Designation: D4650 – 19

Standard Specification for Normal Butane Thermophysical Property Tables[1]

This standard is issued under the fixed designation D4650; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 The thermophysical property tables for normal butane are for use in the calculation of the pressure-volume-temperature (PVT), thermodynamic, and transport properties of normal butane for process design and operations. Two tables provide properties at the conditions of liquid-vapor equilibrium (saturation properties), one for liquid and one for vapor, at temperatures between 135 K and the critical point, 425.13 K. A third table provides properties at selected T, p points for the equilibrium phase at temperatures between 140 K and 570 K at pressures to 20 MPa. The tables were developed using the National Institute of Standards and Technology Standard Reference Database product REFPROP, version 10.0.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Applicability

2.1 These tables apply directly only to pure normal butane. They may also be used in mathematical models and tables for the thermophysical properties of mixtures containing normal butane.

3. Tables

3.1 These tables were produced by equations from a computer package, "NIST Standard Reference Database 23; Reference Fluid Thermodynamic and Transport Properties Database (REFPROP): Version 10.0."[2] A wide selection of units (SI units, engineering units, chemical units) and additional properties are available with this program.

3.2 These thermophysical property tables are:

3.2.1 *Thermophysical Properties of Normal Butane Liquid at Vapor-Liquid Equilibrium, in SI units*. See Table 1.

3.2.2 *Thermophysical Properties of Normal Butane Vapor at Vapor-Liquid Equilibrium, in SI units*. See Table 2.

3.2.3 *Thermophysical Properties of Normal Butane Along Isobars, in SI units*. See Table 3.

3.3 The symbols are:

T, temperature (K)
ρ, molar density (mol·L^{-1})
H, molar enthalpy (J·mol^{-1})
S, molar entropy (J·K^{-1}·mol^{-1})
Cv, constant volume molar heat capacity (J·K^{-1} ·mol^{-1})
Cp, constant pressure molar heat capacity (J·K^{-1}·mol^{-1})
c, speed of sound (m·s^{-1})
η, viscosity (μPa·s)
λ, thermal conductivity (mW·m^{-1}·K^{-1})

3.4 The tabulated thermophysical properties are:

ρ, molar density (mol·L^{-1})
H, molar enthalpy (J·mol^{-1})
S, molar entropy (J·K^{-1}·mol^{-1})
Cv, constant volume molar heat capacity (J·K^{-1}·mol^{-1})
Cp, constant pressure molar heat capacity (J·K^{-1}·mol^{-1})
c, speed of sound (m·s^{-1})
η, viscosity (μPa·s)
λ, thermal conductivity (mW·m^{-1}·K^{-1})

4. Additional Information

4.1 Reference state properties are required to calculate the thermodynamic properties enthalpy and entropy from an equation of state formulation. The reference state properties used are those specified by the International Institute of Refrigeration (IIR): enthalpy, H= 200 J/g, and entropy, S= 1 J/(g·K), for the saturated liquid at 273.15 K (0 °C).

4.2 The molar mass of normal butane is 58.122 g/mol.

5. Keywords

5.1 butane; N-butane; natural gas; normal butane gas tables; thermodynamic properties of normal butane; transport properties of normal butane

[1] This specification is under the jurisdiction of ASTM Committee D03 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.08 on Thermophysical Properties.

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[2] Available from Standard Reference Data, National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

TABLE 1 Thermophysical Properties of Normal Butane Liquid at Vapor-Liquid Equilibrium

