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A CORRELATION FOR PREDICTING THE VISCOSITY OF NIGERIAN CRUDE OILS

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ABSTRACT

An empirical equation that could be used for predicting the viscosity of Nigerian crudes is presented in this paper.

The correlation uses oil specific gravity as the main correlating parameter, and also incorporates the effects of reservoir pressure, temperature and oil formation volume factor.

Data from well over 400 samples of Nigerian crudes were used for developing the correlation, with most samples however, from reservoirs at or above saturation pressure. The results show however that the correlation could have general applicability.

The correlation when compared with some earlier works proved to be more accurate for Nigerian crudes. Graphical and Statistical error analyses undertaken suggest good performance and accuracy.

The correlation should prove valid for estimating the viscosity of Nigerian crudes, as well as other crude types having properties that fall within the range of the data used in this work.

References, tables and figures are at the end of text.

INTRODUCTION

The evaluation of the viscosity of hydrocarbons is essential in the design of production facilities, reservoir engineering studies and in enhanced recovery projects.

In many instances where viscosity of a crude is not available, it is desirable to estimate it from available field parameters such as reservoir pressure, temperature, oil gravity and the gas-oil ratio.

The development of correlations for viscosity dates back to the works of Philips(1) in 1912. Since then, several investigators have worked on improved correlations. Correlations that have been formulated have varied from simple empirical relations(2) to complex mathematical equations(3). Such correlations that have been widely used include those of Little and Kennedy(4), Lohrenz et al(5), Chew and Connally(6), Beal(7) and Vasquez and Beggs(8).

The accuracy of some of these correlations was investigated for several samples of Nigerian crudes, and were found not to be very accurate. This is not unexpected, because most of them used data obtained

Table 1: VISCOSITY ESTIMATES FOR RESERVOIRS ABOVE THEIR BUBBLE POINTS

Res No	P,psi	R_s, SCF/STB	B_o rb/STB	T °F	S.G	Exp. μ cp	V	Dev	μ* cp	Dev
8	5947	1007	1.656	220	0.617	0.34	0.32	5.60	0.30	11.98
18	3719	471	1.246	184	0.789	1.64	1.37	16.34	1.42	13.67
28	1932	316	1.136	140	0.823	3.82	2.39	37.32	2.54	33.54
38	2397	264	1.114	134	0.865	7.09	5.98	15.67	6.45	9.08
48	2953	586	1.764	164	0.562	0.28	0.26	8.28	0.23	17.06
58	3076	765	1.372	157	0.679	0.45	0.46	1.15	0.45	0.85
68	3598	1237	1.627	183	0.609	0.30	0.31	0.14	0.29	3.78
78	4593	1510	1.651	173	0.631	0.27	0.34	27.25	0.32	19.25
88	5027	1291	1.749	248	0.597	0.30	0.29	2.08	0.27	11.47
98	4871	2060	2.409	237	0.509	0.15	0.22	44.99	0.17	16.40
108	3282	318	1.125	144	0.855	5.16	4.68	9.31	5.06	1.97
118	4780	1740	2.112	243	0.537	0.21	0.24	12.53	0.20	5.25
128	4001	1034	1.504	180	0.653	0.38	0.39	1.82	0.37	1.78
138	4247	1034	1.488	179	0.650	0.39	0.38	2.48	0.37	5.35
148	3239	386	1.197	174	0.823	2.86	2.39	16.29	2.50	12.45
158	3080	727	1.366	164	0.688	0.52	0.48	6.80	0.48	7.12
168	4049	1062	1.554	189	0.645	0.35	0.37	5.68	0.35	0.50
178	4901	743	1.550	218	0.644	0.46	0.37	20.03	0.35	23.95
188	3733	827	1.305	162	0.736	0.62	0.73	17.23	0.74	19.63
198	2349	657	1.342	141	0.667	0.50	0.42	15.82	0.42	15.63
208	5084	1227	1.661	209	0.643	0.31	0.37	18.02	0.34	9.69
218	4879	1900	1.990	209	0.602	0.24	0.30	25.03	0.26	8.46
228	5136	2229	2.153	190	0.599	0.23	0.30	28.80	0.25	9.13
238	3613	394	1.144	131	0.856	5.06	4.97	5.30	5.19	2.51
248	3941	1130	1.462	162	0.669	0.39	0.43	9.30	0.42	7.06
258	4082	1545	1.818	202	0.610	0.26	0.31	19.54	0.28	6.88
268	3145	333	1.148	127	0.839	3.72	3.28	11.82	3.54	4.92
278	4378	1333	1.825	127	0.591	0.22	0.29	30.26	0.26	16.15
288	3430	467	1.161	129	0.849	3.82	4.08	6.68	4.38	14.76
298	4831	1726	1.979	207	0.577	0.23	0.27	17.94	0.24	2.54
308	4636	179	1.166	191	0.818	2.35	2.19	6.97	2.32	1.12
318	3414	365	1.138	141	0.862	6.14	5.54	9.71	5.98	2.59
328	2379	312	1.141	155	0.817	2.70	2.15	20.46	2.28	15.65
338	2729	385	1.231	167	0.752	1.15	0.86	25.29	0.89	22.94
348	4239	448	1.232	176	0.763	1.19	0.98	18.06	1.02	14.58
358	3588	332	1.129	149	0.835	3.73	3.02	19.00	3.26	12.47
368	3983	636	1.251	165	0.762	1.00	0.96	3.65	1.00	0.00
378	3039	362	1.149	124	0.878	11.18	8.47	24.28	9.13	18.37
388	3846	800	1.600	227	0.640	0.39	0.36	7.69	0.34	14.04
398	2948	44	1.072	130	0.913	33.65	26.20	22.13	28.89	14.13
		AVERAGE DEVIATION						13.48		10.24

