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History-Matching and Forecasting Tight Oil and Gas Condensate Wells Using Analytical, Semi-Analytical and Empirical Methods

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Summary

The primary focus of the majority of current, and foreseeable future drilling within North American will be on low permeability light oil, liquids-rich gas and gas condensate reservoirs, where the liquid fraction is now a significant part of the revenue. These wells are often developed using multi-fractured horizontal wells (MFHWs). Research on analyzing and forecasting these complex reservoirs is in its infancy and further research is required to appropriately manage these reservoirs to maximize hydrocarbon recovery.

The appropriate foreasting methodologies of these tight liquids-rich plays is the focus of the current research. Although numerical simulation, which can account for complex PVT, reservoir and fracture chatracteristics of these complex plays, can commonly not be used for every well in a field due to the lack of supporting details required and the time for such rigerous analysis. Empirical methods provide an alternative for routine forecasting, but the lack of physical basis means that model fitting paramteres are difficult to contrain, leading to large uncertainties in forecasting. Analytical methods, while capable of incorporating more rigerous physics, require more information than empirical methods and likely also cannot be applied to every well in a field

In order to address the limitations of existing empirical and analytical methods for forecasting MFHWs producing from liquid-rich tight gas/shale, we demonstrate application of a workflow recently introduced by Clarkson (2013). In this workflow, analytical models are first used to history-match and forecast MFHWs that have sufficient data, and then empirical models are used to match the analytical model forecast to constrain model parameters for wells in which the analytical methods cannot be applied. For this purpose, a suite of analytical models are proposed, that can model a range in flow-regime sequences from simple linear-to-boundary flow scenarios, to more complex flow regime sequences exhibited by MFHWs with branched fractures. Similarly, a suite of empirical methods are used, and the models yielding the most accurate matches to the analytical models are selected for forecasting. Lastly, in order to bridge the gap between analytical and empirical methods, we utilize the recently developed semi-analytical method introduced by Clarkson and Qanbari (2014), which has as its basis the contacted gas-in-place calculations of Agarwal (2010).

Although the analytical and semi-analytical models used in this work are strictly applicable to single-phase flow scenarios, we have demonstrated using simulation cases (as have others) that constant condensate gas ratios can occur for tight/shale gas condensate wells exhibiting transient linear flow and flowing at near constant flowing bottomhole pressure. For these cases, the single-phase forecasting methods can be applied, and both gas and condensate phases may be forecast accurately, even if multi-

phase flow is occurring in the reservoir. We demonstrate the accuracy of these methods using simulated cases, and apply our workflow to an actual field example of a liquid-rich shale MFHW.

This study will be of interest to those petroleum engineers who are faced with forecasting a large number of liquid-rich shale wells, and desire methods that can be simply applied to constrain forecasts and improve accuracy. This study was originally published as SPE 171593 and was presented at the SPE/CSUR Unconventional Resources Conference-Canada held in Calgary, Alberta, 30 September-2 October 2014.

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