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Viscosity Measurements on Gaseous Propane: Re-evaluation

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Measurements of the viscosity (η) of propane by Wilhelm and Vogel, performed by means of a vibrating-wire viscometer with a freely suspended weight using measurements of temperature (T) and pressure (p) for the determination of the required density (ρ) with an older equation of state by Span and Wagner,[1] have been re-evaluated. The re-evaluation concerns the determination of the wire radius using an improved calibration as well as the calculation of the density by means of the recent equation of state by Lemmon et al.[2] The re-evaluated data are to be used together with new accurate $\eta\rho pT$ data[3] to test, particularly in the vicinity of the critical point, their performance in comparison with the viscosity surface correlation by Scalabrin et al.[4]

The recalibration of the old vibrating-wire viscometer was performed using a value for the radius of the wire that was newly determined using old measurements on argon[5] and the currently accepted value for the zero-density viscosity coefficient of argon derived by Vogel et al.[6] from an ab initio potential for argon on the basis of the kinetic theory of dilute gases ($\eta_{0,\mathrm{Ar},298.15\mathrm{K}} = 22.552\ \mu\mathrm{Pa\cdot s}$ with an uncertainty of $\pm$ 0.1 %).

The results reported in Table 1 of the previous paper of Wilhelm and Vogel were restricted to $\eta\rho p$ triples along the measured isotherms. In this correction, we include more details about the re-evaluated measurements in order to make the information comparable to that given for the new $\eta\rho pT$ measurements by Seibt et al.[3] The individual points were not exactly measured at the nominal temperature of an isotherm (T_{nom}) but could be kept within small deviations. The experimental viscosity data were adjusted to $\eta_{T_{\mathrm{nom}}}$ values at the nominal temperature using a Taylor series expansion restricted to the first power in temperature. For that purpose, the value of the temperature dependence for the low-density region, $(\partial\eta/\partial T)_\rho$ = (0.025 to 0.027) $\mu\mathrm{Pa\cdot s\cdot K^{-1}}$, determined experimentally by Vogel[7] for propane was used. Furthermore, it was assumed that the density values $\rho_{\mathrm{eos}(T,p)}$ calculated from the measured values for T and p using the equation of state by Lemmon et al.[2] and those for the isotherms are the same. As a consequence, the pressures $p_{T_{\mathrm{nom}},\rho_{\mathrm{eos}}}$ at the nominal temperature changed and were recalculated from the densities. The corrected and improved experimental $\eta\rho pT$ data from the earlier measurements of Wilhelm and Vogel on propane (seven isotherms at 298.15 K, 323.15 K, 348.15 K, 366.15 K, 373.15 K, 398.15 K, and 423.15 K) are summarized in Tables 1 to 7. It should be noted that some experimental points at the lowest densities could be influenced by the slip effect, and these values are marked in the tables.

The experimental results for each nominal isotherm for propane were correlated as a function of the reduced density ($\delta = \rho/\rho_{\mathrm{c,C_3H_8}}$) by means of a power-series representation in which the highest power (n) was restricted to 6 or lower depending on the density range and the reduced temperature ($\tau = T/T_{\mathrm{c,C_3H_8}}$):

Table 1. Corrected Experimental $\eta\rho pT$ Data for Propane at 298.15 K

T	p	$p_{298.15\mathrm{K},\rho_{\mathrm{eos}}}$	$\rho_{\mathrm{eos}(T,p)}$	η	$\eta_{298.15\mathrm{K}}$
K	MPa	MPa	$\mathrm{kg\cdot m^{-3}}$	$\mu\mathrm{Pa\cdot s}$	$\mu\mathrm{Pa\cdot s}$
298.21	0.039382	0.039374	0.70478	8.116[a]	8.114[a]
298.21	0.066942	0.066929	1.2033	8.119	8.117
298.21	0.093547	0.093528	1.6889	8.120	8.118
298.19	0.11053	0.11051	2.0012	8.118	8.117
298.21	0.12184	0.12182	2.2100	8.118	8.117
298.20	0.13585	0.13583	2.4700	8.117	8.116
298.21	0.15473	0.15470	2.8221	8.118	8.116
298.20	0.16719	0.16716	3.0559	8.117	8.116
298.18	0.17777	0.17775	3.2554	8.118	8.117
298.21	0.18944	0.18940	3.4756	8.115	8.114
298.21	0.20013	0.20008	3.6784	8.117	8.116
298.18	0.20911	0.20908	3.8499	8.116	8.115
298.21	0.22444	0.22439	4.1427	8.115	8.113
298.18	0.23895	0.23893	4.4224	8.116	8.115
298.21	0.25229	0.25223	4.6796	8.116	8.114
298.18	0.26413	0.26410	4.9102	8.114	8.113
298.21	0.28129	0.28123	5.2447	8.116	8.114
298.18	0.29872	0.29869	5.5879	8.115	8.115
298.18	0.33908	0.33904	6.3899	8.116	8.115
298.21	0.35154	0.35146	6.6393	8.116	8.115
298.18	0.36020	0.36016	6.8148	8.112	8.111
298.19	0.39256	0.39250	7.4721	8.117	8.116
298.19	0.42870	0.42864	8.2171	8.117	8.116
298.19	0.46202	0.46194	8.9138	8.118	8.117
298.19	0.49882	0.49874	9.6951	8.121	8.120
298.19	0.53009	0.53000	10.369	8.123	8.122
298.19	0.56644	0.56635	11.165	8.126	8.125
298.20	0.60516	0.60503	12.026	8.129	8.128
298.19	0.63960	0.63949	12.808	8.132	8.131
298.19	0.67731	0.67719	13.678	8.135	8.134
298.18	0.71567	0.71557	14.582	8.141	8.140
298.19	0.75229	0.75215	15.461	8.146	8.145
298.19	0.78826	0.78812	16.342	8.151	8.150
298.20	0.82490	0.82471	17.259	8.158	8.156
298.20	0.85910	0.85890	18.133	8.165	8.164
298.19	0.91615	0.91597	19.637	8.176	8.175

[a] Influenced by slip.

