	2,444	0,01006	1243.0 *	7,045 *	2,459 *
470	0,01335	1283,6 *	7,200 *	2,437	0.01265	1280.0 *	1,180 *	2,458	0,01044	1255,0 *	7,105 *	2,470 *
480	0,01378	1301,5 *	7,255 *	2,454 *	0.01307	1301,0 *	7,235 *	2,475 *	0,01083	1286,7 *	7,160 *	2,485 *
490	0,01420	1325,5 *	7,310 *	2,473 *	0,01348	1322,1 *	7,290 *	2,492 *	0,01120	1308,3 *	7,215 *	2,505 *
500	0,01461	1346,6 *	7.360 *	2,492 *	0,01388	1343,2 *	7,340 *	2,514 *	0,01158	1330,3 *	7,270 *	2,525 *

Продолжение табл. II

T, °K	p = 140 бар				p = 160 бар				p = 180 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
290	0,002579	701,5	5,514	2,543	0,002511	709,9	5,491	2,263	0,002456	699,1	5,470	2,035
300	0,002736	731,8	5,614	3,301	0,002641	727,7	5,582	3,064	0,002567	724,9	5,555	2,890
310	0,002941	765,8	5,722	3,623	0,002804	758,9	5,680	3,369	0,002704	754,2	5,647	3,097
320	0,003199	802,2	5,839	3.781	0,003000	792,5	5,789	3,492	0,002865	786,1	5,750	3,232
330	0,003517	839,9	5,954	3,835	0,003234	827,0	5,895	3,553	0,003050	818,5	5,850	3,317
340	0,003893	878,2	6,069	3,820	0,003506	862,3	6,001	3,567	0,003262	851,7	5,950	3,363
350	0,004308	916,0	6,179	3,694	0,003813	898,6	6,106	3,537	0,003500	886,8	6,051	3,375
360	0,004739	952.7	6,283	3,461	0,004144	932,9	6,203	3.461	0,003759	919,0	6,142	3,356
370	0,005170	987,9	6,381	3,300	0,004437	966,4	6,300	3.349	0,004034	950,9	6,235	3,290
380	0,005592	1018,3	6,460	3,115	0,004836	999,8	6,384	3,220	0,004320	984,8	6,320	3,211
390	0,005998	1049,0	6,540	2,960	0.005181	1031,3	6,466	3,080	0,004610	1016,4	6,403	3,115
400	0,006388	1078,1	6,613	2,823	0,005519	1061,4	6,542	2,932	0,004900	1047,0	6,480	2,996
410	0,006764	1105,8	6,682	2,704	0,005848	1090,0	6,612	2,790	0,005186	1076,2	6,552	2,854
420	0,007128	1132,3	6,746	2,593	0,006167	1117,3	6,678	2,656	0,005465	1104,0	6,619	2,713
430	0,007483	1157,7	6,805	2,511 *	0,006479	1143,2	6,739	2,554 *	0,005739	1130,5	6,681	2,603 *

[Continued]

Table II (Continued)

T, °K	p = 140 бар				p = 160 бар				p = 180 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
440	0,007834	1182,3	6,862	2,479 *	0,006787	1168,0	6,796	2,504 *	0,006008	1155,6	6,738	2,527 *
450	0,008182	1206,1	6,915	2,468 *	0,007093	1191,9	6,850	2,485 *	0,006274	1179,5	6,792	2,496 *
460	0,008530	1225,1 *	6,965 *	2,468 *	0,007400	1213,3 *	6,910 *	2,478 *	0,006542	1202,2 *	6,850 *	2,485 *
470	0,008879	1243,0 *	7,030 *	2,472 *	0,007711	1236,0 *	6,960 *	2,479 *	0,006813	1225,2 *	6,905 *	2,484 *
480	0,009230	1270,0 *	7,090 *	2,484 *	0,008027	1258,1 *	7,025 *	2,486 *	0,007090	1248,0 *	6,965 *	2,488 *
490	0,009581	1293,2 *	7,140 *	2,504 *	0,008319	1280,7 *	7,080 *	2,505 *	0,007377	1270,6 *	7,020 *	2,506 *
500	0,009933	1314,5 *	7,200 *	2,522 *	0,008676	1303,0 *	7,135 *	2,522 *	0,007673	1294,0 *	7,075 *	2,522 *

Продолжение табл. II

T, °K	p = 200 бар				p = 250 бар				p = 300 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
290	0,002110	690,0	5,453	1,843	0,002320	700,3	5,415	2,380	0,002251	689,0	5,345	2,325
300	0,002508	723,2	5,532	2,746	0,002397	721,4	5,485	2,510	0,002317	717,0	5,433	2,406
310	0,002627	750,9	5,619	2,944	0,002488	746,3	5,564	2,624	0,002392	744,7	5,520	2,540
320	0,002764	781,6	5,720	3,063	0,002590	775,0	5,657	3,043	0,002474	772,3	5,609	2,661
330	0,002918	812,6	5,814	3,147	0,002700	803,9	5,745	2,825	0,002562	800,0	5,694	2,757
340	0,003091	844,2	5,909	3,209	0,002821	833,1	5,833	2,904	0,002656	827,9	5,777	2,819
350	0,003284	878,5	6,008	3,243	0,002952	862,4	5,932	2,961	0,002756	855,9	5,880	2,857
360	0,003495	908,8	6,093	3,250	0,003094	892,9	6,004	2,996	0,002863	884,7	5,940	2,883
370	0,003720	941,6	6,181	3,220	0,003245	922,7	6,091	3,017	0,002977	913,3	6,030	2,896
380	0,003956	973,0	6,267	3,170	0,003404	953,6	6,169	3,015	0,003096	943,0	6,098	2,899
390	0,004200	1001,3	6,349	3,101	0,003571	983,5	6,247	2,995	0,003220	971,8	6,173	2,888
400	0,004448	1034,8	6,426	3,005	0,003744	1013,3	6,322	2,953	0,003349	1000,7	6,246	2,866
410	0,004696	1064,4	6,499	2,892	0,003921	1042,6	6,394	2,894	0,003482	1029,2	6,316	2,830
420	0,004941	1092,6	6,567	2,760	0,004100	1071,1	6,463	2,815	0,003619	1057,2	6,384	2,792
430	0,005181	1119,5	6,630	2,640 *	0,004279	1098,7	6,527	2,700 *	0,003758	1084,9	6,449	2,737 *
440	0,005417	1145,0	6,688	2,550 *	0,004455	1125,2	6,588	2,590 *	0,003897	1111,8	6,510	2,674 *
450	0,005649	1169,1	6,743	2,510 *	0,004627	1150,1	6,644	2,528 *	0,004034	1126,9	—	2,613 *
460	0,005880	1193,0 *	6,800 *	2,494 *	0,004794	1175,0 *	6,710 *	2,506 *	0,004168	1145,0 *	6,635 *	2,565 *
470	0,006112	1215,5 *	6,860 *	2,490 *	0,004956	1198,5 *	6,770 *	2,496 *	0,004296	1159,5 *	6,695 *	2,529 *
480	0,006350	1238,9 *	6,915 *	2,492 *	0,005114	1223,0 *	6,825 *	2,494 *	0,004418	1170,0 *	6,755 *	2,516 *
490	0,006696	1262,3 *	6,975 *	2,503 *	0,005270	1248,0 *	6,890 *	2,503 *	0,004533	1180,0 *	6,820 *	2,512 *
500	0,006854	1285,1 *	7,030 *	2,522 *	0,005426	1272,3 *	6,950 *	2,522 *	0,004641	1188,5 *	6,880 *	2,522 *

[Continued]

Table II (Continued)

T, °K	p = 350 бар				p = 400 бар				p = 450 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
290	0,002197	684,5 *	5,322 *	2,194 *	0,002151	695,0	5,295	—	0,002113	723,5	5,260	—
300	0,002251	714,4 *	5,400 *	2,280	0,002202	720,0	5,370	2,160	0,002159	727,0	5,343	2,039
310	0,002318	744,9	5,484	2,446	0,002260	746,2	5,452	2,344	0,002211	751,3	5,425	2,246
320	0,002388	771,8	5,570	2,570	0,002321	772,7	5,537	2,483	0,002265	774,5	5,507	2,407
330	0,002462	798,7	5,652	2,663	0,002385	799,0	5,617	2,577	0,002322	800,5	5,586	2,507
340	0,002540	825,7	5,733	2,728	0,002452	825,4	5,696	2,665	0,002381	826,4	5,664	2,583
350	0,002622	852,4	5,812	2,776	0,002522	849,9	5,782	2,703	0,002442	848,9	5,743	2,639
360	0,002708	880,5	5,890	2,805	0,002595	878,7	5,848	2,733	0,002506	878,5	5,813	2,677
370	0,002800	908,9	5,870	2,822	0,002671	905,9	5,921	2,751	0,002573	901,9	5,881	2,698
380	0,002895	937,2	6,044	2,824	0,002751	934,4	5,999	2,757	0,002642	933,4	5,961	2,703
390	0,002994	965,1	6,116	2,816	0,002831	961,5	6,070	2,750	0,002713	959,9	6,031	2,700
400	0,003096	993,3	6,187	2,792	0,002919	989,3	6,140	2,730	0,002786	987,5	6,100	2 682
410	0,003202	1021,1	6,256	2,758	0,003007	1016,6	6 207	2,695	0,002861	1014,4	6,166	2,656
420	0,003311	1048,5	6,322	2,720 *	0,003097	1043,3	6,272	2,653 *	0,002938	1040,6	6,229	2,622 *
430	0,003423	1075,7	6,386	2,676 *	0,003189	1069,9	6,334	2,614 *	0,003016	1066,7	6,290	2,591 *
440	0,003537	1102,4	6,447	2,625 *	0,003285	1096,3	6,394	2,590 *	0,003097	1092,5	6,350	2,564 *
450	0,003652	1128,8	6,506	2,576 *	0,003382	1122,4	6,453	2,551 *	0,003180	1118,2	6,407	2,538 *
460	0,003765	1151,5 *	6,650 *	2,541 *	0,003481	1142,0 *	6,510 *	2,527 *	0,003266	1139,0 *	6,465 *	2,518 *
470	0,003876	1171,5 *	6,625 *	2,520 *	0,003579	1161,0 *	6,575 *	2,514 *	0,003354	1157,0 *	6,520 *	2,504 *
480	0,003982	1189,5 *	6,690 *	2,513 *	0,003675	1176,5 *	6,630 *	2,506 *	0,003442	1171,0 *	6,580 *	2,500 *
490	0,004082	1206,5 *	6,750 *	2,512 *	0,003768	1191,0 *	6,690 *	2,506 *	0,003528	1183,5 *	6,640 *	2,506 *
500	0,004175	1223,0 *	6,815 *	2,522 *	0,003855	1205,0 *	6,750 *	2,521 *	0,003612	1195,0 *	6,695 *	2,521 *

Продолжение табл. II

T, °K	p = 500 бар				p = 600 бар			p = 700 бар		
	v	i	s	C_p	v	i	s	v	i	s
290	0,002079	695,4 *	5,240 *	—	0,002022	702,5 *	5,184 *	0,001976	701,5 *	5,170 *
300	0,002122	723,5 *	5,322 *	1,970	0,002060	730,3 *	5,265 *	0,002009	739,0 *	5,243 *
310	0,002169	751,1	5,400	2,180	0,002100	757,8	5,356	0,002045	765,7	5,318
320	0,002218	777,0	5,480	2,337	0,002142	783,6	5,434	0,002082	791,4	5,394

[Continued]

Table II (Continued)

T, °K	p = 500 бар				p = 600 бар			p = 700 бар		
	v	i	s	C_p	v	i	s	v	i	s
330	0,002270	802,7	5,558	2,449	0,002186	808,8	5,510	0,002120	816,4	5,469
340	0,002323	829,3	5,636	2,531	0,002230	834,9	5,586	0,002153	839,0	5,545
350	0,002377	856,4	5,715	2,590	0,002276	860,4	5,665	0,002198	866,9	5,610
360	0,002434	881,5	5,782	2,631	0,002323	886,6	5,729	0,002238	892,7	5,684
370	0,002493	907,4	5,850	2,658	0,002371	911,9	5,796	0,002280	917,4	5,750
380	0,002554	933,7	5,928	2,670	0,002421	937,1	5,872	0,002322	942,9	5,825
390	0,002617	959,7	5,996	2,668	0,002472	963,1	5,938	0,002366	967,0	5,889
400	0,002682	987,1	6,065	2,657	0,002525	989,5	6,006	0,002410	994,6	5,958
410	0,002747	1013,8	6,131	2,627	0,002578	1016,0	6,072	0,002455	1020,4	6,023
420	0,002814	1039,7	6,193	2,604 *	0,002631	1041,8	6,133	0,002500	1051,4	6,084
430	0,002882	1065,4	6,253	2,575 *	0,002684	1066,9	6,192	0,002544	1071,9	6,144
440	0,002951	1091,9	6,313	2,550 *	0,002738	1097,7	6,249	0,002588	1096,8	6,201
450	0,003023	1117,4	6,368	2,528 *	0,002793	1116,1	6,304	0,002631	1115,1	6,255
460	0,003098	1136,0 *	6,425 *	2,508 *	0,002849	1131,0 *	6,360 *	0,002674	1134,0 *	6,310 *
470	0,003175	1153,5 *	6,480 *	2,496 *	0,002907	1145,0 *	6,420 *	0,002717	1151,5 *	6,370 *
480	0,003254	1169,5 *	6,540 *	2,495 *	0,002968	1158,5 *	6,475 *	0,002762	1169,0 *	6,425 *
490	0,003335	1185,0 *	6,595 *	2,506 *	0,003032	1171,5 *	6,535 *	0,002808	1185,5 *	6,480 *
500	0,003415	1201,0 *	6,650 *	2,522 *	0,003101	1185,0 *	6,590 *	0,002857	1201,0 *	6,540 *

Продолжение табл. II

T, °K	p = 800 бар			p = 900 бар			p = 1000 бар			p = 1100 бар		
	v	i	s	v	i	s	v	i	s	v	i	s
290	0,001937	723,7 *	5,135 *	0,001903	731,5 *	5,122 *	0,001874	741,0 *	5,085 *	0,001848	753,5 *	5,062 *
300	0,001967	749,3 *	5,210 *	0,001931	757,8 *	5,190 *	0,001899	767,2 *	5,156 *	0,001871	779,1 *	5,130 *
310	0,001999	774,5	5,284	0,001960	783,7	5,259	0,001926	793,3	5,226	0,001896	804,2	5,200
320	0,002033	800,1	5,358	0,001990	809,7	5,326	0,001954	819,5	5,297	0,001922	829,7	5,270
330	0,002066	825,1	5,433	0,002021	834,4	5,401	0,001982	844,3	5,371	0,001948	854,4	5,344
340	0,002101	849,3	5,508	0,002052	859,4	5,476	0,002011	868,9	5,446	0,001975	878,9	5,419
350	0,002136	874,9	5,575	0,002084	884,5	5,551	0,002040	894,4	5,505	0,002001	904,0	5,480
360	0,002171	900,9	5,645	0,002116	909,9	5,610	0,002069	914,3	5,579	0,002028	927,9	5,550

[Continued]

Table II (Continued)

T, °K	*p* = 800 бр			*p* = 900 бар			*p* = 1000 бар			*p* = 1100 бар		
	v	*i*	*s*	*v*	*i*	*s*	*v*	*i*	*s*	*v*	*i*	*s*
370	0,002208	925,9	5,710	0,002148	935,6	5,665	0,002098	944,9	5,638	0,002055	953,4	5,620
380	0,002245	950,1	5,785	0,002182	960,5	5,750	0,002129	970,7	5,713	0,002083	977,5	5,689
390	0,002283	976,9	5,848	0,002216	984,7	5,811	0,002159	995,9	5,777	0,002111	1002,9	5,747
400	0,002322	1001,3	5,916	0,002250	1010,3	5,879	0,002190	1021,1	5,846	0,002139	1027,5	5,816
410	0,002361	1028,0	5,981	0,002285	1036,1	5,945	0,002222	1046,0	5,912	0,002168	1053,7	5,882
420	0,002399	1053,2	6,043	0,002319	1061,3	6,006	0,002253	1071,2	5,974	0,002196	1078,9	5,944
430	0,002437	1079,1	6,103	0,002353	1087,5	6,067	0,002283	1096,9	6,036	0,002224	1103,9	6,007
440	0,002474	1104,4	6,161	0,002385	1113,4	6,127	0,002312	1123,5	6,097	0,002251	1129,1	6,069
450	0,002510	1129,2	6,216	0,002416	1139,1	6,184	0,002340	1148,1	6,150	0,002276	1154,8	6,130
460	0,002544	1150,0 *	6,275 *	0,002445	1162,0 *	6,215 *	0,002365	1171,0 *	6,210 *	0,002299	1178,0 *	6,190 *
470	0,002577	1171,5 *	6,325 *	0,002471	1184,0 *	6,305 *	0,002387	1193,5 *	6,270 *	0,002319	1201,0 *	6,230 *
480	0,002610	1191,0 *	6,385 *	0,002496	1206,0 *	6,360 *	0,002407	1215,5 *	6,325 *	0,002336	1225,0 *	6,315 *
490	0,002641	1210,0 *	6,445 *	0,002517	1226,0 *	6,425 *	0,002423	1236,5 *	6,390 *	0,002350	1247,5 *	6,380 *
500	0,002672	1228,0 *	6,500 *	0,002536	1295,5 *	6,480 *	0,002436	1256,5 *	6,450 *	0,002360	1269,5 *	6,440 *

Продолжение табл. II

T, °K	*p* = 1200 бар			*p* = 1300 бар			*p* = 1400 бар			*p* = 1500 бар		
	v	*i*	*s*	*v*	*i*	*s*	*v*	*i*	*s*	*v*	*i*	*s*
290	0,001824	762,7 *	5,040 *	0,001802	771,0 *	5,020	0,001783	781,0 *	4,995 *	0,001764	793,2 *	4,980 *
300	0,001845	788,8 *	5,108 *	0,001822	798,0 *	5,089	0,001801	808,0 *	5,065 *	0,001782	821,2 *	5,050 *
310	0,001869	814,4	5,176	0,001844	824,9	5,154	0,001822	834,9	5,132	0,001802	849,0	5,113
320	0,001893	839,9	5,244	0,001867	851,1	5,221	0,001844	860,6	5,199	0,001822	873,0	5,177
330	0,001918	864,8	5,318	0,001891	875,4	5,294	0,001866	885,4	5,272	0,001843	897,7	5,250
340	0,001942	888,3	5,393	0,001914	899,2	5,367	0,001888	908,6	5,340	0,001864	920,2	5,327
350	0,001967	913,4	5,460	0,001937	923,9	5,435	0,001909	933,9	5,418	0,001884	946,0	5,384
360	0,001992	938,5	5,524	0,001960	948,6	5,505	0,001931	959,5	5,477	0,001905	970,4	5,454
370	0,002017	963,5	5,595	0,001981	973,9	5,570	0,001953	983,9	5,515	0,001926	995,6	5,519
380	0,002043	987,8	5,662	0,002007	998,6	5,637	0,001976	1008,1	5,610	0,001947	1020,6	5,592
390	0,002069	1012,4	5,719	0,002032	1023,4	5,698	0,001998	1032,9	5,671	0,001968	1044,8	5,646
400	0,002095	1037,4	5,789	0,002056	1048,7	5,768	0,002021	1057,7	5,741	0,001990	1069,3	5,717
410	0,002121	1063,9	5,855	0,002081	1075,2	5,830	0,002044	1085,2	5,808	0,002012	1093,9	5,784
420	0,002148	1088,8	5,917	0,002105	1099,4	5,892	0,002067	1108,1	5,870	0,002033	1118,7	5,845
430	0,002174	1112,4	5,980	0,002129	1125,0	5,956	0,002090	1134,7	5,934	0,002055	1143,8	5,910

