

УДК 622.276(06); <https://doi.org/10.37878/2708-0080/2023-6.17>

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## COMPREHENSIVE FLUID DESCRIPTION THROUGH LUMPING PROCEDURES: FOR KAZAKHSTANI OIL



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*Reservoir modeling requires a multitude of phase equilibrium calculations, particularly in the context of compositional reservoir simulations. To accelerate these calculations, the many components of the heptane plus fraction should be grouped into pseudocomponents. Moreover, accurate fluid compositions demand extensive laboratory analysis, a process both costly and time-consuming. The exercise of grouping and splitting are important for reservoir modeling.*

*In our research, we introduce a lumping methodology for fluid characterization, focusing on the unique context of Kazakhstani oil. More specifically, we delve into the Whitson lumping and splitting techniques.*

*For this study, a sample was taken from the X field, and detailed fluid composition data was acquired through laboratory analysis. We employed both numerical and analytical approaches to study the lumping process. Additionally, we compared our calculations with simulation results. As we navigate the intricacies of fluid characterization, we highlighted the advantages and limitations of lumping procedures and emphasized the effectiveness of Whitson method.*

*Detailed fluid compositions obtained through laboratory PVT analysis were then compared with the results of simulation using PVTsim software and numerical delumping procedures. The results of this work demonstrated the effectiveness of Whitson methods for lumping and splitting procedures for describing Kazakhstani fluids.*

**KEY WORDS:** lumping, fluid characterization, modeling, Whitson method, simulation tool, PVTsim, pseudocomponents.

## ПОДРОБНОЕ ОПИСАНИЕ ФЛЮИДА С ПОМОЩЬЮ ПРОЦЕДУР ГРУППИРОВАНИЯ ДЛЯ КАЗАХСТАНСКОЙ НЕФТИ

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*Композиционное моделирование резервуара требует многочисленных расчетов, что приводит к высоким вычислительным затратам. В результате описание флюида, используемое в этих моделях, часто упрощается и включает только небольшое количество компонентов или псевдо-компонентов. Этот процесс упрощения, известный как "лампинг", включает группировку определенных компонентов из композиции флюида. Более того точное определение состава флюида требует лабораторного анализа, что является дорогостоящим и время затратным процессом.*

*В данной статье представлено описание точного состава казахстанской нефти. В частности, в этом исследовании используются методы группировки по Уитсону. Компоненты жидкости были вычислены с помощью процедур группирования.*

*Для данной была взята проба с месторождения X. Подробные данные о составе флюида были получены с помощью лабораторного анализа. Мы применили как численные, так и аналитические подходы для изучения процесса лампирования. Кроме того, чтобы сравнить расчеты с результатами моделирования, и проверить эффективность метода Уитсона при группировке псевдокомпонентов нефти. При определении характеристик жидкости, были выделены преимущества и ограничения процедур группирования метода Уитсона.*

*Подробные составы жидкостей, полученные с помощью лабораторного PVT-анализа, затем сравнивались с результатами моделирования с использованием программного обеспечения PVTsim и численных процедур группирования. Результаты этой работы продемонстрировали эффективность методов Уитсона для процедур группирования.*

**КЛЮЧЕВЫЕ СЛОВА:** группирование, характеристика жидкости, моделирование, метод Уитсона, PVTsim, инструменты моделирования, псевдокомпоненты.

## ТОПТАСТЫРУ ӘДІСІ АРҚЫЛЫ ҚАЗАҚСТАНДЫҚ МҰНАЙДЫҢ КОМПОНЕНТТІК ҚҰРАМЫН СИПАТТАУ

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*Резервуардың композициялық құрамын модельдеу процесі көптеген фазалық тепе-теңдіктің есептеулерін қажет етеді. Бұл есептеулерді жеделдету үшін "гептан плюс" фракциясының көптеген компоненттерін псевдокомпоненттерге топтастыру керек. Сонымен қатар, сұйықтықтың нақты құрамын сипаттау үшін зертханалық талдау өткізу қажет. Бұл көп уақытты қажет ететін шығынды тәсіл.*

Бұл мақалада қазақстандық мұнайдың сипаттамасын анықтайтын әдіс зерттелген. Атап айтқанда, бұл зерттеуде Уитсонның топтастыру мен бөліну әдістері қолданылады. Сұйықтықтың компоненттері топтастыру процедуралары арқылы бағаланды.

Бұл мақалада Х кен орнынан сынама алынды және зертханалық талдау сұйықтықтың құрамы туралы егжей-тегжейлі мәліметтер берілді. Топтастыру процесін зерттеу барысында сандық және аналитикалық тәсілдер қолданылды. Сонымен қатар, біз аналитикалық есептеулерді зертханалық деректермен салыстыру мақсатында және Уитсон әдісі мұнайдың псевдокомпоненттерін топтастыруда тиімді екенін анықтау үшін модельдеу құралдарын қолдандық. Сұйықтықтың сипаттамаларын анықтау барысында, Уитсон әдісінің артықшылықтары мен шектеулерін белгілеп, тиімділігін атап өттік.

