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AN ALTERNATIVE CORRELATION FOR THE COMPUTATION OF PSEUDO-CRITICAL TEMPERATURE AND PRESSURE

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ABSTRACT

Pseudo-critical temperature (T_{pc}) and pressure (P_{pc}) of natural gases are required for the application of the principle of corresponding states which is used in correlating several gas properties such as compressibility factor and viscosity. For a natural gas sample of unknown composition, a number of correlations exist that can be used to evaluate the T_{pc} and P_{pc} of the gas as a function of its specific gravity. This paper presents an alternative correlation for obtaining these parameters, also as a function of the gas specific gravity. The development of the correlation with a regressional tool in Microsoft Excel package - as well as a comparison of results with other methods (such as Standing's, Sutton's, etc) is made. The results, based on Brown et al's correlation, show that ou: correlation gives comparatively lower absolute errors than the other methods, and as such may be used in their stead. Finally, the coefficients of correlation, when plots of the equations in the correlation developed in this study were made, show a high degree of correlation between T_{pc}, P_{pc} and specific gravity

KEYWORDS: Correlation, composition, compressibility, pseudo-critical temperature, and pseudo-critical pressure

INTRODUCTION

The critical constants of gases are prerequisite for the application of corresponding states. This principle has been very useful in correlating the properties of gases (Bradley, 1987). For instance, with the critical temperature and pressure of a gas having being determined the reduced temperature and pressure of the gas is calculated and the compressibility factor of the gas can subsequently be read off from the appropriate charts

In applying the principle of corresponding states to natural gas, which is a mixture of various gases, the critical temperature and pressure of any of the individual constituent gases cannot be used to represent the mixture. Rather, it is necessary to obtain a more representative "pseudo-critical" temperature and pressure for the gaseous mixture. There are basically two methods for determining the pseudo-critical temperature and pressure of hydrocarbon gas mixtures. The first method is used when the composition of the gas is known. This method involves the employment of mixing rules, such as Stewart et al's mixing rules (Lee and Wittenberg, 1996), and Kay's mixing rules (Bradley, 1987; Golan, and Whitson, 1986; Joshi, 1991, and Lee and Wittenberg, 1996), to determine the pseudo-critical temperature and pressure of the gas.

The second method is used for gas mixtures of unknown composition. This method involves the use of correlations that relate the pseudo-critical temperature and pressure of the gas to its specific gravity. There are a number of such correlations available among which are those by Standing, Joshi, Sutton, and others.

Development of the Correlation

The equations were developed using the data in Table 1 obtained from the Brown et al correlation. Several values of specific gravity were selected and Brown et al read the corresponding values of pseudo-critical temperature and pressure from the chart. Using the Microsoft Excel, various specific gravity values were regressed with the corresponding values of pseudo-critical temperature and pressure respectively with the specific gravity as the independent variable. This process yielded two equations of the form

$$X_{pc} = A(\gamma_g)^2 + B(\gamma_g) + C \qquad (1)$$

Where:

X_{pc} = Pseudo-critical constant (temperature or pressure)

γ_g = Specific gravity of natural gas

and

A, B, C are constants.

The data used for the regression and the resultant equations are in Table 1

The following equations resulted from the regression.

$$T_{PC} = 158.01 + 342\ 12\ (\gamma_g) - 16.04(\gamma_g)^2 \qquad (2)$$

$$P_{PC} = 688\ 634 - 21\ 983(\gamma_g) - 13\ 886\ (\gamma_g)^2 \qquad (3)$$

Table 1: Regression Data Obtained from Brown et al Pseudo-critical constant Chart

Specific	T_{PC}	P_{PC}
0.60	357.0	670 0
0.65	373.7	669 0
0.70	390.0	666 0
0.75	405.0	664.5
0.80	423.0	663.0
0.85	437.0	660.0
0.90	453.0	658.0
0.95	468.0	656.0