T K	p MPa	ρ mol·l^{-1}	H J·mol^{-1}	S J·mol^{-1}·K^{-1}	C_v J·mol^{-1}·K^{-1}	C_p J·mol^{-1}·K^{-1}	c m·s^{-1}	η μPa·s	λ mW·m^{-1}·K^{-1}
135	6.7910E-07	12.643	-5208.7	-26.944	83.783	114.67	1826.10	2350.5	176.53
137	9.8726E-07	12.611	-4979.3	-25.257	83.793	114.77	1812.80	2172.0	175.86
139	1.4181E-06	12.579	-4749.6	-23.593	83.799	114.87	1799.60	2012.7	175.19
141	2.0137E-06	12.547	-4519.8	-21.951	83.805	114.97	1786.60	1870.2	174.49
143	2.8282E-06	12.515	-4289.8	-20.331	83.809	115.07	1773.70	1742.4	173.79
145	3.9306E-06	12.483	-4059.5	-18.732	83.814	115.17	1761.00	1627.4	173.06
147	5.4080E-06	12.451	-3829.1	-17.154	83.819	115.27	1748.50	1523.8	172.33
149	7.3695E-06	12.419	-3598.4	-15.596	83.827	115.38	1736.00	1430.1	171.58
151	9.9501E-06	12.387	-3367.6	-14.056	83.836	115.50	1723.70	1345.2	170.81
153	1.3316E-05	12.355	-3136.5	-12.536	83.848	115.61	1711.40	1268.1	170.04
155	1.7670E-05	12.323	-2905.1	-11.034	83.864	115.73	1699.30	1197.9	169.25
157	2.3258E-05	12.291	-2673.5	-9.5491	83.883	115.85	1687.20	1133.8	168.45
159	3.0374E-05	12.259	-2441.7	-8.0818	83.906	115.98	1675.20	1075.2	167.64
161	3.9370E-05	12.227	-2209.6	-6.6312	83.933	116.11	1663.20	1021.4	166.82
163	5.0664E-05	12.194	-1977.2	-5.1968	83.965	116.25	1651.30	971.95	165.99
165	6.4747E-05	12.162	-1744.6	-3.7782	84.002	116.39	1639.50	926.37	165.15
167	8.2193E-05	12.130	-1511.6	-2.3750	84.044	116.54	1627.70	884.28	164.30
169	0.00010367	12.098	-1278.4	-0.98666	84.092	116.69	1616.00	845.31	163.44
171	0.00012996	12.066	-1044.9	0.38715	84.145	116.85	1604.30	809.16	162.58
173	0.00016194	12.034	-810.99	1.7469	84.204	117.02	1592.60	775.56	161.70
175	0.00020064	12.002	-576.79	3.0928	84.269	117.19	1581.00	744.25	160.82
177	0.00024721	11.969	-342.24	4.4255	84.340	117.36	1569.40	715.03	159.94
179	0.00030297	11.937	-107.33	5.7452	84.418	117.54	1557.90	687.71	159.04
181	0.00036941	11.905	127.95	7.0523	84.501	117.73	1546.40	662.11	158.14
183	0.00044817	11.873	363.61	8.3471	84.592	117.93	1534.90	638.07	157.24
185	0.00054113	11.840	599.67	9.6300	84.688	118.13	1523.40	615.48	156.33
187	0.00065035	11.808	836.14	10.901	84.792	118.34	1512.00	594.20	155.41
189	0.00077813	11.775	1073.0	12.161	84.902	118.55	1500.60	574.13	154.49
191	0.0009270	11.743	1310.4	13.410	85.018	118.77	1489.20	555.16	153.57
193	0.0010997	11.710	1548.2	14.649	85.142	119.00	1477.80	537.22	152.64
195	0.0012994	11.678	1786.4	15.877	85.272	119.24	1466.50	520.21	151.71
197	0.0015293	11.645	2025.1	17.095	85.409	119.48	1455.20	504.08	150.78
199	0.0017931	11.612	2264.4	18.303	85.553	119.73	1443.90	488.76	149.84
201	0.0020948	11.580	2504.1	19.501	85.704	119.99	1432.60	474.18	148.90
203	0.0024385	11.547	2744.3	20.691	85.861	120.25	1421.30	460.30	147.96
