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New Pvt Correlations Applicable for Various Crude Oils

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Abstract: This paper seeks to overcome the shortcomings of previous correlations work on physical properties (PVT) of various crude oils. More than eighty samples were collected from different sources in the literature [1,2,3,4,5,6]. These samples screened and divided into two groups. This division was made at a value of oil gravity of 30° API. Equations were developed using multiple regression analysis to predict solubility of gas in oil at any pressure less or equal the bubble point pressure, the bubble point pressure, oil formation volume factor, and oil compressibility. The new correlations found adequately fit the measured data compared with previous correlations in the literature.

INTRODUCTION

Early accurate determination of the PVT properties of crude oils is always desirable in oil field development. These properties are determined in PVT laboratory from pressure – volume – temperature relationships, also can be determined from well – known correlations available in the literature[1,2,3,4,5,6,7]. Most of these correlations related to a specific geographical areas and some of theme has some restrictions and give a rowing results at low pressures[8]. Average gas gravity was used and do not consider the separator operating conditions in developing these new correlations. Average Absolute Percent Error (AAPE) and Maximum Absolute Percent Error (MAPE) used to Compare the results of these correlations with those in the literature [1,2,3]. It found that these new correlations had the lowest values of both AAPE & MAPE especially for crude oils of API less than 30° and at low pressures less than 1000 psi.

NEWLY DEVELOPED CORRELATIONS

The correlations in this study based on reservoir pressure, stock tank oil gravity, average gas gravity, and solution gas oil ratio. The multiple regression technique employed to investigate the mathematical models that match the measured parameters most closely (with maximum correlation coefficient).

Table (1) shows the range of input data used in this study, but the ranges can increased.
Table (2 & 3) shows the measured properties of crude oils.
The newly developed correlations given below and all constants shown in Table (4)

1- **Solution of Gas Oil Ratio:**

X1= G^c1*API^c2*Tr^c3
X2=(EXP(PI^C4))^c5
Rs= C6*EXP(C7*X1*X2)

2- **Bubble- Point Pressure:**

X1= X1= G^c1*API^c2*Tr^c3
X2= (Ln(Rs/c4)/(c5*X1))^(1/c6)
Pb= (Ln(X2))^(1/c7)

3- **Oil Formation Volume Factor:**

X1= (Rs^C1*G^C2)^C3
X2= (Log(API^C4*Tr^C5))^C6

X3= (X1^C7*X2)
Bo= C8*X3^2+C9*X3+C10

4- **Oil Compressibility:**

X1= C1*Rs^C2 *G^C3
X2= API^C4 *Tr^C5*P^C6
Co= (X1 * X2)

DISCUSSION OF RESULTS

After applying the new correlations on a wide range of measured properties of PVT data, it appeared that these correlations are more adequately match the measured properties than the previous correlations; since it has the minimum of AAPE & MAPE. These results are shown in tables (4) through (12) and in figures (1) through (8).
Figures (9) through (14) depict the error distribution about the measured properties which represents the zero line, from these figures it seemed that the new correlations are more stable than the other correlations.

CONCLUSIONS

1- New and more accurate correlations developed using multiple regression technique for predicting solution gas oil ratio, saturation pressure, oil formation volume factor, and oil compressibility.
2- The developed correlations can be used in the range of 20 – 5000 psi and solution gas oil ratio in the range of 80 – 2000 Scf/Stb., it should be used with care when the bubble point pressure less than 100 psi
3- The new correlations cover a larger geographical area than previous correlations.
4- The new correlations found to fit adequately random PVT data in the available literature, which means it has the generality.
5- The developed correlation has the lowest AAPE and MAPE among the other correlations.
6- This work adds a new correlation to the existing one in the literature.

NOMENCLATURE

AAPE	= Average Absolute percent Error
API	= Stock-Tank Oil Gravity.(API^o).
Bo	= Oil formation volume factor, Bbl/Stb
C	= Constant for calculation.
Co	= Oil compressibility, $Psia^{-1}$.
EXP	=2.718281828.
G	= Gas Gravity(air=1).
Ln	= Natural Logarithm base e
MAPE	= Maximum Absolute Percent Error.
P	= Pressure, psia
Tr	= Reservoir Temperature, F^o
Rs	= Solution Gas Oil Ratio.

