Viscosity of n-Pentane

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Experimental n-pentane viscosity data are presented for temperatures from 100° to 340° F. and pressures from 200 to 3000 p.s.i.a. The methods for correlation are discussed, and the data are compared with literature values. A table of recommended viscosity values is presented.

RESULTS of the ethane, propane, and n-butane viscosity investigations have been presented (4, 6, 16). A detailed study of the viscosity behavior of ethane, propane, and n-butane in the vicinity of their critical points (15), and that of binary mixtures of methane-n-butane has also been reported (3, 10).

Experimental results of this investigation were used to test two correlations. Recommended values for n-pentane viscosity are presented for temperatures from 100° to 460° F. and pressures from atmospheric to 8000 p.s.i.a.

APPARATUS AND MATERIALS

The viscometer used for this investigation has been described in detail (3, 5, 7). The n-pentane used was Phillips Petroleum Co. pure grade, certified 99 mole % minimum purity.

EXPERIMENTAL DATA

All the data are for the liquid phase, and they were obtained only to the extent necessary to obtain a residual viscosity correlation and test the generalized 9-parameter equation of Lee and coworkers (10). In previous work (4, 6, 16), the residual concept was satisfactory for representing the viscosity behavior of light hydrocarbons. Therefore, extensive data were not required for all regions, particularly for high density regions.

Isobars of n-pentane viscosity are presented in Figure 1, and a crossplot of viscosity vs. pressure is also presented in Figure 2. These plots are based on the authors' experimental data and correlations to be discussed. Experimental

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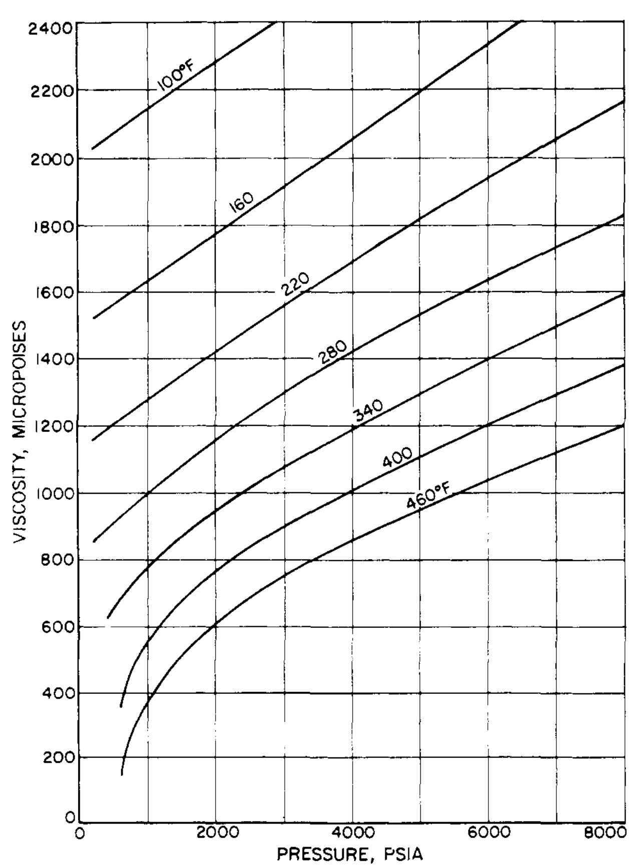

