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P–V–T, Thermodynamic and Related Properties of Oxygen from the Triple Point to 300 K at Pressures to 33 MN/m²*

L. A. Weber**

Institute for Basic Standards, National Bureau of Standards, Boulder, Colorado 80302

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The results of new experimental pressure-volume-temperature measurements on oxygen are presented. The data range in temperature from 54 to 300 K and in pressure from 0.1 to about 33 MN/m². The following properties are tabulated for selected isobars: molar volume, $(\partial P/\partial \rho)_T$, $(\partial P/\partial T)_\rho$, internal energy, enthalpy, entropy, specific heats at constant volume and at constant pressure, and the velocity of sound. Additional tables present the above properties for saturated liquid and vapor, the freezing liquid P–V–T relationship, and the derived Joule-Thomson inversion curve. New values for the critical density and triple point density are presented, and the second and third virial coefficients are tabulated.

Key words: Density; enthalpy; entropy; equation of state; fixed points (PVT); Joule-Thomson; latent heat; melting curve; oxygen; properties of fluids; saturated liquid and vapor; specific heat; vapor pressure; velocity of sound.

List of Symbols and Units

The symbols and units used here are listed below. Values of fixed points and other quantities used here are given where applicable.

R	= gas constant; 8.3147 N-m/mol-K (Note: this value differs by less than 1/20000 from the currently accepted best value.)
P	= pressure, MN/m².
P_{sat}	= vapor pressure.
P_{melt}	= melting pressure.
P_c	= critical pressure, 5.043 ± .002 MN/m².
P_t	= triple point pressure, 152 ± 6 N/m².
V	= molar volume, cm³/mol.
T	= absolute temperature, Kelvins International Practical Temperature Scale of 1948 where the triple point of water is 273.16 K; below the oxygen boiling point the NBS 1955 temperature scale is used.
T_c	= critical temperature, 154.576 ± .010 K.
T_t	= triple point temperature, 54.3507 ± .0010*K*.
T_b	= boiling point temperature, 90.18 K (90.188 K on the IPTS 1968 scale).
ρ	= density, mol/cm³ = 1/V.
ρ_c	= critical density, 0.01363 ± .00002 mol/cm³.
ρ_t	= liquid triple point density, 0.04083 ± .00004 mol/cm³.
$\rho_{sat\,L}$	= saturated liquid density.
$\rho_{sat\,G}$	= saturated vapor density.
$\rho_{melt\,L}$	= density of the liquid along the liquid-solid boundary.
ρ_1	= a selected density in the compressed liquid, 0.028687 mol/cm³.
A_J	= generalized coefficients in approximating equations; numerical values given in tables.
$B(T)$	= second virial coefficient, cm³/mol.
$C(T)$	= third virial coefficient, (cm³/mol)².
$C_v(T, \rho)$	= heat capacity at constant volume, J/mol K $C_v^\circ(T)$ heat capacity of the ideal gas.
$C_p(T, \rho)$	= heat capacity at constant pressure, J/mol K.
C_{sat}	= heat capacity of the saturated liquid, J/mol K.
$S(T, \rho)$	= entropy, J/mol K.
$H(T, \rho)$	= enthalpy, J/mol.
$U(T, \rho)$	= internal energy, J/mol.
W	= velocity of sound, m/s.
Molecular Weight	= 31.9988 g.

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**Cryogenics Division, National Bureau of Standards, Boulder, Colo. 80302.

1. Introduction

The importance of oxygen in the U.S. space program and the lack of comprehensive and accurate data for many of its physical properties have led to an extensive research program at the NBS Institute for Basic Standards. The results of part of that program are presented here in the form of extensive tables of P–V–T data and derived thermodynamic properties.

Prior to 1960 there were relatively few measurements of the P–V–T properties of oxygen at low temperatures. This condition was especially true for the compressed liquid. In 1960 and 1961 Timrot and Borisoglebskii [1, 2] [1] and Van Itterbeek and Verbeke [3, 4] published new P–V–T results for the liquid. However, these results were limited in scope and there was disagreement in the region in which they overlapped.

The results of the present investigation consist of approximately 1500 P–V–T points at 111 different densities varying from 0.0047 to 3 times the critical density. This constitutes approximately two-thirds of all the P–V–T data published for oxygen.

The data range from the triple point temperature to 300 K for the high densities and from 85 K to 300 K for the low (subcritical) density points. The data range in pressure up to about 33 MN/m².

The highest and lowest density data were represented by two analytic surfaces while the intermediate densities were fitted to a large number of isotherm polynomials. Second and third virial coefficients were extracted from the low density data.

This representation of the P–V–T surface together with the specific heat of the ideal gas [5] allowed the calculation of thermodynamic properties of the gas at temperatures below critical and of all densities at temperatures above critical. Thermodynamic calculations for the compressed liquid at subcritical temperatures made use of additional data in the form of new experimental determinations of the heat capacity at constant volume [6] and heat capacity of the saturated liquid [7] from this laboratory.

The properties calculated using this smoothed surface are compared with some of the P–V–T and thermodynamic property data from the literature.

Due to limitations of space only skeleton tables of thermodynamic properties are presented here. A more complete set of tables will be issued as NBS Tech. Note 384.

2. Experimental P–V–T Measurements

2.1. Apparatus

The cryostat designed and described by Goodwin [8] was used with minor modifications. These modifications are listed below in terms of the nomenclature used in reference [8]. Early vapor pressure measurements yielded results which were lower than published values by 4000 to 6000 N/m², indicating the presence of a cold spot in the stainless steel transition capillary which connects the sample holder to the top of the cryostat. Jacketing the capillary with $\frac{1}{8}$ in OD copper tubing removed this difficulty. For the high temperature ($T > 150$ K) portion of the measurements the shield, shown in figure 2 of reference [8], was replaced with one that completely surrounded the sample holder thereby reducing heat losses to the cold wall. For measurements above 200 K the only refrigerant used was the liquid nitrogen in the open dewar surrounding the cryostat. The oil operated dead-weight gage pressure measuring system was modified, as shown in figure 1 here, for safety. Two null pressure detectors were used. The first separated the oil in the gage from an intermediate nitrogen gas system. The second separated the nitrogen from the oxygen sample. Thus in the event of a diaphragm failure there was no chance of high pressure oxygen coming in contact with the oil.

With practice the two-diaphragm system could be operated with as much sensitivity as the one diaphragm system in reference [8]. All external capillary lines, valves, and gages were cleaned by flushing with liquid Freon. Repairs to several of the glass flasks in the gasometer system necessitated recalibration of these volumes. The 1-liter flask, which was the primary standard of volume, was calibrated by weighing with water and agreed with the original calibration by Goodwin [8] to within 0.02 percent. The 2- and 6-liter flasks were calibrated by both water weighing and by gas expansion from the 1-liter flask. These two independent determinations agreed to better than one part in ten thousand in each case. The 21-liter flask was calibrated by gas expansion only, with an estimated uncertainty of 0.04 percent. The volume of the sample holder was recalibrated by gas expansion into the 1- and 2-liter flasks. The volume obtained was 25.852 ± 0.015 cm³ in good agreement with the earlier measurements, by weighing with water, of reference [8].

The relationship used to calculate the elastic stretching of the sample holder due to pressure was modified to correspond more closely to experimental results on similar thick walled vessels [9]. Thus, eq (5.2–7) of reference [8] was modified to become

$$V/V_0 = 1 + a\,[1 + 4.35 \cdot 10^{-4}\,T] \cdot P, \tag{1}$$

with $a = 2.3 \times 10^{-5}$ m²/MN. This modification changed the calculated densities by 0.04 percent at 30 MN/m². A quartz bourdon gage with a sensitivity of 7 N/m² was used to measure the pressure in the gasometer flasks for the density determinations.

The estimated relative error in the measured pressures is 0.01 percent, increasing somewhat at the lower pressures. Corrections were made for the hydrostatic pressure of the oxygen in the capillaries, which often amounted to several thousandths of a MN/m². Temperature readings may deviate from the thermometer calibration by 2 millidegrees at 50 K, increasing to 28 millidegrees at 300 K, due to the specifications of the potentiometer used. The uncertainty of the calibration itself is probably less than 0.002 K. To this must be added the deviations of the International Practical

[1] Figures in brackets indicate the literature references at the end of this paper.

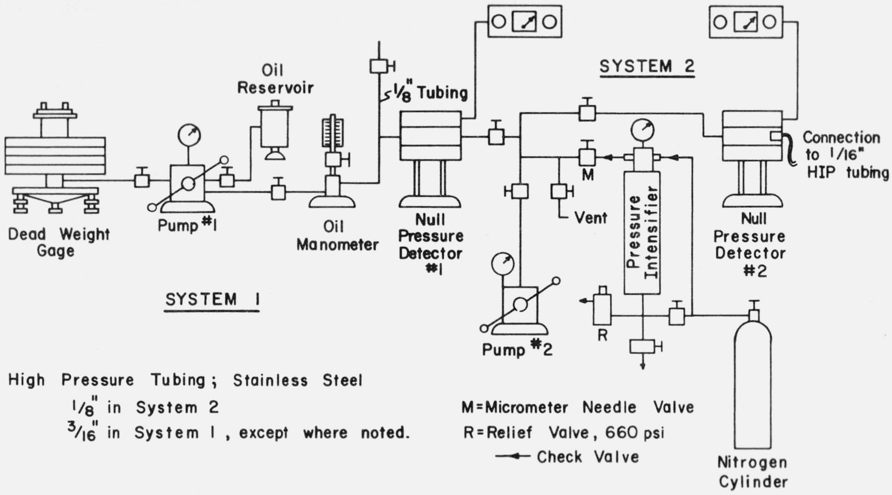

FIGURE 1. *Dead weight gage pressure measuring system.*

Temperature Scale (1948) from the thermodynamic temperature scale, perhaps as much as 0.04 K. With this apparatus, however, temperatures are reproducible to within 1 millidegree. Uncertainty in the density determinations is estimated at 0.1 percent for low pressures, increasing to 0.14 percent at the highest pressures. A precision of the order of 0.025 percent in density has been realized.

The samples used came from commercially available cylinders of ultra pure oxygen with a nominal purity of 99.99 percent and were passed through a molecular sieve trap at 76 K to remove water.

2.2 The Data

The measuring technique used here is the modified Reichsanstalt method described by Goodwin [8]. The data were taken along experimental pseudo-isochores, hereafter referred to as runs. Due to the precisely reproducible nature of the temperature control system, data on the various runs were measured at the same temperatures and therefore, could be rearranged into isotherms at the conclusion of the experimental work. Data were taken at integral temperatures with 2 K spacing from 56 K to 160 K, 5 K spacing from 160 K to 200 K, and 10 K spacing from 200 K to 300 K. In the low density gas phase a 5 K spacing was used between 85 K and 150 K.

For convenience the data may be divided chronologically into four series. Table 1 shows the distribution of the data between the series. Between Series I and II certain changes were made in the apparatus which necessitated recalibration of some of the volumes external to the cryostat. Between Series II and III the apparatus was moved to a new building and most of the external volumes were rebuilt. Series IV differed from the others by the way in which the density and pressure were determined.

The data were checked for systematic deviations between Series I, II, and III in the following way. Isotherm polynomials were fitted to the data in the regions where the data of different series overlapped. The deviations of all points in a series, expressed as percent error in density, were averaged. The results showed that the internal precision within each series was good (0.015 to 0.025 percent). However, while Series I and III were in agreement, the data of Series II differed systematically by an average of 0.066 percent in density. The origin of this difference is not clear. However, since the smoothness of the P–V–T surface is of utmost importance in the calculation of thermodynamic properties, the densities of the data of Series II were arbitrarily multiplied by 1.00066. This difference falls within the estimated overall uncertainty of the data.

TABLE 1. *Four series of experimental runs*

Series	No. of data points	Run No.
I	239	33–51
II	922	53–108
III	275	109–137
IV	67	138–145

Series IV consisted of data in the very low density ($0.0047 \leq \rho/\rho_c \leq 0.14$) gas phase between 85 K and 150 K. Pressures were measured with a quartz bourdon gage. Densities were too low for the use of the gasometer and were extracted from the measured pressure at 160 K, using virial coefficients obtained from the data of Series II and III.

The single-phase experimental P–V–T data are presented in table 2. The column labeled "IDENT" contains the identification number of each point. The first two or three digits are the number of the run or experimental isochore and the last two are the number of the point. The entries in runs 132 and 133 which contain no value for the density are pressures measured on the melting curve. In addition some pressures were measured along the vapor pressure curve. They are given in table 3 and were used mainly as a check on the vapor pressure curve taken from the literature. Because of the rather large vertical dimensions of the apparatus no attempt was made to take data in close proximity to the critical point.

TABLE 2. *Temperature-pressure-density observations on oxygen.*

T K	P MN/m²	Density mol/cm³	Ident
85.0	0.0444	0.0000644	14501
90.0	0.0472	0.0000644	14502
95.0	0.0500	0.0000643	14503
100.0	0.0527	0.0000643	14504
85.0	0.0506	0.0000739	14401
90.0	0.0540	0.0000739	14402
95.0	0.0572	0.0000738	14403
100.0	0.0603	0.0000738	14404
105.0	0.0634	0.0000737	14405
110.0	0.0665	0.0000737	14406
115.0	0.0696	0.0000736	14407
85.0	0.0566	0.0000895	14301
90.0	0.0652	0.0000894	14302
95.0	0.0691	0.0000893	14303
100.0	0.0729	0.0000893	14304
105.0	0.0766	0.0000892	14305
110.0	0.0804	0.0000892	14306
115.0	0.0840	0.0000891	14307
120.0	0.0877	0.0000891	14308
125.0	0.0914	0.0000890	14309
95.0	0.1353	0.0001787	14201
100.0	0.1431	0.0001786	14202
105.0	0.1507	0.0001785	14203
110.0	0.1583	0.0001784	14204
115.0	0.1658	0.0001783	14205
120.0	0.1733	0.0001782	14206
125.0	0.1807	0.0001781	14207
130.0	0.1882	0.0001780	14208
135.0	0.1956	0.0001778	14209
140.0	0.2030	0.0001777	14210
145.0	0.2104	0.0001776	14211
154.0	0.2236	0.0001774	14212
100.0	0.2112	0.0002684	14101
105.0	0.2229	0.0002683	14102
110.0	0.2344	0.0002681	14103
115.0	0.2458	0.0002679	14104
120.0	0.2572	0.0002678	14105
125.0	0.2685	0.0002676	14106
130.0	0.2799	0.0002675	14107
135.0	0.2911	0.0002673	14108
140.0	0.3024	0.0002672	14109
145.0	0.3135	0.0002670	14110
105.0	0.3435	0.0004259	14001
110.0	0.3623	0.0004256	14002
115.0	0.3811	0.0004254	14003
120.0	0.3996	0.0004251	14004
125.0	0.4179	0.0004249	14005
130.0	0.4363	0.0004246	14006
135.0	0.4543	0.0004243	14007
140.0	0.4723	0.0004241	14008
145.0	0.4904	0.0004238	14009

T K	P MN/m²	Density mol/cm³	Ident
120.0	0.8598	0.0009979	13901
125.0	0.9060	0.0009972	13902
130.0	0.9515	0.0009966	13903
135.0	0.9970	0.0009959	13904
140.0	1.0417	0.0009953	13905
145.0	1.0865	0.0009947	13906
150.0	1.1308	0.0009940	13907
152.0	1.1484	0.0009938	13908
156.0	1.1837	0.0009933	13910
158.0	1.2011	0.0009930	13911
130.0	1.4564	0.0016669	13801
135.0	1.5375	0.0016657	13802
140.0	1.6176	0.0016646	13803
145.0	1.6966	0.0016635	13804
150.0	1.7748	0.0016624	13805
152.0	1.8059	0.0016619	13806
160.0	2.2294	0.0019671	12201
165.0	2.3220	0.0019658	12202
170.0	2.4140	0.0019644	12203
175.0	2.5054	0.0019630	12204
180.0	2.5964	0.0019617	12205
185.0	2.6867	0.0019603	12206
190.0	2.7767	0.0019589	12207
195.0	2.8663	0.0019576	12208
200.0	2.9554	0.0019562	12209
210.0	3.1328	0.0019534	12210
220.0	3.3086	0.0019507	12211
230.0	3.4832	0.0019479	12212
240.0	3.6571	0.0019452	12213
250.0	3.8298	0.0019423	12214
260.0	4.0014	0.0019395	12215
270.0	4.1723	0.0019366	12216
280.0	4.3423	0.0019337	12217
290.0	4.5115	0.0019308	12218
300.0	4.6800	0.0019279	12219
160.0	3.1728	0.0030701	10701
165.0	3.3268	0.0030660	10702
170.0	3.4788	0.0030619	10703
175.0	3.6296	0.0030579	10704
180.0	3.7787	0.0030538	10705
185.0	3.9267	0.0030498	10706
190.0	4.0735	0.0030457	10707
195.0	4.2193	0.0030417	10708
200.0	4.3642	0.0030377	10709
210.0	4.6508	0.0030298	10710
220.0	4.9342	0.0030219	10711
230.0	5.2143	0.0030140	10712
240.0	5.4914	0.0030061	10713
250.0	5.7663	0.0029982	10714
260.0	6.0384	0.0029903	10715
270.0	6.3082	0.0029824	10716
280.0	6.5757	0.0029745	10717

TABLE 2. *Temperature-pressure-density observations on oxygen.*—Continued

T K	P MN/m²	Density mol/cm³	Ident	T K	P MN/m²	Density mol/cm³	Ident
290.0	6.8411	0.0029667	10718	280.0	8.5202	0.0038995	10626
300.0	7.1046	0.0029590	10719	290.0	8.8839	0.0038880	10627
				300.0	9.2427	0.0038783	10628
140.0	2.6702	0.0033734	12101				
142.0	2.7450	0.0033723	12102	146.0	3.4249	0.0046103	10502
144.0	2.8190	0.0033713	12103	148.0	3.5322	0.0046058	10503
146.0	2.8924	0.0033703	12104	150.0	3.6353	0.0045729	10504
148.0	2.9652	0.0033692	12105	152.0	3.7403	0.0045701	10505
150.0	3.0373	0.0033681	12106	154.0	3.8443	0.0045674	10506
152.0	3.1087	0.0033672	12107	156.0	3.9471	0.0045647	10507
154.0	3.1799	0.0033661	12108	158.0	4.0491	0.0045623	10508
156.0	3.2505	0.0033651	12109	160.0	4.1507	0.0045596	10509
158.0	3.3208	0.0033641	12110	165.0	4.4004	0.0045529	10510
160.0	3.3908	0.0033631	12111	170.0	4.6470	0.0045463	10511
165.0	3.5635	0.0033606	12112	175.0	4.8898	0.0045397	10512
170.0	3.7358	0.0033581	12113	180.0	5.1302	0.0045333	10513
175.0	3.9057	0.0033556	12114	185.0	5.3678	0.0045269	10514
180.0	4.0742	0.0033530	12115	190.0	5.6034	0.0045204	10515
185.0	4.2415	0.0033505	12116	195.0	5.8366	0.0045140	10516
190.0	4.4076	0.0033481	12117	200.0	6.0683	0.0045077	10517
195.0	4.5727	0.0033454	12118	210.0	6.5252	0.0044948	10518
200.0	4.7368	0.0033430	12119	220.0	6.9767	0.0044822	10519
210.0	5.0624	0.0033378	12120	230.0	7.4220	0.0044695	10520
220.0	5.3852	0.0033329	12121	240.0	7.8623	0.0044571	10521
230.0	5.7048	0.0033278	12122	250.0	8.2968	0.0044445	10522
240.0	6.0220	0.0033227	12123	260.0	8.7279	0.0044321	10523
250.0	6.3369	0.0033176	12124	270.0	9.1541	0.0044196	10524
260.0	6.6496	0.0033123	12125	280.0	9.5772	0.0044073	10525
270.0	6.9606	0.0033072	12126	290.0	9.9958	0.0043949	10526
280.0	7.2697	0.0033019	12127	300.0	10.4111	0.0043827	10527
290.0	7.5765	0.0032967	12128				
300.0	7.8823	0.0032914	12129	148.0	3.7532	0.0052554	10402
				150.0	3.8810	0.0052520	10403
142.0	3.0360	0.0040880	10601	152.0	4.0068	0.0052487	10404
144.0	3.1304	0.0040841	10602	154.0	4.1312	0.0052454	10405
146.0	3.2226	0.0040803	10603	156.0	4.2543	0.0052423	10406
148.0	3.3134	0.0040765	10604	158.0	4.3761	0.0052392	10407
150.0	3.4031	0.0040728	10605	160.0	4.4971	0.0052361	10408
152.0	3.4918	0.0040691	10606	165.0	4.7947	0.0052282	10409
154.0	3.5765	0.0040376	10607	170.0	5.0875	0.0052204	10410
156.0	3.6646	0.0040353	10608	175.0	5.3761	0.0052126	10411
158.0	3.7519	0.0040329	10609	180.0	5.6612	0.0052049	10412
160.0	3.8385	0.0040306	10610	185.0	5.9432	0.0051971	10413
165.0	4.0528	0.0040248	10611	190.0	6.2223	0.0051896	10414
170.0	4.2643	0.0040192	10612	195.0	6.4989	0.0051822	10415
175.0	4.4730	0.0040134	10613	200.0	6.7727	0.0051745	10416
180.0	4.6796	0.0040079	10614	210.0	7.3142	0.0051597	10417
185.0	4.8842	0.0040022	10615	220.0	7.8480	0.0051448	10418
190.0	5.0869	0.0039967	10616	230.0	8.3747	0.0051300	10419
195.0	5.2879	0.0039911	10617	240.0	8.8948	0.0051153	10420
200.0	5.4875	0.0039857	10618	250.0	9.4093	0.0051008	10421
210.0	5.8823	0.0039748	10619	260.0	9.9184	0.0050864	10422
220.0	6.2716	0.0039639	10620	270.0	10.4217	0.0050719	10423
230.0	6.6563	0.0039531	10621	280.0	10.9169	0.0050571	10424
240.0	7.0367	0.0039424	10622	290.0	11.4114	0.0050426	10425
250.0	7.4130	0.0039316	10623	300.0	11.9005	0.0050281	10426
260.0	7.7856	0.0039209	10624				
270.0	8.1550	0.0039103	10625	150.0	3.9962	0.0056510	10301

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TABLE 2. *Temperature-pressure-density observations on oxygen.*—Continued

