Int. J. Bio-Inorg. Hybr. Nanomater., 10(2): 73-81, Summer 2021

Fluid Characterization in a Gas Condensate Reservoir: The Effect of Lumping Techniques

Sh. Shahsavari*1, Z. Shokri[2]

[1] Department of Chemical Engineering, Varamin-Pishva Branch, Islamic Azad University, Varamin, Iran
[2] Process Engineering Department, Faculty of Chemical Engineering, Tarbiat Modares University, Tehran, Iran

Received: 4 November 2020; Accepted: 7 January 2021

ABSTRACT: Several problems are associated with "regrouping" the original components into a smaller number without losing the predicting power of the equation of state. These problems include (A) How to select the groups of pure components to be represented by one pseudo-component. (B) What mixing rules should be used for determining the EOS constants (pc, Tc, and ω) for the new lumped pseudo- components? In this paper the results of the lumping methods are compared with the data for gas condensate systems to find accurate lumping method for accurate fluid characterization. For this purpose, Whitson's lumping scheme, Pedersen lumping scheme, Danesh *et al.* lumping scheme, Lee *et al.* lumping scheme, Behras and Stanndler lumping scheme are used as lumping scheme and Lee mixing rules was used for calculation of thermodynamics properties of lumped group. To compare the Impact of each Lumping method, its effect was examined on the phase diagram. The results show that the Whitson lumping scheme (it is grouping the hydrocarbon from C_7 to C_{16+} into 4 groups) can predict the phase diagram of this gas condensate systems fluid with good approximation, the Pedersen lumping scheme (it is grouping the hydrocarbon from C_7 to C_{16+} into 3 groups) can predict the phase diagram of this gas condensate systems fluid somewhat and the Pedersen lumping schemes and Danesh *et al.* lumping schemes (it is grouping the hydrocarbon from C_7 to C_{16+} into 4 groups) approximately predicted the same phase diagram and the Lee *et al.* lumping scheme (it is grouping the hydrocarbon from C_7 to C_{16+} into 3 groups) can predict the phase diagram of this gas condensate systems fluid exactly. Therefore, the Lee at al. lumping scheme has very good accuracy compared to the other methods. Also, All Lumping Scheme has an effect on dew point line of phase diagram.

Keywords: *Groping, Lumping, Mixing rule, Pseudoization, Pseudo component*

INTRODUCTION

Petroleum is composed of various hydrocarbon and non-hydrocarbon components. For characterizing and simulating the oil reservoir, the reservoir fluid must be characterized. The large number of components is necessary to describe the hydrocarbon mixture for accurate phase behavior modeling frequently burdens EOS calculations.

Generally, with a sufficiently large number of pseudo-components used in characterizing the heavy fraction

(*) Corresponding Author - e-mail: shadab.sh@gmail.com

of a hydrocarbon mixture, a satisfactory prediction of the PVT behavior by the equation of state can be obtained. However the cost and computing time can be increased significantly with the increased number of components in the system. Therefore, strict limitations are placed on the maximum number of components that can be used in compositional models and the original components have to be lumped into a smaller number of pseudo components [1].

Several problems are associated with "regrouping" the original components into a smaller number without losing the predicting power of the equation of state. These problems include How to select the groups of pure components to be represented by one pseudo-component each.

Several unique techniques have been published that can be used to address the above lumping problems; notably the methods proposed by Mehra et al, Schlijper, Gonzalez, Colonomos, and Rusinek, Aguilar and McCain, Pedersen *et al.* [2], Whitson [3], Lee *et al.* [4], Montel and Gouel [5], Behrens and Sandler [6], Hong [7] and Danesh *et al.* [8].

For describing the phase behavior of a fluid mixture, critical pressure, critical temperature, critical volume, acentric factor, molecular weight and binary interaction parameters of component must be specified. Different mixing rules were evaluated for, characterizing the lumped C_{7+} fraction from its constituent component properties [9,10].