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Table 2. Corrected Experimental $\eta\rho pT$ Data for Propane at 323.15 K

T	p	$p_{323.15\mathrm{K},\rho_{\mathrm{eos}}}$	$\rho_{\mathrm{eos}(T,p)}$	η	$\eta_{323.15\mathrm{K}}$
K	MPa	MPa	kg·m^{-3}	μPa·s	μPa·s
323.19	0.050861	0.050854	0.83987	8.775[a]	8.774[a]
323.19	0.10250	0.10249	1.7036	8.791	8.789
323.19	0.12214	0.12212	2.0351	8.792	8.791
323.18	0.14081	0.14080	2.3519	8.793	8.793
323.18	0.16133	0.16131	2.7016	8.792	8.791
323.19	0.18177	0.18175	3.0519	8.794	8.793
323.19	0.19995	0.19992	3.3650	8.793	8.792
323.19	0.22094	0.22091	3.7286	8.795	8.794
323.18	0.24249	0.24246	4.1040	8.797	8.796
323.18	0.26057	0.26055	4.4208	8.796	8.795
323.19	0.28278	0.28274	4.8117	8.796	8.795
323.19	0.29931	0.29927	5.1043	8.798	8.797
323.19	0.32326	0.32321	5.5307	8.797	8.796
323.19	0.34137	0.34133	5.8552	8.799	8.798
323.19	0.35998	0.35993	6.1902	8.800	8.799
323.19	0.38153	0.38148	6.5805	8.801	8.800
323.19	0.40017	0.40011	6.9199	8.801	8.800
323.19	0.42515	0.42509	7.3778	8.804	8.803
323.19	0.46612	0.46605	8.1364	8.808	8.807
323.18	0.49369	0.49364	8.6525	8.811	8.810
323.18	0.53175	0.53169	9.3718	8.817	8.816
323.19	0.57440	0.57432	10.188	8.820	8.819
323.19	0.61344	0.61335	10.945	8.825	8.824
323.19	0.65097	0.65087	11.682	8.829	8.828
323.19	0.69023	0.69012	12.463	8.836	8.835
323.19	0.72953	0.72942	13.256	8.840	8.839
323.20	0.77581	0.77566	14.203	8.849	8.848
323.20	0.81123	0.81107	14.938	8.853	8.852
323.20	0.84968	0.84951	15.748	8.862	8.861
323.21	0.88543	0.88522	16.511	8.871	8.869
323.19	0.97078	0.97062	18.381	8.891	8.890
323.18	1.0047	1.0045	19.141	8.898	8.898
323.18	1.0651	1.0649	20.524	8.918	8.917
323.17	1.1316	1.1315	22.092	8.935	8.935
323.16	1.1925	1.1925	23.571	8.954	8.953
323.15	1.2285	1.2285	24.467	8.965	8.965
323.17	1.2817	1.2815	25.814	8.984	8.983
323.16	1.3313	1.3312	27.112	9.003	9.003
323.17	1.3879	1.3878	28.636	9.028	9.027
323.18	1.4212	1.4210	29.556	9.041	9.041
323.18	1.4714	1.4712	30.979	9.065	9.064
323.20	1.5375	1.5371	32.925	9.100	9.099
323.20	1.5906	1.5902	34.559	9.132	9.131
323.20	1.6122	1.6118	35.244	9.146	9.145
323.20	1.6321	1.6317	35.884	9.163	9.161

[a] Influenced by slip.

Table 3. Corrected Experimental $\eta\rho pT$ Data for Propane at 348.15 K

T	p	$p_{348.15\mathrm{K},\rho_{\mathrm{eos}}}$	$\rho_{\mathrm{eos}(T,p)}$	η	$\eta_{348.15\mathrm{K}}$
K	MPa	MPa	kg·m^{-3}	μPa·s	μPa·s
348.19	0.062611	0.062604	0.95951	9.434[a]	9.433[a]
348.19	0.10709	0.10708	1.6484	9.443	9.442
348.19	0.12044	0.12043	1.8563	9.443	9.442
348.19	0.14090	0.14088	2.1761	9.447	9.446
348.19	0.16500	0.16498	2.5545	9.450	9.449
348.19	0.18064	0.18062	2.8010	9.453	9.452
348.19	0.20030	0.20027	3.1120	9.452	9.451
348.19	0.22222	0.22219	3.4603	9.455	9.454
348.19	0.24272	0.24269	3.7875	9.459	9.458
348.19	0.26033	0.26030	4.0696	9.461	9.460
348.19	0.28118	0.28114	4.4051	9.463	9.462
348.20	0.30137	0.30132	4.7312	9.465	9.464
348.20	0.32368	0.32363	5.0933	9.467	9.465
348.20	0.34185	0.34179	5.3895	9.467	9.466
348.18	0.36108	0.36105	5.7047	9.469	9.468
348.18	0.38092	0.38088	6.0308	9.471	9.471
348.18	0.40111	0.40107	6.3641	9.472	9.471
348.18	0.43328	0.43324	6.8985	9.478	9.477
348.18	0.46689	0.46685	7.4607	9.483	9.482
348.18	0.50154	0.50149	8.0448	9.487	9.487
348.18	0.53746	0.53741	8.6555	9.492	9.491
348.18	0.56465	0.56459	9.1209	9.496	9.495
348.18	0.59846	0.59840	9.7038	9.502	9.501
348.19	0.64635	0.64627	10.538	9.511	9.510
348.18	0.69021	0.69014	11.310	9.516	9.515
348.19	0.73667	0.73657	12.137	9.526	9.525
348.19	0.77796	0.77786	12.880	9.535	9.534
348.19	0.81826	0.81815	13.613	9.542	9.541
348.19	0.84955	0.84943	14.187	9.548	9.547
348.19	0.88955	0.88942	14.929	9.555	9.554
348.19	0.89017	0.89004	14.940	9.556	9.554
348.18	0.96406	0.96396	16.332	9.574	9.573
348.18	0.98589	0.98578	16.748	9.580	9.579
348.18	1.0094	1.0093	17.200	9.585	9.585
348.19	1.0583	1.0582	18.147	9.599	9.598
348.19	1.1042	1.1040	19.048	9.612	9.611
348.20	1.1555	1.1553	20.071	9.626	9.625
348.20	1.2034	1.2031	21.039	9.640	9.639
348.20	1.2527	1.2524	22.052	9.658	9.657
348.17	1.3012	1.3011	23.069	9.670	9.670
348.18	1.3566	1.3564	24.243	9.691	9.690
348.18	1.4059	1.4058	25.309	9.710	9.710
348.18	1.4418	1.4417	26.095	9.723	9.722
348.19	1.4760	1.4758	26.853	9.736	9.735
348.18	1.5556	1.5554	28.658	9.770	9.769
348.18	1.5985	1.5983	29.651	9.790	9.789
348.17	1.6586	1.6585	31.076	9.815	9.815
348.16	1.7159	1.7159	32.465	9.844	9.844
348.14	1.7597	1.7597	33.550	9.867	9.867
348.14	1.8231	1.8231	35.155	9.900	9.900
348.14	1.8934	1.8935	36.990	9.940	9.940
348.14	1.9774	1.9775	39.265	9.991	9.992
348.15	2.0388	2.0388	40.986	10.030	10.030
348.15	2.1077	2.1077	42.989	10.079	10.079