T K	P MN/m²	Density mol/cm³	Ident
152.0	4.1356	0.0056473	10302
154.0	4.2729	0.0056436	10303
156.0	4.4080	0.0056401	10304
158.0	4.5419	0.0056367	10305
160.0	4.6747	0.0056330	10306
165.0	5.0014	0.0056242	10307
170.0	5.3224	0.0056156	10308
175.0	5.6383	0.0056070	10309
180.0	5.9505	0.0055985	10310
185.0	6.2594	0.0055901	10311
190.0	6.5649	0.0055817	10312
195.0	6.8673	0.0055734	10313
200.0	7.1671	0.0055651	10314
210.0	7.7596	0.0055486	10315
220.0	8.3425	0.0055323	10316
230.0	8.9185	0.0055163	10317
240.0	9.4859	0.0054999	10318
250.0	10.0481	0.0054840	10319
260.0	10.6040	0.0054681	10320
270.0	11.1528	0.0054529	10321
280.0	11.6973	0.0054364	10322
290.0	12.2359	0.0054208	10323
300.0	12.7691	0.0054051	10324
150.0	4.1753	0.0064527	10201
152.0	4.3425	0.0064484	10202
154.0	4.5061	0.0064441	10203
156.0	4.6673	0.0064399	10204
158.0	4.8266	0.0064357	10205
160.0	4.9842	0.0064316	10206
165.0	5.3714	0.0064212	10207
170.0	5.7514	0.0064109	10208
175.0	6.1252	0.0064010	10209
180.0	6.4955	0.0063909	10210
185.0	6.8595	0.0063810	10211
190.0	7.2201	0.0063710	10212
195.0	7.5777	0.0063605	10213
200.0	7.9320	0.0063516	10214
210.0	8.6317	0.0063324	10215
220.0	9.3205	0.0063132	10216
230.0	9.9994	0.0062939	10217
240.0	10.6695	0.0062755	10218
250.0	11.3322	0.0062568	10219
260.0	11.9871	0.0062380	10220
270.0	12.6345	0.0062194	10221
280.0	13.2754	0.0062009	10222
290.0	13.9096	0.0061825	10223
300.0	14.5392	0.0061644	10224
154.0	4.6059	0.0068794	10101
156.0	4.7815	0.0068747	10102
158.0	4.9549	0.0068702	10103
160.0	5.1265	0.0068653	10104
165.0	5.5472	0.0068540	10105
170.0	5.9599	0.0068428	10106
175.0	6.3664	0.0068319	10107
180.0	6.7682	0.0068210	10108
185.0	7.1637	0.0068100	10109
190.0	7.5556	0.0067993	10110
195.0	7.9437	0.0067883	10111
200.0	8.3285	0.0067782	10112
210.0	9.0876	0.0067571	10113
220.0	9.8356	0.0067362	10114
230.0	10.5727	0.0067158	10115
240.0	11.3005	0.0066948	10116
250.0	12.0189	0.0066750	10117
260.0	12.7291	0.0066550	10118
270.0	13.4311	0.0066350	10119
280.0	14.1273	0.0066158	10120
290.0	14.8133	0.0065950	10121
300.0	15.4953	0.0065748	10122
160.0	5.1253	0.0068611	12301
165.0	5.5484	0.0068550	12302
170.0	5.9640	0.0068490	12303
175.0	6.3735	0.0068430	12304
180.0	6.7784	0.0068371	12305
185.0	7.1794	0.0068312	12306
190.0	7.5768	0.0068253	12307
195.0	7.9707	0.0068194	12308
200.0	8.3621	0.0068135	12309
210.0	9.1370	0.0068018	12310
220.0	9.9022	0.0067901	12311
230.0	10.6600	0.0067784	12312
240.0	11.4094	0.0067667	12313
250.0	12.1533	0.0067550	12314
260.0	12.8904	0.0067433	12315
270.0	13.6219	0.0067316	12316
280.0	14.3480	0.0067199	12317
290.0	15.0693	0.0067082	12318
300.0	15.7857	0.0066965	12319
154.0	4.8414	0.0084740	10001
156.0	5.0735	0.0084681	10002
158.0	5.3014	0.0084620	10003
160.0	5.5259	0.0084560	10004
165.0	6.0777	0.0084410	10005
170.0	6.6172	0.0084263	10006
175.0	7.1487	0.0084119	10007
180.0	7.6740	0.0083977	10008
185.0	8.1922	0.0083834	10009
190.0	8.7060	0.0083693	10010
195.0	9.2140	0.0083555	10011
200.0	9.7185	0.0083415	10012
210.0	10.7147	0.0083141	10013
220.0	11.6953	0.0082872	10014
230.0	12.6624	0.0082605	10015
240.0	13.6170	0.0082344	10016
250.0	14.5610	0.0082088	10017
260.0	15.4914	0.0081834	10018
270.0	16.4137	0.0081580	10019
280.0	17.3251	0.0081334	10020
290.0	18.2257	0.0081089	10021
300.0	19.1188	0.0080843	10022
154.0	4.9185	0.0097086	9901
156.0	5.1960	0.0097003	9902

TABLE 2. *Temperature-pressure-density observations on oxygen.*—Continued

T K	P MN/m²	Density mol/cm³	Ident	T K	P MN/m²	Density mol/cm³	Ident
158.0	5.4669	0.0096936	9903	250.0	19.9644	0.0113263	9716
160.0	5.7333	0.0096862	9904	260.0	21.4189	0.0112897	9717
165.0	6.3882	0.0096689	9905	270.0	22.8569	0.0112531	9718
170.0	7.0310	0.0096510	9906	280.0	24.2784	0.0112171	9719
175.0	7.6648	0.0096342	9907	290.0	25.6871	0.0111835	9720
180.0	8.2922	0.0096172	9908	300.0	27.0831	0.0111495	9721
185.0	8.9127	0.0096003	9909				
190.0	9.5269	0.0095835	9910	156.0	5.2986	0.0121578	9601
195.0	10.1359	0.0095668	9911	158.0	5.6505	0.0121487	9602
200.0	10.7398	0.0095504	9912	160.0	6.0001	0.0121393	9603
210.0	11.9332	0.0095175	9913	165.0	6.8698	0.0121155	9604
220.0	13.1084	0.0094853	9914	170.0	7.7308	0.0120922	9605
230.0	14.2678	0.0094534	9915	175.0	8.5873	0.0120690	9606
240.0	15.4065	0.0094199	9916	180.0	9.4375	0.0120455	9607
250.0	16.5349	0.0093888	9917	185.0	10.2825	0.0120225	9608
260.0	17.6497	0.0093582	9918	190.0	11.1205	0.0119999	9609
270.0	18.7530	0.0093291	9919	195.0	11.9535	0.0119773	9610
280.0	19.8415	0.0092984	9920	200.0	12.7799	0.0119549	9611
290.0	20.9230	0.0092706	9921	210.0	14.4167	0.0119107	9612
300.0	21.9884	0.0092422	9922	220.0	16.0293	0.0118674	9613
				230.0	17.6212	0.0118240	9614
156.0	5.2598	0.0108709	9801	240.0	19.1929	0.0117824	9615
158.0	5.5700	0.0108625	9802	250.0	20.7463	0.0117418	9616
160.0	5.8766	0.0108537	9803	260.0	22.2789	0.0117037	9617
165.0	6.6321	0.0108333	9804	270.0	23.7979	0.0116668	9618
170.0	7.3766	0.0108131	9805	280.0	25.2927	0.0116298	9619
175.0	8.1125	0.0107927	9806	290.0	26.7829	0.0115936	9620
180.0	8.8432	0.0107729	9807	300.0	28.2536	0.0115602	9621
185.0	9.5654	0.0107538	9808				
190.0	10.2823	0.0107343	9809	156.0	5.3093	0.0127557	10802
195.0	10.9936	0.0107149	9810	158.0	5.6813	0.0127459	10803
200.0	11.6997	0.0106963	9811	160.0	6.0514	0.0127360	10804
210.0	13.0945	0.0106578	9812	165.0	6.9743	0.0127115	10805
220.0	14.4703	0.0106220	9813	170.0	7.8956	0.0126866	10806
230.0	15.8269	0.0105837	9814	175.0	8.8084	0.0126620	10807
240.0	17.1698	0.0105373	9815	180.0	9.7181	0.0126374	10808
250.0	18.4871	0.0105121	9816	185.0	10.6227	0.0126131	10809
260.0	19.7940	0.0104786	9817	190.0	11.5216	0.0125891	10810
270.0	21.0829	0.0104432	9818	195.0	12.4146	0.0125652	10811
280.0	22.3607	0.0104101	9819	200.0	13.3026	0.0125416	10812
290.0	23.6247	0.0103788	9820	210.0	15.0596	0.0124949	10813
300.0	24.8740	0.0103471	9821	220.0	16.7936	0.0124496	10814
				230.0	18.5030	0.0124050	10815
156.0	5.2876	0.0117217	9701	240.0	20.1940	0.0123615	10816
158.0	5.6258	0.0117126	9702	250.0	21.8609	0.0123194	10817
160.0	5.9613	0.0117035	9703	260.0	23.5072	0.0122786	10818
165.0	6.7902	0.0116814	9704	270.0	25.1341	0.0122388	10819
170.0	7.6122	0.0116591	9705	280.0	26.7459	0.0122002	10820
175.0	8.4263	0.0116365	9706	290.0	28.3407	0.0121635	10821
180.0	9.2345	0.0116151	9707	300.0	29.9184	0.0121274	10822
185.0	10.0364	0.0115927	9708				
190.0	10.8326	0.0115723	9709	156.0	5.3268	0.0136248	9301
195.0	11.6231	0.0115504	9710	158.0	5.7260	0.0136142	9302
200.0	12.4078	0.0115292	9711	160.0	6.1269	0.0136036	9303
210.0	13.9600	0.0114876	9712	165.0	7.1321	0.0135765	9304
220.0	15.4907	0.0114454	9713	170.0	8.1371	0.0135494	9305
230.0	17.0017	0.0114047	9714	175.0	9.1405	0.0135222	9306
240.0	18.4909	0.0113652	9715	180.0	10.1405	0.0134950	9307

TABLE 2. *Temperature-pressure-density observations on oxygen.*—Continued

T K	P MN/m^2	Density mol/cm^3	Ident
185.0	11.1353	0.0134680	9308
190.0	12.1252	0.0134417	9309
195.0	13.1093	0.0134148	9310
200.0	14.0870	0.0133885	9311
210.0	16.0226	0.0133369	9312
220.0	17.9342	0.0132865	9313
230.0	19.8171	0.0132386	9314
240.0	21.6805	0.0131899	9315
250.0	23.5231	0.0131476	9316
260.0	25.3416	0.0131025	9317
270.0	27.1349	0.0130590	9318
280.0	28.9124	0.0130177	9319
290.0	30.6783	0.0129802	9320
156.0	5.3444	0.0145565	9501
158.0	5.7755	0.0145455	9502
160.0	6.2112	0.0145337	9503
165.0	7.3110	0.0145036	9504
170.0	8.4162	0.0144737	9505
175.0	9.5206	0.0144438	9506
180.0	10.6244	0.0144140	9507
185.0	11.7237	0.0143843	9508
190.0	12.8167	0.0143549	9509
195.0	13.9051	0.0143257	9510
200.0	14.9866	0.0142970	9511
210.0	17.1296	0.0142405	9512
220.0	19.2423	0.0141857	9513
230.0	21.3305	0.0141316	9514
240.0	23.3915	0.0140813	9515
250.0	25.4265	0.0140321	9516
260.0	27.4425	0.0139864	9517
270.0	29.4323	0.0139423	9518
280.0	31.4036	0.0138997	9519
156.0	5.3779	0.0156909	9401
158.0	5.8544	0.0156782	9402
160.0	6.3383	0.0156648	9403
165.0	7.5656	0.0156315	9404
170.0	8.8044	0.0155983	9405
175.0	10.0455	0.0155649	9406
180.0	11.2866	0.0155316	9407
185.0	12.5248	0.0154978	9408
190.0	13.7562	0.0154657	9409
195.0	14.9816	0.0154330	9410
200.0	16.2004	0.0154011	9411
210.0	18.6148	0.0153388	9412
220.0	21.0010	0.0152805	9413
230.0	23.3507	0.0152212	9414
240.0	25.6751	0.0151658	9415
250.0	27.9759	0.0151156	9416
260.0	30.2501	0.0150694	9417
270.0	32.4981	0.0150249	9418
156.0	5.4346	0.0167364	9202
158.0	5.9624	0.0167225	9203
160.0	6.4993	0.0167081	9204
165.0	7.8629	0.0166713	9205
170.0	9.2396	0.0166348	9206
175.0	10.6217	0.0165974	9207
180.0	12.0026	0.0165600	9208
185.0	13.3800	0.0165235	9209
190.0	14.7508	0.0164880	9210
195.0	16.1152	0.0164514	9211
200.0	17.4706	0.0164161	9212
210.0	20.1560	0.0163477	9213
220.0	22.8057	0.0162839	9214
230.0	25.4257	0.0162217	9215
240.0	28.0091	0.0161638	9216
250.0	30.5648	0.0161100	9217
156.0	5.5827	0.0180496	6304
158.0	6.1910	0.0180333	6305
160.0	6.8069	0.0180167	6306
165.0	8.3678	0.0179745	6307
170.0	9.9452	0.0179319	6308
175.0	11.5215	0.0178896	6309
180.0	13.0983	0.0178475	6310
185.0	14.6689	0.0178061	6311
190.0	16.2316	0.0177653	6312
195.0	17.7871	0.0177252	6313
200.0	19.3307	0.0176860	6314
210.0	22.3876	0.0176104	6315
220.0	25.4037	0.0175391	6316
230.0	28.3808	0.0174726	6317
154.0	5.1333	0.0190870	9101
156.0	5.8032	0.0190691	9102
158.0	6.4840	0.0190507	9103
160.0	7.1717	0.0190325	9104
165.0	8.9088	0.0189849	9105
170.0	10.6555	0.0189387	9106
175.0	12.4031	0.0188922	9107
180.0	14.1455	0.0188457	9108
185.0	15.8814	0.0188001	9109
190.0	17.6046	0.0187559	9110
195.0	19.3175	0.0187133	9111
200.0	21.0180	0.0186698	9112
210.0	24.3878	0.0185888	9113
220.0	27.7085	0.0185138	9114
230.0	30.9821	0.0184442	9115
240.0	34.2235	0.0183832	9116
154.0	5.3612	0.0199362	9001
156.0	6.1026	0.0199167	9002
158.0	6.8525	0.0198965	9003
160.0	7.6077	0.0198760	9004
165.0	9.5075	0.0198249	9005
170.0	11.4133	0.0197742	9006
175.0	13.3163	0.0197246	9007
180.0	15.2115	0.0196751	9008
185.0	17.0956	0.0196266	9009
190.0	18.9669	0.0195792	9010
195.0	20.8269	0.0195317	9011
200.0	22.6685	0.0194883	9012
210.0	26.3129	0.0194036	9013
220.0	29.9058	0.0193259	9014
230.0	33.4607	0.0192574	9015

TABLE 2. *Temperature-pressure-density observations on oxygen.*—Continued

T K	P MN/m^2	Density mol/cm³	Ident	T K	P MN/m^2	Density mol/cm³	Ident
152.0	4.8922	0.0207491	8901	170.0	16.2685	0.0229021	8610
154.0	5.6977	0.0207282	8902	175.0	18.8486	0.0228383	8611
156.0	6.5111	0.0207064	8903	180.0	21.4030	0.0227773	8612
158.0	7.3309	0.0206843	8904	185.0	23.9358	0.0227180	8613
160.0	8.1540	0.0206626	8905	190.0	26.4455	0.0226621	8614
165.0	10.2182	0.0206074	8906	195.0	28.9325	0.0226094	8615
170.0	12.2836	0.0205531	8907	200.0	31.4012	0.0225604	8616
175.0	14.3415	0.0204994	8908				
180.0	16.3874	0.0204470	8909	144.0	3.4424	0.0241115	5901
185.0	18.4256	0.0203979	8910	146.0	4.6016	0.0240796	5902
190.0	20.4446	0.0203481	8911	148.0	5.7616	0.0240495	5903
195.0	22.4490	0.0203003	8912	150.0	6.9230	0.0240173	5904
200.0	24.4409	0.0202543	8913	152.0	8.0797	0.0239864	5905
210.0	28.3778	0.0201695	8914	154.0	9.2364	0.0239558	5906
220.0	32.2607	0.0200932	8915	156.0	10.3883	0.0239253	5907
				158.0	11.5364	0.0238951	5908
150.0	4.4935	0.0216871	8801	160.0	12.6804	0.0238651	5909
152.0	5.3844	0.0216635	8802	165.0	15.5240	0.0237922	5910
154.0	6.2821	0.0216398	8803	170.0	18.3300	0.0237212	5911
156.0	7.1852	0.0216154	8804	175.0	21.1062	0.0236531	5912
158.0	8.0910	0.0215911	8805	180.0	23.8578	0.0235882	5913
160.0	8.9981	0.0215670	8806	185.0	26.5823	0.0235273	5914
165.0	11.2654	0.0215073	8807	190.0	29.2880	0.0234701	5915
170.0	13.5244	0.0214480	8808	195.0	31.9645	0.0234173	5916
175.0	15.7711	0.0213901	8809				
180.0	18.0013	0.0213343	8010	144.0	4.0468	0.0245557	8502
185.0	20.2159	0.0212800	8811	146.0	5.2654	0.0245240	8503
190.0	22.4139	0.0212267	8812	148.0	6.4826	0.0244899	8504
195.0	24.5897	0.0211771	8813	150.0	7.6966	0.0244579	8505
200.0	26.7526	0.0211299	8814	152.0	8.9074	0.0244256	8506
210.0	31.0295	0.0210424	8815	154.0	10.1149	0.0243937	8507
				156.0	11.3177	0.0243627	8508
148.0	4.0774	0.0225087	8701	158.0	12.5132	0.0243309	8509
150.0	5.0499	0.0224821	8702	160.0	13.7050	0.0242999	8510
152.0	6.0286	0.0224568	8703	165.0	16.6622	0.0242242	8511
154.0	7.0117	0.0224301	8704	170.0	19.5864	0.0241525	8512
156.0	7.9954	0.0224035	8705	175.0	22.4752	0.0240836	8513
158.0	8.9804	0.0223775	8706	180.0	25.3386	0.0240185	8514
160.0	9.9644	0.0223511	8707	185.0	28.1758	0.0239570	8515
165.0	12.4179	0.0222870	8708	190.0	30.9888	0.0239022	8516
170.0	14.8570	0.0222231	8709	195.0	33.7711	0.0238486	8517
175.0	17.2765	0.0221614	8710				
180.0	19.6783	0.0221040	8711	142.0	3.6026	0.0250985	8201
185.0	22.0531	0.0220468	8712	144.0	4.8902	0.0250632	8202
190.0	24.4119	0.0219923	8713	146.0	6.1763	0.0250283	8203
195.0	26.7541	0.0219405	8714	148.0	7.4576	0.0249944	8204
200.0	29.0778	0.0218914	8715	150.0	8.7342	0.0249604	8205
210.0	33.6683	0.0218061	8716	152.0	10.0046	0.0249267	8206
				154.0	11.2713	0.0248936	8207
146.0	3.6426	0.0232356	8601	156.0	12.5293	0.0248604	8208
148.0	4.6947	0.0232067	8602	158.0	13.7817	0.0248277	8209
150.0	5.7514	0.0231796	8603	160.0	15.0311	0.0247958	8210
152.0	6.8101	0.0231506	8604	165.0	18.1219	0.0247183	8211
154.0	7.8704	0.0231220	8605	170.0	21.1793	0.0246445	8212
156.0	8.9296	0.0230937	8606	175.0	24.1977	0.0245747	8213
158.0	9.9869	0.0230657	8607	180.0	27.1899	0.0245091	8214
160.0	11.0426	0.0230377	8608	185.0	30.1612	0.0244499	8215
165.0	13.6660	0.0229691	8609	190.0	33.1017	0.0243940	8216

TABLE 2. *Temperature-pressure-density observations on oxygen.*—Continued

T K	P MN/m^2	Density mol/cm^3	Ident
140.0	2.9844	0.0255208	6401
142.0	4.3289	0.0254839	6402
144.0	5.6699	0.0254472	6403
146.0	7.0069	0.0254118	6404
148.0	8.3375	0.0253768	6405
150.0	9.6613	0.0253417	6406
152.0	10.9798	0.0253070	6407
154.0	12.2914	0.0252727	6408
156.0	13.5268	0.0252405	6409
158.0	14.8935	0.0252054	6410
160.0	16.1822	0.0251726	6411
165.0	19.3802	0.0250928	6412
170.0	22.5416	0.0250173	6413
175.0	25.6668	0.0249463	6414
180.0	28.7565	0.0248806	6415
185.0	31.8246	0.0248202	6416
140.0	3.5318	0.0258049	8401
142.0	4.9176	0.0257671	8402
144.0	6.2966	0.0257298	8403
146.0	7.6697	0.0256933	8404
148.0	9.0394	0.0256518	8405
150.0	10.3966	0.0256218	8406
152.0	11.7472	0.0255864	8407
154.0	13.0917	0.0255515	8408
156.0	14.4295	0.0255170	8409
158.0	15.7605	0.0254835	8410
165.0	20.3576	0.0253692	8412
170.0	23.5952	0.0252943	8413
175.0	26.7970	0.0252237	8414
180.0	29.9705	0.0251597	8415
185.0	33.1131	0.0251002	8416
138.0	3.2401	0.0263501	8301
140.0	4.7034	0.0263104	8302
142.0	6.1593	0.0262711	8303
144.0	7.6076	0.0262331	8304
146.0	9.0479	0.0261951	8305
148.0	10.4778	0.0261578	8306
150.0	11.8976	0.0261198	8307
152.0	13.3104	0.0260824	8308
154.0	14.7130	0.0260463	8309
156.0	16.1089	0.0260120	8310
158.0	17.4975	0.0259772	8311
160.0	18.8815	0.0259431	8312
165.0	22.3006	0.0258609	8313
170.0	25.6842	0.0257848	8314
175.0	29.0322	0.0257147	8315
180.0	32.3448	0.0256520	8316
136.0	3.1979	0.0269549	6201
138.0	4.7513	0.0269125	6202
140.0	6.2944	0.0268710	6203
142.0	7.8278	0.0268306	6204
144.0	9.3501	0.0267903	6205
146.0	10.8599	0.0267504	6206
148.0	12.3609	0.0267111	6207
150.0	13.8523	0.0266724	6208
152.0	15.3345	0.0266345	6209
154.0	16.8057	0.0265973	6210
156.0	18.2678	0.0265608	6211
158.0	19.7213	0.0265251	6212
160.0	21.1703	0.0264904	6213
165.0	24.7576	0.0264076	6214
170.0	28.3036	0.0263312	6215
175.0	31.8143	0.0262620	6216
134.0	2.4353	0.0272899	6501
136.0	4.0412	0.0272455	6502
138.0	5.6349	0.0272020	6503
140.0	7.2192	0.0271604	6504
142.0	8.7920	0.0271189	6505
144.0	10.3512	0.0270777	6506
146.0	11.9004	0.0270372	6507
148.0	13.4382	0.0269972	6508
150.0	14.9657	0.0269580	6509
152.0	16.4808	0.0269236	6510
154.0	17.9937	0.0268821	6511
156.0	19.4930	0.0268456	6512
158.0	20.9821	0.0268099	6513
160.0	22.4666	0.0267753	6514
165.0	26.1395	0.0266927	6515
170.0	29.7724	0.0266173	6516
175.0	33.3743	0.0265493	6517
134.0	3.6213	0.0276729	8101
136.0	5.2856	0.0276273	8102
138.0	6.9337	0.0275841	8103
140.0	8.5697	0.0275414	8104
142.0	10.1897	0.0274986	8105
144.0	11.8000	0.0274564	8106
146.0	13.3971	0.0274152	8107
148.0	14.9791	0.0273744	8108
150.0	16.5533	0.0273338	8109
152.0	18.1184	0.0272988	8110
154.0	19.6721	0.0272580	8111
156.0	21.2147	0.0272206	8112
158.0	22.7532	0.0271849	8113
160.0	24.2849	0.0271500	8114
165.0	28.0785	0.0270686	8115
170.0	31.8365	0.0269965	8116
132.0	2.7155	0.0279362	6101
134.0	4.4246	0.0278891	6102
136.0	6.1187	0.0278436	6103
138.0	7.7995	0.0277991	6104
140.0	9.4641	0.0277550	6105
142.0	11.1144	0.0277114	6106
144.0	12.7511	0.0276687	6107
146.0	14.3767	0.0276270	6108
148.0	15.9898	0.0275859	6109
150.0	17.5914	0.0275456	6110
152.0	19.1801	0.0275097	6111
154.0	20.7647	0.0274681	6112
156.0	22.3354	0.0274309	6113
158.0	23.9003	0.0273929	6114