The correlation was also compared with those of Beal, Chew and Connally as well as Beggs and Vasquez correlatioins. Tables 3 and 4 show that the correlation developed in this study performed better for Nigerian crudes.

ERROR ANALYSIS

Graphic and Statistical error analyses were undertaken to assess the performance and accuracy of the viscosity correlation developed in this study.

Graphic Error Analysis

This was done by making crossplots of the estimated values against the experimental values. This is shown in Figures 4 and 5. From the distribution of the data points around the 45° crossplot straightline, a visual assessment of the correlation can be made.

Statistical Error Analysis

Two statistical criteria were used to assess the accuracy of the correlation presented in this paper.

1) Average Absolute Deviation (AAD)

This gives a measure of the deviation of estimated values from experimental data.

$$AAD = \frac{1}{N} \sum_{1}^{nd} \left| \frac{Y - Y^*}{Y} \right| \qquad (4)$$

2) Coefficient of Correlation

$$\gamma^2 = \frac{\sum_{1}^{nd} (Y^* - \bar{Y})^2}{\sum_{1}^{nd} (Y - \bar{Y})^2}$$

$$= \sqrt{\sum_{1}^{nd} \frac{(Y^* - \bar{Y})^2}{S^2 N}} \qquad (5)$$

where

$$\bar{Y} = \frac{1}{nd} \sum_{1}^{nd} Y_i$$

$$S^2 = \text{Variance} = \frac{\sum_{1}^{nd} (Y - \bar{Y})^2}{N}$$

CONCLUSION

A simple correlation for estimating the viscosity of Nigerian crudes has been developed. The correlation however, should perform equally well for other crude types having properties within the range of data used in this study.

The correlation presented in this paper proved to be more accurate for Nigerian crudes than many earlier works, and the statistical error analyses indicated that the average deviation of between 3.96 - 11.78% for various types of reservoirs, while the coefficient of correlation is very close to 1.

Table 2 shows also, that even though not many samples below bubble point were tested, correlation developed here could prove to have more general applicability.

REFERENCES

1. Phillips, P.: "The viscosity of Carbon dioxide," Proc. Roy. Soc. (1912) 87A, 48.

2. Lederer, E.L.: "Viscosity of Binary Mixtures," Nature (1937), 139, 37.

3. Brush, S.G.: "Theories of Liquid viscosity,". Chem. Review (1962), 62, 513.

4. Little, J.E. and Kennedy, H.T.: "A correlation of the viscosity of Hydrocarbon systems with Pressure, Temperature and Copmposition," Trans. AIME (1968), 243, II-157.

5. Lohrenz, J., Bray, B.G., and Clark, C.R.: "Calculating Viscosities of Reservoir Fluids from

their Compositions," Trans., AIME (1964), 231, I-1171.