Table 3. Continued

T (K)	p (MPa)	$p_{348.15K,\rho_{eos}}$ (MPa)	$\rho_{eos(T,p)}$ ($kg \cdot m^{-3}$)	η ($\mu Pa \cdot s$)	$\eta_{348.15K}$ ($\mu Pa \cdot s$)
348.15	2.1859	2.1859	45.364	10.140	10.140
348.15	2.2450	2.2450	47.233	10.188	10.188
348.15	2.3255	2.3255	49.902	10.259	10.259
348.15	2.3933	2.3933	52.269	10.322	10.322
348.15	2.4585	2.4585	54.669	10.393	10.393
348.15	2.5270	2.5270	57.339	10.473	10.473
348.15	2.5891	2.5891	59.918	10.556	10.556
348.15	2.6553	2.6553	62.856	10.650	10.650
348.15	2.7010	2.7010	65.022	10.722	10.722
348.14	2.7313	2.7314	66.542	10.774	10.774

[a] Influenced by slip.

Table 4. Corrected Experimental $\eta \rho p T$ Data for Propane at 366.15 K

T (K)	p (MPa)	$p_{366.15K,\rho_{eos}}$ (MPa)	$\rho_{eos(T,p)}$ ($kg \cdot m^{-3}$)	η ($\mu Pa \cdot s$)	$\eta_{366.15K}$ ($\mu Pa \cdot s$)
366.13	0.063480	0.063483	0.92438	9.908[a]	9.908[a]
366.13	0.10203	0.10203	1.4905	9.916	9.917
366.13	0.12049	0.12050	1.7630	9.918	9.919
366.16	0.13722	0.13722	2.0105	9.927	9.927
366.14	0.14318	0.14318	2.0989	9.920	9.920
366.14	0.16082	0.16082	2.3610	9.924	9.924
366.14	0.16574	0.16575	2.4344	9.922	9.923
366.14	0.18260	0.18261	2.6859	9.924	9.925
366.14	0.19838	0.19838	2.9218	9.927	9.927
366.14	0.22005	0.22006	3.2471	9.932	9.932
366.14	0.23016	0.23016	3.3992	9.929	9.929
366.14	0.23976	0.23977	3.5440	9.932	9.932
366.14	0.26090	0.26091	3.8635	9.932	9.933
366.14	0.27875	0.27876	4.1343	9.937	9.937
366.14	0.30001	0.30002	4.4579	9.938	9.939
366.14	0.30533	0.30534	4.5390	9.937	9.938
366.14	0.31849	0.31850	4.7402	9.941	9.941
366.14	0.34467	0.34468	5.1417	9.944	9.945
366.14	0.35901	0.35902	5.3624	9.946	9.947
366.15	0.37821	0.37821	5.6587	9.947	9.947
366.14	0.37847	0.37848	5.6629	9.949	9.949
366.14	0.40417	0.40418	6.0613	9.951	9.952
366.14	0.42051	0.42052	6.3156	9.954	9.955
366.14	0.43365	0.43366	6.5206	9.956	9.956
366.14	0.43794	0.43796	6.5878	9.957	9.958
366.14	0.46355	0.46356	6.9891	9.959	9.959
366.14	0.48034	0.48036	7.2534	9.962	9.962
366.14	0.50260	0.50261	7.6050	9.967	9.967
366.14	0.53427	0.53429	8.1077	9.972	9.972
366.15	0.55503	0.55503	8.4386	9.974	9.974
366.14	0.55907	0.55909	8.5036	9.976	9.976
366.13	0.59044	0.59048	9.0072	9.981	9.981
366.13	0.61673	0.61677	9.4315	9.989	9.990
366.15	0.64581	0.64581	9.9027	9.988	9.988
366.13	0.65172	0.65176	9.9996	9.992	9.993

Table 4. Continued

T (K)	p (MPa)	$p_{366.15K,\rho_{eos}}$ (MPa)	$\rho_{eos(T,p)}$ ($kg \cdot m^{-3}$)	η ($\mu Pa \cdot s$)	$\eta_{366.15K}$ ($\mu Pa \cdot s$)
366.14	0.69712	0.69714	10.742	9.999	9.999
366.14	0.75126	0.75128	11.637	10.009	10.010
366.16	0.75559	0.75557	11.708	10.007	10.007
366.14	0.82041	0.82044	12.794	10.025	10.025
366.16	0.84809	0.84806	13.261	10.027	10.026
366.14	0.84914	0.84917	13.280	10.029	10.029
366.15	0.88069	0.88069	13.816	10.039	10.039
366.15	0.95539	0.95539	15.101	10.048	10.048
366.15	0.98588	0.98588	15.632	10.056	10.056
366.15	1.0298	1.0298	16.402	10.065	10.065
366.15	1.0979	1.0979	17.613	10.085	10.085
366.15	1.1362	1.1362	18.301	10.094	10.094
366.15	1.1708	1.1708	18.928	10.103	10.103
366.15	1.2452	1.2452	20.295	10.125	10.125
366.15	1.3048	1.3048	21.407	10.142	10.142
366.12	1.3621	1.3623	22.496	10.159	10.160
366.12	1.4287	1.4288	23.776	10.182	10.183
366.12	1.4940	1.4942	25.054	10.206	10.207
366.12	1.5640	1.5642	26.449	10.232	10.233
366.12	1.6327	1.6329	27.844	10.257	10.258
366.12	1.6943	1.6945	29.117	10.283	10.284
366.13	1.7509	1.7510	30.304	10.308	10.309
366.14	1.8632	1.8633	32.725	10.359	10.360
366.14	1.9236	1.9237	34.062	10.388	10.388
366.14	1.9775	1.9776	35.277	10.415	10.415
366.14	2.0473	2.0473	36.882	10.450	10.450
366.14	2.1247	2.1248	38.709	10.496	10.497
366.14	2.1774	2.1774	39.980	10.526	10.526
366.12	2.2195	2.2198	41.020	10.553	10.554
366.11	2.3138	2.3142	43.399	10.609	10.611
366.11	2.3705	2.3709	44.871	10.653	10.654
366.12	2.4406	2.4409	46.735	10.705	10.706
366.12	2.5104	2.5108	48.653	10.758	10.758
366.13	2.5693	2.5695	50.312	10.806	10.806
366.13	2.6227	2.6230	51.862	10.850	10.851
366.14	2.6980	2.6982	54.109	10.921	10.921
366.15	2.7596	2.7596	56.011	10.974	10.974
366.15	2.8306	2.8306	58.286	11.049	11.049
366.15	2.9194	2.9194	61.269	11.145	11.145
366.15	2.9806	2.9806	63.419	11.215	11.215
366.13	3.0484	3.0488	65.917	11.305	11.305
366.12	3.1078	3.1084	68.200	11.393	11.394
366.13	3.1714	3.1718	70.743	11.478	11.479
366.08	3.2574	3.2588	74.449	11.620	11.621
366.10	3.3142	3.3153	77.010	11.713	11.714
366.10	3.3670	3.3681	79.537	11.825	11.827
366.15	3.4159	3.4159	81.939	11.921	11.921
366.15	3.4846	3.4846	85.635	12.077	12.077
366.15	3.5441	3.5441	89.107	12.223	12.223
366.15	3.5974	3.5974	92.472	12.382	12.382
366.19	3.6427	3.6415	95.489	12.530	12.529
366.13	3.6903	3.6909	99.157	12.697	12.697
366.15	3.7038	3.7038	100.17	12.762	12.762
366.16	3.7483	3.7480	103.90	12.933	12.933
366.18	3.7977	3.7967	108.52	13.166	13.165
366.19	3.8343	3.8328	112.42	13.361	13.360

