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RESEARCH IN THE FIELD OF PVT-CALCULATIONS FOR ACCURATE FLUID DESCRIPTION

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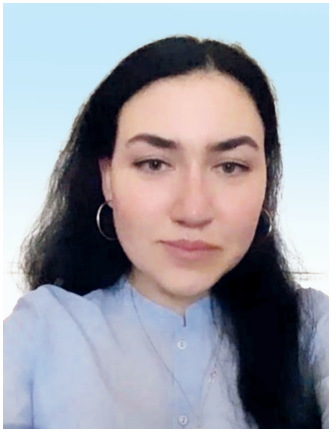

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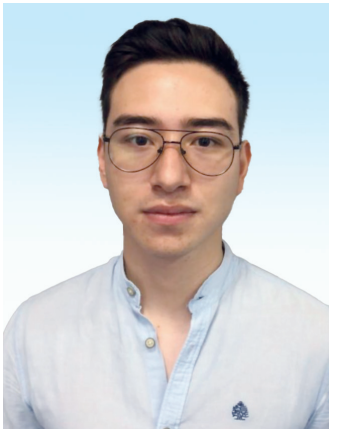

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Lumping methods for oil components require a more detailed approach to refine the description of fluids in an oil production area. These methods allow you to gradually increase the dynamics of the behavior of hydrocarbon deposits and increase their reserves. To date, the lumping method is relevant as an attractive way to spend on reservoir compositional modeling.

The authors of the article describe PVT-calculations that have been developed for many years of illness, in the treatment of diseases of the cardiovascular system. They explain the approaches of different lumping methods. This article discusses different types of lumping methods such as classical, statistical, and machine learning based lumping.

Classical lumping methods involve grouping the similarities of components based on their chemical structure and properties. This is a widely used approach and found to be effective in obtaining an accurate description of fluids. Pooling methods use mathematical models for group molecules based on their thermodynamic and beneficial properties. This approach is more likely, but may have a more accurate representation of the properties of the oil.

The paper also discusses machine learning-based lumping techniques that have recently received attention in this area. These algorithms use artificial algorithms to group components based on their properties and have shown promising results in predicting the behavior of oil.

The authors emphasize exclusive group methods in modeling consumption statistics and offer insights into the advantages and limitations of each method. Recommendations are also given on choosing a lumping method for determining oil components and describing an algorithm for calculating Kazakhstan fields. This document is a valuable resource for investigators and engineers involved in the production and use of oil.

KEY WORDS: *lumping, hydrocarbons, fluids, compositional modeling, reservoir, oil production, heavy components, machine learning.*

ИССЛЕДОВАНИЯ В ОБЛАСТИ PVT-РАСЧЕТОВ ДЛЯ ПОЛУЧЕНИЯ ТОЧНОГО ОПИСАНИЯ ФЛЮИДОВ

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Методы группировки компонентов нефти становятся все более популярным подходом для уточнения описания флюидов в области нефтедобычи. Данные методы позволяют получить значительный прогресс в понимании поведения залежей углеводородов и оптимизации добычи. На сегодняшний день метод группировок актуален как способ снижения затрат на композиционное моделирование коллектора.

Авторы статьи описывают PVT-расчеты, которые разрабатываются при заболевании многих лет, при лечении заболеваний сердечно-сосудистой системы. Они объясняют подходы различных методов группировки В данной статье рассматриваются различные типы методов группировки, такие как классическая, статистическая и группировка на основе машинного обучения.

Классические методы группировки включают в себя групповые сходства компонентов на основе их химической структуры и свойств. Этот широко используемый подход и обнаружение эффективности для получения точного описания флюидов. Методы объединения используют математические модели для групповых молекул на основе их термодинамических и выгодных свойств. Этот подход является более вероятным, но может иметь более точное представление о свойствах нефти.

Рассматриваются также методы группирования на основе машинного обучения, которые в последнее время привлекают внимание в этой области. В этих алгоритмах используются алгоритмы искусственного для группировки компонентов на основе их свойств, и они продемонстрировали многообещающие результаты в прогнозировании поведения нефти.

Авторы подчеркивают исключительные групповые методы при моделировании статистики потребления и предлагают представления о преимуществах и ограничениях каждого метода. Также даны рекомендации по выбору метода группировки определения компонентов нефти и описания алгоритма расчета месторождений Казахстана. Этот документ является ценным ресурсом для следственных действий и инженеров, занимающихся вопросами добычи и использования нефти.