Impact of these lumping schemes on one system, especially gas condensate systems, isn't studied. In this work, the accuracy and impact of Whitson, Pedersen, Danesh *et al.*, Lee *et al.*, Behras and stanndler lumping scheme on phase diagram of the gas condensate systems are researched. Lee's mixing rule is one of these mixing rules which are used in this research.

METHODS

Experimental

A sample of reservoir fluid is prepared from one of gas condensate oil fields. In the laboratory, it composition is determined by using gas chromatography. Also, the properties of heavy oil fraction were measured with the existing standards methods in the laboratory.

Lee's mixing rules:

There are many mixing rules which obtained by researchers. Lee's mixing rules is one of useful rules. Lee *et al.* [11] used Kay's mixing rules as the characterizing approach for determining the properties of the lumped fractions in their suggested regrouping model. To using this rule, normalized mole fraction of the component i in the lumped fraction must be defined. It was defined by:

$$\varphi_i = \frac{z_i}{\sum_{i}^{L} z_i} \tag{1}$$

After that, Lee *et al.* are proposed the following rules for calculation of thermodynamic property of multi component mixture:

$$Mw_1 = \sum \varphi_i Mw_i \tag{2}$$

$$\gamma_L = \frac{Mw_L}{\sum_{i}^{L} \varphi_i Mw_i} \tag{3}$$

$$V_{CL} = \sum \frac{\varphi_i Mw_i V_{cl}}{Mw_L} \tag{4}$$

$$P_{cl} = \sum_{i}^{L} \varphi_i P_{cl} \tag{5}$$

$$T_{cl} = \sum_{i}^{L} \varphi_i T_{cl} \tag{6}$$

$$\omega_l = \sum_{i}^{L} \varphi_i \omega_i \tag{7}$$

RRSULTS

In this paper, Whitson's lumping scheme, Pedersen lumping scheme, Danesh *et al.* lumping scheme, Lee *et al.* lumping scheme, Behras and Stanndler lumping scheme are used. Calculation of the method described in the appendix. A compositional analysis of gas condensate systems fluid described in Table 1 and the molecular weight and the specific gravity of C_{16+} is equal to 259 and 0.908 respectively. The phase diagram of this gas condensate system is shown in Figure 1.

Whitson's lumping scheme:

Whitson proposed a regrouping scheme whereby the

Table 1. Composition of reservoir fluid

Component	zi	Component	zi
C_1	0.413506	C_8	0.00268
C_2	0.0403	C_9	0.00207
C_3	0.2153	C_{10}	0.00159
i-C_4	0.0539	C_{11}	0.00123
n-C_4	0.0543	C_{12}	0.00095
i-C_5	0.0515	C_{13}	0.00073
n-C_5	0.0519	C_{14}	0.000566
C_6	0.1039	C_{15}	0.000437
C_7	0.00347	C_{16+}	0.001671

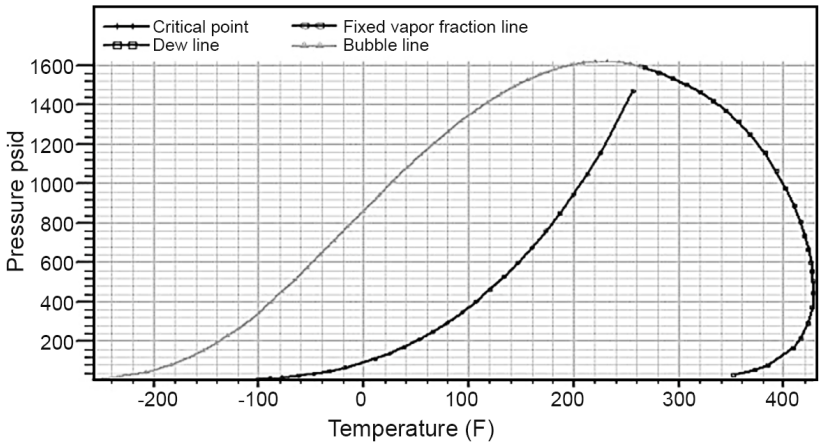

Fig. 1. Phase diagram of reservoir fluid

compositional distribution of the C_{7+} fraction is reduced to only a few multiple carbon- number (MCN) groups. Whitson suggested that the number of MCN groups is necessary to describe the plus fraction is given by the following empirical rule [12]:

$$N_G = \mathrm{Int}\left[1 + 3.3\log(N - n)\right] \tag{8}$$

Not that, for black oil system this number probably can be reduced by one.[6]

Components with molecular weight falling with-

Table 2. Whitson's lumping scheme results

Group I	Component	z_i	z_I	Mw_I	γ_I	V_{cl} (ft^3/lb)	P_{cl} (psia)	T_{cl} (R)	ω_l
1	C_7	0.00347	0.00822	105.9	0.746	0.0627	424	1020	0.3076
	C_8	0.00268							
	C_9	0.00207							
2	C_{10}	0.001596	0.002826	139.7	0.787	0.0628	339.7	1144.5	0.4000
	C_{11}	0.00123							
3	C_{12}	0.00095	0.002246	172.9	0.814	0.0631	288	1230.6	0.4794
	C_{13}	0.00073							
	C_{14}	0.000566							
4	C_{15}	0.000437	0.002108	248	0.892	0.0637	223.3	1433	0.6531
	C_{16+}	0.001671							

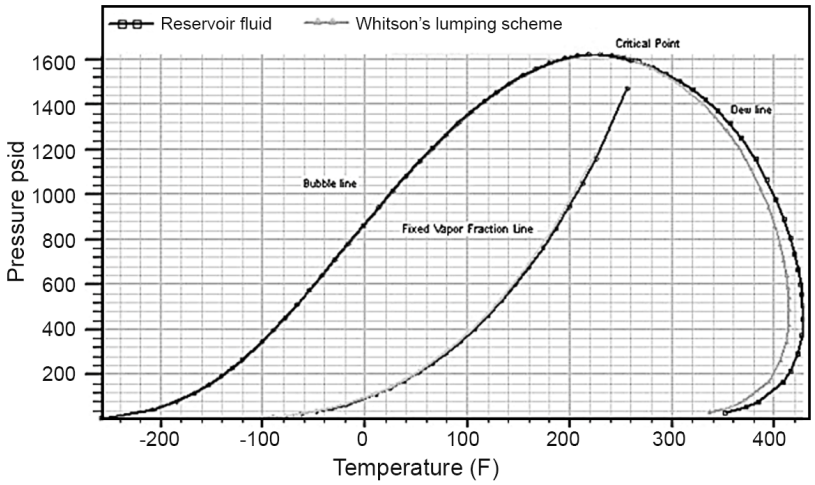

Fig. 2. Impact of Whitson's lumping scheme on phase diagram

in the boundaries of M_{I-1} to MI are included in the I'th MCN group. By applying the Whitson lumping scheme can see that it is grouping the hydrocarbon from C_7 to C_{16+} into 4 groups. The results of Whitson's lumping scheme are shown in Table 2. The impact of this scheme on the phase diagram is shown in Figure 2. Thus, this figure shows that the Whitson lumping scheme can predict the phase diagram of this gas condensate systems fluid with good approximation.

Whitson's lumping scheme accuracy can be attributed to function of the number of MCN groups (equation 8) and iterative method to find the molecular weight of each group Determination of the number of groups is the excellent characteristics of this approach.