205	0.0028290	11.514	2985.1	21.871	86.026	120.52	1410.10	447.06	147.02
207	0.0032710	11.481	3226.5	23.042	86.197	120.80	1398.80	434.43	146.07
209	0.0037700	11.448	3468.4	24.205	86.375	121.09	1387.60	422.36	145.12
211	0.0043316	11.415	3710.9	25.360	86.559	121.38	1376.40	410.82	144.17
213	0.0049618	11.382	3954.0	26.506	86.751	121.68	1365.20	399.77	143.23
215	0.0056671	11.349	4197.7	27.645	86.949	121.99	1354.10	389.19	142.28
217	0.0064543	11.316	4442.1	28.776	87.153	122.31	1342.90	379.04	141.33
219	0.0073306	11.282	4687.0	29.899	87.365	122.63	1331.80	369.29	140.38
221	0.0083037	11.249	4932.7	31.015	87.582	122.96	1320.60	359.94	139.43
223	0.0093815	11.215	5179.0	32.124	87.807	123.30	1309.50	350.94	138.48
225	0.010573	11.182	5426.1	33.227	88.037	123.65	1298.40	342.29	137.53
227	0.011886	11.148	5673.8	34.322	88.274	124.01	1287.40	333.96	136.58
229	0.013331	11.114	5922.2	35.411	88.517	124.37	1276.30	325.94	135.63
231	0.014917	11.080	6171.4	36.494	88.767	124.74	1265.20	318.20	134.68
233	0.016655	11.046	6421.4	37.571	89.022	125.12	1254.20	310.74	133.74
235	0.018554	11.012	6672.1	38.642	89.284	125.50	1243.20	303.54	132.80
237	0.020627	10.978	6923.6	39.707	89.551	125.90	1232.10	296.59	131.85
239	0.022885	10.943	7176.0	40.766	89.824	126.30	1221.10	289.88	130.91
241	0.025338	10.909	7429.1	41.820	90.104	126.71	1210.20	283.38	129.98
243	0.028001	10.874	7683.1	42.868	90.388	127.12	1199.20	277.10	129.04
245	0.030885	10.840	7937.9	43.912	90.679	127.55	1188.20	271.02	128.11
247	0.034005	10.805	8193.6	44.950	90.975	127.98	1177.30	265.14	127.18
249	0.037372	10.770	8450.2	45.983	91.276	128.42	1166.30	259.44	126.25
251	0.041002	10.735	8707.7	47.012	91.583	128.87	1155.40	253.91	125.32
253	0.044908	10.700	8966.1	48.036	91.894	129.32	1144.50	248.55	124.40
255	0.049106	10.664	9225.4	49.055	92.211	129.79	1133.60	243.35	123.48
257	0.053611	10.629	9485.7	50.070	92.534	130.26	1122.70	238.31	122.57
259	0.058438	10.593	9747.0	51.081	92.861	130.74	1111.80	233.41	121.65
261	0.063604	10.557	10009	52.088	93.193	131.23	1101.00	228.65	120.75
263	0.069124	10.521	10272	53.091	93.529	131.73	1090.10	224.03	119.84
265	0.075015	10.485	10537	54.090	93.871	132.23	1079.30	219.53	118.94
267	0.081295	10.449	10802	55.085	94.217	132.74	1068.40	215.16	118.04
269	0.087981	10.412	11068	56.076	94.567	133.26	1057.60	210.91	117.15
271	0.095090	10.375	11336	57.064	94.922	133.79	1046.80	206.76	116.26
273	0.10264	10.338	11604	58.049	95.281	134.33	1036.00	202.73	115.38
275	0.11065	10.301	11874	59.030	95.645	134.88	1025.20	198.80	114.50
277	0.11914	10.264	12145	60.007	96.012	135.43	1014.40	194.97	113.62
279	0.12813	10.227	12416	60.982	96.384	135.99	1003.60	191.24	112.75
281	0.13763	10.189	12689	61.954	96.760	136.57	992.87	187.60	111.89