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1.00	484.0	653.0
1.05	499.0	650.0
1.10	515.0	647.5
1.15	530.0	645.0
1.20	546.0	642.5

RESULTS AND DISCUSSION

Pseudo-critical Temperature

Pseudo-critical temperature values obtained from equation (2) were compared with those obtained from other methods (Table 6), which expressed T_{PC} as a function of gas specific gravity. Table 2 shows T_{PC} values obtained from the various methods for a range of specific gravity values

Table 2: T_{PC} Values Obtained from the Various Methods

Specific gravity	This method	Standing	Joshi	Sutton	Brown et al
0.63	367.179	367.789	366.82	360.014	367.5
0.78	415.105	413.895	413.92	396.788	415.0
0.82	427.763	426.095	426.48	406.032	427.5
0.94	465.430	462.455	464.16	432.344	465.0
0.99	480.988	477.499	479.86	442.678	480.0
1.02	490.284	486.495	489.28	448.700	490.0
1.07	505.714	501.439	504.98	458.442	505.0
1.12	521.064	516.320	520.68	467.814	520.0
1.17	536.333	531.139	536.38	476.816	537.5
1.20	545.456	540.000	545.80	482.040	545.0

Setting the method of Brown et al (Bradley, 1987, Ikoku, 1984) as an arbitrary standard, Tables 3 and 4 show the extent to which results obtained from each of the other methods deviate from those from the Brown et al method These results are also plotted in Figs 1 and 2

Table 3: Absolute Error in T_{PC}, % (Deviation from Brown et al)

Specific gravity	Standing	Joshi	Sutton	This Method
0.63	0.0786	0.185	2.037	0.0873
0.78	0.2663	0.2602	4.3884	0.0253
0.82	0.3287	0.2386	5.0218	0.0615
0.94	0.5473	0.1806	7.0228	0.0925
0.99	0.521	0.0292	7.7754	0.2058
1.02	0.7153	0.1469	8.4286	0.058
1.07	0.7051	0.004	9.2194	0.1414
1.12	0.7077	0.1308	10.0358	0.2048
1.17	1.1834	0.2084	11.29	0.2171
1.20	0.9174	0.1468	11.5523	0.0837

A look at this table reveals that results from other methods are seen to be generally in agreement with those obtained from this method. The largest differences, however, are obtained in the case of result from Sutton's correlation - it can be seen that, in general, Sutton's correlation yields results that differ markedly from those obtained from the other methods