6. Chew, J. and Connally, C.: "A viscosity correlation for Gas-saturated crude oils," Trans. AIME (1959), 216, 23.

7. Beal, C.: "The Viscosity of Air, Water, Natural Gas, Crude Oil and its Associated Gas at oil-field temperature and pressure," Trans. AIME (1946), 165, 94.

8. Vasquez, M. and Beggs, H.D.: "Correlations for fluid Physical Property Prediction," JPT., (June 1980), 968.

9. Wu, R.S. and Fish, R.M.: "C_7^+ Characterization for fluid properties predictions," Journal of Canadian Petroleum Technology, (July-August 1939), 112.

10. Nobles, M.A.: Using the Computer to Solve Petroleum Engineering Problems, Gulf Publishing Co.; Texas, (1974), 245-322.

NOMENCLATURE

a,b,c,d	-	Constants as defined in Equation 1.
B_o	-	Oil formation volume factor, rb/stb.
P	-	Reservoir Pressure; psia
S	-	Variance
T	-	Reservoir Temperature, of.
X	-	Constant defined in equation 2.
Y	-	Experimental Values
Y*	-	Estimated Values.
Y	-	Average Y
γ_o	-	Specific gravity
μ	-	Viscosity
μ^*	-	Viscosity (with specific gravity as only correlation parameter).

Subscripts

o	-	Oil
Sc	-	Standard Conditions.

mainly from other regions. Since every reservoir has its own unique composition and since the properties depend significantly upon the interaction of the various components[9], it has become needful to develop correlations essentially based on Nigerian crudes.

In developing empirical correlations like the one presented in this paper, there are perhaps three major possible techniques. The first is to use the graphical approach, while the second approach utilises linear or non-linear multiple regression analysis. The third approach is a combination of the earlier two techniques. This paper uses this last approach. Graphical technique is first used, and the results fine-tuned using a simple linear regression technique. The results show that oil specific gravity could be used as the main correlator for viscosity of Nigerian crudes.

Development of the Correlation

Since the work of Enskog in 1917 which investigated the effect of density on viscosity, nearly all empirical models developed to date incude density as a correlating parameter. This paper has also used specific gravity as the main correlating parameter.

Data from about 400 samples were examined and a plot on semi-log paper was done for viscosity versus oil specific gravity. The least squares approach of Noble[10] was adapted and used to develop an equation that described the curve

This equation did not give very accurate predictions. This observation is not unexpected as specific gravity alone cannot be used to develop a very accurate correlation for viscosity. It is evident that the effects of other parameters such as temperature, gas gravity, pressure and solution gas-oil ratio must be accounted for.

A simple way of accounting for these effects is the use of a "multiplication factor", which depend on some of these variables. This "multiplication factor" was used to fine-tune the earlier equation.

RESULTS AND DISCUSSION

The correlation developed is of the form

$$\mu = k e^{(a + b\gamma_o + c e^{d\gamma_o})} \qquad (1)$$

where,

$$k = f(P, T, B_o)$$

$$= \left[\frac{\log P}{\log T^x} \right]^{1/4}$$

and

$$x = B_o^{1.5} \qquad (2)$$

In Eqs. 1 and 2, a,b,c,d are constants whose values are as follows:

a = - 2.4 3623085
b = 1.465319171
c = 0.002655228
d = 8.110263689.

Also, B_o and γ_o are defined as follows:

B_o = oil formation volume factor, rb/stb
γ_o = oil specific gravity at reservoir conditions.

If however, only the oil gravity at surface condition is available, corrections can be made to estimate oil gravity at reservoir conditions. The following equations can be used:

$$\gamma_o \text{ (T, 14.7 psia)} = \gamma_{osc}^i$$

$$\gamma_o \text{ (T, P)} = \gamma_o^j \text{ (T, 14.7 psia)}$$

where

$$i = \left[\frac{460 + T}{520} \right]^{1.579}$$

$$j = \left[\log \frac{P + 14.7}{14.7} \right]^{1/2} \qquad (3)$$

These correlations were applied to over 400 samples of Nigerian crude. The distribution of the data is shown in Table 2.

