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Improved Recovery in Gas-Condensate Reservoirs Considering Compositional Variations

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Abstract

The objective of this work was to develop a methodology to increase the productivity of gas/condensate from gas-condensate reservoirs. Presently, gas-condensate reservoirs experience reductions in productivity by as much as a factor of 10 due to the dropout of liquid close to the wellbore. The liquid dropout blocks the flow of gas to the well and lowers the overall energy output by a very substantial degree. The combination of condensate phase behavior and rock relative permeability results in a composition change of the reservoir fluid, as heavier components separate into the dropped-out liquid while the flowing gas phase becomes lighter in composition. This effect has been sparsely recognized in the literature, although there is clear evidence of it in field observations. This work quantified the effect, developed a scientific understanding of the phenomena, and used the results to investigate ways to enhance the productivity by controlling the liquid composition that drops out close to the well. By optimizing the producing pressure strategy, it should be possible to cause a lighter liquid to be condensed in the reservoir, after which the productivity loss would be more easily remedied.

The research made use of experimental measurements of gas-condensate flow, as well as compositional numerical simulations. Different strategies have been compared, and the optimum producing sequences are suggested for maximum condensate recovery. Results show that composition varies significantly as a function of fluid phase behavior and producing sequence; condensate recovery can be improved with proper producing strategy, and productivity loss can be reduced by changing the producing sequence.

This study can be used to determine the optimum producing strategy when the well is brought into production and reduce the productivity loss caused by the condensate banking effect.

Introduction

Gas-condensate reservoirs represent an important source of hydrocarbon reserves and have long been recognized as a reservoir type, possessing the most intricate flow and complex thermodynamic behaviors. The gas-condensate reservoir is initially gas at the reservoir condition. Liquid forms in the reservoir when the bottom-hole pressure drops below the dew-point pressure. The accumulated condensate in the vicinity of the well bore causes a blocking effect and reduces the effective permeability appreciably, and also causes the losses of well productivity and of the recovery of heavy components at the surface.

The effect of condensate blocking on well productivity is a broad and active research area that has attracted many researchers, including Fussell (1973), Hinchman and Barree (1985), Aziz (1985), Clark (1985) and Vo et al. (1989). The productivity loss caused by condensate buildup is striking. According to Whitson (2005), in some cases, the decline can be as high as a factor of 30. Several examples of severe productivity decline are available in the literature (Engineer, 1985, Duggan, 1972, Allen and Roe, 1950, Abel et al., 1970 and Afidick et al., 1994). Even in very lean gas-condensate reservoirs with a maximum liquid dropout of only 1%, the productivity may be reduced by a factor of about two as the pressure drops below the dewpoint pressure (Fevang and Whitson, 1996). Barnum et al. (1995) reviewed data from 17 fields, conducted a survey on field examples from published industrial cases, and concluded that a severe drop in gas recovery occurs primarily in low productivity reservoirs with a permeability-thickness below 1000 md-ft.

Condensate blocking is not the only factor that influences the degree of productivity loss. It has been recognized in the literature that the relative permeability does impact the degree of productivity loss below the dewpoint. Hinchman and Barree (1985) showed how the choice between the imbibition and the drainage relative permeability curves used in the numerical reservoir simulations could dramatically alter the productivity forecast below the saturation pressure for gas-condensate reservoirs.