TABLE 2. *Temperature-pressure-density observations on oxygen.*—Continued

T K	P MN/m²	Density mol/cm³	Ident
160.0	25.4595	0.0273601	6115
165.0	29.3210	0.0272787	6116
170.0	33.1481	0.0272056	6117
130.0	1.9644	0.0282691	8001
132.0	3.7305	0.0282200	8002
134.0	5.4786	0.0281728	8003
136.0	7.2122	0.0281273	8004
138.0	8.9282	0.0280815	8005
140.0	10.6303	0.0280366	8006
142.0	12.3164	0.0279926	8007
144.0	13.9897	0.0279501	8008
146.0	15.6477	0.0279070	8009
148.0	17.2999	0.0278657	8010
150.0	18.9348	0.0278252	8011
152.0	20.5621	0.0277892	8012
154.0	22.1841	0.0277479	8013
156.0	23.7927	0.0277109	8014
158.0	25.4000	0.0276764	8015
160.0	26.9994	0.0276436	8016
165.0	30.9550	0.0275640	8017
128.0	2.3713	0.0288775	6702
130.0	4.2335	0.0288261	6703
132.0	6.0769	0.0287770	6704
134.0	7.8983	0.0287287	6705
136.0	9.7048	0.0286808	6706
138.0	11.4930	0.0286337	6707
140.0	13.2662	0.0285875	6708
142.0	15.0161	0.0285426	6709
144.0	16.7645	0.0284985	6710
146.0	18.4948	0.0284554	6711
148.0	20.2117	0.0284137	6712
150.0	21.9178	0.0283731	6713
152.0	23.6195	0.0283339	6714
154.0	25.3119	0.0282959	6715
156.0	26.9952	0.0282594	6716
158.0	28.6739	0.0282246	6717
160.0	30.3434	0.0281913	6718
165.0	34.4943	0.0281153	6719
126.0	2.8771	0.0294561	7501
128.0	4.8428	0.0294031	7502
130.0	6.7841	0.0293525	7503
132.0	8.7049	0.0293020	7504
134.0	10.6061	0.0292524	7505
136.0	12.4883	0.0292043	7506
138.0	14.3534	0.0291570	7507
140.0	16.2006	0.0291100	7508
142.0	18.0375	0.0290651	7509
144.0	19.8600	0.0290217	7510
146.0	21.6706	0.0289789	7511
148.0	23.4713	0.0289381	7512
150.0	25.2612	0.0288996	7513
152.0	27.0409	0.0288613	7514
154.0	28.8206	0.0288239	7515
156.0	30.5910	0.0287899	7516
158.0	32.3536	0.0287579	7517

T K	P MN/m²	Density mol/cm³	Ident
124.0	2.1104	0.0297581	3401
126.0	4.1084	0.0297011	3402
128.0	6.0901	0.0296468	3403
130.0	8.0454	0.0295931	3404
132.0	9.9760	0.0295401	3405
134.0	11.8876	0.0294884	3406
136.0	13.7784	0.0294378	3407
138.0	15.6572	0.0293882	3408
140.0	17.5120	0.0293401	3409
142.0	19.3736	0.0292935	3410
144.0	21.2096	0.0292481	3411
146.0	23.0408	0.0292039	3412
148.0	24.8835	0.0291617	3413
150.0	26.7045	0.0291210	3414
152.0	28.5164	0.0290824	3415
154.0	30.3258	0.0290454	3416
156.0	32.1204	0.0290107	3417
158.0	33.9185	0.0289777	3418
124.0	2.4906	0.0298327	3902
126.0	4.5012	0.0297757	3903
128.0	6.4903	0.0297215	3904
130.0	8.4523	0.0296674	3905
132.0	10.3898	0.0296143	3906
134.0	12.3076	0.0295626	3907
136.0	14.2138	0.0295122	3908
138.0	16.1014	0.0294627	3909
140.0	17.9733	0.0294142	3910
142.0	19.8321	0.0293674	3911
144.0	21.6795	0.0293219	3912
146.0	23.5223	0.0292780	3913
148.0	25.3593	0.0292355	3914
150.0	27.1780	0.0291949	3915
152.0	28.9939	0.0291564	3916
154.0	30.8030	0.0291195	3917
156.0	32.5978	0.0290848	3918
122.0	1.5045	0.0300885	5801
124.0	3.5853	0.0300301	5802
126.0	5.6416	0.0299753	5803
128.0	7.6720	0.0299216	5804
130.0	9.6778	0.0298684	5805
132.0	11.6604	0.0298166	5806
134.0	13.6259	0.0297660	5807
136.0	15.5763	0.0297171	5808
138.0	17.5050	0.0296696	5809
140.0	19.4202	0.0296221	5810
142.0	21.3249	0.0295768	5811
144.0	23.2160	0.0295330	5812
146.0	25.1035	0.0294909	5813
148.0	26.9727	0.0294508	5814
150.0	28.8442	0.0294124	5815
152.0	30.7008	0.0293759	5816
154.0	32.5574	0.0293415	5817
122.0	3.0971	0.0303754	7601
124.0	5.2176	0.0303187	7602

TABLE 2. *Temperature-pressure-density observations on oxygen.*—Continued

T K	P MN/m²	Density mol/cm³	Ident	T K	P MN/m²	Density mol/cm³	Ident
126.0	7.3153	0.0302640	7603	136.0	24.2720	0.0308888	4312
128.0	9.3831	0.0302089	7604	138.0	26.3720	0.0308414	4313
130.0	11.4278	0.0301557	7605	140.0	28.4675	0.0307964	4314
132.0	13.4542	0.0301041	7606	142.0	30.5548	0.0307539	4315
134.0	15.4565	0.0300530	7607	144.0	32.6389	0.0307139	4316
136.0	17.4427	0.0300036	7608				
138.0	19.4169	0.0299566	7609	114.0	1.1925	0.0316910	7801
140.0	21.3819	0.0299100	7610	116.0	3.5782	0.0316243	7802
142.0	23.3248	0.0298649	7611	118.0	5.9272	0.0315631	7803
144.0	25.1294	0.0298245	7612	120.0	8.2441	0.0315011	7804
146.0	27.2006	0.0297814	7613	122.0	10.5249	0.0314415	7805
148.0	29.1284	0.0297431	7614	124.0	12.7809	0.0313840	7806
150.0	31.0539	0.0297066	7615	126.0	15.0139	0.0313277	7807
152.0	32.9587	0.0296710	7616	128.0	17.2189	0.0312723	7808
				130.0	19.4118	0.0312187	7809
120.0	1.8317	0.0305760	3503	132.0	21.5882	0.0311671	7810
122.0	3.9817	0.0305144	3504	134.0	23.7537	0.0311175	7811
124.0	6.1040	0.0304567	3505	136.0	25.9088	0.0310703	7812
126.0	8.1901	0.0303990	3506	138.0	28.0581	0.0310268	7813
128.0	10.2555	0.0303427	3507	140.0	30.1939	0.0309830	7814
130.0	12.2974	0.0302881	3508	142.0	32.3228	0.0309431	7815
132.0	14.3198	0.0302342	3509				
134.0	16.3141	0.0301819	3510	114.0	1.6723	0.0317542	3601
136.0	18.2971	0.0301309	3511	116.0	4.0458	0.0316862	3602
138.0	20.2666	0.0300820	3512	118.0	6.3776	0.0316230	3603
140.0	22.2342	0.0300334	3513	120.0	8.6721	0.0315592	3604
142.0	24.1917	0.0299871	3514	122.0	10.9361	0.0314980	3605
144.0	26.1323	0.0299431	3515	124.0	13.1733	0.0314380	3606
146.0	28.0750	0.0299007	3516	126.0	15.3804	0.0313799	3607
148.0	29.9939	0.0298608	3517	128.0	17.5761	0.0313231	3608
150.0	31.9298	0.0298226	3518	130.0	19.7850	0.0312682	3609
152.0	33.8303	0.0297873	3519	132.0	21.9571	0.0312151	3610
				134.0	24.1236	0.0311642	3611
120.0	4.6411	0.0310159	5601	136.0	26.2706	0.0311158	3612
122.0	6.8570	0.0309577	5602	138.0	28.4258	0.0310694	3613
124.0	9.0357	0.0308992	5603	140.0	30.5788	0.0310259	3614
126.0	11.1895	0.0308427	5604	142.0	32.7111	0.0309851	3615
128.0	13.3215	0.0307876	5605				
130.0	15.4214	0.0307340	5606	114.0	3.1928	0.0319426	6001
132.0	17.5178	0.0306813	5607	116.0	5.6146	0.0318793	6002
134.0	19.5936	0.0306304	5608	118.0	7.9924	0.0318148	6003
136.0	21.6614	0.0305812	5609	120.0	10.3328	0.0317539	6004
138.0	23.7302	0.0305343	5610	122.0	12.6486	0.0316940	6005
140.0	25.7819	0.0304892	5611	124.0	14.9309	0.0316357	6006
142.0	27.8251	0.0304458	5612	126.0	17.1917	0.0315791	6007
144.0	29.8568	0.0304050	5613	128.0	19.4386	0.0315240	6008
146.0	31.8845	0.0303665	5614	130.0	21.6625	0.0314713	6009
116.0	2.4087	0.0314615	4302	114.0	3.4335	0.0319827	4401
118.0	4.7189	0.0313964	4303	116.0	5.8265	0.0319178	4402
120.0	6.9894	0.0313346	4304	118.0	8.1737	0.0318519	4403
122.0	9.2248	0.0312732	4305	120.0	10.4832	0.0317892	4404
124.0	11.4280	0.0312137	4306	122.0	12.7639	0.0317278	4405
126.0	13.6026	0.0311555	4307	124.0	15.0271	0.0316680	4406
128.0	15.7621	0.0310987	4308	126.0	17.2542	0.0316097	4407
130.0	17.9023	0.0310434	4309	128.0	19.4810	0.0315532	4408
132.0	20.0292	0.0309899	4310	130.0	21.6969	0.0314984	4409
134.0	22.1447	0.0309381	4311	132.0	23.9049	0.0314459	4410

TABLE 2. *Temperature-pressure-density observations on oxygen.*—Continued

T K	P MN/m^2	Density mol/cm^3	Ident
134.0	26.1218	0.0313961	4411
136.0	28.3244	0.0313487	4412
138.0	30.5134	0.0313039	4413
140.0	32.7007	0.0312620	4414
110.0	1.3810	0.0324614	3301
112.0	3.8894	0.0323894	3302
114.0	6.3591	0.0323218	3303
116.0	8.7833	0.0322556	3304
118.0	11.1786	0.0321914	3305
120.0	13.5419	0.0321287	3306
122.0	15.8805	0.0320677	3307
124.0	18.2001	0.0320083	3308
126.0	20.5350	0.0319516	3309
128.0	22.8186	0.0318968	3310
130.0	25.1045	0.0318442	3311
132.0	27.3950	0.0317940	3312
134.0	29.6685	0.0317468	3313
136.0	31.9258	0.0317028	3314
138.0	34.1856	0.0316615	3315
108.0	1.7919	0.0328693	7701
110.0	4.4111	0.0327978	7702
112.0	6.9761	0.0327302	7703
114.0	9.5060	0.0326645	7704
116.0	12.0031	0.0326001	7705
118.0	14.4653	0.0325375	7706
120.0	16.9084	0.0324767	7707
122.0	19.3194	0.0324183	7708
124.0	21.7076	0.0323618	7709
126.0	24.1061	0.0323079	7710
128.0	26.4967	0.0322573	7711
130.0	28.8700	0.0322077	7712
132.0	31.2479	0.0321626	7713
134.0	33.6213	0.0321216	7714
108.0	3.1007	0.0330134	4101
110.0	5.7025	0.0329415	4102
112.0	8.2546	0.0328722	4103
114.0	10.7654	0.0328050	4104
116.0	13.2418	0.0327392	4105
118.0	15.7200	0.0326761	4106
120.0	18.1513	0.0326184	4107
122.0	20.5679	0.0325543	4108
124.0	22.9783	0.0324967	4109
126.0	25.3676	0.0324421	4110
128.0	27.7500	0.0323901	4111
130.0	30.1463	0.0323410	4112
132.0	32.5168	0.0322954	4113
104.0	0.6819	0.0334558	7901
106.0	3.4351	0.0333777	7902
108.0	6.1367	0.0333056	7903
110.0	8.7923	0.0332370	7904
112.0	11.4019	0.0331694	7905
114.0	13.9827	0.0331042	7906
116.0	16.5276	0.0330397	7907
118.0	19.0577	0.0329835	7908
120.0	21.5622	0.0329196	7909
122.0	24.0594	0.0328629	7910
124.0	26.5419	0.0328092	7911
126.0	29.0289	0.0327583	7912
128.0	31.5034	0.0327109	7913
104.0	2.7447	0.0336423	4001
106.0	5.4804	0.0335653	4002
108.0	8.1584	0.0334933	4003
110.0	10.7880	0.0334226	4004
112.0	13.3821	0.0333534	4005
114.0	15.9470	0.0332863	4006
116.0	18.4948	0.0332212	4007
118.0	21.0292	0.0331584	4008
120.0	23.6101	0.0331000	4009
122.0	26.1304	0.0330430	4010
124.0	28.6680	0.0329889	4011
126.0	31.1985	0.0329387	4012
102.0	2.4536	0.0339664	5301
104.0	5.2772	0.0338885	5302
106.0	8.0304	0.0338166	5303
108.0	10.7372	0.0337455	5304
110.0	13.4307	0.0336756	5305
112.0	16.0496	0.0336088	5306
112.0	16.0483	0.0336092	5306
114.0	18.6581	0.0335444	5307
116.0	21.2724	0.0334816	5308
118.0	23.8799	0.0334216	5309
120.0	26.4646	0.0333652	5310
122.0	29.0434	0.0333119	5311
124.0	31.6233	0.0332627	5312
100.0	0.7417	0.0341475	5401
102.0	3.6253	0.0340649	5402
104.0	6.4406	0.0339892	5403
106.0	9.1978	0.0339171	5404
108.0	11.9114	0.0338463	5405
110.0	14.5967	0.0337775	5406
112.0	17.2500	0.0337109	5407
114.0	19.8976	0.0336463	5408
114.0	19.9333	0.0336478	5408
116.0	22.5629	0.0335864	5409
118.0	25.1980	0.0335279	5410
120.0	27.8054	0.0334726	5411
122.0	30.4268	0.0334209	5412
124.0	33.0483	0.0333729	5413
99.0	1.6534	0.0343798	5500
100.0	3.1209	0.0343387	5501
102.0	6.0143	0.0342606	5502
104.0	8.8357	0.0341871	5503
106.0	11.6386	0.0341151	5504
108.0	14.3917	0.0340449	5505
110.0	17.1172	0.0339769	5506
112.0	19.8187	0.0339113	5507
114.0	22.5087	0.0338491	5508

TABLE 2. *Temperature-pressure-density observations on oxygen.*—Continued

T K	P MN/m^2	Density mol/cm^3	Ident
116.0	25.2057	0.0337891	5509
118.0	27.8901	0.0337326	5510
98.0	1.8866	0.0345541	7001
100.0	4.8696	0.0344737	7002
102.0	7.7887	0.0343977	7003
104.0	10.6519	0.0343240	7004
106.0	13.4715	0.0342521	7005
108.0	16.2612	0.0341824	7006
110.0	19.0241	0.0341152	7007
112.0	21.7870	0.0340507	7008
114.0	24.5320	0.0339893	7009
116.0	27.2792	0.0339315	7010
118.0	30.0073	0.0338777	7011
120.0	32.7273	0.0338276	7012
98.0	2.3008	0.0345829	11001
100.0	5.6357	0.0345341	11002
102.0	8.9409	0.0344906	11003
104.0	12.2000	0.0344479	11004
106.0	15.3871	0.0344073	11005
108.0	18.5961	0.0343677	11006
110.0	21.7798	0.0343303	11007
98.0	4.6684	0.0347714	6801
100.0	7.6506	0.0346931	6802
102.0	10.5760	0.0346172	6803
104.0	13.4535	0.0345432	6804
106.0	16.2991	0.0344715	6805
108.0	19.1240	0.0344024	6806
110.0	21.9346	0.0343363	6807
112.0	24.7305	0.0342735	6808
114.0	27.5177	0.0342143	6809
116.0	30.3147	0.0341590	6810
118.0	33.1174	0.0341080	6811
96.0	3.5267	0.0350023	7201
98.0	6.5819	0.0349220	7202
100.0	9.5691	0.0348452	7203
102.0	12.4989	0.0347704	7204
104.0	15.3955	0.0346975	7205
106.0	18.2560	0.0346272	7206
108.0	21.0983	0.0345598	7207
110.0	23.9336	0.0344954	7208
112.0	26.7622	0.0344345	7209
114.0	29.5901	0.0343775	7210
116.0	32.4298	0.0343246	7211
94.0	2.0325	0.0352031	6901
96.0	5.1647	0.0351187	6902
98.0	8.2265	0.0350409	6903
100.0	11.2273	0.0349642	6904
102.0	14.1864	0.0348896	6905
104.0	17.1083	0.0348172	6906
106.0	20.0017	0.0347479	6907
108.0	22.8816	0.0346816	6908
110.0	25.7600	0.0346187	6909
112.0	28.6413	0.0345593	6910
114.0	31.5159	0.0345044	6911
94.0	3.6749	0.0353210	4201
96.0	6.7597	0.0352370	4202
98.0	9.7756	0.0351563	4203
100.0	12.7369	0.0350779	4204
102.0	15.6649	0.0350015	4205
104.0	18.5748	0.0349277	4206
106.0	21.4663	0.0348569	4207
108.0	24.3527	0.0347893	4208
110.0	27.2442	0.0347258	4209
112.0	30.1416	0.0346662	4210
114.0	33.0409	0.0346116	4211
90.0	0.5790	0.0357295	4601
92.0	3.7985	0.0356349	4602
94.0	6.9363	0.0355490	4603
96.0	9.9960	0.0354662	4604
98.0	13.0042	0.0353856	4605
100.0	15.9823	0.0353080	4606
102.0	18.9273	0.0352328	4607
104.0	21.8793	0.0351603	4608
106.0	24.8244	0.0350914	4609
108.0	27.7800	0.0350264	4610
110.0	30.7253	0.0349663	4611
90.0	2.1354	0.0358257	7101
92.0	5.4112	0.0357379	7102
94.0	8.6090	0.0356560	7103
96.0	11.7449	0.0355756	7104
98.0	14.8297	0.0354978	7105
100.0	17.8893	0.0354226	7106
102.0	20.9328	0.0353505	7107
104.0	23.9672	0.0352820	7108
106.0	27.0073	0.0352176	7109
108.0	30.0554	0.0351578	7110
110.0	33.0707	0.0351031	7111
88.0	1.1986	0.0360762	4801
90.0	4.4953	0.0359820	4802
92.0	7.6900	0.0358952	4803
94.0	10.8170	0.0358109	4804
96.0	13.8938	0.0357292	4805
98.0	16.9363	0.0356499	4806
100.0	19.9936	0.0355740	4807
102.0	23.0452	0.0355010	4808
104.0	26.0566	0.0354331	4809
106.0	29.0753	0.0353689	4810
108.0	32.1434	0.0353088	4811
88.0	3.7829	0.0362485	3801
90.0	7.0649	0.0361587	3802
92.0	10.2597	0.0360721	3803
94.0	13.3723	0.0359887	3804
96.0	16.4770	0.0359072	3805
98.0	19.5564	0.0358288	3806
100.0	22.6519	0.0357533	3807

TABLE 2. *Temperature-pressure-density observations on oxygen.*—Continued

T K	P MN/m^2	Density mol/cm^3	Ident
102.0	25.7577	0.0356832	3808
104.0	28.8557	0.0356166	3809
106.0	31.9572	0.0355554	3810
86.0	2.5495	0.0364373	5101
88.0	5.9034	0.0363448	5102
90.0	9.1630	0.0362568	5103
92.0	12.3548	0.0361711	5104
94.0	15.5098	0.0360881	5105
96.0	18.6580	0.0360082	5106
98.0	21.7512	0.0359313	5107
98.0	21.7694	0.0359315	5107
100.0	24.9373	0.0358575	5108
102.0	28.0181	0.0357899	5109
104.0	31.2240	0.0357250	5110
86.0	2.1952	0.0364340	7401
88.0	5.6350	0.0363425	7402
90.0	8.9713	0.0362567	7403
92.0	12.2324	0.0361731	7404
94.0	15.4555	0.0360921	7405
96.0	18.6461	0.0360142	7406
98.0	21.8211	0.0359398	7407
100.0	24.9894	0.0358695	7408
102.0	28.1582	0.0358035	7409
104.0	31.3296	0.0357426	7410
86.0	2.4864	0.0364717	4501
88.0	5.8392	0.0363791	4502
90.0	9.0913	0.0362913	4503
92.0	12.2843	0.0362055	4504
94.0	15.4423	0.0361222	4505
96.0	18.5601	0.0360428	4506
98.0	21.6686	0.0359648	4507
100.0	24.7791	0.0358919	4508
102.0	27.8932	0.0358232	4509
86.0	4.0717	0.0365538	11601
86.0	4.0742	0.0365538	11601
88.0	8.0270	0.0365007	11602
90.0	11.9176	0.0364498	11603
92.0	15.7524	0.0364013	11604
94.0	19.5665	0.0363550	11605
96.0	23.3657	0.0363112	11606
98.0	27.1523	0.0362700	11607
100.0	30.9404	0.0362326	11608
102.0	34.7284	0.0361989	11609
84.0	1.1839	0.0366764	6601
86.0	4.6859	0.0365818	6602
88.0	8.1053	0.0364940	6603
90.0	11.4530	0.0364085	6604
92.0	14.7392	0.0363259	6605
94.0	17.9906	0.0362463	6606
96.0	21.2208	0.0361700	6607
98.0	24.4510	0.0360977	6608
100.0	27.6686	0.0360301	6609
102.0	30.9163	0.0359673	6610
104.0	34.1576	0.0359101	6611
84.0	3.5900	0.0368114	5701
86.0	7.0633	0.0367205	5702
88.0	10.4638	0.0366324	5703
90.0	13.7910	0.0365473	5704
92.0	17.0873	0.0364644	5705
94.0	20.3732	0.0363856	5706
96.0	23.6500	0.0363098	5707
98.0	26.9280	0.0362393	5708
100.0	30.2151	0.0361737	5709
102.0	33.5198	0.0361140	5710
84.0	3.8384	0.0368285	4901
86.0	7.2501	0.0367359	4902
88.0	10.5740	0.0366462	4903
90.0	13.8416	0.0365592	4904
92.0	17.0941	0.0364749	4905
94.0	20.3134	0.0363949	4906
96.0	23.5705	0.0363178	4907
98.0	26.8186	0.0362451	4908
100.0	30.0772	0.0361775	4909
102.0	33.3393	0.0361160	4910
84.0	3.8882	0.0368308	7301
86.0	7.3692	0.0367405	7302
88.0	10.7646	0.0366530	7303
90.0	14.1014	0.0365684	7304
92.0	17.3952	0.0364875	7305
94.0	20.6605	0.0364088	7306
96.0	23.9280	0.0363345	7307
98.0	27.1992	0.0362646	7308
100.0	30.4830	0.0361999	7309
102.0	33.7693	0.0361410	7310
82.0	2.8589	0.0370683	3701
84.0	6.3331	0.0369734	3702
86.0	9.7564	0.0368824	3703
88.0	13.0916	0.0367940	3704
90.0	16.4016	0.0367082	3705
92.0	19.6937	0.0366255	3706
94.0	22.9780	0.0365468	3707
96.0	26.2652	0.0364725	3708
98.0	29.5698	0.0364032	3709
100.0	32.8893	0.0363398	3710
84.0	7.7004	0.0370189	5001
86.0	11.0964	0.0369277	5002
88.0	14.4374	0.0368397	5003
90.0	17.7589	0.0367543	5004
92.0	21.0792	0.0366723	5005
94.0	24.3975	0.0365946	5006
96.0	27.7112	0.0365219	5007
98.0	31.0432	0.0364546	5008
100.0	34.3986	0.0363933	5009
80.0	2.9120	0.0373729	4701
82.0	6.4557	0.0372762	4702
84.0	9.9139	0.0371829	4703
86.0	13.3193	0.0370923	4704

