HYDROCARBON MINIMUM MISCIBILITY PRESSURE CORRELATIONS

Me'ad I. Al-Huwadi, Ghazwan N. Saad, and Muzher M. Al-Doury*
Petroleum Engineering Department, College of Engineering, University of Baghdad
*Chemical Engineering Department, College of Engineering, Tikrit University

ABSTRACT

Special correlations for predicting minimum miscibility pressure (M.M.P) for Jambour-Cretaceous oil reservoir under gas injection conditions are developed using a multi-variable regression technique.

Data are obtained from equation of state (E.O.S) phase behavior model that simulates the multi-contact by (M.C.M), vaporization and condensation process.

INTRODUCTION

Many definitions for M.M.P are found in the literature (1-5). Each of them describe this pressure according to the used criteria for the achievement of miscibility.

The most general definition is "the lowest pressure required for miscibility between gas and oil leading to the disappearance of interfacial tension between the two fluids (gas/liquid).

M.M.P determination by empirical correlations follows one of the following branches: (1) M.M.P correlations based on experimental data (1,2,5,6). (2) M.M.P. correlation based on E.O.S (3,4,9) (phase behavior modeling). (3) M.M.P. correlations based on combination of the above[8].

Experimental measurements for M.M.P. of gas oil mixtures has traditionally been obtained by performing slim-tube displacements. These experiments include constant temperature displacement of oil from slim-tube by an injection gas. Series of runs are performed till the M.M.P. is detected at pressure of maximum recovery.

Another method that is used to predict M.M.P. experimentally is the rising bubble apparatus (R.B.A). During such measurements, a small bubble of gas is injected at the base of the column of oil. This procedure is repeated over a range of pressures and M.M.P., is detected depending on behavior and shape of the rising bubble.

Equation of state M.M.P. calculation deals with compositional phase behavior for (gas-oil) mixtures with the aid of phase ternary diagram. Detection of critical region and tie-line limitation is important to M.M.P. detection.

M.M.P. have important consequence for the design of miscible displacement processes. Therefore, prediction of this parameter is essential for the understanding of the concept of miscible displacement.

Miscible displacement is represented mostly by ternary diagram. Fig. (1) [6] shows a pseudo ternary representation, since the apexes consist of light, intermediate and heavy components respectively, it can be used to qualitative description of the process of miscible displacement. Fig. (1) has been divided into three zones, Zone-1, Zone-2, and Zone-3.

Zone-1

Represent the area of first contact miscibility. Any solvent lies in this part of the ternary mixes with the reservoir oil at any condition because the mixtures falls outside the two phase region.

Zone-2

Represents the region of M.C.M. solvent within this area are not initially miscible with the oil, therefore multi-contacts are required in order to achieve miscibility.

There two types of M.C.M. processes. Vaporization gas drive is when the solvent is enriched by component vaporized from the reservoir oil while condensing or enriched gas drive is when the reservoir oil is enriched by components that condensed from the injected gas. Each of the M.C.M. processes type depend on mass transfer of intermediate components between fluids.

Zone –3

This refers to the phase region through which immiscible case ooccur, that results in multiphase flow.

Yurkiw, F.J. and Flock, D.L. [8] (1994,submitted, a comparative study about M.M.P. correlations for E.Q.R. with statistical analysis among them. The general observation obtained is that, none of the M.M.P. correlations evolution would appear to be sufficiently accurate for more than preliminary M.M.P. calculation process. Experimental measurements of M.M.P. would likely be required for final M.M.P. determination.

Their recommendation was that, the Kuo [3] correlation based on E.O.S. was found to be the most reliable of the rich gas correlations. Nawar and Flock [9] (E.O.S based), Fairoozabadi & Aziz [4] (E.O.S//statistical based) was found to be the most reliable of the lean gas correlations.

THE PRESENT WORK

Based on data obtained from phase behavior model "MIS-Model" using MSRK-E.O.S., a multi-variable regression technique is used to develop a correlation for predicting M.M.P. for Jambour Cretaceous oil reservoir.

The general dependent variables that are included in the correlation representing M.M.P. are the following: (1) PR, reservoirs pressure at a depletion stage. (2) MWC_2^+, Molecular weight of C_2-C_6 in the injected gas. (3) MWC_7^+, Molecular weight of C_7^+ in the oil. (4) C_1, mole fraction of methane in the injected gas.

The general equation obtained for Jambour-Cretaceous reservoir are:

$$M.P.P. = 7575 - \delta_1 MWC_7 - \delta_2 MWC_2^+ + \delta_3 C_1 - \delta_4 PR$$

$$M.M.P = 2068 - \delta_1 MWC_7 - \delta_2 MWC_2^+ + \delta_3 C_1 + \delta_4 PR$$

for vaporization and condensation respectively.

For vaporization:

$\delta_1 = 5.4$, $\delta_2 = 2.04$, $\delta_3 = 28.2$, and $\delta_4 = 0.744$.

For condensation:

$\delta_1 = 1.4$, $\delta_2 = 14.1$, $\delta_3 = 7.98$, and $\delta_4 = 0.68$.