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SI METRIC CONVERSION FACTORS

141.5/(131.5+ API^o)	= gm/cm^3
Bbl x 1.589783E-01	= m^3
Ft x 3.048E-01	= m
(F^o -32)/1.8	= C^o
Psi x 6.894757	= Kpa

TABLE (1) RANGE Of INPUT DATA

Parameter	API>30	API<=30
Pb,psig	20 -4500	2100 -4239
T,F	130 - 260	80 - 260
Rs,SCF/STB	80 - 1400	397 - 869
G	0.7 -1.17	.785 -.975
API	33.6 -48.6	21.5 - 30
Tsep,F	60 - 173	75 - 173
Psep,psia	75 -215	100 - 100

TABLE (2) INPUT DATA FOR OIL API> 30

OIL #	T,F	Pb,psig	Rs	API	G	Bo	Psep,psig	Tsep,F
1	130	2500	567	40	0.7	1.333	85	73
2	220	2620	768	40.7	0.855	1.474	100	75
3	260	2051	693	48.6	0.911	1.529	100	72
4	237	2884	968	40.5	0.898	1.619	60	120
5	218	3045	943	44.2	0.781	1.570	200	60
6	260	4480	1409	42.5	0.799	1.854	85*	75*
7	230	3486	756	35.1	0.759	1.440	85	75
8	180	4720	1280	38.6	0.756	1.664	85	75
9	192	3668	860	37.6	0.758	1.610	85	75
10	130	2400	554	40	0.7	1.310	85	75
11	130	1800	436	40	0.7	1.263	85	75
12	130	1200	337	40	0.7	1.210	85	75
13	253	1525	326	37.2	0.863	1.326	85	75
14	242	3395	688	36.6	0.71	1.406	85	75
15	210	1126	267	34.8	1.173	1.217	85	75
16	100	500	181	37.6	1.024	1.460	85	75
17	80	250	169	42.5	1.265	1.087	85	75
18	100	500	200	38.2	1.054	1.105	85	75
19	210	931	228	44.8	0.729	1.450	85	75
20	200	20	80	32.6	1.276	1.162	85	75
21	193	3748	1258	37.4	1.052	1.577	85	75
22	155	1000	338	42.9	0.998	1.204	85	75

TABLE (3) INPUT DATA FOR OIL API < = 30

OIL #	T,F	Pb,psig	Rs	API	G	Bo	Psep,psig	Tsep,F
1	240	2125	415	29.0	0.841	1.343	85	173
2	225	2550	470	25.8	0.833	1.362	85*	75*
3	260	2100	397	23.3	0.892	1.345	85	75
4	210	2770	540	30	0.867	1.36	85	75
5	195	3200	490	21.5	0.784	1.356	85	75
6	180	4239	807	27.3	0.848	1.432	85	75
7	200	4215	851	28.1	0.975	1.380	85	75
8	200	4210	869	28.4	0.968	1.410	85	75
9	220	2980	600	29.9	0.973	1.382	85	75

* assumed values

Table (4) Constants & Equations used to Calculate The Oil PVT Properties

	Rs		Pb		Bo		Co	
Constant	API<=30	API>30	API<=30	API>30	API<=30	API>30	API<=30	API>30
C1	1.11E-01	0.1211858	1.11E-01	0.1211858	0.70	0.70	1.8113E-06	520.4156E-09
C2	0.117	0.6888	0.117	0.6888	0.001	0.001	1.1	1.1052
C3	-0.0031	-0.00172	-0.0031	-0.00172	0.38	0.38	-0.87	-0.319
C4	0.0255	0.0234	3.599	60	1	1	0.77	1.012
C5	5.64	16.1581	0.003515	7.17E-10	3.8	1.65	0.039	0.017
C6	3.599	6.00E+01	5.64	16.158	0.2	2.8	-1	-0.9616
C7	0.003515	7.17E-10	0.0255	0.0234	1.95	1.95		
					-0.0002	2.00E-08		
					0.0205	4.00E-05		
					0.88	1.08		

	X1 =G^C1*API^C2*Tr^C3
	X2 = (EXP(P^C4))^C5
Rs =	C6*EXP(C7*X1*X2)

	X1 =G^C1*API^C2*Tr^C3
	X2 =(Ln(Rs/C4)/(C5*X1))^(1/C6)
Pb=	(Ln(X2))^(1/C7)