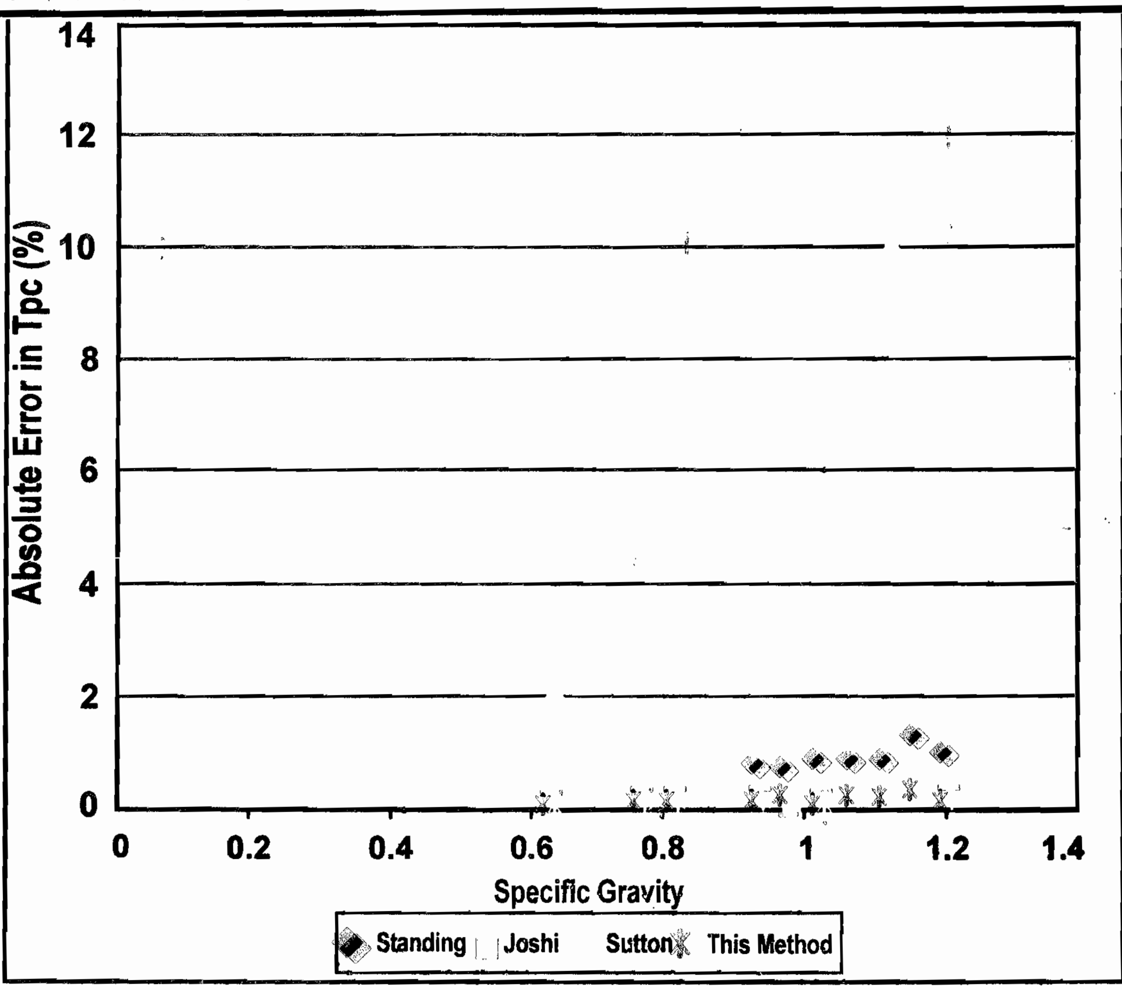

Fig. 1: Absolute error in T_{PC} (%) vs. Specific gravity for various correlations.

Pseudo-critical Pressure: Just as in the case of the pseudo-critical temperature, results given by equation (3) for P_{PC} were compared with those obtained from the following methods (Table 6)

Table 4 presents the results.

Table 4: P_{pc} values obtained from the various Methods

Specific gravity	This Methods	Standing	Joshi	Sutton	Brown et al
0.63	669.273	671.566	671.775	672.841	670.0
0.78	663.039	665.885	663.150	652.430	665.0
0.82	661.271	664.085	660.850	646.959	662.5
0.94	655.700	657.965	653.950	630.479	655.0
0.99	653.261	655.096	651.075	623.582	654.0
1.02	651.764	653.285	649.350	619.435	652.5
1.07	649.214	650.116	646.475	612.508	650.0
1.12	646.594	646.760	643.600	605.564	647.5
1.17	643.905	643.216	640.725	698.602	645.0
2.20	642.259	641.000	639.750	594.416	642.0

In general, it can be seen that the results from the various methods are not too different from those obtained from this method. The exceptions, however, are the results derived from Sutton's correlation; here pronounced errors which increase with increasing gravity are observed. Such pronounced deviation is, however, not exclusive to the results from this method but are also evident between the results obtained from the other methods and those obtained from Sutton's correlation.

Table 5 shows the absolute errors between each of the results derived from the various methods based on the Brown et al method. The table helps one to perceive the extent to which these results deviate from the Brown et al method.