Сұйықтықтардың толық құрамдары, лабораториялық PVT талдау арқылы алынды, содан кейін PVTsim бағдарламасы мен аналитикалық процедураларының нәтижелерімен салыстырылды. Бұл жұмыстың нәтижелері Уитсон топтастыру әдістерінің қолдануының маңыздылығын көрсетті.

**ТҮЙІН СӨЗДЕР:** топтастыру, сұйықтықтың сипаттамасы, модельдеу, Уитсон әдісі, модельдеу құралы, PVTsim, жалған компоненттер.

**I**ntroduction. Fluid characterization is a fundamental aspect of numerous scientific and engineering disciplines, including petroleum engineering and chemical engineering. Understanding the behavior of complex fluid systems is often essential in fields ranging from petrochemicals to environmental science. However, the intricate nature of fluids can make this a challenging endeavor. In response to this complexity, the concept of "lumping" has emerged as a powerful tool to simplify the description of complex fluid behavior. [1]

Working with a large number of components for compositional reservoir simulation and EOR evaluation is computationally intensive, and the demand for computer storage can become very high. To address this problem, it has been proposed to group/lump the components of a complex EOS model into a smaller number of pseudocomponents. The success of such lumping procedures is dependent on the reduced model's fidelity in reflecting the phase behavior of composition mixtures formed during a displacement operation in comparison to the detailed EOS model. [2]

The current innovation pertains to a technique known as the "lumping" or "pseudoization" method, which involves describing a fluid comprised of several different components by condensing them into a smaller set of constituents [3]. Essentially, there are two major issues related with "regrouping" the original components into a lower number without compromising the equation of state's predictive power [4]:

1. How to choose the pure component groups to be represented by one pseudo component each.
2. What mixing procedures should be utilized to determine the physical parameters of the new lumped pseudo components (e.g.,  $p_c$ ,  $T_c$ ,  $M$ ,  $\gamma$ , and  $\omega$ ).

Splitting schemes are procedures for dividing heptanes-plus fractions into hydrocarbon groups with a single carbon number ( $C_7$ ,  $C_8$ ,  $C_9$ , and so on), which are described by the same physical properties as pure components. [4]

When using any of the proposed splitting models, three important requirements must be met:

1. The mole fraction of  $C_{7+}$  is equal to the sum of the mole fractions of the individual pseudo components.

2. The sum of the mole fraction and molecular weight products of the individual pseudo components equals the mole fraction and molecular weight product of  $C_{7+}$ .

3. The sum of the mole fraction and molecular weight products divided by the specific gravity of each individual component equals  $C_{7+}$ .

Numerous authors have put forward different methods for expanding the molar distribution patterns of  $C_{7+}$  with respect to mole fraction, taking into account molecular weight or the number of carbon atoms. Generally, these proposed methods rely on the observation that lighter systems like condensates tend to display molar distributions that follow an exponential trend, while heavier systems often show distributions skewed to the left. [4]

In order to solve these problems, there are a lot of methods, such as Whitson's lumping scheme, Pedersen's lumping scheme, Danesh et al.'s lumping scheme, Lee et al.'s lumping scheme, Behras and Stannler's lumping scheme, and Lee mixing rules were used to calculate the thermodynamic parameters of the lumped group. The results show that the Whitson lumping approach can accurately forecast the phase diagram systems fluid. [5]

## Methods and materials

**Laboratory analysis:** The deep sample of reservoir fluid was taken from the X field and was sent to the laboratory of Weatherford-CARE LLP (Aktau) for PVT research. Information on that is provided in *Table 1* - General information.

*Table 1 – General Information of deep oil sample*

Perforation interval	610-617 m
Selection point	600 m
Sample type	Deep oil sample
Reservoir pressure	53.83 kg/cm <sup>2</sup>
Reservoir temperature	30.22 °C
Reservoir oil volume coefficient	1.0053
Reservoir gas volume coefficient	1.0349
Gas density	0.00151g/cm <sup>3</sup>
Compressibility (Z-factor) of oil / gas	1.083×10 <sup>-4</sup> cm <sup>2</sup> /kg
Reservoir fluid density	0.8162g/cm <sup>3</sup>

The differential liberation experiment (DLE or DL), also known as differential vaporization, represents a fundamental technique among depletion experiments. The primary results obtained from the DLE experiment include data on the oil formation volume factor, gas-oil ratio (GOR), and oil viscosity. Initially, DLE was developed to simulate the depletion production process within oil reservoirs. [10]

Procedure: A certain volume of reservoir fluid was transferred to a PVT (Pressure-Volume-Temperature) cell. The fluid volume was measured under single-phase conditions and at reservoir conditions. The volume of fluid at saturation pressure was determined for reference. Pressure stages were defined, and the pressure was reduced to the first stage.

The fluid was mixed until it reached an equilibrium state, and the total volume of gas and liquid was measured.