Pedersen Lumping Scheme:

Pedersen *et al.* suggested the process of grouping the components on the basis of each group containing approximately the same weight fraction (equal weight fraction), which will give all hydrocarbon segments of the C_{7+} fractions equal importance. The C_{7+} fraction is divided into three or more groups that, by weight, are equal size approximately. The weight for each pseudo component, W_j, can be calculated as:

$$w_j = \sum_{i=1}^{n_c} z_i \times Mw_i \qquad (9)$$

By applying the Pedersen lumping scheme can see

Table 3. Pedersen lumping scheme results

Group I	Component	z_i	z_I	Mw_I	γ_I	V_{cl} (ft^3/lb)	P_{cl} (psia)	T_{cl} (R)	ω_l
1	C7	0.00347	0.00615	100.794	0.73657	0.06277	438.184	1007.2	0.29395
	C8	0.00268							
2	C9	0.00207	0.00584	136.522	0.78409	0.06279	348.896	1123.4	0.39027
	C10	0.001596							
	C11	0.00123							
	C12	0.00095							
3	C13	0.00073	0.003404	222.709	0.86866	0.06353	244.507	1363.8	0.59401
	C14	0.000566							
	C15	0.000437							
	C16+	0.001671							

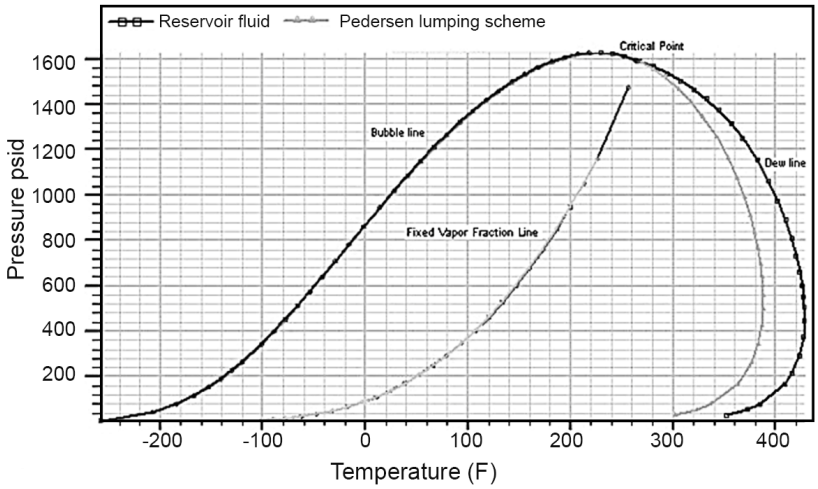

Fig. 3. Impact of Pedersen lumping scheme on phase diagram

that it is grouping the hydrocarbon from C_7 to C_{16+} into 3 groups (3 groups is selected according to some restrictions). The results of Pedersen lumping scheme are shown in Table 3. The phase diagram of this system is under the impact of Pedersen lumping scheme is shown in Figure 3. Therefore, this figure shows that the Pedersen lumping scheme can predict the phase diagram of this gas condensate systems fluid somewhat.

As you can see, a simple relationship exists between the concentration and molecular weight in Pedersen lumping scheme. Choosing the number of groups is based on the limitations and experiences, so, the accuracy of this method would not be high.

Danesh et al. lumping scheme:

Danesh *et al.* proposed a lumping method based on the concentration and molecular weight of compounds in a mixture. This grouping method arranged the original components in order of their normal boiling point temperatures and grouped together in ascending order to form N_p groups so that the values of $\Sigma (z_i \ln M_i)$ for all the groups become nearly equal, (Quasi-equal-weight criterion).