A look at Table 5 reveals that the error evident between the Brown et al method and this method is small implying that results from equation (3) compare favorably with those from the Brown et al method and indeed with result from the other methods in general. Figure 2 also illustrates the extent to which results from the various correlations deviate from results from the Brown et al correlation.

Finally, plots of T_{pc} and P_{pc} versus specific gravity for the correlations developed in the study were made and presented in fig. 3. Their coefficients of correlation, R^2, are displayed conspicuously on the graph, showing good correlation between T_{pc}, P_{pc} and specific gravity.

The Brown et al correlation is displayed graphically in fig. A1 (Appendix A attached).

Table 5: Absolute Error in P_{pr} % (Deviation from Brown et al)

Specific gravity	Standing	Joshi	Sutton	This Methods
0 63	0 2337	0 2649	0 4240	0 1085
0.78	0.1331	0.2782	1.8902	0.2949
0.82	0.2392	0.2491	2.3458	0.1855
0 94	0.4527	0.1603	3.7437	0 1069
0.99	0.1676	0.4472	4.6511	0.1130
1.02	0.1203	0.4828	5.0674	0.1128
1 07	0.0178	0 5423	5 7680	0 1209
1 12	0 1143	0 6023	6 4766	0 1399
1 17	0.2766	0.6628	8.3104	0 1698
1.20	0.1558	0.3505	7.4118	0.0403

Table 6 Developed correlations for T_{pc} and P_{pc} versus specific gravity, γ_g

Author(s)	T_{pc}	P_{pc}
Brown et al (Ikoku, 1984)	$T_{PC} = 170.491 + 307.344 (\gamma_g)$	$P_{PC} = 709.604 + 58.718 (\gamma_g)$
Standing(Golan and Whitson, 1986)	$T_{PC} = 168 + 325 (\gamma_g) - 12.5 (\gamma_g)^2$	$P_{PC}=677+15.0 (\gamma_g) - 7.5 (\gamma_g)^2$
Joshi (1991)	$T_{PC} = 169 + 314 (\gamma_g)$	$P_{PC} = 708.75 - 57.5 (\gamma_g)$
Sutton(Lee and Wattenbarger, 1996)	$T_{PC} = 169.2 + 349.5 (\gamma_g) - 74 (\gamma_g)^2$	$P_{PC}=756.8-131 (\gamma_g) - 3.6 (\gamma_g)^2$
This method	$T_{PC} = 158.01 + 342.12 (\gamma_g) - 6.04 (\gamma_g)^2$	$P_{PC} = 688.634 - 21.983 (\gamma_g) - 13.886 (\gamma_g)^2$