[Continued]

Table II (Continued)

T, °K	p = 1200 бар			p = 1300 бар			p = 1400 бар			p = 1500 бар		
	v	i	s	v	i	s	v	i	s	v	i	s
440	0,002198	1137,4	6,044	0,002153	1150,2	6,021	0,002112	1158,9	5,999	0,002076	1168,0	5,978
450	0,002222	1162,7	6,107	0,002175	1174,7	6,085	0,002133	1183,9	6,063	0,002096	1193,2	6,045
460	0,002243	1187,5 *	6,170 *	0,002195	1200,0 *	6,145 *	0,002152	1209,5 *	6,130 *	0,002115	1217,5 *	6,115 *
470	0,002262	1211,5 *	6,230 *	0,002212	1224,0 *	6,210 *	0,002169	1233,5 *	6,195 *	0,002132	1241,5 *	6,180 *
480	0,002277	1235,0 *	6,300 *	0,002228	1218,0 *	6,275 *	0,002184	1258,0 *	6,260 *	0,002146	1266,5 *	6,250 *
490	0,002290	1258,0 *	6,360 *	0,002210	1271,5 *	6,310 *	0,002196	1283,0 *	6,325 *	0,002158	1291,0 *	6,315 *
500	0,002299	1281,5 *	6,450 *	0,002218	1295,0 *	6,405 *	0,002205	1308,5 *	6,390 *	0,002168	1315,0 *	6,380 *

Продолжение табл. II

T, °K	p = 1600 бар			p = 1700 бар			p = 1800 бар			p = 1900 бар		
	v	i	s	v	i	s	v	i	s	v	i	s
290	0,001748	804,0 *	4,970 *	0,001732	813,3 *	4,956 *	0,001717	824,0 *	4,935 *	0,001703	834,5 *	4,925 *
300	0,001764	831,7 *	5,032 *	0,001747	842,0 *	5,016 *	0,001731	853,0 *	4,998 *	0,001716	865,0 *	4,981 *
310	0,001783	860,4	5,094	0,001765	870,9	5,076	0,001749	882,5	5,058	0,001733	893,9	5,048
320	0,001802	882,2	5,156	0,001784	895,1	5,136	0,001767	906,2	5,118	0,001751	917,5	5,099
330	0,001822	909,0	5,229	0,001803	920,1	5,210	0,001785	931,6	5,192	0,001768	943,2	5,174
340	0,001842	931,4	5,297	0,001822	944,4	5,280	0,001803	955,8	5,265	0,001786	966,7	5,252
350	0,001862	956,9	5,355	0,001840	969,4	5,350	0,001821	980,4	5,335	0,001803	991,4	5,321
360	0,001881	981,4	5,433	0,001859	993,9	5,414	0,001839	1004,9	5,395	0,001820	1015,9	5,377
370	0,001901	1006,5	5,495	0,001878	1018,6	5,476	0,001857	1029,9	5,457	0,001837	1040,4	5,445
380	0,001921	1032,0	5,572	0,001897	1043,5	5,552	0,001875	1055,0	5,535	0,001854	1066,1	5,516
390	0,001941	1056,3	5,625	0,001916	1067,9	5,614	0,001893	1078,9	5,595	0,001872	1089,8	5,568
400	0,001961	1080,6	5,696	0,001935	1091,9	5,675	0,001912	1103,6	5,724	0,001889	1114,9	5,639
410	0,001982	1105,5	5,763	0,001955	1117,4	5,743	0,001930	1128,4	5,785	0,001907	1139,3	5,706
420	0,002003	1129,5	5,824	0,001975	1142,6	5,807	0,001949	1152,5	5,788	0,001925	1163,5	5,766
430	0,002023	1154,1	5,889	0,001994	1166,9	5,871	0,001968	1177,6	5,853	0,001943	1188,0	5,831

[Continued]

Table II (Continued)

T, °K	p = 1600 бар			p = 1700 бар			p = 1800 бар			p = 1900 бар		
	v	i	s	v	i	s	v	i	s	v	i	s
440	0,002043	1178,9	5,957	0,002013	1192,2	5,942	0,001986	1202,5	5,924	0,001961	1212,5	5,901
450	0,002062	1203,9	6,025	0,002032	1215,9	5,996 *	0,002004	1226,5	5,985	0,001978	1237,6	5,971
460	0,002081	1230,0 *	6,095 *	0,002050	1241,5 *	6,065 *	0,002021	1252,0 *	6,055 *	0,001995	1264,0 *	6,040 *
470	0,002097	1254,5 *	6,160 *	0,002066	1266,5 *	6,135 *	0,002038	1277,0 *	6,120 *	0,002011	1288,5 *	6,110 *
480	0,002112	1280,0 *	6,225 *	0,002081	1291,0 *	6,200 *	0,002052	1302,5 *	6,180 *	0,002026	1314,0 *	6,175 *
490	0,002124	1305,0 *	6,295 *	0,002094	1315,5 *	6,270 *	0,002066	1326,5 *	6,255 *	0,002039	1339,0 *	6,245 *
500	0,002134	1330,0 *	6,360 *	0,002104	1341,5 *	6,335 *	0,002077	1352,5 *	6,320 *	0,002051	1365,0 *	6,315

Продолжение табл. II

T, °K	p = 2000			T, °K	p = 2000		
	v	i	s		v	i	s
290	0,001690	845,7 *	4,905 *	400	0,001869	1126,2	5,621
300	0,001702	878,2 *	4,965 *	410	0,001886	1151,1	5,688
310	0,001719	904,9	5,025	420	0,001903	1174,9	5,743
320	0,001736	928,7	5,082	430	0,001920	1199,6	5,803
330	0,001753	953,6	5,157	440	0,001937	1224,0	5,883
340	0,001769	978,5	5,236	450	0,001954	1247,7	5,954
350	0,001786	1002,6	5,305	460	0,001971	1272,5 *	6,050 *
360	0,001802	1027,5	5,350	470	0,001987	1298,0 *	6,100 *
370	0,001819	1052,4	5,432	480	0,002002	1321,5 *	6,170 *
380	0,001835	1078,9	5,499	490	0,002015	1346,5 *	6,235 *
390	0,001852	1101,9	5,549	500	0,002027	1371,0 *	6,305 *

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* Extrapolated values.

Table III. Specific Volume of Liquid Ethylene

T, °K	$v \cdot 10^3$ при p									
	180	190	200	210	220	230	240	250	260	270
70	1,792	1,837	1,888	1,943	2,006	2,078	2,161	2,260	2,381	2,541
75	1,790	1,835	1,885	1,940	2,002	2,072	2,154	2,250	2,367	2,517
80	1,788	1,833	1,882	1,936	2,998	2,067	2,146	2,240	2,353	2,496
85	1,786	1,830	1,879	1,933	1,993	2,062	2,140	2,231	2,340	2,476
90	1,784	1,828	1,876	1,930	1,989	2,056	2,133	2,222	2,328	2,458
95	1,782	1,826	1,874	1,926	1,985	2,051	2,127	2,214	2,317	2,442
100	1,780	1,824	1,871	1,923	1,981	2,047	2,121	2,206	2,306	2,426
120	1,773	1,815	1,861	1,911	1,967	2,028	2,098	2,176	2,267	2,372
140	1,766	1,807	1,852	1,900	1,953	2,012	2,077	2,151	2,233	2,328
160	1,760	1,800	1,813	1,890	1,941	1,997	2,059	2,128	2,204	2,291
180	1,753	1,792	1,834	1,880	1,929	1,983	2,042	2,107	2,179	2,259
200	1,748	1,786	1,827	1,870	1,918	1,970	2,026	2,088	2,156	2,230
250	1,734	1,770	1,809	1,850	1,893	1,941	1,992	2,047	2,106	2,170
300	1,722	1,756	1,792	1,831	1,872	1,916	1,962	2,012	2,066	2,122
350	1,711	1,744	1,778	1,814	1,852	1,893	1,936	1,982	2,031	2,082
400	1,701	1,732	1,765	1,799	1,835	1,873	1,913	1,956	2,001	2,048
450	1,692	1,721	1,752	1,785	1,819	1,855	1,893	1,932	1,974	2,018
500	1,683	1,711	1,741	1,772	1,804	1,838	1,874	1,911	1,950	1,991

Table IV. Velocity of Sound w, Index of Adiabatics k_v, Ratio of Heat Capacities κ of Gaseous Ethylene

T, °K	$p = 0{,}01$ бар			$p = 5$ бар			$p = 10$ бар			$p = 15$ бар		
	w	k_v	κ	w	k_v	κ	w	k_v	κ	w	k_v	κ
210	—	—	—	271,2	—	—	—	—	—	—	—	—
220	—	—	—	278,7	—	—	—	—	—	—	—	—
230	296,0	1,286	1,285	285,6	1,278	1,372	272,7	1,260	—	—	—	—
240	301,7	1,278	1,278	292,2	1,270	1,351	280,9	1,255	1,449	266,6	—	—
250	307,2	1,171	1,272	298,5	1,262	1,333	288,5	1,250	1,410	276,5	1,233	1,548
260	312,3	1,263	1,264	304,5	1,256	1,317	295,5	1,245	1,380	285,1	1,231	1,478

[Continued]

Table IV (Continued)

T, °K	p = 0,01 бар			p = 5 бар			p = 10 бар			p = 15 бар		
	w	k_v	$\varkappa$	w	k_v	$\varkappa$	w	k_v	$\varkappa$	w	k_v	$\varkappa$
270	317,2	1,256	1,257	310,1	1,249	1,302	302,0	1,240	1,354	293,1	1,229	1,426
280	322,0	1,249	1,249	315,4	1,243	1,287	308,3	1,235	1,331	300,5	1,226	1,388
290	326,8	1,242	1,241	320,6	1,236	1,275	314,3	1,230	1,313	307,5	1,223	1,357
300	331,5	1,235	1,235	325,8	1,229	1,265	320,3	1,226	1,299	314,2	1,220	1,336
310	336,1	1,229	1,228	330,9	1,223	1,254	326,2	1,221	1,285	320,7	1,217	1,317
320	340,6	1,223	1,222	336,0	1,218	1,244	331,7	1,216	1,271	326,9	1,214	1,300
330	345,1	1,218	1,215	341,0	1,214	1,236	337,1	1,212	1,259	332,8	1,211	1,284
340	349,4	1,212	1,210	345,9	1,209	1,228	342,4	1,208	1,248	338,5	1,207	1,270
350	353,6	1,206	1,205	350,5	1,205	1,220	347,4	1,204	1,238	344,0	1,203	1,256
360	357,8	1,201	1,200	355,1	1,200	1,215	352,2	1,198	1,230	349,3	1,196	1,246
370	362,1	1,198	1,195	359,7	1,197	1,208	357,1	1,195	1,222	354,2	1,194	1,237
380	366,3	1,193	1,190	364,0	1,193	1,202	361,7	1,192	1,215	359,2	1,192	1,228
390	370,4	1,187	1,186	368,4	1,188	1,197	366,2	1,189	1,208	364,1	1,190	1,220
400	374,5	1,182	1,182	372,6	1,184	1,192	370,6	1,185	1,202	368,8	1,186	1,212
410	378,5	1,179	1,178	376,8	1,180	1,186	375,0	1,181	1,196	373,3	1,182	1,205
420	382,5	1,175	1,175	380,9	1,176	1,183	379,2	1,177	1,192	377,8	1,178	1,200
430	386,4	1,171	1,171	385,0	1,172	1,178	383,6	1,174	1,186	382,2	1,175	1,195
440	390,4	1,167	1,167	389,0	1,169	1,174	387,8	1,171	1,182	386,6	1,173	1,189
450	394,2	1,164	1,164	393,0	1,166	1,171	392,0	1,168	1,177	391,0	1,170	1,184
460	398,0	1,161	1,161	397,0	1,163	1,167	396,1	1,165	1,172	395,2	1,167	1,178
470	401,8	1,159	1,159	401,0	1,161	1,164	400,2	1,163	1,169	399,5	1,165	1,175

Продолжение табл. IV

T, °K	p = 20 бар			p = 25 бар			p = 30 бар			p = 35 бар		
	w	k_v	$\varkappa$	w	k_v	$\varkappa$	w	k_v	$\varkappa$	w	k_v	$\varkappa$
250	261,6	1,221	1,731	—	—	—	—	—	—	—	—	—
260	273,4	1,219	1,620	259,9	—	1,868	240,4	—	—	—	—	—
270	283,3	1,217	1,532	272,4	1,206	1,680	259,4	1,194	1,925	243,4	—	2,382
280	292,1	1,215	1,463	283,0	1,207	1,561	273,1	1,195	1,702	262,5	1,199	1,929
290	300,2	1,213	1,412	292,5	1,207	1,483	284,4	1,196	1,581	275,5	1,198	1,717
300	307,9	1,211	1,380	301,1	1,206	1,435	294,2	1,197	1,504	286,6	1,197	1,595
310	315,0	1,209	1,354	309,1	1,205	1,397	302,8	1,198	1,450	296,5	1,196	1,517
320	321,8	1,207	1,332	316,5	1,204	1,369	311,0	1,197	1,411	305,6	1,194	1,462

[Continued]

Table IV (Continued)

T, °K	p = 20 бар			p = 25 бар			p = 30 бар			p = 35 бар		
	w	k_v	κ	w	k_v	κ	w	k_v	κ	w	k_v	κ
330	328,4	1,205	1,312	323,5	1,202	1,344	318,7	1,197	1,378	314,1	1,193	1,418
340	334,5	1,202	1,294	330,3	1,200	1,320	326,0	1,196	1,349	322,0	1,192	1,381
350	340,4	1,200	1,276	336,6	1,198	1,299	332,9	1,195	1,324	329,4	1,192	1,351
360	346,0	1,195	1,263	342,8	1,194	1,283	339,4	1,192	1,304	336,4	1,192	1,327
370	351,4	1,193	2,253	348,8	1,192	1,269	345,6	1,192	1,288	342,8	1,191	1,309
380	356,6	1,192	1,243	354,3	1,191	1,258	351,5	1,191	1,274	349,1	1,191	1,292
390	361,8	1,190	1,233	359,6	1,190	1,247	357,2	1,191	1,261	355,0	1,191	1,277
400	366,7	1,186	1,223	364,7	1,186	1,235	362,8	1,188	1,249	360,8	1,188	1,263
410	371,5	1,183	1,216	369,8	1,185	1,227	368,1	1,187	1,238	366,4	1,187	1,250
420	376,2	1,181	1,209	374,7	1,183	1,219	373,2	1,185	1,229	371,8	1,186	1,240
430	380,9	1,178	1,203	379,6	1,180	1,212	378,2	1,183	1,221	377,0	1,184	1,230
440	385,5	1,175	1,197	384,3	1,178	1,205	383,2	1,181	1,213	382,1	1,181	1,222
450	389,9	1,172	1,191	388,9	1,175	1,198	388,0	1,179	1,205	387,4	1,179	1,213
460	394,3	1,169	1,185	393,5	1,172	1,192	392,7	1,177	1,198	391,9	1,176	1,206
470	398,7	1,167	1,180	398,0	1,169	1,187	397,3	1,172	1,193	396,5	1,174	1,199

Продолжение табл. IV

T, °K	p = 40 бар			p = 45 бар			p = 50 бар			p = 55 бар		
	w	k_v	κ	w	k_v	κ	w	k_v	κ	w	k_v	κ
280	249,9	1,194	2,347	234,0	—	—	—	—	—	—	—	—
290	266,3	1,194	1,923	256,3	—	—	244,7	1,257	—	232,0	—	—
300	279,0	1,193	1,722	271,4	1,202	1,898	263,4	1,217	2,159	255,4	1,257	2,550
310	290,0	1,193	1,600	283,9	1,194	1,710	277,4	1,203	1,855	271,3	1,225	2,034
320	300,0	1,192	1,523	294,7	1,192	1,598	289,3	1,196	1,691	284,4	1,208	1,806
330	309,1	1,191	1,467	304,5	1,192	1,522	299,9	1,192	1,588	295,7	1,201	1,670
340	317,7	1,190	1,420	313,3	1,192	1,462	309,5	1,189	1,513	305,8	1,199	1,573
350	325,6	1,190	1,383	321,6	1,191	1,416	318,1	1,188	1,456	315,1	1,198	1,502
360	333,0	1,190	1,353	329,5	1,191	1,381	326,4	1,188	1,413	323,8	1,197	1,448
370	339,9	1,191	1,330	336,9	1,191	1,353	334,3	1,189	1,379	332,0	1,195	1,407
380	346,5	1,191	1,311	344,0	1,191	1,330	341,7	1,191	1,352	339,8	1,193	1,374

[Continued]

Table IV (Continued)

T, °K	p = 40 бар			p = 45 бар			p = 50 бар			p = 55 бар		
	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$
390	352,8	1,191	1,294	359,6	1,191	1,310	348,7	1,192	1,328	347,0	1,191	1,347
400	359,0	1,189	1,278	357,0	1,190	1,291	355,4	1,192	1,307	353,8	1,193	1,321
410	364,9	1,189	1,263	363,1	1,183	1,276	361,7	1,192	1,290	360,4	1,194	1,305
420	370,5	1,187	1,251	369,1	1,138	1,263	367,8	1,191	1,276	366,6	1,195	1,289
430	375,9	1,186	1,211	374,6	1,187	1,252	373,6	1,190	1,263	372,6	1,194	1,274
440	381,1	1,184	1,232	380,0	1,185	1,241	372,2	1,189	1,251	378,3	1,193	1,260
450	386,2	1,180	1,222	385,2	1,183	1,231	381,4	1,191	1,239	383,7	1,193	1,249
460	391,0	1,178	1,213	390,2	1,181	1,221	389,5	1,189	1,228	388,8	1,193	1,237
470	395,8	1,176	1,206	395,0	1,179	1,213	394,4	1,182	1,220	393,8	1,187	1,228