Table 4. Continued

T	p	$p_{366.15\mathrm{K},\rho_{\mathrm{eos}}}$	$\rho_{\mathrm{eos}(T,p)}$	η	$\eta_{366.15\mathrm{K}}$
K	MPa	MPa	$\mathrm{kg \cdot m^{-3}}$	$\mu\mathrm{Pa \cdot s}$	$\mu\mathrm{Pa \cdot s}$
366.20	3.8694	3.8675	116.68	13.585	13.584

[a] Influenced by slip.

Table 5. Corrected Experimental $\eta\rho pT$ Data for Propane at 373.15 K

T	p	$p_{373.15\mathrm{K},\rho_{\mathrm{eos}}}$	$\rho_{\mathrm{eos}(T,p)}$	η	$\eta_{373.15\mathrm{K}}$
K	MPa	MPa	$\mathrm{kg \cdot m^{-3}}$	$\mu\mathrm{Pa \cdot s}$	$\mu\mathrm{Pa \cdot s}$
373.08	0.099279	0.099298	1.4223	10.095[a]	10.097[a]
373.08	0.12201	0.12204	1.7512	10.102	10.104
373.08	0.14278	0.14281	2.0526	10.103	10.105
373.08	0.16327	0.16330	2.3510	10.109	10.110
373.08	0.18263	0.18267	2.6340	10.110	10.112
373.08	0.20377	0.20381	2.9439	10.112	10.114
373.08	0.22131	0.22135	3.2017	10.115	10.117
373.08	0.24277	0.24281	3.5183	10.118	10.120
373.08	0.26560	0.26565	3.8564	10.123	10.125
373.08	0.28932	0.28937	4.2088	10.126	10.128
373.08	0.31154	0.31160	4.5404	10.130	10.131
373.09	0.32964	0.32969	4.8113	10.132	10.134
373.09	0.34817	0.34823	5.0895	10.136	10.138
373.09	0.37722	0.37729	5.5276	10.138	10.140
373.09	0.40760	0.40767	5.9880	10.143	10.144
373.09	0.43785	0.43792	6.4486	10.149	10.151
373.09	0.47306	0.47314	6.9881	10.154	10.156
373.13	0.49871	0.49874	7.3822	10.157	10.158
373.09	0.50317	0.50326	7.4520	10.160	10.161
373.09	0.53115	0.53125	7.8853	10.165	10.167
373.10	0.56606	0.56614	8.4286	10.171	10.173
373.10	0.60082	0.60091	8.9733	10.178	10.179
373.10	0.61977	0.61986	9.2716	10.182	10.184
373.10	0.66903	0.66913	10.052	10.192	10.193
373.10	0.72797	0.72808	10.995	10.200	10.201
373.10	0.79058	0.79071	12.009	10.213	10.214
373.10	0.82214	0.82227	12.524	10.220	10.221
373.11	0.86308	0.86319	13.197	10.229	10.230
373.10	0.95538	0.95553	14.735	10.253	10.254
373.10	1.0268	1.0270	15.945	10.272	10.273
373.10	1.0814	1.0816	16.880	10.287	10.288
373.10	1.1429	1.1431	17.948	10.303	10.304
373.10	1.2201	1.2203	19.307	10.325	10.327
373.10	1.2909	1.2911	20.574	10.346	10.348
373.10	1.3470	1.3473	21.594	10.365	10.366
373.10	1.4034	1.4037	22.631	10.382	10.383
373.10	1.4800	1.4802	24.060	10.409	10.410
373.10	1.5284	1.5287	24.977	10.426	10.427
373.11	1.6212	1.6215	26.766	10.461	10.462
373.11	1.6710	1.6712	27.741	10.479	10.480
373.11	1.7272	1.7275	28.859	10.504	10.505
373.12	1.8221	1.8223	30.781	10.547	10.548
373.12	1.8632	1.8634	31.630	10.564	10.564
373.13	1.9519	1.9520	33.491	10.606	10.606