Figure 1. n-Pentane viscosity vs. temperature

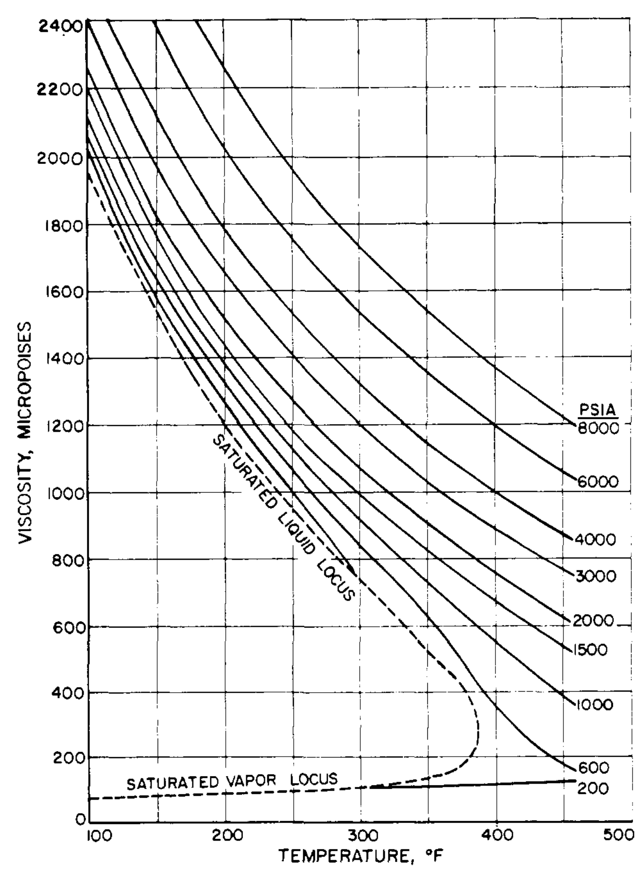

Figure 2. n-Pentane viscosity vs. pressure

data have been omitted in Figures 1 and 2 for clarity. Detailed tables of the experimental data have been prepared and are available from ADI.

COMPARISON WITH LITERATURE

Few investigations of the viscosity behavior of *n*-pentane have been reported for the range of temperatures and pressure studied in this paper. In 1938, Sage and Lacey (*13*) reported some data on viscosity of liquid *n*-pentane for temperatures from 100° to 200° F. and pressures from saturation to 1500 p.s.i.a. In 1943, Hubbard and Brown (*8*) reported data of *n*-pentane for temperatures from 25° to 250° C. and pressures from saturation to 1000 p.s.i.a.; in 1959, Reamer and coworkers (*12*) reported data of *n*-pentane for temperatures from 100° to 280° F. and pressures from 99.4 to 5070.2 p.s.i.a. Recently, Agaev and Golubev (*1*) reported a set of recommended values for *n*-pentane for temperatures from 25° to 275° C. and pressures from 1 to 500 atm. They also reported the investigation of *n*-pentane near the critical region. The recommended values of Agaev and Golubev differ from the authors' experimental data by 0.5 to 2.5% (Figure 3), and the data reported by Sage and Lacey also agree well with this investigation. However, the data reported by Hubbard and Brown and Reamer and coworkers have much higher values than those measured by the authors. A comparison of various investigators' data is presented in Figure 4. The atmospheric pressure data of Agaev and Golubev, Lambert and coworkers (*9*), McCoubrey and Singh (*11*), Sevhla (*17*), and the predicted values by a 9-parameter equation developed by Lee and coworkers (*10*) are presented in Figure 5.

CORRELATION

The residual viscosity concept which has been discussed elsewhere (*2, 4*) was used successfully in this work. Residual viscosity is defined as the difierence between the viscosity at a given pressure and temperature and μ_0, the viscosity at one atmosphere and the same temperature. The residual viscosity is then plotted *vs.* density on linear coordinates, and a smooth continuous curve may be obtained, Figure 6. If the density values for a system are known for various temperatures and pressures, the viscosity values at those conditions may be interpolated from this plot. To use this correlation, it is essential to know the viscosity values at atmospheric pressure, the density values of a system at various conditions, and enough experimental viscosity values to construct the residual viscosity-density plot.

Equation 1 with the constants recommended by Lee and coworkers (*10*) and density values by Sage and Lacey (*14*) were used to generate a set of viscosity values for *n*-pentane; the results are presented in Figure 3.

$$\mu = K \exp\left[x \rho^{y}\right] \quad (1)$$

where

$$K = \frac{(7.77 + 0.0063M)\, T^{1.5}}{122.4 + 12.9M + T}$$

$$x = 2.57 + \frac{1914.5}{T} + 0.0095M$$

$$y = 1.11 + 0.04x$$

The results are significant in that the viscosity behavior of *n*-pentane was described by this 9-parameter equation by simply inserting its molecular weight and density values and without any knowledge of experimental *n*-pentane viscosity data. Figure 3 shows that the agreement between predicted values and experimental data of this investigation and that of Agaev and Golubev is good for the high temperature region—i.e., low density region—even near the critical region. However, the prediction becomes less accurate as density increases. This is expected because the