Продолжение табл. IV

T, °K	p = 60 бар			p = 65 бар			p = 70 бар			p = 75 бар		
	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$
290	—	—	—	291,7	—	—	337,7	—	—	374,5	—	—
300	248,0	1,328	—	241,1	1,517	—	252,2	1,870	—	279,6	2,180	—
310	265,9	1,264	2,260	261,2	1,323	2,566	260,0	1,400	—	260,1	1,536	—
320	279,9	1,232	1,936	275,8	1,260	2,095	273,1	1,300	2,299	272,5	1,368	2,540
330	291,7	1,220	1,763	288,6	1,235	1,869	286,0	1,275	1,994	285,0	1,306	2,141
340	302,2	1,211	1,642	299,6	1,221	1,719	297,3	1,242	1,802	296,1	1,268	1,891
350	312,0	1,205	1,553	309,6	1,212	1,609	307,4	1,228	1,667	306,4	1,246	1,729
360	321,1	1,201	1,486	318,9	1,207	1,527	316,9	1,220	1,570	315,3	1,234	1,614
370	329,6	1,198	1,437	327,7	1,206	1,469	325,8	1,217	1,502	321,4	1,229	1,534
380	337,7	1,198	1,398	335,8	1,206	1,423	334,3	1,215	1,449	333,1	1,224	1,476
390	345,3	1,198	1,368	343,6	1,206	1,389	342,3	1,214	1,410	341,3	1,220	1,432
400	352,4	1,199	1,342	351,0	1,206	1,361	349,8	1,211	1,379	349,0	1,216	1,399
410	359,2	1,199	1,321	358,0	1,205	1,336	356,9	1,209	1,353	356,1	1,213	1,371
420	365,6	1,198	1,302	364,6	1,204	1,316	363,6	1,207	1,330	362,9	1,210	1,360
430	371,7	1,197	1,286	370,8	1,201	1,298	369,9	1,204	1,311	369,2	1,208	1,324
440	377,5	1,196	1,272	376,7	1,199	1,282	375,8	1,202	1,293	375,2	1,205	1,304
450	383,0	1,193	1,258	382,3	1,197	1,268	381,6	1,199	1,277	381,0	1,201	1,288
460	388,3	1,191	1,245	387,6	1,194	1,254	387,1	1,196	1,262	386,6	1,202	1,271
470	393,4	1,188	1,235	392,9	1,191	1,243	392,5	1,193	1,250	392,2	1,201	1,258

[Continued]

Table IV (Continued)

T, °K	$p = 80$ бар			$p = 85$ бар			$p = 90$ бар			$p = 95$ бар		
	w	k_v	$\varkappa$	w	k_v	$\varkappa$	w	k_v	$\varkappa$	w	k_v	$\varkappa$
290	401,0	—	—	430,0	—	—	452,7	—	—	474,9	—	—
300	310,7	3,280	—	340,4	—	—	368,7	4,600	—	392,8	—	—
310	269,5	1,816	—	285,2	2,108	—	304,8	2,530	—	326,6	2,940	—
320	273,7	1,496	—	277,7	1,620	—	286,0	1,792	—	296,8	2,008	—
330	285,0	1,356	2,314	286,7	1,428	2,462	290,2	1,534	—	296,6	1,660	—
340	295,6	1,300	1,991	296,5	1,343	2,094	298,3	1,432	2,198	301,6	1,485	—
350	305,6	1,277	1,792	306,1	1,316	1,858	306,7	1,360	1,928	307,9	1,394	1,999
360	314,8	1,255	1,659	314,8	1,280	1,703	315,2	1,320	1,750	315,3	1,342	1,794
370	323,8	1,246	1,570	323,8	1,264	1,602	323,6	1,284	1,636	323,5	1,306	1,668
380	332,4	1,238	1,504	332,1	1,254	1,530	332,0	1,271	1,556	332,0	1,286	1,584
390	340,6	1,232	1,456	340,2	1,244	1,478	340,0	1,259	1,500	339,9	1,272	1,525
400	348,2	1,226	1,418	347,9	1,236	1,438	347,4	1,248	1,457	347,4	1,258	1,478
410	355,5	1,221	1,386	355,0	1,229	1,404	354,6	1,238	1,421	354,6	1,247	1,439
420	362,3	1,216	1,360	361,8	1,223	1,375	361,4	1,230	1,390	361,3	1,238	1,406
430	368,6	1,213	1,336	368,2	1,219	1,349	367,8	1,224	1,363	367,7	1,231	1,377
440	374,7	1,209	1,316	374,4	1,215	1,327	374,1	1,219	1,310	373,9	1,226	1,352
450	380,6	1,207	1,298	380,4	1,211	1,307	380,2	1,215	1,319	380,0	1,228	1,329
460	386,3	1,204	1,280	386,1	1,209	1,289	386,0	1,213	1,298	386,9	1,218	1,307
470	391,9	1,202	1,266	391,8	1,206	1,274	391,7	1,211	1,282	391,7	1,215	1,290

Продолжение табл. IV

T, °K	$p = 100$ бар			T, °K	$p = 100$ бар		
	w	k_v	$\varkappa$		w	k_v	$\varkappa$
290	495,8	—	—	390	339,9	1,285	1,549
300	416,3	—	—	400	347,4	1,269	1,499
310	346,2	3,348	—	410	354,6	1,257	1,458
320	309,3	2,232	—	420	361,3	1,247	1,422
330	303,5	1,790	—	430	367,8	1,240	1,390
340	305,8	1,564	—	440	373,9	1,234	1,364
350	310,2	1,438	2,071	450	380,0	1,229	1,340
360	315,9	1,370	1,838	460	385,9	1,225	1,317
370	323,6	1,333	1,700	470	391,8	1,221	1,298
380	331,9	1,303	1,612				

Table V. Thermodynamic Properties p, v, i, r, s, C_p of Propylene on Saturation Line as Functions of Temperature

T, °K	p	v'	v''	i'	i''	r	s'	s''	C_p'
160	0,01225	0,001453	25,66	285,0	783,9	498,9	3,281	6,399	2,080
165	0,01976	0,001465	16,36	295,4	789,4	494,0	3,345	6,339	2,082
170	0,03096	0,001477	10,73	305,9	795,1	489,2	3,407	6,285	2,083
175	0,04707	0,001491	7,218	316,2	800,6	484,4	3,466	6,231	2,085
180	0,06969	0,001504	5,025	326,5	806,1	479,6	3,524	6,188	2,087
185	0,1008	0,001517	3,563	337,2	812,1	471,9	3,582	6,149	2,088
190	0,1426	0,001531	2,581	347,8	818,1	470,3	3,639	6,114	2,090
195	0,1976	0,001545	1,909	358,2	823,9	465,7	3,694	6,082	2,092
200	0,2638	0,001559	1,435	368,9	829,9	461,0	3,747	6,052	2,091
205	0,3595	0,001573	1,098	379,5	836,0	456,5	3,800	6,027	2,098
210	0,4731	0,001588	0,8528	390,1	842,0	451,9	3,851	6,003	2,102
215	0,6137	0,001603	0,6719	401,3	848,7	447,4	3,902	5,983	2,110
220	0,7852	0,001619	0,5354	412,2	854,8	412,6	3,952	5,961	2,120
225	0,9924	0,001636	0,4310	423,4	861,1	437,7	4,001	5,946	2,132
230	1,240	0,001653	0,3511	434,7	867,1	432,4	4,050	5,930	2,145
235	1,532	0,001671	0,2886	446,1	873,1	427,0	4,099	5,916	2,160
240	1,876	0,001690	0,2390	457,5	879,0	421,5	4,147	5,903	2,178
245	2,276	0,001709	0,1996	468,9	884,7	415,8	4,194	5,891	2,198
250	2,736	0,001728	0,1680	480,1	889,8	409,7	4,240	5,879	2,220
255	3,263	0,001748	0,1421	492,2	895,3	403,1	4,288	5,869	2,244
260	3,864	0,001769	0,1210	503,3	899,8	396,5	4,320	5,845	2,272
265	4,543	0,001793	0,1035	515,2	904,5	389,3	4,366	5,835	2,301
270	5,311	0,001816	0,08895	527,3	909,0	381,7	4,409	5,823	2,340
275	6,170	0,001840	0,07678	539,3	913,0	373,7	4,451	5,810	2,383
280	7,129	0,001866	0,06653	551,8	917,0	365,2	4,493	5,797	2,434
285	8,198	0,001893	0,05785	563,9	920,5	356,6	4,535	5,786	2,490
290	9,376	0,001923	0,05052	575,9	923,7	347,8	4,576	5,775	2,550
295	10,68	0,001954	0,01125	588,3	927,0	338,7	4,617	5,765	2,619

[Continued]

Table V (Continued)

T, °K	p	v'	v''	i'	i''	r	s'	s''	C_p'
300	12,11	0,001987	0,03890	600,6	930,0	329,4	4,657	5,755	2,694
305	13,67	0,002023	0,03428	612,9	932,8	319,9	4,696	5,745	2,780
310	15,37	0,002062	0,03023	625,4	935,2	309,8	4,736	5,735	2,870
315	17,21	0,002102	0,02676	638,3	937,3	299,0	4,776	5,725	2,983
320	19,21	0,002149	0,02364	651,3	938,7	287,4	4,817	5,715	3,115
325	21,38	0,002202	0,02094	664,8	939,8	275,0	4,859	5,705	3,265
330	23,73	0,002261	0,01819	678,8	940,0	261,2	4,900	5,692	3,438
335	26,26	0,002328	0,01626	694,0	939,5	245,5	4,944	5,677	3,648
340	28,99	0,002406	0,01419	710,6	937,5	226,9	4,993	5,660	3,920
345	31,93	0,002502	0,01230	728,0	934,0	206,0	5,043	5,640	4,265
350	35,09	0,002626	0,01054	747,7	929,0	181,3	5,099	5,617	4,750
355	38,49	0,002794	0,008853	771,5	922,7	151,2	5,166	5,592	5,500
360	42,14	0,003069	0,007136	802,6	913,0	110,4	5,248	5,555	6,750
365,05	46,41	0,004329	0,004329	873,38	873,38	0	5,432	5,432	—

Table VI. Thermodynamic Properties v, i, s, C_p of Propylene

T, °K	p = 0,5 бар				p = 0,6 бар				p = 0,7 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001504	326,4	3,526	2,086	0,001504	326,4	3,526	2,086	0,001504	326,4	3,526	2,086
190	0,001532	347,3	3,639	2,090	0,001532	347,3	3,639	2,090	0,001532	347,4	3,639	2,090
200	0,001559	368,2	3,746	2,094	0,001559	368,2	3,746	2,094	0,001559	368,2	3,746	2,094
210	0,001588	389,3	3,848	2,102	0,001588	389,3	3,848	2,102	0,001588	389,3	3,818	2,102
220	0,8528	855,2	6,056	1,209 *	0,7078	855,2	6,038	1,304 *	0,6042	855,2	5,998	1,342 *
230	0,8940	867,5	6,117	1,250 *	0,7425	867,5	6,085	1,332 *	0,6342	867,5	6,055	1,365 *
240	0,9350	880,0	6,172	1,290 *	0,7769	880,0	6,143	1,358 *	0,6640	880,0	6,110	1,388 *
250	0,9758	892,5	6,227	1,330 *	0,8111	892,0	6,195	1,384 *	0,6934	892,0	6,172	1,412 *
260	1,0163	905,2	6,280	1,370 *	0,8451	904,7	6,250	1,411 *	0,7227	904,7	6,222	1,434 *
270	1,0568	917,8	6,335	1,410 *	0,8796	917,3	6,303	1,440 *	0,7519	917,0	6,276	1,458 *
280	1,0971	931,0	6,390	1,450 *	0,9126	930,5	6,355	1,470 *	0,7802	930,2	6,328	1,482 *

[Continued]

Table VI (Continued)

T, °K	p = 0,5 бар				p = 0,6 бар				p = 0,7 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
290	1,1373	944,5	6,440	1,490 *	0,9162	944,0	6,410	1,501 *	0,8098	943,8	6,380	1,510 *
300	1,1774	958,9	6,494	1,530	0,9798	958,7	6,457	1,538	0,8386	958,4	6,426	1,540
310	1,2170	974,4	6,545	1,570	1,0133	974,1	6,508	1,573	0,8674	973,9	6,477	1,573
320	1,2575	990,3	6,595	1,601	1,0468	990,1	6,558	1,606	0,8962	989,8	6,528	1,609
330	1,2975	1006,7	6,645	1,645	1,0802	1006,4	6,609	1,647	0,9249	1006,2	6,578	1,647
340	1,3375	1023,4	6,696	1,683	1,1135	1023,2	6,659	1,685	0,9536	1023,0	6,629	1,687
350	1,3774	1040,4	6,745	1,720	1,1468	1040,2	6,708	1,723	0,9822	1040,0	6,677	1,725
360	1,4173	1057,9	6,794	1,759	1,1801	1057,7	6,757	1,761	1,0108	1057,5	6,727	1,765
370	1,4571	1075,7	6,843	1,797	1,2134	1075,6	6,807	1,797	1,0393	1075,4	6,776	1,799
380	1,4969	1094,0	6,892	1,832	1,2467	1093,8	6,856	1,835	1,0679	1093,6	6,825	1,835
390	1,5367	1112,6	6,940	1,868	1,2799	1112,5	6,904	1,868	1,0964	1112,3	6,873	1,870
400	1,5764	1131,7	6,989	1,906	1,3130	1131,6	6,953	1,908	1,1248	1131,5	6,922	1,908
410	1,6161	1151,2	7,036	1,939	1,3460	1151,1	7,000	1,942	1,1532	1151,1	6,970	1,942
420	1,6556	1171,1	7,085	1,975	1,3789	1171,1	7,049	1,977	1,1814	1171,1	7,019	1,977
430	1,6949	1191,5	7,133	2,010	1,4117	1191,6	7,097	2,013	1,2094	1191,7	7,067	2,013
440	1,7341	1212,3	7,180	2,016	1,4443	1212,5	7,145	2,049	1,2373	1212,6	7,115	2,048
450	1,7730	1233,6	7,228	2,082	1,4767	1233,8	7,193	2,082	1,2650	1231,1	7,163	2,081

Продолжение табл. VI

T, °K	p = 0,8 бар				p = 0,9 бар				p = 1 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001504	326,5	3,526	2,086	0,001504	326,5	3,526	2,086	0,001504	326,5	3,526	2,086
190	0,001532	347,4	3,639	2,090	0,001532	347,4	3,639	2,090	0,001532	347,4	3,639	2,090
200	0,001559	368,2	3,746	2,094	0,001559	368,3	3,746	2,094	0,001559	368,3	3,746	2,094
210	0,001588	389,3	3,848	2,102	0,001588	389,3	3,848	2,102	0,001588	389,3	3,848	2,102
220	0,001620	410,3	3,946	2,119	0,001620	410,3	3,916	2,119	0,001620	410,3	3,916	2,119
230	0,5530	867,5	6,026	1,365 *	0,4899	867,5	5,995	1,392 *	0,4393	867,5	5,973	1,404 *
240	0,5792	880,0	6,085	1,389 *	0,5133	880,0	6,050	1,408 *	0,4606	879,5	6,028	1,418 *
250	0,6052	892,0	6,140	1,413 *	0,5365	892,0	6,110	1,426 *	0,4816	891,8	6,074	1,436 *
260	0,6309	904,7	6,194	1,434 *	0,5596	904,5	6,165	1,445 *	0,5025	904,0	6,136	1,453 *
270	0,6566	917,0	6,250	1,458 *	0,5824	917,0	6,220	1,465 *	0,5231	916,8	6,190	1,472 *
280	0,6821	920,2	6,305	1,483 *	0,6052	930,2	6,275	1,487 *	0,5437	929,7	6,215	1,492 *

[Continued]

Table VI (Continued)

T, °K	$p = 0,8$ бар				$p = 0,9$ бар				$p = 1$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
290	0,7074	943,8	6,360	1,510 *	0,6278	943,8	6,325	1,512 *	0,5642	943,2	6,300	1,518 *
300	0,7327	958,1	6,399	1,540	0,6504	957,9	6,375	1,542	0,5845	957,6	6,354	1,545
310	0,7580	973,6	6,450	1,573	0,6730	973,3	6,426	1,576	0,6049	973,1	6,405	1,578
320	0,7833	989,6	6,501	1,609	0,6954	989,4	6,477	1,611	0,6252	989,1	6,456	1,611
330	0,8085	1006,0	6,551	1,649	0,7179	1005,8	6,527	1,619	0,6454	1005,6	6,506	1,652
340	0,8336	1022,8	6,601	1,687	0,7403	1022,6	6,578	1,687	0,6656	1022,4	6,557	1,690
350	0,8588	1039,9	6,651	1,725	0,7626	1039,7	6,627	1,725	0,6858	1039,5	6,606	1,728
360	0,8837	1057,4	6,700	1,763	0,7849	1057,0	6,676	1,763	0,7059	1057,0	6,655	1,766
370	0,9088	1075,2	6,749	1,799	0,8072	1075,0	6,725	1,799	0,7260	1074,9	6,704	1,801
380	0,9338	1093,5	6,798	1,835	0,8295	1093,3	6,775	1,835	0,7461	1093,2	6,754	1,837
390	0,9588	1112,2	6,847	1,870	0,8517	1112,1	6,823	1,873	0,7661	1111,9	6,802	1,873
400	0,9837	1131,4	6,895	1,908	0,8739	1131,3	6,872	1,911	0,7861	1131,1	6,851	1,911
410	1,0085	1151,0	6,943	1,942	0,8960	1150,9	6,920	1,914	0,8060	1150,9	6,899	1,944
420	1,0332	1171,1	6,992	1,977	0,9179	1171,1	6,969	1,980	0,8257	1171,1	6,949	1,980
430	1,0577	1191,7	7,041	2,013	0,9379	1191,8	7,018	2,015	0,8454	1191,8	6,997	2,015
440	1,0821	1212,8	7,089	2,049	0,9614	1212,9	7,066	2,049	0,8648	1213,0	7,049	2,049
450	1,1063	1234,3	7,137	2,084	0,9828	1256.6	7,115	2,084	0,8841	1234,8	7,095	2,085

Продолжение табл. VI

T, °K	$p = 1,1$ бар				$p = 1,2$ бар				$p = 1,3$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001504	326,5	3,526	2,086	0,001504	326,5	3,526	2,086	0,001504	326,6	3,526	2,086
190	0,001532	347,4	3,639	2,090	0,001532	347,4	3,639	2,090	0,001532	347,5	3,639	2,090
200	0,001559	368,3	3,746	2,094	0,001559	368,3	3,746	2,093	0,001559	368,6	3,746	2,093
210	0,001588	389,3	3,848	2,102	0,001588	389,4	3,848	2,102	0,001588	390,0	3,848	2,102
220	0,001620	410,4	3,946	2,119	0,001620	410,4	3,946	2,119	0,001620	411,6	3,946	2,118
230	0,3979	867,4	5,960	1,420 *	0,3635	867,2	5,952	1,436 *	0,001654	433,7	4,040	2,138
240	0,4175	879,4	6,015	1,429 *	0,3815	879,2	6,008	1,440 *	0,3510	879,1	5,990	1,450 *
250	0,4367	891,7	6,070	1,412 *	0,3992	891,5	6,065	1,450 *	0,3675	891,4	6,040	1,458 *
260	0,4557	903,8	6,124	1,459 *	0,4168	903,6	6,120	1,463 *	0,3838	903,5	6,099	1,468 *

[Continued]

Table VI (Continued)