Table 5. Continued

T	p	$p_{373.15\mathrm{K},\rho_{\mathrm{eos}}}$	$\rho_{\mathrm{eos}(T,p)}$	η	$\eta_{373.15\mathrm{K}}$
K	MPa	MPa	$\mathrm{kg \cdot m^{-3}}$	$\mu\mathrm{Pa \cdot s}$	$\mu\mathrm{Pa \cdot s}$
373.13	2.0041	2.0043	34.612	10.631	10.631
373.13	2.0877	2.0879	36.439	10.675	10.676
373.13	2.1522	2.1524	37.881	10.709	10.710
373.14	2.2204	2.2204	39.433	10.746	10.746
373.14	2.2810	2.2811	40.845	10.781	10.781
373.10	2.3457	2.3462	42.392	10.820	10.821
373.10	2.4275	2.4280	44.386	10.874	10.876
373.10	2.4697	2.4702	45.437	10.901	10.903
373.09	2.5473	2.5480	47.417	10.955	10.957
373.09	2.6046	2.6053	48.913	10.997	10.998
373.08	2.6766	2.6775	50.845	11.055	11.057
373.08	2.7500	2.7509	52.868	11.108	11.110
373.08	2.8397	2.8407	55.431	11.190	11.192
373.08	2.8799	2.8810	56.612	11.229	11.231
373.09	2.9419	2.9428	58.472	11.289	11.290
373.09	3.0147	3.0156	60.733	11.367	11.368
373.10	3.0773	3.0781	62.739	11.430	11.432
373.11	3.1412	3.1419	64.857	11.504	11.505
373.12	3.2312	3.2317	67.970	11.614	11.614
373.12	3.2899	3.2904	70.095	11.698	11.699
373.17	3.3525	3.3521	72.415	11.778	11.778
373.19	3.4214	3.4205	75.098	11.884	11.883
373.20	3.4841	3.4830	77.665	11.988	11.986
373.20	3.5585	3.5574	80.884	12.113	12.111
373.21	3.6575	3.6560	85.467	12.317	12.315
373.12	3.7420	3.7428	89.860	12.514	12.515
373.11	3.8069	3.8080	93.419	12.666	12.667
373.10	3.8668	3.8682	96.955	12.835	12.837
373.10	3.9578	3.9594	102.85	13.125	13.126
373.10	4.0432	4.0449	109.15	13.440	13.442
373.11	4.1489	4.1505	118.43	13.949	13.950
373.12	4.2121	4.2134	125.12	14.343	14.344
373.14	4.2866	4.2871	134.79	14.898	14.898
373.06	4.3708	4.3755	151.30	15.982	15.984
373.12	4.3982	4.3999	157.71	16.359	16.360
373.08	4.4249	4.4291	167.53	17.183	17.185
373.12	4.4384	4.4403	172.24	17.351	17.352
373.12	4.4600	4.4619	183.76	18.274	18.275
373.10	4.4661	4.4695	188.76	18.567	18.568
373.11	4.4787	4.4816	198.17	19.205	19.206
373.10	4.4991	4.5030	218.37	21.060	21.061
373.10	4.5126	4.5167	231.22	22.480	22.482
373.15	4.5286	4.5286	240.76	23.633	23.633
373.11	4.5401	4.5437	250.41	24.999	25.000
373.12	4.5655	4.5684	261.77	26.823	26.823
373.17	4.5838	4.5818	266.46	27.481	27.481
373.12	4.5911	4.5942	270.15	28.087	28.087
373.12	4.6414	4.6447	281.48	29.839	29.840
373.13	4.6975	4.6999	290.07	31.300	31.300
373.14	4.7421	4.7433	295.36	32.198	32.198
373.17	4.8610	4.8583	305.94	34.022	34.021
373.08	4.9512	4.9609	313.00	35.311	35.313
373.08	5.0513	5.0614	318.68	36.361	36.363

Table 5. Continued

T	p	$p_{373.15K,\rho_{eos}}$	$\rho_{eos}(T,p)$	η	$\eta_{373.15K}$
K	MPa	MPa	$kg \cdot m^{-3}$	$\mu Pa \cdot s$	$\mu Pa \cdot s$
373.08	5.1844	5.1950	324.97	37.577	37.579
373.08	5.3256	5.3367	330.57	38.703	38.704
373.08	5.4398	5.4513	334.54	39.532	39.534
373.10	5.6885	5.6972	341.83	41.064	41.065
373.11	5.9153	5.9226	347.47	42.280	42.281
373.15	6.1207	6.1207	351.83	43.258	43.258
373.19	6.3680	6.3602	356.55	44.345	44.344
373.24	6.6856	6.6673	361.91	45.620	45.617
373.10	7.0739	7.0845	368.26	47.190	47.191
373.11	7.5127	7.5216	374.07	48.708	48.709
373.11	7.9642	7.9735	379.38	50.114	50.115
373.11	8.5122	8.5219	385.12	51.708	51.709
373.11	8.9446	8.9546	389.21	52.869	52.870
373.11	9.3678	9.3781	392.91	53.978	53.979
373.11	9.8857	9.8964	397.10	55.218	55.219
373.11	10.416	10.427	401.07	56.485	56.486
373.11	10.981	10.992	404.98	57.701	57.702
373.11	11.520	11.532	408.47	58.868	58.869
373.11	12.147	12.159	412.27	60.138	60.139
373.13	12.845	12.851	416.18	61.501	61.502
373.14	13.421	13.424	419.22	62.567	62.567
373.15	13.911	13.911	421.68	63.457	63.457
373.13	14.442	14.449	424.29	64.441	64.442
373.13	14.892	14.899	426.38	65.212	65.212
373.14	15.495	15.498	429.06	66.241	66.241
373.15	16.144	16.144	431.81	67.338	67.338
373.16	17.037	17.033	435.42	68.761	68.761
373.17	17.790	17.783	438.29	69.919	69.918
373.17	18.397	18.390	440.53	70.863	70.863
373.17	18.944	18.936	442.48	71.709	71.709
373.18	19.569	19.557	444.63	72.600	72.599
373.20	20.305	20.286	447.05	73.674	73.673

[a] Influenced by slip.