	X1 =(Rs^C1*G^C2)^C3
	X2 =(LOG(API^C4*Tr^C5)^C6
	X3 =(X1^C7*X2)
Bo =	C8 *X3^2+C9*X3+C10

	X1 =C1*Rs^C2*G^C3
	X2 = API^C4*Tr^C5*P^C6
Co =	X1 *X2

TABLE (5) OUTPUT FOR (Rs) CALCULATION FOR OIL API> 30

		Standing		Vasquez-Beggs		Glaso		Marhoun		Jawad	
OIL #	**Rsm**	**Rs**	**AAPE**	**Rs**	**AAPE**	**Rs**	**AAPE**	**Rs**	**AAPE**	**Rs**	**AAPE**
1	567	788	28.06	673	15.75	601	5.66	556	1.98	605	6.32
2	768	833	7.83	727	5.64	710	8.17	785	2.17	692	10.91
3	693	786	11.88	699	0.86	683	1.46	723	4.15	725	4.42
4	968	935	3.49	778	24.42	820	18.05	971	0.31	777	24.55
5	943	1036	8.98	942	0.11	862	9.40	839	12.40	931	1.27
6	1409	1434	1.74	1245	13.17	1349	4.45	1311	7.48	1462	3.65
7	756	838	9.83	724	4.42	744	1.61	721	4.85	716	5.53
8	1280	1542	16.97	1294	1.08	1321	3.10	1373	6.77	1258	1.76
9	860	1068	19.49	903	4.76	897	4.12	915	6.01	859	0.07
10	554	750	26.16	642	13.71	573	3.32	525	5.52	580	4.51
11	436	530	17.73	456	4.39	414	5.31	351	24.22	440	0.89
12	337	325	3.79	282	19.50	270	24.81	199	69.35	316	6.69
13	326	357	8.57	324	0.62	342	4.68	324	0.62	364	10.37
14	688	777	11.41	677	1.62	700	1.71	587	17.21	732	5.98
15	267	344	22.42	300	11.00	323	17.34	488	45.29	286	6.51
16	181	164	10.66	144	25.69	169	7.10	165	9.70	186	2.81
17	169	50	239.65	45	275.56	82	106.10	58	191.38	153	10.42
18	200	109	83.44	103	94.17	141	41.84	132	51.52	189	5.64
19	228	172	32.63	152	50.00	177	28.81	180	26.67	240	4.86
20	80	1089	92.65	936	91.45	894	91.05	795	89.94	81	1.36
21	1258	283	345.14	246	411.38	272	362.50	452	178.32	1148	9.55
22	338	1519	77.74	1308	74.16	1336	74.70	2078	83.73	321	5.29
23	338	386	12.41	339	0.29	336	0.60	391	13.55	321	5.29
AAPE		**47.51**		**49.73**		**35.91**		**37.09**		**6.03**	
MAPE		**345.14**		**411.38**		**362.50**		**191.38**		**24.55**	

AAPE is the average Absolute Percent Error
MAPE is the Maximum Absolute Percent Error

TABLE (6) OUTPUT FOR (Pb)CALCULATION FOR OIL API> 30

		Standing		Vasquez-Beggs		Glaso		Marhoun		Jawad	
OIL #	**Pbm**	**Pb**	**APE**	**Pb**	**AAPE**	**Pb**	**AAPE**	**Pb**	**AAPE**	**Pb**	**AAPE**
1	2500	1921	30.17	2160	15.74	2378	5.13	2535	1.38	2347	6.52
2	2620	2488	5.30	2741	4.41	2797	6.33	2578	1.63	2870	8.71
3	2051	1868	9.81	2043	0.39	2083	1.54	1992	2.96	1970	4.13
4	2884	3026	4.68	2476	16.48	3295	12.47	2877	0.24	3453	16.48
5	3045	2870	6.10	3049	0.13	3269	6.85	3309	7.98	3076	1.00
6	4480	4530	1.10	4968	9.82	4622	3.07	4718	5.04	4367	2.58
7	3486	3265	6.77	3613	3.52	3529	1.22	3607	3.35	3653	4.58
8	4720	4140	14.01	4674	0.98	4617	2.23	4489	5.15	4779	1.23
9	3668	3124	17.40	3518	4.26	3553	3.24	3509	4.53	3670	0.06

10	2400	1883	27.45	2119	13.26	2332	2.92	2493	3.73	2294	4.63
11	1800	1536	17.16	1731	3.99	1888	4.66	2101	14.33	1782	1.00
12	1200	1233	2.67	1394	13.92	1489	19.41	1747	31.31	1307	8.20
13	1525	1420	7.40	1556	1.99	1469	3.81	1559	2.18	1326	15.01
14	3395	3133	8.38	3443	1.39	3349	1.37	3802	10.70	3214	5.62
15	1126	899	25.28	1020	10.39	927	21.47	732	53.83	1020	10.42
16	500	518	3.38	607	17.63	540	7.41	535	6.54	472	6.01
18	250	328	23.77	380	34.21	311	19.61	298	16.11	316	20.81
19	500	541	7.61	631	20.76	572	12.59	538	7.06	556	10.11
20	931	761	22.32	875	6.40	774	20.28	571	63.05	857	8.62
21	20	255	92.14	315	93.65	190	89.47	260	92.31	18	12.18
22	3748	3274	14.47	3628	3.31	3580	4.69	2618	43.16	4005	6.42
23	1000	882	13.44	997	0.30	1006	0.60	902	10.86	1070	6.58
AAPE		**16.40**		**12.59**		**11.38**		**17.61**		**7.31**	
MAPE		**92.14**		**93.65**		**89.47**		**92.31**		**20.81**	