КЛЮЧЕВЫЕ СЛОВА: *группировка, углеводороды, флюиды, композиционное моделирование, коллектор, нефтедобыча, тяжелые компоненты, машинное обучение.*

ФЛЮИДТАРДЫҢ НАҚТЫ СИПАТТАМАСЫН АЛУ ҮШІН PVT-ЕСЕПТЕУЛЕР САЛАСЫНДАҒЫ ЗЕРТТЕУЛЕР

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Мұнай компоненттерін топтастыру әдістері мұнай өндіру аймағындағы флюидтердің сипаттамасын нақтылау үшін егжей-тегжейлі көзқарасты талап етеді. Бұл әдістер көмірсутегі кен орындарының әрекет динамикасын біртіндеп арттыруға және олардың қорларын арттыруға мүмкіндік береді. Бүгінгі күні топтастыру әдісі коллектордың композициялық модельдеуге жұмсаудың оңтайлы тәсілі ретінде өзекті болып табылады. Мақаланың авторлары жүрек-тамыр жүйесі ауруларын емдеуде көп жылдар бойы ауруға шалдыққан PVT-есептерді сипаттайды. Олар әртүрлі топтастыру әдістерінің тәсілдерін түсіндіреді. Бұл мақалада классикалық, статистикалық және машиналық оқытуға негізделген топтастыру әдістерінің әртүрлі түрлері талқыланады.

Классикалық топтастыру әдістері химиялық құрылымы мен қасиеттеріне қарай компоненттердің ұқсастықтарын топтастыруды қамтиды. Бұл кеңінен қолданылатын әдіс және флюидтердің нақты сипаттамасын алуда тиімді болып табылады. Біріктіру әдістері топтық молекулалардың термодинамикалық және пайдалы қасиеттеріне негізделген математикалық модельдерді пайдаланады. Бұл тәсіл ықтимал болып табылады, бірақ мұнайдың қасиеттерін дәлірек көрсетуі мүмкін.

Сондай-ақ, мақалада осы салада жақында назар аударылған машиналық оқытуға негізделген топтау әдістері талқыланады. Бұл алгоритмдер компоненттерді қасиеттеріне қарай топтастыру үшін жасанды алгоритмдерді пайдаланады және мұнайдың әрекетін болжауда перспективалы нәтижелер көрсетті.

Авторлар тұтыну статистикасын модельдеуде эксклюзивті топтық әдістерді атап көрсетеді және әрбір әдістің артықшылықтары мен шектеулері туралы түсініктер ұсынады. Сондай-ақ, мұнай компоненттерін анықтау үшін топтастыру әдісін таңдау және Қазақстанның кен орындарын есептеу алгоритмін сипаттау бойынша ұсыныстар берілген. Бұл құжат мұнай өндірумен және пайдаланумен айналысатын тергеу әрекеттері мен инженерлер үшін құнды ресурс болып табылады.

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Introduction. The accurate characterization of hydrocarbons is essential for the successful application of compositional simulation in the oil and gas industry. Hydrocarbon characterization involves determining the composition and properties of the different hydrocarbon fractions. However, the analysis of hydrocarbons can be time-consuming and costly, making it difficult to obtain accurate results. This paper reviews recent research on hydrocarbon characterization and compares the different methods used.

Lumping methods involve grouping similar compounds into a single component with similar thermodynamic properties. The lumping process simplifies the compositional analysis of hydrocarbons and reduces the number of components in the hydrocarbon model. Several lumping methods have been proposed, including the key compound lumping method, the statistical lumping method, and the SARA-based lumping method. The key compound lumping method involves selecting a set of key hydrocarbons that are representative of the hydrocarbon mixture, while the statistical lumping method groups compounds based on their statistical similarities. The SARA-based lumping method groups compounds based on their saturate, aromatic, resin, and asphaltene (SARA) content.

Materials and methods. For decades, the views of engineers and scientists of the oil and gas industry have been focused on the study of oil and gas chemistry. A huge number of papers have been published, including papers considering various methods for

grouping oil components into pseudo-components and calculating properties for pseudo-components. The high cost of compositional modeling and the exhaustive computing power required are solved by grouping heavy oil components into pseudo-components.