Table 6. Corrected Experimental $\eta\rho pT$ Data for Propane at 398.15 K

T	p	$p_{398.15K,\rho_{eos}}$	$\rho_{eos}(T,p)$	η	$\eta_{398.15K}$
K	MPa	MPa	$kg \cdot m^{-3}$	$\mu Pa \cdot s$	$\mu Pa \cdot s$
398.09	0.11272	0.11273	1.5125	10.754[a]	10.755[a]
398.09	0.13741	0.13743	1.8467	10.759	10.761
398.09	0.15854	0.15856	2.1336	10.758	10.760
398.08	0.18255	0.18258	2.4606	10.763	10.764
398.08	0.19885	0.19889	2.6832	10.767	10.769
398.08	0.21913	0.21917	2.9607	10.770	10.772
398.08	0.23823	0.23828	3.2228	10.771	10.773
398.08	0.25900	0.25905	3.5086	10.773	10.775
398.08	0.28104	0.28109	3.8126	10.777	10.778
398.08	0.30560	0.30565	4.1524	10.780	10.782
398.08	0.32341	0.32347	4.3996	10.784	10.786
398.08	0.34204	0.34210	4.6588	10.784	10.786
398.08	0.36210	0.36217	4.9386	10.788	10.790
398.08	0.39273	0.39280	5.3673	10.793	10.795
398.08	0.41376	0.41384	5.6627	10.797	10.799
398.08	0.43457	0.43465	5.9557	10.800	10.802
398.08	0.46038	0.46047	6.3205	10.805	10.807
398.08	0.48808	0.48817	6.7133	10.810	10.812
398.08	0.54324	0.54335	7.5001	10.818	10.820
398.08	0.57685	0.57696	7.9824	10.824	10.826
398.08	0.64065	0.64077	8.9043	10.835	10.837
398.08	0.67084	0.67097	9.3435	10.840	10.842
398.08	0.72282	0.72296	10.104	10.850	10.852
398.09	0.77424	0.77437	10.862	10.861	10.862
398.09	0.82738	0.82752	11.651	10.870	10.871
398.09	0.86530	0.86545	12.218	10.878	10.880
398.10	0.95254	0.95268	13.534	10.903	10.904
398.10	1.0407	1.0409	14.883	10.924	10.925
398.10	1.0884	1.0886	15.620	10.934	10.935
398.10	1.1735	1.1737	16.948	10.956	10.957
398.10	1.2416	1.2418	18.025	10.975	10.976
398.10	1.2816	1.2818	18.662	10.987	10.988
398.10	1.3457	1.3459	19.692	11.006	11.007
398.10	1.4410	1.4412	21.245	11.036	11.037
398.10	1.4981	1.4983	22.186	11.055	11.056
398.10	1.5454	1.5456	22.974	11.070	11.071
398.10	1.6439	1.6441	24.634	11.105	11.106
398.10	1.6839	1.6842	25.317	11.118	11.119
398.10	1.7559	1.7562	26.556	11.147	11.148
398.10	1.8267	1.8270	27.793	11.174	11.175
398.10	1.8886	1.8889	28.886	11.197	11.199
398.11	1.9548	1.9550	30.068	11.227	11.228
398.11	2.0280	2.0283	31.395	11.255	11.256
398.11	2.0683	2.0686	32.133	11.272	11.273
398.11	2.1722	2.1725	34.062	11.323	11.324
398.12	2.2494	2.2496	35.520	11.362	11.362
398.12	2.2871	2.2874	36.242	11.377	11.377
398.12	2.3399	2.3401	37.261	11.402	11.403
398.13	2.3791	2.3792	38.023	11.425	11.425
398.13	2.4187	2.4189	38.802	11.449	11.450
398.13	2.4724	2.4726	39.869	11.477	11.477
398.14	2.5236	2.5237	40.896	11.504	11.504
398.11	2.5992	2.5996	42.441	11.550	11.551
398.12	2.7459	2.7463	45.504	11.634	11.635
398.12	2.8300	2.8304	47.308	11.686	11.687
398.13	2.8771	2.8774	48.332	11.717	11.717
398.13	2.9244	2.9246	49.374	11.747	11.748
398.12	2.9827	2.9831	50.680	11.793	11.793
398.12	3.0635	3.0639	52.518	11.855	11.855
398.11	3.1282	3.1287	54.019	11.902	11.903
398.12	3.2969	3.2973	58.048	12.039	12.040
398.12	3.4120	3.4125	60.911	12.142	12.143
398.11	3.4763	3.4770	62.556	12.195	12.196
398.10	3.5610	3.5618	64.770	12.279	12.280
398.08	3.6462	3.6474	67.060	12.366	12.368
398.08	3.7317	3.7329	69.413	12.454	12.456

Table 6. Continued

T	p	$p_{398.15K,\rho_{eos}}$	$\rho_{eos}(T,p)$	η	$\eta_{398.15K}$
K	MPa	MPa	kg·m^{-3}	μPa·s	μPa·s
398.08	3.8088	3.8101	71.592	12.548	12.550
398.08	3.9119	3.9133	74.597	12.667	12.669
398.12	4.0272	4.0278	78.059	12.812	12.813
398.11	4.1286	4.1295	81.258	12.939	12.940
398.11	4.2273	4.2282	84.483	13.090	13.091
398.11	4.3562	4.3572	88.892	13.287	13.288
398.11	4.4439	4.4449	92.027	13.431	13.432
398.11	4.5161	4.5171	94.700	13.557	13.558
398.11	4.6715	4.6727	100.76	13.860	13.861
398.11	4.7959	4.7972	105.94	14.130	14.131
398.11	4.8988	4.9001	110.47	14.376	14.377
398.12	4.9996	5.0006	115.14	14.629	14.630
398.13	5.1352	5.1359	121.83	15.025	15.025
398.14	5.2473	5.2477	127.76	15.381	15.381
398.14	5.3322	5.3326	132.53	15.683	15.683
398.15	5.4210	5.4210	137.76	16.015	16.015
398.15	5.5288	5.5288	144.51	16.474	16.474
398.15	5.6209	5.6209	150.64	16.885	16.885
398.15	5.7245	5.7245	157.92	17.426	17.426
398.15	5.8201	5.8201	165.00	17.955	17.955
398.15	5.9251	5.9251	173.16	18.614	18.614
398.15	6.0014	6.0014	179.31	19.114	19.114
398.15	6.0898	6.0898	186.62	19.752	19.752
398.15	6.1717	6.1717	193.49	20.363	20.363
398.16	6.2589	6.2581	200.79	21.061	21.061
398.17	6.3418	6.3403	207.68	21.737	21.736
398.18	6.4347	6.4324	215.27	22.507	22.506
398.18	6.5354	6.5329	223.29	23.348	23.347
398.16	6.6039	6.6031	228.68	23.946	23.946
398.17	6.7137	6.7120	236.65	24.879	24.879
398.18	6.8104	6.8076	243.21	25.663	25.662
398.20	6.9297	6.9248	250.70	26.584	26.583
398.15	7.0315	7.0315	257.00	27.358	27.358
398.15	7.1726	7.1726	264.62	28.400	28.400
398.12	7.2811	7.2845	270.15	29.172	29.173
398.09	7.4276	7.4345	276.94	30.158	30.160
398.08	7.5750	7.5834	283.04	31.094	31.096
398.08	7.7838	7.7927	290.73	32.299	32.300
398.08	8.0234	8.0328	298.50	33.569	33.571
398.09	8.2768	8.2852	305.70	34.776	34.778
398.10	8.5478	8.5552	312.52	36.012	36.013
398.11	8.8900	8.8963	320.12	37.408	37.409
398.11	9.2145	9.2210	326.52	38.607	38.608
398.12	9.5689	9.5741	332.75	39.838	39.839
398.12	9.9412	9.9465	338.65	41.063	41.064
398.14	10.450	10.452	345.79	42.603	42.604
398.17	10.836	10.832	350.64	43.697	43.697
398.20	11.433	11.423	357.43	45.237	45.235
398.22	11.931	11.917	362.57	46.462	46.460
398.24	12.483	12.463	367.77	47.730	47.728
398.12	13.161	13.167	373.86	49.318	49.319
398.12	13.927	13.934	379.86	50.895	50.896
398.13	14.618	14.623	384.78	52.286	52.287