TABLE 1 *Continued*

T K	p MPa	ρ mol·l^{-1}	H J·mol^{-1}	S J·mol^{-1}·K^{-1}	C_v J·mol^{-1}·K^{-1}	C_p J·mol^{-1}·K^{-1}	c m·s^{-1}	η μPa·s	λ mW·m^{-1}·K^{-1}
283	0.14768	10.151	12964	62.923	97.139	137.15	982.11	184.05	111.03
285	0.15828	10.113	13239	63.889	97.522	137.74	971.36	180.58	110.17
287	0.16945	10.074	13516	64.852	97.909	138.34	960.61	177.19	109.33
289	0.18122	10.036	13793	65.812	98.300	138.95	949.87	173.89	108.48
291	0.19362	9.9968	14072	66.770	98.694	139.56	939.14	170.66	107.64
293	0.20665	9.9577	14353	67.726	99.092	140.19	928.41	167.50	106.81
295	0.22034	9.9183	14634	68.679	99.494	140.83	917.68	164.41	105.98
297	0.23471	9.8786	14917	69.630	99.898	141.48	906.96	161.39	105.16
299	0.24979	9.8387	15201	70.578	100.31	142.14	896.24	158.43	104.34
301	0.26559	9.7985	15487	71.525	100.72	142.81	885.52	155.54	103.53
303	0.28214	9.7579	15774	72.469	101.13	143.49	874.80	152.71	102.72
305	0.29946	9.7171	16062	73.412	101.55	144.18	864.09	149.93	101.92
307	0.31757	9.6760	16352	74.352	101.97	144.88	853.37	147.21	101.12
309	0.33650	9.6345	16643	75.291	102.39	145.59	842.65	144.54	100.33
311	0.35627	9.5927	16936	76.228	102.82	146.32	831.93	141.93	99.552
313	0.37690	9.5506	17230	77.164	103.25	147.06	821.21	139.36	98.774
315	0.39842	9.5081	17525	78.098	103.68	147.81	810.48	136.85	98.003
317	0.42084	9.4652	17822	79.030	104.12	148.58	799.74	134.38	97.237
319	0.44420	9.4220	18121	79.961	104.56	149.36	789.00	131.95	96.478
321	0.46852	9.3784	18421	80.891	105.00	150.16	778.25	129.57	95.725
323	0.49382	9.3343	18723	81.820	105.44	150.97	767.49	127.23	94.978
325	0.52012	9.2899	19026	82.747	105.89	151.79	756.71	124.93	94.236
327	0.54746	9.2450	19331	83.674	106.34	152.64	745.93	122.67	93.502
329	0.57585	9.1996	19638	84.599	106.79	153.50	735.13	120.44	92.773
331	0.60532	9.1538	19946	85.524	107.25	154.38	724.32	118.25	92.050
333	0.63590	9.1075	20256	86.448	107.70	155.28	713.48	116.10	91.334
335	0.66761	9.0607	20568	87.371	108.17	156.20	702.63	113.98	90.623
337	0.70048	9.0134	20882	88.294	108.63	157.14	691.75	111.89	89.919
339	0.73453	8.9656	21197	89.216	109.10	158.10	680.85	109.83	89.222
341	0.76979	8.9171	21514	90.138	109.57	159.09	669.93	107.81	88.530
343	0.80629	8.8681	21834	91.059	110.04	160.11	658.97	105.81	87.844
345	0.84406	8.8185	22155	91.981	110.52	161.15	647.99	103.83	87.165
347	0.88311	8.7683	22478	92.902	111.00	162.22	636.97	101.89	86.492
349	0.92348	8.7173	22803	93.823	111.49	163.32	625.91	99.970	85.824
351	0.96521	8.6657	23131	94.745	111.97	164.46	614.82	98.075	85.163
353	1.0083	8.6134	23460	95.667	112.47	165.63	603.68	96.204	84.508
355	1.0528	8.5603	23792	96.589	112.96	166.84	592.49	94.355	83.859
357	1.0987	8.5065	24126	97.512	113.46	168.09	581.26	92.528	83.216
359	1.1461	8.4517	24462	98.435	113.97	169.39	569.97	90.722	82.578
361	1.1950	8.3962	24800	99.359	114.48	170.74	558.63	88.935	81.946
363	1.2454	8.3397	25141	100.28	115.00	172.14	547.22	87.167	81.320
365	1.2974	8.2822	25485	101.21	115.52	173.60	535.75	85.417	80.700
367	1.3509	8.2237	25831	102.14	116.05	175.13	524.21	83.684	80.084
369	1.4061	8.1642	26180	103.07	116.58	176.72	512.59	81.967	79.475
371	1.4629	8.1035	26531	104.00	117.12	178.40	500.90	80.265	78.870
373	1.5214	8.0416	26886	104.93	117.67	180.16	489.12	78.577	78.271
375	1.5816	7.9783	27243	105.87	118.23	182.02	477.25	76.902	77.676
377	1.6436	7.9138	27603	106.81	118.79	184.00	465.28	75.238	77.086
379	1.7074	7.8477	27967	107.75	119.37	186.09	453.21	73.585	76.501
381	1.7730	7.7801	28334	108.69	119.95	188.33	441.03	71.942	75.921
383	1.8404	7.7108	28705	109.64	120.55	190.72	428.73	70.307	75.344
385	1.9098	7.6397	29080	110.59	121.16	193.31	416.32	68.679	74.772
387	1.9811	7.5666	29458	111.55	121.79	196.10	403.77	67.056	74.203
389	2.0544	7.4913	29841	112.51	122.42	199.15	391.08	65.437	73.638
391	2.1298	7.4137	30228	113.48	123.08	202.48	378.24	63.820	73.077
393	2.2072	7.3335	30621	114.45	123.75	206.17	365.25	62.203	72.519
395	2.2868	7.2504	31018	115.43	124.45	210.28	352.08	60.583	71.964
397	2.3686	7.1642	31421	116.42	125.16	214.89	338.74	58.958	71.412
399	2.4526	7.0743	31831	117.42	125.90	220.14	325.20	57.324	70.864
401	2.5389	6.9805	32248	118.43	126.67	226.18	311.45	55.678	70.319
403	2.6276	6.8820	32672	119.46	127.47	233.23	297.48	54.014	69.779
405	2.7187	6.7782	33105	120.49	128.31	241.60	283.26	52.328	69.245
407	2.8124	6.6682	33549	121.55	129.19	251.74	268.78	50.612	68.720
409	2.9087	6.5506	34004	122.63	130.12	264.33	254.01	48.856	68.209
411	3.0077	6.4239	34474	123.74	131.11	280.44	238.91	47.047	67.721
413	3.1095	6.2858	34962	124.89	132.18	301.89	223.46	45.168	67.274
415	3.2142	6.1328	35473	126.08	133.34	331.95	207.59	43.192	66.904
417	3.3219	5.9597	36014	127.34	134.63	377.22	191.25	41.080	66.689
419	3.4329	5.7569	36601	128.70	136.13	453.23	174.33	38.761	66.824
421	3.5474	5.5057	37261	130.22	137.97	607.03	156.63	36.101	67.898
423	3.6656	5.1554	38071	132.09	140.57	1074.8	137.67	32.776	72.300
425	3.7881	4.3042	39674	135.81	147.29	21816	114.85	27.096	137.01
425.12	3.7957	4.0037	40191	137.02	149.26	648340	112.67	25.373	501.00