T, °K	$p = 1{,}1$ бар				$p = 1{,}2$ бар				$p = 1{,}3$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
270	0,4746	916,6	6.177	1,475 *	0,4342	916,4	6,166	1,479 *	0,3999	916,2	6,150	1,482 *
280	0,4934	929,5	6,232	1,493 *	0,4515	929,3	6,222	1.498 *	0,4160	929,0	6,200	1,501 *
290	0,5121	943,0	6,285	1,519 *	0,4688	942,8	6,270	1,521 *	0,4319	942,6	6,255	1,524 *
300	0,5306	957,4	6,336	1,547	0,4857	957,1	6,320	1,545	0,4477	956,8	6,305	1,557
310	0,5492	972,8	6.385	1,578	0,5028	972,6	6,368	1,580	0,4635	972,3	6,351	1,583
320	0,5677	988,9	6,436	1,614	0.5198	988,7	6,418	1,616	0,4792	988,4	6,402	1,618
330	0,5861	1005,4	6,487	1,652	0,5367	1005,2	6,469	1,654	0,4949	1004,9	6,453	1,656
340	0,6045	1022,2	6,537	1,692	0,5536	1022,0	6,520	1,692	0,5106	1021,8	6,504	1,697
350	0,6229	1039,3	6.587	1,728	0,5705	1039,1	6,569	1,730	0,5262	1038,9	6,553	1.732
360	0,6412	1056,8	6.636	1,766	0,5873	1056,6	6,618	1,768	0,5417	1056,4	6,602	1,770
370	0,6595	1074,7	6,685	1,804	0,6041	1074,5	6,668	1,804	0,5573	1074,3	6,651	1,806
380	0,6778	1093,0	6,735	1,839	0,6209	1092,8	6,717	1,839	0,5728	1092,7	6,701	1,842
390	0,6960	1111,8	6.783	1,873	0,6377	1111,6	6,766	1,875	0,5883	1111,5	6,750	1,877
400	0,7142	1131,0	6,832	1,911	0,6543	1130,9	6,815	1,913	0,6037	1130,8	6,799	1,903
410	0,7323	1150,8	6,880	1,944	0,6709	1150,7	6,863	1,946	0,6190	1150,6	6,847	1,949
420	0,7503	1171,1	6,930	1,982	0,6874	1171,0	6,913	1,982	0,6342	1171,0	6,897	1,984
430	0,7681	1191,9	6,979	2,015	0,7038	1191,9	6,962	2,018	0,6493	1191,9	6,946	2,020
440	0,7858	1213,2	7,027	2,051	0,7200	1213,3	7,010	2,051	0,6643	1213,4	6,995	2,053
450	0,8033	1235,0	7.076	2,087	0,7360	1235,2	7.060	2.087	0,6790	1235,4	7,045	2,089

Продолжение табл. VI

T, °K	$p = 1{,}4$ бар				$p = 1{,}5$ бар				$p = 1{,}6$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001504	326,6	3,526	2,086	0,001504	326,6	3,526	2,086	0,001504	326,6	3,526	2,086
190	0,001532	347,5	3,639	2,090	0,001532	347,6	3,639	2,090	0,001532	347,6	3,639	2,090
200	0,001559	368,7	3.746	2.093	0,001559	368,7	3,746	2,093	0,001559	368,7	3,716	2,093
210	0,001588	390,0	3,848	2,102	0,001588	390,0	3,848	2,102	0,001588	390,0	3,848	2,102
220	0,001620	411,6	3,946	2,118	0,001620	411,6	3,946	2,118	0,001620	411,6	3,946	2,118
230	0,001653	433,7	4,010	2,138	0,001653	433,7	4,010	2,138	0,001653	433,7	4,010	2,138
240	0,3249	879,0	5,975	1,462 *	0,3023	878,9	5,960	1,476 *	0,2825	878,8	5,949	1,428 *
250	0,3404	891,3	6,030	1,468 *	0,3168	891,2	6,015	1,475 *	0,2962	891,1	6,000	1,494 *
260	0,3556	903,4	6,080	1,473 *	0,3311	903,3	6,068	1,478 *	0,3097	903,2	6,055	1,490 *
270	0,3706	916,0	6,145	1,484 *	0,3452	915,8	6,112	1,488 *	0,3230	915,6	6,110	1,496 *
280	0,3856	328,7	6,190	1,501 *	0,3592	928,4	6,175	1,505 *	0,3361	928,2	6,156	1,510 *

[Continued]

Table VI (Continued)

T, °K	$p = 1,4$ бар				$p = 1,5$ бар				$p = 1,6$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
290	0,4004	942,4	6,242	1,526 *	0,3731	942,1	6,225	1,527 *	0,3492	941,8	6,215	1,532 *
300	0,4151	956,6	6,290	1,552	0,3869	956,3	6,279	1,554	0,3622	956,0	6,260	1,564
310	0,4298	972,1	6,335	1,583	0,4007	971,8	6,330	1,585	0,3751	971,6	6,309	1,592
320	0,4445	988,2	6,387	1,618	0,4144	988,0	6,375	1,618	0,3880	987,7	6,360	1,626
330	0,4591	1004,7	6,438	1,654	0,4280	1004,5	6,424	1,656	0,4009	1004,3	6,411	1,664
340	0,4736	1021,6	6,488	1,694	0,4416	1021,4	6,474	1,697	0,4136	1021,2	6,461	1,702
350	0,4882	1038,8	6,538	1,730	0,4552	1038,7	6,524	1,732	0,4264	1038,6	6,511	1,740
360	0,5026	1056,3	6,587	1,768	0,4688	1056,1	6,573	1,773	0,4391	1055,9	6,560	1,778
370	0,5171	1074,2	6,636	1,806	0,4823	1074,0	6,623	1,806	0,4518	1073,8	6,609	1,813
380	0,5315	1092,5	6,686	1,842	0,4958	1092,4	6,672	1,842	0,4645	1092,2	6,659	1,847
390	0,5459	1111,4	6,735	1,877	0,5092	1111,2	6,721	1,877	0,4771	1111,1	6,708	1,882
400	0,5602	1130,7	6,784	1,903	0,5226	1130,6	6,770	1,903	0,4897	1130,5	6,757	1,920
410	0,5745	1150,6	6,832	1,949	0,5359	1150,5	6,819	1,949	0,5022	1150,4	6,806	1,953
420	0,5886	1171,0	6,882	1,982	0,5491	1171,0	6,869	1,984	0,5145	1170,9	6,856	1,987
430	0,6026	1192,0	6,932	2,018	0,5622	1192,0	6,918	2,020	0,5268	1192,0	6,905	2,022
440	0,6165	1213,5	6,980	2,053	0,5751	1213,6	6,967	2,053	0,5389	1213,7	6,955	2,056
450	0,6302	1235,6	7,030	2,087	0,5879	1235,8	7,017	2,087	0,5509	1236,0	7,005	2,091

Продолжение табл. VI

T, °K	$p = 1,7$ бар				$p = 1,8$ бар				$p = 1,9$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001504	326,6	3,526	2,086	0,001504	326,6	3,526	2,086	0,001504	326,6	3,526	2,086
190	0,001531	347,6	3,639	2,090	0,001531	347,7	3,639	2,090	0,001531	347,6	3,639	2,090
200	0,001559	368,7	3,746	2,093	0,001559	368,7	3,746	2,093	0,001559	368,7	3,746	2,093
210	0,001588	390,0	3,848	2,102	0,001588	390,0	3,848	2,102	0,001588	390,0	3,848	2,102
220	0,001620	411,6	3,946	2,118	0,001620	411,6	3,946	2,118	0,001620	411,6	3,946	2,118
230	0,001652	433,7	4,040	2,138	0,001652	433,7	4,040	2,138	0,001652	433,7	4,040	2,138
240	0,2650	878,7	6,035	1,521 *	0,2495	878,6	5,920	1,540 *	0,001691	456,4	4,132	2,170
250	0,2780	891,0	5,989	1,510 *	0,2618	890,9	5,972	1,524 *	0,2473	890,8	6,957	1,541 *
260	0,2907	903,1	6,040	1,501 *	0,2739	903,2	6,025	1,515 *	0,2589	902,8	6,012	1,530 *
270	0,3033	915,4	6,095	1,504 *	0,2859	915,2	6,080	1,513 *	0,2702	915,0	6,066	1,524 *
280	0,3158	928,0	6,146	1,515 *	0,2977	927,8	6,135	1,520 *	0,2815	927,6	6,117	1,526 *
290	0,3281	941,5	6,200	1,533 *	0,3094	941,2	6,185	1,538 *	0,2926	940,9	6,170	1,542 *

[Continued]

Table VI (Continued)

T, °K	p = 1,7 бар				p = 1,8 бар				p = 1,9 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
300	0,3104	955,8	6,250	1,559	0,3210	955,5	6,235	1,568	0,3036	955,2	6,224	1,561
310	0,3526	971,3	6,298	1,587	0,3326	971,0	6,284	1,597	0,3147	970,8	6,273	1,526
320	0,3618	987,5	6,345	1,623	0,3441	987,2	6,335	1,630	0,3256	987,0	6,324	1,626
330	0,3769	1004,1	6,395	1,661	0,3556	1003,8	6,386	1,666	0,3365	1003,6	6,375	1,661
340	0,3889	1021,0	6,450	1,699	0,3670	1020,8	6,437	1,706	0,3473	1020,5	6,426	1,702
350	0,4010	1038,4	6,495	1,735	0,3784	1038,2	6,487	1,742	0,3581	1038,0	6,476	1,737
360	0,4130	1055,7	6,545	1,773	0,3897	1055,5	6,536	1,780	0,3689	1055,3	6,525	1,775
370	0,4219	1073,6	6,598	1,808	0,4010	1073,5	6,585	1,816	0,3796	1073,3	6,574	1,811
380	0,4369	1092,0	6,648	1,844	0,4123	1091,9	6,635	1,849	0,3904	1093,7	6,624	1,847
390	0,4488	1110,9	6,698	1,880	0,4236	1110,8	6,684	1,885	0,4010	1110,6	6,673	1,882
400	0,4606	1130,3	6,748	1,918	0,4348	1130,2	6,733	1,923	0,4117	1130,1	6,723	1,918
410	0,4721	1150,3	6,795	1,949	0,4459	1150,2	6,782	1,953	0,4222	1150,2	6,771	1,951
420	0,4810	1170,9	6,845	1,987	0,4569	1170,9	6,833	1,989	0,4327	1170,8	6,822	1,987
430	0,4956	1192,1	6,893	2,022	0,4678	1192,1	6,882	2.025	0,4430	1192,1	6,872	2.022
440	0,5070	1213,8	6,943	2,056	0,4786	1213,9	6,932	2,058	0,4532	1214,0	6,921	2,056
450	0,5182	1236,1	6,993	2,089	0.4892	1236,3	6,983	2,091	0.4632	1236,5	6,973	2,091

Продолжение табл. VI

T, °K	p = 2 бар				p = 3 бар				p = 4 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001504	326,6	3,526	2,086	0,001504	326,7	3,256	2,086	0,001504	326,8	3,526	2,086
190	0,001531	317,6	3,639	2,090	0,001531	347,6	3,639	2,089	0,001531	347,7	3,639	2,089
200	0,001559	368,7	3,746	2,093	0,001559	368,5	3,746	2,092	0,001558	368,6	3,746	2,092
210	0,001588	390,0	3,848	2,101	0,001588	389,5	3,848	2,101	0,001588	389,6	3,848	2,101
220	0,001619	411,6	3,946	2,118	0,001619	410,5	3,946	2,117	0,001619	410,6	3,946	2,116
230	0,001652	433,7	4,010	2,138	0,001652	431,8	4,010	2,137	0,001652	431,8	4,040	2,135
240	0,001691	456,1	4,132	2,167	0,001691	453,4	4,132	2,164	0,001690	453,4	4,132	2,162
250	0,2313	890,5	5,945	1,557 *	0,001729	475,2	—	—	0,001728	475,3	4,220	2,216
260	0,2453	902,5	5,999	1,540 *	0,1594	901,0	5,915	1,623 *	0,001769	497,6	4,308	2,268
270	0,2562	914,8	6,051	1,533 *	0,1617	912,8	5,965	1,598 *	0,1223	910,2	5,900	1,647 *
280	0,2669	927,5	6,105	1,533 *	0,1744	925,0	6,020	1,580 *	0,1281	921,8	5,955	1,620 *
290	0,2775	940,8	6,158	1,543 *	0,1818	938,3	6.070	1,577 *	0,1339	935,0	6,010	1,607 *
300	0,2880	954,9	6,211	1,561	0,1891	952,2	6,124	1,587	0,1396	949,3	6.061	1,611
310	0,2985	970,5	6,262	1,592	0,1963	967,9	6,176	1,608	0,1452	965,2	6,113	1,628

[Continued]

Table VI (Continued)

T, °K	p = 2 бар				p = 3 бар				p = 4 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
320	0,3090	986,8	6,313	1,626	0,2035	984,3	6,228	1,640	0,1507	981,9	6,166	1,659
330	0,3193	1003,4	6,365	1,664	0,2106	1001,2	6,280	1,678	0,1562	998,9	6,218	1,692
340	0,3296	1020,3	6,415	1,702	0,2176	1018,3	6,331	1,716	0,1616	1016,1	6,270	1,730
350	0,3399	1037,8	6,465	1,740	0,2246	1035,8	6,381	1,751	0,1669	1033,7	6,320	1,763
360	0,3502	1055,2	6,515	1,778	0,2316	1053,3	6,431	1,792	0,1722	1051,4	6,370	1,801
370	0,3604	1073,1	6,564	1,813	0,2385	1071,4	6,481	1,823	0,1775	1069,6	6,420	1,835
380	0,3706	1091,5	6,614	1,847	0,2454	1089,9	6,531	1,858	0,1828	1088,3	6,471	1,868
390	0,3808	1110,5	6,663	1,882	0,2523	1109,0	6,580	1,892	0,1880	1107,5	6,520	1,901
400	0,3909	1130,0	6,712	1,920	0,2591	1128,7	6,630	1,930	0,1932	1127,4	6,571	1,937
410	0,4009	1150,1	6,761	1,953	0,2659	1149,1	6,680	1,961	0,1984	1148,0	6,621	1,968
420	0,4108	1170,8	6,812	1,987	0,2726	1170,2	6,731	1,996	0,2034	1169,4	6,674	2,006
430	0,4207	1192,1	6,862	2,022	0,2792	1192,0	6,783	2,030	0,2084	1191,6	6,726	2,037
440	0,4303	1214,1	6,912	2,056	0,2856	1214,5	6,834	2,063	0,2134	1214,6	6,778	2,068
450	0,4399	1236,6	6,963	2,091	0,2920	1237,8	6,886	2,096	0,2182	1238,4	6,832	2,101

Продолжение табл. VI

T, °K	p = 5 бар				p = 6 бар				p = 7 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001504	326,9	3,526	2,085	0,001503	327,0	3,526	2,085	0,001503	327,1	3,526	2,085
190	0,001531	317,8	3,639	2,089	0,001531	317,9	3,639	2,089	0,001531	348,0	3,639	2,089
200	0,001558	368,7	3,746	2,092	0,001558	368,8	3,746	2,092	0,001558	368,9	3,746	2,092
210	0,001588	389,7	3,848	2,100	0,001588	389,8	3,848	2,100	0,001588	389,9	3,848	2,100
220	0,001619	410,7	3,946	2,115	0,001619	410,9	3,946	2,114	0,001619	410,9	3,946	2,114
230	0,001652	431,9	4,040	2,134	0,001652	432,0	4,040	2,133	0,001652	432,1	4,040	2,132
240	0,001690	453,5	4,131	2,160	0,001690	453,6	4,131	2,158	0,001689	453,6	4,131	2,156
250	0,001728	475,4	4,220	2,210	0,001727	475,4	4,220	2,208	0,001727	475,4	4,220	2,206
260	0,001768	497,6	4,308	2,260	0,001768	497,6	4,308	2,254	0,001768	497,7	4,308	2,252
270	0,09531	909,6	5,850	1,677 *	0,001816	521,0	4,394	2,338	0,001815	521,0	4,394	2,336
280	0,1003	921,3	5,903	1,647 *	0,08150	918,4	5,873	1,706 *	0,06850	917,6	5,836	1,756 *
290	0,1051	934,5	5,955	1,633 *	0,08600	931,5	5,923	1,675 *	0,07220	930,0	5,884	1,717 *
300	0,1099	948,6	6,009	1,635	0,08996	945,1	5,966	1,664	0,07570	943,3	5,928	1,697
310	0,1145	964,0	6,063	1,650	0,09395	959,6	6,020	1,671	0,07925	956,7	5,983	1,697
320	0,1190	979,3	6,116	1,676	0,09786	976,7	6,074	1,692	0,08271	974,1	6,038	1,713

[Continued]

Table VI (Continued)

T, °K	$p = 5$ бар				$p = 6$ бар				$p = 7$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
330	0,1235	996,5	6,169	1,708	0,1017	994,1	6,128	1,725	0,08609	991,7	6,092	1,744
340	0,1279	1014,0	6,221	1,745	0,1055	1011,7	6,182	1,763	0,08942	1009,5	6,145	1,780
350	0,1323	1031,8	6,272	1,780	0,1092	1029,7	6,232	1,792	0,09269	1027,5	6,197	1,809
360	0,1366	1049,5	6,322	1,814	0,1129	1047,6	6,283	1,830	0,09591	1045,6	6,248	1,844
370	0,1409	1067,8	6,373	1,848	0,1165	1066,0	6,333	1,858	0,09910	1064,1	6,299	1,873
380	0,1452	1086,6	6,423	1,882	0,1202	1084,9	6,384	1,892	0,1022	1083,2	6,351	1,901
390	0,1495	1106,0	6,474	1,914	0,1237	1104,4	6,435	1,923	0,1054	1102,8	6,401	1,935
400	0,1537	1126,0	6,525	1,947	0,1273	1124,6	6,486	1,956	0,1085	1123,1	6,453	1,965
410	0,1578	1146,9	6,575	1,980	0,1308	1145,6	6,537	1,984	0,1115	1144,3	6,505	1,994
420	0,1620	1168,5	6.628	2,012	0,1343	1167,4	6,591	2,020	0,1146	1166,2	6,558	2,030
430	0,1660	1191,0	6,681	2,044	0,1378	1190,1	6,614	2,053	0,1176	1189,1	6,612	2,060
440	0,1700	1214,3	6,734	2,076	0,1412	1213,7	6,698	2,082	0,1205	1212,9	6,666	2,089
450	0,1740	1238,5	6,789	2,108	0,1445	1238,3	6,733	2,113	0,1235	1237,7	6,722	2,120