TABLE 2. *Temperature-pressure-density observations on oxygen.*—Continued

T K	P MN/m^2	Density mol/cm^3	Ident
88.0	16.6838	0.0370047	4705
90.0	20.0421	0.0369203	4706
90.0	20.0658	0.0369214	4706
92.0	23.4213	0.0368414	4707
94.0	26.8034	0.0367658	4708
96.0	30.1975	0.0366956	4709
98.0	33.6100	0.0366321	4710
82.0	3.6237	0.0371162	11101
84.0	7.8486	0.0370596	11102
86.0	11.9380	0.0370062	11103
88.0	15.9849	0.0369553	11104
90.0	20.0043	0.0369079	11105
92.0	24.0034	0.0368617	11106
94.0	28.0024	0.0368196	11107
96.0	31.9946	0.0367814	11108
80.0	2.5494	0.0373439	11301
82.0	6.8412	0.0372846	11302
84.0	11.0122	0.0372297	11303
86.0	15.1259	0.0371773	11304
88.0	19.2156	0.0371273	11305
90.0	23.3042	0.0370801	11306
92.0	27.3871	0.0370368	11307
94.0	31.4658	0.0369970	11308
80.0	4.7682	0.0374570	11401
82.0	9.0390	0.0374008	11402
84.0	13.2375	0.0373466	11403
86.0	17.4016	0.0372953	11404
88.0	21.5532	0.0372464	11405
90.0	25.6953	0.0372011	11406
92.0	29.8415	0.0371593	11407
94.0	33.9782	0.0371218	11408
79.0	3.0352	0.0375170	10901
80.0	5.2592	0.0374867	10902
82.0	9.5525	0.0374315	10903
84.0	13.7847	0.0373783	10904
86.0	17.9590	0.0373281	10905
88.0	22.1268	0.0372804	10906
90.0	26.2913	0.0372360	10907
92.0	30.4444	0.0371957	10908
94.0	34.6000	0.0371595	10909
78.0	1.6179	0.0375849	11701
80.0	6.0004	0.0375223	11702
82.0	10.2597	0.0374663	11703
84.0	14.4605	0.0374126	11704
86.0	18.6351	0.0373613	11705
88.0	22.8052	0.0373124	11706
90.0	26.9628	0.0372679	11707
92.0	31.1310	0.0372269	11708
78.0	3.0283	0.0376563	12001
80.0	7.3749	0.0375973	12002
82.0	11.6562	0.0375411	12003
84.0	15.8755	0.0374877	12004
86.0	20.0777	0.0374369	12005
88.0	24.2731	0.0373892	12006
90.0	28.4721	0.0373447	12007
92.0	32.6712	0.0373049	12008
76.0	2.4072	0.0379133	12501
78.0	6.8711	0.0378520	12502
80.0	11.2315	0.0377948	12503
82.0	15.5493	0.0377403	12504
84.0	19.8582	0.0376882	12505
86.0	24.1591	0.0376391	12506
88.0	28.4717	0.0375940	12507
90.0	32.7823	0.0375534	12508
76.0	4.0138	0.0379820	11801
78.0	8.4856	0.0379228	11802
80.0	12.8759	0.0378659	11803
82.0	17.2191	0.0378119	11804
84.0	21.5454	0.0377607	11805
86.0	25.8751	0.0377125	11806
88.0	30.2153	0.0376688	11807
90.0	34.5593	0.0376299	11808
74.0	3.3886	0.0382372	11201
76.0	7.9765	0.0381756	11202
78.0	12.4678	0.0381172	11203
80.0	16.9121	0.0380619	11204
82.0	21.3359	0.0380093	11205
84.0	25.7713	0.0379602	11206
86.0	30.2058	0.0379156	11207
88.0	34.6623	0.0378759	11208
74.0	3.9031	0.0382532	11901
76.0	8.5252	0.0381918	11902
78.0	13.0201	0.0381335	11903
80.0	17.4597	0.0380783	11904
82.0	21.8961	0.0380259	11905
84.0	26.3326	0.0379773	11906
86.0	30.7832	0.0379331	11907
88.0	35.2581	0.0378937	11908
72.0	2.5060	0.0384810	12401
74.0	7.1914	0.0384173	12402
76.0	11.7895	0.0383572	12403
78.0	16.3164	0.0383004	12404
80.0	20.8216	0.0382466	12405
82.0	25.3408	0.0381963	12406
84.0	29.8739	0.0381504	12407
86.0	34.4176	0.0381095	12408
70.0	1.9433	0.0387405	12601
72.0	6.7402	0.0386743	12602
74.0	11.4313	0.0386129	12603
76.0	16.0558	0.0385548	12604
78.0	20.6678	0.0384996	12605
80.0	25.2822	0.0384482	12606
82.0	29.9312	0.0384011	12607
84.0	34.5863	0.0383594	12608

TABLE 2. *Temperature-pressure-density observations on oxygen.* — Continued

T K	P MN/m²	Density mol/cm³	Ident
68.0	2.0696	0.0390250	12701
70.0	6.9852	0.0389576	12702
72.0	11.7921	0.0388945	12703
74.0	16.5223	0.0388352	12704
76.0	21.2456	0.0387790	12705
78.0	25.9818	0.0387267	12706
80.0	30.7343	0.0386793	12707
82.0	35.5145	0.0386375	12708
66.0	1.8168	0.0392920	12801
68.0	6.8449	0.0392227	12802
70.0	11.7582	0.0391582	12803
72.0	16.6110	0.0390975	12804
74.0	21.4597	0.0390399	12805
76.0	26.3164	0.0389866	12806
78.0	31.1907	0.0389391	12807
80.0	36.0790	0.0388971	12808
64.0	2.2554	0.0395872	12901
66.0	7.4132	0.0395174	12902
68.0	12.4516	0.0394518	12903
70.0	17.4275	0.0393900	12904
72.0	22.4034	0.0393318	12905
74.0	27.3975	0.0392782	12906
76.0	32.4068	0.0392303	12907
62.0	1.4944	0.0398369	13001
64.0	6.7815	0.0397637	13002
66.0	11.9273	0.0396963	13003
68.0	17.0229	0.0396332	13004
70.0	22.0984	0.0395735	13005
72.0	27.1927	0.0395188	13006
74.0	32.3081	0.0394700	13007
60.0	2.2489	0.0401416	13101
62.0	7.6364	0.0400686	13102
64.0	12.8871	0.0400007	13103
66.0	18.1156	0.0399367	13104
68.0	23.3568	0.0398767	13105
70.0	28.6098	0.0398218	13106
72.0	33.9010	0.0397732	13107
58.0	3.3328	0.0404544	13401
60.0	8.8263	0.0403815	13402
62.0	14.2016	0.0403132	13403
64.0	19.5644	0.0402476	13404
66.0	24.9459	0.0401870	13405
68.0	30.3712	0.0401322	13406
70.0	35.8335	0.0400846	13407
56.0	2.6086	0.0407032	13501
58.0	8.2297	0.0406280	13502
60.0	13.7153	0.0405578	13503
62.0	19.2048	0.0404909	13504
64.0	24.7113	0.0404287	13505
66.0	30.2676	0.0403725	13506
68.0	35.8689	0.0403239	13507
56.0	7.9532	0.0408851	13601
58.0	13.5708	0.0408129	13602
60.0	19.1563	0.0407448	13603
62.0	24.7914	0.0406812	13604
64.0	30.4853	0.0406240	13605
66.0	36.2267	0.0405746	13606
56.0	10.4922	0.0409650	13701
58.0	16.1270	0.0408944	13702
60.0	21.8078	0.0408273	13703
62.0	27.5211	0.0407659	13704
64.0	33.2989	0.0407117	13705
54.5	1.3028		13201
55.0	5.6750		13202
55.5	10.0802		13203
56.0	14.3361	0.0410947	13204
58.0	20.0847	0.0410255	13205
60.0	25.8750	0.0409613	13206
62.0	31.7297	0.0409040	13207
54.5	1.2974		13302
54.6	2.1701		13303
54.7	3.0519		13304
54.8	3.9222		13305
54.9	4.7926		13306
55.0	5.6718		13307
55.1	6.5512		13308
55.2	7.4260		13309
55.3	8.3066		13310
55.4	9.1872		13311
55.5	10.0759		13312
55.6	10.9541		13313
55.7	11.8427		13314
55.8	12.7347		13315
55.9	13.6302		13316
56.0	14.5154		13317
56.1	15.4029		13318
56.2	16.2890		13319
56.3	16.5715	0.0411341	13320
56.4	16.8619	0.0411309	13321
57.0	18.5956	0.0411097	13322
58.0	21.4877	0.0410759	13323
60.0	27.3250	0.0410127	13324
62.0	33.2259	0.0409570	13325

TABLE 3. *Comparison of vapor pressure data with equation* (7)

Temp	P_{exp}	$P_{\text{exp}}-P_{\text{eq}(7)}$
K	MN/m^2	MN/m^2
114.0	0.7088	0.0000
116.0	.8039	.0000
118.0	.9082	.0001
122.0	1.1451	.0001
126.0	1.4234	−.0002
138.0	2.5500	−.0003
139.0	2.6669	.0003
139.1	2.6787	.0003
139.2	2.6906	.0003
139.3	2.7026	.0004
139.4	2.7146	.0005
140.0	2.7863	−.0002
142.0	3.0380	−.0003
142.0	3.0386	.0003
146.0	3.5910	−.0008
154.0	4.9321	.0001
154.0	4.9320	.0000
154.1	4.9504	−.0006
154.2	4.9697	−.0005
154.3	4.9885	−.0008

2.3. Representation of the Data

a. Representation of Experimental Data

The purpose of the present calculations is the determination of the derived properties in the best possible way. Therefore no attempt was made to fit all the data with one wide-range equation of state. Instead the data were divided into three regions and the data in each region were smoothed and interpolated by the means which seemed most appropriate. These regions are illustrated in figure 2 and are considered separately below.

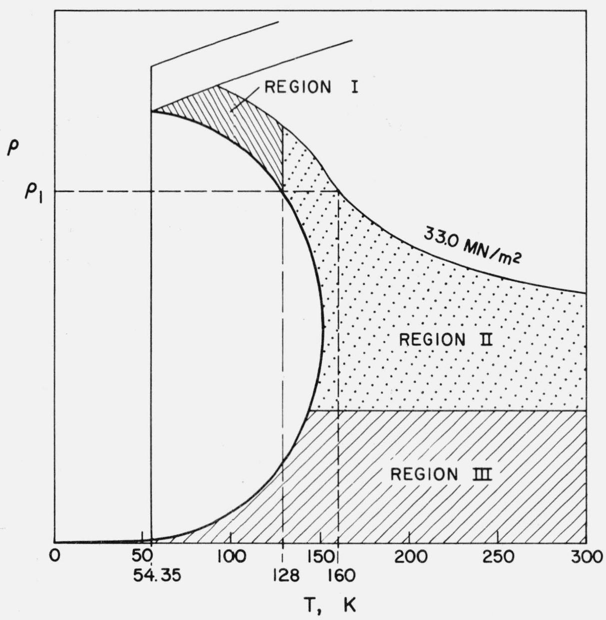

FIGURE 2. *Temperature—density phase diagram showing regions for thermodynamic computations.*

In all of the curve fitting the data were weighted in a manner appropriate to the expected uncertainties in the variables involved. In some cases curves were constrained to pass through a given point or to have a particular value of a derivative at a given point. For details of this technique see Hust and McCarty [12].

Low Density Gas.—At densities of 0.006709 mol/cm³ and less (Region III in fig. 2) the data were represented with a virial surface,

$$P=RT[\rho+B(T)\rho^2+C(T)\rho^3]. \qquad (2)$$

The second and third virial coefficients were expressed as a function of temperature of the form

$$B(T)=\sum_{J=1}^{5} A_J T^{(1-J)/4} \qquad (3a)$$

$$C(T)=\sum_{J=1}^{6} A_J T^{(1-J)/2}. \qquad (3b)$$

The parameters used in eqs (3a) and (3b) are given in table 4. In addition to 296 P–V–T data points, 14 experimental C_v data points [6] between 150 K and 300 K, were included as data in fitting the surface. The average deviation of the calculated heat capacities is 1.36 percent, approximately equivalent to the uncertainties in the experimental points. Between 150 K and 300 K the standard deviation of the P–V–T points is 0.048 percent in density. At temperatures below 150 K the data of Series IV show an average deviation of 0.12 percent in density which is systematic and which becomes worse with decreasing temperature. These data carried relatively low weighting, and it is expected that eqs (2, 3a, 3b) represent the best approximation to the P–V–T surface at low temperatures. One possible explanation for this discrepancy would be physical adsorption on the walls of the sample holder. It is more likely, however, that we are seeing small systematic errors in the pressure measurements. The virial coefficients, calculated by means of eqs (3a) and (3b) are tabulated in table 5. The columns labeled "ISOTHERM" contain the results obtained by fitting equation (2) to the data along individual isotherms.

High Density Liquid.—The high density compressed liquid, (Region I, fig. 2), bounded by the melting curve, vapor pressure curve, 33 MN/m² isobar, and the 128 K isotherm, was represented by a 12 parameter empirical surface given by eq (4):

$$P=RT\rho+(A_1+A_2T+A_3T^2)+(A_4+A_5T+A_6T^2+A_7T^3)\rho+(A_8+A_9T+A_{10}T^2)\rho^2+(A_{11}+A_{12}T)\rho^3. \qquad (4)$$

The values of the parameters are given in table 4. The surface was constrained to a value of 0.02869 mol/cm³ for the density of the saturated liquid at 128 K. The 557 experimental points in this region exhibited a standard deviation from the surface of 0.024 percent in density.

TABLE 4. *Parameter values for the various equations*

	Eq (3a)	Eq (3b)	Eq (4)	Eq (7)	Eq (13)	Eq (14)	Eq (9)	Eq (11)
A_1	$-1.5226420059 \times 10^{3}$	$3.3711154314 \times 10^{5}$	$-1.641561252 \times 10^{3}$	-64.8861406	$2.105614214 \times 10^{2}$	$-3.222372953 \times 10^{-1}$	0.01363	1.81187
A_2	$2.7768311172 \times 10^{4}$	$-2.5369852041 \times 10^{7}$	$1.147287363 \times 10^{1}$	2.47450429	$3.741590387 \times 10^{1}$	$1.727532883 \times 10^{2}$	$6.02582799 \times 10^{-5}$	2.77986×10^{-1}
A_3	$-1.8606884996 \times 10^{5}$	$7.6407469222 \times 10^{8}$	$-1.893991658 \times 10^{-2}$	$-4.68973315 \times 10^{-2}$	$-8.007073541 \times 10^{-2}$	$-2.255944223 \times 10^{4}$	$1.00932845 \times 10^{-7}$	-7.60653×10^{-1}
A_4	$5.5834774260 \times 10^{5}$	$-1.1480733696 \times 10^{10}$	$1.855069328 \times 10^{5}$	$5.48202337 \times 10^{-4}$	$-2.742842302 \times 10^{-4}$	$1.171338217 \times 10^{6}$		
A_5	$-6.5056457930 \times 10^{5}$	$8.6044663037 \times 10^{10}$	$-1.163758279 \times 10^{3}$	$-4.09349868 \times 10^{-6}$				
A_6		$-2.5679270159 \times 10^{11}$	1.470658133	$1.91471914 \times 10^{-8}$				
A_7			$5.082303291 \times 10^{-4}$	$-5.13113688 \times 10^{-11}$				
A_8			$-6.905607063 \times 10^{6}$	$6.02656934 \times 10^{-14}$				
A_9			$3.696268789 \times 10^{4}$					
A_{10}			$-3.493447874 \times 10^{1}$					
A_{11}			$7.817570089 \times 10^{7}$					
A_{12}			$-2.981428648 \times 10^{5}$					

Intermediate Densities.—The data in Region II of figure 2 were approximated by 35 isotherm polynomials of the form

$$P = RT\rho + \sum_{J=1}^{N} A_J \rho^{(J-1)}, \tag{5}$$

$$A_1 = A_2 = 0 \text{ for } T > T_c.$$

The number of coefficients used varied from four at 128 K and at 300 K to a maximum of fourteen for the 156 K isotherm. The standard deviations of the 650 data points averaged about 0.02 percent in density for the various isotherms.

Melting Curve.—Experimental runs #132 and #133 included 21 values of the melting pressure at 0.1 K intervals. The measured pressures varied from 1.2 to 16 MN/m². These data were fitted with the Simon melting equation in the form

$$P = P_t + P_o\left[(T/T_t)^c - 1\right], \tag{6}$$

with c and T_t being varied to obtain the best fit. The first row of table 6 gives the set of parameters obtained with σ being the standard deviation of the fit in MN/m². The value obtained for T_t, 54.3507 ± 0.0010 K, will be used here as the best value for the triple point temperature.

The second row of table 6 shows the fit of eq (6), with the value of T_t obtained above, to the data of Mills and Grilly [13]. These data are less precise but extend in pressure from 36 to 350 MN/m². The third row of table 6 gives the parameters obtained by fitting eq (6) to both sets of data, using a relative weighting equal to $1/\sigma^2$. Table 7 illustrates this last fit.

b. Additional Data Used

Certain data from other sources were used as supplemental information for these calculations. Vapor pressures used here are based on the data of Hoge [10]. These were published in analytical form by Stewart [11], whose equation is reproduced here for convenience.

$$\ln P(\mathrm{MN/m^2}) = A_1 + A_2T + A_3T^2 + A_4T^3 + A_5T^4 + A_6T^5 + A_7T^6 + A_8T^7. \tag{7}$$

Values of the coefficients for eq (7) are given in table 4.

The critical temperature, 154.576 ± 0.01 K on the IPTS 1948, is taken from [14]. Densities of saturated liquid and vapor in the critical region are difficult

TABLE 5. *The second and third virial coefficients.*

Units are (cm³/mol) and (cm³/mol)² respectively. The quantities δB and δC are the estimated uncertainties.

Temp K	Second virial Eq (3)	Second virial Isotherm	δB	Third virial Eq (3)	Third virial Isotherm	δC
85	−267.78		30.	−21462		15000
90	−240.67			−12764		
95	−217.51			−7058		
100	−197.54		15.	−3326		4000
105	−180.20			−904		
110	−165.05			644		
115	−151.71			1609		
120	−139.91		5.	2187		1000
125	−129.41			2507		
130	−120.02			2659		
135	−111.59			2702		
140	−103.98		1.	2677		100
145	−97.08			2611		
150	−90.81	−90.81	0.25	2522	2515	40
155	−85.09			2423		
160	−79.84	−79.85	0.25	2320	2322	30
165	−75.02	−74.99		2219	2213	
170	−70.58	−70.50		2122	2107	
175	−66.48	−66.38		2031	2014	
180	−62.67	−62.58		1948	1932	
185	−59.14	−59.03		1871	1853	
190	−55.85	−55.74		1801	1784	
195	−52.77	−52.67		1738	1722	
200	−49.89	−49.80	0.30	1680	1666	30
205	−47.20			1628		
210	−44.66	−44.59		1580	1570	
215	−42.27			1537		
220	−40.02	−39.98		1498	1490	
225	−37.90			1461		
230	−35.89	−35.87		1428	1424	
235	−33.98			1397		
240	−32.17	−32.18		1368	1369	
245	−30.45			1342		
250	−28.81	−28.85		1317	1322	
255	−27.25			1294		
260	−25.77	−25.81		1273	1280	
265	−24.34			1253		
270	−22.98	−23.04		1234	1243	
275	−21.68			1217		
280	−20.44	−20.51		1201	1213	
285	−19.24			1186		
290	−18.09	−18.13		1172	1179	
295	−16.98			1160		
300	−15.92	−16.01	0.30	1149	1162	30

TABLE 6. *Parameters for the Simon melting equation for oxygen*

Data used	P_0	c	T_t	σ, MN/m²
This data only	266.27	1.775	54.3507	0.0041
Data of Mills and Grilly [13]	270.1	1.754	54.3507	.51
Both sets of data	267.21	1.769	54.3507	

to derive from PVT data and were also taken from [14]. These densities appear in the center section of table 8. The critical pressure, P_c, was calculated from (7) at the critical temperature. The thermodynamic properties calculations are based on the thermodynamic functions of the ideal gas calculated by Woolley [5].

TABLE 7. *Fit of the Simon equation to melting curve data*

Data in lower part are from [13].

T K	P_{exp} MN/m²	P_{calc} MN/m²	Diff MN/m²
54.50	1.303	1.300	−0.003
54.50	1.297	1.300	.003
54.60	2.170	2.172	.002
54.70	3.052	3.045	−.007
54.80	3.922	3.920	−.002
54.90	4.793	4.796	.003
55.00	5.675	5.673	−.002
55.00	5.672	5.673	.001
55.10	6.551	6.551	.000
55.20	7.426	7.431	.005
55.30	8.307	8.311	.004
55.40	9.187	9.193	.006
55.50	10.080	10.076	−.004
55.50	10.076	10.076	.000
55.60	10.954	10.961	.007
55.70	11.843	11.847	.004
55.80	12.735	12.733	−.002
55.90	13.630	13.621	−.009
56.00	14.515	14.511	−.004
56.10	15.403	15.401	−.002
56.20	16.289	16.293	.004
58.57	37.399	37.783	.384
59.79	49.386	49.111	−.275
61.92	70.036	69.317	−.719
63.93	88.781	88.881	.100
65.79	106.938	107.413	.475
67.85	128.956	128.411	−.545
69.92	150.964	150.012	−.952
71.96	172.212	171.786	−.426
74.40	199.033	198.459	−.574
76.54	223.067	222.414	−.653
77.06	227.971	228.313	.342
79.03	250.303	250.942	.639
81.04	274.814	274.481	−.333
83.39	301.594	302.576	.982
85.33	325.963	326.233	.270
87.31	551.162	350.809	−.353

c. Derived Data

The representations of the experimental data, in the previous section, allow us to derive other useful properties.