Table 6. Continued

T	p	$p_{398.15K,\rho_{eos}}$	$\rho_{eos}(T,p)$	η	$\eta_{398.15K}$
K	MPa	MPa	kg·m^{-3}	μPa·s	μPa·s
398.14	15.308	15.310	389.34	53.561	53.561
398.14	15.974	15.976	393.45	54.780	54.780
398.15	16.472	16.472	396.34	55.671	55.671
398.16	17.215	17.212	400.44	56.908	56.908
398.17	17.722	17.717	403.08	57.777	57.776
398.17	18.357	18.351	406.27	58.782	58.781
398.18	18.645	18.636	407.64	59.260	59.259
398.19	19.299	19.287	410.69	60.267	60.266
398.23	19.912	19.888	413.38	61.183	61.181
398.24	20.706	20.678	416.76	62.341	62.338

[a] Influenced by slip.

Table 7. Corrected Experimental $\eta\rho pT$ Data for Propane at 423.15 K

T	p	$p_{423.15K,\rho_{eos}}$	$\rho_{eos}(T,p)$	η	$\eta_{423.15K}$
K	MPa	MPa	kg·m^{-3}	μPa·s	μPa·s
423.09	0.12532	0.12533	1.5811	11.382[a]	11.384[a]
423.09	0.15180	0.15182	1.9179	11.387	11.388
423.09	0.17206	0.17209	2.1763	11.393	11.394
423.09	0.19419	0.19422	2.4591	11.397	11.399
423.09	0.21847	0.21850	2.7700	11.400	11.401
423.09	0.24460	0.24464	3.1057	11.404	11.405
423.09	0.27073	0.27077	3.4422	11.407	11.408
423.09	0.29452	0.29456	3.7494	11.412	11.414
423.09	0.31732	0.31737	4.0447	11.416	11.417
423.09	0.33738	0.33743	4.3050	11.420	11.421
423.09	0.36655	0.36660	4.6845	11.422	11.424
423.09	0.38835	0.38841	4.9690	11.427	11.429
423.09	0.40880	0.40886	5.2364	11.431	11.433
423.09	0.43744	0.43750	5.6119	11.435	11.437
423.09	0.46518	0.46525	5.9769	11.439	11.440
423.10	0.49204	0.49210	6.3310	11.442	11.443
423.10	0.53019	0.53026	6.8362	11.449	11.450
423.10	0.57022	0.57029	7.3685	11.456	11.457
423.10	0.60734	0.60742	7.8642	11.465	11.466
423.10	0.63638	0.63646	8.2534	11.469	11.470
423.10	0.66815	0.66823	8.6807	11.475	11.476
423.10	0.70061	0.70070	9.1190	11.480	11.481
423.10	0.73944	0.73953	9.6452	11.487	11.489
423.10	0.78101	0.78111	10.211	11.496	11.498
423.10	0.82281	0.82291	10.783	11.506	11.507
423.10	0.87036	0.87048	11.437	11.516	11.517
423.10	0.97313	0.97326	12.863	11.539	11.540
423.10	1.0331	1.0333	13.703	11.554	11.555
423.10	1.0876	1.0878	14.472	11.566	11.568
423.10	1.1555	1.1557	15.436	11.585	11.586
423.10	1.1953	1.1955	16.005	11.593	11.594
423.10	1.2778	1.2779	17.193	11.618	11.619
423.10	1.3409	1.3411	18.111	11.633	11.635
423.10	1.4359	1.4361	19.505	11.663	11.664
423.10	1.4852	1.4854	20.236	11.675	11.676