Table 2: ESTIMATED BUBBLE-POINT VISCOSITY

Res No	P,psi	R_S, SCF/STB	B_O rb/STB	T °F	S.G	Exp. μ cp	V	Dev	μ* cp	Dev
405	2666	110	1.326	161	0.855	0.66	0.70	6.53	0.71	6.97
406	2760	114	1.346	167	0.855	0.63	0.68	7.18	0.67	6.95
407	2632	98	1.265	162	0.863	0.90	0.81	10.54	0.82	8.63
408	2676	116	1.346	160	0.855	0.63	0.71	12.14	0.71	12.02
409	2501	178	1.370	166	0.841	0.42	0.56	33.82	0.56	32.20
410	4741	226	1.833	271	0.839	0.25	0.33	31.25	0.29	15.94
411	4415	267	1.974	255	0.806	0.20	0.27	32.60	0.23	13.99
412	2996	120	1.380	181	0.839	0.49	0.49	0.55	0.49	0.73
413	4070	179	1.569	217	0.932	4.72	3.85	18.41	3.63	23.17
414	2630	71	1.300	160	0.925	4.30	4.91	14.27	4.97	15.59
415	2871	73	1.218	167	0.885	1.50	1.21	19.02	1.26	16.01
416	4175	62	1.197	203	0.895	2.27	1.14	49.97	1.19	47.66
417	3175	286	2.006	221	0.825	0.30	0.36	18.77	0.30	1.13
418	5952	211	1.774	240	0.844	0.32	0.37	16.10	0.34	5.09
419	3751	134	1.360	150	0.919	4.20	3.73	11.13	3.77	10.34
420	4101	178	1.500	160	0.876	0.85	0.95	12.23	0.93	9.08
421	5620	182	1.511	220	0.852	0.57	0.44	22.09	0.43	24.93
422	3250	53	1.250	215	0.928	3.00	3.46	15.43	3.53	17.60
423	3290	116	1.450	217	0.803	0.20	0.30	48.19	0.29	42.80
424	2626	70	1.211	160	0.925	4.30	4.92	14.33	5.11	18.75
425	2650	105	1.313	161	0.860	0.85	0.77	9.83	0.77	9.14
426	3970	196	1.563	239	0.840	0.32	0.38	17.85	0.35	10.55
427	4751	178	1.614	258	0.833	0.29	0.32	11.26	0.30	3.32
428	2250	687	1.390	175	0.846	0.56	0.59	5.06	0.57	2.66
429	3160	647	1.360	214	0.841	0.45	0.43	3.54	0.43	4.85
430	3375	890	1.450	205	0.831	0.37	0.40	7.55	0.38	4.00
431	3614	950	1.480	214	0.826	0.29	0.36	24.89	0.35	19.84
432	2283	503	1.290	183	0.854	0.67	0.63	5.24	0.64	4.93
433	2575	521	1.310	188	0.861	0.80	0.68	15.54	0.68	15.53
434	2269	598	1.371	186	0.845	0.53	0.55	3.48	0.54	1.38
435	2965	1053	1.720	216	0.834	0.37	0.40	8.58	0.36	2.16
436	3710	1137	1.640	212	0.806	0.23	0.31	32.93	0.28	22.90
437	3963	1232	1.660	216	0.807	0.22	0.30	37.22	0.28	26.43
438	2470	712	1.440	185	0.838	0.54	0.49	8.44	0.48	11.68
439	4662	3100	2.885	234	0.807	0.23	0.28	22.20	0.21	8.38
440	4340	3100	2.385	215	0.800	0.23	0.28	23.78	0.21	7.03
441	2384	520	1.320	185	0.856	0.62	0.64	3.66	0.64	3.20
442	2113	516	1.320	182	0.857	0.66	0.68	3.16	0.68	2.37
443	1989	268	1.150	170	0.916	3.84	3.42	10.96	3.58	6.82
444	2200	703	1.430	178	0.853	0.67	0.65	3.50	0.62	6.84
445	1989	268	1.150	170	0.916	3.84	3.42	10.96	3.58	6.82
446	1680	210	1.138	154	0.914	3.91	3.79	3.00	3.98	1.83
447	2636	773	1.435	154	0.827	0.46	0.49	7.36	0.48	4.85
448	2020	690	1.422	170	0.825	0.44	0.47	6.79	0.45	3.25
449	2655	1237	1.712	180	0.809	0.31	0.37	18.14	0.33	7.19
450	1560	519	1.347	187	0.839	0.49	0.54	10.74	0.53	7.83
451	1840	384	1.230	171	0.867	0.96	0.89	6.78	0.91	5.15
452	1420	314	1.201	158	0.862	1.22	0.94	22.91	0.96	21.24
453	2760	908	1.546	188	0.832	0.37	0.45	20.33	0.42	13.34
454	2858	977	1.566	188	0.828	0.37	0.42	14.41	0.40	7.36
455	2736	1119	1.580	183	0.822	0.30	0.41	36.11	0.38	27.29
456	2951	1042	1.663	219	0.94	0.25	0.28	12.82	0.26	2.87
		AVERAGE DEVIATION						15.84		11.78