The gas at equilibrium was sequentially transferred from the PVT cell to a glass separator, and condensate from the gas was collected. Gas transfer was carried out until complete release from the cell and brought to a single-phase state at that pressure stage. The volume of fluid in the cell under these conditions was determined. The volume of transferred gas was measured under atmospheric conditions and sent for analysis using gas chromatography, following standard procedures. The volume of condensed liquid accumulated in the glass separator was also measured.

The procedure described above is repeated at each pressure stage until atmospheric pressure is reached. The following parameters were calculated as a result of the differential vaporization (DV):

- Reservoir oil volume coefficient;
- Reservoir gas volume coefficient;
- Gas density;
- Gas content at each pressure stage;
- Compressibility (Z-factor) of oil and gas;
- Reservoir fluid density;
- Relative gas density;
- Component composition of the extracted gas at each pressure stage;
- Component composition of the remaining oil.

So, the results are presented in the *Table 1*.

**Table 2 – The component composition of the reservoir fluid retrieved from Laboratory analysis**

Component		Zi, %	Zi, %	Mi, g/mol	Density, g/ml
Nitrogen	N <sub>2</sub>	0,12	0,0012	28,014	0,808
Carbon dioxide	CO <sub>2</sub>	0,001	0,00001	44,01	11,3
Methane	C <sub>1</sub>	0	0	16	0,717
Ethane	C <sub>2</sub>	0	0	30	0,001342
Propane	C <sub>3</sub>	0,002	0,00002	44,097	0,002019
Isobutane	i-C <sub>4</sub>	2,288	0,02288	58,124	0,00251
Butane	n-C <sub>4</sub>	0,005	0,00005	58,124	0,5
Isopentane	i-C <sub>5</sub>	3,103	0,03103	72,151	0,626
Pentane	n-C <sub>5</sub>	2,600	0,026	72,151	0,626
Hexane	C <sub>6</sub>	4,495	0,04495	86,178	0,664
Heptane	C <sub>7</sub>	9,912	0,09912	96,000	0,738
Octane	C <sub>8</sub>	14,982	0,14982	107,000	0,765
Nonan	C <sub>9</sub>	7,527	0,07527	121,000	0,781
Dean	C <sub>10</sub>	6,945	0,06945	134,000	0,792
Undecane	C <sub>11</sub>	5,741	0,05741	147,000	0,796
Dodecan	C <sub>12</sub>	4,841	0,04841	160,920	0,8032
Tridecan	C <sub>13</sub>	4,446	0,04446	174,983	0,8129
Tetradecan	C <sub>14</sub>	3,765	0,03765	187,934	0,7865

Table 2 – The component composition of the reservoir fluid retrieved from Laboratory analysis

Pentadecan	C <sub>15</sub>	3,947	0,03947	205,836	0,8254
Hexadecane	C <sub>16</sub>	3,098	0,03098	220,122	0,8069
Heptadecane	C <sub>17</sub>	2,678	0,02678	236,948	0,8401
Octadecane	C <sub>18</sub>	2,493	0,02493	250,969	0,8464
Nonadecan	C <sub>19</sub>	2,132	0,02132	262,991	0,8524
Eicosane	C <sub>20</sub>	1,834	0,01834	274,993	0,8577
Geneicosane	C <sub>21</sub>	1,615	0,01615	290,995	0,8628
Docosane	C <sub>22</sub>	1,389	0,01389	304,996	0,8676
Triclosane	C <sub>23</sub>	1,232	0,01232	317,996	0,8722
Tetracosanee	C <sub>24</sub>	1,024	0,01024	330,996	0,8766
Pentacosane	C <sub>25</sub>	0,924	0,00924	344,996	0,8808
Hexacosan	C <sub>26</sub>	0,797	0,00797	358,996	0,8849
Heptacosane	C <sub>27</sub>	0,714	0,00714	373,996	0,8888
Octacosane	C <sub>28</sub>	0,620	0,0062	387,996	0,8926
Nonacosane	C <sub>29</sub>	0,605	0,00605	401,995	0,8962
Triacontane	C <sub>30</sub>	0,477	0,00477	416,000	0,8997
Gentriacontane	C <sub>31</sub>	0,445	0,00445	430,000	0,9031
Dotriacontane	C <sub>32</sub>	0,368	0,00368	444,000	0,9064
Tritriacontane	C <sub>33</sub>	0,343	0,00343	458,000	0,9096
Tetratriacontane	C <sub>34</sub>	0,251	0,00251	472,000	0,9127
Pentatriacontane	C <sub>35</sub>	0,242	0,00242	486,000	0,9157
Hexatriacontane plus	C <sub>36+</sub>	1,999	0,01999	632,257	0,9442
Balance		100,000	1,000		

### Analytical approach:

In this study, we did analytical approach of the Whitson lumping method and compare its results with the output data of simulation in the PVTsim software. In order to compare our data, firstly we have to split and lump input data by calculations.