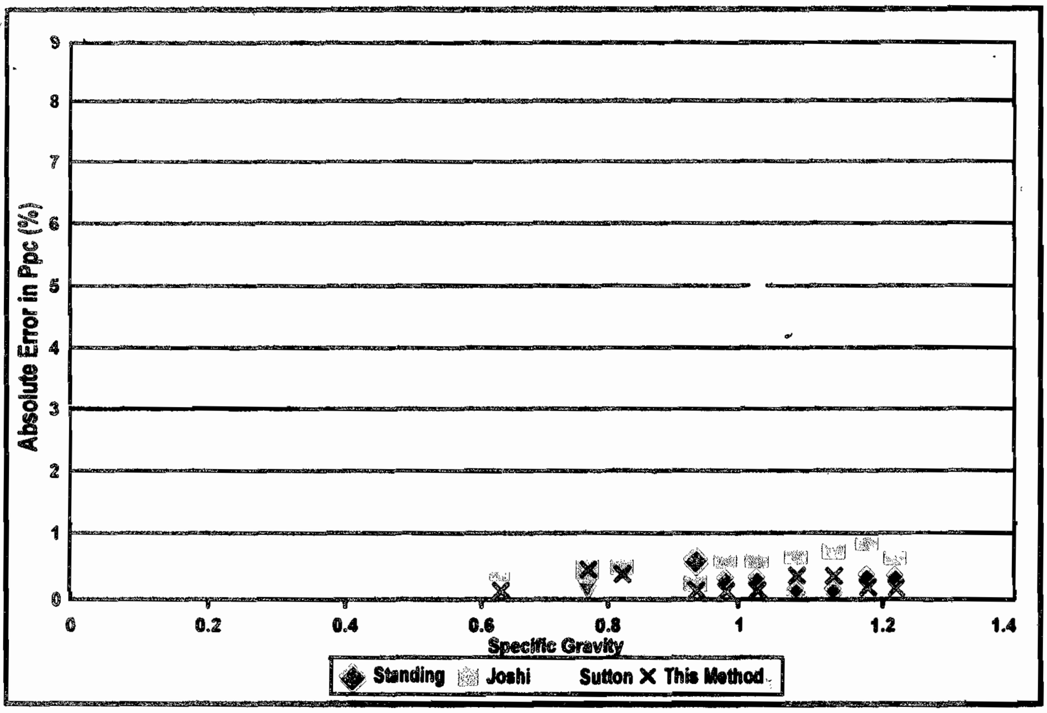

Fig. 2: Absolute error in P_{PC} (%) vs. Specific gravity for various correlations.

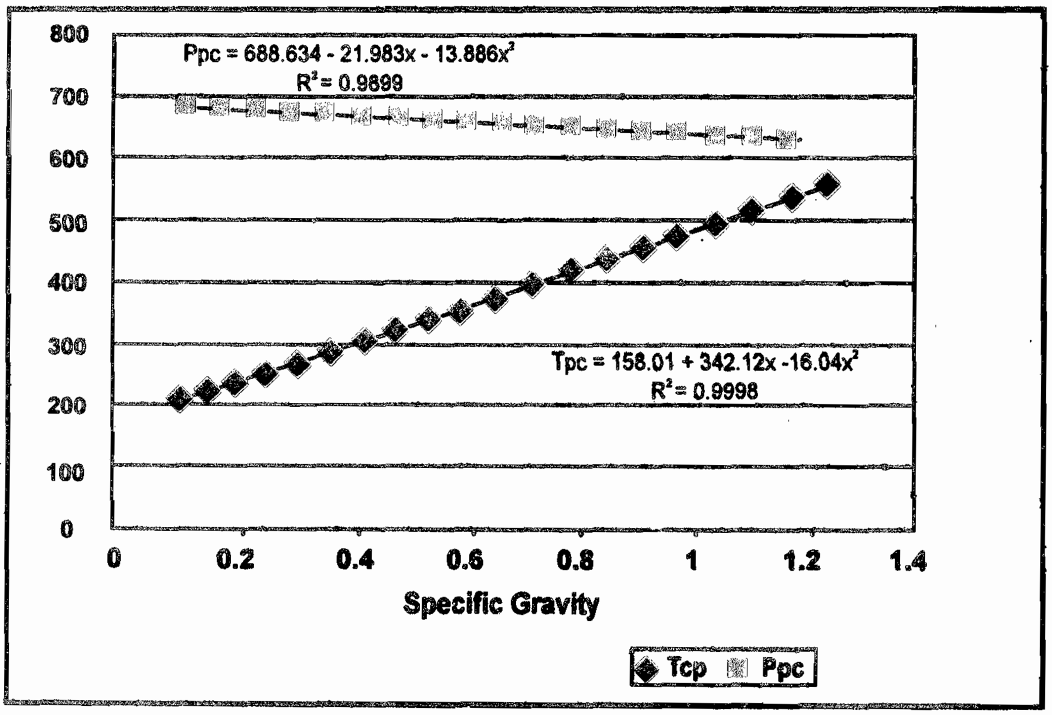

Fig. 3: Plot of T_{PC} and P_{PC} versus specific gravitty for the correlations developed.

