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Evaluation of The Fluid Contact Estimation Using Phase Equilibrium and Irreversible Thermodynamics in The Hydrocarbon Column of Porous Media; A Case Study in Oil Fractured Saturated Reservoir in The Southwest of Iran

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Introduction

Determining the volume of fluid in place in the reservoir is based on several factors, one of which is the proper definition of fluid contact levels [1]. Depending on the data available, fluid levels can be determined directly from the drilled well or indirectly from a seismic analysis [2]. The indirect technique of gas-oil contact (GOC) assessment requires only that, which it has penetrated the oil or gas zone, rather than penetrating both zones (if both exist) [3, 4]. Pressure-volume-temperature (PVT) relationships and pressure transient analysis are examples of indirect techniques. Moreover, the PVT technique is based on the principle of compositional gradient. This technique assumes that oil and gas have reached equilibrium thermodynamics in geological history (static) before the reservoir is produced. Therefore, this method uses valid PVT data obtained from the oil or gas region to investigate the presence or absence of counterpart hydrocarbon and the possible interface (GOC) of contact between the two hydrocarbons or hydrocarbons and water [5].
When there is limited information about the newly discovered field, methods can be used to determine the location of the GOC [6]. Some of these methods include interval halving, modified phase envelope calculation or modified critical point calculation and improved method. The interval halving method requires only one reference condition and is reliable as long as the saturation type is correctly determined. The predictability of the modified phase envelope method in near critical systems with large compositional gradients and saturated GOC is less than the interval halving method. In this method, the region near the GOC with large compositional gradients is not approximated correctly, if the reference conditions are far away from this region. In addition, one needs two known reference conditions, one of them in the oil zone and the other in the gas zone, instead of one. The improved algorithm does not depend on whether GOC conditions are saturated or not. The computational speed of this method in different types of oil reservoirs is at least with a factor of 1.5 - 4 in comparison with the interval halving method. This method is a very useful suggestion for cases where the fluids of compositional gradient reservoirs are low, as well as those that have GOC [7].
In this study, the evaluation of GOC level in porous media by PVT concept using the simulation of crude

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oil sample of one of the supermassive fields located in the south of Iran has been demonstrated in a practical way. In addition to demonstrating the workflow, the robustness of the method and its limitations are highlighted.

Methodology

The workflow of evaluation GOC using phase Equilibrium and irreversible thermodynamics presented in Figure 1 that includes collecting and preparation key data required for calculations, modeling reservoir fluids (adjusting equation of state), performing simulation of compositional gradient using Gravitational/Chemical equilibrium thermodynamic model (molecular diffusion) or collaborators, and irreversible models of static thermo-diffusion and validation. Data collection includes fluid composition, laboratory tests of differential liberation and constant composition, pressure determination, temperature at the reference depth and review of repeat formation test (RFT). Reservoir fluid modeling involves grouping components and matching equation of state with laboratory data. Compositional gradient simulation using phase equilibrium or isothermal model and irreversible thermodynamics that includes zero thermal diffusion factor, Hasse and Kempers models. These models have been tested in the field to evaluate the level of GOC in the studied field. Finally, thermodynamic models have been validated with other fluid contact assessment techniques in reservoir studies. According to Figure 1, in the validation stage, if the contact surface obtained by the compositional gradient method does not match with RFT, Again, the fluid model made in terms of assigning fitness parameters, considering the initial composition model or grouping, the type of compositional gradient model has been revised.

Results and Discussion

The results of all thermodynamic models are analyzed in three wells that have been very well matched with the RFT. Other models that do not match the RFT have been avoided. Figure 2 shows the reservoir pressure and saturation pressures curves predicted by the isothermal, non-isothermal models and pressure data in other wells in the field to assess the GOC level in each well.

In general, only at the GOC level is the pressure of the oil bubble point equal to the dew point pressure. In the gas cap, the dew point pressure increases with an increase in depth to the GOC level. Below the GOC, the pressure of the oil bubble decreases due to the lower accumulation of lighter components down the structure of the reservoir. Static pressure has increased with a significant slope in the oil region due to the more significant oil density than the gas phase. According to Figure 2, the isothermal model with grouped fluid composition and the Hasse model for Well-01, the zero thermal diffusion factor model with the grouped fluid composition for Well-05 and the Kempers model for Well-18 are the best models to match. They are very close to the RFT. According to Table 1, Well-05 has a sampling depth closer to the GOC than the other two wells, but the accuracy of calculating the GOC is based on RFT in comparison with the other two wells whose contact surface is further from the reference from the above discussion, it can be deduced that compositional gradients occur not only in conventional reservoirs but also in fracture reservoirs.