**Whitson's lumping scheme:** Whitson (1983) presented a regrouping approach in which the C7+ fraction's compositional distribution is restricted to only a few multiple carbon-number (MCN) groups. Whitson proposed that the number of MCN groups required to describe the plus fraction is dictated by the empirical rule:

$$Ng = \text{Int} [1 + 3.3 \log (N - n)] \quad (\text{Eq. 1})$$

where  $Ng$  = number of MCN groups,  $\text{Int}$  = integer,  $N$  = number of carbon atoms of the last component in the hydrocarbon system and  $n$  = number of carbon atoms of the first component in the plus fraction, that is,  $n = 7$  for  $C_{7+}$ .

The final component and C7 molecular weights are utilized to calculate the new molecular weights, which serve as the foundation for the separation process. Separation is performed so that the values of the two corresponding calculated molecular weights are between those of the components associated with the molecular weights of a produced pseudo component:

$$M_1 = M_{C7} \left( \frac{M_{N+}}{M_{C7}} \right)^{1/N_g} \tag{Eq. 2}$$

where  $(M)_{N+}$  = molecular weight of the last reported component in the extended analysis of the hydrocarbon system,  $M_{C7}$  = molecular weight of  $C_7$  and  $I = 1, 2, \dots, N_g$ .

**Whitson Splitting Method:** Whitson (1983) claimed that the gamma probability function with three parameters can be utilized to characterize the molar distribution of the  $C_7+$  percentage. Unlike all prior splitting approaches, the gamma function can depict a larger range of distributions by altering its variance, which is left as a variable. Whitson stated the function in the following way:

$$p(M) = \frac{(M-\eta)^{\alpha-1} \exp \left\{ -\left[ \frac{M-\eta}{\beta} \right] \right\}}{\beta^\alpha \Gamma(\alpha)} \tag{Eq. 3}$$

with

$$\beta = \frac{M_{C7+} - \eta}{\alpha} \tag{Eq. 4}$$

where  $\Gamma$  = gamma function.

According to Whitson, the three parameters of the gamma distribution are, and  $M_{C7+}$ . The key parameter defines the form of the distribution, and its value for reservoir fluids typically ranges from 0.5 to 2.5;  $\alpha = 1$  yields an exponential distribution. When applied to heavy oils, bitumen, and petroleum dregs, the gamma distribution shows that the maximum limit for is 25 to 30, which statistically approaches a log-normal distribution.

Figure 1 depicts Whitson's model for various values of the parameter. The distribution is exponential for  $\alpha = 1$ . The model produces accelerated exponential distributions for values less than one, while values more than one produce left-skewed distributions.

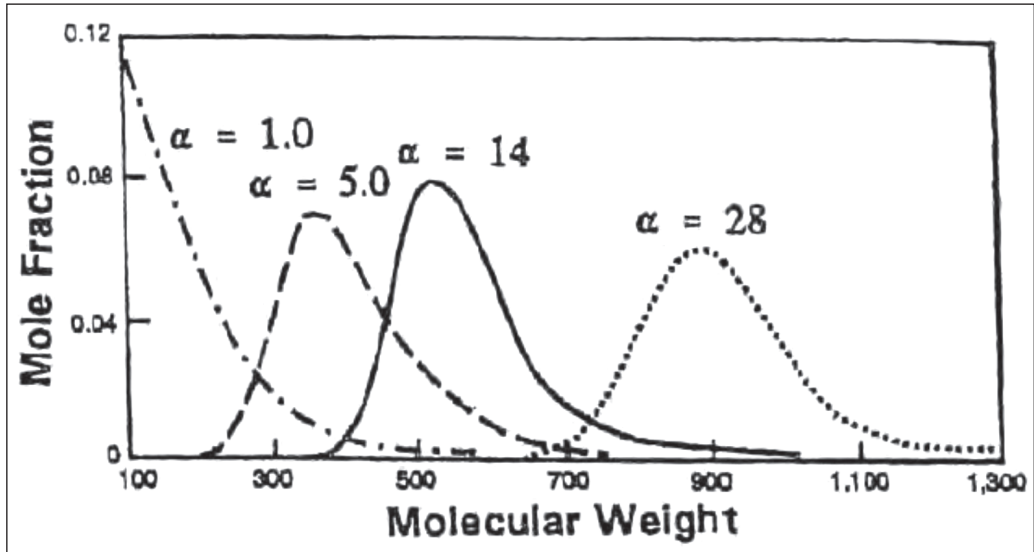


Figure 1 - Gamma distributions for  $C_{7+}$ .