TABLE (7) OUTPUT FOR (Bo) CALCULATION FOR OIL API> 30

		Standing		**Vasquez-Beggs**		**Glaso**		**Marhoun**		**Jawad**	
OIL #	**Bom**	**Bo**	**APE**	**Bo**	**AAPE**	**Bo**	**AAPE**	**Bo**	**AAPE**	**Bo**	**AAPE**
1	1.333	1.279	4.23	1.313	1.52	1.282	4.01	1.282	3.95	1.312	1.57
2	1.474	1.487	0.87	1.450	1.64	1.496	1.49	1.477	0.23	1.495	1.41
3	1.529	1.494	2.31	1.451	5.38	1.499	2.03	1.511	1.19	1.528	0.09
4	1.619	1.635	0.96	1.556	4.07	1.650	1.90	1.595	1.54	1.609	0.60
5	1.570	1.571	0.05	1.546	1.59	1.585	0.95	1.554	1.00	1.588	1.12
6	1.854	1.892	2.03	1.797	3.19	1.903	2.60	1.807	2.63	1.875	1.11
7	1.440	1.455	1.00	1.448	0.58	1.458	1.22	1.445	0.36	1.478	2.60
8	1.664	1.719	3.19	1.676	0.74	1.744	4.56	1.641	1.41	1.639	1.55
9	1.610	1.487	8.27	1.482	8.64	1.500	7.37	1.465	9.93	1.488	8.16
10	1.310	1.273	2.95	1.306	0.29	1.275	2.79	1.277	2.60	1.308	0.14
11	1.263	1.216	3.87	1.250	1.01	1.212	4.23	1.226	2.99	1.268	0.42
12	1.210	1.170	3.41	1.204	0.52	1.162	4.18	1.183	2.27	1.234	1.94
13	1.326	1.259	5.33	1.248	6.22	1.241	6.89	1.294	2.47	1.294	2.44
14	1.406	1.416	0.70	1.434	1.97	1.413	0.52	1.423	1.19	1.465	4.03
15	1.217	1.222	0.41	1.176	3.51	1.208	0.72	1.244	2.16	1.241	1.96
16	1.460	1.100	32.76	1.101	32.58	1.092	33.74	1.100	32.78	1.161	25.71
17	1.087	1.093	0.56	1.087	0.04	1.088	0.11	1.089	0.21	1.151	5.58
18	1.105	1.111	0.55	1.110	0.44	1.104	0.11	1.112	0.60	1.168	5.39
19	1.450	1.173	23.56	1.147	26.38	1.183	22.59	1.216	19.20	1.235	17.39
20	1.162	1.110	4.70	1.086	6.99	1.089	6.73	1.133	2.54	1.143	1.63
21	1.577	1.847	14.64	1.674	5.77	1.900	16.99	1.769	10.85	1.648	4.34
22	1.204	1.218	1.17	1.205	0.09	1.213	0.70	1.235	2.48	1.255	4.09
AAPE		**5.34**		**5.14**		**5.75**		**4.75**		**4.24**	
MAPE		**32.76**		**32.58**		**33.74**		**32.78**		**25.71**	

Fig.(1)

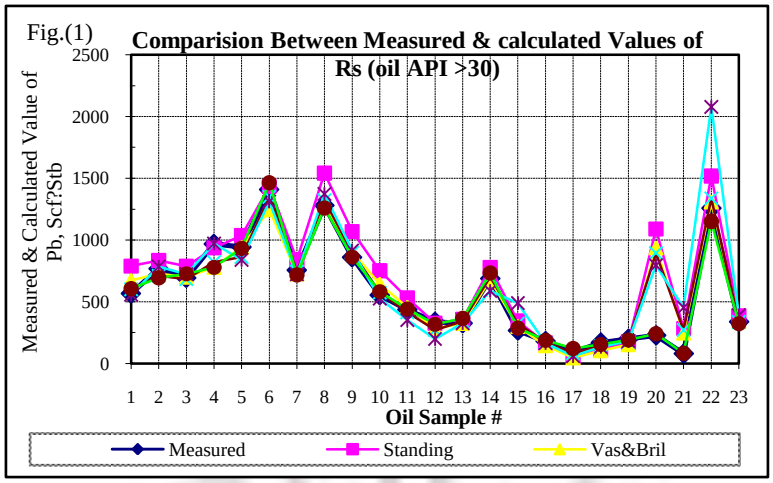


Fig.(2)