Продолжение табл. VI

T, °K	$p = 8$ бар				$p = 9$ бар				$p = 10$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001503	327,2	3,526	2,085	0,001503	327,3	3,526	2,085	0,001503	327,4	3,526	2,085
190	0,001530	348,1	3,639	2,089	0,001530	348,2	3,639	2,088	0,001530	348,3	3,639	2,088
200	0,001558	369,0	3,746	2,092	0,001558	369,1	3,746	2,091	0,001558	369,2	3,746	2,091
210	0,001588	390,0	3,848	2,100	0,001588	390,1	3.848	2,099	0,001588	390,2	3,848	2,098
220	0,001619	411,0	3,946	2,113	0,001619	411,1	3,946	2,112	0,001618	411,2	3,946	2,111
230	0,001652	432,2	4,040	2,131	0,001651	432,3	4,040	2,130	0,001651	432,4	4,040	2,129
240	0,001689	453,7	4,131	2,154	0,001688	453,8	4,131	2,152	0,001688	453.8	4,131	2,150
250	0,001727	475,5	4,220	2,204	0,001726	475,5	4,220	2,202	0,001726	475.6	4,220	2,200
260	0,001768	497,7	4,308	2,250	0,001767	497,8	4,307	2,252	0,001767	497,8	4,307	2,250
270	0,001815	520,9	4,394	2,334	0,001814	520,9	4,394	2,332	0,001813	520,8	4,393	2,330
280	0,001865	544,7	4,480	2,434	0,001864	544,6	4,480	2,427	0,001864	514,6	4,479	2,420
290	0,06173	928,3	5,845	1,755 *	0,05355	925,3	5,810	1,810 *	0,001921	569,3	5,556	2,540
300	0,06496	940,7	5,893	1,728	0,05656	938,8	5,861	1,766	0,04979	936,0	5,831	1,823
310	0,06819	955,3	5,949	1,725	0,05956	952,9	5,919	1,756	0,05261	951,0	5,890	1,795
320	0,07133	971,3	6,005	1,735	0,06244	968,4	5,975	1,759	0,05531	967,0	5,948	1,788
330	0,07438	989,1	6,060	1,763	0,06524	986,5	6,031	1,785	0,05791	983,8	6,004	1,805
340	0,07736	1007,1	6,114	1,797	0,06797	1004,7	6,086	1,816	0,06044	1002,3	6,060	1,833

[Continued]

Table VI (Continued)

T, °K	$p = 8$ бар				$p = 9$ бар				$p = 10$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
350	0,08029	1025,4	6,166	1,825	0,07063	1023,1	6,138	1,842	0,06289	1021,0	6,113	1,861
360	0,08317	1043,6	6,218	1,858	0,07324	1041,6	6,191	1,875	0,06530	1039,5	6,116	1,889
370	0,08601	1062,3	6,269	1,887	0,07582	1060,4	6,242	1,899	0,06766	1058,5	6,218	1,916
380	0,08882	1081,4	6,321	1,915	0,07836	1079,7	6,294	1,927	0,06996	1077,9	6,270	1,944
390	0,09159	1101,2	6,372	1,944	0,08086	1099,5	6,346	1,956	0,07228	1097,9	6,322	1,971
400	0,09434	1121,6	6,424	1,975	0,08334	1120,1	6,398	1,987	0,07454	1118,5	6,374	1,999
410	0,09706	1142,9	6,476	2,003	0,08580	1141,4	6,450	2,013	0,07678	1139,9	6,427	2,028
420	0,09976	1164,9	6,530	2,039	0,08823	1163,6	6,504	2,049	0,07900	1162,2	6,481	2,056
430	0,1051	1188,0	6,584	2,070	0,09064	1186,7	6,559	2,077	0,08120	1185,4	6,536	2,083
440	0,1077	1211,9	6,638	2,096	0,09303	1210,8	6,613	2,103	0,08339	1209,6	6,590	2,110
450	0,1102	1236,9	6,695	2,125	0,09539	1235,9	6,670	2,131	0,08556	1234,8	6,648	2,137

Продолжение табл. VI

T, °K	$p = 11$ бар				$p = 12$ бар				$p = 13$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001503	327,5	3,526	2,085	0,001503	327,6	3,526	2,084	0,001503	327,8	3,526	2,084
190	0,001530	348,4	3,639	2,088	0,001530	348,5	3,639	2,088	0,001530	348,6	3,639	2,087
200	0,001558	369,3	3,746	2,091	0,001558	369,4	3,748	2,090	0,001558	369,5	3,746	2,090
210	0,001588	390,3	3,848	2,098	0,001588	390,4	3,848	2,098	0,001587	390,5	3,818	2,097
220	0,001618	411,3	3,946	2,111	0,001618	411,4	3,946	2,110	0,001618	411,5	3,946	2,109
230	0,001651	432,5	4,040	2,128	0,001651	432,6	4,040	2,127	0,001650	432,6	4,010	2,125
240	0,001688	453,9	4,131	2,148	0,001687	453,9	4,131	2,146	0,001687	451,0	4,130	2,144
250	0,001725	475,6	4,219	2,198	0,001725	475,7	4,219	2,196	0,001724	475,8	4,219	2,194
260	0,001766	497,8	4,306	2,248	0,001766	497,8	4,306	2,246	0,001765	497,8	4,306	2,244
270	0,001812	520,8	4,393	2,328	0,001812	520,8	4,393	2,326	0,001811	520,8	4,393	2,324
280	0,001863	544,5	4,479	2,414	0,001862	544,5	4,478	2,409	0,001861	544,4	4,478	2,404
290	0,001920	569,2	4,556	2,537	0,001919	569,1	4,555	2,533	0,001918	569,0	4,554	2,528
300	0,04419	925,2	5,802	1,823	0,03918	923,4	5,780	1,850	0,001987	595,2	4,655	2,690
310	0,04689	943,6	5,863	1,835	0,04209	941,9	5,841	1,884	0,03799	938,4	5,817	1,942
320	0,04945	955,8	5,906	1,813	0,04155	960,7	5,901	1,847	0,04037	957,6	5,804	1,832
330	0,05190	981,1	5,979	1,830	0,04687	979,5	5,950	1,856	0,04260	976,7	5,937	1,885
340	0,05426	999,8	6,036	1,854	0,04911	998,3	6,015	1,877	0,04473	995,8	5,994	1,901
350	0,05655	1019,1	6,089	1,880	0,05126	1017,2	6,069	1,901	0,04677	1015,0	6,049	1,923

[Continued]

Table VI (Continued)

T, °K	p = 11 бар				p = 12 бар				p = 13 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
360	0,05879	1037,4	6,143	1,908	0,05336	1036,1	6,123	1,925	0,04885	1034,1	6,103	1,944
370	0,06098	1056,5	6,195	1,930	0,05540	1055,3	6,176	1,941	0,05068	1053,3	6,156	1,961
380	0,06313	1076,1	6,248	1,953	0,05741	1074,9	6,229	1,968	0,05257	1073,1	6,209	1,982
390	0,06526	1096,2	6,300	1,980	0,05938	1095,0	6,281	1,991	0,05442	1093,4	6,262	2,003
400	0,06733	1116,9	6,353	2,006	0,06133	1115,8	6,334	2,018	0,05624	1114,3	6,315	2,030
410	0,06910	1138,4	6,405	2,032	0,06325	1137,4	6,386	2,041	0,05804	1135,9	6,368	2,051
420	0,07145	1160,8	6,460	2,065	0,06515	1159,8	6,441	2,077	0,05981	1158,4	6,423	2,084
430	0,07318	1184,1	6,515	2,096	0,06703	1183,1	6,496	2,103	0,06157	1181,7	6,478	2,110
440	0,07549	1208,3	6,569	2,120	0,06890	1207,4	6,551	2,125	0,06331	1206,1	6,533	2,134
450	0,07719	1233,5	6,627	2,146	0,07076	1232,6	6,608	2,153	0,06505	1231,4	6,590	2,160

Продолжение табл VI

T, °K	p = 14 бар				p = 15 бар				p = 16 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001502	327,9	3,526	2,084	0,001502	328,0	3,526	2,084	0,001502	328,1	3,526	2,083
190	0,001530	348,7	3,639	2,087	0,001530	348,8	3,639	2,087	0,001530	348,9	3,639	2,087
200	0,001558	369,6	3,746	2,090	0,001557	369,6	3,746	2,090	0,001557	369,7	3,746	2,090
210	0,001587	390,6	3,848	2,097	0,001587	390,7	3,848	2,096	0,001587	390,8	3,848	2,096
220	0,001617	411,6	3,946	2,109	0,001617	411,6	3,946	2,108	0,001617	411,7	3,946	2,107
230	0,001650	432,7	4,040	2,124	0,001650	432,8	4,040	2,123	0,001649	432,9	4,040	2,122
240	0,001686	454,0	4,130	2,142	0,001686	454,1	4,130	2,140	0,001686	454,2	4,130	2,138
250	0,001724	475,8	4,219	2,192	0,001723	475,8	4,219	2,190	0,001723	475,9	4,219	2,188
260	0,001765	497,9	4,306	2,242	0,001764	497,9	4,306	2,240	0,001764	498,0	4,305	2,238
270	0,001810	520,8	4,393	2,322	0,001809	520,7	4,393	2,320	0,001809	520,7	4,393	2,318
280	0,001860	544,4	4,478	2,399	0,001860	544,4	4,477	2,395	0,001859	544,3	4,476	2,391
290	0,001917	569,0	4,554	2,523	0,001916	568,9	4,553	2,518	0,001915	568,8	4,553	2,513
300	0,001985	595,0	4,654	2,680	0,001984	594,9	4,653	2,670	0,001982	594,7	4,652	2,662
310	0,03443	937,0	5,793	2,010	0,03130	937,7	5,769	2,103	0,02870	927,2	5,750	2,164
320	0,03676	954,3	5,855	1,927	0,03360	954,0	5,834	1,983	0,03080	947,4	5,812	2,105
330	0,03892	973,9	5,916	1,918	0,03571	972,9	5,895	1,953	0,03288	967,8	5,875	2,048
340	0,04096	993,2	5,974	1,925	0,03769	990,6	5,954	1,953	0,03481	987,9	5,936	2,008
350	0,04292	1012,5	6,029	1,946	0,03959	1010,1	6,011	1,961	0,03662	1008,2	5,993	2,001
360	0,04480	1031,8	6,084	1,963	0,014137	1029,6	6,066	1,976	0,03835	1027,4	6,048	2,006
370	0,04663	1051,4	6,138	1,977	0,04311	1049,3	6,120	1,991	0,04003	1047,3	6,103	2,015

[Continued]

Table VI (Continued)

T, °K	p = 14 бар				p = 15 бар				p = 16 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
380	0,04842	1071,3	6,191	1,996	0,04481	1069,4	6,174	2,013	0,04165	1067,5	6,158	2,030
390	0,05016	1091,6	6,244	2,015	0,04647	1089,9	6,227	2,033	0,04323	1088,2	6,211	2,044
400	0,05188	1112,7	6,297	2,041	0,04810	1111,0	6,281	2,055	0,04478	1109,4	6,265	2,065
410	0,05357	1134,4	6,351	2,063	0,04970	1132,9	6,334	2,079	0,04630	1131,4	6,319	2,084
420	0,05524	1157,0	6,406	2,096	0,05127	1155,5	6,389	2,102	0,04780	1154,1	6,374	2,115
430	0,05688	1180,4	6,461	2,120	0,05282	1179,0	6,445	2,126	0,01927	1177,7	6,430	2,139
440	0,05852	1204,8	6,516	2,144	0,05136	1203,5	6,500	2,149	0,05072	1202,2	6,485	2,160
450	0,06014	1200,1	6,573	2,167	0,05588	1228,8	6,558	2,173	0,05216	1227,6	6,543	2,182

Продолжение табл. VI

T, °K	p = 17 бар				p = 18 бар				p = 19 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001502	328,2	3,526	2,083	0,001502	328,3	3,526	2,083	0,001502	328,4	3,526	2,083
190	0,001530	349,0	3,639	2,086	0,001530	349,1	3,639	2,086	0,001530	349,2	3,639	2,086
200	0,001557	369,8	3,746	2,090	0,001557	369,9	3,746	2,089	0,001556	370,0	3,746	2,089
210	0,001587	390,9	3,848	2,096	0,001587	391,0	3,848	2,095	0,001586	391,0	3,848	2,095
220	0,001617	411,7	3,946	2,107	0,001617	411,8	3,946	2,105	0,001616	411,9	3,946	2,105
230	0,001649	433,0	4,040	2,121	0,001619	433,0	4,040	2,120	0,001648	431,1	4,040	2,119
240	0,001685	454,3	4,130	2,136	0,001685	454,4	4,130	2,134	0,001684	454,4	4,130	2,132
250	0,001722	475,9	4,219	2,186	0,001722	476,0	4,219	2,184	0,001722	476,0	4,219	2,182
260	0,001763	497,0	4,305	2,236	0,001763	498,0	4,305	2,234	0,001762	498,0	4,304	2,232
270	0,001808	520,7	4,393	2,316	0,001807	520,7	4,392	2,314	0,001807	520,7	4,392	2,312
280	0,001858	544,3	4,476	2,387	0,001857	544,2	4,476	2,383	0,001856	541,2	4,475	2,379
290	0,001914	568,8	4,552	2,509	0,001913	568,7	4,551	2,505	0,001912	568,6	4,550	2,501
300	0,001981	594,6	4,652	2,654	0,001979	594,4	4,651	2,646	0,001978	594,3	4,650	2,638
310	0,002061	622,0	4,743	2,850	0,002059	621,7	4,742	2,840	0,002057	621,5	4,740	2,280
320	0,02830	938,7	5,791	2,179	0,02604	939,9	5,770	2,263	0,02397	935,6	5,749	2,377
330	0,03036	964,6	5,865	2,101	0,02810	961,3	5,877	2,161	0,02606	957,8	5,818	2,231
340	0,03225	985,0	5,917	2,047	0,02997	982,1	5,900	2,091	0,02790	979,1	5,882	2,140
350	0,03401	1005,2	5,975	2,030	0,03169	997,6	5,959	2,060	0,02960	999,8	5,942	2,096
360	0,03569	1025,1	6,032	2,030	0,03332	1002,5	6,016	2,053	0,03118	1020,5	6,000	2,077
370	0,03740	1045,2	6,087	2,034	0,03187	1043,1	6,072	2,056	0,03269	1041,0	6,057	2,082
380	0,03886	1065,6	6,142	2,046	0,03637	1063,6	6,127	2,063	0,03415	1061,7	6,112	2,082
390	0,04038	1087,0	6,196	2,058	0,03783	1084,6	6,181	2,072	0,03556	1082,7	6,167	2,089
400	0,04186	1107,8	6,250	2,077	0,03926	1106,1	6,236	2,091	0,03693	1104,4	6,222	2,106
410	0,04331	1129,8	6,304	2,096	0,04065	1128,3	6,290	2,108	0,03827	1126,7	6,277	2,122

[Continued]

Table VI (Continued)

T, °K	p = 17 *бар*				p = 18 *бар*				p = 19 *бар*			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
420	0,04424	1152,6	6,360	2,127	0,04201	1151,2	6,346	2,139	0,03958	1149,7	6,333	2,148
430	0,04613	1176,3	6,415	2,148	0,04335	1175,0	6,402	2,158	0,04086	1173,6	6,389	2,167
440	0,04751	1200,9	6,471	2,170	0,04466	1199,6	6,458	2,177	0,04212	1198,4	6,445	2,186
450	0,04887	1226,4	6,529	2,189	0,04595	1225,2	6,516	2,196	0,04335	1224,0	6,503	2,205

Продолжение табл. VI

T, °K	p = 20 *бар*				p = 25 *бар*				p = 30 *бар*			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001502	328,5	3,526	2,083	0,001502	329,0	3,526	2,082	0,001502	329,5	3,526	2,081
190	0,001529	349,3	3,639	2,086	0,001528	349,8	3,639	2,085	0,001528	350,3	3,639	2,084
200	0,001556	370,1	3,746	2,089	0,001556	370,7	3,746	2,087	0,001555	371,2	3,746	2,086
210	0,001586	391,1	3,848	2,094	0,001586	391,6	3,848	2,092	0,001586	392,0	3,848	2,091
220	0,001616	412,0	3,946	2,101	0,001617	412,5	3,946	2,101	0,001616	413,0	3,945	2,097
230	0,001648	431,2	4,040	2,118	0,001648	433,6	4,039	2,114	0,001647	434,0	4,038	2,109
240	0,001684	451,4	4,130	2,130	0,001682	454,8	4,129	2,125	0,001680	455,1	4,128	2,120
250	0,001721	476,0	4,219	2,180	0,001719	476,3	4,218	2,170	0,001717	476,5	4,217	2,160
260	0,001762	498,0	4,304	2,230	0,001759	498,2	4,303	2,220	0,001756	498,4	4,302	2,210
270	0,001806	520,7	4,392	2,310	0,001803	520,8	4,390	2,300	0,001800	520,9	4,388	2,285
280	0,001855	544,2	4,474	2,375	0,001851	544,2	4,472	2,362	0,001847	544,0	4,471	2,350
290	0,001911	568,6	4,550	2,497	0,001906	568,4	4,547	2,478	0,001901	568,0	4,544	2,455
300	0,001976	594,2	4,649	2,630	0,001970	593,7	4,645	2,600	0,001963	593,2	4,641	2,570
310	0,002054	621,3	4,738	2,800	0,002046	620,5	4,733	2,752	0,002038	619,5	4,727	2,700
320	0,002139	650,9	4,833	3,120	0,002130	649,4	4,825	3,031	0,002122	647,8	4,817	2,949
330	0,02419	955,1	5,799	—	0,002259	681,5	4,924	3,380	0,002242	678,8	4,917	3,260
340	0,02603	976,0	5,865	—	0,01873	958,4	5,779	—	0,002400	714,5	5,015	3,870
350	0,02771	996,2	5,926	2,137	0,02037	983,2	5,849	2,357	0,01526	960,0	5,772	2,860
360	0,02926	1018,0	5,985	2,102	0,02184	1005,0	5,913	2,275	0,01674	987,5	5,844	2,550
370	0,03073	1038,8	6,042	2,094	0,02319	1027,1	5,974	2,223	0,01813	1014,1	5,911	2,423
380	0,03214	1059,6	6,098	2,098	0,02446	1049,1	6,033	2,202	0,01934	1037,5	5,974	2,352
390	0,03350	1080,9	6,154	2,108	0,02566	1071,1	6,091	2,196	0,02043	1060,5	6,034	2,310
400	0,03483	1102,7	6,209	2,121	0,02683	1093,5	6,148	2,200	0,02145	1083,6	6,092	2,292
410	0,03613	1125,1	6,264	2,138	0,02797	1116,6	6,204	2,209	0,02246	1107,0	6,150	2,290
420	0,03739	1148,3	6,320	2,156	0,02910	1140,3	6,262	2,221	0,02347	1131,1	6,209	2,293
430	0,03863	1172,2	6,377	2,174	0,03020	1155,9	6,320	2,233	0,02451	1156,1	6,267	2,297
440	0,03983	1197,1	6,433	2,192	0,03127	1190,4	6,378	2,245	0,02557	1182,1	6,326	2,301
450	0,04101	1222,9	6,491	2,210	0,03232	1216,9	6,438	2,256	0,02662	1209,2	6,388	2,305

[Continued]

Table VI (Continued)