1. Based on Danesh A. 1998. «PVT and Phase Behavior of Petroleum Reservoir Fluids» (Vol. 47. Elsevier) and Whitson C. H., Brule M.R. 2000. «Phase Behavior» (Monograph Volume 20. SPE Henry L. Doherty Series.), an algorithm was developed for lumping calculations. Phase behavior calculations using cubic equation of state to predict properties of reservoir fluid require components characteristics such as critical pressure, critical temperature, acentric factor, binary interaction parameters. Separation techniques including gas chromatography and distillation are not able to identify all components in mixture, particularly, heavier than C7. These components are grouped in heptane-plus fraction and next calculations are performed to simulate C7+ characterization. Methodology:

The three parameters gamma distribution model is used for describing molar distribution

$$f(M) = \frac{(M-\tau)^{\gamma-1}\exp\left(-\frac{[M-\tau]}{\beta}\right)}{\beta^{\gamma}\,\Gamma(\gamma)}, \quad (1)$$

Where Γ – gamma function and β is given by:

$$\beta = \frac{M_{C7+}-\tau}{\gamma}, \quad (2)$$

The parameter τ is a minimum molecular weight of the C7+ tail
The key parameter γ controls the shape of f(M).
Change integration variable to:

$$X = \frac{M-\tau}{\beta}, \quad (3)$$

Range of integration $\tau < M < \infty$ changes to $0 < X < \infty$

$$dX = \frac{1}{\beta}dM \rightarrow dM = \beta dX, \quad (4)$$

$$\int_{\tau}^{\infty} f(M)dM = \int_{0}^{\infty} \frac{(M-\tau)^{\gamma-1}\exp\left(-\frac{[M-\tau]}{\beta}\right)}{\beta^{\gamma}\,\Gamma(\gamma)}\beta dX = , \quad (5)$$

$$= \int_{0}^{\infty} \frac{M-\tau^{\gamma-1}}{\beta}\exp\left\{-\left[\frac{M-\tau}{\beta}\right]\right\}\frac{1}{\Gamma(\gamma)}dX$$

$$\int_{0}^{\infty} X^{\gamma-1}\exp(-X)\frac{1}{\Gamma(\gamma)}dX = 1, \quad (6)$$

$$F(X) = \frac{X^{\gamma-1}}{\Gamma(\gamma)}, \quad (7)$$

$$\int_{0}^{\infty} F(X)\exp(X)\,dX = 1, \quad (8)$$

Gauss-Laguerre quadrature

$$\int_0^\infty F(I)\exp(-I)\,dI = \sum_{k=1}^{n} W_k^{(n)} F(I_k)^n\,, \tag{9}$$

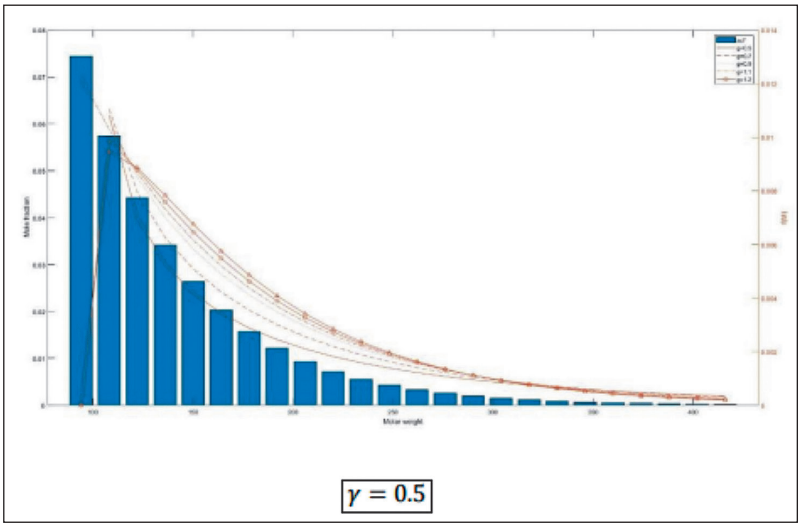
$$\sum_{k=1}^{n} W_k^{(n)} = 1\,, \tag{10}$$

$$\sum_{k=1}^{n} W_k^{(n)} z_{total} = z_{total} \sum_{k=1}^{n} W_k^{(n)} = z_{total}, \tag{11}$$

$$z_k = \sum_{k=1}^{n} W_k^{(n)} z_{total}\,, \tag{12}$$

$$M_k = \frac{M_{total}}{z_{total}} \frac{1}{\Gamma(\gamma)} X^{\gamma-1}, \tag{13}$$

The only unknown in equations above is γ. The range of γ is usually from 0.5 to 2.5. In order to determine γ, the C7+ tail is constructed and density distribution curves with different values of γ are drawn in order to find the best match with the shape of the C7+.