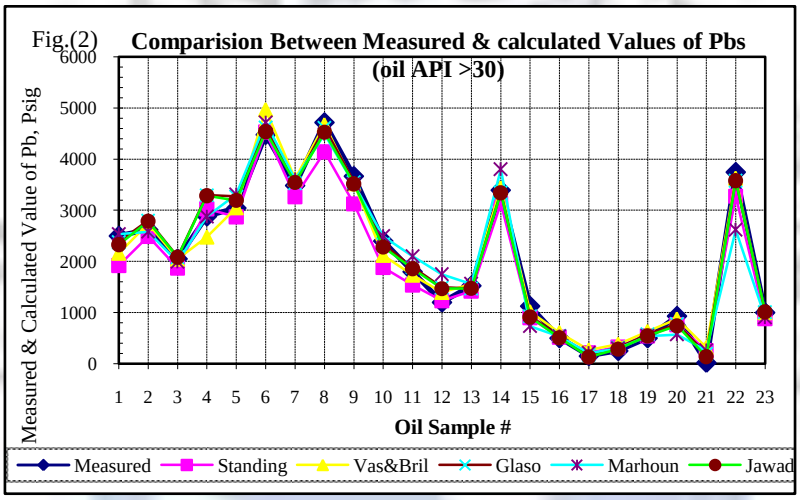


Fig.(3)

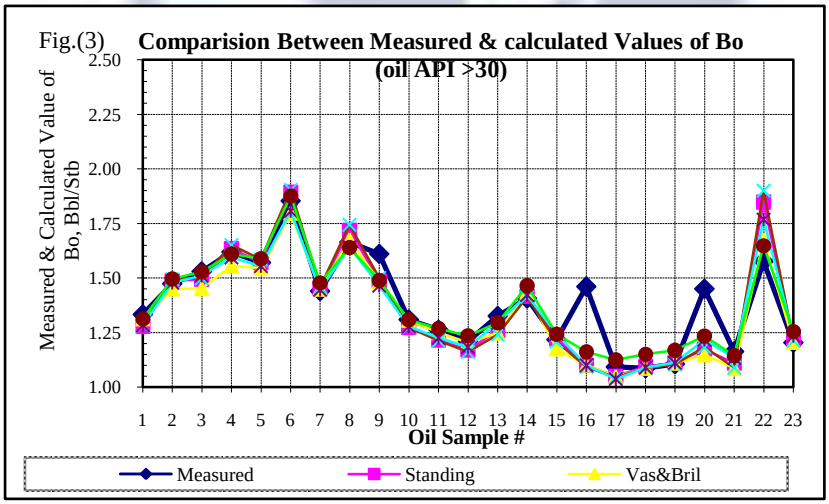


Fig.(4)

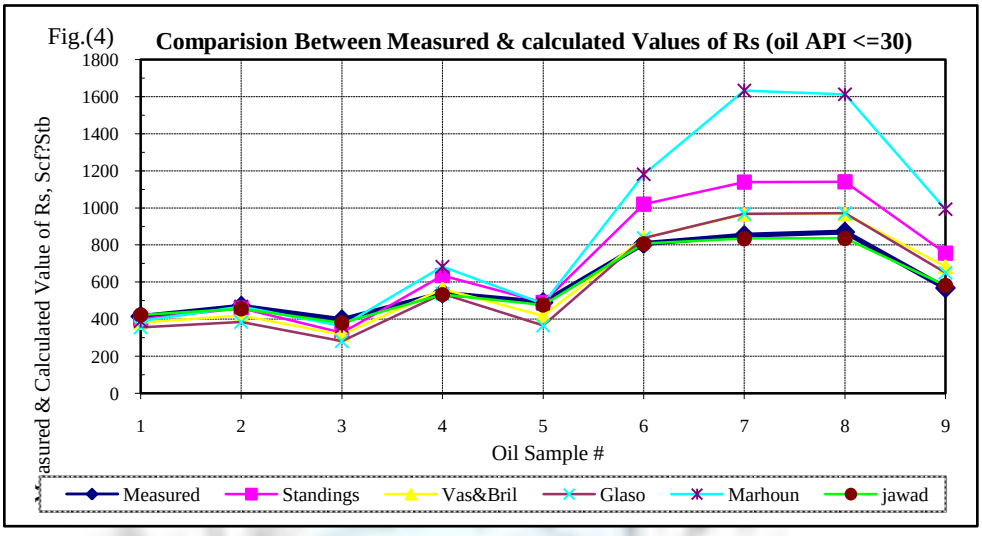


Fig.(5)