(Downloaded from Ahmed, T., «Equation of State and PVT Analysis, Applications for Improved Reservoir Modeling» Gulf Publishing Company, Houston, Texas (2007))

According to Whitson, the parameter can be physically interpreted as the lowest molecular weight found in the  $C_{7+}$  fraction. An approximation of the relationship between  $\alpha$  and  $\eta$  is:

$$H = \frac{110}{1-(1+4/\alpha^{0.7})} \quad (\text{Eq. 5})$$

Whitson, Anderson, and Soreide (1989) improved on the gamma model by using the «Gaussian quadrature function» to describe the molar distribution of the  $C_{7+}$  fraction.

n = 2	
$\chi_1 = 0.5858$	$W_1 = 0.8536$
$\chi_2 = 0.34142$	$W_2 = 0.1464$
n = 3	
$\chi_1 = 0.4158$	$W_1 = 0.7111$
$\chi_2 = 2.2943$	$W_2 = 0.2785$
$\chi_3 = 6.2960$	$W_3 = 0.0104$
n = 4	
$\chi_1 = 0.3226$	$W_1 = 0.6032$
$\chi_2 = 1.7458$	$W_2 = 0.3574$
$\chi_3 = 4.5366$	$W_3 = 0.0384$
$\chi_4 = 9.3951$	$W_4 = 0.0005$

**Figure 2 - Gaussian quadrature function**

(Downloaded from Ahmed, T., «Equation of State and PVT Analysis, Applications for Improved Reservoir Modeling», Gulf Publishing Company, Houston, Texas (2007)

Whitson and colleagues describe the following procedure for splitting:

**Step 1.** Watson or Universal Oil Products (UOP) characterization factor:

$$K_{wC_{7+}} = 4.5579M^{0.15178}\gamma^{-0.84573} \quad (\text{Eq. 6})$$

**Step 2.** Mole fraction (Katz, 1983):

$$z_{cn} = 1.38205z_{C_{7+}} \exp(-0.25903n) \quad (\text{Eq. 7})$$

**Step 3.** Boiling point, R:

$$T_{bi} = (K_w \gamma_i)^3 = (K_{wC_{7+}} \gamma_i)^3 \quad (\text{Eq. 8})$$

**Step 4.** Knowing boiling temperature and specific gravity of all components, other characteristics can be calculated using Lee-Kesler correlation. Lee-Kesler correlations,  $T_c$  in  $^{\circ}R$ ,  $c$  in  $psia$ :

$$T_{ci} = 341.1 + 811\gamma_i + (0.4244 + 0.1174\gamma_i)T_{bi} + (0.4669 - 3.2623\gamma_i) \cdot 10^{-5}T_{bi}^{-1} \quad (\text{Eq. 9})$$



$$\ln P_{ci} = 8.3634 - \frac{0.0566}{\gamma_i} - \left[ \left( 0.24244 + \frac{2.2898}{\gamma_i} + \frac{0.11857}{\gamma_i^2} \right) * 10^{-3} \right] T_{bi} + \left[ \left( 1.4685 + \frac{3.648}{\gamma_i} + \frac{0.47227}{\gamma_i^2} \right) * 10^{-7} \right] T_{bi}^2 - \left[ \left( 0.42019 + \frac{1.6977}{\gamma_i^2} \right) * 10^{-10} \right] T_{bi}^3 \quad (\text{Eq. 10})$$

**Step 5.** Acentric factor:

$$\text{If } \frac{T_{bi}}{T_{ci}} \leq 0.8 \quad \omega_i = \frac{-\ln\left(\frac{P_{ci}}{14.7}\right) + A_1 + A_2 T_{bri}^{-1} + A_3 \ln T_{bri} + A_4 T_{bri}^6}{A_5 + A_6 T_{bri}^{-1} + A_7 \ln T_{bri} + A_8 T_{bri}^6} \quad (\text{Eq. 11})$$

where  $A_1 = -5.92714$ ;  $A_2 = 6.09648$ ;  $A_3 = 1.28862$ ;  $A_4 = -0.169347$ ;  $A_5 = 15.2518$ ;  $A_6 = -15.6875$ ;  $A_7 = -13.4721$ ;  $A_8 = 0.43577$

if  $\frac{T_{bi}}{T_{ci}} > 0.8$

$$\omega_i = -7.904 + 0.1352 K_{wc7+} - 0.007465 K_{wc7+}^2 + 8.359 T_{bri} + (1.408 - 0.01063 K_{wc7+}) T_{bri}^{-1} \quad (\text{Eq. 12})$$

In the end, to calculate the molar distribution we use Equation 13.

$$M_k = \frac{M_{\text{total}}}{Z_{\text{total}}} * \frac{1}{\Gamma(\gamma)} X^{\gamma-1} \quad (\text{Eq. 13})$$

The only unknown in equations above is  $\gamma$ . The range of  $\gamma$  is usually form 0.5 to 2.5.

