3. A. N. Dashuk, A. Zh. Greben'kov, Yu. D. Il'yukhin, et al., "An experimental apparatus for investigating the isobaric heat capacity of liquids at low pressures in the room-temperature range," Vestsi Akad. Nauk BSSR. Ser. FEN, No. 4, 129-134 (1978).
4. B. V. Biryukov, M. A. Danilov, and S. S. Kivilis, Exact Measurements for the Flow Rate of Liquids (Handbook) [in Russian], Mashinostroenie, Moscow (1977).
5. F. T. Selleck, H. H. Reamer, and B. H. Sage, "Volumetric and phase behavior of mixtures of nitric oxide and nitrogen dioxide," Ind. Eng. Chem., 45, No. 4, 814-819 (1953).
6. A. M. Sirota, "Investigation of the caloric properties of water over a broad range of parameters of state (25-1000 kg/cm^2, 0-700°C)," Author's Abstract of Doctoral Dissertation, VTI, Moscow (1970).
7. E. P. Kovaleva, L. T. Lomako, V. Ya. Timofeeva, and V. P. Trubnikov, "Methods for the operational chemical monitoring of a nitrogen tetroxide coolant," Vestsi Akad. Nauk BSSR. Ser. FEN, No. 2, 40-46 (1975).
8. Yu. D. Il'yukhin, "Experimental investigation of the isobaric heat capacity of equilibrium-dissociating nitrogen tetroxide at P = 150-175 kg/cm^2 and T = 150-500°C," Author's Abstract of Candidate's Dissertation, IYaE AN BSSR, Minsk (1973).
9. H. H. Reamer and B. H. Sage, "Volumetric behavior of nitrogen dioxide in the liquid phase," Ind. Eng. Chem., 144, No. 1, 185-187 (1952).
10. V. M. Simonov, "Experimental investigation of the caloric properties of nitrogen tetroxide and a diphenyl mixture," Author's Abstract of Candidate's Dissertation, IVT AN SSR, Moscow (1977).
11. A. A. Bilyk, N. F. Gladkii, Yu. G. Kotelevskii, and B. D. Timofeev, "Experimental investigation of the thermal conductivity of nitrogen tetroxide in the liquid and the dense gaseous state for supercritical pressures," Vestsi Akad. Nauk BSSR. Ser. FEN, No. 1, 102-108.
12. N. B. Vargaftik, L. P. Filippov, A. A. Tarzimanov, and E. E. Totskii, Thermal Conductivity of Gases and Liquids (Handbook) [in Russian], Standartov, Moscow (1978).
13. A. A. Bilyk, N. F. Gladkii, Yu. G. Kotelevskii, and B. D. Timofeev, "Thermal conductivity of liquid nitrogen tetroxide at temperatures of 270-400°K and pressures of 0.1-20 MPa," Teploenergetika, No. 6, 75-76 (1975).

EXPERIMENTAL STUDY OF THE DENSITY OF ALIPHATIC ALCOHOLS AT VARIOUS TEMPERATURES AND PRESSURES

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Using a hydrostatic suspension method, the densities of ethyl, n-propyl, isopropyl, n-butyl, and isobutyl alcohols were measured in the temperature range 200-570°K and in the pressure range 10.86-491.4 bar.

The density of aliphatic alcohols in the liquid state were previously investigated mostly at atmospheric pressure and at the saturation line. At higher pressure measurements were carried out by a number of authors [1-5] in a quite wide range of state parameters with an error of 0.4-0.5%.

A device using the method of hydrostatic suspension was designed with the purpose of obtaining more accurate p, V, T data for alcohols. It differed from those used earlier [6] by more refined device construction, providing reliable operation at high temperatures and pressures, using more accurate measurement techniques and new electronic components, simpler and more convenient to use.

A correction was included in the calculation, including the effect of an external magnetic field on the power coil.