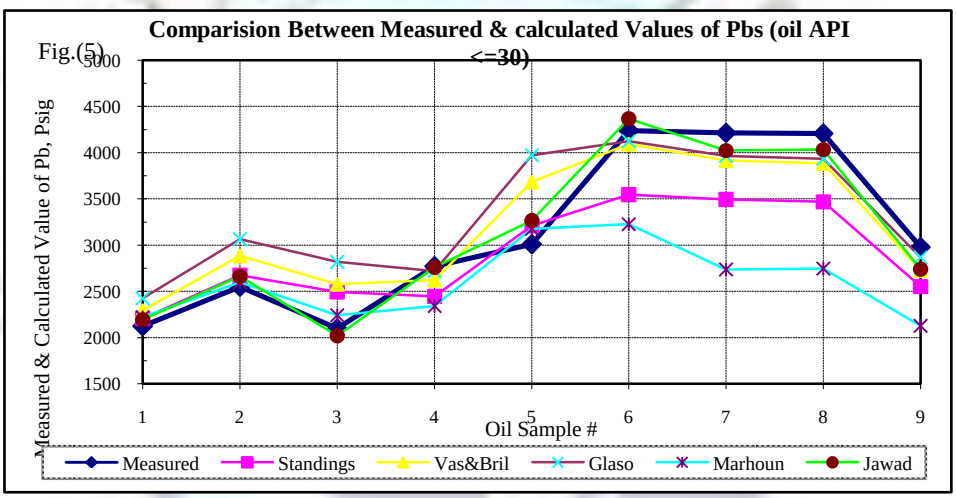


Fig.(6)