Moreover, in order to compare Whiston lumping method, we choose Lee's lumping and mixing rule (1979). Defining the normalized mole fraction of a component,  $i$ , within the set of the lumped fraction, that is  $i \in L$ , as

$$z_i^* = \frac{z_i}{\sum_{i \in L} z_i} \quad (\text{Eq. 14})$$

Equations for calculation of pseudo-physical and pseudo-critical properties of pseudo component by using Lee's Mixing Rules

$$M_L = \sum_{i \in L} z_i^* * M_i \quad (\text{Eq. 15})$$

$$P_{cL} = \sum_{i \in L} [z_i^* * p_{ci}] \quad (\text{Eq. 16})$$

$$T_{cL} = \sum_{i \in L} [z_i^* * T_{ci}] \quad (\text{Eq. 17})$$

$$\gamma_L = M_L / \sum_{i \in L} [z_i^* * M_i / \gamma_i] \quad (\text{Eq. 18})$$

$$\omega_L = \sum_{i \in L} [z_i^* * \omega_i] \quad (\text{Eq. 19})$$

$$V_{cL} = \sum_{i \in L} [z_i^* * M_i * V_{ci} / M_L] \quad (\text{Eq. 20})$$

**Numerical approach:**

In order to check Whiston lumping method, we compared the results from analytical approach with PVTsim software. **PVTsim** is a simulation tool that can be used across multiple technical fields. You may rely on PVTsim forecasts whether you are looking for fluid qualities deep in the reservoir, in the well, in a subsea pipeline, or on the surface.

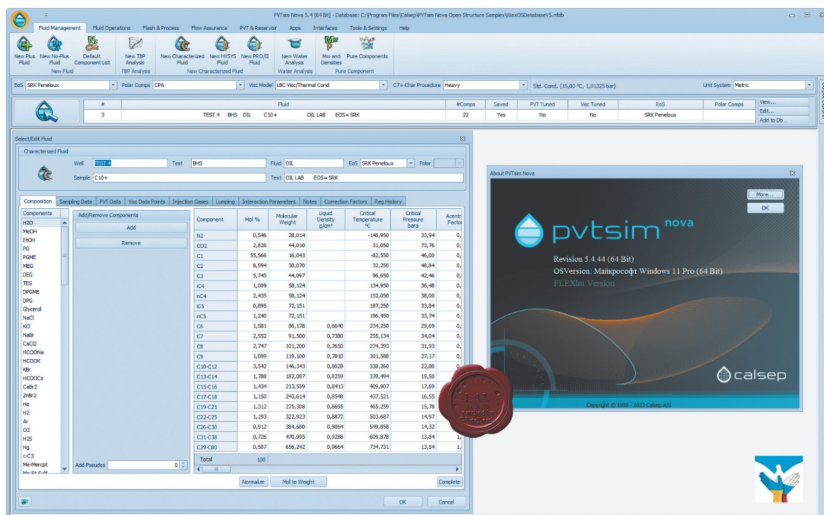


Figure 3 - Interface of PVTsim

PVTsim enables reservoir engineers, flow assurance specialists, and process engineers to match fluid characteristics and experimental data by combining trustworthy fluid characterisation processes with robust and efficient regression algorithms. The fluid parameters can be exported in order to generate high-quality input data for reservoir, pipeline, and process simulators.

### Results:

#### Analytical approach results:

**Whitson's method.** According to the analytical method of fluid characterization, in our case it is Whitson lumping and splitting method, we get results. In the results, applying methods of Whitson, we get lumped fluid description through analytical methods. Then in comparison with simulation tool, we can observe that output data, especially Molar weights of components and pseudo-components are identical which were needed to prove.

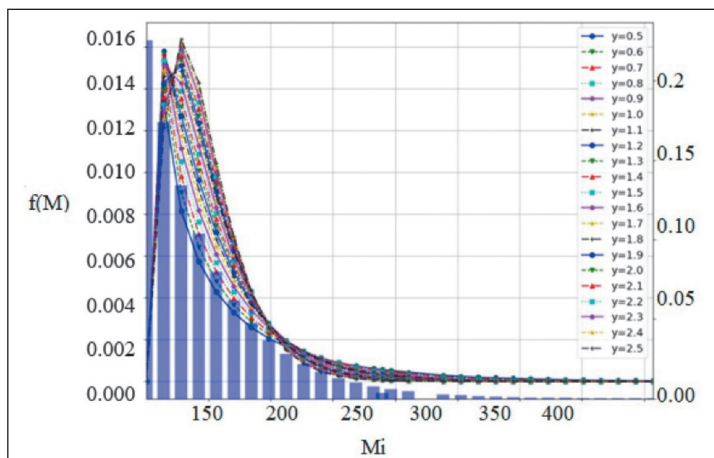


Figure 4 - Molar distribution (Jamilyam et al., 2023)

Figure 4 is represent the molar distribution graph, which is relative proportions or concentrations of various chemical species or components within a mixture. There is the ratio of molar fraction  $f(M)$  to molar weights  $M_i$ . In order to determine  $\gamma$ , the splitted  $C_{7+}$  tail is constructed and density distribution curves with different values of  $\gamma$  are drawn in order to find the best match with the shape of the  $C_{7+}$ . The range of  $\gamma$  is usually form 0.5 to 2.5. Consequently, the best fit was found for  $\gamma$ . It is equal to 0.5.