According to the Danesh *et al.* lumping scheme can see that it is grouping the hydrocarbon from C_7 to C_{16+}

Table 4. Danesh et al. lumping scheme results

Group I	Component	z_i	z_I	Mw_I	γ_I	V_{cl} (ft³/lb)	P_{cl} (psia)	T_{cl} (R)	ω_l
1	C_7	0.00347	0.00347	96	0.727	0.06289	453	985	96
2	C_8 C_9	0.00268 0.00207	0.00475	113.101	0.75719	0.06261	403.312	1045.59	113.101
3	C_{10} C_{11} C_{12}	0.001596 0.00123 0.00095	0.00377	145.045	0.79169	0.06288	330.17	1159.3	145.045
4	C_{13} C_{14} C_{15} C_{16+}	0.00073 0.000566 0.000437 0.001671	0.003404	222.709	0.86866	0.06353	244.507	1363.78	222.709

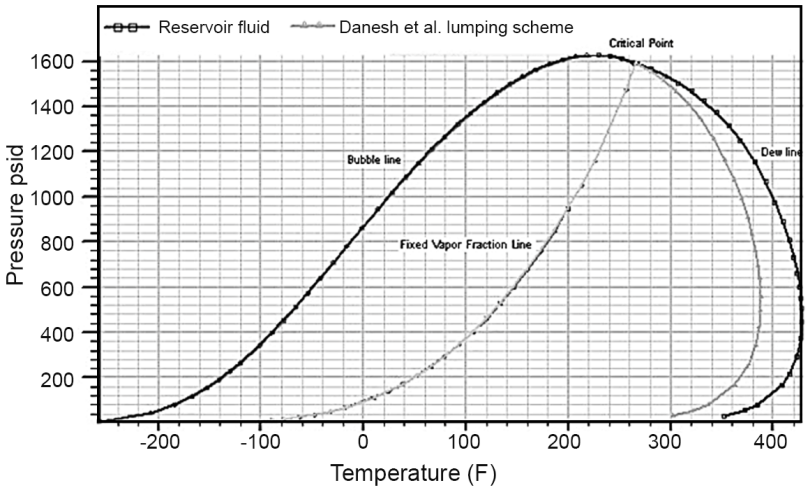

Fig. 4. Impact of Danesh et al. lumping scheme on phase diagram

into 4 groups. The results of Danesh *et al.* lumping scheme are shown in Table 4. The phase diagram of this system is under the impact of Danesh *et al.* lumping scheme is shown in Figure 4. The predicted phase diagram of this gas condensate systems fluid by the Danesh *et al.* lumping scheme is look like the phase diagram was predicted by Pedersen lumping scheme. Figure 4 show that this lumping scheme can predict the phase diagram somewhat.

In this method, choosing the number of groups was done similar to the Pedersen lumping scheme. In Danesh *et al.* lumping scheme some limitation is defined for choosing the molecular weight of groups, so it would be more accurate than the Pedersen lumping scheme.

Lee et al. lumping scheme:

Lee *et al.* devised a simple procedure that can be served as a guideline for lumping the oil fractions. The idea for the procedure lies in the physical reasoning that crude-oil fractious having relatively close physicochemical properties can be represented fairly accurately by a single fraction, the closeness of these properties can be reflected by the slopes of curve when these properties are plotted against some characteristic independent variables.

Table 5. Lee et al. lumping scheme results

Group I	Component	z_i	z_I	Mw_I	γ_I	V_{cl} (ft³/lb)	P_{cl} (psia)	T_{cl} (R)	ω_I
1	C_7	0.00347	0.00615	100.794	0.73657	0.06277	438.184	1007.2	0.29395
	C_8	0.00268							
2	C_9	0.00207	0.007573	148.237	0.79453	0.0629	331.518	1155.6	0.41792
	C_{10}	0.001596							
	C_{11}	0.00123							
	C_{12}	0.00095							
	C_{13}	0.00073							
	C_{14}	0.000566							
	C_{15}	0.000437							
3	C_{16+}	0.001671	0.001671	259	0.908	0.0638	215	1467	0.68