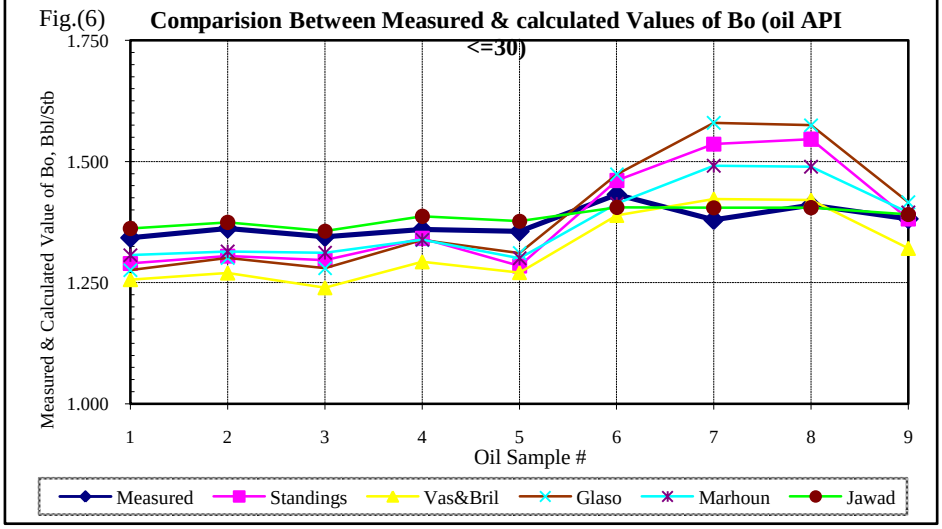


Fig.(7 **Comparision Between Measured & calculated Values of Co(Oil API>30)**

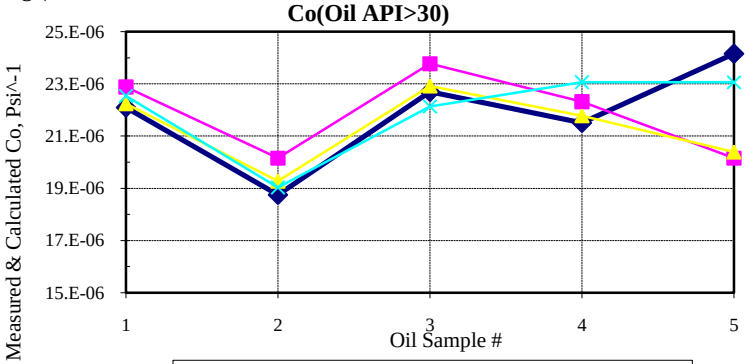


Fig.(8 **Comparision Between Measured & calculated Values of Co(Oil API<=30)**

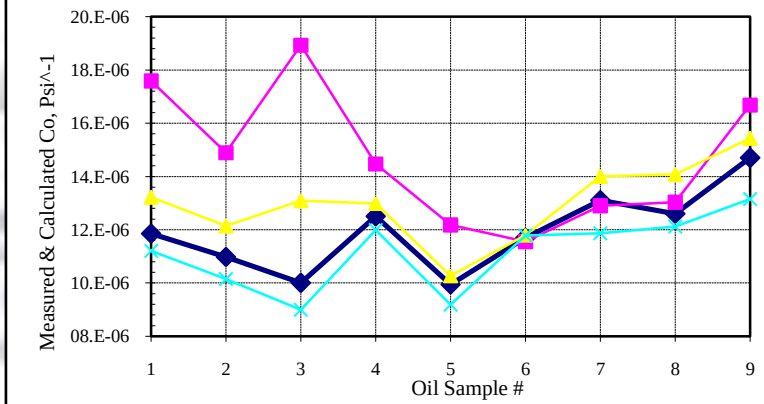
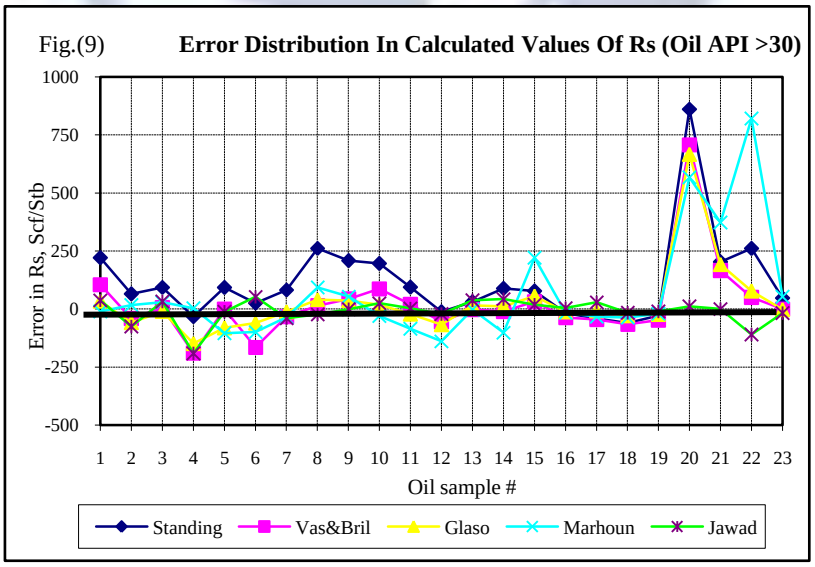
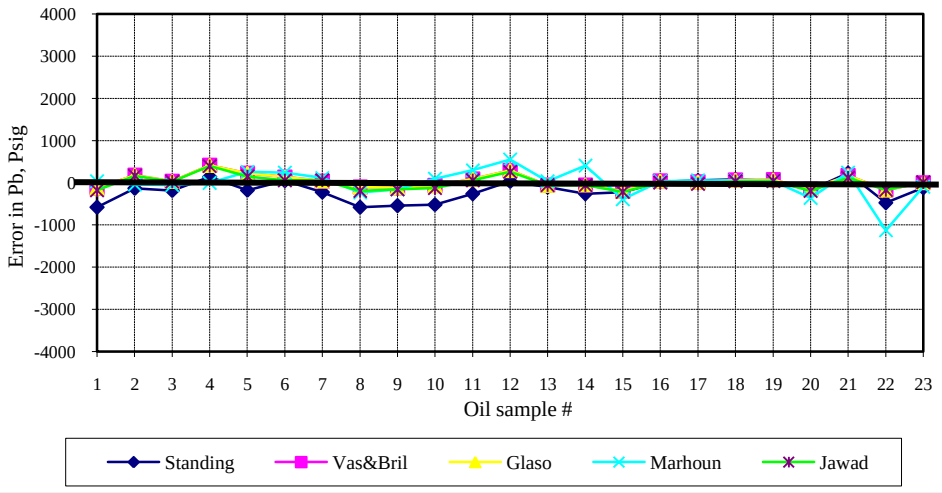