Table 3: COMPARISON OF RESULT OF VISCOSITY (ABOVE BUBBLE-POINTS) ESTIMATES

Res	S.G	Exp. μ	Est. μ	Dev	Beal	Dev	Chew	Dev	Beggs	Dev
1	0.807	1.87	1.92	2.86	0.74	60.43	0.92	50.80	1.15	38.50
2	0.701	0.58	0.53	8.38	0.27	53.43	0.26	55.17	0.42	27.59
3	0.790	1.94	1.46	24.69	0.90	53.61	0.93	52.06	1.08	44.33
4	0.905	23.50	21.76	7.24	11.50	51.06	11.82	49.70	13.42	42.89
5	0.852	5.04	4.70	6.66	5.70	13.10	10.43	106.94	6.92	37.30
6	0.821	3.07	2.47	19.57	0.70	77.20	0.87	71.66	1.18	61.56
7	0.865	7.09	6.45	9.08	5.00	29.48	3.69	27.95	5.44	23.27
8	0.851	5.96	4.62	22.52	6.60	10.74	6.54	9.73	8.10	35.91
9	0.890	14.62	13.20	9.72	11.00	24.76	11.69	20.04	14.80	1.23
10	0.875	9.30	8.41	9.61	4.40	52.69	4.05	56.45	4.80	48.39
11	0.797	1.79	1.64	8.42	0.60	66.48	0.69	61.45	0.76	57.54
94	0.863	7.10	6.20	12.69	7.40	4.23	7.70	8.45	9.40	32.39
95	0.818	2.35	2.32	1.12	1.80	23.40	1.70	27.66	3.30	40.43
96	0.792	1.50	1.51	0.66	0.70	53.33	0.72	52.00	0.78	48.00
97	0.866	5.16	6.63	28.58	3.00	41.86	3.20	37.98	3.59	30.43
98	0.854	3.42	4.94	44.50	2.90	15.20	3.10	9.36	3.47	1.46
99	0.838	2.83	3.46	22.16	1.40	50.53	1.45	48.76	1.68	40.64
100	0.797	1.59	1.63	2.74	1.40	11.95	1.30	18.24	1.45	8.81
101	0.862	6.14	5.98	2.59	2.70	56.03	2.70	56.03	3.40	44.63
102	0.850	4.73	4.49	5.06	3.20	32.35	2.95	37.63	4.01	15.22
103	0.812	2.03	2.10	3.68	0.80	60.59	1.10	45.81	1.01	50.25
104	0.888	12.97	12.14	6.39	5.70	56.05	5.30	59.14	6.15	52.58
105	0.858	7.56	5.38	28.89	3.60	52.38	3.50	53.70	3.95	47.75
106	0.846	4.50	4.08	9.44	3.30	26.67	3.20	28.89	3.65	18.89
107	0.817	2.70	2.28	15.65	1.30	51.85	1.30	51.85	1.50	44.44
108	0.920	39.72	38.59	2.85	18.00	54.68	22.10	44.36	20.62	48.09
109	0.901	16.56	19.16	15.68	9.60	42.03	9.90	40.22	11.87	28.32
110	0.886	11.05	11.85	7.26	4.20	61.99	4.20	61.99	5.15	53.39
111	0.891	12.46	13.56	8.81	6.80	45.43	7.15	42.62	7.83	37.16
112	0.927	52.70	50.26	4.63	43.00	18.41	57.00	8.16	62.25	18.12
113	0.923	34.50	42.83	24.13	52.00	50.72	71.90	108.41	61.95	79.57
114	0.906	22.90	22.70	0.86	32.00	39.74	36.50	59.39	38.75	69.21
115	0.923	34.70	42.82	23.40	27.00	22.19	37.60	8.36	46.95	35.30
116	0.917	34.45	34.29	0.46	22.40	34.98	30.40	11.76	41.67	20.96
117	0.903	19.37	20.45	5.58	15.00	22.56	20.80	7.38	27.41	41.51
118	0.892	19.99	14.46	27.68	11.50	42.47	12.80	35.97	15.76	21.16
119	0.884	13.50	11.07	18.01	6.50	51.85	8.20	39.26	9.40	30.37
120	0.870	9.06	7.46	17.61	3.90	56.95	4.06	55.19	5.70	37.09
121	0.835	3.73	3.26	12.47	2.35	37.00	2.45	34.32	3.36	9.92
122	0.893	13.04	14.79	13.40	5.60	57.06	6.40	50.92	8.45	35.20
123	0.861	5.96	5.84	2.09	3.00	49.66	3.03	49.16	4.19	29.70
124	0.893	8.44	14.27	69.09	5.50	34.83	5.60	33.65	7.68	9.00
125	0.861	5.58	5.85	4.80	2.40	56.99	2.65	52.51	3.43	38.53
126	0.829	2.10	2.84	35.27	1.25	40.48	1.43	31.90	1.83	12.86
127	0.860	4.86	5.68	16.97	2.35	51.65	2.44	49.79	3.36	30.86
128	0.898	23.72	17.55	26.03	11.50	51.52	10.90	54.05	15.49	34.70
129	0.878	11.18	9.13	18.37	2.90	74.06	3.20	71.38	5.25	53.04
130	0.865	6.83	6.46	5.43	3.30	51.68	3.20	53.15	3.90	42.90
131	0.859	4.55	5.56	22.30	3.10	31.87	3.30	27.47	2.15	52.75
132	0.913	33.65	28.89	14.13	28.50	15.30	42.60	26.60	50.00	48.59
133	0.906	26.38	22.46	14.85	21.00	20.39	28.20	6.90	40.33	52.88
134	0.887	11.84	12.16	2.71	8.20	30.74	8.60	27.36	15.32	29.39
135	0.849	4.93	4.52	8.35	5.80	17.65	6.90	39.96	11.58	134.89
136	0.893	19.51	14.30	26.71	11.00	43.62	11.20	42.59	13.55	30.55
AVERAGE DEVIATION				12.29		46.50		45.35		37.55