Isochores.—In the calculation of most of the thermodynamic properties the quantities $(\partial P/\partial T)_\rho$ and $(\partial^2 P/\partial T^2)_\rho$ are needed. In Regions I and III of figure 2 these quantities are calculated from the analytic surfaces. In Region II the isotherm polynomials were used to calculate pressures at even increments of density. The pressure-temperature pairs (true isochores) thus obtained were fitted using functions of the form

$$P=\sum_{J=1}^{N} A_J T^{(3-2J)}. \qquad (8)$$

A density increment of 0.0005 mol/cm³ was used. The number of terms used in eq (8) varied between 6 at the lowest densities and 3 at the highest. Between the densities 0.0290 and 0.0330 mol/cm^3 the isochores were constrained to have their second derivatives, $(\partial^2 P/\partial T^2)_\rho$, match those calculated by the liquid surface, eq (4), at 128 K.

Two-Phase Boundaries.—Derived "experimental" densities of the saturated liquid and saturated vapor may be found from the intersections of the experimental isochores with the vapor pressure curve eq (7). The first several points of an experimental run are fitted with a low order polynomial, $P=P(T)$, either a quadratic or cubic. The expected uncertainty in this temperature of intersection may be calculated from the estimated uncertainty in the vapor pressure, the slopes of the two curves, quality of the fit of the polynomial, the temperature range over which the fit was made, and the length of the extrapolation to the intersection temperature. This procedure was applied to the experimental runs, and the calculated uncertainties varied from 1 millidegree in the best cases to 100 millidegrees near the critical point where the isochores and the vapor pressure curve are almost colinear.

The densities of the saturated liquid were found in this way, between 120 K and 150 K, and were smoothed and interpolated by means of a 7-term polynomial. For the saturated vapor over the same temperature range the number of experimental runs proved to be too small for this technique to be applied with good results. Therefore, the vapor densities were found from the intersection of the virial surface, eq (2), with the vapor pressure curve. The saturation densities thus obtained were computed at 1 K intervals and averaged to obtain the rectilinear diameter,

$$\rho_{RD}=\tfrac{1}{2}(\rho_{\mathrm{sat}\,L}+\rho_{\mathrm{sat}\,G}).$$

The resulting rectilinear diameter was fitted by means of a function of the form,

$$\rho_{RD}=A_1+A_2(T_c-T)+A_3(T_c-T)^2 \tag{9}$$

with an average deviation of 2×10^{-6} mol/cm^3. From eq (9), a value of 0.01363 mol/cm^3 was obtained for the critical density, A_1. Values of the other parameters are given in table 4.

The isochore-vapor pressure intersection temperatures were considered unreliable above about 152 K because of the small angle of intersection. Densities calculated from the dielectric measurements of [14]. were used in the temperature range 150 K to T_c.

All of the saturation densities, ρ_{sat}, both liquid and vapor, were fitted with a function of the form

$$|\rho_{\mathrm{sat}}-\rho_{RD}|=\sum_{J=1}^{3}A_J\left(\frac{T_c-T}{T_c}\right)^{(2J-1)\beta} \tag{10}$$

with $\beta=0.353$. The fit of eq (10) is illustrated in table 8, where ΔT_{est} is the uncertainty in the intersection temperature, calculated as indicated above, and ΔT_{calc} is found from $|\rho_{\mathrm{exp}}-\rho_{\mathrm{calc}}|/|d\rho/dT|$.

TABLE 8. *Fit of the derived saturation density data*

Data in center section are dielectric measurements from [14]. Above the line—vapor, below—liquid.

ID	Temp. K	Density exp mol/cm^3	Density calc mol/cm^3	Diff. %	Delta T calc[a] K	Delta T est K	Relative weight
121	138.573	0.003374	0.003376	0.07	0.013	0.005	1060
104	146.387	.005258	.005265	0.14	.023	.008	726.4
103	147.512	.005656	.005652	−.07	.011	.020	209.8
102	149.463	.006454	.006451	−.05	.007	.012	334.0
101	150.379	.006888	.006905	.25	.033	.014	217.4
100	152.695	.008478	.008505	.31	.029	.021	41.10
	150.000	.006716	.006709	−.10	.013	.000	474.7
	153.000	.008815	.008806	−.09	.008	.000	1844
	153.500	.009410	.009401	−.09	.006	.000	469.6
	153.600	.009544	.009541	−.03	.002	.000	468.8
	154.000	.010213	.010226	.13	.006	.000	462.3
	154.100	.010441	.010445	.04	.002	.000	458.8
	154.101	.010444	.010447	.03	.001	.000	458.7
	154.200	.010694	.010697	.02	.001	.000	453.1
	154.300	.010994	.010997	.03	.001	.000	204.6
	154.397	.011357	.011368	.10	.003	.000	199.9
	154.490	.011885	.011882	−.02	.000	.000	356.5
	154.500	.011904	.011956	.44	.007	.000	29.02
	154.510	.012025	.012037	.10	.001	.000	174.9
	154.523	.012182	.012156	−.21	.003	.000	49.42
	154.540	.012338	.012344	.05	.000	.000	65.35
	154.544	.012416	.012396	−.16	.001	.000	27.66
	154.546	.012450	.012424	−.22	.002	.000	35.10
	154.560	.012591	.012664	.58	.004	.000	8.40
	154.566	.012875	.012811	−.50	.002	.000	2.06
	154.566	.012763	.012811	.38	.002	.000	2.06

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TABLE 8. *Fit of the derived saturation density data* — Continued

Data in center section are dielectric measurements from [14]. Above the line — vapor, below — liquid.

ID	Temp. K	Density exp mol/cm³	Density calc mol/cm³	Diff. %	Delta T calc[a] K	Delta T est K	Relative weight
	154.566	.014457	.014452	−.03	.000	.000	2.06
	154.566	.014429	.014452	.16	.001	.000	2.06
	154.560	.014551	.014600	.34	.002	.000	8.04
	154.546	.014819	.014842	.15	.002	.000	35.10
	154.544	.014869	.014870	.00	.000	.000	35.37
	154.540	.014932	.014923	−.06	.001	.000	65.35
	154.523	.015126	.015113	−.09	.001	.000	49.42
	154.510	.015241	.015233	−.06	.001	.000	174.9
	154.500	.015304	.015315	.07	.001	.000	29.02
	154.490	.015401	.015390	−.07	.001	.000	356.5
	154.397	.015926	.015915	−.06	.002	.000	199.9
	154.300	.016285	.016298	.08	.004	.000	204.6
	154.200	.016616	.016611	−.03	.002	.000	453.1
	154.101	.016863	.016872	.05	.004	.000	458.7
	154.100	.016882	.016875	−.04	.003	.000	458.8
	154.000	.017094	.017106	.07	.005	.000	462.3
	153.600	.017829	.017838	.05	.006	.000	468.8
	153.500	.017982	.017991	.05	.006	.000	469.6
	153.000	.018635	.018646	.06	.009	.000	1844
	150.000	.021104	.021108	.02	.007	.000	474.7
91	152.627	.019099	.019056	−.23	.042	.025	30.63
90	151.668	.019959	.019929	−.15	.037	.020	76.56
89	150.539	.020764	.020760	−.02	.006	.005	734.0
88	149.012	.021699	.021691	−.04	.015	.002	1094
87	147.447	.022516	.022503	−.06	.027	.003	1055
86	145.865	.023238	.023227	−.05	.025	.002	1123
59	143.692	.024116	.024111	−.02	.013	.004	1053
85	142.442	.024580	.024576	−.02	.012	.002	1136
82	140.910	.025118	.025110	−.03	.023	.002	1140
64	139.642	.025527	.025528	.01	.004	.002	1142
84	138.704	.025829	.025825	−.01	.012	.004	1094
83	136.892	.026372	.026373	.00	.003	.001	1157
62	134.715	.026982	.026991	.03	.034	.001	1158
65	133.556	.027300	.027306	.02	.021	.001	1158
81	131.980	.027719	.027718	−.00	.004	.002	1151
61	130.975	.027960	.027973	.05	.050	.001	1159
80	129.729	.028276	.028280	.01	.017	.001	1159
67	127.077	.028901	.028907	.02	.028	.002	1153
75	124.417	.029498	.029503	.02	.025	.002	1154
34	123.117	.029783	.029784	.00	.004	.003	1147
39	122.723	.029869	.029868	−.00	.006	.002	1155
58	121.635	.030099	.030096	−.01	.016	.001	1160
76	120.071	.030430	.030416	−.05	.068	.002	1156

[a] equal to $|\Delta\rho|/|d\rho/dT|$.

Then the densities of the saturated liquid and saturated vapor are given by

$$\rho_{\mathrm{sat}\,L}=\rho_{RD}+\sum_{J=1}^{3} A_J\left(\frac{T_c-T}{T_c}\right)^{(2J-1)\beta} \tag{11a}$$

and

$$\rho_{\mathrm{sat}\,G}=\rho_{RD}-\sum_{J=1}^{3} A_J\left(\frac{T_c-T}{T_c}\right)^{(2J-1)\beta} \tag{11b}$$

where the coefficients are given in table 4. Equation (11a) is used to represent the liquid densities between 128 K and the critical temperature. Between the triple point and 128 K the densities are determined by the intersection of the liquid surface, eq (4), and the vapor pressure curve. Equation (11b) is used to obtain the vapor density between 150 K and T_c, while the intersection of the virial surface and the vapor pressure curve is used at lower temperatures. The isotherm polynomials, eq (5), were constrained to agree with the saturation densities calculated by equations (11a) and (11b), where applicable.

The intersection of the liquid surface, eq (4), with the melting curve was used to obtain the density of the liquid in equilibrium with solid. This density may be approximated either as a function of pressure or as a function of temperature by

$$\rho_{\text{melt }L}=\rho_t+1.79\times10^{-5}\,P(\text{MN/m}^2) \tag{12a}$$

or

$$\rho_{\text{melt }L}=\rho_t+1.60\times10^{-4}\,(T-T_t), \tag{12b}$$

using a value of 0.04083 mol/cm³ for ρ_t, as given in table 13.

Equation (6) may be combined with the heat of fusion, 444.8±1.3 j/mol, given by Giauque and Johnston [15], to obtain a value of 0.94±0.01 cm³/mol for the volume change upon melting at the triple point.

2.4. Comparison With Literature

The present results have been compared with some of the data published in the literature. The following survey is not comprehensive, but comparisons are made with many of the more significant contributions. Other comparisons and a critical survey of all the literature to 1966 may be found in reference [11].

The virial coefficients, calculated from eqs (3a) and (3b), are compared with the experimental values of seven other investigators in table 9. The values attributed to Michels, Schamp, and de Graaff [16] were derived from their precise P–V–T data by the author and are seen to agree well with the results of this research. The older works of reference [17] and [18] agree less well. The values of B of Nijhoff and Keesom [19] are based on fewer data points of lower precision, and show a systematic difference of about 2–3 cm³/mol from the present work. The values of B of Van Itterbeek and Van Paemel [20] and of Van Lammeren [21] were calculated from velocity of sound measurements and are based upon the high temperature data of reference [19]. They are seen to differ considerably from the present results at the lower temperatures. The data of Cath and Onnes [31] were derived in the course of gas thermometry measurements and agree reasonably well with this research. Estimates of the uncertainty in the present results are given in the columns labeled "δB" and "δC" in table 5.

Comparisons are made with the compressed liquid P–V–T data of Van Itterbeek and Verbeke [3] in figure 3. It may be seen that there are some systematic differences with respect to both temperature and pressure, and in general, the agreement is not as good as might be expected. The densities of Timrot and Borisoglebskii [1, 2] are systematically lower than ours by about 0.5 percent in the compressed liquid between 83 K and 153 K. Figure 4 shows a comparison with the data of Michels et al. [16] near room temperature.

Table 3 compares the vapor pressure measurements with eq (7) taken from reference [11], which is based upon the data of Hoge [10]. Tables 6 and 7 compare the melting pressure data with the results of Mills and Grilly [13]. In both cases the agreement is very good. In addition, 15 determinations of the vapor pressure were made at 0.1 K intervals between 75 K and 76.5 K with the quartz bourdon gage. The results fell between the curve of eq (7) and the recent curve of Muijlwijk, Moussa, and van Dijk [22], agreeing with each to within 34 N/m².

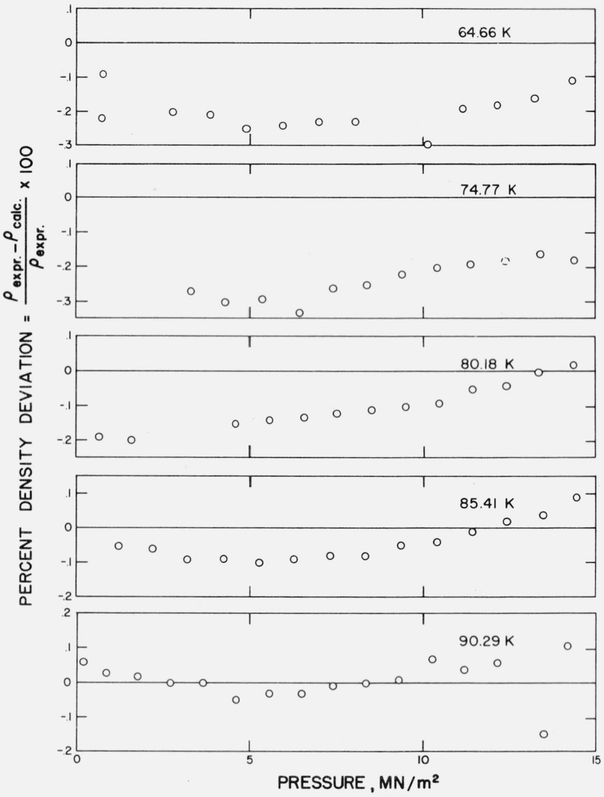

FIGURE 3. *Density deviation of the data of Van Itterbeek and Verbeke [3] from eq (4).*

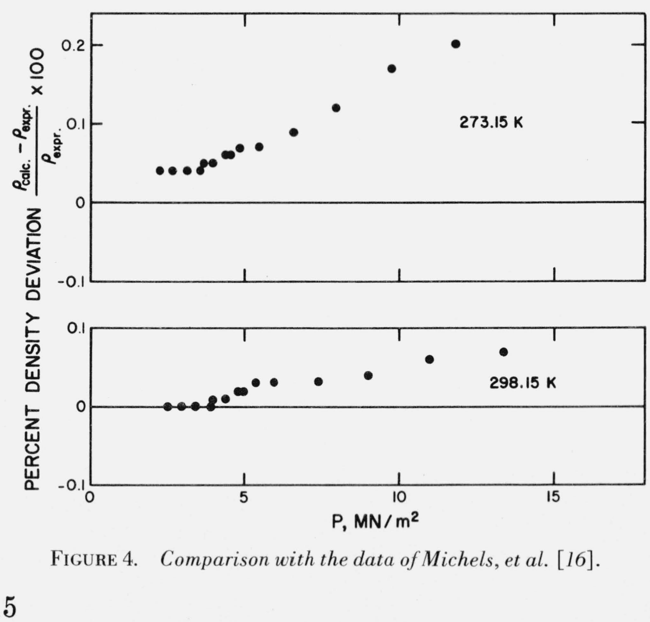

FIGURE 4. *Comparison with the data of Michels, et al. [16].*

TABLE 9. *Comparison of the calculated virial coefficients with other experimental values from the literature*

T	B_{exp}	B_{calc}	ΔB	C_{exp}	C_{calc}	ΔC	
K	cm³/mol			(cm³/mol)²			
273.15	−21.44	−22.16	0.72	1033.0	1223.0	−190.0	Ref. [17]
298.15	−16.76	−16.31	−.45	962.0	1153.0	−191.0	
273.15	−21.67	−22.16	.49	1354.0	1223.0	131.0	Ref. [18]
298.15	−16.70	−16.31	−.39	1174.0	1153.0	21.0	
120.59	−134.90	−138.61	3.71				
127.76	−121.80	−124.11	2.31				
137.86	−104.40	−107.14	2.74				
148.20	−90.42	−93.00	2.58				
154.57	−82.66	−85.56	2.90				
156.14	−81.39	−83.85	2.46				Ref. [19]
157.14	−79.78	−82.79	3.01				
159.21	−78.26	−80.64	2.38				
163.16	−73.71	−76.75	3.04				
170.66	−67.51	−70.02	2.51				
193.15	−51.25	−53.88	2.63				
233.14	−32.99	−34.68	1.69				
83.15	−289.00	−279.02	−9.98				
93.15	−226.20	−225.69	−0.51				
103.15	−185.90	−186.36	.46				
113.15	−155.70	−156.46	.76				
123.15	−133.10	−133.16	.06				
133.15	−114.20	−114.61	.41				
143.15	−99.20	−99.56	.36				Ref. [31]
153.15	−86.20	−87.14	.94				
163.15	−75.30	−76.76	1.46				
173.15	−65.90	−67.96	2.06				
183.15	−57.80	−60.42	2.62				
193.15	−51.50	−53.88	2.38				
203.15	−46.40	−48.17	1.77				
213.15	−41.90	−43.14	1.24				
223.15	−37.40	−38.67	1.27				
233.15	−33.60	−34.67	1.07				
243.15	−30.90	−31.08	0.18				
253.15	−27.80	−27.82	.02				
263.15	−24.60	−24.86	.26				
273.15	−23.10	−22.16	−.94				
75.00	−278.00	−337.99	59.99				
80.00	−246.00	−299.82	53.82				
90.00	−208.00	−240.70	32.70				
100.00	−181.00	−197.56	16.56				Ref. [20]
110.00	−157.00	−165.06	8.06				
120.00	−136.00	−139.92	3.92				
125.00	−126.00	−129.41	3.41				
150.00	−88.00	−90.81	2.81				
200.00	−47.50	−49.89	2.39				
80.00	−278.00	−299.82	21.82				
90.00	−222.00	−240.70	18.70				
100.00	−186.00	−197.56	11.56				Ref. [21]
110.00	−159.00	−165.06	6.06				
273.15	−21.91	−22.16	0.25	1231.0	1223.0	8.0	
298.15	−16.25	−16.31	0.06	1164.0	1153.0	11.0	Ref. [16]
323.15	−11.62	−11.49	−0.13	1143.0	1115.6	27.4	

Table 10 is a comparison of the critical densities found by various authors. It is seen that different experimenters found widely divergent values.

No experimental values were found in the literature for the triple point density. In table 11 a comparison is made of various values for the triple point temperature. With the possible exception of the work of Furukawa and McCoskey, the different authors agree reasonably well considering the sources of errors in thermometry listed above. It might be mentioned, however, that Furukawa and McCoskey were the only workers who measured a melting curve, i.e.,

TABLE 10. *Comparison of values of the critical density from the literature*

Mathias and Onnes [23]	0.01344 mol/cm³
Timrot, et al. [1]	.0127
Hoge [10]	.012
Stewart [11]	.01333
This research	.01363 ± 0.00002

TABLE 11. *Comparison of values of the triple point temperature from several sources*

Hoge [10]	[a] 54.353 K
Muijlwijk, Moussa, van Dijk [22]	[b] 54.349_3
Furukawa and McCoskey [24]	[a] 54.360
This research	54.350_7

[a] Converted to NBS–1955 Temperature Scale.
[b] Using an NBS calibrated thermometer.

a curve of temperature vs. fraction melted. When only about 15 percent of their sample was liquid they found an equilibrium temperature of 54.350 K.

The calculated volume change with melting at the triple point depends primarily on which melting pressure curve is used. The results from the four published experimental melting curves are compared in table 12. The agreement with Mills and Grilly is surprisingly good when it is remembered that all their data were taken at pressures greater than 35 MN/m². The molar volume of the solid at the triple point, calculated here is 23.55 ± 0.03 cm³/mol. This value is in good agreement with the value of 23.49 ± 0.07 measured by Talkachev and Manzhelii [27] at 52.2 K, when allowance is made for thermal expansion of the solid from 52.2 K to 53.35 K.

TABLE 12. *Comparison with published values for the volume change on melting at the triple point*

Lisman and Keesom [25]	1.01 cm³/mol
Mills and Grilly [13]	0.93
Jahnke [26]	0.918 ± 0.02
This research	0.94 ± 0.01

3. Derived Thermodynamic Properties

3.1. Calculation of the Properties

a. Additional Data Used

Calculations of the thermodynamic properties of the compressed liquid make use of the heat capacity of the saturated liquid, C_{sat} from reference [6]. The expression used for C_{sat} is

$$C_{\text{sat}}=\frac{A_1}{(T_0-T)^{1/2}}+A_2+A_3T+A_4T^2 \qquad (13)$$

with $T_0 = 154.77$ and the coefficients given in table 4. This expression fits the data to within about 2 K of T_c.

Use was also made of new experimental measurements, reference [7], of C_v at a particular density ρ_1(0.028687mol/cm³) in the compressed liquid. This isochore intersects the vapor pressure curve at 128 K and intersects the 160 K isotherm at a pressure of about 33 MN/m². The heat capacity may be expressed as

$$C_v(\rho_1)=\sum_{J=1}^{4} A_J T^{(2-J)}, \qquad (14)$$

with the coefficients given in table 4.

b. Methods of Calculation

A high speed digital computer was used along with the surface representations for the three regions in figure 2 to calculate density from a given input of temperature and pressure. Once the density had been established the thermodynamic calculations proceeded as follows.

The following equations were used for densities less than critical at $T<$ 160 K and for all densities at $T \geqslant 160$ K:

$$H(T,\rho)=H^\circ(T)+\frac{P}{\rho}-RT+\int_0^\rho\left[\frac{P}{\rho^2}-\frac{T}{\rho^2}\left(\frac{\partial P}{\partial T}\right)_\rho\right]d\rho, \qquad (15)$$

$$S(T,\rho)=S^\circ(T)-R\ln\left(\frac{RT\rho}{P_0}\right)+\int_0^\rho\left[\frac{R}{\rho}-\frac{1}{\rho^2}\left(\frac{\partial P}{\partial T}\right)_\rho\right]d\rho, \qquad (16)$$

where $P_0 = 1$ atm;

$$C_v(T,\rho)=C_v^\circ(T)-T\int_0^\rho\frac{1}{\rho^2}\left(\frac{\partial^2 P}{\partial T^2}\right)_\rho d\rho. \qquad (17)$$

The values of H°, S°, and C_v° for the ideal gas at 1 atm were obtained from Woolley [5]. All integrations in Region II, figure 2 were performed numerically, using the trapezoidal rule.