T, °K	$p = 35$ бар				$p = 40$ бар				$p = 45$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001502	330,0	3,526	2,080	0,001502	330,5	3,526	2,079	0,001502	331,0	3,526	2,078
190	0,001528	350,8	3,639	2,083	0,001528	351,3	3,638	2,081	0,001528	351,8	3,638	2,080
200	0,001554	371,6	3,746	2,085	0,001554	372,1	3,745	2,083	0,001553	372,6	3,745	2,082
210	0,001584	392,5	3,848	2,089	0,001584	393,0	3,847	2,087	0,001583	393,5	3,847	2,085
220	0,001615	413,4	3,945	2,093	0,001613	413,8	3,944	2,090	0,001612	414,3	3,944	2,088
230	0,001645	434,4	4,038	2,104	0,001644	434,8	4,037	2,100	0,001643	435,2	4,037	2,096
240	0,001679	455,5	4,128	2,116	0,001677	455,8	4,127	2,112	0,001675	456,2	4,126	2,108
250	0,001715	476,8	4,216	2,150	0,001713	477,1	4,215	2,145	0,001711	477,5	4,213	2,140
260	0,001754	498,6	4,300	2,200	0,001752	498,8	4,299	2,192	0,001949	499,1	4,298	2,184
270	0,001797	520,9	4,385	2,270	0,001794	521,1	4,383	2,260	0,001791	521,2	4,382	2,250
280	0,001844	544,0	4,469	2,340	0,001840	544,0	4,468	2,330	0,001837	544,1	4,466	2,320
290	0,001897	567,9	4,541	2,440	0,001892	567,8	4,539	2,425	0,001888	567,8	4,537	2,410
300	0,001956	592,8	4,638	2,552	0,001950	592,6	4,435	2,534	0,001945	592,4	4,632	2,520
310	0,002030	618,9	4,722	2,659	0,002022	618,4	4,718	2,631	0,002014	618,0	4,715	2,604
320	0,002113	646,6	4,811	2,880	0,002104	645,7	4,805	2,830	0,002096	645,0	4,800	2,799
330	0,002225	676,8	4,904	3,150	0,002210	675,3	4,896	3,025	0,002195	674,1	4,890	3,026
340	0,002373	710,6	5,002	3,620	0,002346	707,6	4,992	3,445	0,002320	705,5	4,984	3,320
350	0,01083	930,5	—	—	0,002563	746,1	5,103	4,295	0,002507	742,3	5,090	4,005
360	0,01278	967,5	—	3,048	0,009292	937,0	5,701	4,774	0,002967	791,2	5,229	5,741
370	0,01423	997,5	5,846	2,708	0,01117	978,0	5,776	3,295	0,008437	950,6	5,689	4,931
380	0,01546	1023,4	5,916	2,550	0,01250	1008,1	5,857	2,859	0,01008	989,6	5,794	3,396
390	0,01656	1048,0	5,976	2,461	0,01363	1035,2	5,927	2,664	0,01128	1020,6	5,874	2,955
400	0,01757	1072,0	6,040	2,411	0,01412	1060,8	5,992	2,560	0,01229	1048,5	5,945	2,750
410	0,01852	1095,6	6,098	2,384	0,01554	1085,6	6,053	2,501	0,01320	1074,9	6,010	2,639
420	0,01942	1118,9	6,155	2,372	0,01639	1109,9	6,112	2,465	0,01402	1100,4	6,071	2,572
430	0,02028	1142,2	6,210	2,366	0,01720	1134,0	6,169	2,443	0,01480	1125,4	6,130	2,530
440	0,02111	1165,5	6,262	2,362	0,01798	1157,9	6,223	2,424	0,01553	1150,1	6,186	2,497
450	0,02192	1188,8	6,315	2,358	0,01872	1181,8	6,277	2,410	0,01623	1174,5	6,242	2,473

[Continued]

Table VI (Continued)

T, °K	$p = 50$ бар				$p = 55$ бар				$p = 60$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
180	0,001501	331,5	3,526	2,077	0,001501	332,0	3,526	2,077	0,001500	332,5	3,526	2,076
190	0,001528	352,3	3,638	2,079	0,001527	352,8	3,638	2,078	0,001527	353,3	3,638	2,077
200	0,001554	373,1	3,745	2,080	0,001554	373,6	3,745	2,079	0,001553	374,1	3,745	2,078
210	0,001583	393,9	3,847	2,083	0,001582	394,4	3,846	2,081	0,001581	394,8	3,846	2,080
220	0,001611	414,3	3,944	2,086	0,001610	415,2	3,943	2,084	0,001609	415,7	3,943	2,082
230	0,001641	435,2	4,037	2,092	0,001610	436,1	4,036	2,089	0,001639	436,5	4,036	2,085
240	0,001673	456,2	4,126	2,105	0,001672	457,0	4,126	2,102	0,001671	457,4	4,125	2,100
250	0,001709	477,5	4,212	2,136	0,001707	478,2	4,212	2,133	0,001705	478,6	4,211	2,130
260	0,001747	499,1	4,297	2,176	0,001745	499,7	4,296	2,168	0,001742	500,0	4,295	2,160
270	0,001788	521,2	4,380	2,240	0,001785	521,7	4,379	2,230	0,001783	521,9	4,378	2,220
280	0,001833	544,1	4,464	2,310	0,001829	544,3	4,462	2,300	0,001826	544,5	4,460	2,290
290	0,001883	567,8	4,536	2,400	0,001878	567,8	4,534	2,390	0,001875	567,8	4,532	2,380
300	0,001939	592,4	4,629	2,501	0,001934	592,2	4,626	2,491	0,001929	592,1	4,624	2,480
310	0,002007	618,0	4,712	2,586	0,002000	617,5	4,709	2,565	0,001992	617,4	4,707	2,570
320	0,002086	645,0	4,796	2,773	0,002077	644,0	4,794	2,751	0,002068	643,9	4,790	2,740
330	0,002181	674,1	4,885	2,962	0,002167	672,5	4,881	2,931	0,002155	672,2	4,878	2,920
340	0,002298	705,5	4,978	3,235	0,002276	703,2	4,973	3,184	0,002257	702,6	4,968	3,160
350	0,002461	742,3	5,080	3,801	0,002422	737,1	5,072	3,630	0,002390	736,0	5,066	3,512
360	0,002811	791,2	5,204	5,002	0,002695	777,9	5,186	4,531	0,002606	774,5	5,174	4,190
370	0,001746	879,6	5,485	—	0,003184	821,9	5,317	6,888	0,002954	810,1	5,279	5,109
380	0,007037	965,8	5,719	4,533	0,005868	930,6	5,617	7,817	0,004080	882,7	5,485	9,986
390	0,009322	1003,7	5,817	3,408	0,007629	983,4	5,755	4,175	0,006125	958,5	5,682	5,386
400	0,01039	1035,0	5,897	3,011	0,008789	1019,8	5,847	3,371	0,007420	1002,7	5,794	3,860
410	0,01130	1063,4	5,966	2,810	0,009728	1051,0	5,923	3,024	0,008400	1037,6	5,879	3,294
420	0,01212	1090,4	6,032	2,695	0,01054	1079,7	5,993	2,842	0,009225	1068,5	5,955	3,014
430	0,01287	1116,4	6,093	2,620	0,01128	1107,1	6,058	2,734	0,009954	1097,3	6,022	2,854
440	0,01357	1142,0	6,151	2,566	0,01196	1133,6	6,118	2,659	0,01062	1124,9	6,085	2,750
450	0,01424	1167,1	6,208	2,530	0,01261	1159,5	6,176	2,675	0,01125	1151,7	6,146	2,675

[Continued]

Table VI (Continued)

T, °K	p = 65 бар				p = 70 бар				p = 75 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
370	0,002828	803,1	5,256	4,403	0,002741	798,2	5,239	3,978	0,002676	794,3	5,225	3,713
380	0,003428	857,5	5,414	6,302	0,003158	845,2	5,377	5,192	0,003000	837,4	5,353	4,510
390	0,004856	911,6	5,560	—	0,004023	903,8	5,530	6,110	0,003578	887,2	5,481	5,293
400	0,006241	983,4	5,737	4,436	0,005259	962,7	5,678	5,006	0,004512	942,9	5,623	5,273
410	0,007268	1023,0	5,834	3,597	0,006302	1007,4	5,788	3,948	0,005495	991,4	5,742	4,292
420	0,008106	1056,6	5,916	3,207	0,007150	1044,1	5,877	3,426	0,006334	1031,1	5,838	3,643
430	0,008835	1087,1	5,988	2,990	0,007876	1076,6	5,954	3,134	0,007054	1065,7	5,920	3,288
440	0,009492	1115,9	6,053	2,849	0,008524	1106,7	6,022	3,070	0,007692	1097,3	5,922	3,070
450	0,01010	1143,7	6,116	2,752	0,009115	1135,5	6,087	2,927	0,008270	1127,2	6,059	2,927

Продолжение табл. VI

T, °K	p = 80 бар				p = 85 бар				p = 90 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
370	0,002623	791,2	5,214	3,543	0,002579	788,7	5,204	3,416	0,002541	786,5	5,195	3,320
380	0,002892	831,9	5,334	4,139	0,002811	827,5	5,319	3,884	0,002746	824,0	5,306	3,690
390	0,003322	876,3	5,449	4,773	0,003153	868,6	5,425	4,368	0,003083	862,8	5,406	4,056
400	0,004005	929,8	5,583	5,078	0,003671	914,6	5,542	4,730	0,003444	905,4	5,514	4,398
410	0,004849	975,9	5,698	4,548	0,004359	962,0	5,658	4,612	0,003999	950,4	5,625	4,496
420	0,005648	1018,1	5,800	3,855	0,005083	1005,5	5,764	4,060	0,004630	993,8	5,730	4,179
430	0,006351	1054,7	5,886	3,440	0,005753	1043,8	5,854	3,583	0,005252	1033,2	5,823	3,702
440	0,006974	1087,8	5,962	3,177	0,006357	1078,3	5,933	3,282	0,005828	1069,0	5,904	3,383
450	0,007539	1118,8	6,092	3,015	0,006906	1110,4	6,005	3,095	0,006357	1102,1	5,979	3,176

[Continued]

Table VI (Continued)

T, °K	p = 95 бар				p = 100 бар				p = 120 бар			
	v	i	s	c_p	v	i	s	c_p	v	i	s	c_p
370	0,002508	784,6	5,187	3,245	0,002479	783,0	5,180	3,175	0,002388	778,0	5,155	3,065
380	0,002692	821,1	5,295	3,533	0,002647	818,6	5,285	3,408	0,002514	811,6	5,253	3,183
390	0,002939	853,1	5,386	3,818	0,002866	854,4	5,377	3,639	0,002666	844,1	5,337	3,315
400	0,003280	898,3	5,492	4,109	0,003156	892,6	5,474	3,869	0,002852	877,9	5,473	3,462
410	0,003734	940,9	5,597	4,282	0,003536	933,2	5,574	4,062	0,003078	913,3	5,509	3,602
420	0,004275	983,4	5,700	4,180	0,003998	974,4	5,874	4,053	0,003349	949,8	5,598	3,695
430	0,004838	1023,3	5,794	3,774	0,004499	1014,2	5,767	3,780	0,003662	986,9	5,685	3,694
440	0,005378	1060,0	5,878	3,460	0,004998	1051,4	5,852	3,515	0,004002	1023,5	5,769	3,618
450	0,005882	1094,0	5,954	3,252	0,005475	1086,1	5,931	3,322	0,004354	1059,1	5,849	3,490

Продолжение табл. VI

T, °K	p = 140 бар				p = 160 бар				p = 180 бар			
	v	i	s	c_p	v	i	s	c_p	v	i	s	c_p
370	0,002320	774,9	5,136	2,942	0,002267	772,7	5,119	2,856	0,002294	771,4	5,104	2,792
380	0,002423	807,1	5,228	3,028	0,002355	804,2	5,208	2,925	0,002301	802,2	5,190	2,850
390	0,002543	837,9	5,308	3,118	0,002455	833,8	5,284	2,994	0,002387	831,0	5,265	2,907
400	0,002682	869,5	5,388	3,216	0,002566	864,1	5,361	3,067	0,002483	860,4	5,339	2,966
410	0,002844	902,2	5,468	3,316	0,002695	895,2	5,437	3,143	0,002589	890,4	5,413	3,028
420	0,003032	935,8	5,550	3,407	0,002839	927,0	5,515	3,219	0,002707	920,9	5,487	3,091
430	0,003247	970,2	5,631	3,454	0,003002	959,5	5,591	3,264	0,002838	952,2	5,560	3,123
440	0,003486	1005,0	5,710	3,480	0,003182	992,6	5,666	3,331	0,002981	984,0	5,633	3,206
450	0,003743	1039,7	5,788	3,444	0,003378	1026,0	5,742	3,345	0,003138	1026,2	5,706	3,243

[Continued]

Table VI (Continued)

T, °K	$p = 200$ бар				$p = 250$ бар				$p = 300$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
370	0,002187	770,5	5,091	2,742	0,002113	770,0	5,063	2,651	0,002057	771,0	5,039	2,591
380	0,002256	800,9	5,175	2,793	0,002169	799,7	5,142	2,694	0,002104	800,2	5,116	2,629
390	0,002332	829,1	5,248	2,842	0,002230	826,8	5,213	2,733	0,002155	826,7	5,184	2,664
400	0,002416	857,8	5,320	2,893	0,002294	854,3	5,282	2,772	0,002209	853,5	5,252	2,699
410	0,002507	887,0	5,392	2,945	0,002364	882,3	5,351	2,811	0,002265	880,6	5,319	2,732
420	0,002608	916,7	5,464	2,998	0,002338	910,6	5,420	2,851	0,002325	908,1	5,385	2,765
430	0,002717	947,0	5,535	3,013	0,002517	939,3	5,487	2,830	0,002388	935,9	5,451	2,800
440	0,002837	977,8	5,605	3,107	0,002602	968,5	5,554	2,938	0,002455	964,1	5,515	2,836
450	0,002967	1009,1	5,676	3,152	0,002692	998,1	5,621	2,984	0,002525	992,7	5,580	2,876

Продолжение табл. VI

T, °K	$p = 350$ бар				$p = 400$ бар				$p = 450$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
370	0,002011	772,9	5,019	2,547	0,001972	775,6	5,000	2,513	0,001940	769,7	4,983	2,487
380	0,002053	801,8	5,093	2,582	0,002010	804,3	5,072	2,547	0,001974	807,2	5,054	2,519
390	0,002097	827,8	5,160	2,615	0,002050	829,9	5,139	2,576	0,002010	832,6	5,120	2,549
400	0,002143	854,1	5,227	2,647	0,002091	855,8	5,204	2,609	0,002047	858,3	5,185	2,580
410	0,002192	880,8	5,292	2,678	0,002133	882,1	5,269	2,639	0,002085	884,2	5,248	2,609
420	0,002242	907,7	5,357	2,708	0,002178	908,6	5,333	2,667	0,002125	910,4	5,312	2,636
430	0,002295	934,9	5,421	2,738	0,002224	935,4	5,396	2,694	0,002166	936,9	5,374	2,663
440	0,002351	962,5	5,484	2,770	0,002271	962,5	5,458	2,724	0,002208	972,4	5,440	2,689
450	0,002408	990,3	5,547	2,804	0,002321	989,9	5,520	2,755	0,002251	990,7	5,496	2,719

[Continued]

Table VI (Continued)

T, °K	p = 500 бар				p = 600 бар				p = 700 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
370	0,001911	783,1	4,968	2,466	0,001862	790,2	4,940	2,434	0,001822	798,9	4,915	2,413
380	0,001942	810,7	5,037	2,496	0,001890	818,4	5,007	2,462	0,001846	827,1	4,981	2,438
390	0,001975	835,8	5,102	2,526	0,001918	843,2	5,071	2,490	0,001872	851,6	5,044	2,465
400	0,002009	861,2	5,167	2,556	0,001947	868,3	5,135	2,519	0,001897	876,4	5,107	2,493
410	0,002044	886,9	5,229	2,584	0,001977	893,6	5,197	2,548	0,001924	901,5	5,168	2,521
420	0,002080	912,9	5,293	2,612	0,002008	919,2	5,259	2,575	0,001951	926,8	5,230	2,548
430	0,002117	939,1	5,355	2,637	0,002039	945,1	5,320	2,600	0,001978	952,4	5,290	2,575
440	0,002155	965,7	5,415	2,664	0,002071	971,2	5,379	2,627	0,002006	978,3	5,349	2,601
450	0,002194	992,4	5,475	2,692	0,002104	997,6	5,439	2,653	0,002035	1004,4	5,408	2,628

Продолжение табл. VI

T, °K	p = 800 бар				p = 900 бар				p = 1000 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
370	0,001787	808,1	4,892	2,398	0,001758	817,7	4,871	2,388	0,001731	827,7	4,852	2,382
380	0,001810	836,3	4,957	2,421	0,001778	846,0	4,935	2,409	0,001751	856,0	4,915	2,400
390	0,001833	860,7	5,020	2,446	0,001799	870,2	4,998	2,431	0,001770	880,1	4,978	2,421
400	0,001856	885,3	5,082	2,473	0,001821	894,7	5,060	2,457	0,001790	904,4	5,039	2,445
410	0,001880	910,1	5,143	2,501	0,001842	919,4	5,120	2,484	0,001810	929,0	5,099	2,471
420	0,001904	935,2	5,204	2,528	0,001864	944,3	5,181	2,511	0,001830	953,8	5,160	2,498
430	0,001929	960,7	5,264	2,554	0,001887	969,6	5,240	2,538	0,001851	978,9	5,219	2,524
440	0,001954	986,4	5,323	2,582	0,001910	995,1	5,298	2,566	0,001872	1004,3	5,277	2,552
450	0,001979	1012,3	5,381	2,609	0,001933	1020,9	5,357	2,593	0,001893	1030,0	5,535	2,581

[Continued]

Table VI (Continued)

T, °K	$p = 1100$ бар				$p = 1200$ бар				$p = 1300$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
370	0,001708	837,9	4,833	2,378	0,001686	848,3	4,816	2,376	0,001667	858,8	4,800	2,375
380	0,001726	866,2	4,896	2,394	0,001704	876,6	4,878	2,390	0,001683	887,2	4,862	2,388
390	0,001744	890,3	4,959	2,413	0.001721	900,7	4,941	2,407	0,001700	911.3	4,924	2,403
400	0,001763	914,1	5,020	2,436	0.001738	924,9	5,002	2,428	0,001716	935.4	4,985	2,422
410	0,001781	939,0	5,080	2,461	0,001756	949,2	5,062	2,452	0,001732	959,7	5,045	2,445
420	0.001800	963,7	5,140	2,487	0,001773	973,8	5,122	2,477	0,001749	984,2	5,104	2,469
430	0,001819	988,7	5,199	2,513	0,001791	998,7	5,180	2,503	0,001766	1009,0	5,163	2,494
440	0,001839	1014,0	5,256	2,541	0,001809	1023,9	5,237	2.531	0,001783	1034,2	5,220	2,522
450	0.001858	1039.5	5,314	2,570	0,001828	1049,4	5.895	2,560	0,001800	1059.5	5,277	2,551