TABLE 2 Thermophysical Properties of Normal Butane Vapor at Vapor-LIquid Equilibrium

T K	p MPa	ρ mol·l^{-1}	H J·mol^{-1}	S J·mol^{-1}·K^{-1}	C_v J·mol^{-1}·K^{-1}	C_p J·mol^{-1}·K^{-1}	c m·s^{-1}	η μPa·s	λ mW·m^{-1}·K^{-1}
135	6.7910E-07	6.0501E-07	23611	186.53	56.015	64.330	148.92	3.3445	4.8593
137	9.8726E-07	8.6672E-07	23740	184.37	56.434	64.748	149.95	3.3955	4.9511
139	1.4181E-06	1.2270E-06	23869	182.30	56.845	65.160	150.97	3.4464	5.0443
141	2.0137E-06	1.7177E-06	24000	180.32	57.250	65.565	151.98	3.4973	5.1387
143	2.8282E-06	2.3787E-06	24132	178.42	57.649	65.964	152.99	3.5481	5.2343
145	3.9306E-06	3.2603E-06	24264	176.60	58.042	66.357	153.99	3.5989	5.3313
147	5.4080E-06	4.4248E-06	24397	174.86	58.430	66.745	154.98	3.6497	5.4295
149	7.3695E-06	5.9487E-06	24531	173.19	58.813	67.129	155.97	3.7005	5.5291
151	9.9501E-06	7.9255E-06	24666	171.59	59.193	67.509	156.95	3.7512	5.6299
153	1.3316E-05	1.0468E-05	24801	170.06	59.568	67.885	157.93	3.8020	5.7319
155	1.7670E-05	1.3712E-05	24937	168.59	59.941	68.258	158.89	3.8526	5.8353
157	2.3258E-05	1.7818E-05	25074	167.19	60.310	68.628	159.85	3.9033	5.9400
159	3.0374E-05	2.2977E-05	25211	165.84	60.677	68.996	160.81	3.9539	6.0459
161	3.9370E-05	2.9414E-05	25350	164.54	61.042	69.361	161.76	4.0045	6.1531
163	5.0664E-05	3.7388E-05	25488	163.30	61.406	69.726	162.70	4.0550	6.2616
165	6.4747E-05	4.7203E-05	25628	162.12	61.768	70.089	163.63	4.1055	6.3713
167	8.2193E-05	5.9206E-05	25768	160.98	62.129	70.452	164.56	4.1560	6.4824
169	0.00010367	7.3797E-05	25909	159.89	62.489	70.814	165.48	4.2064	6.5947
171	0.00012996	9.1430E-05	26051	158.84	62.850	71.177	166.40	4.2568	6.7083
173	0.00016194	0.00011262	26193	157.84	63.210	71.540	167.31	4.3072	6.8231
175	0.00020064	0.00013795	26337	156.88	63.571	71.903	168.21	4.3575	6.9392
177	0.00024721	0.00016806	26480	155.96	63.933	72.268	169.10	4.4077	7.0566
179	0.00030297	0.00020368	26625	155.09	64.296	72.634	169.99	4.4579	7.1753
181	0.00036941	0.00024562	26770	154.24	64.660	73.002	170.87	4.5081	7.2952
183	0.00044817	0.00029476	26915	153.44	65.025	73.372	171.75	4.5582	7.4164
185	0.00054113	0.00035209	27062	152.67	65.393	73.744	172.61	4.6082	7.5389
187	0.00065035	0.00041869	27208	151.93	65.762	74.119	173.47	4.6582	7.6626
189	0.00077813	0.00049572	27356	151.22	66.134	74.497	174.32	4.7082	7.7876
191	0.00092700	0.00058446	27504	150.55	66.508	74.878	175.17	4.7580	7.9138
193	0.0010997	0.00068631	27653	149.91	66.885	75.263	176.01	4.8078	8.0413
195	0.0012994	0.00080276	27802	149.29	67.264	75.651	176.83	4.8576	8.1701
197	0.0015293	0.00093542	27952	148.71	67.647	76.044	177.66	4.9072	8.3000
199	0.0017931	0.0010860	28103	148.15	68.033	76.440	178.47	4.9568	8.4313
201	0.0020948	0.0012564	28254	147.61	68.423	76.841	179.27	5.0063	8.5638
203	0.0024385	0.0014486	28406	147.10	68.815	77.246	180.07	5.0558	8.6975