Picture 1 — **Mole fraction VS Molar weight plot**

The paper has introduced a correlation that can be used by hydrocarbon reservoir engineers to simplify the analysis of heavy hydrocarbon fractions. This correlation can reduce the time and computational resources required for simulation and enhance the accuracy of results. The correlation's user-friendliness and simplicity make it an asset for reservoir engineers who face difficulties analyzing heavy hydrocarbon fractions. Consequently, this correlation can be a valuable tool for hydrocarbon reservoir engineers.

2. «Lumped-Component Characterization of Crude Oils for Compositional Simulation» Hong, K. C. (1982). The characterization of crude oil is a crucial step in the process of reservoir simulation, which is used to predict the behavior of oil reservoirs over time. In 1982, K. C. Hong proposed a lumped-component characterization method for crude oils that simplifies the compositional analysis and enables more efficient simulation.

Hong's lumped-component characterization method is based on the concept of lumping similar components together. The lumping process groups similar compounds into a single component with similar thermodynamic properties, such as molecular weight, critical temperature, and critical pressure. This simplification reduces the number of components in the oil model and, consequently, reduces the computation time for simulation. In this study, six different mixing rules were evaluated for characterizing the lumped C7+ fraction from its constituent component properties.

The lumping process is achieved by selecting a set of key hydrocarbons that are representative of the crude oil. The key hydrocarbons are chosen based on their molecular structure, carbon number, and boiling point range. Once the key hydrocarbons are identified, a series of lumping rules are applied to combine the similar compounds into lumped components. The lumped components are then used to create a simplified oil model for reservoir simulation.

Hong's lumped-component characterization method has several advantages in reservoir simulation. The simplified oil model reduces the computational time required for simulation, allowing for more extensive reservoir modeling studies. Additionally, the simplified model is more manageable, making it easier to interpret the simulation results.

The lumped-component characterization method also enables the prediction of phase behavior of crude oil in the reservoir. The lumped components are used to create an equation of state that describes the thermodynamic behavior of the oil. This equation of state is used to calculate the saturation pressure and temperature of the oil, which are essential in predicting the phase behavior of the oil in the reservoir

3. "A Generalized Correlation for Characterizing the Hydrocarbon Heavy Fractions" is a paper published in 1985 by T.H. Ahmed, G.V. Cady, and A.L. Story. The paper presents a correlation for characterizing the heavy fractions of hydrocarbons, which are essential for compositional simulation in the oil and gas industry.

The correlation presented in the paper is based on the molecular weight of the heavy fractions and the total number of carbon atoms in the hydrocarbon mixture. The correlation uses a set of coefficients that are determined through regression analysis of experimental data. The experimental data used to develop the correlation includes the boiling point and molecular weight of hydrocarbon samples. The regression analysis is used to determine the coefficients that provide the best fit to the experimental data.

$$z_n = z_{n+} * \frac{MW_{(n+1)+} - MW_{n+}}{MW_{(n+1)+} - MW_n}, \quad (14)$$

where:

z_n = mole fraction of component with numbers of carbon atoms of c_n (i.e., z_7, z_8, … etc.)

MW_n = Katz-Firoozabad: recommended molecular weight for component c_n

MW_{n+} = molecular weight of the c_n – plus fraction as calculated by next equation

$$MW_{n+} = MW_{7+} + s * (c_n - 7), \quad (15)$$

c_n = number of carbon atoms

s = slope

The correlation presented in the paper provides a useful tool for the characterization of hydrocarbon heavy fractions. The correlation simplifies the compositional analysis of hydrocarbons, reduces the computational time required for simulation, and improves the accuracy of the simulation results. The correlation's simplicity and ease of use make it a valuable tool for hydrocarbon reservoir engineers, especially in cases where the compositional analysis of heavy fractions is challenging.

4. "Heavy Fraction C7+ Characterization for PR-EOS" is a paper published in 2007 by G.F. Sancet. The paper presents a methodology for characterizing the heavy fraction of hydrocarbons, specifically the C7+ fraction, using the Peng-Robinson equation of state (PR-EOS). The paper provides a detailed description of the methodology and its implementation, along with the results of its application to several hydrocarbon mixtures.

There are two modifications for EOS to determine C7+: Twu-Coon-Cunningham and Twu-Tilton-Bluck.