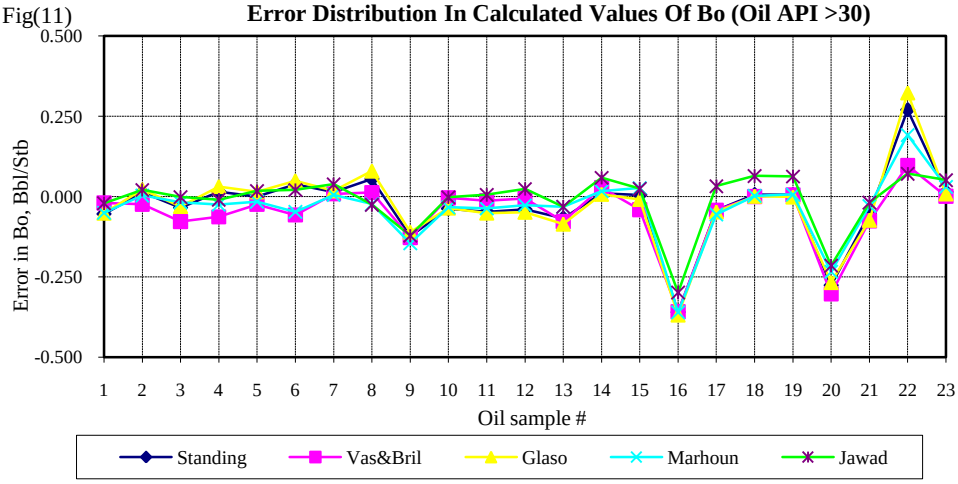
Fig.(9) **Error Distribution In Calculated Values Of Rs (Oil API >30)**



Fig(10) **Error Distribution In Calculated Values Of Pbs (Oil API >30)**



Fig(11) **Error Distribution In Calculated Values Of Bo (Oil API >30)**



Fig(12) **Error Distribution In Calculated Values Of Rs (Oil API <=30)**

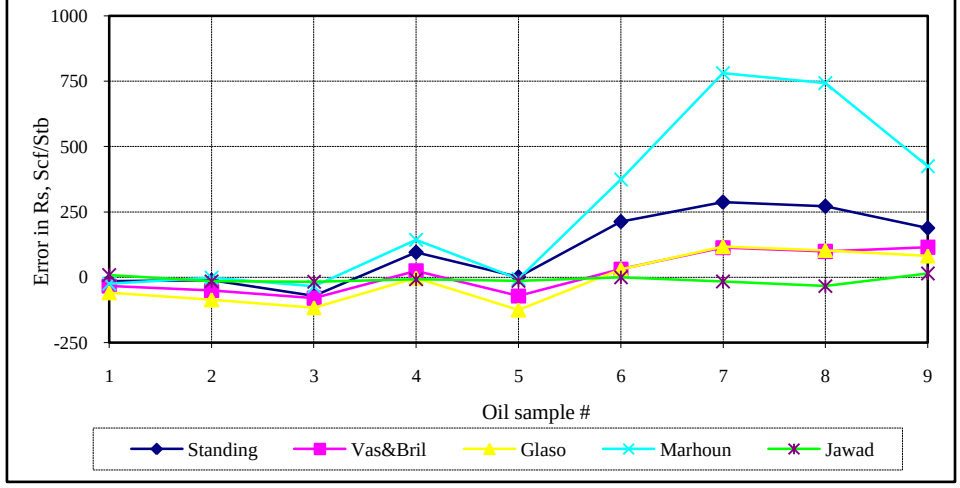


Fig.(13) **Error Distribution In Calculated Values Of Pbs (Oil API <=30)**

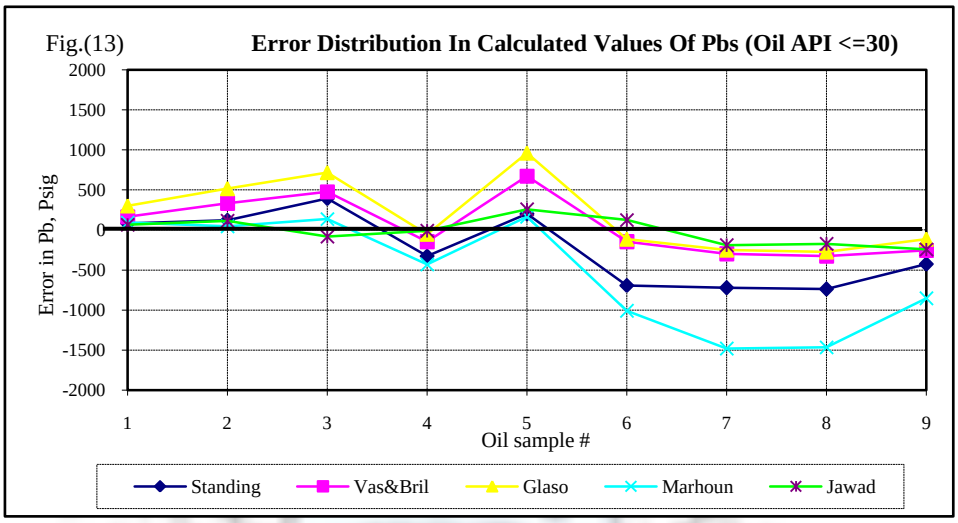


Fig.(14) **Error Distribution In Calculated Values Of Bo (Oil API<=30)**