205	0.0028290	0.0016647	28558	146.62	69.212	77.657	180.85	5.1051	8.8324
207	0.0032710	0.0019069	28711	146.16	69.612	78.072	181.63	5.1544	8.9686
209	0.0037700	0.0021776	28865	145.72	70.017	78.492	182.40	5.2036	9.1061
211	0.0043316	0.0024792	29019	145.30	70.425	78.918	183.15	5.2527	9.2448
213	0.0049618	0.0028145	29173	144.91	70.838	79.349	183.90	5.3018	9.3847
215	0.0056671	0.0031862	29328	144.53	71.254	79.787	184.64	5.3507	9.5258
217	0.0064543	0.0035973	29484	144.18	71.675	80.229	185.37	5.3995	9.6682
219	0.0073306	0.0040506	29640	143.84	72.101	80.678	186.08	5.4483	9.8118
221	0.0083037	0.0045495	29797	143.52	72.530	81.134	186.79	5.4970	9.9567
223	0.0093815	0.0050973	29954	143.22	72.965	81.595	187.48	5.5456	10.103
225	0.010573	0.0056973	30111	142.94	73.403	82.063	188.16	5.5940	10.250
227	0.011886	0.0063533	30269	142.67	73.847	82.537	188.83	5.6424	10.399
229	0.013331	0.0070689	30428	142.42	74.295	83.018	189.49	5.6907	10.548
231	0.014917	0.0078481	30587	142.19	74.747	83.506	190.13	5.7389	10.699
233	0.016655	0.0086947	30746	141.97	75.205	84.001	190.77	5.7870	10.852
235	0.018554	0.0096130	30906	141.76	75.667	84.503	191.39	5.8351	11.005
237	0.020627	0.010607	31066	141.57	76.134	85.011	191.99	5.8830	11.160
239	0.022885	0.011682	31227	141.40	76.605	85.527	192.58	5.9309	11.316
241	0.025338	0.012841	31388	141.23	77.081	86.051	193.16	5.9786	11.473
243	0.028001	0.014090	31549	141.08	77.562	86.581	193.72	6.0263	11.632
245	0.030885	0.015434	31711	140.94	78.047	87.120	194.27	6.0739	11.792
247	0.034005	0.016877	31873	140.82	78.537	87.665	194.80	6.1214	11.953
249	0.037372	0.018424	32035	140.70	79.032	88.219	195.32	6.1689	12.116
251	0.041002	0.020081	32198	140.60	79.531	88.780	195.82	6.2163	12.280
253	0.044908	0.021853	32361	140.51	80.035	89.349	196.30	6.2636	12.445
255	0.049106	0.023746	32524	140.42	80.544	89.926	196.77	6.3109	12.611
257	0.053611	0.025765	32688	140.35	81.057	90.511	197.22	6.3581	12.779
259	0.058438	0.027915	32852	140.29	81.575	91.104	197.65	6.4053	12.949
261	0.063604	0.030204	33016	140.24	82.097	91.705	198.07	6.4524	13.119
263	0.069124	0.032636	33180	140.19	82.623	92.315	198.47	6.4995	13.292
265	0.075015	0.035219	33345	140.16	83.154	92.933	198.85	6.5466	13.465
267	0.081295	0.037958	33509	140.13	83.689	93.560	199.21	6.5937	13.640
269	0.087981	0.040860	33674	140.11	84.228	94.195	199.55	6.6407	13.817
271	0.095090	0.043931	33840	140.10	84.772	94.839	199.87	6.6878	13.995
273	0.10264	0.047179	34005	140.10	85.320	95.492	200.18	6.7348	14.175
275	0.11065	0.050611	34170	140.11	85.872	96.154	200.46	6.7819	14.357
277	0.11914	0.054232	34336	140.12	86.428	96.825	200.72	6.8290	14.540
279	0.12813	0.058052	34502	140.14	86.988	97.506	200.96	6.8761	14.725
281	0.13763	0.062077	34667	140.17	87.552	98.196	201.18	6.9233	14.912