RESULTS AND DISCUSSION

Based on equation of state phase behavior model "MIS-Model", Jambour data are analyzed including all the factors that affects M.M.P.

Table 1 presents the data obtained by vaporization correlation for Jambour- Cretaceous oil reservoir. This correlation was tested by statistical parameters such as standard deviation, average, absolute percentage error and coefficient of variation.

Table 2 presents the data obtained by condensation correlation for Jambour Cretaceous oil reservoir. Also this correlation was tested by the statistical parameters mentioned above.

C_7^+ mole fraction plays a significant role in affecting the predicated M.M.P., while the temperature of the reservoir is essential constant and was removed from the correlation.

Miscibility process for Jambour-Cretaceous oil reservoir seems to be either vaporization or condensation depending on C_1-mole fraction content in the injected gas.

Table 3 shows the results obtained by applying Fairooz A. and Aziz.K. [4] correlation for vaporization miscibility with lean gas on our data, while Table 4 presents the results obtained by applying Kuo, S.S. [3] correlation for condensation miscibility on our data.

As mentioned before the above correlations were recommended [8] for vaporization and condensation miscibilities, respectively.

However, when they are applied on the available data for Jambour Cretaceous oil reservoir at 210° F, the results show a deviation of about 48.85 % with Fairooz & aziz correlation and about 8.89% with Kuo's correlation (These high statistical deviations are acceptable when compared with the high % error that were allowed initially for the above mentioned correlations).

Accordingly, these correlations seem to be not applicable when investigating the correlations of this study.

CONCLUSION

The correlations developed in this study seem to be the best for application in the case of Jambour-Cretaceous oil reservoir.

REFERENCES

1. Al-khafaji, A.H. et al. " Correlation for Minimum Miscibility Pressure, Hydrocarbon Oil system", J.P.R, Vol.8 No.1 (1989), PP.15-23.
2. Glaso, O."Generalized Minimum Miscibility Pressure Correlation", SPEJ, Des. 1985, PP.927-934.
3. Kuo, S.S. " Prediction of Miscibility for Enriched –Gas Drive Process", SPE, 14152, 1985.
4. Fairooz, A. and Aziz, Kh., "Analysis and Correlation of Nitrogen and Lean Gas Miscibility Pressure", SPE RE, Nov. 1986, PP.575-582.
5. Emanuel, A.S. et al. "A Generalized Method for Predicting G/O Miscibility", SPE RE, Sep. 1986, PP.463-473.
6. Alson, R.B. et al. "CO_2 Minimum Miscibility Pressure: A Correlation for impure CO_2 Streams and Live Oil System", SPEJ April, 1985, PP.268-274.
7. Benmekki, E.H.3 & Mansoori, G.A. "Minimum Miscibility Pressure Prediction with equation of State", SPE RE, May, 1988, PP. 559-564.
8. Yurkiw, F.J. and Flock, D.I. "A Comparative Investigation of Minimum Miscibility Pressure Correlations for E.O.R", JCPT, Sep. 1994, Vol.33, Nov. 8, PP.35-41.
9. Nouar, A., Flock, D.I. and Dranchuk, P.M. " Minimum Miscibility Pressure Prediction for Nitrogen Vaporizing Gas drives", Part (A and B), AOSTRA Journal of Research, 1990.

Table (1) vaporization Miscibility

M.M.P. by Ph. Beh	M.M.P. by Correl.	M.M.P by Ph Beh.	M.M.P. by Correl
5300	5321.541	5150	5124.791
5500	5440.473	5200	5256.168
5600	5532.324	5450	5441.219
5680	5621.038	5500	5533.07
5720	5658.544	5540	5621.784
5100	5134.616	5570	5659.29
5200	5253.549	5300	5227.147
5300	5345.399	5400	5346.08
5440	5434.113	5450	5437.93
5560	5471.62	5500	5526.645
5300	5322.287		

Statistical Testing: Standard deviation S.D.= 0.9927826, Absolute average percentage error A.A.P.E.=0.85633565, Coefficient of variation C.O.V= 1.83343E-04

Table (2) Condensation Miscibility

M.M.P. by Ph. Beh	M.M.P. by Correl.	M.M.P by Ph Beh.	M.M.P. by Correl
4750	4550.392	3982	3804.415
4600	4170.969	3982	3728.154
4400	3822..931	3556	3724.034
4000	3349.257	3556	3711.477
3450	2862.307	3556	3596.131
3600	4390.792	3556	3456.377
3400	4011.369	3556	3380.116
330	3663.331	2987	3250.36
3225	3189.657	2987	3237.803
3175	2702.708	2987	3122.457
4452	4451.495	2987	2982.704
4452	4438.938	2987	2906.443
4452	4323.938	2418	2763.41
4452	4183.838	2418	2750.853
4452	4107.578	2418	2635.507
3982	4072.071	2418	2495.754
3982	4059.514	2418	2419.493
3982	3944.168		

Statistical Testing: Standard deviation S.D.= 9.22252, Absolute average percentage error A.A.P.E.=6.934415, Coefficient of variation C.O.V= 2.597677E-03

Table (3) Comparison of M.M.P. predicted by behavior study and Fairooz A, and Aziz, K. correlation.