Table 4: COMPARISON OF BUBBLE-POINT VISCOSITY RESULTS

Res NO.	S.G	Exp. μ	Est. μ	Dev	Beal	Dev	Chew	Dev
137	0.855	0.66	0.71	6.97	1.40	112.12	1.35	104.55
138	0.855	0.63	0.67	6.95	1.40	122.22	1.35	114.29
139	0.863	0.90	0.82	8.63	1.45	61.11	1.60	77.78
140	0.855	0.63	0.71	12.02	1.40	122.22	1.35	114.29
141	0.841	0.42	0.56	32.27	0.90	114.29	1.00	138.10
142	0.839	0.49	0.49	0.73	0.82	67.35	0.82	67.35
143	0.932	4.70	3.63	23.10	3.40	27.97	3.30	30.08
144	0.925	4.30	4.97	15.59	3.90	9.30	4.30	2.33
145	0.885	1.50	1.26	16.01	1.60	6.67	1.65	10.00
146	0.895	2.27	1.19	47.66	2.30	1.32	2.60	14.54
147	0.825	0.30	0.30	1.13	0.24	20.00	0.24	20.00
148	0.919	4.20	3.77	10.34	5.00	19.05	8.00	90.48
149	0.876	0.85	0.93	9.08	1.55	82.35	2.00	135.29
150	0.852	0.57	0.43	24.93	0.69	21.05	0.74	29.82
151	0.928	3.00	3.53	17.60	6.00	100.00	5.80	93.33
152	0.925	4.30	5.11	18.75	4.30	0.00	4.30	0.00
153	0.860	0.85	0.77	9.14	1.50	76.47	1.80	111.76
154	0.846	0.56	0.57	2.66	0.50	7.14	0.55	1.79
155	0.841	0.45	0.43	4.85	0.41	8.89	0.42	6.67
156	0.831	0.37	0.38	4.00	0.32	13.51	0.31	16.22
157	0.826	0.29	0.35	19.84	0.28	3.45	0.27	6.90
158	0.854	0.67	0.64	4.93	0.66	1.49	0.70	4.48
159	0.861	0.80	0.68	15.53	0.72	10.00	0.73	8.75
160	0.845	0.53	0.54	1.38	0.55	3.77	0.55	3.77
161	0.834	0.37	0.36	2.16	0.27	27.03	2.27	27.03
162	0.838	0.54	0.48	11.68	0.43	20.37	0.42	22.22
163	0.856	0.62	0.64	3.20	0.65	4.84	0.67	8.06
164	0.857	0.66	0.68	2.37	0.67	1.52	0.66	0.00
165	0.916	3.84	3.58	6.82	3.30	14.06	4.00	4.17
166	0.853	0.67	0.62	6.84	0.37	0.00	0.68	1.49
167	0.916	3.84	3.58	6.82	3.30	14.06	4.00	4.17
177	0.822	0.30	0.38	27.29	0.28	6.67	0.31	3.33
	AVERAGE DEVIATION			12.01		42.41		42.87