Twu-Coon-Cunningham. This modification consider a new relation of the attraction term: the α parameter, temperature and accentric factor. They propose the next equation:

$$\alpha = \alpha^{(0)} + \omega * \left(\alpha^{(1)} - \alpha^{(0)}\right), \quad (16)$$

Twu-Tilton-Bluck. Presents a volume-change factor for improving the liquid density predictions. They propose the next equations:

$$c = v_{s,CEOS} - v_{s,RA}, \quad (17)$$

$$v_{s,RA} = \left(\frac{RT_c}{P_c}\right) * Z_{RA}^{\left(1-(1-Tr)^{\frac{2}{7}}\right)}, \quad (18)$$

$$v = v_{CEOS} - \sum x_i c_i, \quad (19)$$

Where:

Vs,CEOS = volume of saturated liquid calculated by a cubic EOS

Vs,RA = volume of saturated liquid calculated by Rackett's equation

ZRA = Rackett's parameter

The methodology presented in the paper involves the characterization of the C7+ fraction using PR-EOS based on its specific density and its molecular weight distribution. The specific density of the C7+ fraction is determined using experimental data, and the molecular weight distribution is determined using a novel algorithm based on the individual molecular weights of the C7+ compounds. The algorithm takes into account the structural differences between the C7+ compounds, allowing for a more accurate characterization of the C7+ fraction.

Correlation for the C7+:

P_c[psia] = 82.82+653 exp(-0.007427MW) (20)

T_c[R] = -778.5+383.5 ln(MW-4.075) (21)

T_b[R] = 194+0.001241 $(T_c[R])^{1.869}$ (22)

The methodology presented in the paper provides a valuable tool for the characterization of the C7+ fraction of hydrocarbons. The methodology is based on the widely used PR-EOS, making it applicable to a wide range of hydrocarbon mixtures. The use of experimental data for determining the specific density of the C7+ fraction and the novel algorithm for determining its molecular weight distribution make the methodology more accurate and reliable than previous methods. The methodology's accuracy and reliability make it a valuable tool for various industrial processes that require the prediction of hydrocarbon properties and behavior.

5. "Validation of Splitting the Hydrocarbon Plus Fraction First Step in Tuning Equation-of-State" is a paper published in 2007 by Al-Meshari and McCain Jr. The paper describes a methodology for tuning equation-of-state (EOS) models for hydrocarbon mixtures, which involves splitting the hydrocarbon plus fraction into two subfractions based on the molecular weight distribution. The paper presents the results of applying the methodology to several hydrocarbon mixtures, and it provides a comparison of the results obtained using the tuned EOS models with experimental data.

The methodology presented in the paper involves splitting the hydrocarbon plus fraction into two subfractions based on the molecular weight distribution, with the first subfraction containing the heaviest compounds and the second subfraction containing the lighter compounds. The tuning process involves adjusting the EOS model parameters using experimental data for the two subfractions separately. The paper presents the results of applying the methodology to several hydrocarbon mixtures, including crude oil and natural gas liquids.

The methodology presented in the paper provides a valuable tool for tuning EOS models for hydrocarbon mixtures, improving their accuracy and reliability. The splitting of the hydrocarbon plus fraction into two subfractions allows for a more accurate characterization of the hydrocarbon mixture and a better estimation of its properties and behavior. The use of experimental data for tuning the EOS model parameters makes the methodology more reliable than previous methods that relied on empirical correlations or simplified models.

6. "SARA-Based Lumping Scheme: An Application Example" is a research paper published in 2019 by Altowilib and Fraim. The paper describes a lumping scheme based on the SARA (saturates, aromatics, resins, and asphaltenes) analysis of crude oil for improving the computational efficiency of reservoir simulation. The lumping scheme reduces the number of components in the simulation model by grouping similar compounds into lumped components based on their SARA fraction. The paper presents an application example of the lumping scheme and compares the results with those obtained using the original composition model.

The meaning of this study is that all dead oil is run to analyze the saturated, asphaltenes, resins and aromatics in it, and from there compute heavy fractions C7+.

The methodology presented in the paper involves grouping similar compounds in the crude oil into lumped components based on their SARA fraction. The lumping scheme reduces the number of components in the simulation model and improves computational efficiency without compromising accuracy. The paper presents an application example

of the lumping scheme for a complex crude oil, comparing the results obtained using the lumped component model with those obtained using the original composition model. The comparison includes the prediction of phase behavior, viscosity, and API gravity.