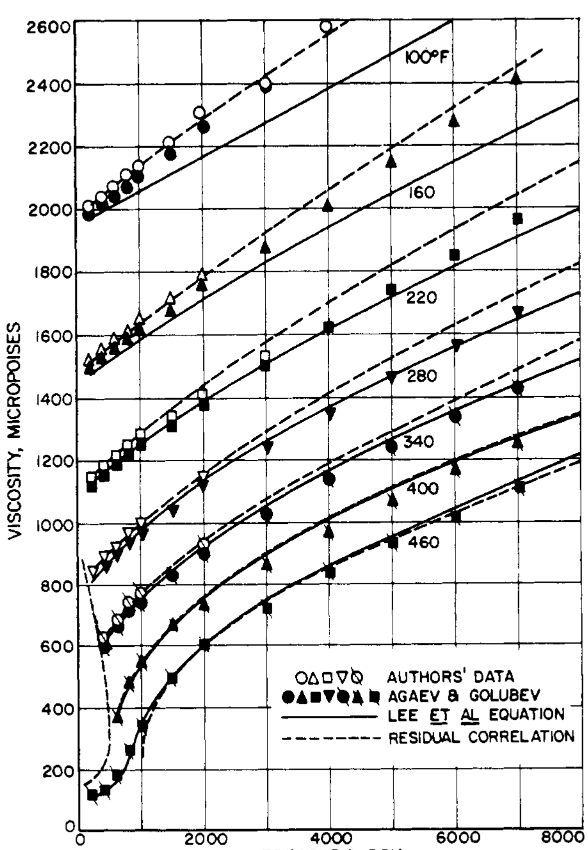

Figure 3. Comparison of viscosity values of *n*-pentane

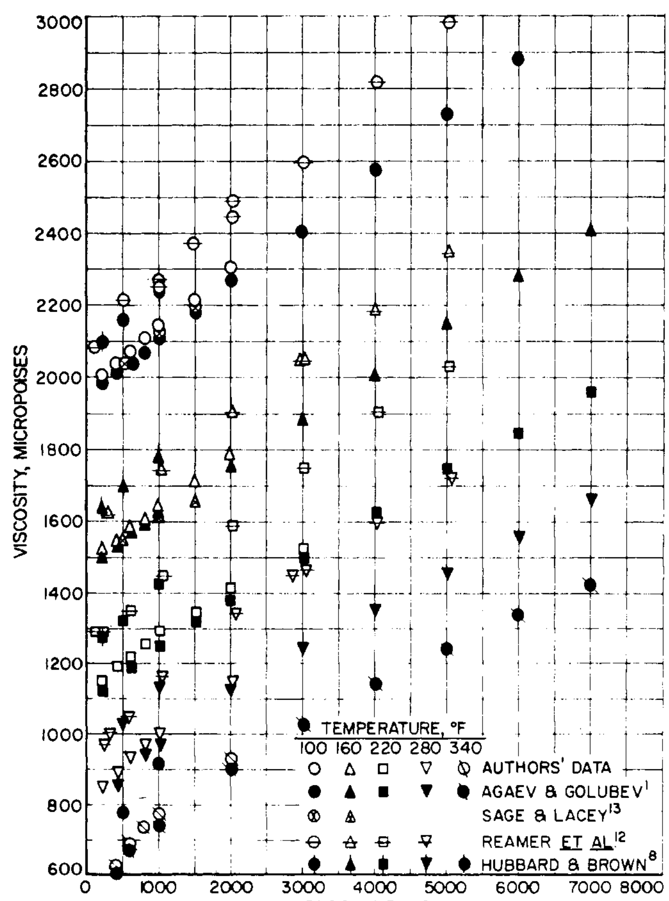

Figure 4. Comparison of experimental data of *n*-pentane

Table I. Viscosity of *n*-Pentane

Pressure, P.S.I.A.	Density, G./Cc.	Visc., μp.		Density, G./Cc.	Visc., μp.	Density, G./Cc.	Visc., μp.		Density, G./Cc.	Visc., μp.
	100° F.			130° F.		160° F.			190° F.	
14.7	0.00294	72		0.00277	76	0.00262	80		0.0025	84
100	0.6082	2018		0.5893	1725	0.5704	1510		0.5506	1315
200	0.6089	2028	(2003.9)	0.5905	1740	0.5715	1523	(1521.0)	0.5522	1330
300	0.6095	2043		0.5914	1758	0.5730	1535		0.5537	1345
400	0.6102	2056	(2042.3)	0.5927	1770	0.5741	1550	(1555.3)	0.5553	1360
500	0.6108	2070		0.5936	1786	0.5753	1560		0.5569	1375
600	0.6118	2081	(2076.0)	0.5945	1800	0.5767	1575	(1582.1)	0.5588	1388
800	0.6131	2109	(2111.2)	0.5966	1830	0.5790	1601	(1613.2)	0.5616	1418
1000	0.6144	2133	(2140.8)	0.5982	1860	0.5813	1629	(1643.4)	0.5643	1445
1250	0.6164	2170		0.6007	1895	0.5843	1663		0.5682	1480
1500	0.6180	2200	(2219.3)	0.6025	1930	0.5869	1700	(1715.9)	0.5715	1510
1750	0.6197	2239		0.6047	1966	0.5896	1733		0.5747	1550
2000	0.6210	2270	(2302.6)	0.6070	2000	0.5920	1770	(1787.6)	0.5775	1580
2500	0.6243	2339		0.6108	2072	0.5969	1840		0.5837	1655
3000	0.6273	2405		0.6147	2140	0.6016	1911		0.5884	1720
3500	0.6305	2471		0.6180	2210	0.6057	1980		0.5930	1790
4000	0.6332	2535		0.6213	2283	0.6095	2050		0.5969	1855
4500	0.6361	2602		0.6250	2345	0.6134	2120		0.6013	1925
5000	0.6388	2670		0.6281	2412	0.6167	2185		0.6057	1990
6000	0.6442	2800		0.6336	2540	0.6233	2320		0.6131	2110
7000	0.6489	2930		0.6392	2656	0.6294	2455		0.6193	2230
8000	0.6551	3060		0.6453	2775	0.6357	2590		0.6254	2340