CONCLUSION

It is seen from the tabulated results that the equations derived from the regression process in equations (2) and (3) for the determination of T_{pc} and P_{pc} respectively compare favorably with those from the other methods considered These equations may therefore be used to in lieu of the other correlations to determine pseudo-critical temperature and pressure for a natural gas sample of unknown composition

Nomenclature

γ_g - Gas specific gravity

P_{pc} - Pseudo-critical pressure, psia

T_{pc} - Pseudo-critical temperature, ^0R

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Appendix A

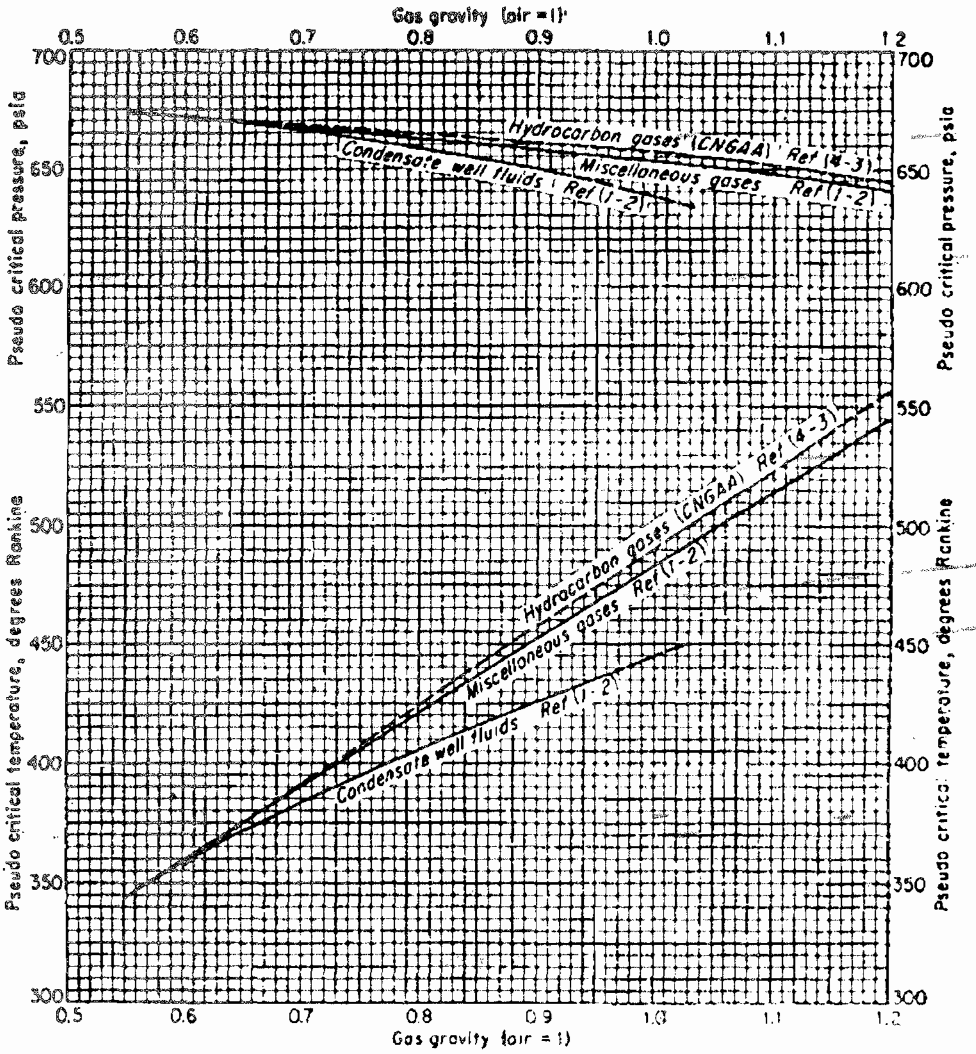

Fig. A1: Pseudo-critical properties of natural gases (after Brown et al)