For densities greater than critical and temperatures between 128 K and 160 K the properties, calculated by the equations above, at 160 K and density ρ_1(ρ_1= 0.028687 g mole/cm³) serve as the starting point. For this particular density values of the heat capacity at constant volume, given by eq (14), were used to compute changes in the properties with temperature:

$$H(T,\rho_1)=U(160,\rho_1)$$
$$+\int_{160}^{T} C_v(T,\rho_1)dT+P(T,\rho_1)/\rho_1, \qquad (18)$$

$$S(T,\rho_1)=S(160,\rho_1)+\int_{160}^{T}[C_v(T,\rho_1)/T]dT. \qquad (19)$$

Then computations were made along isotherms as follows:

$$H(T,\rho)=H(T,\rho_1)+\int_{\rho_1}^{\rho}[P-T(\partial P/\partial T)_\rho]/\rho^2 d\rho$$
$$+P(T,\rho)/\rho-P(T,\rho_1)/\rho_1, \tag{20}$$

$$S(T,\rho)=S(T,\rho_1)-\int_{\rho_1}^{\rho}[(\partial P/\partial T)_\rho/\rho^2]d\rho, \tag{21}$$

$$C_v(T,\rho)=C_v(T,\rho_1)-T\int_{\rho_1}^{\rho}[(\partial^2 P/\partial T^2)_\rho/\rho^2]d\rho. \tag{22}$$

For the compressed liquid at temperatures less than 128 K the properties of the saturated liquid at 128 K ($\rho=\rho_1$) serve as the starting point. First the changes with temperature are computed along the saturation line:

$$H(T,\rho_{\mathrm{sat}L})=H(128,\rho_{\mathrm{sat}L})$$
$$+\int_{128}^{T}C_{\mathrm{sat}}dT+\int_{P_{\mathrm{sat}}(128)}^{P_{\mathrm{sat}}(T)}(1/\rho_{\mathrm{sat}L})dP, \tag{23}$$

$$S(T,\rho_{\mathrm{sat}L})=S(128,\rho_{\mathrm{sat}L})+\int_{128}^{T}(C_{\mathrm{sat}}/T)dT, \tag{24}$$

and

$$C_v(T,\rho_{\mathrm{sat}L})=C_{\mathrm{sat}}(T)+\frac{T}{\rho^2_{\mathrm{sat}L}}\left(\frac{d\rho_{\mathrm{sat}L}}{dT}\right)\left(\frac{\partial P}{\partial T}\right)_\rho. \tag{25}$$

Next the isothermal changes are computed using eqs (20, 21, 22) and substituting $\rho_{\mathrm{sat}L}(T)$ in place of ρ_1.

The internal energy and heat capacity at constant pressure are computed from

$$U(T,\rho)=H(T,\rho)-P/\rho, \tag{26}$$

and

$$C_p(T,\rho)=C_v(T,\rho)+(T/\rho^2)(\partial P/\partial T)^2_\rho/(\partial P/\partial\rho)_T. \tag{27}$$

Two other quantities have been calculated. The velocity of sound, W, is given by the relation

$$W=((C_p/C_v)(\partial P/\partial\rho)_T)^{1/2}, \tag{28}$$

and the Joule-Thomson inversion curve may be defined by the locus of points where

$$T(\partial P/\partial T)_\rho=\rho(\partial P/\partial\rho)_T. \tag{29}$$

3.2. Results

Tables 13 and 14 present the results of all calculations on the saturation boundary and on selected isobars respectively. The terms isochore and isotherm derivative refer to $(\partial P/\partial T)_\rho$ and $(\partial P/\partial\rho)_T$ respectively.

The derived Joule-Thomson inversion curve is given in table 15, where δP is the uncertainty in the inversion pressure calculated from an assumed 1 percent error in either the isotherm or the isochore derivative.

Figure 5 illustrates the variation of C_p with temperature along several isobars, and Figure 6 shows the variation of C_v with density along several isotherms.

3.3. Estimate of Uncertainties in the Derived Properties

Probably the best estimate of the uncertainties in the derived properties is obtained through comparisons with experimental values for these properties published in the literature. Unfortunately, these measurements are often either nonexistent or limited in scope.

Because of the rather roundabout process, detailed in section 3.1, used to obtain the enthalpy of the liquid, it is desirable to make a comparison with liquid enthalpies obtained by other methods. This is best done by comparing heats of vaporization from various sources, in table 16. Here the second column is the difference between the enthalpies of the vapor and liquid states taken from table 13, while column four contains the change in enthalpy calculated using the Clapeyron equation. The values from reference [11]

TABLE 13. *Thermodynamic properties of oxygen on the saturation boundaries.**

T	P	V	$\left(\frac{\partial P}{\partial\rho}\right)_T$	$\left(\frac{\partial P}{\partial T}\right)_\rho$	Internal Energy	Enthalpy	Entropy	C_v	C_p	Vel. of Sound
K	MN/m^2	cm^3/mol	J/mol	MN/m^2-K	J/mol	J/mol	J/mol-K	J/mol-K	J/mol-K	m/s
54.3507	0.00015	24.49	28792	3.945	−6189.6	−6189.6	67.00	35.65	53.27	1159
54.3507	0.00015	2974819.07	452	0.000	1120.0	1571.8	209.44	20.81	29.13	141
56	0.00025	24.63	28001	3.849	−6101.7	−6101.7	68.59	35.29	53.26	1149
56	0.00025	1876345.27	465	0.0000	1154.2	1619.7	206.23	20.81	29.13	143
58	0.00043	24.80	27058	3.736	−5995.2	−5995.2	70.46	34.86	53.25	1136
58	0.00043	1111925.72	482	0.0000	1195.6	1677.6	202.60	20.81	29.14	145
60	0.00073	24.97	26134	3.624	−5888.7	−5888.7	72.27	34.45	53.25	1124
60	0.00073	683074.11	498	0.0000	1237.0	1735.5	199.26	20.81	29.15	148
62	0.00119	25.14	25228	3.516	−5782.2	−5782.2	74.01	34.06	53.26	1110
62	0.00119	433699.56	514	0.0000	1278.2	1793.2	196.16	20.82	29.16	150
64	0.00187	25.32	24341	3.410	−5675.7	−5675.6	75.70	33.67	53.27	1097
64	0.00187	283821.73	530	0.0000	1319.3	1850.6	193.29	20.82	29.18	152

TABLE 13. *Thermodynamic properties of oxygen on the saturation boundaries.** —Continued

T	P	V	$\left(\frac{\partial P}{\partial \rho}\right)_T$	$\left(\frac{\partial P}{\partial T}\right)_\rho$	Internal Energy	Enthalpy	Entropy	C_v	C_p	Vel. of Sound
K	MN/m²	cm³/mol	J/mol	MN/m²-K	J/mol	J/mol	J/mol-K	J/mol-K	J/mol-K	m/s
66	0.00287	25.50	23471	3.306	-5569.1	-5569.0	77.34	33.30	53.29	1083
66	0.00287	190960.14	546	0.0000	1360.2	1907.7	190.63	20.83	29.21	155
68	0.00428	25.69	22619	3.205	-5462.5	-5462.4	78.94	32.94	53.31	1070
68	0.00428	131788.10	562	0.0001	1400.9	1964.5	188.16	20.84	29.25	157
70	0.00623	25.87	21784	3.106	-5355.9	-5355.7	80.48	32.59	53.34	1056
70	0.00623	93094.99	577	0.0001	1441.2	2020.9	185.87	20.85	29.30	159
72	0.00886	26.07	20966	3.009	-5249.2	-5248.9	81.98	32.26	53.38	1041
72	0.00886	67181.69	592	0.0001	1481.2	2076.6	183.73	20.87	29.35	161
74	0.01236	26.26	20164	2.914	-5142.4	-5142.0	83.45	31.93	53.43	1027
74	0.01236	49440.13	607	0.0002	1520.8	2131.8	181.74	20.89	29.43	163
76	0.01691	26.47	19379	2.822	-5035.5	-5035.0	84.87	31.61	53.49	1012
76	0.01691	37043.15	621	0.0002	1560.0	2186.2	179.88	20.91	29.51	165
78	0.02273	26.67	18610	2.732	-4928.5	-4927.9	86.26	31.31	53.56	997
78	0.02273	28215.79	634	0.0003	1598.5	2239.8	178.14	20.95	29.62	167
80	0.03006	26.88	17857	2.644	-4821.3	-4820.5	87.62	31.01	53.64	982
80	0.03006	21819.46	647	0.0004	1636.5	2292.5	176.51	20.98	29.74	169
82	0.03918	27.10	17119	2.557	-4714.0	-4713.0	88.94	30.73	53.73	967
82	0.03918	17109.05	659	0.0005	1673.8	2344.1	174.98	21.03	29.89	171
84	0.05036	27.32	16397	2.473	-4606.6	-4605.2	90.24	30.45	53.84	952
84	0.05036	13587.75	670	0.0006	1710.3	2394.5	173.54	21.08	30.06	173
86	0.06391	27.55	15689	2.391	-4498.9	-4497.1	91.50	30.18	53.96	936
86	0.06391	10918.43	680	0.0008	1745.9	2443.7	172.18	21.13	30.26	174
88	0.08015	27.78	14997	2.311	-4391.0	-4388.8	92.74	29.92	54.10	921
88	0.08015	8868.59	690	0.0010	1780.7	2491.5	170.90	21.20	30.49	176
90	0.09943	28.02	14319	2.232	-4282.8	-4280.1	93.96	29.67	54.26	905
90	0.09943	7275.38	698	0.0012	1814.5	2537.9	169.68	21.28	30.74	178
92	0.12210	28.27	13655	2.156	-4174.4	-4171.0	95.15	29.42	54.44	889
92	0.12210	6023.11	706	0.0014	1847.2	2582.6	168.53	21.36	31.04	179
94	0.14852	28.52	13005	2.081	-4065.7	-4061.4	96.32	29.18	54.64	872
94	0.14852	5028.47	712	0.0017	1878.8	2625.6	167.43	21.45	31.37	180
96	0.17909	28.79	12370	2.008	-3956.6	-3951.4	97.47	28.95	54.87	856
96	0.17909	4230.71	717	0.0021	1909.2	2666.8	166.38	21.56	31.73	182
98	0.21420	29.06	11748	1.936	-3847.1	-3840.9	98.60	28.73	55.13	839
98	0.21420	3585.00	721	0.0024	1938.2	2706.2	165.38	21.68	32.14	183
100	0.25425	29.34	11139	1.866	-3737.2	-3729.7	99.71	28.51	55.42	823
100	0.25425	3057.86	723	0.0029	1966.0	2743.4	164.42	21.80	32.60	184
102	0.29965	29.63	10544	1.797	-3626.8	-3617.9	100.81	28.30	55.74	806
102	0.29965	2624.08	724	0.0034	1992.3	2778.6	163.49	21.94	33.11	185
104	0.35083	29.93	9961	1.731	-3515.8	-3505.3	101.88	28.10	56.10	788
104	0.35083	2264.42	724	0.0040	2017.1	2811.5	162.60	22.09	33.68	186
106	0.40822	30.24	9392	1.665	-3404.3	-3392.0	102.95	27.90	56.51	771
106	0.40822	1964.12	722	0.0046	2040.3	2842.1	161.74	22.26	34.30	187
108	0.47226	30.57	8836	1.601	-3292.1	-3277.7	104.00	27.71	56.96	753
108	0.47226	1711.70	719	0.0053	2061.8	2870.1	160.91	22.44	34.99	187
110	0.54339	30.90	8292	1.538	-3179.2	-3162.4	105.03	27.52	57.47	736
110	0.54339	1498.21	714	0.0062	2081.5	2895.6	160.10	22.63	35.76	188

TABLE 13. *Thermodynamic properties of oxygen on the saturation boundaries.** — Continued

T	P	V	$\left(\frac{\partial P}{\partial \rho}\right)_T$	$\left(\frac{\partial P}{\partial T}\right)_\rho$	Internal Energy	Enthalpy	Entropy	C_v	C_p	Vel. of Sound
K	MN/m^2	cm^3/mol	J/mol	MN/m^2-K	J/mol	J/mol	J/mol-K	J/mol-K	J/mol-K	m/s
112	0.62207	31.26	7761	1.476	−3065.5	−3046.0	106.06	27.34	58.05	718
112	0.62207	1316.57	708	0.0071	2099.4	2918.4	159.31	22.83	36.61	188
114	0.70876	31.63	7242	1.415	−2950.9	−2928.5	107.08	27.16	58.70	699
114	0.70876	1161.16	700	0.0081	2115.2	2938.2	158.53	23.05	37.55	189
116	0.80391	32.02	6736	1.356	−2835.2	−2809.5	108.09	26.99	59.43	681
116	0.80391	1027.49	690	0.0093	2129.0	2955.0	157.78	23.28	38.59	189
118	0.90801	32.42	6242	1.297	−2718.5	−2689.1	109.09	26.83	60.25	662
118	0.90801	911.95	678	0.0106	2140.6	2968.6	157.03	23.52	39.75	189
120	1.0215	32.85	5760	1.239	−2600.5	−2566.9	110.08	26.67	61.19	643
120	1.0215	811.59	664	0.0120	2149.8	2978.8	156.30	23.78	41.04	189
122	1.1450	33.31	5292	1.182	−2481.1	−2442.9	111.07	26.53	62.27	623
122	1.1450	724.02	649	0.0137	2156.4	2985.4	155.57	24.06	42.49	189
124	1.2788	33.79	4836	1.126	−2360.1	−2316.8	112.06	26.39	63.49	603
124	1.2788	647.27	631	0.0155	2160.3	2988.0	154.85	24.35	44.13	189
126	1.4236	34.31	4394	1.070	−2237.3	−2188.4	113.05	26.26	64.91	583
126	1.4236	579.72	612	0.0176	2161.2	2986.4	154.12	24.65	45.99	189
128	1.5797	34.86	3965	1.015	−2112.4	−2057.3	114.04	26.15	66.56	562
128	1.5797	520.03	590	0.0199	2158.8	2980.3	153.40	24.97	48.12	188
130	1.7478	35.45	3688	0.987	−1984.8	−1922.9	115.03	26.60	69.77	550
130	1.7478	467.05	565	0.0224	2153.0	2969.3	152.68	25.31	50.60	188
132	1.9284	36.09	3314	0.924	−1853.9	−1784.3	116.04	26.48	70.79	526
132	1.9284	419.84	538	0.0254	2143.1	2952.7	151.94	25.68	53.48	187
134	2.1219	36.79	2849	0.868	−1719.9	−1641.8	117.06	26.37	74.38	501
134	2.1219	377.60	509	0.0287	2128.8	2930.0	151.19	26.06	56.90	186
136	2.3291	37.55	2472	0.811	−1582.5	−1495.0	118.09	26.30	77.32	477
136	2.3291	339.63	478	0.0324	2109.4	2900.5	150.42	26.47	61.03	186
138	2.5504	38.40	2100	0.752	−1441.1	−1343.2	119.14	26.30	81.14	450
138	2.5504	305.34	443	0.0368	2084.2	2862.9	149.63	26.90	66.14	185
140	2.7866	39.35	1745	0.696	−1295.0	−1185.4	120.21	26.38	86.51	423
140	2.7866	274.21	406	0.0418	2052.0	2816.1	148.80	27.38	72.63	183
142	3.0383	40.43	1419	0.640	−1143.0	−1020.1	121.31	26.52	93.59	396
142	3.0383	245.75	365	0.0476	2011.3	2757.9	147.92	27.89	81.18	182
144	3.3064	41.68	1124	0.589	−983.4	−845.6	122.45	26.73	103.86	369
144	3.3064	219.53	320	0.0545	1959.8	2685.6	146.98	28.48	93.04	181
146	3.5918	43.17	875	0.532	−813.9	−658.9	123.66	27.06	114.99	341
146	3.5918	195.08	270	0.0630	1894.0	2594.7	145.95	29.14	110.71	179
148	3.8955	44.99	613	0.476	−630.4	−455.2	124.95	27.54	138.37	310
148	3.8955	171.89	215	0.0737	1807.8	2477.4	144.77	29.95	140.18	177
150	4.2190	47.38	391	0.419	−425.1	−225.2	126.39	28.28	179.31	278
150	4.2190	149.13	153	0.0881	1688.2	2317.4	143.35	31.01	200.53	176
152	4.5638	50.90	194	0.353	−179.5	52.7	128.12	29.94	283.23	240
152	4.5638	126.20	84	0.109	1512.3	2088.2	141.52	33.36	373.23	171
154	4.9320	58.46	26	0.267	200.0	488.4	130.84	33.30	1478.52	190
154	4.9320	97.80	17	0.149	1165.1	1647.5	138.37	37.02	1962.81	167
154.576	5.0427	73.37		0.200	662.3	1032.2	134.32			
154.576	5.0427	73.37		0.200	662.3	1032.2	134.32			

*The first entry for each temperature refers to the liquid phase.

TABLE 14. *Thermodynamic properties of oxygen.*

0.101325 MN/m² (1 atm) Isobar

T	V	$\left(\frac{\partial P}{\partial \rho}\right)_T$	$\left(\frac{\partial P}{\partial T}\right)_\rho$	Internal Energy	Enthalpy	Entropy	C_v	C_p	Vel. of Sound
K	cm³/mol	J/mol	MN/m²-K	J/mol	J/mol	J/mol-K	J/mol-K	J/mol-K	m/s
*54.362	24.49	28805	3.945	−6189.4	−6186.9	67.00	35.65	53.26	1160
56	24.62	28019	3.850	−6102.2	−6099.7	68.59	35.29	53.25	1149
58	24.79	27077	3.736	−5995.7	−5993.2	70.45	34.87	53.25	1137
60	24.96	26153	3.625	−5889.2	−5886.7	72.26	34.46	53.25	1124
62	25.14	25247	3.517	−5782.7	−5780.2	74.01	34.06	53.25	1111
64	25.32	24360	3.411	−5676.2	−5673.7	75.70	33.68	53.26	1097
66	25.50	23490	3.307	−5569.7	−5567.1	77.34	33.31	53.28	1084
68	25.68	22638	3.206	−5463.1	−5460.5	78.93	32.95	53.30	1070
70	25.87	21803	3.107	−5356.5	−5353.9	80.47	32.60	53.34	1056
72	26.06	20984	3.010	−5249.8	−5247.2	81.98	32.26	53.37	1042
74	26.26	20182	2.915	−5143.0	−5140.4	83.44	31.93	53.42	1027
76	26.46	19397	2.823	−5036.1	−5033.4	84.86	31.62	53.48	1013
78	26.67	18627	2.732	−4929.1	−4926.4	86.25	31.31	53.55	998
80	26.88	17872	2.644	−4821.9	−4819.2	87.61	31.02	53.63	983
82	27.10	17133	2.558	−4714.6	−4711.8	88.94	30.73	53.72	967
84	27.32	16408	2.474	−4607.0	−4604.3	90.23	30.45	53.83	952
86	27.55	15698	2.391	−4499.3	−4496.5	91.50	30.18	53.96	936
88	27.78	15002	2.311	−4391.2	−4388.4	92.74	29.92	54.10	921
90	28.02	14319	2.232	−4282.9	−4280.0	93.96	29.67	54.26	905
*90.180	28.04	14258	2.225	−4273.1	−4270.3	94.07	29.64	54.28	903
*90.180	7150.15	699	0.0012	1817.5	2542.0	169.58	21.28	30.77	178
92	7309.46	716	0.0012	1857.2	2597.9	170.19	21.25	30.66	180
94	7483.81	735	0.0011	1900.8	2659.1	170.85	21.22	30.55	182
96	7657.47	753	0.0011	1944.2	2720.1	171.49	21.19	30.46	184
98	7830.51	772	0.0011	1987.5	2780.9	172.12	21.16	30.37	186
100	8002.98	790	0.0011	2030.7	2841.6	172.73	21.14	30.29	188
102	8174.94	809	0.0010	2073.7	2902.1	173.33	21.12	30.21	190
104	8346.42	827	0.0010	2116.7	2962.4	173.92	21.10	30.15	192
106	8517.48	845	0.0010	2159.6	3022.7	174.49	21.08	30.09	194
108	8688.15	863	0.0010	2202.4	3082.8	175.05	21.06	30.03	196
110	8858.45	881	0.0010	2245.2	3142.8	175.60	21.05	29.98	198
112	9028.42	898	0.0009	2287.9	3202.7	176.14	21.03	29.93	200
114	9198.08	916	0.0009	2330.5	3262.5	176.67	21.02	29.89	202
116	9367.46	934	0.0009	2373.1	3322.3	177.19	21.01	29.85	204
118	9536.57	951	0.0009	2415.6	3381.9	177.70	21.00	29.81	205
120	9705.43	969	0.0009	2458.1	3441.5	178.20	20.99	29.77	207
122	9874.07	987	0.0009	2500.5	3501.0	178.69	20.98	29.74	209
124	10042.49	1004	0.0008	2542.9	3560.5	179.18	20.97	29.71	211
126	10210.71	1022	0.0008	2585.3	3619.9	179.65	20.96	29.68	213
128	10378.75	1039	0.0008	2627.6	3679.2	180.12	20.95	29.66	214
130	10546.61	1056	0.0008	2669.8	3738.5	180.58	20.94	29.63	216
132	10714.31	1074	0.0008	2712.1	3797.7	181.03	20.94	29.61	218
134	10881.86	1091	0.0008	2754.3	3856.9	181.47	20.93	29.59	220
136	11049.26	1108	0.0008	2796.5	3916.1	181.91	20.92	29.57	221
138	11216.52	1126	0.0007	2838.7	3975.2	182.34	20.92	29.55	223
140	11383.66	1143	0.0007	2880.8	4034.2	182.77	20.91	29.53	225
142	11550.68	1160	0.0007	2922.9	4093.3	183.19	20.91	29.51	226
144	11717.58	1177	0.0007	2965.0	4152.3	183.60	20.90	29.49	228
146	11884.38	1194	0.0007	3007.1	4211.3	184.01	20.90	29.48	229
148	12051.07	1212	0.0007	3049.1	4270.2	184.41	20.89	29.46	231
150	12217.67	1229	0.0007	3091.2	4329.1	184.80	20.89	29.45	233
152	12384.18	1246	0.0007	3133.2	4388.0	185.19	20.88	29.44	234
154	12550.61	1263	0.0007	3175.2	4446.9	185.58	20.88	29.43	236
156	12716.95	1280	0.0007	3217.2	4505.7	185.96	20.88	29.41	237
158	12883.21	1297	0.0006	3259.1	4564.5	186.33	20.87	29.40	239
160	13049.40	1314	0.0006	3301.1	4623.3	186.70	20.87	29.39	240
165	13464.57	1357	0.0006	3405.9	4770.2	187.61	20.86	29.37	244
170	13879.36	1399	0.0006	3510.7	4917.0	188.48	20.86	29.35	248
175	14293.80	1442	0.0006	3615.4	5063.7	189.33	20.85	29.33	252
180	14707.94	1484	0.0006	3720.1	5210.4	190.16	20.85	29.32	255
185	15121.80	1526	0.0006	3824.7	5356.9	190.96	20.85	29.30	259
190	15535.41	1568	0.0005	3929.3	5503.4	191.74	20.85	29.29	262
195	15948.81	1611	0.0005	4033.8	5649.8	192.50	20.85	29.28	266
200	16362.00	1653	0.0005	4138.3	5796.2	193.25	20.85	29.27	269
210	17187.85	1737	0.0005	4347.3	6088.9	194.67	20.85	29.26	276
220	18013.10	1821	0.0005	4556.3	6381.5	196.04	20.85	29.26	283
230	18837.85	1905	0.0004	4765.3	6674.1	197.34	20.86	29.26	289
240	19662.17	1989	0.0004	4974.4	6966.7	198.58	20.88	29.27	295
250	20486.13	2073	0.0004	5183.7	7259.4	199.78	20.90	29.28	301
260	21309.78	2157	0.0004	5393.1	7552.3	200.92	20.92	29.30	307
270	22133.17	2240	0.0004	5602.8	7845.4	202.03	20.95	29.32	313
280	22956.31	2324	0.0004	5812.7	8138.8	203.10	20.99	29.35	319
290	23779.26	2408	0.0004	6023.1	8432.5	204.13	21.03	29.39	324
300	24602.02	2491	0.0003	6233.8	8726.6	205.13	21.08	29.43	330

*Two-phase boundary.