Table 7. Continued

T	p	$p_{423.15K,\rho_{eos}}$	$\rho_{eos(T,p)}$	η	$\eta_{423.15K}$
K	MPa	MPa	$kg \cdot m^{-3}$	$\mu Pa \cdot s$	$\mu Pa \cdot s$
423.10	1.5504	1.5506	21.208	11.697	11.698
423.10	1.6487	1.6490	22.691	11.728	11.729
423.10	1.6943	1.6946	23.385	11.744	11.745
423.10	1.7412	1.7415	24.103	11.760	11.761
423.10	1.8380	1.8383	25.599	11.791	11.792
423.10	1.8947	1.8950	26.485	11.816	11.818
423.10	1.9546	1.9549	27.428	11.839	11.841
423.10	2.0385	2.0388	28.761	11.866	11.868
423.10	2.0929	2.0932	29.634	11.889	11.890
423.10	2.1512	2.1515	30.577	11.913	11.914
423.10	2.2029	2.2032	31.419	11.932	11.933
423.11	2.2649	2.2652	32.438	11.961	11.962
423.12	2.3421	2.3424	33.718	11.994	11.994
423.12	2.4271	2.4273	35.145	12.035	12.036
423.12	2.4785	2.4788	36.018	12.058	12.059
423.12	2.5294	2.5297	36.888	12.081	12.082
423.12	2.6110	2.6112	38.295	12.122	12.123
423.12	2.6681	2.6684	39.292	12.152	12.153
423.12	2.7566	2.7569	40.853	12.191	12.191
423.13	2.8598	2.8600	42.699	12.245	12.246
423.13	2.9774	2.9776	44.841	12.308	12.309
423.13	3.0854	3.0856	46.844	12.373	12.374
423.13	3.1658	3.1660	48.358	12.419	12.420
423.14	3.2550	3.2551	50.062	12.477	12.478
423.15	3.3639	3.3639	52.174	12.553	12.553
423.15	3.4554	3.4554	53.984	12.610	12.610
423.16	3.5866	3.5865	56.624	12.701	12.701
423.18	3.6878	3.6874	58.701	12.780	12.780
423.20	3.7980	3.7973	61.006	12.864	12.863
423.22	3.9061	3.9050	63.311	12.954	12.952
423.24	4.0330	4.0315	66.078	13.056	13.054
423.12	4.1737	4.1743	69.283	13.183	13.184
423.11	4.3445	4.3452	73.242	13.342	13.343
423.10	4.4981	4.4991	76.924	13.495	13.496
423.10	4.6846	4.6857	81.548	13.696	13.697
423.09	4.8628	4.8642	86.148	13.914	13.915
423.09	5.0548	5.0563	91.300	14.148	14.150
423.10	5.2715	5.2728	97.378	14.446	14.447
423.11	5.4975	5.4987	104.04	14.804	14.805
423.12	5.6233	5.6242	107.90	15.023	15.024
423.13	5.8371	5.8378	114.71	15.387	15.387
423.13	6.0311	6.0318	121.20	15.791	15.791
423.14	6.2299	6.2303	128.12	16.201	16.201
423.15	6.4010	6.4010	134.32	16.601	16.601
423.16	6.5542	6.5537	140.04	16.973	16.972
423.17	6.7501	6.7492	147.61	17.484	17.484
423.22	6.8839	6.8805	152.83	17.864	17.862
423.26	7.0220	7.0164	158.34	18.267	18.264
423.09	7.1764	7.1796	165.07	18.774	18.776
423.09	7.3389	7.3423	171.89	19.327	19.328
423.10	7.4943	7.4973	178.43	19.881	19.882
423.10	7.6597	7.6629	185.44	20.465	20.466
423.11	7.8613	7.8640	193.93	21.242	21.243
423.12	8.0666	8.0687	202.44	22.048	22.048
423.13	8.2387	8.2403	209.42	22.733	22.733
423.14	8.4087	8.4095	216.13	23.429	23.429
423.14	8.5574	8.5582	221.86	24.025	24.025
423.14	8.7391	8.7400	228.62	24.740	24.741
423.14	8.9251	8.9260	235.24	25.500	25.500
423.15	9.1088	9.1088	241.45	26.254	26.254
423.16	9.2648	9.2638	246.49	26.867	26.867
423.09	9.4193	9.4253	251.51	27.507	27.509
423.09	9.6185	9.6248	257.40	28.249	28.251
423.09	9.9238	9.9304	265.80	29.343	29.344
423.09	10.260	10.267	274.27	30.559	30.560
423.09	10.547	10.554	280.87	31.522	31.524
423.10	10.951	10.958	289.36	32.828	32.829
423.11	11.321	11.326	296.39	33.918	33.919
423.11	11.713	11.718	303.24	35.074	35.075
423.12	12.358	12.363	313.28	36.819	36.819
423.11	12.722	12.729	318.42	37.765	37.766
423.12	13.282	13.287	325.62	39.116	39.116
423.13	13.662	13.666	330.12	40.006	40.007
423.14	14.260	14.261	336.66	41.313	41.314
423.16	14.802	14.800	342.10	42.470	42.469
423.17	15.262	15.259	346.42	43.412	43.411
423.18	15.728	15.722	350.53	44.308	44.307
423.15	16.414	16.414	356.25	45.635	45.635
423.24	17.030	17.011	360.84	46.729	46.727
423.09	17.532	17.545	364.69	47.677	47.679
423.10	18.261	18.273	369.64	48.917	48.918
423.11	18.826	18.835	373.23	49.855	49.856
423.12	19.407	19.414	376.75	50.780	50.780
423.13	19.984	19.988	380.08	51.653	51.654

[a] Influenced by slip.

$$\eta(\tau, \delta) = \sum_{i=0}^{n} \eta_i(\tau)\delta^i \quad (1)$$

The values of the critical density and temperature, ρ_{c,C_3H_8} = 220.48 $kg \cdot m^{-3}$ and T_{c,C_3H_8} = 369.89 K, are those given by Lemmon et al.[2] Weighting factors of η_{exp}^{-2} were used in the multiple linear-least-squares regression to minimize the relative deviations for the different isotherms. The weighted standard deviation was employed as the criterion for the quality of the representation of the considered isotherm. The coefficients $\eta_i(\tau)$ in eq 1 and their standard deviations σ_{η_i} [expressed as $\eta_i(\tau) \pm \sigma_{\eta_i}$] along with the weighted standard deviations σ are given in Table 8.

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Table 8. Coefficients of Equation 1 for the Re-evaluated Viscosity Measurements on Propane

T / K	n	ρ_{max} / kg·m^{-3}	η_0 / μPa·s	η_1 / μPa·s	η_2 / μPa·s	η_3 / μPa·s	η_4 / μPa·s	η_5 / μPa·s	η_6 / μPa·s	σ
298.15	2	20.48	8.122 ± 0.001	−0.689 ± 0.029	14.445 ± 0.317					0.012
323.15	2	38.26	8.787 ± 0.001	0.073 ± 0.025	13.595 ± 0.151					0.021
348.15	3	70.64	9.436 ± 0.001	0.910 ± 0.023	13.370 ± 0.197	−5.732 ± 0.454				0.018
366.15	3	116.68	9.907 ± 0.001	1.300 ± 0.019	12.107 ± 0.101	−2.675 ± 0.140				0.030
373.15	6	447.05	10.090 ± 0.001	1.716 ± 0.025	11.764 ± 0.180	−6.092 ± 0.470	7.765 ± 0.511	−3.993 ± 0.245	0.980 ± 0.043	0.027
398.15	6	416.76	10.743 ± 0.001	1.801 ± 0.027	13.969 ± 0.176	−10.536 ± 0.444	10.920 ± 0.510	−4.905 ± 0.269	1.061 ± 0.053	0.035
423.15	6	380.08	11.370 ± 0.001	2.192 ± 0.031	13.610 ± 0.213	−9.894 ± 0.576	10.274 ± 0.712	−4.764 ± 0.405	1.089 ± 0.086	0.033

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