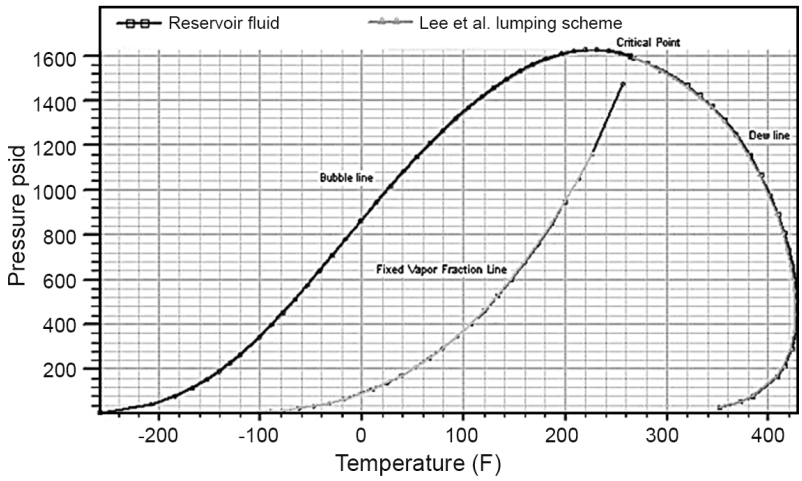

Fig. 5. Impact of Lee et al. lumping scheme on phase diagram

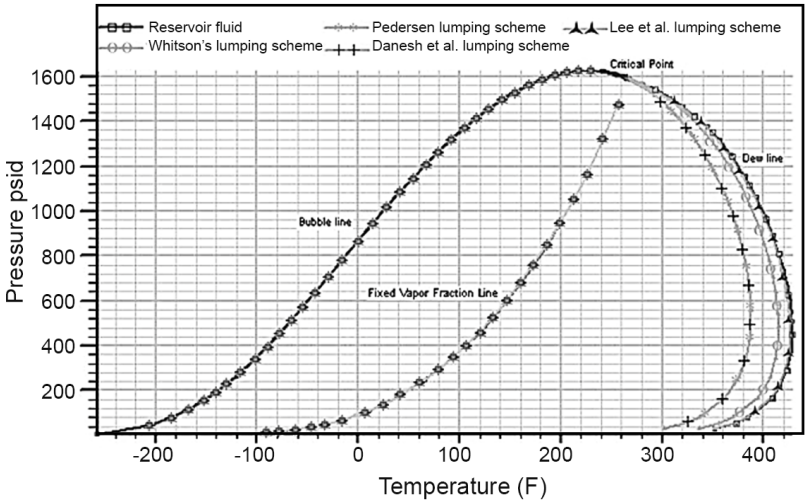

Fig. 6. All lumping scheme

According to the Lee *et al.* lumping scheme can see that it is grouping the hydrocarbon from C_7 to C_{16+} into 3 groups. The results of Lee *et al.* lumping scheme are shown in Table 5. The accuracy of this scheme can be seen in the phase diagram in Figure 5. Hence, Figure 5 shows that the Lee *et al.* lumping scheme can predict the phase diagram of this gas condensate systems fluid exactly.

Lee *et al.* lumping scheme is more complex than lumping schemes which is discussed in this paper but it gives highly accurate answer. On the other hand, this lumping scheme is determined number of groups which is the key points of this method.

Behras And Stanndler Lumping Scheme:

Behrens and Standler have been used a semi continuous thermodynamic description to model the C_{7+} fraction for equation of state (EOS) calculations. The step-by-step procedure will be illustrated.

Step 1: Finding the ends of the distribution

the ends of the distribution can be calculated by:

$$A = \text{starting carbon number} - 1/2 \quad (10)$$

$$B = \text{ending carbon number} + 1/2 \quad (11)$$

The parameters of the semi continuous distribution in this system are

A = 7 - 1/2 = 6.5

B =16 + 1/2 =16.5.

Step 2 – determining the slope of the distribution

The slope of the distribution is found from the average

carbon number C_n which is related to the where average MW approximately as

$$C_n = \frac{(MW + 4)}{14} \tag{12}$$

The slope of the distribution, α, is then found from the following equation:

$$\frac{1}{\alpha} = C_n - A + \left[\frac{(B - A)e^{-B\alpha}}{e^{-A\alpha} - e^{-B\alpha}} \right] \tag{13}$$

If the upper endpoint were infinity, the term in the brackets would vanish and l/α could be found explicitly.