TABLE 14. *Thermodynamic properties of oxygen.*—Continued

1 MN/m² Isobar

T	V	$\left(\frac{\partial P}{\partial \rho}\right)_T$	$\left(\frac{\partial P}{\partial T}\right)_\rho$	Internal Energy	Enthalpy	Entropy	C_v	C_p	Vel. of Sound
K	cm³/mol	J/mol	MN/m²-K	J/mol	J/mol	J/mol-K	J/mol-K	J/mol-K	m/s
*54.466	24.48	28917	3.946	−6187.9	−6163.4	67.03	35.65	53.23	1161
56	24.61	28182	3.857	−6106.4	−6081.8	68.51	35.32	53.22	1152
58	24.77	27241	3.744	−6000.1	−5975.3	70.38	34.90	53.21	1139
60	24.94	26319	3.633	−5893.9	−5868.9	72.18	34.49	53.21	1126
62	25.12	25416	3.524	−5787.6	−5762.5	73.93	34.09	53.21	1113
64	25.29	24531	3.418	−5681.4	−5656.1	75.62	33.71	53.21	1100
66	25.47	23663	3.315	−5575.1	−5549.6	77.25	33.34	53.23	1087
68	25.66	22813	3.214	−5468.8	−5443.2	78.84	32.98	53.25	1073
70	25.84	21980	3.115	−5362.5	−5336.6	80.39	32.64	53.27	1059
72	26.04	21164	3.018	−5256.1	−5230.0	81.89	32.30	53.31	1045
74	26.23	20364	2.924	−5149.6	−5123.4	83.35	31.98	53.35	1030
76	26.43	19581	2.832	−5043.0	−5016.6	84.77	31.66	53.40	1016
78	26.63	18813	2.741	−4936.4	−4909.7	86.16	31.36	53.46	1001
80	26.84	18062	2.654	−4829.6	−4802.7	87.51	31.06	53.54	986
82	27.06	17325	2.568	−4722.6	−4695.6	88.84	30.78	53.62	971
84	27.28	16603	2.484	−4615.5	−4588.2	90.13	30.50	53.72	956
86	27.50	15896	2.402	−4508.1	−4480.6	91.40	30.23	53.84	941
88	27.74	15203	2.321	−4400.5	−4372.8	92.64	29.97	53.97	925
90	27.97	14524	2.243	−4292.7	−4264.7	93.85	29.72	54.12	909
92	28.22	13858	2.166	−4184.5	−4156.3	95.04	29.47	54.29	893
94	28.47	13205	2.092	−4076.0	−4047.5	96.21	29.24	54.48	877
96	28.73	12566	2.018	−3967.1	−3938.3	97.36	29.00	54.70	861
98	29.00	11939	1.947	−3857.7	−3828.7	98.49	28.78	54.94	844
100	29.28	11324	1.876	−3747.8	−3718.5	99.60	28.56	55.22	827
102	29.57	10720	1.808	−3637.3	−3607.8	100.70	28.35	55.53	810
104	29.87	10129	1.740	−3526.2	−3496.3	101.78	28.14	55.89	793
106	30.18	9548	1.674	−3414.4	−3384.2	102.85	27.94	56.29	775
108	30.51	8977	1.609	−3301.7	−3271.1	103.91	27.74	56.74	758
110	30.85	8417	1.546	−3188.0	−3157.2	104.95	27.55	57.26	739
112	31.21	7867	1.483	−3073.3	−3042.1	105.99	27.36	57.85	721
114	31.59	7326	1.421	−2957.3	−2925.7	107.02	27.18	58.52	702
116	31.99	6794	1.359	−2839.9	−2807.9	108.05	27.00	59.29	683
118	32.41	6270	1.299	−2720.8	−2688.4	109.07	26.83	60.18	663
*119.633	32.77	5848	1.250	−2622.2	−2589.4	109.90	26.70	61.01	646
*119.633	828.96	667	0.0118	2148.3	2977.2	156.43	23.73	40.79	189
120	833.40	672	0.0117	2158.7	2992.1	156.56	23.68	40.59	190
122	857.19	703	0.0112	2215.0	3072.2	157.22	23.43	39.53	193
124	880.39	733	0.0108	2270.0	3150.3	157.85	23.22	38.62	195
126	903.07	762	0.0105	2323.7	3226.8	158.47	23.02	37.85	198
128	925.30	790	0.0102	2376.5	3301.8	159.06	22.85	37.17	200
130	947.14	817	0.0099	2428.4	3375.5	159.63	22.70	36.58	203
132	968.63	843	0.0096	2479.5	3448.2	160.18	22.57	36.05	205
134	989.81	869	0.0093	2530.0	3519.8	160.72	22.45	35.59	207
136	1010.71	894	0.0091	2579.8	3590.6	161.25	22.34	35.17	210
138	1031.37	918	0.0089	2629.2	3660.5	161.76	22.24	34.80	212
140	1051.80	942	0.0087	2678.0	3729.8	162.25	22.15	34.46	214
142	1072.02	966	0.0085	2726.4	3798.4	162.74	22.07	34.15	216
144	1092.06	989	0.0083	2774.4	3866.4	163.22	21.99	33.88	218
146	1111.92	1012	0.0081	2822.0	3933.9	163.68	21.92	33.62	220
148	1131.63	1035	0.0079	2869.3	4000.9	164.14	21.86	33.39	222
150	1151.19	1058	0.0078	2916.3	4067.5	164.59	21.80	33.17	224
152	1170.62	1080	0.0076	2963.0	4133.6	165.02	21.75	32.97	226
154	1189.92	1102	0.0075	3009.4	4199.4	165.45	21.70	32.79	228
156	1209.11	1123	0.0073	3055.7	4264.8	165.87	21.65	32.62	230
158	1228.19	1145	0.0072	3101.7	4329.9	166.29	21.61	32.46	232
160	1247.17	1166	0.0071	3147.5	4394.6	166.70	21.57	32.31	234
165	1294.21	1218	0.0068	3261.1	4555.3	167.69	21.48	31.99	238
170	1340.76	1270	0.0065	3373.8	4714.6	168.64	21.41	31.71	242
175	1386.86	1320	0.0063	3485.6	4872.5	169.55	21.34	31.47	247
180	1432.59	1370	0.0061	3596.7	5029.3	170.44	21.29	31.26	251
185	1477.99	1419	0.0059	3707.2	5185.2	171.29	21.24	31.08	255
190	1523.10	1468	0.0057	3817.1	5340.2	172.12	21.20	30.92	259
195	1567.94	1516	0.0055	3926.5	5494.4	172.92	21.17	30.79	262
200	1612.56	1563	0.0054	4035.5	5648.0	173.70	21.13	30.66	266
210	1701.20	1657	0.0051	4252.4	5953.6	175.19	21.09	30.46	274
220	1789.17	1750	0.0048	4468.2	6257.4	176.60	21.05	30.30	281
230	1876.58	1842	0.0046	4683.1	6559.7	177.94	21.03	30.17	287
240	1963.54	1932	0.0043	4897.3	6860.9	179.23	21.02	30.07	294
250	2050.11	2022	0.0042	5111.1	7161.2	180.45	21.02	29.99	300
260	2136.35	2111	0.0040	5324.5	7460.8	181.63	21.02	29.94	307
270	2222.31	2200	0.0038	5537.7	7760.0	182.76	21.04	29.90	313
280	2308.03	2288	0.0037	5750.9	8058.9	183.84	21.06	29.88	319
290	2393.53	2376	0.0035	5964.1	8357.6	184.89	21.09	29.86	324
300	2478.85	2464	0.0034	6177.4	8656.2	185.90	21.13	29.87	330

*Two-phase boundary.

TABLE 14. *Thermodynamic properties of oxygen.*—Continued

5 MN/m² Isobar

T	V	$\left(\frac{\partial P}{\partial \rho}\right)_T$	$\left(\frac{\partial P}{\partial T}\right)_\rho$	Internal Energy	Enthalpy	Entropy	C_v	C_p	Vel. of Sound
K	cm³/mol	J/mol	MN/m²-K	J/mol	J/mol	J/mol-K	J/mol-K	J/mol-K	m/s
*54.923	24.43	29411	3.950	-6181.2	-6059.0	67.15	35.68	53.07	1169
56	24.52	28901	3.888	-6124.5	-6001.8	68.18	35.45	53.06	1163
58	24.68	27968	3.775	-6019.2	-5895.7	70.04	35.03	53.04	1150
60	24.85	27054	3.665	-5913.9	-5789.7	71.84	34.63	53.03	1138
62	25.02	26159	3.557	-5808.7	-5683.6	73.58	34.24	53.01	1125
64	25.19	25282	3.452	-5703.6	-5577.6	75.26	33.86	53.01	1112
66	25.37	24424	3.349	-5598.4	-5471.6	76.90	33.50	53.00	1099
68	25.54	23583	3.249	-5493.3	-5365.6	78.48	33.15	53.00	1086
70	25.72	22759	3.151	-5388.2	-5259.6	80.01	32.81	53.01	1072
72	25.91	21953	3.055	-5283.1	-5153.5	81.51	32.48	53.02	1058
74	26.10	21163	2.961	-5177.9	-5047.4	82.96	32.16	53.05	1044
76	26.29	20390	2.870	-5072.8	-4941.3	84.38	31.85	53.07	1030
78	26.49	19633	2.781	-4967.6	-4835.1	85.76	31.55	53.11	1016
80	26.69	18891	2.694	-4862.3	-4728.8	87.10	31.27	53.15	1002
82	26.89	18166	2.609	-4756.9	-4622.5	88.41	30.99	53.21	987
84	27.10	17456	2.526	-4651.5	-4516.0	89.70	30.72	53.27	973
86	27.32	16760	2.445	-4545.9	-4409.3	90.95	30.45	53.34	958
88	27.54	16080	2.366	-4440.2	-4302.5	92.18	30.20	53.43	943
90	27.77	15413	2.289	-4334.4	-4195.6	93.38	29.95	53.53	928
92	28.00	14761	2.214	-4228.4	-4088.4	94.56	29.71	53.65	913
94	28.24	14123	2.140	-4122.1	-3980.9	95.71	29.48	53.78	897
96	28.48	13498	2.068	-4015.6	-3873.2	96.85	29.25	53.93	882
98	28.73	12886	1.998	-3908.8	-3765.1	97.96	29.03	54.10	866
100	28.99	12287	1.930	-3801.7	-3656.7	99.06	28.81	54.30	851
102	29.26	11700	1.863	-3694.2	-3547.9	100.13	28.60	54.51	835
104	29.54	11126	1.798	-3586.4	-3438.7	101.20	28.39	54.76	819
106	29.83	10564	1.734	-3478.0	-3328.9	102.24	28.19	55.03	803
108	30.12	10013	1.671	-3369.1	-3218.5	103.27	27.99	55.34	787
110	30.43	9474	1.610	-3259.7	-3107.5	104.29	27.79	55.68	770
112	30.75	8945	1.550	-3149.5	-2995.8	105.30	27.60	56.07	754
114	31.09	8428	1.492	-3038.7	-2883.2	106.29	27.41	56.50	737
116	31.44	7921	1.434	-2926.9	-2769.7	107.28	27.22	56.98	720
118	31.80	7425	1.377	-2814.2	-2655.2	108.26	27.04	57.53	703
120	32.19	6938	1.321	-2700.4	-2539.5	109.23	26.85	58.15	685
122	32.60	6461	1.266	-2585.4	-2422.5	110.20	26.67	58.85	667
124	33.02	5995	1.212	-2469.0	-2303.9	111.16	26.49	59.64	649
126	33.48	5537	1.158	-2351.0	-2183.6	112.13	26.32	60.55	631
128	33.96	5089	1.105	-2231.1	-2061.3	113.09	26.16	61.59	612
130	34.49	4674	1.056	-2107.3	-1934.9	114.07	26.66	63.52	590
132	35.05	4241	1.014	-1981.3	-1806.0	115.05	26.52	65.87	574
134	35.65	3844	0.9500	-1853.4	-1675.2	116.04	26.39	66.38	550
136	36.31	3434	0.9024	-1721.8	-1540.2	117.04	26.28	68.81	530
138	37.04	3036	0.8457	-1586.4	-1401.2	118.05	26.19	70.78	506
140	37.84	2650	0.7889	-1446.6	-1257.3	119.09	26.14	73.23	482
142	38.76	2272	0.7341	-1300.7	-1106.9	120.15	26.16	76.74	456
144	39.81	1901	0.6775	-1147.1	-948.1	121.26	26.23	81.35	429
146	41.06	1529	0.6208	-982.8	-777.5	122.44	26.39	88.43	400
148	42.59	1179	0.5551	-804.4	-591.5	123.70	26.65	96.78	366
150	44.60	828	0.4898	-602.3	-379.3	125.13	27.11	113.53	329
152	47.63	478	0.4124	-353.9	-115.7	126.87	28.02	150.80	283
154	54.93	105	0.2929	63.4	338.0	129.84	31.40	412.84	207
*154.355	62.15	10	0.2481	338.2	648.9	131.85	34.74	3824.02	182
*154.355	89.32	7	0.1609	1017.8	1464.5	137.14	38.11	4780.17	162
156	125.60	161	0.1073	1634.2	2262.2	142.29	31.23	206.80	183
158	142.14	264	0.0901	1864.4	2575.1	144.28	28.98	127.28	190
160	154.34	343	0.0799	2023.9	2795.6	145.67	27.73	98.79	195
165	177.91	503	0.0655	2316.3	3205.8	148.20	25.92	70.48	207
170	196.80	632	0.0571	2541.8	3525.8	150.11	24.85	58.79	216
175	213.31	743	0.0512	2735.5	3802.0	151.71	24.13	52.24	224
180	228.36	843	0.0468	2910.2	4052.0	153.12	23.62	48.01	231
185	242.38	935	0.0433	3072.3	4284.2	154.39	23.23	45.04	238
190	255.65	1020	0.0404	3225.4	4503.6	155.56	22.93	42.82	244
195	268.33	1101	0.0380	3371.6	4713.3	156.65	22.68	41.11	250
200	280.54	1178	0.0359	3512.6	4915.3	157.68	22.48	39.74	255
210	303.87	1322	0.0325	3782.6	5301.9	159.56	22.18	37.70	265
220	326.10	1457	0.0298	4040.8	5671.3	161.28	21.95	36.25	274
230	347.50	1585	0.0276	4290.6	6028.1	162.87	21.77	35.16	283
240	368.27	1707	0.0258	4534.1	6375.4	164.35	21.64	34.33	291
250	388.53	1825	0.0242	4772.7	6715.3	165.73	21.53	33.68	299
260	408.38	1939	0.0229	5007.5	7049.4	167.04	21.45	33.15	306
270	427.90	2049	0.0217	5239.2	7378.7	168.29	21.39	32.73	313
280	447.14	2157	0.0206	5468.5	7704.2	169.47	21.35	32.39	320
290	466.14	2263	0.0197	5695.9	8026.6	170.60	21.32	32.11	326
300	484.94	2367	0.0188	5921.9	8346.6	171.69	21.31	31.88	333

*Two-phase boundary.

TABLE 14. *Thermodynamic properties of oxygen.*—Continued

10 MN/m² Isobar

T	V	$\left(\frac{\partial P}{\partial \rho}\right)_T$	$\left(\frac{\partial P}{\partial T}\right)_\rho$	Internal Energy	Enthalpy	Entropy	C_v	C_p	Vel. of Sound
K	cm³/mol	J/mol	MN/m²-K	J/mol	J/mol	J/mol-K	J/mol-K	J/mol-K	m/s
*55.491	24.38	30022	3.955	−6172.5	−5928.7	67.30	35.71	52.89	1179
56	24.42	29784	3.926	−6146.0	−5901.8	67.78	35.60	52.88	1176
58	24.58	28861	3.814	−6041.9	−5796.1	69.64	35.20	52.85	1164
60	24.74	27956	3.704	−5937.8	−5690.4	71.43	34.80	52.82	1152
62	24.90	27071	3.597	−5833.8	−5584.8	73.16	34.42	52.79	1139
64	25.07	26204	3.493	−5729.9	−5479.2	74.84	34.05	52.77	1127
66	25.24	25355	3.390	−5626.1	−5373.7	76.46	33.69	52.75	1114
68	25.41	24524	3.291	−5522.3	−5268.2	78.04	33.35	52.73	1101
70	25.58	23711	3.193	−5418.6	−5162.7	79.56	33.02	52.72	1088
72	25.76	22915	3.098	−5314.9	−5057.3	81.05	32.70	52.71	1075
74	25.94	22137	3.006	−5211.3	−4951.9	82.49	32.38	52.71	1061
76	26.13	21375	2.915	−5107.7	−4846.4	83.90	32.08	52.71	1048
78	26.31	20629	2.827	−5004.1	−4741.0	85.27	31.79	52.72	1034
80	26.51	19900	2.741	−4900.6	−4635.5	86.60	31.51	52.74	1020
82	26.70	19186	2.657	−4797.0	−4530.0	87.91	31.24	52.76	1006
84	26.90	18488	2.576	−4693.4	−4424.4	89.18	30.98	52.79	992
86	27.11	17806	2.496	−4589.9	−4318.8	90.42	30.72	52.82	978
88	27.31	17138	2.418	−4486.2	−4213.1	91.64	30.47	52.87	964
90	27.53	16485	2.342	−4382.5	−4107.3	92.83	30.23	52.93	950
92	27.74	15847	2.268	−4278.8	−4001.3	93.99	30.00	52.99	935
94	27.97	15223	2.196	−4174.9	−3895.3	95.13	29.77	53.07	921
96	28.20	14613	2.126	−4071.0	−3789.0	96.25	29.55	53.16	906
98	28.43	14016	2.058	−3966.9	−3682.6	97.35	29.33	53.26	892
100	28.67	13433	1.991	−3862.7	−3576.0	98.42	29.11	53.38	877
102	28.92	12863	1.926	−3758.3	−3469.1	99.48	28.90	53.51	863
104	29.17	12305	1.863	−3653.6	−3361.9	100.52	28.70	53.66	848
106	29.43	11761	1.801	−3548.8	−3254.5	101.55	28.49	53.82	833
108	29.70	11228	1.741	−3443.6	−3146.6	102.55	28.29	54.01	818
110	29.98	10708	1.682	−3338.2	−3038.4	103.55	28.09	54.22	804
112	30.27	10199	1.625	−3232.4	−2929.7	104.53	27.89	54.45	789
114	30.56	9703	1.569	−3126.2	−2820.6	105.49	27.69	54.70	774
116	30.87	9217	1.514	−3019.6	−2710.9	106.45	27.49	54.99	759
118	31.19	8743	1.461	−2912.5	−2600.6	107.39	27.29	55.30	744
120	31.52	8280	1.408	−2804.8	−2489.6	108.32	27.09	55.65	729
122	31.87	7828	1.357	−2696.5	−2377.8	109.25	26.88	56.04	714
124	32.23	7387	1.307	−2587.5	−2265.3	110.16	26.67	56.47	699
126	32.60	6957	1.258	−2477.8	−2151.7	111.07	26.46	56.94	684
128	33.00	6537	1.210	−2367.1	−2037.2	111.97	26.25	57.47	669
130	33.41	6091	1.161	−2253.9	−1919.8	112.88	26.76	58.90	647
132	33.85	5685	1.112	−2140.1	−1801.6	113.78	26.64	59.51	630
134	34.31	5309	1.066	−2024.8	−1681.7	114.68	26.52	60.27	614
136	34.79	4941	1.019	−1908.4	−1560.4	115.58	26.39	61.00	597
138	35.31	4583	0.9747	−1790.6	−1437.5	116.48	26.26	61.92	581
140	35.86	4239	0.9307	−1671.2	−1312.6	117.38	26.15	62.93	565
142	36.44	3899	0.8875	−1550.0	−1185.6	118.28	26.05	64.15	548
144	37.07	3572	0.8434	−1427.0	−1056.3	119.18	25.97	65.36	530
146	37.74	3263	0.7974	−1301.9	−924.6	120.09	25.91	66.42	511
148	38.47	2956	0.7602	−1173.9	−789.2	121.01	25.87	68.68	495
150	39.26	2665	0.7139	−1043.4	−650.8	121.94	25.85	70.06	475
152	40.12	2384	0.6722	−909.6	−508.3	122.88	25.84	72.22	456
154	41.08	2120	0.6321	−771.8	−361.0	123.85	25.85	74.84	438
156	42.14	1863	0.5894	−630.1	−208.7	124.83	25.88	77.55	418
158	43.34	1632	0.5506	−482.9	−49.5	125.84	25.93	81.05	399
160	44.70	1413	0.5105	−330.2	116.7	126.89	26.61	85.56	377
165	49.05	952	0.4112	84.2	574.7	129.71	26.69	97.19	329
170	55.48	642	0.3220	547.9	1102.7	132.86	26.93	111.47	288
175	64.63	501	0.2483	1038.8	1685.1	136.23	26.89	116.90	261
180	75.66	496	0.1960	1493.8	2250.4	139.42	26.39	106.18	250
185	86.75	564	0.1611	1872.3	2739.8	142.10	25.74	89.82	248
190	97.07	655	0.1376	2183.6	3154.3	144.32	25.12	76.87	250
195	106.54	753	0.1209	2447.8	3513.2	146.18	24.59	67.52	254
200	115.30	851	0.1083	2679.5	3832.4	147.80	24.14	60.83	259
210	131.20	1037	0.0909	3080.3	4392.3	150.53	23.47	52.29	269
220	145.55	1211	0.0789	3429.1	4884.6	152.82	23.00	46.97	278
230	158.86	1373	0.0701	3746.4	5334.9	154.83	22.65	43.42	287
240	171.39	1525	0.0634	4042.4	5756.3	156.62	22.37	40.98	295
250	183.34	1670	0.0581	4323.1	6156.6	158.25	22.14	39.16	304
260	194.84	1807	0.0538	4592.4	6540.9	159.76	21.94	37.76	312
270	205.98	1940	0.0502	4852.9	6912.7	161.17	21.78	36.65	319
280	216.81	2068	0.0471	5106.5	7274.6	162.48	21.64	35.77	327
290	227.41	2192	0.0445	5354.5	7628.6	163.72	21.53	35.05	334
300	237.81	2312	0.0421	5598.0	7976.1	164.90	21.44	34.47	341

*Two-phase boundary.