Продолжение табл. VI

T, °K	$p = 1400$ бар				$p = 1500$ бар				$p = 1600$ бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
370	0,001649	869,4	4,784	2,376	0,001633	880,1	4,770	2,377	0.001618	890,9	4,755	2,378
380	0,001665	898,0	4,846	2,387	0,001648	908,8	4,831	2,387	0,001632	919,7	4,816	2,387
390	0,001680	922,0	4,908	2,400	0,001663	932,8	4,893	2,398	0,001646	943,7	4,879	2,398
400	0,001696	946,0	4,969	2,418	0,001677	956,8	4,954	2,415	0,001660	967,7	4,939	2,413
410	0,001712	970,3	5.028	2,439	0,001692	981,1	5,013	2,435	0,001674	991,9	5.00	2,431
420	0,001727	994,8	5.088	2,463	0,001707	1005,5	5,073	2.457	0,001689	1016,3	5,058	2,453
430	0,001743	1019,5	5,146	2.488	0,001722	1030,2	5,131	2,482	0,001703	1040,9	5,116	2,477
440	0,001759	1014,6	5,203	2,515	0,001738	1055,1	5,188	2,508	0,001718	1065,9	5,173	2,502
450	0,001775	1069,8	5,260	2,543	0,001753	1080,3	5,245	2,536	0,001732	1090,9	5,230	2,529

[Continued]

Table VI (Continued)

T, °K	p = 1700 бар				p = 1800 бар				p = 1900 бар			
	v	i	s	C_p	v	i	s	C_p	v	i	s	C_p
370	0,001604	901,8	4,742	2,379	0,001591	912,8	4,729	2,380	0,001578	923,8	4,716	2,381
380	0,001617	930,7	4,802	2,388	0,001604	941,7	4,789	2,389	0,001591	952,8	4,776	2,390
390	0,001631	954,7	4,865	2,397	0,001617	965,8	4,851	2,398	0,001603	976,9	4,839	2,398
400	0,001644	978,7	4,926	2,412	0,001630	989,8	4,912	2,411	0,001616	1000,9	4,900	2,411
410	0,001658	1002,9	4,985	2,429	0,001643	1014,0	4,971	2,428	0,001628	1025,1	4,959	2,427
420	0,001672	1027,2	5,044	2,450	0,001656	1038,3	5,031	2,447	0,001641	1049,4	5,018	2,445
430	0,001685	1051,8	5,105	2,472	0,001669	1062,8	5,089	2,469	0,001653	1073,9	5,076	2,465
440	0,001699	1076,7	5,158	2,496	0,001682	1087,7	5,145	2,492	0,001666	1098,7	5,132	2,488
450	0,001713	1101,7	5,215	2,523	0,001695	1112,6	5,202	2,518	0,001679	1123,6	5,189	2,513

Продолжение табл. VI

T, °K	p = 2000 бар			
	v	i	s	C_p
370	0,001566	934,9	4,704	2,381
380	0,001579	964,0	4,764	2,390
390	0,001591	988,1	4,826	2,399
400	0,001603	1012,1	4,887	2,411
410	0,001615	1036,2	4,946	2,426
420	0,001627	1060,5	5,006	2,443
430	0,001639	1085,0	5,063	2,463
440	0,001651	1109,8	5,119	2,484
450	0,001663	1134,7	5,176	2,509

Table VII. Specific Volume of Liquid Propylene

T, °K	v·10³ при p								
	280	290	300	310	320	330	340	350	360
65	1,838	1,871	1,923	1,936	2,060	2,143	2,240	2,365	2,542
70	1,820	1,867	1,918	1,980	2,051	2,132	2,225	2,342	2,498
75	1,816	1,863	1,913	1,973	2,043	2,122	2,211	2,320	2,465
80	1,813	1,859	1,909	1,967	2,035	2,112	2,198	2,302	2,435
85	1,810	1,855	1,904	1,962	2,029	2,103	2,185	2,285	2,408
90	1,807	1,851	1,900	1,956	2,022	2,093	2,174	2,269	2,384
95	1,804	1,848	1,895	1,951	2,015	2,084	2,162	2,254	2,362
100	1,801	1,844	1,891	1,946	2,008	2,076	2,152	2,240	2,344
120	1,789	1,830	1,876	1,926	1,984	2,046	2,115	2,193	2,280
140	1,778	1,818	1,862	1,909	1,962	2,020	2,083	2,154	2,231
160	1,768	1,806	1,849	1,893	1,942	1,997	2,056	2,120	2,190
180	1,758	1,795	1,836	1,878	1,925	1,977	2,031	2,091	2,156
200	1,749	1,786	1,825	1,865	1,909	1,959	2,010	2,066	2,126
250	1,729	1,764	1,800	1,837	1,876	1,920	1,965	2,013	2,064
300	1,711	1,744	1,778	1,812	1,849	1,888	1,927	1,970	2,014
350	1,695	1,727	1,758	1,791	1,825	1,860	1,896	1,934	1,974
400	1,681	1,710	1,740	1,771	1,803	1,836	1,870	1,905	1,941
450	1,668	1,696	1,725	1,754	1,784	1,814	1,845	1,877	1,910
500	1,658	1,684	1,711	1,738	1,766	1,795	1,824	1,854	1,885
550	1,648	1,672	1,697	1,723	1,749	1,776	1,803	1,831	1,860
600	1,638	1,661	1,685	1,709	1,734	1,759	1,785	1,811	1,838

Table VIII. Velocity of Sound w, Index of Adiabatics k_V, Ratio of Heat Capacities of Gaseous Propylene κ

T, °K	p = 0,01 бар			p = 5 бар			p = 10 бар			p = 15 бар		
	w	k_v	κ	w	k_v	κ	w	k_v	κ	w	k_v	κ
190	213,8	1,219	1,219	—	—	—	—	—	—	—	—	—
200	218,4	1,210	1,210	—	—	—	—	—	—	—	—	—
210	223,0	1,202	1,202	—	—	—	—	—	—	—	—	—
220	227,5	1,194	1,194	—	—	—	—	—	—	—	—	—
230	232,0	1,187	1,187	—	—	—	—	—	—	—	—	—
240	236,4	1,180	1,180	—	—	—	—	—	—	—	—	—
250	240,7	1,174	1,174	—	—	—	—	—	—	—	—	—
260	244,9	1,169	1,169	—	—	—	—	—	—	—	—	—
270	249,0	1,163	1,163	229,5	1,100	1,251	—	—	—	—	—	—
280	253,1	1,158	1,158	235,5	1,101	1,232	—	—	—	—	—	—
290	257,1	1,153	1,153	241,2	1,102	1,216	—	—	—	—	—	—
300	260,9	1,148	1,148	246,6	1,102	1,202	229,3	1,054	1,298	—	—	—
310	264,9	1,144	1,146	251,7	1,103	1,190	237,0	1,067	1,269	215,9	0,993	1,425
320	268,6	1,140	1,140	256,5	1,103	1,182	243,6	1,073	1,244	226,7	1,022	1,353
330	272,3	1,137	1,137	261,2	1,102	1,172	249,4	1,075	1,223	235,0	1,034	1,298
340	275,9	1,133	1,133	265,6	1,102	1,164	254,7	1,075	1,205	242,0	1,040	1,260
350	279,6	1,130	1,130	269,9	1,101	1,157	260,0	1,075	1,190	248,5	1,042	1,236
360	283,2	1,127	1,127	274,2	1,101	1,150	265,0	1,076	1,179	254,7	1,046	1,217
370	286,7	1,124	1,124	278,4	1,100	1,144	269,9	1,077	1,169	260,5	1,050	1,201
380	290,3	1,122	1,122	282,5	1,099	1,139	274,6	1,077	1,161	266,1	1,053	1,187
390	293,8	1,119	1,118	286,6	1,099	1,134	279,2	1,078	1,152	271,5	1,056	1,176
400	297,2	1,117	1,116	290,4	1,098	1,130	283,7	1,078	1,146	276,7	1,060	1,166
410	300,5	1,114	1,114	294,3	1,097	1,126	288,0	1,079	1,142	281,6	1,063	1,158
420	303,7	1,112	1,112	298,1	1,096	1,123	292,2	1,079	1,137	286,4	1,065	1,151
430	307,0	1,110	1,110	301,8	1,095	1,119	296,3	1,080	1,132	290,9	1,067	1,145
440	310,3	1,108	1,108	305,3	1,095	1,116	300,3	1,081	1,128	295,3	1,069	1,139
450	313,5	1,105	1,106	308,8	1,094	1,114	304,2	1,081	1,124	299,6	1,071	1,135
460	316,7	1,104	1,104	312,3	1,093	1,112	308,0	1,082	1,120	303,7	1,073	1,131
470	319,8	1,102	1,102	315,7	1,092	1,110	311,7	1,083	1,117	307,8	1,074	1,127

[Continued]

Table VIII (Continued)

T, °K	$p = 20$ бар			$p = 25$ бар			$p = 30$ бар			$p = 35$ бар		
	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$
330	216,3	0,967	1,433	—	—	—	—	—	—	—	—	—
340	226,7	0,987	1,360	208,1	0,929	—	—	—	—	—	—	—
350	235,7	1,001	1,308	220,7	0,957	1,429	202,8	0,909	1,656	179,2	0,856	—
360	243,4	1,013	1,272	231,1	0,978	1,354	217,1	0,941	1,492	200,1	0,899	1,764
370	250,6	1,022	1,244	240,0	0,994	1,301	228,6	0,963	1,391	215,5	0,930	1,535
380	257,2	1,029	1,222	247,8	1,005	1,266	238,1	0,980	1,331	227,4	0,953	1,424
390	263,5	1,034	1,201	255,0	1,014	1,243	246,5	0,992	1,291	237,3	0,970	1,356
400	269,4	1,039	1,192	261,7	1,021	1,222	253,9	1,002	1,260	245,9	0,982	1,310
410	274,8	1,044	1,180	267,9	1,027	1,206	260,9	1,010	1,237	253,6	0,992	1,275
420	280,1	1,048	1,170	273,8	1,032	1,193	267,4	1,016	1,218	260,8	1,000	1,249
430	285,1	1,052	1,162	279,4	1,038	1,182	273,5	1,023	1,204	267,6	1,008	1,228
440	290,0	1,056	1,154	284,8	1,042	1,172	279,4	1,028	1,191	274,1	1,015	1,212
450	294,6	1,059	1,148	289,9	1,046	1,163	285,0	1,034	1,180	280,2	1,023	1,198
460	299,3	1,061	1,142	295,0	1,050	1,156	290,4	1,039	1,170	286,0	1,029	1,186
470	303,7	1,063	1,138	299,8	1,054	1,150	295,7	1,044	1,162	291,7	1,036	1,176

Продолжение табл. VIII

T, °K	$p = 40$ бар			$p = 45$ бар			$p = 50$ бар			$p = 55$ бар		
	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$
360	177,6	0,857	2,508	—	—	—	—	—	—	—	—	—
370	199,9	0,898	1,831	181,4	0,868	2,595	162,5	0,907	—	227,2	2,961	3,326
380	215,5	0,929	1,574	202,9	0,907	1,839	189,8	0,913	2,396	177,5	0,980	3,968
390	227,6	0,950	1,447	217,7	0,933	1,581	207,3	0,925	1,800	197,3	0,929	2,159
400	237,6	0,966	1,373	229,5	0,951	1,457	221,0	0,940	1,571	212,9	0,936	1,731
410	246,4	0,978	1,322	239,4	0,965	1,381	232,5	0,957	1,454	225,8	0,953	1,548
420	254,4	0,987	1,286	248,3	0,977	1,329	242,5	0,969	1,379	236,7	0,966	1,442
430	261,8	0,996	1,258	256,3	0,988	1,291	251,2	0,977	1,329	246,2	0,972	1,374
440	268,8	1,005	1,236	263,8	0,997	1,263	259,2	0,989	1,292	254,6	0,982	1,326
450	275,4	1,013	1,218	270,8	1,006	1,240	266,5	0,999	1,264	262,4	0,995	1,291
460	281,6	1,022	1,204	277,5	1,015	1,222	273,6	1,009	1,243	269,8	1,006	1,264
470	288,0	1,030	1,190	284,2	1,024	1,207	280,7	1,019	1,226	277,3	1,015	1,244

[Continued]

Table VIII (Continued)

T, °K	$p = 60$ бар			$p = 65$ бар			$p = 70$ бар			$p = 75$ бар		
	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$
370	273,5	4,233	2,651	308,3	5,176	2,370	337,8	5,904	2,202	363,0	6,535	2,092
380	187,1	1,425	4,889	226,0	2,298	3,140	260,2	3,021	2,680	290,5	3,751	2,399
390	190,4	0,987	2,709	191,5	1,164	4,297	211,2	1,579	3,462	236,7	2,094	2,701
400	205,9	0,951	1,949	202,4	1,007	2,208	203,6	1,123	2,490	211,9	1,327	2,616
410	219,6	0,963	1,668	215,5	0,981	1,810	213,2	1,030	1,972	213,8	1,109	2,135
420	231,4	0,967	1,517	227,2	0,978	1,603	221,0	1,000	1,703	223,0	1,045	1,803
430	241,5	0,976	1,427	237,5	0,981	1,487	231,3	0,993	1,552	232,4	1,016	1,621
440	250,4	0,981	1,365	246,8	0,985	1,409	243,8	0,996	1,455	241,8	1,010	1,504
450	258,7	0,993	1,321	255,5	0,994	1,352	252,7	1,004	1,387	250,9	1,011	1,422
460	266,3	1,003	1,289	263,4	1,003	1,311	261,1	1,013	1,338	259,6	1,018	1,365
470	274,1	1,013	1,263	271,4	1,013	1,282	269,3	1,020	1,303	267,8	1,025	1,326

Продолжение табл. VIII

T, °K	$p = 80$ бар			$p = 85$ бар			$p = 90$ бар			$p = 95$ бар		
	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$	ω	k_v	$\varkappa$
370	384,3	7,046	2,017	403,4	7,409	1,960	420,5	7,720	1,910	436,2	7,968	1,870
380	316,6	4,350	2,238	339,3	4,803	2,125	359,9	5,233	2,028	378,0	5,570	1,956
390	261,2	2,573	2,470	285,0	3,034	2,288	308,0	3,462	2,148	329,3	3,882	2,041
400	227,5	1,611	2,570	246,8	1,950	2,415	267,2	2,299	2,260	287,9	2,660	2,126
410	218,3	1,229	2,252	228,1	1,402	2,303	242,1	1,624	2,263	258,8	1,874	2,170
420	223,6	1,103	1,919	227,0	1,187	2,006	233,4	1,302	2,071	243,5	1,468	2,084
430	232,0	1,057	1,693	233,4	1,109	1,761	237,0	1,182	1,820	243,2	1,272	1,859
440	240,9	1,035	1,555	241,2	1,069	1,604	243,2	1,120	1,652	247,0	1,180	1,692
450	249,8	1,030	1,462	249,5	1,054	1,498	250,4	1,091	1,538	252,4	1,134	1,574
460	258,3	1,031	1,394	258,0	1,051	1,424	258,3	1,077	1,454	259,4	1,108	1,485
470	266,7	1,036	1,347	266,4	1,054	1,372	266,4	1,072	1,396	266,7	1,093	1,422

[Continued]

Table VIII (Continued)

T, °K	$p = 100$ бар		
	w	k_v	$\varkappa$
370	451,5	8,213	1,833
380	396,1	5,921	1,895
390	348,2	4,230	1,956
400	308,0	3,004	2,018
410	275,4	2,145	2,068
420	257,7	1,660	2,036
430	252,2	1,405	1,870
440	253,8	1,266	1,721
450	258,2	1,177	1,606
460	260,8	1,138	1,516
470	267,0	1,114	1,450

Table IX. Viscosity $\eta \cdot 10^6$ and Thermoconductivity $\lambda \cdot 10^3$ of Ethylene and Propylene on Saturation Line as Functions of Temperature

T, °K	Ethylene				T, °K	Propylene		
	η'	λ'	η''	λ''		η'	η''	λ''
110	446	—	—	—	110	1710	—	—
120	357	—	—	—	120	1170	—	—
130	290	—	—	—	130	853	—	—
140	243	—	—	—	140	658	—	—
150	209	—	—	—	150	527	—	—
160	182	201	—	6,7	160	436	—	5,8
170	161	188	—	7,6	170	369	—	6,4
180	143	176	—	8,5	180	318	—	7,1
190	126	165	6,69	9,4	190	281	5,31	7,8
200	112	153	7,12	10,5	200	245	5,64	8,6
210	98,4	142	7,57	11,7	210	220	5,97	9,4
220	86,7	131	8,04	13,0	220	198	6,31	10,2
230	76,4	121	8,58	14,5	230	179	6,65	11,1
240	67,0	111	9,16	16,4	240	163	7,01	12,1
250	58,3	101	9,87	18,7	250	147	7,40	13,2
260	50,6	92	10,8	21,5	260	134	7,78	14,3
270	41,9	81	12,1	25,6	270	121	8,21	15,6

[Continued]

Table IX (Continued)

T, °K	Ethylene				T, °K	Propylene		
	η′	λ′	η″	λ″		η′	η″	λ″
280	31,7	67	—	33,9	280	110	8,65	16,9
					290	99,2	9,16	18,4
					300	89,6	9,67	20,1
					310	80,7	10,3	22,1
					320	71,9	10,9	24,5
					330	63,9	11,7	27,4
					340	55,8	12,6	31,1
					350	48,8	14,1	—
					360	40,6	17,3	—

Table X. Viscosity of Gaseous Ethylene $\eta_1 \cdot 10^8$ and Propylene $\eta_2 \cdot 10^8$ at Atmospheric Pressure

T, °K	η_1	η_2	T, °K	η_1	η_2	T, °K	η_1	η_2	T, °K	η_1	η_2
190	656	529	410	1371	1175	630	1948	1719	850	2434	2187
200	692	562	420	1399	1201	640	1972	1742	860	2455	2208
210	728	593	430	1428	1228	650	1996	1765	870	2475	2228
220	763	624	440	1457	1255	660	2018	1787	880	2495	2247
230	799	655	450	1484	1280	670	2042	1809	890	2515	2266
240	833	686	460	1512	1307	680	2065	1832	900	2535	2286
250	868	716	470	1539	1332	690	2088	1854	910	2556	2306
260	901	746	480	1566	1358	700	2111	1876	920	2575	2324
270	935	777	490	1594	1383	710	2134	1897	930	2595	2345
280	968	806	500	1620	1408	720	2156	1919	940	2614	2363
290	1002	836	510	1647	1433	730	2178	1940	950	2633	2381
300	1034	866	520	1673	1458	740	2200	1961	960	2653	2400
310	1067	895	530	1699	1483	750	2223	1983	970	2672	2419
320	1098	924	540	1725	1507	760	2244	2004	980	2691	2437
330	1130	953	550	1750	1531	770	2266	2025	990	2710	2456
340	1161	981	560	1776	1555	780	2287	2046	1000	2729	2474
350	1192	1009	570	1801	1579	790	2309	2066	—	—	—
360	1222	1037	580	1826	1603	800	2330	2086	—	—	—
370	1253	1065	590	1851	1627	810	2351	2107	—	—	—
380	1283	1093	600	1875	1650	820	2372	2128	—	—	—
390	1312	1121	610	1900	1673	830	2393	2148	—	—	—
400	1342	1148	620	1924	1696	840	2414	2168	—	—	—