The pressure was created and measured by means of class 0.05 MP-60 and MP-600, and the

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TABLE 1. Smoothed Density Values of Ethyl, n-Propyl, Isopropyl, and n-Butyl Alcohols, kg/m³

P, bar	Temperature, °K										
	200	250	300	350	400	450	500	520	540	560	570
Ethyl alcohol											
10	873,9	828,8	784,6	740,3	684,1	—	—	—	—	—	—
20	874,5	829,5	785,5	741,5	686,1	605,1	—	—	—	—	—
50	876,1	831,7	788,3	745,1	691,7	617,0	466,5	—	—	—	—
75	877,4	833,4	790,4	748,0	696,0	625,4	508,5	397,2	154,9	118,5	109,3
100	878,7	835,1	792,5	750,8	700,1	632,7	531,2	465,6	350,1	214,5	183,2
150	881,2	838,3	796,6	756,0	707,5	645,3	560,5	515,9	461,4	394,4	357,7
200	883,5	841,4	800,4	760,9	714,3	656,0	581,0	544,5	503,4	457,5	433,1
250	885,8	844,4	804,1	765,5	720,6	665,4	597,0	565,2	530,6	493,4	474,1
300	888,1	847,3	807,6	769,9	726,4	673,8	610,3	581,6	551,0	518,8	502,3
400	892,4	852,9	814,4	778,1	737,0	688,5	632,0	607,3	581,6	555,1	541,7
500	896,6	858,3	820,7	785,6	746,5	701,1	649,5	627,4	604,7	581,5	569,8
n-Propyl alcohol											
10	881,1	839,6	799,9	757,9	705,2	—	—	—	—	—	—
20	881,6	840,2	800,7	759,0	706,9	637,2	—	—	—	—	—
50	883,0	842,1	803,0	762,2	711,7	646,0	550,9	488,3	139,2	101,2	88,5
75	884,2	843,6	805,0	764,7	715,4	652,5	566,8	519,3	451,4	310,1	184,5
100	885,4	845,0	806,8	767,2	719,0	658,4	579,3	538,9	489,3	422,9	331,6
150	887,7	848,0	810,5	772,0	725,6	668,8	598,8	565,9	529,4	488,1	441,4
200	890,0	850,9	813,9	776,4	731,8	678,0	614,1	585,3	554,6	521,6	486,5
250	892,3	853,5	817,3	780,7	737,5	686,2	626,8	600,7	573,5	545,0	515,4
300	894,4	856,2	820,5	784,5	742,9	693,7	637,7	613,6	588,8	563,2	536,9
400	898,4	861,2	826,5	792,0	752,5	706,9	656,2	634,8	613,0	591,0	568,9
500	902,3	865,9	832,0	798,8	761,3	718,3	671,4	651,9	632,3	612,4	592,8
Isopropyl alcohol											
10	860,4	821,6	780,5	734,1	671,9	—	—	—	—	—	—
20	861,0	822,4	781,5	735,4	674,1	585,7	—	—	—	—	—
50	862,7	824,7	784,2	739,2	680,4	599,9	455,5	142,7	106,5	91,4	82,1
75	864,1	826,5	786,4	742,2	685,2	609,6	497,8	421,3	282,3	185,8	149,8
100	865,5	828,3	788,5	745,1	689,7	618,0	521,1	468,3	399,4	314,3	242,6
150	868,2	831,7	792,5	750,6	698,0	632,2	551,4	513,5	471,5	425,1	375,7
200	870,8	834,9	796,4	755,7	705,5	644,0	572,4	540,9	507,5	472,4	436,0
250	873,5	838,0	800,0	760,5	712,3	654,3	588,9	561,0	532,3	502,8	472,7
300	876,0	841,0	803,5	765,1	718,6	663,4	602,5	577,2	551,4	525,3	499,0
400	881,0	846,6	810,1	773,6	730,0	679,2	624,7	602,6	580,5	558,5	536,7
500	885,9	851,8	816,1	781,3	740,3	692,7	642,5	622,5	602,7	583,1	563,9
n-Butyl alcohol											
10	883,3	841,9	804,1	764,1	715,6	654,6	—	—	—	—	—
20	883,8	842,5	804,9	765,1	717,1	657,1	575,5	—	—	—	—
50	885,2	844,3	807,1	768,1	721,4	664,2	591,0	553,5	505,7	429,1	166,3
75	886,4	845,7	808,9	770,5	724,8	669,6	601,3	568,2	529,7	481,9	415,5
100	887,5	847,1	810,7	772,8	728,0	674,6	610,1	580,0	546,4	507,9	462,1
150	889,8	849,9	814,1	777,2	734,1	683,6	624,9	598,7	570,7	540,5	507,7
200	892,0	852,6	817,4	781,4	739,7	691,6	637,1	613,4	588,7	562,7	535,4
250	894,2	855,2	820,6	785,4	745,0	698,8	647,6	625,8	603,2	579,9	555,9
300	896,3	857,7	823,7	789,2	749,9	705,5	656,9	636,4	615,5	594,1	572,2
400	900,4	862,6	829,5	796,3	759,0	717,4	672,8	654,4	635,7	616,9	597,9
500	904,3	867,2	834,9	802,9	767,2	727,8	686,2	669,2	652,2	635,1	618,0