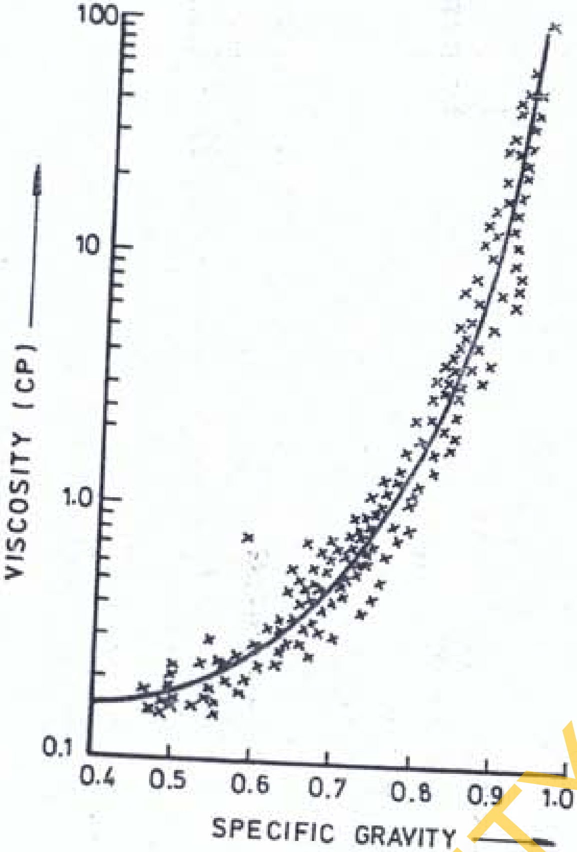

FIG. 1: EXPERIMENTAL VISCOSITY VERSUS SPECIFIC GRAVITY OF NIGERIAN CRUDES.

