Influence of oil/gas reservoir driving conditions on reserves estimation using computer simulation

Jerzy Stopa*[1], *Stanisław Rychlicki* and *Paweł Wojnarowski

Vplyv vrtných podmienok plynových zásobníkov na odhad zásob použitím počítačovej simulácie

One of the methods of assessing reserves is a calibration of a numerical model of a field with assumed driving conditions of the field. The influence of various energy systems assumed for the calculation on the calibration results are presented in the paper. A light oil field was selected for verification of resources on the basis of an analysis of driving conditions. At the first stage of calculations, a „Black Oil" type numerical model was used. The results of a classical „Black – Oil" model made the authors search for an alternative description of energy conditions in the reservoir. Therefore, a modified „Black-Oil" model with „vaporized oil" option, assuming that initially, after evaporation, the condensate in the reservoir was in a gaseous phase was used. The obtained simulation results for the analyzed reservoir prove the accuracy of energy conditions in the reservoir.

Key words: *reservoir simulation, Black-Oil, vaporized oil, condensate reservoir*

Introduction

One of the methods of assessing reserves is a calibration of a numerical model of a field with assumed driving conditions of the field (Ariadji T. et al., 2005). The results of the calibration depend on the assumed model, which initially may be dubious. Therefore, in the process of determining the oil resources, it is crucial to correctly identify driving conditions in the field (Coats K., 1985; Izgec B., Barrufet M.A., 2005). The assumed driving conditions model may be verified by simulating various reservoir conditions. The influence of various energy systems assumed for the calculation on the calibration results are presented in the paper.

Numerical modeling of the field

A light oil field of ca 1.5 km^2 surface area was selected for the verification of resources on the basis of an analysis of driving conditions. This is layered field with one stratum at a depth of about 3150 m. The average primary reservoir pressure was 68 MPa. According to the preliminary documentation, the main mineral there was oil and the accompanying natural gas. The reservoir structure is built of strongly fractured dolomites.

At the first stage of calculations, a „Black Oil" type numerical model was used, where the calibration was made on the basis of initial data from the reservoir documentation. Owing to the build of the reservoir, the double porosity, i.e. the porosity of arock matrix and a system of highly permeable fractures was assumed. According to the initial assumption, the analysed field was an oil field with an initial pressure slightly below the saturation pressure. The rates of the produced fluids for a classical „Black – Oil" model were fitted. The results are presented in Fig. 1 – 6.The calibration calculations for a long exploitation period did not produce positive results.

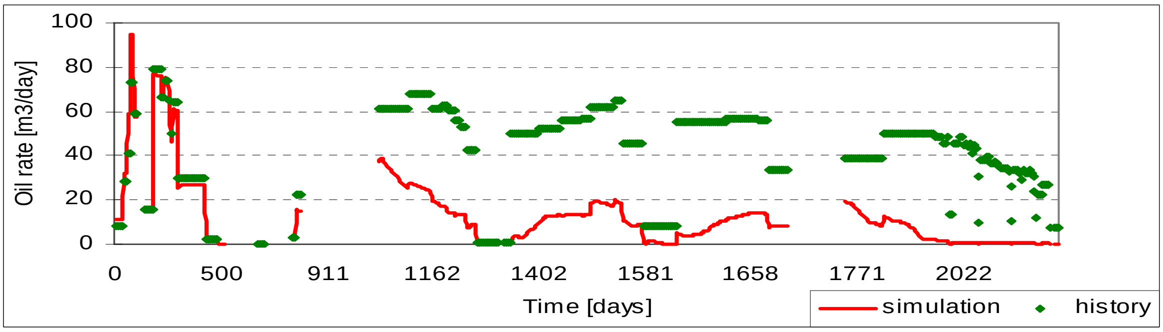

Fig. 1. Changes of oil rate in the well W-1.