TABLE 2 *Continued*

T K	p MPa	ρ mol·l^{-1}	H J·mol^{-1}	S J·mol^{-1}·K^{-1}	C_v J·mol^{-1}·K^{-1}	C_p J·mol^{-1}·K^{-1}	c m·s^{-1}	η μPa·s	λ mW·m^{-1}·K^{-1}
283	0.14768	0.066316	34833	140.20	88.120	98.896	201.38	6.9706	15.100
285	0.15828	0.070775	34999	140.24	88.692	99.605	201.56	7.0180	15.291
287	0.16945	0.075463	35165	140.29	89.267	100.33	201.71	7.0654	15.483
289	0.18122	0.080389	35331	140.34	89.847	101.06	201.85	7.1130	15.677
291	0.19362	0.085560	35497	140.40	90.430	101.80	201.96	7.1606	15.874
293	0.20665	0.090986	35663	140.46	91.017	102.55	202.04	7.2084	16.072
295	0.22034	0.096676	35829	140.53	91.607	103.31	202.10	7.2564	16.273
297	0.23471	0.10264	35995	140.60	92.201	104.08	202.14	7.3045	16.476
299	0.24979	0.10888	36161	140.68	92.798	104.87	202.15	7.3529	16.681
301	0.26559	0.11542	36326	140.76	93.399	105.67	202.14	7.4014	16.888
303	0.28214	0.12226	36492	140.85	94.004	106.48	202.10	7.4502	17.099
305	0.29946	0.12941	36657	140.94	94.611	107.30	202.04	7.4992	17.311
307	0.31757	0.13689	36823	141.03	95.222	108.14	201.95	7.5485	17.527
309	0.33650	0.14470	36988	141.13	95.837	108.99	201.83	7.5981	17.745
311	0.35627	0.15286	37152	141.23	96.454	109.85	201.69	7.6480	17.966
313	0.37690	0.16138	37317	141.34	97.075	110.73	201.52	7.6983	18.190
315	0.39842	0.17027	37481	141.45	97.699	111.63	201.32	7.7490	18.417
317	0.42084	0.17954	37645	141.56	98.327	112.54	201.09	7.8001	18.647
319	0.44420	0.18921	37809	141.68	98.957	113.47	200.83	7.8516	18.881
321	0.46852	0.19929	37972	141.80	99.591	114.41	200.54	7.9036	19.118
323	0.49382	0.20980	38135	141.92	100.23	115.38	200.22	7.9561	19.359
325	0.52012	0.22075	38297	142.04	100.87	116.36	199.87	8.0091	19.604
327	0.54746	0.23215	38459	142.17	101.51	117.36	199.48	8.0628	19.853
329	0.57585	0.24403	38620	142.30	102.16	118.39	199.07	8.1171	20.105
331	0.60532	0.25640	38781	142.43	102.81	119.44	198.62	8.1720	20.363
333	0.63590	0.26929	38941	142.56	103.46	120.51	198.14	8.2277	20.624
335	0.66761	0.28270	39100	142.69	104.12	121.61	197.62	8.2842	20.890
337	0.70048	0.29666	39259	142.83	104.78	122.73	197.06	8.3415	21.162
339	0.73453	0.31119	39417	142.96	105.44	123.89	196.47	8.3997	21.438
341	0.76979	0.32632	39574	143.10	106.10	125.07	195.85	8.4589	21.720
343	0.80629	0.34206	39730	143.24	106.76	126.28	195.18	8.5191	22.007
345	0.84406	0.35845	39886	143.37	107.43	127.53	194.48	8.5804	22.300
347	0.88311	0.37550	40040	143.51	108.10	128.81	193.73	8.6428	22.600
349	0.92348	0.39326	40193	143.65	108.76	130.13	192.95	8.7066	22.906
351	0.96521	0.41175	40346	143.79	109.43	131.49	192.12	8.7717	23.219
353	1.0083	0.43100	40496	143.93	110.10	132.90	191.25	8.8383	23.539
355	1.0528	0.45105	40646	144.07	110.77	134.35	190.34	8.9064	23.867
357	1.0987	0.47194	40794	144.20	111.45	135.86	189.38	8.9763	24.202
359	1.1461	0.49370	40941	144.34	112.12	137.44	188.37	9.0479	24.547
361	1.1950	0.51639	41086	144.47	112.80	139.08	187.32	9.1216	24.900
363	1.2454	0.54004	41229	144.60	113.48	140.79	186.22	9.1973	25.263
365	1.2974	0.56471	41370	144.73	114.17	142.59	185.07	9.2754	25.636
367	1.3509	0.59046	41509	144.86	114.86	144.49	183.86	9.3560	26.020
369	1.4061	0.61735	41646	144.98	115.56	146.49	182.61	9.4392	26.415
371	1.4629	0.64544	41781	145.10	116.27	148.61	181.29	9.5254	26.823
373	1.5214	0.67480	41913	145.22	116.99	150.87	179.93	9.6148	27.244
375	1.5816	0.70553	42043	145.33	117.73	153.28	178.50	9.7077	27.680
377	1.6436	0.73770	42169	145.44	118.47	155.85	177.01	9.8044	28.131
379	1.7074	0.77141	42293	145.55	119.24	158.62	175.46	9.9053	28.599
381	1.7730	0.80678	42413	145.64	120.01	161.61	173.84	10.011	29.085
383	1.8404	0.84392	42529	145.73	120.81	164.85	172.16	10.121	29.592
385	1.9098	0.88298	42641	145.82	121.62	168.37	170.41	10.237	30.121
387	1.9811	0.92411	42750	145.89	122.46	172.23	168.58	10.360	30.675
389	2.0544	0.96749	42853	145.96	123.31	176.46	166.69	10.489	31.257
391	2.1298	1.0133	42951	146.02	124.18	181.14	164.71	10.626	31.869
393	2.2072	1.0618	43044	146.06	125.08	186.36	162.65	10.772	32.516
395	2.2868	1.1133	43130	146.09	126.00	192.20	160.51	10.927	33.203
397	2.3686	1.1681	43209	146.11	126.95	198.82	158.28	11.094	33.936
399	2.4526	1.2266	43281	146.12	127.92	206.37	155.97	11.274	34.723
401	2.5389	1.2891	43344	146.10	128.93	215.09	153.55	11.468	35.573
403	2.6276	1.3564	43396	146.07	129.97	225.31	151.04	11.680	36.497
405	2.7187	1.4291	43437	146.01	131.06	237.46	148.41	11.913	37.514
407	2.8124	1.5080	43465	145.92	132.19	252.18	145.68	12.170	38.644
409	2.9087	1.5944	43476	145.79	133.38	270.43	142.83	12.456	39.918
411	3.0077	1.6898	43469	145.63	134.65	293.73	139.85	12.780	41.380
413	3.1095	1.7962	43438	145.41	136.00	324.58	136.74	13.151	43.096
415	3.2142	1.9169	43376	145.13	137.48	367.52	133.47	13.584	45.175
417	3.3219	2.0567	43275	144.75	139.12	431.61	130.02	14.103	47.804
419	3.4329	2.2240	43115	144.24	141.00	538.03	126.37	14.751	51.355
421	3.5474	2.4360	42861	143.52	143.26	750.33	122.47	15.617	56.723
423	3.6656	2.7399	42419	142.37	146.19	1383.4	118.16	16.975	67.053
425	3.7881	3.5364	41020	138.97	150.45	26744	112.63	21.993	151.07
425.12	3.7957	3.8414	40474	137.68	149.99	685360	112.3	24.281	522.98