The lumping scheme based on the SARA analysis of crude oil provides a valuable tool for improving the computational efficiency of reservoir simulation without compromising accuracy. The reduction in the number of components in the simulation model simplifies the simulation process and reduces computational time, making the simulation more practical for real-world applications. The application example presented in the paper demonstrates the effectiveness of the lumping scheme for complex crude oils, providing a benchmark for future applications.

7. "An Artificial Intelligence Approach to Predict Molar Compositions of Reservoir Fluid Components" is a research paper published in 2019 by AlMatouq, Alabbad, and Anifowose. The paper proposes an artificial intelligence (AI) approach to predict the molar compositions of reservoir fluid components. The approach is based on a deep neural network (DNN) trained on a large dataset of molar compositions and fluid properties. The paper presents the methodology, validation, and comparison of the proposed approach with existing methods for predicting molar compositions in reservoir fluid analysis.

The methodology presented in the paper involves building a DNN model trained on a large dataset of molar compositions and fluid properties obtained from a range of reservoirs. The model takes various input parameters, including reservoir temperature, pressure, and other fluid properties, and predicts the molar compositions of reservoir fluid components. The paper presents the validation and comparison of the DNN model with existing methods for predicting molar compositions, including the use of empirical correlations and thermodynamic models.

The proposed AI approach provides a valuable tool for predicting the molar compositions of reservoir fluid components, improving the accuracy and efficiency of reservoir fluid analysis. The DNN model can handle complex fluid mixtures and provides a more accurate prediction compared to existing methods. The methodology is also applicable to various reservoirs and can improve reservoir management by providing accurate predictions of fluid behavior and properties.

Results and discussions. In this study seven studies with different methods were described. For each study, the calculation algorithm was described and viewpoint was given. The method based on studies Danesh A. (1998) and Whitson C. (2000) is recommended as the main lumping algorithm for oil fields in Kazakhstan, due to the minimized deviation from the actual data from fields and the use of the most common and relevant relationships of oil chemical parameters. The initial data necessary for this method are available at most of the known fields in Kazakhstan.

Conclusion. In conclusion, hydrocarbon characterization is essential for the successful application of compositional simulation in the oil and gas industry. Lumping methods and artificial intelligence approaches are two of the most commonly used methods for hydrocarbon characterization. The choice of method depends on the complexity of the hydrocarbon mixture and the accuracy required for the simulation results. The use of these methods has contributed to significant advancements in the understanding of hydrocarbon reservoir behavior and production optimization.

Table 2 – **Overall**

Study	Result
Based on Danesh A. 1998. «PVT and Phase Behavior of Petroleum Reservoir Fluids» and Whitson C. H., Brule M.R. 2000. «Phase Behavior» study	Introduced C7+ components lumping algorithm.
«Lumped-Component Characterization of Crude Oils for Compositional Simulation» by Hong (1982)	Lumping method to group similar components of crude oil into a smaller number of pseudo-components, which reduces the computational complexity and improves the accuracy of reservoir simulations.
«A Generalized Correlation for Characterizing the Hydrocarbon Heavy Fractions» by Ahmed, Cady, and Story (1985)	Estimated the heavy fraction compositions of crude oils based on the API gravity of the crude oil.
«Heavy Fraction C7+ Characterization for PR-EOS» by Sancet (2007)	The pseudo-component grouping method, which uses a binary interaction parameter to improve the characterization of heavy hydrocarbons.
«Splitting the Hydrocarbon Plus Fraction First Step in Tuning Equation-of-State» by Al-Meshari and McCain Jr. (2007)	Showed that splitting and lumping the C7+ fraction could lead to better accuracy in predicting phase behavior and physical properties of reservoir fluids.
«SARA-Based Lumping Scheme: An Application Example» by Altowilib and Fraim (2019)	Modified lumping method based on SARA analysis to create a smaller number of pseudo-components that accurately represent the crude oil.
«Artificial Intelligence Approach to Predict Molar Compositions of Reservoir Fluid Components» by AlMatouq, Alabbad, and Anifowose (2019)	Artificial neural networks (ANNs) to predict the molar compositions of reservoir fluid components. They trained and tested the ANN on a large dataset of crude oil samples and achieved accurate predictions.

To summarize, it is recommended to perform lumping calculations for Kazakhstani oil fields based on the first reviewed method, in order to reduce cash costs and computing power costs for compositional modeling, by developing software using algorithm from this method.

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