temperature — by a platinum resistance thermometer and a class P 363-2 potentiometer of accuracy 0.002. The temperature of the experiment was maintained by a VRT-2 temperature regulator. The experimental error at densities above 300 kg/m³ is 0.1%, and at lower densities can reach 0.3%.

Measurements were performed of the density of ethyl, propyl, isopropyl, butyl, and isobutyl alcohols at temperatures from 200 to 570°K in the pressure region 10.86-491.4 bar. In these studies we used alcohols with basic product content not exceeding 99.84%. The experimental data obtained were processed analytically and are shown in Tables 1 and 2.

For ethyl alcohol the deviation between our data and the results of [1,2] does not exceed 0.4%. For n-propyl, isopropyl, n-butyl, and isobutyl alcohols most experimental points of [4] agree within 0.5% with our results, but at low pressures and temperatures exceeding

TABLE 2. Smoothed Density Values of Isobutyl Alcohol, kg/m³

P, bar	Temperature, °K										
	240	300	350	400	450	500	520	540	560	580	
10	842,2	797,2	755,7	704,3	636,9	—	—	—	—	—	—
20	842,8	798,0	756,8	706,0	640,1	—	—	—	—	—	—
50	844,6	800,5	760,1	710,8	648,6	566,6	521,9	456,7	210,6	132,8	
75	846,1	802,5	762,7	714,6	654,9	580,0	542,8	497,8	437,8	347,2	
100	847,5	804,5	765,3	718,2	660,7	590,9	558,1	521,0	477,6	425,4	
150	850,3	808,2	770,1	724,9	670,9	608,4	580,8	551,2	519,5	485,3	
200	853,0	811,8	774,6	731,0	679,8	622,4	597,8	572,3	545,6	517,9	
250	855,6	815,2	778,8	736,7	687,8	634,2	611,7	588,7	565,1	541,1	
300	858,1	818,4	782,8	741,9	695,1	644,5	623,6	602,4	580,9	559,2	
400	862,9	824,5	790,3	751,5	707,9	661,9	643,2	624,6	605,9	587,3	
500	867,4	830,1	797,1	760,1	719,1	676,4	659,4	642,4	625,6	609,0	

473°K the deviations reach several percent. The maximum deviation between our data on isopropyl alcohol and the data of [5] is 1.1% at 413°K and 2.4% at 573°K.

Results of p, V, T measurements of ethyl, propyl, and butyl alcohols for 293-423°K and pressures up to 2000 bar, carried out by the method of a sylphon piezometer, were given in [3]. The maximum deviations between the results of [3] and ours occur at 423°K and 500 bar, and are 1.4, 0.65, and 0.4% for ethyl, propyl, and n-butyl alcohols, respectively, which significantly exceeds the total error of both measurements. This is, possibly, explained by the fact that in calculating the density at high pressures insufficiently accurate data were selected in [3] near the saturation line, as well as by the difficulty of accounting for the deformations of separate piezometer elements with temperature and pressure.

The p, V, T data obtained are recommended for constructing equations of state of ethyl, n-propyl, isopropyl, n-butyl, and isobutyl alcohols, and for calculating their thermodynamic properties.

LITERATURE CITED

1. W. Seitz and G. Lechner, Ann. Phys., 49, 93-115 (1916).
2. H. Lo and L. Stiel, Ind. Eng. Chem. Fundament., 8, 713-718 (1969).
3. E. I. Konikevich, Thesis, MÉI (1977).
4. I. F. Golubev and É. N. Vagina, Tr. GIAP, No. 15, 39-55, Moscow (1963).
5. J. Tseng and L. Stiel, AIChE J., 17, 1283-1286 (1971).
6. I. F. Golubev and O. A. Dobrovol'skii, Gazov. Promyshl., 5, 43-47 (1964).