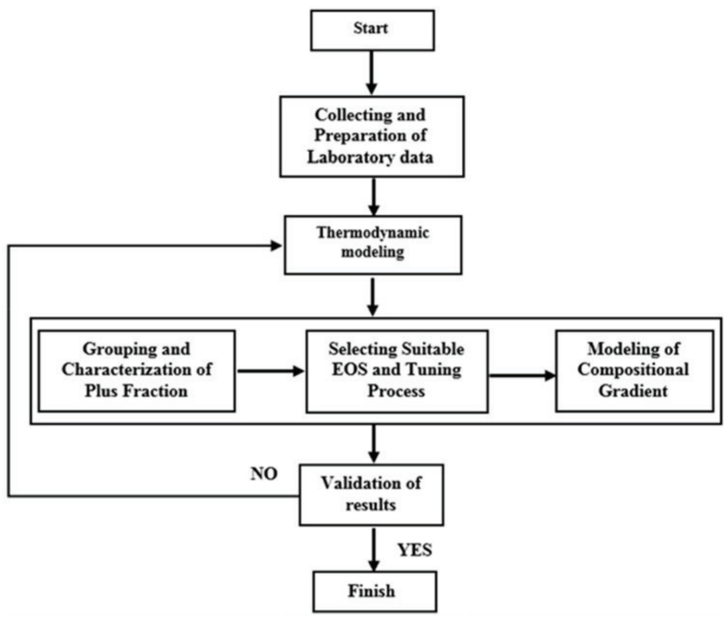

Fig .1 workflow of modeling GOC.

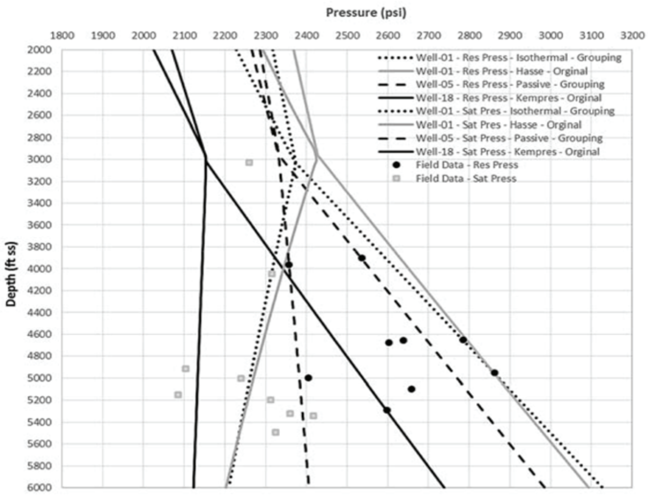

Fig. 2 Comparison of pressure and saturation pressure graphs.

Table 1: Depth of GOC for each of the model.

model	Well Name	Reference Depth (ft ss)	GOC Depth From CG (ft ss)	GOC Depth From RFT (ft ss)
Isothermal	Well-01	4950.8	3034.0	3035.0
Hasse	Well-01	4950.8	2962.0	
Passive	Well-05	3901.0	2960.0	
Kempers	Well-18	5095.0	3022.0	

However, in fractured reservoirs, the rate of change of composition is less than homogeneous reservoirs due to the presence of convection phenomenon.

Conclusions

• Compositional gradient estimation can help ensure the reliability of fluid samples taken from different depths.

• It has been observed that in non-isothermal models, the changes in composition with depth are greater than in the isothermal model.

• The choice of equation of state type, relations property estimation and viscosity have a significant impact on calculating the GOC depth.

• This study shows that one of the factors that is very effective in calculating the depth of GOC and changing the composition with depth in commercial software is convergence control. This convergence control can be done by considering the parameter "Successive Substitution (λ)," which is very low accuracy of the calculations, and without considering the parameter λ and the use of nonlinear solvent, which the experience of this research shows, the accuracy of the calculations is very high.

• In reservoir dynamic simulation to investigate the effect of change in composition on fluid in place and oil recovery from the reservoir, the fluid model as input is more valid for the dynamic model that has undergone a process such as the present study and has reached a safe GOC in accordance with the methods of RFT or logs.

Nomenclatures

GOC: Gas-oil contact
RFT: Repeat formation test

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