Pressure, P.S.I.A.	Density, G./Cc.	Visc., μp.		Density, G./Cc.	Visc., μp.	Density, G./Cc.	Visc., μp.		Density, G./Cc.	Visc., μp.
	220° F.			250° F.		280° F.			310° F.	
14.7	0.00237	87		0.00227	91	0.00217	95		0.00209	98
100	0.5292	...		0.0177	...	0.0166	...		0.0156	...
200	0.5316	1160	(1151.4)	0.5078	1000	0.4775	850	(856.6)	0.0367	...
300	0.5336	1175		0.5105	1019	0.4846	872		0.4539	745
400	0.5358	1190	(1189.2)	0.5132	1035	0.4878	895	(894.8)	0.4588	770
500	0.5375	1205		0.5155	1052	0.4911	910		0.4636	788
600	0.5393	1222	(1219.7)	0.5180	1070	0.4943	935	(936.3)	0.4681	805
800	0.5431	1254	(1254.6)	0.5229	1100	0.5003	967	(964.2)	0.4764	845
1000	0.5464	1280	(1285.6)	0.5272	1130	0.5060	1000	(1000.8)	0.4839	883
1250	0.5506	1310		0.5326	1170	0.5125	1036		0.4924	925
1500	0.5548	1340	(1347.9)	0.5373	1200	0.5187	1075		0.4999	965
1750	0.5586	1375		0.5421	1242	0.5241	1111		0.5067	1005
2000	0.5621	1410	(1415.2)	0.5464	1275	0.5296	1148	(1141.6)	0.5125	1040
2500	0.5690	1480		0.5543	1345	0.5388	1221		0.5234	1110
3000	0.5752	1550	(1535.2)	0.5613	1410	0.5472	1290		0.5323	1170
3500	0.5807	1620		0.5673	1472	0.5543	1360		0.5398	1232
4000	0.5860	1695		0.5732	1535	0.5605	1418		0.5464	1285
4500	0.5902	1755		0.5781	1590	0.5660	1480		0.5524	1345
5000	0.5945	1813		0.5828	1650	0.5707	1530		0.5580	1397
6000	0.6019	1930		0.5911	1760	0.5796	1620		0.5682	1500
7000	0.6086	2040		0.5985	1865	0.5878	1722		0.5770	1600
8000	0.6150	2150		0.6051	1970	0.5951	1825		0.5851	1700