Applying Whitson's methods, we obtain a lumped fluid description using analytical techniques. When we compare this description with the output data from simulation tools, we observe that the data, particularly the molar weights of components and pseudocomponents, are identical. This serves as a validation, affirming the precision and reliability of the approach.

Table 2 - Lumped fluid description by analytical method

Pseudocomponent	Zi×Mi	M (total)	Zi	Z (total)	Zi, %	Zi, %
C <sub>7+</sub>	9,516	52,400	0,099	0,451	45,107	0,45107
	16,031		0,150			
	9,108		0,075			
	9,306		0,069			
	8,439		0,057			
C <sub>12+</sub>	7,790	55,798	0,048	0,274	27,400	0,274
	7,780		0,044			
	7,076		0,038			
	8,124		0,039			
	6,819		0,031			
	6,345		0,027			
	6,257		0,025			
	5,607		0,021			
C <sub>20+</sub>	5,043	34,843	0,018	0,108	10,754	0,10754
	4,700		0,016			
	4,236		0,014			
	3,918		0,012			
	3,389		0,010			
	3,188		0,009			
	2,861		0,008			
	2,670		0,007			
	2,406		0,006			
	2,432		0,006			
C <sub>30+</sub>	1,984	22,102	0,005	0,041	4,125	0,04125
	1,914		0,004			
	1,634		0,004			
	1,571		0,003			
	1,185		0,003			
	1,176		0,002			
	12,639		0,020			

Table 2 shows us the results of the lumping into pseudocomponents. Based on them, it can be understood that we have grouped our fluid components into four pseudocomponents ( $C_{7+}$ ,  $C_{12+}$ ,  $C_{20+}$ ,  $C_{30+}$ ). We obtained them using the analytical method, which is shown above. The table shows the data we need for the following calculation of molecular weight using Equation 13. At the beginning, we calculated the critical properties of each component, then multiplied compressibility factors and molecular weights of each of them. After that we take Z total and M total for next calculation of  $M_k$ .

Table 3 -  $M_k$  results

$C_{7+}$	$M_k$	190,86
$C_{12+}$	$M_k$	264,35
$C_{20+}$	$M_k$	375,15
$C_{30+}$	$M_k$	508,438

Using the analytical method of calculating the  $M_k$ , the following data were obtained (Table 3). The calculation took place using Equation 13, after which the results were compared with Lee method and the simulation tool.

$$M_k = \frac{M_{total}}{Z_{total}} * \frac{1}{\Gamma(\gamma)} X^{\gamma-1} \quad (\text{Eq. 21})$$

M and Z totals we obtained from Table 2. X is data from “Gaussian quadrature function” (Figure 2).  $\Gamma$  is gamma function.  $\gamma$  is taken from Molar distribution graph which was equal to 0.5 (Figure 4). After the simple mathematical calculation, we get  $M_k$  for each pseudocomponents.

### Lee’s method.

Table 4 -  $M_L$  results

Pseudocomponent	Components	zi	zl	Zi*	MI	$M_L$
C7+	C7	0,09912	0,45107	0,21973	21,09404	116,1594
	C8	0,14982		0,332121	35,537	
	C9	0,07527		0,166859	20,18991	
	C10	0,06945		0,153957	20,63024	
	C11	0,05741		0,127267	18,7082	
C12+	C12	0,04841	0,274	0,176679	28,43116	203,6439
	C13	0,04446		0,162263	28,39323	
	C14	0,03765		0,137409	25,82378	
	C15	0,03947		0,144051	29,6509	
	C16	0,03098		0,113066	24,88825	
	C17	0,02678		0,097737	23,15864	
	C18	0,02493		0,090985	22,83452	
	C19	0,02132		0,07781	20,46339	

Table 4 -  $M_L$  results

C20+	C20	0,01834	0,10754	0,170605	46,91508	324,1245
	C21	0,01615		0,150233	43,71692	
	C22	0,01389		0,129209	39,40832	
	C23	0,01232		0,114605	36,44382	
	C24	0,01024		0,095256	31,52929	
	C25	0,00924		0,085953	29,65361	
	C26	0,00797		0,07414	26,6158	
	C27	0,00714		0,066419	24,84029	
	C28	0,0062		0,057674	22,37744	
	C29	0,00605		0,056279	22,6239	
C30+	C30	0,00477	0,04125	0,115496	48,04649	535,1656
	C31	0,00445		0,107748	46,33172	
	C32	0,00368		0,089104	39,56223	
	C33	0,00343		0,083051	38,03729	
	C34	0,00251		0,060775	28,68571	
	C35	0,00242		0,058596	28,47748	
	C36+	0,01999		0,484019	306,0246	

After the analytical approaches from Whitson’s and Lee’s methods, we compared results with numerical approach. Especially, we use PVTsim simulation tool to calculate molecular weight of each pseudocomponents. The results are shown below.