[1] *Jerzy Stopa, Stanisław Rychlicki, Paweł Wojnarowski***,** AGH University of Science and Technology, Kraków, Poland; Faculty of Drilling, Oil and Gas, 30-059 Kraków, al. Mickiewicza 30, Poland.
(Recenzovaná a revidovaná verzia dodaná 6. 10. 2006)

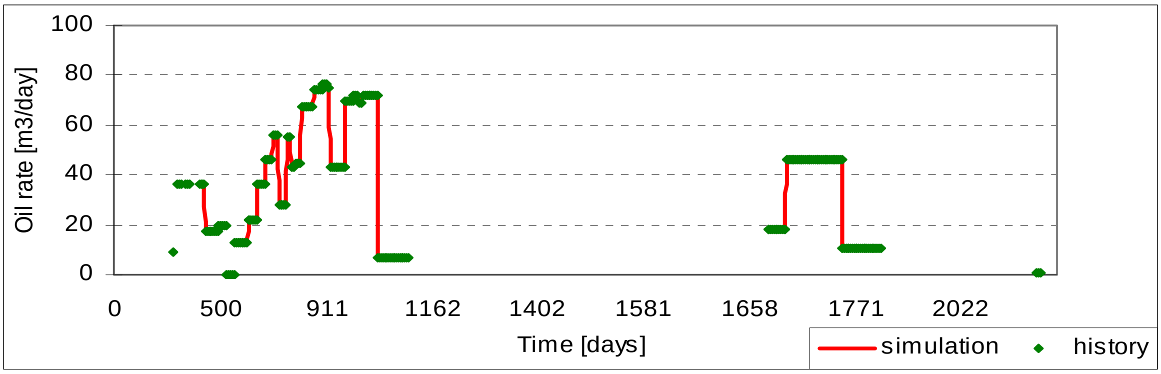

Fig. 2. Changes of oil rate in the well W-2.

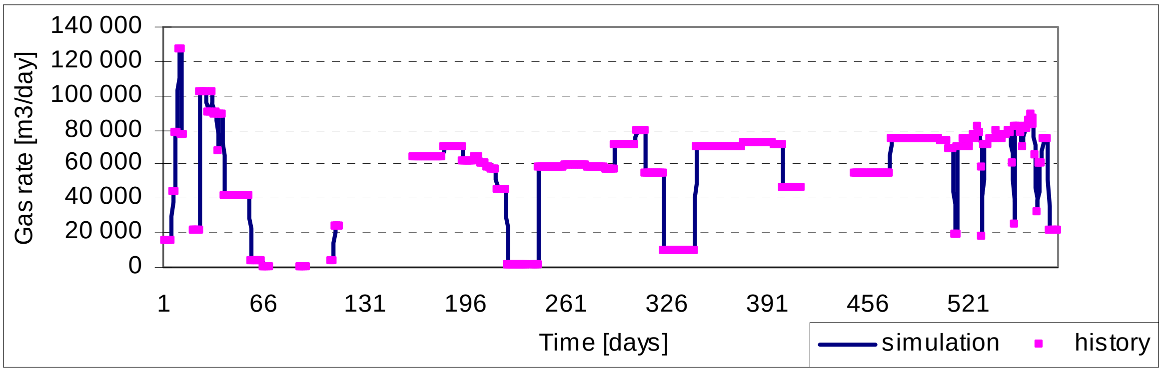

Fig. 3. Changes of gas rate in the well W-1.

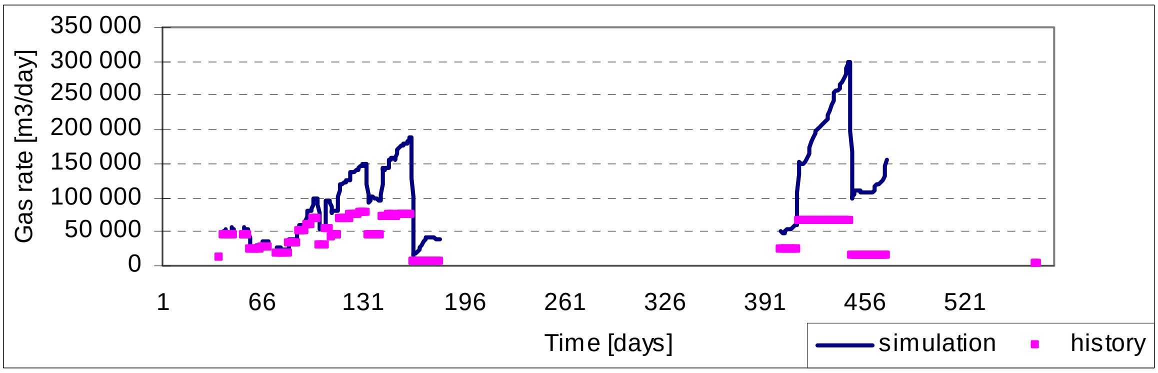

Fig .4. Changes of gas rate in the well W-2.