Pressure, P.S.I.A.	Density, G./Cc.	Visc., μp.		Density, G./Cc.	Visc., μp.	Density, G./Cc.	Visc., μp.	Density, G./Cc.	Visc., μp.	Density, G./Cc.	Visc., μp.
	340° F.			370° F.		400° F.		430° F.		460° F.	
14.7	0.0020	102		0.00193	106	0.00185	110	0.00179	114	0.00173	118
100	0.0148	105		0.0141	108	0.0135	111	0.0128	115	0.0123	119
200	0.0335	107		0.0312	111	0.0293	114	0.0276	119	0.0262	122
300	0.0618	...		0.0540	...	0.0491	118	0.0452	125	0.0422	126
400	0.4196	625	(624.8)	0.0937	...	0.0767	130	0.0675	135	0.0613	133
500	0.4285	660		0.3764	480	0.1284	200	0.0985	160	0.0854	145
600	0.4363	683	(685.1)	0.3939	530	0.3166	360	0.1519	230	0.1176	160
800	0.4486	730	(748.0)	0.4165	605	0.3716	475	0.3049	380	0.2257	245
1000	0.4590	775	(768.0)	0.4322	660	0.3973	558	0.3578	455	0.3057	360
1250	0.4698	822		0.4460	723	0.4184	629	0.3872	530	0.3502	445
1500	0.4793	866		0.4577	770	0.4333	682	0.4061	590	0.3764	510
1750	0.4874	906		0.4675	815	0.4450	727	0.4205	636	0.3942	550
2000	0.4947	942	(929.6)	0.4758	853	0.4548	766	0.4325	680	0.4087	600
2500	0.5069	1010		0.4897	920	0.4711	833	0.4514	754	0.4311	680
3000	0.5171	1070		0.5016	980	0.4842	897	0.4667	820	0.4478	748
3500	0.5253	1128		0.5111	1032	0.4949	950	0.4787	875	0.4612	800
4000	0.5328	1181		0.5194	1085	0.5044	1001	0.4891	930	0.4729	855
4500	0.5393	1234		0.5265	1140	0.5125	1050	0.4981	982	0.4835	900
5000	0.5454	1287		0.5330	1190	0.5199	1096	0.5067	1030	0.4932	948
6000	0.5567	1395		0.5446	1290	0.5328	1205	0.5210	1120	0.5091	1035
7000	0.5660	1490		0.5556	1388	0.5438	1271	0.5336	1205	0.5215	1116
8000	0.5752	1583		0.5654	1475	0.5545	1375	0.5438	1285	0.5331	1196

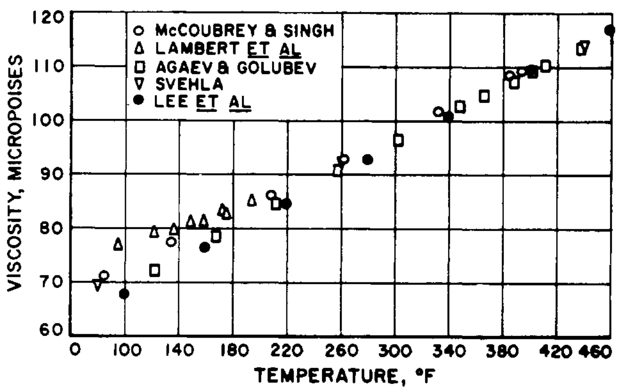

Figure 5. Comparison of atmospheric pressure n-pentane viscosity values

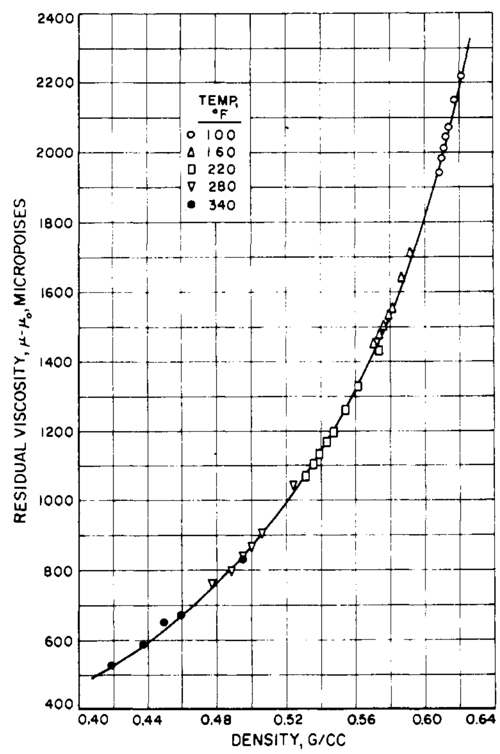

Figure 6. Residual n-pentane viscosity *vs.* density

9 constants in Equation 1 were evaluated with data primarily for the gas, supercritical fluid, and liquid at reduced temperature greater than 0.73 (*10*).

RECOMMENDED VALUES

Recommended values for viscosity of n-pentane for temperatures from 100° to 460° F. and pressures from atmospheric pressure to 8000 p.s.i.a. are presented in Table I, in which experimental data are also presented in parentheses. Density values used in this work were those of Sage and Lacey (*14*). The recommended values were determined from smoothed large-scale viscosity-pressure, viscosity-temperature, and residual viscosity-density plots based on the authors' experimental data.

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NOMENCLATURE

M = molecular weight
T = absolute temperature, ° R.
μ = viscosity, micropoise
ρ = density, g./cc.

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