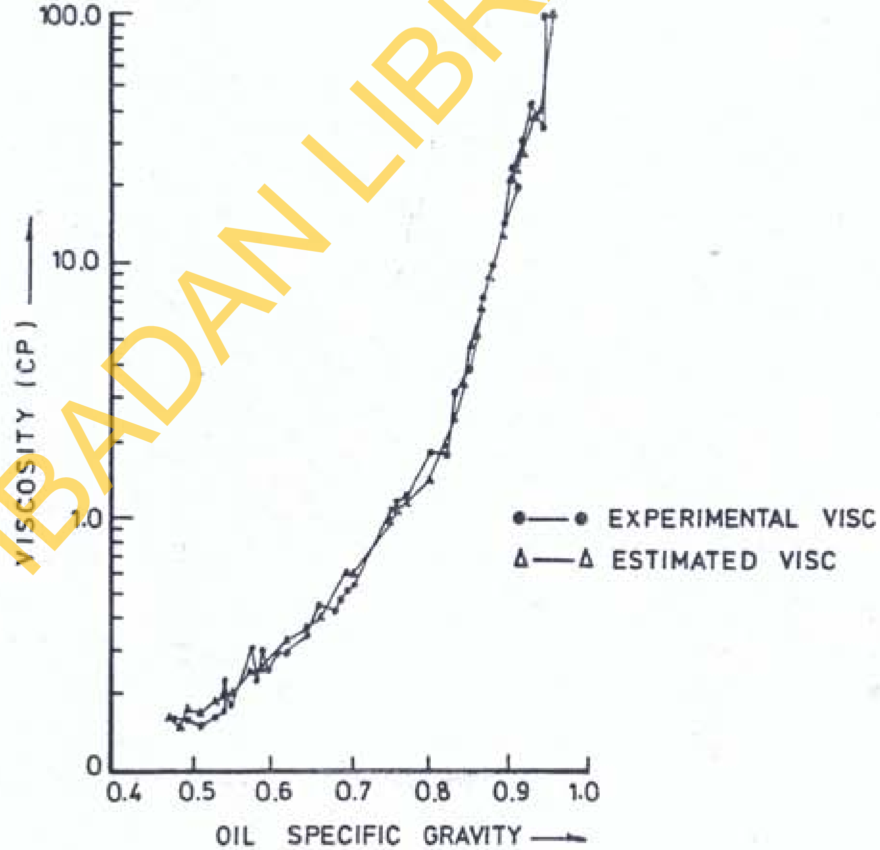

FIG. 2: VISCOSITY VERSUS OIL SPECIFIC GRAVITY FOR RESERVOIRS ABOVE BUBBLE POINT.

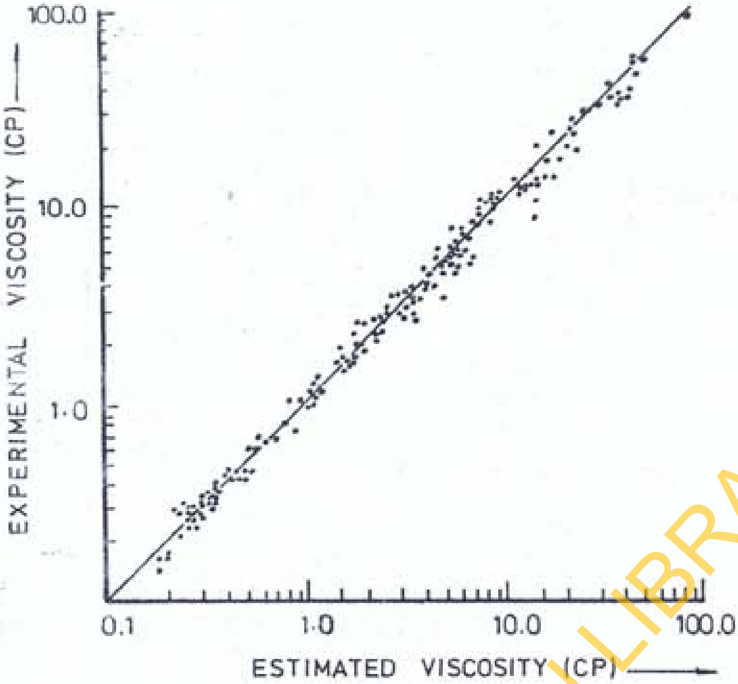

FIG. 3: CROSS PLOT FOR RESERVOIRS ABOVE BUBBLE POINT.

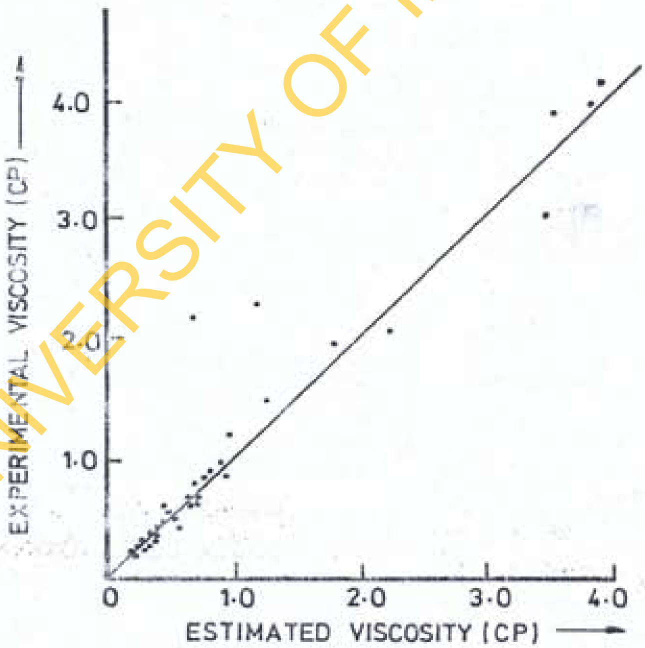

FIG. 4: CROSS PLOT FOR RESERVOIR AT SATURATION PRESSURE..