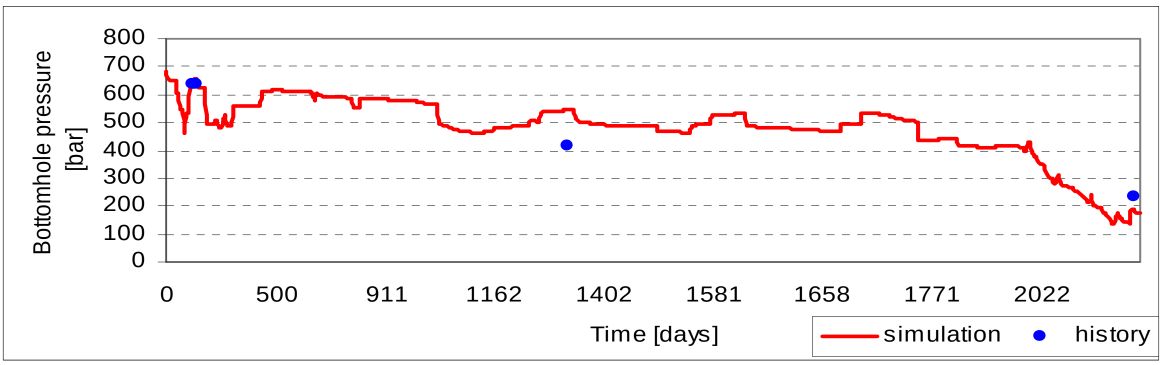

Fig. 5. Change of bottomhole pressure in the well W-1.

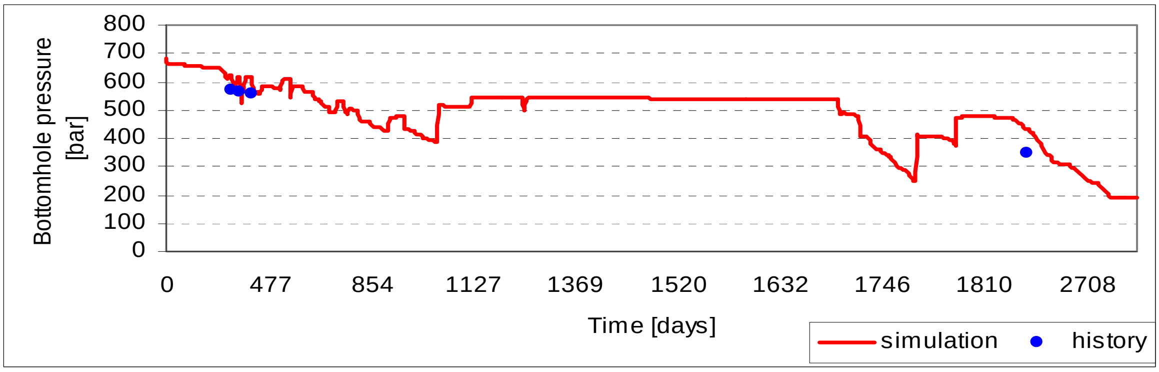

Fig. 6. Change of bottomhole pressure in the well W-2.

It follows from the plots that a relatively good fit was obtained in the initial phase of exploitation. However, further on bigger and bigger discrepancies can be observed between the simulation and the measurement. Moreover, the exploitation was accompanied by a quick drop of the reservoir pressure, which may prove a considerable overrate of the initial resources.

The results of the classical „Black – Oil" model made the authors search for an alternative description of energy conditions in the reservoir. A high initial pressure, reservoir temperature, color of the exploited fluid and the course of exploitation suggested that the analyzed reservoir was of the gas-condensate type. Therefore, a decision was made to use a modified „Black-Oil" model with „the vaporized oil" option, assuming that initially, after evaporation, the condensate in the reservoir was in a gaseous phase. Similar to the previous case, a double porosity was assumed. The model was calibrated with respect to the flow rates, measured static pressures in wells and the bottomhole dynamic pressure calculated for the wellhead pressure. The results of calibrations for selected wells (W-1, W-2) are presented in Fig. 7 – 12.