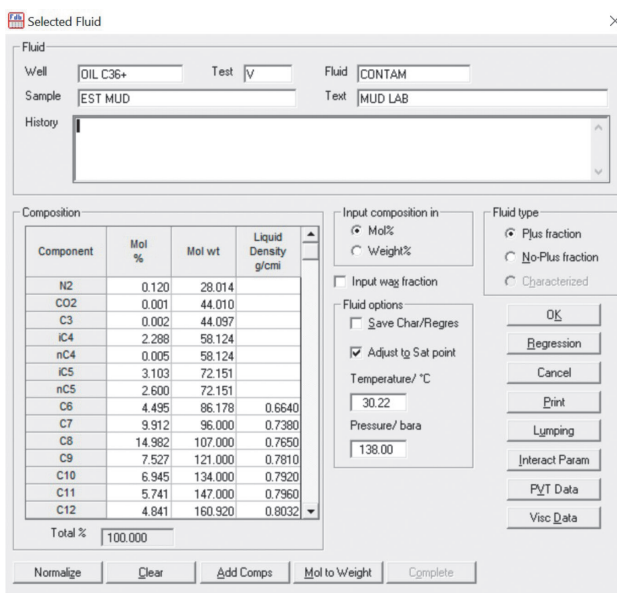


Figure 5 - PVTsim’s data for fluid description

The data from the laboratory work were delivered to the selected fluid section at a certain temperature and pressure ( $T = 30.22^{\circ}\text{C}$  and  $P = 138.00 \text{ bar}$ ). Then PVTsim simulation tool is automatically calculated the results of Lumping. When push the button “Lumping”, we get results which is shown on *Figure 6*.

Component	Mol %	Mol wt	Liquid Density g/cm³
N2	0.120	28.014	
CO2	1.0E-03	44.010	
C3	0.002	44.097	
iC4	2.283	58.124	
nC4	0.005	58.124	
iC5	3.096	72.151	
nC5	2.594	72.151	
C6	4.485	86.178	0.6640
Pseudo_1	54.273	192.000	0.7801
Pseudo_2	19.903	265.000	0.8277
Pseudo_3	9.376	377.000	0.8790
Pseudo_4	3.862	508.000	0.9307

**Figure 6 – Results from lumping (PVTsim)**

We used a numerical approach to calculate pseudocomponents 1, 2, 3, and 4. This approach provided us with the molar weights of each pseudocomponent. Subsequently, we compared these numerical results with the data obtained through an analytical approaches. We have identified that Whitson’ lumping method is more accurate calculate the properties of fluid. The comparison revealed that the data from both methods, numerical and Whitson’s analytical, were identical, demonstrating the effectiveness of the Whitson lumping method. This consistency in the results confirms that the Whitson method accurately characterizes fluid properties through lumping procedures.


**Discussion.** Based on the data highlighted in *Table 3*, it can be seen that calculations made manually by the analytical lumping approach are very close to the values obtained during numerical approach. There are results from PVTsim software. According to *Figure 6*, we can see the results from PVTsim software and with comparison with analytical method, they showed identical data. Calculations made manually by the analytical lumping approach are very close to the values obtained during laboratory analysis. There are some deviations in the PVTsim program results. However, the same trend of mole fraction range is clearly visible. This comparison confirmed the effectiveness of the modeling approach and validated the accuracy of the results.

In comparison with other methods for lumping, Whitson methods is more accurately estimate lumping process. For instance, Lee et al. (1982) suggest that  $C_{7+}$  fractions can be grouped into two pseudo-components, which in turn limits the number of pseudo components [9]. What about other correlations, there is also some limitations for lumping, such as the Coats lumping methodology is allows “partial lumping” of original components into several pseudocomponents [9].

In the oil and gas industry, lumping is often used in kinetic models for chemical reactions, phase equilibrium models, and other simulation and modeling tasks. Engineers and scientists must carefully consider the trade-offs between simplification and accuracy when deciding to use lumping procedures, taking into account the specific needs of the project or analysis.

**Conclusion.** The present study pertains a lumping technique that serves two key purposes. Firstly, it enables the estimation of critical properties of both liquid and vapor phases in complex mixtures, which are commonly encountered in real-world scenarios such as oil or gas reservoirs and their production processes. This is achieved by employing a simplified representation that relies on a reduced number of pseudo-components. Secondly, it facilitates the prediction of the detailed composition of fluids produced over time.

We checked the Whitson's lumping and splitting methods to characterize the fluid description. As the result, we totally observed that this method is accurate for splitting and lumping the components for Kazakhstani oil characterization.

This invention is especially valuable in reducing number of calculations during the simulation of underground hydrocarbon reservoir production. Such a model empowers reservoir engineers to significantly reduce the time required for simulating reservoir behavior during production, while still maintaining a high-quality representation of the interactions between different hydrocarbon phases. Additionally, it allows for the creation of detailed compositional profiles, which are vital for tasks like designing and managing surface facilities including separators, treatment plants, transportation systems, and more. Consequently, this innovation has practical applications in both surface and process engineering. 

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