Table XI. Viscosity $\eta \cdot 10^6$ and Thermoconductivity $\lambda \cdot 10^3$ of Ethylene

T, °K	p = 1		p = 10		p = 20		p = 30		p = 40		p = 50		p = 60		p = 70		p = 80		p = 90		p = 100		p = 120	
	η	λ	η	λ	η	λ	η	λ	η	λ	η	λ	η	λ	η	λ	η	λ	η	λ	η	λ	η	λ
170	161	7,5	163	—	164	—	166	—	168	—	170	—	172	—	174	—	175	—	177	—	179	—	182	—
180	—	8,3	144	176	146	177	148	178	150	179	151	179	153	180	155	181	156	182	158	183	160	184	161	186
190	6,56	9,1	127	165	128	166	130	167	131	168	133	169	134	170	136	171	138	172	139	173	141	174	144	176
200	9,62	10,0	112	154	113	155	115	156	116	157	118	158	119	160	120	161	122	162	123	163	125	164	127	166
210	7,28	10,9	98,6	143	100	144	102	146	103	147	104	148	106	149	107	150	109	151	110	153	111	154	114	156
220	7,68	11,8	86,7	132	88,3	133	89,9	135	91,4	136	93,0	138	94,4	139	96,0	140	97,4	141	98,8	143	100	144	103	147
230	7,99	12,8	8,39	14,0	77,0	122	78,5	124	80,0	126	81,6	127	83,0	129	84,6	130	86,0	131	87,4	133	88,8	134	91,8	137
240	8,33	13,8	8,71	14,9	67,4	111	69,0	113	70,4	115	72,0	117	73,5	119	75,0	120	76,5	122	78,0	124	79,4	125	82,2	128
250	8,68	14,9	9,04	15,9	9,63	17,9	59,2	103	60,8	105	62,4	107	64,0	109	65,6	111	67,2	113	68,7	114	70,2	115	73,1	119
260	9,01	16,0	9,31	17,0	9,86	18,7	10,8	91,5	52,4	94,6	51,2	97,2	56,1	99,9	57,8	102	59,4	104	61,1	106	62,8	108	65,8	111
270	9,35	17,1	9,67	18,0	10,1	19,4	10,8	21,7	42,4	81,0	45,2	86,0	47,8	89,8	50,1	92,4	52,2	95,0	54,0	97,4	55,7	99.5	58,8	103
280	9,68	18,2	9,99	19,1	10,4	20,4	11,0	22,3	12,2	25,2	35,0	—	39,2	—	42,6	—	45,2	—	47,4	—	49,2	—	52,6	—
290	10,0	19,4	10,3	20,2	10,7	21,4	11,2	23,1	11,9	25,5	13,7	30,1	23,02	52,1	33,3	69,9	37,0	75,9	39,7	79,8	42,0	83,1	45,9	88,9
300	10,3	20,6	10,6	21,3	11,0	22,5	11,4	24,0	12,1	26,0	13,2	29,1	15,2	35,1	21,8	49,3	28,7	63,1	33,0	70,2	36,1	74,9	40,7	81,6
310	10,7	21,8	10,9	22,5	11,2	23,6	11,7	25,0	12,2	26,8	13,1	29,6	14,5	32,6	16,8	39,2	21,2	49,2	25,9	59,0	29,9	65,8	35,5	74,5
320	11,0	23,1	11,2	23,8	11,5	24,8	11,9	26,1	12,4	27,7	13,1	29,7	14,2	32,4	15,6	36,4	17,9	42,4	21,2	49,9	24,8	57,3	30,7	67,8
330	11,3	24,4	11,5	25,1	11,8	26.0	12,2	27,2	12,6	28,7	13,2	30,4	14,0	32,6	15,2	36,6	16,7	39,7	18,7	45,0	21,4	50,9	26,7	61,6
340	11,6	25,7	11,8	26,4	12,1	27,3	12,4	28,4	12,9	29,7	13,4	31,3	14,1	33,1	15,0	35,6	16,1	38,7	17,7	42,6	19,5	47,1	23,8	56,7
350	11,9	27,1	12,1	27,7	12,4	28,6	12,7	29,6	13,1	30,9	13,6	32,3	14,1	34,0	14,9	36,0	15,8	38,5	17,0	41,6	18,4	45,2	21,9	53,3
360	12,2	28,5	12,4	29,1	12,7	29,9	13,0	30,9	13,3	32,1	13,8	33,4	14,3	34,9	14,9	36,6	15,7	38,8	16,6	41,3	17,9	44,2	20,6	51,0
370	12,5	29,9	12,7	30,5	12,9	31,2	13,2	32,2	13,6	33,3	14,0	34,5	14,4	35,9	15,0	37,4	15,7	39,3	16,5	41,5	17,4	43,9	19,6	49,7
380	12,8	13,4	13,0	32,0	13,2	32,7	13,5	33,6	13,8	34,6	14,2	35,8	14,6	37,0	15,1	38,4	15,7	40,1	16,4	42,0	17,2	44,1	19,2	49,1
390	13,1	32,9	13,3	33,4	13,5	34,2	13,8	35,0	14,1	36,0	14,4	37,1	14,8	38,3	15,3	39,6	15,8	41,0	16,4	42,7	17,1	44,6	18,8	49,0
400	13,4	34,4	13,6	34,9	13,8	35,6	14,0	36,4	14,3	37,4	14,6	38,4	15,0	39,5	15,4	40.7	15,9	42,0	16,5	43,6	17,1	45,1	18,6	49,1
410	13,7	36,0	13,8	36,5	14,0	37,2	14,3	38,0	14,6	38,9	14,9	39,8	15,2	40,9	15,6	42,0	16,0	43,7	16,5	44,6	17,1	46,1	18,5	49,6
420	14,0	37,5	14,1	38,0	14,3	38,6	14,6	39,4	14,8	40,2	15,1	41,2	15,4	42,2	15,8	43,2	16,2	41,4	16,7	45,6	17,2	47,0	18,4	50,2
430	14,3	39,1	14,5	39,6	14,7	40,2	14,9	40,9	15,1	41,8	15,4	42,6	15,7	43,6	16,1	44,6	16,4	45,7	16,9	46,8	17,3	48,1	18,4	51,0
440	14,6	40,8	14,7	41,3	14,9	41,9	15,2	42,6	15,4	43,4	15,7	44,2	15,9	45,1	16,3	46,1	16,6	47,1	17,2	48,1	17,5	49,3	18,5	51,8
450	14,8	42,5	15,0	43,0	15,2	43,5	15,4	44,2	15,6	45,0	15,9	45,8	16,2	46,6	16,5	47,6	16,8	48,5	17,3	49,5	17,6	50,6	18,5	53,0

[Continued]

Table XI (Continued)

T, °K	$p = 140$		$p = 160$		$p = 180$		$p = 200$		$p = 300$		$p = 400$		$p = 500$		$p = 600$		$p = 700$	
	η	λ	η	λ	η	λ	η	λ	η	λ	η	λ	η	λ	η	λ	η	λ
170	186	—	189	—	193	—	196	—	213	—	229	—	244	—	—	—	—	—
180	166	188	169	190	173	192	176	193	191	200	206	207	220	212	—	—	—	—
190	147	178	150	180	153	182	156	184	171	192	185	198	198	204	210	—	—	—
200	130	168	133	170	136	172	139	174	153	183	168	190	181	197	194	—	—	—
210	117	158	120	161	122	163	125	165	138	174	152	182	164	189	177	—	—	—
220	106	149	108	151	111	154	114	156	126	166	139	174	151	182	163	—	—	—
230	94,6	140	97,3	142	100	145	103	147	115	158	127	167	138	175	149	—	—	—
240	95,0	131	87,6	134	90,4	136	92,9	139	105	150	116	169	127	167	138	—	—	—
250	75,8	122	78,6	125	81,2	128	83,8	131	95,4	142	106	152	117	160	128	—	—	—
260	68,6	114	71,3	117	73,8	120	76,2	123	87,0	135	97,2	145	107	153	118	—	—	—
270	61,6	106	64,2	109	66,8	112	69,3	115	80,0	128	89,6	138	99,2	146	109	—	—	—
280	55,2	—	57,8	—	60,2	—	62,6	—	73,1	—	82,7	—	91,6	—	101	—	—	—
290	49,8	92,7	52,3	96,5	54,7	99,9	57,0	103	67,0	116	75,4	127	83,4	136	91,4	145	—	152
300	44,1	86,5	47,2	90,8	49,8	94,6	52,2	97,9	61,9	111	70,4	122	77,9	132	85,1	140	92,5	148
310	39,4	80,5	42,8	85,1	45,6	89,1	47,9	92,6	58,2	106	66,1	117	73,3	127	80,5	136	88,2	144
320	34,9	74,7	38,6	80,0	41,6	84,2	44,1	87,9	54,6	102	62,5	113	69,4	123	76,5	132	83,2	139
330	31,3	69,5	34,9	75,2	37,7	80,0	40,5	83,8	51,1	98,6	59,4	110	66,1	119	73,0	128	78,8	136
340	28,0	64,7	31,7	71,5	34,7	75,9	37,7	80,2	48,1	95,2	56,1	106	65,1	116	69,3	124	75,2	132
350	25,5	60,9	28,9	67,3	32,0	72,5	34,7	76,8	45,4	92,3	53,3	104	60,0	113	66,0	121	71,9	129
360	23,7	58,0	26,8	64,2	29,8	69,5	32,6	74,0	42,8	89,7	50,9	101	57,7	110	63,7	119	69,1	126
370	22,4	55,9	24,1	61,9	27,8	67,0	30,3	71,3	40,9	87,5	48,4	98,7	55,2	108	61,1	116	66,6	124
380	21,5	54,6	23,9	60,1	26,4	65,1	28,7	69,5	38,9	85,6	46,3	96,8	53,0	106	58,8	114	64,3	122
390	20,8	53,8	23,0	58,8	25,3	63,6	27,4	68,0	37,1	84,0	44,4	95,1	51,0	104	56,7	112	62,3	120
400	20,4	53,5	22,3	58,0	24,2	62,5	26,3	66,8	35,4	82,7	42,6	93,8	49,3	103	54,8	111	59,9	118
410	20,0	53,6	21,7	57,7	23,5	61,9	25,4	65,9	34,0	81,7	41,2	92,7	48,9	102	52,7	109	58,2	117
420	19,8	53,8	21,3	57,6	23,0	61,5	24,7	65,3	32,8	80,8	39,8	91,7	46,1	100	51,2	108	56,2	115
430	19,2	54,3	21,1	57,8	22,6	61,5	24,3	65,1	31,9	80,1	38,4	91,0	44,4	99,7	49,7	107	54,8	114
440	19,4	55,0	20,9	58,3	22,3	61,7	23,8	65,1	30,9	79,8	37,4	90,6	43,2	99,2	48,4	107	53,3	114
450	19,5	55,3	20,4	58,9	22,0	62,1	23,4	65,4	30,1	79,6	36,4	90,1	42,0	98,5	47,2	106	52,1	113

[Continued]

Table XI (Continued)

T, °K	$p = 800$ бар		$p = 900$ бар		$p = 1000$ бар		$p = 1500$ бар	$p = 2000$ бар	$p = 2500$ бар	$p = 3000$ бар
	η	λ	η	λ	η	λ	λ	λ	λ	λ
290	—	159	—	166	—	173	199	221	238	253
300	99,5	155	108	162	114	168	196	219	237	251
310	94,4	151	102	158	110	164	192	215	234	248
320	89,9	147	96,4	154	104	160	188	211	230	246
330	86,1	143	91,8	150	98,5	156	185	208	227	243
340	81,4	140	87,6	147	93,7	153	182	204	224	241
350	77,4	136	84,1	143	89,4	150	178	202	222	239
360	74,7	134	80,9	140	85,6	147	175	199	219	236
370	71,7	131	76,8	138	82,3	144	172	196	216	234
380	69,7	128	74,5	135	79,3	142	170	194	214	232
390	67,2	126	72,3	133	76,7	139	167	191	211	229
400	64,9	124	69,6	131	75,1	137	165	189	209	227
410	62,9	123	67,8	129	72,1	135	163	187	207	225
420	61,0	122	65,5	128	70,1	134	161	184	206	223
430	59,4	121	63,9	127	68,2	133	160	182	204	222
440	58,1	120	62,4	126	66,6	152	158	181	202	220
450	56,7	120	61,1	126	65,1	131	157	179	200	219

Table XII. Viscosity $\eta\cdot10^6$ and Thermoconductivity $\lambda\cdot10^3$ of Propylene

T, °K	$p = 1$		$p = 10$		$p = 20$		$p = 30$		$p = 40$		$p = 50$		$p = 60$	$p = 70$	$p = 80$	$p = 90$	$p = 100$	$p = 120$
	η	λ	η	λ	η	λ	η	λ	η	λ	η	λ	η	η	η	η	η	η
270	7,77	14,7	126	—	128	—	130	—	132	—	134	—	136	138	139	141	143	146
280	8,08	15,7	115	—	116	—	118	—	120	—	122	—	124	126	127	129	131	134
290	8,36	16,7	103	—	105	—	107	—	109	—	111	—	113	115	117	118	120	123
300	8,66	17,7	9,41	19,5	95,1	—	97,0	—	98,9	—	101	—	103	104	106	108	110	113
310	8,95	18,8	9,72	20,4	85,4	—	87,2	—	89,1	—	91,3	—	93,0	94,8	96,7	98,5	100	104
320	9,24	19,9	10,0	21,4	11,0	—	78,2	—	80,2	—	88,5	—	84,2	86,2	88,0	89,8	91,7	95,0
330	9,53	21,0	10,2	22,5	11,2	25,5	69,6	—	71,8	—	74,3	—	76,2	78,2	80,0	81,8	83,7	87,0
340	9,81	22,1	10,5	23,6	11,3	26,2	60,7	—	63,5	—	66,4	—	68,6	70,8	72,9	75,0	76,7	80,3

[Continued]

Table XII (Continued)

T, °K	p = 1		p = 10		p = 20		p = 30		p = 40		p = 50		p = 60	p = 70	p = 80	p = 90	p = 100	p = 120
	η	λ	η	λ	η	λ	η	λ	η	λ	η	λ	η	η	η	η	η	η
350	10,1	23,3	10,7	24,7	11,5	27,1	12,7	31,5	54,3	—	57,7	—	60,7	63,4	65,9	68,2	70,6	74,0
360	10,4	24,5	11,0	25,8	11,7	28,0	12,7	31,8	15,0	—	48,2	—	52,6	56,2	59,0	61,4	63,7	67,6
370	10,7	25,8	11,2	27,0	12,0	29,0	12,8	31,1	14,3	—	16,6	—	32,1	50,0	53,2	55,8	58,1	62,3
380	10,9	27,0	11,5	28,2	12,2	30,1	13.0	33,0	14,2	37,3	16,2	—	29,7	41,0	46,1	49,7	52,6	57,1
390	11,2	28,3	11,7	29,4	12,4	31,2	13,1	33,9	14,2	37,7	15,9	—	20,2	30,5	38,8	43,5	47,1	52,4
400	11,5	29,6	12,1	30,7	12,6	32,4	13,3	34,9	14,2	38,2	15,5	—	17,9	23,2	30,9	37,1	41,6	47,8
410	11,7	30,9	12,3	32,0	12,8	33,6	13,5	35,9	14,3	39,0	15,4	—	17,1	20,3	27,0	31,2	36,2	43,3
420	12,0	32,3	12,5	33,3	13,1	34,8	13,7	37,0	14,4	39,8	15,4	—	16,7	18,9	23,3	26,8	31,5	39,0
430	12,3	33,7	12,7	34,7	13,3	36,1	13,9	38,1	14,6	40,7	15,4	43,7	16,5	18,7	20,6	23,9	27,8	35,2
440	12,5	35,1	13,0	36,0	13,5	37,4	14,1	39,3	14,7	41,7	15,5	44,5	16,5	17,8	19,7	22,2	25,3	32,4
450	12,8	36,5	13,3	37,5	13,7	39,1	14,3	40,5	14,9	42,8	15,6	45,5	16,5	17,6	19,1	21,3	23,8	29,5

Продолжение табл. XII

T, °K	p = 140	p = 160	p = 180	p = 200	p = 300	p = 400	p = 500	p = 600	p = 700	p = 800	p = 900	p = 1000
	η	η	η	η	η	η	η	η	η	η	η	η
270	149	152	155	158	172	186	199	212	225	237	249	—
280	138	141	144	149	161	173	186	199	211	224	236	247
290	126	129	132	135	149	162	174	187	199	210	223	234
300	116	119	122	125	138	151	164	176	188	199	211	222
310	107	110	111	116	129	142	154	166	177	188	200	211
320	98,1	101	105	107	121	133	145	156	168	178	190	200
330	90,4	93,5	94,6	99,6	113	125	136	147	158	169	180	190
340	83,6	86,9	90,0	92,5	106	118	129	140	150	160	171	181
350	77,2	80,3	83,0	85,8	99,1	111	122	133	139	153	163	172
360	71,2	74,2	77,0	80,0	93,0	105	115	126	136	145	155	165
370	65,8	68,8	71,5	74,2	86,6	97,6	108	117	126	137	145	155
380	60,9	64,1	67,1	69,8	81,7	92,5	103	112	121	130	139	148
390	56,2	59,7	62,8	65,5	77,5	87,9	97,5	107	116	125	133	142
400	52,3	55,1	58,8	61,7	75,4	83,7	93,0	102	111	120	128	136
410	48,3	52,1	55,4	58,1	70,1	79,9	89,1	97,8	106	115	123	131
420	44,4	48,7	52,1	54,9	66,8	76,5	85,3	93,8	102	110	118	126
430	36,6	46,3	48,9	52,1	63,8	73,4	81,9	90,1	97,5	106	114	122
440	35,7	42,3	45,9	49,3	61,2	70,6	78,9	86,8	93,9	102	110	117
450	34,9	39,3	43,2	46,5	57,3	67,9	76,2	83,8	91,4	98,8	106	113

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NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. **BIBLIOGRAPHIC DATA SHEET**	1. PUBLICATION OR REPORT NO. NBSIR 75-763	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

Thermodynamic and Transport Properties of Ethylene and Propylene

5. Publication Date

6. Performing Organization Code

7. AUTHOR(S)

I. A. Neduzhii (Principal Author)

8. Performing Organ. Report No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)*

Same as item 9.

13. Type of Report & Period Covered

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

A comprehensive review of the data on the thermodynamic and transport properties of ethylene and propylene is given. Subjects covered include equation of state for liquid and vapor, second virial coefficient, ethalpy, etc., heat capacity, speed of sound, viscosity, and thermal conductivity. New experimental measurements are given for several properties, especially speed of sound, densities of the liquid and transport properties. Tables of properties covering the temperature range from 160 K to 500 K are given. The book has been translated into English from the original Russian.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Critically evaluated data; ethylene; propylene; thermodynamic properties data; transport properties data

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19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED	21. NO. OF PAGES 210
20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. Price $ 7.25