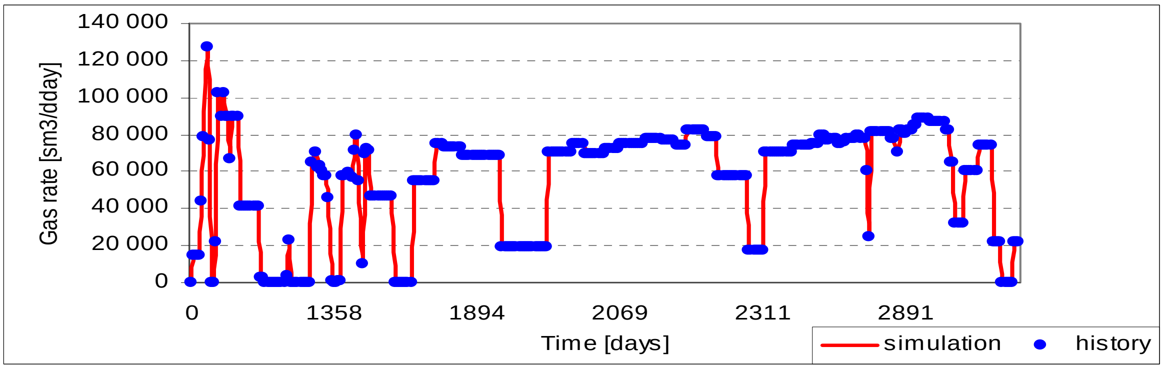

Fig. 7. Change of gas rate in the well W-1.

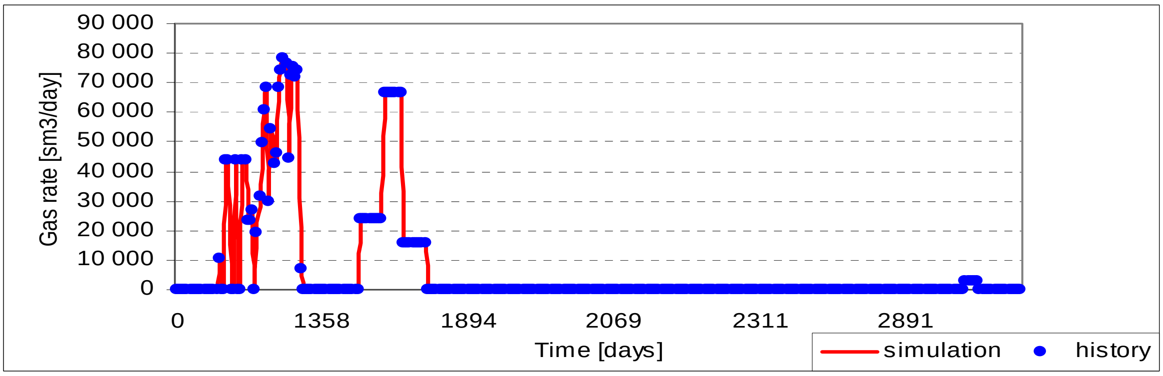

Fig. 8. Change of gas rate in the well W-2.

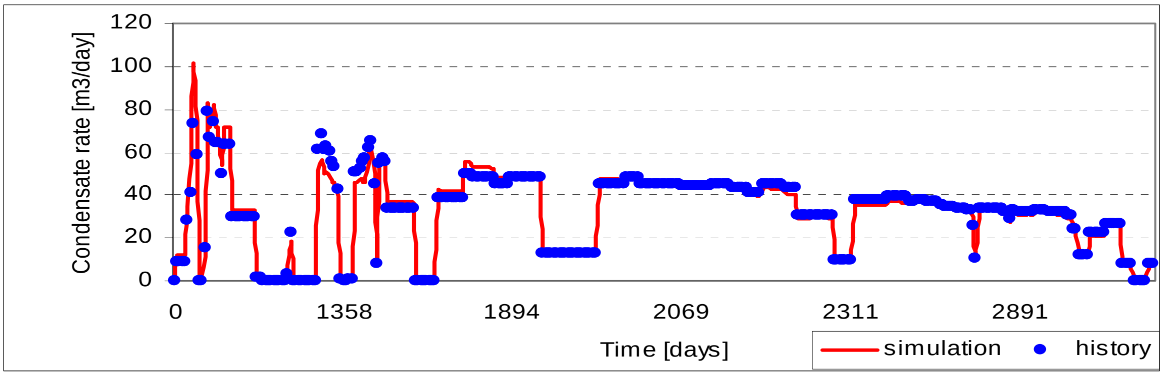

Fig. 9. Change of condensate rate in the well W-1.