TABLE 14. *Thermodynamic properties of oxygen.*—Continued

20 MN/m² Isobar

T	V	$\left(\frac{\partial P}{\partial \rho}\right)_T$	$\left(\frac{\partial P}{\partial T}\right)_\rho$	Internal Energy	Enthalpy	Entropy	C_v	C_p	Vel. of Sound
K	cm³/mol	J/mol	MN/m²-K	J/mol	J/mol	J/mol-K	J/mol-K	J/mol-K	m/s
*56.614	24.27	31225	3.963	-6154.6	-5669.2	67.59	35.79	52.56	1197
58	24.38	30599	3.887	-6083.9	-5596.3	68.86	35.51	52.53	1189
60	24.53	29711	3.778	-5981.9	-5491.3	70.64	35.13	52.47	1178
62	24.68	28842	3.672	-5880.1	-5386.4	72.36	34.76	52.42	1166
64	24.84	27992	3.569	-5778.4	-5281.6	74.03	34.41	52.37	1154
66	25.00	27160	3.468	-5676.9	-5176.9	75.64	34.07	52.33	1142
68	25.16	26346	3.370	-5575.5	-5072.3	77.20	33.74	52.28	1130
70	25.32	25551	3.274	-5474.2	-4967.8	78.71	33.42	52.24	1117
72	25.49	24773	3.180	-5373.0	-4863.3	80.19	33.11	52.20	1105
74	25.65	24012	3.089	-5272.0	-4759.0	81.62	32.81	52.16	1092
76	25.82	23269	3.000	-5171.1	-4654.7	83.01	32.53	52.13	1080
78	26.00	22542	2.913	-5070.4	-4550.4	84.36	32.25	52.10	1067
80	26.17	21832	2.829	-4969.7	-4446.2	85.68	31.98	52.07	1054
82	26.35	21138	2.746	-4869.2	-4342.1	86.96	31.72	52.04	1041
84	26.53	20460	2.666	-4768.7	-4238.0	88.22	31.47	52.02	1028
86	26.72	19797	2.588	-4668.4	-4134.0	89.44	31.23	52.01	1015
88	26.91	19150	2.513	-4568.1	-4029.9	90.64	30.99	52.00	1002
90	27.10	18518	2.439	-4467.9	-3925.9	91.81	30.76	51.99	989
92	27.30	17901	2.367	-4367.8	-3821.9	92.95	30.54	51.99	976
94	27.49	17298	2.297	-4267.8	-3718.0	94.07	30.32	51.99	963
96	27.70	16710	2.229	-4167.9	-3613.9	95.16	30.10	52.00	950
98	27.90	16135	2.163	-4068.0	-3509.9	96.23	29.89	52.01	937
100	28.11	15574	2.099	-3968.1	-3405.9	97.29	29.68	52.04	924
102	28.33	15027	2.036	-3868.3	-3301.8	98.32	29.48	52.06	911
104	28.55	14493	1.976	-3768.6	-3197.6	99.33	29.27	52.10	898
106	28.77	13972	1.917	-3668.8	-3093.4	100.32	29.07	52.14	885
108	29.00	13464	1.859	-3569.1	-2989.0	101.30	28.86	52.19	872
110	29.24	12968	1.804	-3469.4	-2884.6	102.25	28.66	52.25	860
112	29.48	12485	1.750	-3369.6	-2780.0	103.20	28.45	52.31	847
114	29.73	12014	1.697	-3269.8	-2675.3	104.12	28.23	52.39	835
116	29.98	11554	1.646	-3170.0	-2570.5	105.04	28.02	52.47	822
118	30.24	11106	1.597	-3070.2	-2465.4	105.93	27.79	52.56	810
120	30.50	10670	1.549	-2970.2	-2360.1	106.82	27.56	52.66	798
122	30.78	10245	1.502	-2870.2	-2254.7	107.69	27.32	52.77	786
124	31.06	9831	1.456	-2770.1	-2148.9	108.55	27.07	52.88	775
126	31.35	9428	1.412	-2669.9	-2042.9	109.40	26.81	53.01	763
128	31.65	9036	1.370	-2569.6	-1936.6	110.23	26.54	53.16	752
130	31.96	8637	1.326	-2467.7	-1828.6	111.07	27.06	54.07	734
132	32.27	8262	1.279	-2365.9	-1720.5	111.90	26.97	54.20	720
134	32.60	7889	1.237	-2263.8	-1611.8	112.71	26.87	54.48	707
136	32.94	7532	1.200	-2161.0	-1502.2	113.53	26.77	54.99	695
138	33.29	7186	1.159	-2057.9	-1392.1	114.33	26.65	55.23	682
140	33.65	6854	1.121	-1954.4	-1281.3	115.13	26.53	55.63	670
142	34.03	6538	1.079	-1850.7	-1170.2	115.91	26.41	55.71	657
144	34.42	6218	1.040	-1746.9	-1058.6	116.70	26.28	55.93	643
146	34.83	5928	1.017	-1641.9	-945.4	117.48	26.15	57.04	636
148	35.24	5644	0.9704	-1537.3	-832.4	118.24	26.04	56.71	620
150	35.68	5372	0.9374	-1432.1	-718.5	119.01	25.93	57.17	608
152	36.13	5107	0.9000	-1326.8	-604.2	119.77	25.83	57.30	595
154	36.60	4853	0.8747	-1220.5	-488.4	120.52	25.74	58.27	586
156	37.09	4627	0.8343	-1114.4	-372.5	121.27	25.65	57.94	571
158	37.60	4371	0.8127	-1007.2	-255.2	122.02	25.57	59.33	563
160	38.14	4148	0.7778	-899.7	-136.9	122.76	26.10	60.04	546
165	39.57	3630	0.7022	-627.0	164.5	124.62	25.72	60.82	518
170	41.18	3172	0.6337	-351.7	471.8	126.45	25.60	62.09	490
175	42.97	2777	0.5699	-73.8	785.6	128.27	25.53	63.32	464
180	44.97	2447	0.5119	206.1	1105.5	130.07	25.43	64.41	440
185	47.21	2180	0.4601	486.5	1430.7	131.86	25.26	65.29	420
190	49.68	1973	0.4127	764.5	1758.0	133.60	25.08	65.56	401
195	52.37	1818	0.3710	1038.1	2085.5	135.30	24.88	65.38	386
200	55.26	1709	0.3339	1304.8	2410.1	136.95	24.67	64.49	374
210	61.53	1598	0.2747	1812.4	3042.9	140.03	24.29	61.83	357
220	68.17	1594	0.2307	2279.1	3642.5	142.82	23.90	58.03	348
230	74.91	1648	0.1980	2705.1	4203.3	145.32	23.54	54.25	344
240	81.62	1736	0.1736	3095.8	4728.1	147.55	23.21	50.97	345
250	88.15	1851	0.1535	3456.3	5219.3	149.56	22.90	47.62	347
260	94.51	1971	0.1386	3793.2	5683.3	151.38	22.62	45.25	351
270	100.70	2095	0.1265	4111.0	6125.0	153.05	22.36	43.25	356
280	106.73	2220	0.1163	4413.3	6547.9	154.58	22.11	41.52	361
290	112.62	2347	0.1077	4702.7	6955.1	156.01	21.86	40.06	367
300	118.38	2469	0.1006	4981.1	7348.7	157.35	21.61	38.84	372

*Two-phase boundary.

TABLE 14. *Thermodynamic properties of oxygen.*—Continued

30 MN/m² Isobar

T	V	$\left(\frac{\partial P}{\partial \rho}\right)_T$	$\left(\frac{\partial P}{\partial T}\right)_\rho$	Internal Energy	Enthalpy	Entropy	C_v	C_p	Vel. of Sound
K	cm³/mol	J/mol	MN/m²-K	J/mol	J/mol	J/mol-K	J/mol-K	J/mol-K	m/s
*57.720	24.17	32404	3.970	−6135.9	−5410.8	67.88	35.87	52.27	1215
58	24.19	32280	3.955	−6121.8	−5396.2	68.13	35.82	52.26	1213
60	24.33	31406	3.847	−6021.7	−5291.7	69.90	35.45	52.19	1202
62	24.48	30551	3.742	−5921.8	−5187.4	71.61	35.09	52.12	1191
64	24.63	29714	3.640	−5822.0	−5083.2	73.26	34.75	52.05	1179
66	24.78	28897	3.540	−5722.4	−4979.2	74.86	34.42	51.99	1168
68	24.93	28098	3.442	−5623.1	−4875.3	76.41	34.11	51.92	1156
70	25.08	27316	3.347	−5523.9	−4771.5	77.92	33.80	51.86	1144
72	25.24	26553	3.255	−5424.9	−4667.8	79.38	33.51	51.80	1133
74	25.39	25807	3.165	−5326.0	−4564.3	80.80	33.22	51.74	1121
76	25.55	25078	3.077	−5227.4	−4460.8	82.18	32.95	51.68	1109
78	25.71	24365	2.991	−5128.9	−4357.5	83.52	32.68	51.62	1097
80	25.88	23670	2.908	−5030.6	−4254.3	84.82	32.43	51.56	1085
82	26.04	22991	2.827	−4932.5	−4151.2	86.10	32.18	51.51	1072
84	26.21	22327	2.748	−4834.6	−4048.3	87.34	31.94	51.45	1060
86	26.38	21680	2.671	−4736.8	−3945.4	88.55	31.71	51.40	1048
88	26.55	21047	2.597	−4639.2	−3842.6	89.73	31.48	51.36	1036
90	26.73	20430	2.524	−4541.8	−3739.9	90.88	31.26	51.31	1024
92	26.91	19828	2.454	−4444.5	−3637.3	92.01	31.04	51.26	1012
94	27.09	19240	2.385	−4347.4	−3534.8	93.11	30.83	51.22	999
96	27.27	18667	2.319	−4250.5	−3432.4	94.19	30.62	51.18	987
98	27.46	18108	2.254	−4153.7	−3330.1	95.25	30.42	51.15	975
100	27.64	17562	2.191	−4057.1	−3227.8	96.28	30.21	51.11	964
102	27.84	17030	2.131	−3960.7	−3125.6	97.29	30.01	51.08	952
104	28.03	16511	2.072	−3864.4	−3023.5	98.28	29.81	51.05	940
106	28.23	16005	2.014	−3768.3	−2921.4	99.26	29.61	51.02	928
108	28.43	15512	1.959	−3672.4	−2819.4	100.21	29.40	51.00	917
110	28.64	15031	1.905	−3576.6	−2717.4	101.14	29.19	50.98	906
112	28.85	14562	1.853	−3481.0	−2615.5	102.06	28.97	50.95	895
114	29.06	14105	1.803	−3385.5	−2513.6	102.97	28.75	50.93	884
116	29.28	13660	1.754	−3290.2	−2411.7	103.85	28.52	50.91	873
118	29.50	13227	1.706	−3195.0	−2309.9	104.72	28.29	50.90	862
120	29.73	12804	1.660	−3100.0	−2208.1	105.58	28.04	50.88	852
122	29.96	12393	1.616	−3005.2	−2106.3	106.42	27.77	50.86	842
124	30.20	11992	1.573	−2910.5	−2004.5	107.25	27.50	50.83	832
126	30.44	11602	1.532	−2816.0	−1902.7	108.06	27.21	50.81	823
128	30.69	11223	1.491	−2721.6	−1801.0	108.86	26.90	50.79	814
130	30.94	10917	1.450	−2626.1	−1697.9	109.66	27.43	51.41	800
132	31.20	10519	1.407	−2530.7	−1594.8	110.45	27.35	51.53	787
134	31.46	10272	1.389	−2434.4	−1490.5	111.23	27.26	52.19	784
136	31.73	9873	1.337	−2338.9	−1387.0	112.00	27.17	51.96	768
138	32.01	9515	1.297	−2243.3	−1283.1	112.76	27.07	52.08	756
140	32.29	9174	1.263	−2147.5	−1178.8	113.51	26.97	52.34	746
142	32.58	8878	1.233	−2051.3	−1073.8	114.25	26.86	52.69	738
144	32.87	8523	1.168	−1956.3	−970.1	114.98	26.76	51.68	717
146	33.18	8180	1.158	−1860.2	−864.9	115.70	26.64	52.98	713
148	33.49	7933	1.127	−1763.9	−759.1	116.42	26.52	53.10	705
150	33.82	7660	1.090	−1668.0	−653.5	117.13	26.40	53.03	693
152	34.14	7398	1.053	−1572.4	−548.1	117.83	26.27	52.82	682
154	34.48	7145	1.035	−1476.4	−441.9	118.52	26.14	53.59	677
156	34.83	6844	0.9967	−1380.8	−336.0	119.21	26.01	53.48	663
158	35.18	6674	0.9615	−1285.2	−229.7	119.88	25.90	52.99	653
160	35.54	6372	0.9238	−1190.3	−124.1	120.55	26.41	53.47	635
165	36.49	5863	0.8693	−948.6	146.3	122.21	25.99	54.32	619
170	37.51	5402	0.8055	−707.3	418.0	123.83	25.86	54.59	597
175	38.59	4974	0.7465	−466.3	691.5	125.42	25.79	54.98	576
180	39.74	4569	0.6894	−226.1	966.1	126.97	25.69	55.26	554
185	40.97	4233	0.6380	13.3	1242.3	128.48	25.54	55.40	536
190	42.27	3927	0.5910	251.2	1519.3	129.96	25.34	55.54	519
195	43.65	3665	0.5471	486.6	1796.1	131.40	25.10	55.44	503
200	45.11	3431	0.5076	718.8	2072.2	132.79	24.81	55.38	489
210	48.26	3096	0.4379	1172.7	2620.6	135.47	24.31	54.60	466
220	51.66	2888	0.3794	1610.2	3160.0	137.98	23.98	53.24	448
230	55.28	2741	0.3333	2029.0	3687.4	140.32	23.68	52.16	434
240	59.05	2693	0.2948	2429.8	4201.2	142.51	23.45	50.46	426
250	62.88	2692	0.2627	2809.8	4696.3	144.53	23.22	48.56	420
260	66.77	2701	0.2367	3170.8	5173.8	146.41	22.97	47.02	416
270	70.67	2745	0.2148	3514.9	5635.0	148.15	22.71	45.37	414
280	74.57	2816	0.1970	3844.3	6081.3	149.77	22.46	43.93	415
290	78.44	2908	0.1819	4160.3	6513.6	151.29	22.23	42.53	417
300	82.28	3005	0.1690	4464.0	6932.3	152.71	22.00	41.30	420

*Two-phase boundary.

TABLE 15. *The Joule-Thomson inversion curve*

T K	P MN/m²	Density mol/cm³	ΔP [a] MN/m²
125	1.58	0.02942	0.18
130	5.34	.02907	.20
135	8.76	.02869	.21
140	12.07	.02835	.23
145	15.29	.02802	.26
150	18.07	.02765	.26
155	20.73	.02729	.29
160	23.57	.02700	.29
165	25.97	.02666	.31
170	28.27	.02633	.32
175	30.46	.02600	.34
180	32.55	.02569	.35
185	34.46	.02537	.38
190	36.24	.02504	.38

[a] The uncertainty due to a 1 percent assumed uncertainty in either the isotherm or the isochore derivative.

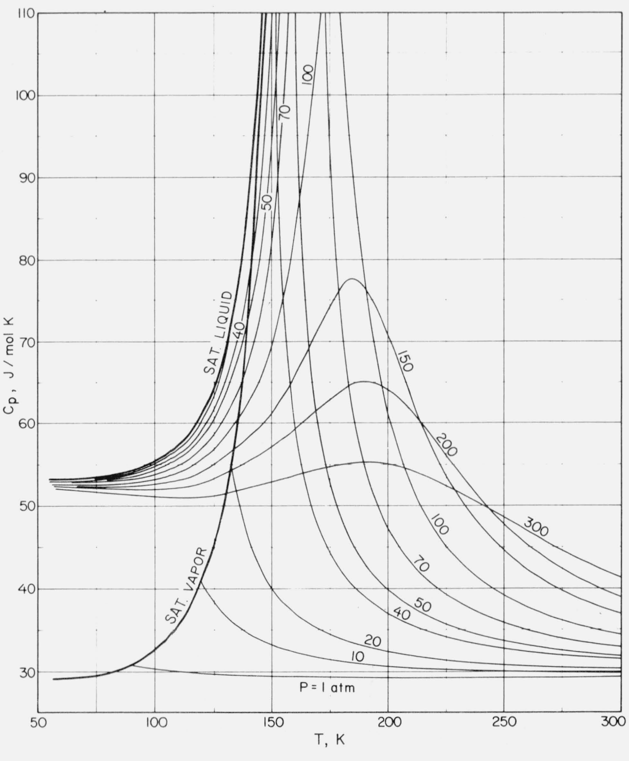

FIGURE 5. C_p *along selected isobars.*

were also calculated by means of the Clapeyron equation, using the same pressure equation, and differ from those in column four only through the use of somewhat different values for the virial coefficients. A comparison of columns 2 and 3 indicates the degree of thermodynamic consistency in the present method of calculation. Differences between ΔH and $T\Delta S$ of 1 to 3 J/mol may be expected in these calculations. However, the first line of table 16 reveals a discrepancy of 20 J/mol at the triple point, which must be explained. The problem arises from the second term, $-R \ln (RT\rho/P_0)$, in eq (16) for the entropy of the vapor phase. The density, ρ, is found from the vapor pressure, eq (7), which is based upon Hoge's [10]

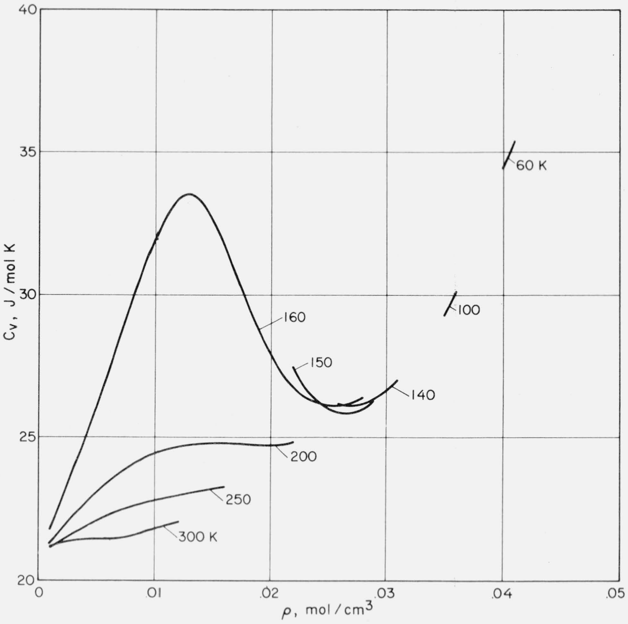

FIGURE 6. C_v *along selected isotherms.*

value of 1.14 mm for the triple point pressure. This value is subject to a large relative uncertainty. In a more recent work Muijlwijk et al. [22], found a value of 1.097_5 mm, or a difference of 3.7 percent. Using this latter triple point pressure results in a value of 7758 J/mol for $T\Delta S$ in much better agreement with the calculated ΔH. Thus we must conclude that the triple point pressure is closer to 1.0975 mm and eq (7) should be modified accordingly. This same error would also be evident in the value of the density of the saturated vapor given in table 13.

The problem is also apparent to a lesser extent in the next three lines of table 16. This inaccuracy affects only the calculated thermodynamic properties of the saturated vapor near the triple point. Values of ΔH calculated by means of the Clapeyron equation suffer from the large relative uncertainty in the slope of the vapor pressure curve at low temperatures. The last two columns of table 16 contain some experimental measurements of the heat of vaporization.

The entropy of the liquid at the triple point, calculated by the path described in section 3.1, is 67.001 J/mol-K. The entropy for this point, calculated by Giauque and Johnston [15] from their calorimetric data on solid oxygen, is 67.095±.15 J/mol-K. Thus we see that the two experiments are consistent with the Third Law.

The calculated velocity of sound in the saturated liquid is compared with the measurements of Blagoi et al. [28], and of Van Itterbeek and Van Dael [29, 32] in figure 7. The change in the P–V–T surface representation from Region I to Region II at 128 K is apparent. Most of the scatter apparent near the critical point occurs in the calculated rather than the experimental values. The agreement is reasonable if we consider that the comparison is made along an edge of the surface representation. Similarly table 17 contains a comparison with the experimental values in the com-

TABLE 16. *Comparison of calculated and measured heats of vaporization in J/mol*

Temp.	Calculated—This Research			Ref. [11]	Ref. [15]	Ref. [24]
	Table 13		Clapeyron equation	Clapeyron equation	Experimental	
	ΔH	$T\Delta S$				
54.350_7	7761	7741	7678			
60	7624	7634	7516			
68.4	7417	7413	7416	7416		7418
70	7377	7381	7379	7384		
76	7221	7220	7240	7244		7228
80	7113	7110	7131	7137		
84.1	6997	6995	7009	7017		7005
90	6818	6815	6820	6832		
90.18	6812	6809	6810	6826	6815±6.8	6825
100	6473	6471	6459	6477		
110	6058	6058	6039	6061		
120	5546	5546	5532	5555		
130	4891	4893	4888	4906		
140	4002	4003	4009	4013		
150	2543	2544	2549	2578		

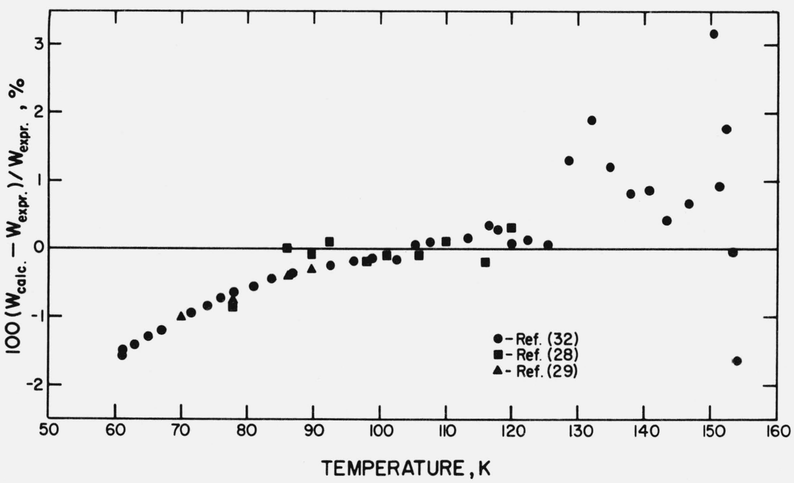

FIGURE 7. *Comparison of experimental and calculated sound velocities in the saturated liquid.*

pressed liquid. The agreement leaves something to be desired. Each isotherm from 67.5 K to 90.4 K shows the same behavior; the disagreement gets worse as the pressure goes up, reaching 2.1 percent at pressures of about 30 MN/m^2. An error in the elastic stretching coefficient of the sample holder, "a" in eq (1) could account for a portion of the error on each isotherm. For example, a 100 percent error in "a" would change the calculated velocities by 0.9 percent at 0.1 MN/m^2 and 1.2 percent at 30 MN/m^2 at 70 K and by 0.6 to 0.9 percent at 90 K. Another 0.5 percent might be attributed to the analytic surface used to fit the data. In addition, close examination of references [28] and [29] will reveal discrepancies of 0.2–0.4 percent between the various experimental measurements. Further experimental measurements on the velocity of sound in the compressed liquid would be very desirable. The last section of table 17 contains a comparison with the work of Van Itterbeek and Van Dael in the low density gas. Here the agreement is somewhat better and it is felt that the calculated values are more reliable than the experimental measurements.

Comparison with the measurements of C_v by Voronel, et al. [30], reveals good agreement at 160 K. The disagreement becomes quite large nearer the critical point, and this is to be expected since no mechanism causing C_v to diverge was incorporated into the P–V–T surface used here. Comparison of the calculated C_v's with the measurements of Goodwin and Weber [6] revealed generally excellent agreement over the whole P–V–T surface. Small irregularities

TABLE 17. *Comparison with experimental measurements of the velocity of sound in compressed liquid and in low density gas*

Temp K	Press MN/m^2	$100(W_{exp}-W_{calc})/W_{exp}$ Ref. [29]
67.53	29.5	2.11
	19.8	1.89
	9.7	1.62
	0.40	1.29
	34.6	2.15
73.43	24.8	1.87
	14.9	1.67
	5.0	1.40
	29.6	2.18
77.72	19.6	1.85
	9.9	1.39
	0.19	0.94
	34.2	2.22
83.83	24.8	1.81
	15.0	1.47
	5.8	1.10
	29.7	2.14
90.40	19.9	1.61
	10.1	1.06
	0.19	0.52
231.8	2.91	−0.07
248.8	5.11	.77
274.2	4.07	.35

may be seen in the 300 K isotherm for C_v in figure 6. These are probably caused by small errors in the second derivatives near the edge of the $P-V-T$ surface.

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