TABLE 3 Thermophysical Properties of Normal Butane Along Isobars

T K	ρ mol·l⁻¹	*H* J·mol⁻¹	*S* J·mol⁻¹·K⁻¹	C_v J·mol⁻¹·K⁻¹	C_p J·mol⁻¹·K⁻¹	*c* m·s⁻¹	η μPa·s	λ mW·m⁻¹·K⁻¹
Pressure = 0.1 MPa								
140	12.564	-4628.2	-22.780	83.808	114.91	1793.4	1941.2	174.87
150	12.404	-3476.5	-14.834	83.837	115.44	1730.2	1387.9	171.22
160	12.243	-2319.2	-7.3651	83.924	116.04	1669.6	1048.8	167.26
170	12.083	-1155.3	-0.30888	84.123	116.77	1610.6	827.73	163.04
180	11.922	16.586	6.3890	84.464	117.63	1552.6	675.38	158.62
190	11.760	1197.9	12.776	84.964	118.65	1495.4	565.07	154.06
200	11.597	2390.2	18.891	85.632	119.85	1438.8	481.85	149.40
210	11.433	3595.4	24.771	86.471	121.22	1382.6	416.93	144.68
220	11.267	4815.3	30.446	87.477	122.79	1326.8	364.91	139.93
230	11.098	6051.8	35.942	88.646	124.54	1271.4	322.32	135.18
240	10.927	7306.7	41.283	89.967	126.49	1216.2	286.83	130.46
250	10.753	8582.2	46.489	91.432	128.63	1161.4	256.82	125.81
260	10.576	9880.0	51.579	93.028	130.97	1106.7	231.11	121.21
270	10.394	11202	56.569	94.744	133.52	1052.3	208.84	116.71
272.31	10.351	11512	57.711	95.158	134.15	1039.7	204.10	115.68
272.31	0.046045	33948	140.10	85.131	95.267	200.07	6.7187	14.113
280	0.044602	34686	142.77	86.833	96.765	203.31	6.9161	14.821
290	0.042873	35664	146.21	89.128	98.841	207.36	7.1707	15.768
300	0.041289	36663	149.59	91.498	101.03	211.28	7.4231	16.747
310	0.039830	37685	152.94	93.928	103.32	215.06	7.6736	17.758
320	0.038480	38730	156.26	96.404	105.67	218.74	7.9223	18.800
330	0.037225	39799	159.55	98.913	108.08	222.31	8.1695	19.873
340	0.036056	40892	162.81	101.45	110.52	225.80	8.4153	20.978
350	0.034963	42009	166.05	103.99	112.99	229.21	8.6598	22.115
360	0.033938	43152	169.27	106.54	115.48	232.55	8.9031	23.284
370	0.032975	44319	172.47	109.10	117.98	235.82	9.1453	24.484
380	0.032067	45511	175.65	111.64	120.48	239.03	9.3864	25.716
390	0.031211	46728	178.81	114.18	122.97	242.19	9.6266	26.980
400	0.030400	47970	181.95	116.69	125.45	245.29	9.8658	28.275
410	0.029633	49237	185.08	119.19	127.91	248.35	10.104	29.602
420	0.028904	50529	188.19	121.67	130.36	251.36	10.342	30.962
430	0.028211	51844	191.29	124.12	132.78	254.33	10.578	32.353
440	0.027552	53184	194.37	126.54	135.18	257.25	10.814	33.775
450	0.026924	54548	197.43	128.93	137.55	260.14	11.050	35.230
460	0.026324	55935	200.48	131.30	139.90	262.99	11.284	36.717
470	0.025751	57346	203.52	133.63	142.21	265.81	11.518	38.235
480	0.025203	58779	206.53	135.93	144.49	268.59	11.751	39.786
490	0.024679	60235	209.54	138.20	146.75	271.34	11.983	41.368
500	0.024176	61714	212.52	140.43	148.97	274.06	12.215	42.982
510	0.023694	63215	215.49	142.63	151.16	276.76	12.446	44.629
520	0.023230	64737	218.45	144.80	153.32	279.42	12.677	46.307
530	0.022785	66281	221.39	146.94	155.44	282.05	12.907	48.017
540	0.022357	67846	224.32	149.05	157.54	284.66	13.136	49.759
550	0.021945	69432	227.23	151.12	159.60	287.25	13.365	51.533
560	0.021548	71038	230.12	153.16	161.64	289.80	13.593	53.339
570	0.021165	72664	233.00	155.17	163.64	292.34	13.821	55.177
Pressure = 1 MPa								
140	12.570	-4569.4	-22.871	83.863	114.88	1796.8	1956.9	175.10
150	12.411	-3418.0	-14.927	83.887	115.40	1733.9	1399.8	171.49
160	12.251	-2261.1	-7.4611	83.972	116.00	1673.5	1058.0	167.55
170	12.091	-1097.6	-0.40765	84.169	116.72	1614.8	835.15	163.36
180	11.931	73.712	6.2871	84.509	117.57	1557.2	681.47	158.97
190	11.770	1254.4	12.670	85.009	118.58	1500.3	570.19	154.44
200	11.608	2446.0	18.782	85.677	119.77	1443.9	486.22	149.81
210	11.444	3650.3	24.658	86.516	121.13	1388.1	420.72	145.12
220	11.279	4869.2	30.328	87.522	122.68	1332.7	368.24	140.40
230	11.112	6104.5	35.819	88.690	124.41	1277.6	325.29	135.68
240	10.942	7358.0	41.153	90.012	126.34	1222.9	289.51	130.99
250	10.770	8631.8	46.353	91.477	128.45	1168.5	259.27	126.35
260	10.594	9927.7	51.435	93.073	130.76	1114.4	233.39	121.79
270	10.413	11248	56.417	94.789	133.27	1060.6	210.98	117.31
280	10.229	12594	61.312	96.613	135.98	1006.9	191.37	112.93
290	10.038	13968	66.134	98.535	138.92	953.24	174.03	108.66
300	9.8412	15373	70.896	100.54	142.09	899.57	158.55	104.51
310	9.6362	16811	75.611	102.63	145.54	845.68	144.60	100.48
320	9.4218	18285	80.290	104.79	149.32	791.34	131.90	96.580
330	9.1956	19799	84.948	107.03	153.51	736.22	120.22	92.797
340	8.9549	21357	89.599	109.33	158.25	679.85	109.37	89.127
350	8.6953	22966	94.264	111.73	163.78	621.53	99.151	85.555
352.62	8.6234	23397	95.491	112.37	165.40	605.80	96.558	84.632
352.62	0.42728	40468	143.90	109.97	132.62	191.42	8.8255	23.478
360	0.40955	41443	146.64	111.18	131.74	197.12	9.0220	24.301
370	0.38891	42758	150.24	113.03	131.50	204.07	9.2847	25.466