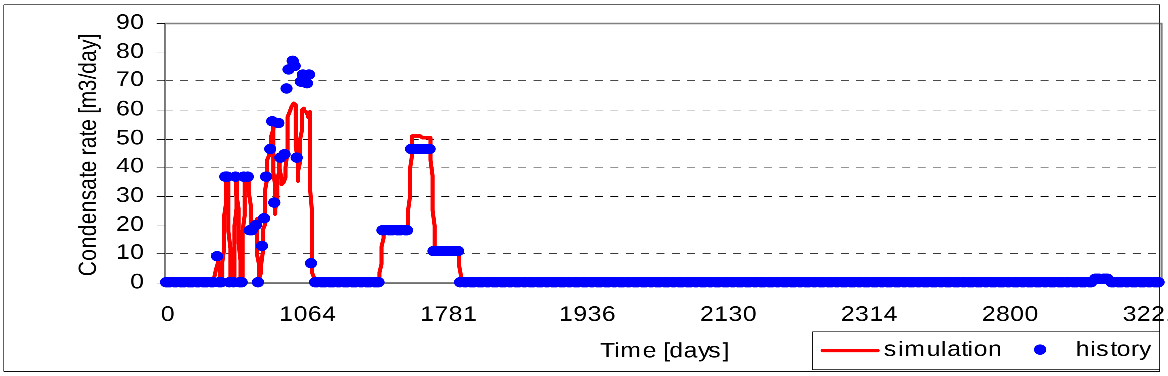

Fig. 10. Change of condensate rate in the well W-2.

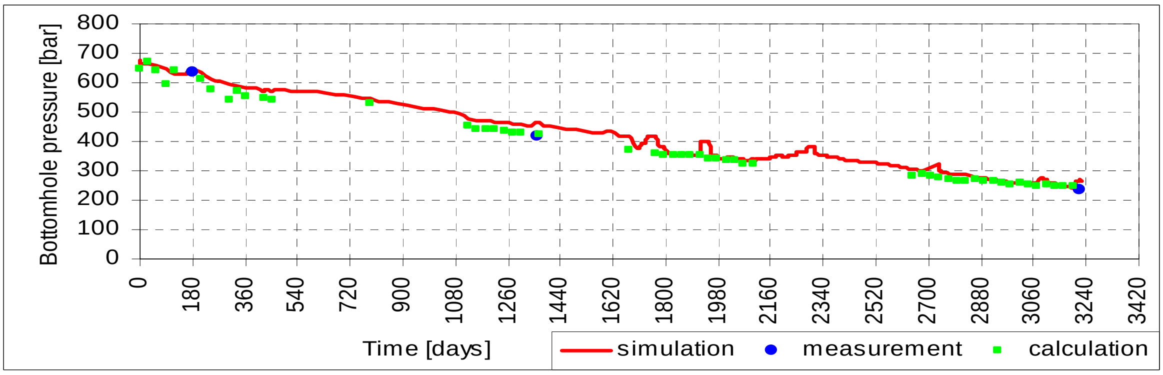

Fig. 11. Change of bottomhole pressure in the well W-1.