Pressure (psi)	MW C_7^+	C_2-C_5	M.M.P. by Fairooze et al	M.M.P. by Ph. Beh
4452	250	13.021	6819.843	5300
3982	=	11.179	7487.677	5450
3556	=	10.019	7098.19	5500
2987	=	8.719	8303.256	5540
2418	=	7.692	8589.351	5570

Statistical Testing: Standard deviation S.D.= 48.85%, Absolute average percentage error , A.A.P.E.=642.74%, Coefficient of variation C.O.V= 0.625

Table (4) Comparison of C1 mole fraction in injected gas when applying natural miscibility at LPG of 40% and 60%

Pressure (psi)	LPG 40%	
	C_1 by Kuo correl.	C_1 by Ph. Beh.
4452	68.843%	61%
3982	64.339%	58.25%
3556	60.077%	55%
2987	54.224%	52.5%
2418	47.285%	48.5%

Pressure (psi)	LPG 60%	
	C_1 by Kuo correl.	C_1 by Ph. Beh.
4452	65.497%	58.5%
3982	61.214%	56.0%
3556	57.158%	54.0%
2987	51.589%	51.5%
2418	45.559%	49.0%

Statistical Testing: Standard deviation S.D.= 8.89%, Absolute average percentage error A.A.P.E.=7.141%, Coefficient of variation C.O.V= 0.159%

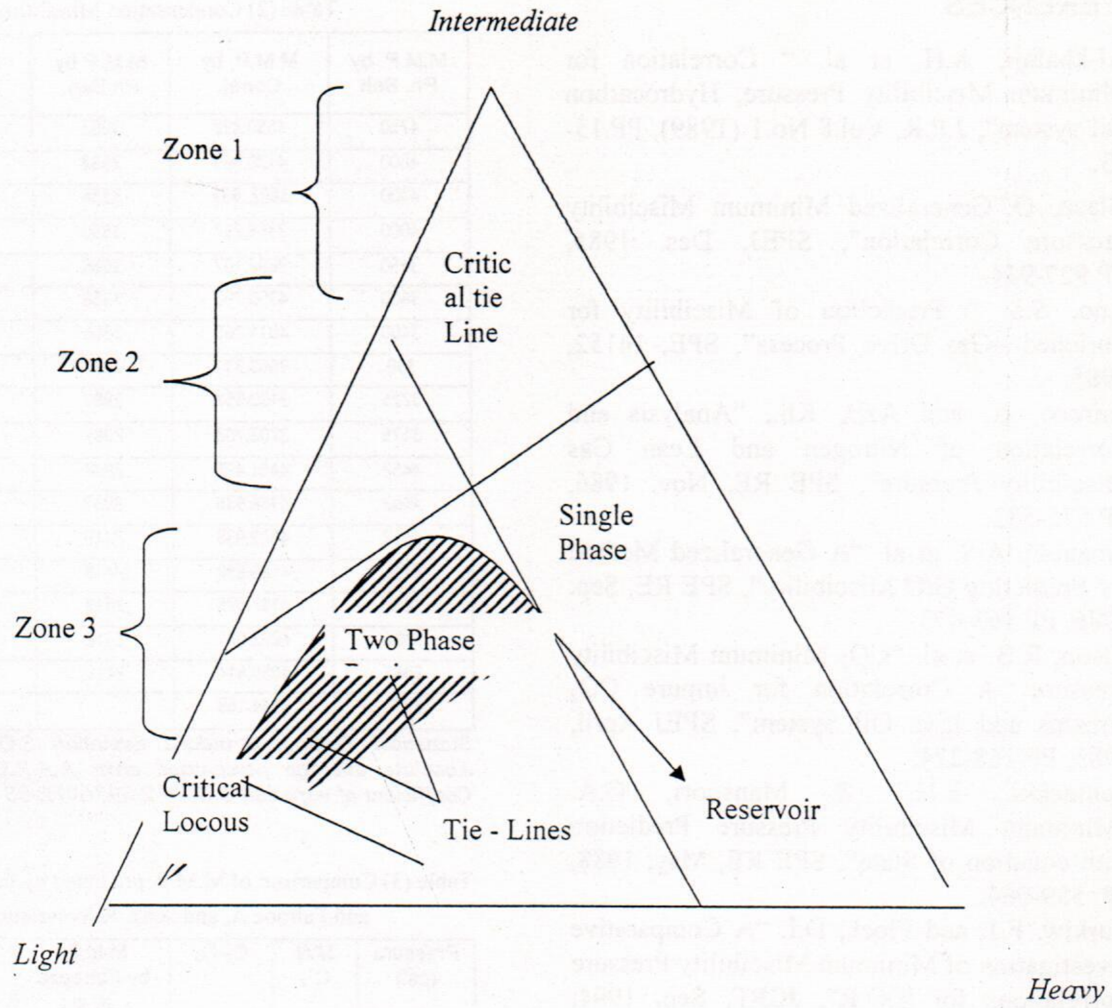

Fig. (1) Types of miscibility by pseudo ternary representation