Since the upper endpoint is finite, α is found by successive substitutions. Slope of the distribution:

$$C_n = \frac{(141.25 + 4)}{14} = 10.375 \tag{14}$$

Conclusions:

By comparing the phase diagram for reservoir fluid (Figure 1), and data that is lumped with some lumping schemes like Whitson's Lumping Scheme (Figure 2), Pedersen lumping scheme (Figure 3), Danesh lumping scheme (Figure 4), Lee *et al.* lumping scheme (Figure 5) and also plot all lumping scheme and the phase diagram of reservoir fluid on one diagram (Figure 6) can be seen that:

1- With the Pedersen Lumping Scheme and Danesh *et al.* Lumping Scheme can reach to the approximately same the phase diagram.

2- Lee at al. Lumping Scheme has very good accuracy related to the other methods in characterization of gas condensate reservoir.

3- All Lumping Scheme has an effect on dew point line.

REFERENCES

[1] Adepoju, O.O., 2007. Coefficient of Isothermal Oil Compressibility- A Study for Reservoir Fluids by Cubic Equation-of-State. VDM Verlag Dr. Mueller e.K Press.

[2] Ahmed, T.H., 1989. Hydrocarbon phase behavior, Contributions in petroleum geology & engineering 7. Gulf Pub. Co Press.

[3] Ahmed, Tarek H., 2010. Reservoir engineering handbook. Gulf Professional Pub Press.

[4] Al-Meshari, A.A., 2004. New strategic method to tune equation-of-state to match experimental data for compositional simulation, Ph.D. thesis, Texas A&M University, Texas

[5] Behrens, R.A., and S.I. Sandler, 1988. The Use of Semicontinuous Description To Model the C_{7+} Fraction in Equation of State Calculations. SPE Reservoir Engineering, 3(3): 1041-1047.

[6] Danesh, Ali, Dong-hai Xu, Adrian C. Todd, and U. Heriot-Watt, 1992. A Grouping Method To Optimize Oil Description for Compositional Simulation of Gas-Injection Processes. SPE Reservoir Engineering, 7(3): 343-348.

[7] Guo, T.M., and L. and Du., 1989. A New Three Parameter Cubic Equation of State for Reservoir Fluids– Part II. Application to Reservoir Crude Oils. SPE pp: 19373.

[8] Hong, K.C., 1982. Lumped-Component Characterization of Crude Oils for Compositional Simulation. In SPE Enhanced Oil Recovery Symposium, Tulsa, Oklahoma

[9] Joergensen, M., and E.H. Stenby, 1995. Optimization of Pseudo-component Selection for Compositional Studies of Reservoir Fluids. In 70th Annul Technical Conference and Exhibition. Daltas, Taxas.

[10] Lee, S.T., R.H. Jacoby, W.H. Chen, W.E. Culham, and Gulf Research and Development Co., 1981. Experimental and Theoretical Studies on the Fluid Properties Required for Simulation of Thermal Processes. SPE Journal., 21(5): 535-550.

[11] Montel, F., and P.L. Gouel., 1984. A New Lumping Scheme of Analytical Data for Compositional Studies.

In SPE Annual Technical Conference and Exhibition. Houston, Texas.

[12] Whitson, C., 1983. Characterizing Hydrocarbon Plus Fractions. SPE Journal, 23(4): 683-694.

AUTHOR (S) BIOSKETCHES

Shadab Shahsavari, Department of Chemical Engineering, Varamin-Pishva Branch Islamic Azad University, Varaminn, Iran, *Email: shadab.sh@gmail.com*

Zahra Shokri, Process Engineering Department, Faculty of Chemical Engineering, Tarbiat Modares University, Tehran, Iran