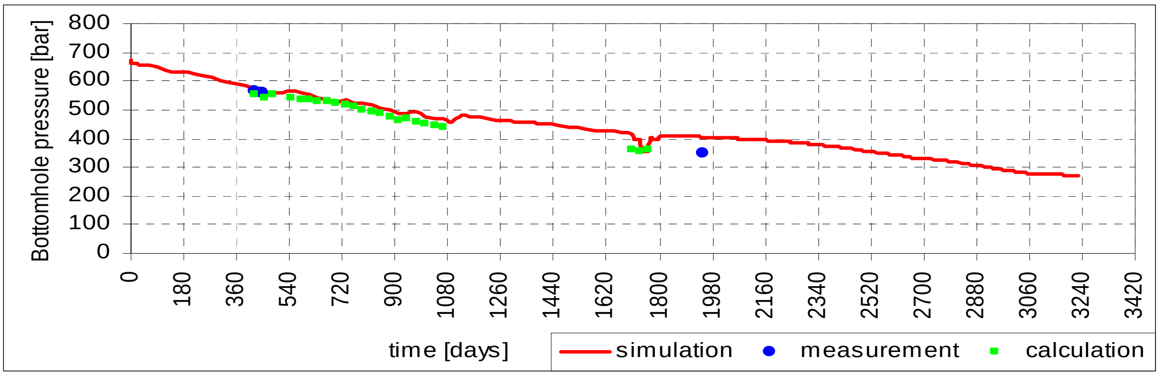

Fig. 12. Change of bottomhole pressure in the well W-2.

As a result of the model calibration, a very good fit of the reservoir fluids rate and pressures in the wells was obtained. However, the determined condensate and the natural gas resources turned out to be smaller than determined initially, after developing the reservoir. A change of the reservoir size is presented in Table 1. This explains a very quick decrease of the reservoir pressure. Moreover, during the exploitation, a gradual precipitation of condensate was observed, first in the near-wellbore zones, then in the lower parts of the reservoir, see Fig. 13.

Tab. 1. Change of the size of initial resources depending on the simulation model used.

	Condensate	**Gas**
„Black-Oil”	100%	100%
„Black-Oil – Vaporized Oil”	45%	75%

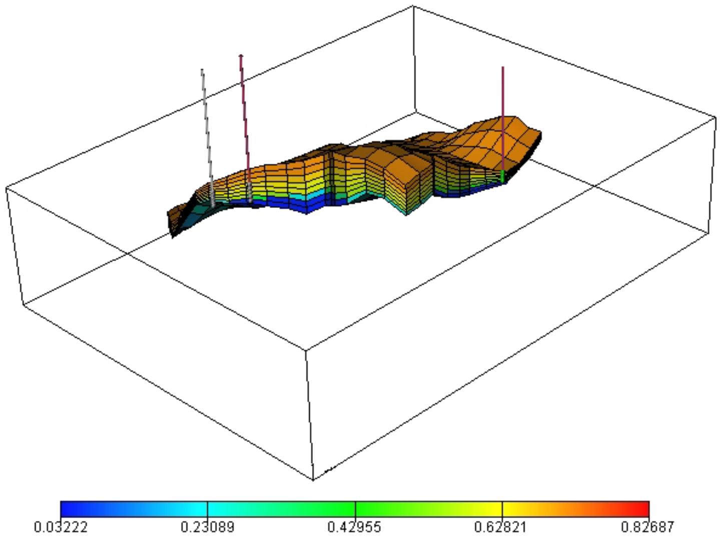

Fig. 13. Gas saturation of the reservoir after a condensate has precipitated.

Conclusions

A good reservoir model can be made if the type of reservoir and its driving conditions are recognized correctly. This has a decisive influence on the calibration process, especially on determining the resources. When diagnosing the driving conditions of hydrocarbon deposits, it is crucial to classify the deposit properly. The type of reservoir fluid may be confirmed by observations made in a field laboratory. The following parameters are important:

- initial gas-oil ratio in the separator (GOR),
- oil density in storage conditions,
- color of fluid in storage conditions.

The gas-condensate reservoirs should be modeled with the use of a composition model; however, the computer simulation with the modified „Black – Oil” model is also a tool for modeling the gas-condensate reservoir exploitation and for calculating the resources (Izgec B., Barrufet M.A., 2005).

The obtained simulation results for the analyzed reservoir prove the accuracy of energy conditions in the reservoir.

References

[1] Coats, K.,H.: Simulation of Gas Condensate Reservoir Performance, *SPE 10512, 1985*.

[2] Izgec, B., Barrufet, M., A.: Performance Analysis of Compositional and Modified Black-Oil Models for a Rich Gas Condensate Reservoir, *SPE 93374, 2005*.

[3] Ariadji, T., Suryanto, H., Mariani, S.: Reservoir Characterization Through Single-Well Numerical Simulation Study Using DST Matching for a Gas-Condensate Reservoir, *SPE 93218, 2005*.