Influence Factors of the Bottom Hole Flow Pressure in a High-Pressure and High-Temperature Condensate Gas Reservoir: Applicability Analysis

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INTRODUCTION

In China, high-pressure and ultra-high-pressure gas reservoirs account for more than one-third of the total gas reservoirs, and their current proven reserves account for about one-ninth of the total proved reserves of natural gas (Wang, et al., 2011; Hong et al., 2018). In recent years, large gas fields such as Kela 2, Dina, Dabei, and Keshen discovered in Tarim area, as well as Heba, Qingxichang, and Shuangmiao gas fields discovered in northeastern Sichuan, are all ultra-high-pressure gas reservoirs. Bottom hole flow pressure is a key parameter to calculate single-well energy storage and dynamic reserves, especially during the production testing. For conventional gas wells, the bottom hole flow pressure can be measured by placing a pressure gauge at the bottom hole. However, for high-pressure and high-temperature gas reservoirs, this conventional method is no longer applicable due to the high bottom hole pressure and temperature.

Thus, analytical and numerical methods have been applied to calculate the bottom hole flow pressure for high-pressure and high-temperature condensate gas reservoirs. Meanwhile, many essential parameters should be considered in the calculating process, such as the deviation factor of natural gas (Li et al., 2001; Zhang et al., 2005), the gas viscosity (John et al., 1964; Dempsey, 1965; Lee, 1966), friction coefficient (Colebrook 1938; Swamee and Jain, 1976), and even the change in the diameter of the tubes. This report reviews the models and methods of calculating the bottom hole flow pressure for single-phase flow in high-pressure and high-temperature gas reservoirs. And the models are calculated to discuss the influence factors of the bottom hole pressure in Figure 1. Then, the relatively reasonable method in gas reservoir engineering can be summarized for the development of high-pressure and high-temperature condensate gas reservoirs.

INFLUENCES OF FLUID PROPERTY

• Gas deviation factor. It is one of the extremely important physical parameters of natural gas, which directly affects the original geological reserves of the gas reservoir. The deviation factor of natural gas is also known as the deviation coefficient; it is the ratio of the actual gas volume to the ideal gas volume of the same mole number at the same temperature and pressure under a given pressure and temperature. The gas deviation factor is related to the characteristics, temperature, and pressure of the gas. At low pressure, natural gas can be regarded as an ideal gas following the ideal gas law. However, when the gas pressure rises, and when the gas temperature approaches the critical temperature, the deviation of the real gas from the ideal gas can be large. At present, there are many calculation models of gas deviation factor, which are mainly divided into two categories: one is the experimental method, and the other is the calculation method. Although the data measured by the experimental method is...
more accurate, the error is low, and the reliability is high, the cost of the experiment is high, the cycle is long, and the operation is difficult, so the calculation method is generally used to determine the deviation factor. The calculation methods can be divided into three categories: the plate method, the plate fitting method, and the equation of state method. The plate method (deviation
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**INFLUENCE OF ENGINEERING PROPERTY**

Usually, corresponding analytical models are used to calculate the bottom hole flow pressure according to wellhead test pressure and gas well characteristics. However, there is little research on the influence of the change in the diameter of tubes on the bottom hole flow pressure. At present, the commonly used methods for calculating the bottom hole flow pressure mainly include the following: average temperature-deviation coefficient method, Cullender–Smith method, Aziz method, and temperature–pressure coupled model.

In the average temperature-deviation coefficient method, the natural gas deviation factor is not applied for correction, and the variation of temperature with wellbore depth is not considered (Wang, 1999). Some scholars did not consider the correction of acid gas in natural gas components when calculating the bottom hole pressure (He and Wang, 2014). In some research in the literature, the effect of friction coefficient on bottom hole flow pressure has not been considered (Li et al., 2001; Zhang et al., 2019).

Different conversion methods can be used to calculate the bottom hole flow pressure. One set of actual data from a typical high-pressure and high-temperature condensate gas reservoir in Northwest China has been used to calculate the bottom hole flow pressure. The effect of change in the tube diameters on the bottom hole pressure is mainly reflected in the friction coefficient. A comparison of different calculated results with different tube diameters shows that the relative errors of different tube diameters are small and have less influence on the bottom hole flow pressure, which are between 0.5% and 1%. Therefore, the change in the tube diameter can be ignored when calculating the bottom hole flow pressure. Meanwhile, a comparison of methods of calculating the bottom hole flow pressure is shown in Figure 1B; the results of average temperature-deviation coefficient method, Cullender–Smith method, and Aziz method are the same, and the errors are about 3.73%. The temperature–pressure coupled model method is more reasonable for the high-pressure and high-temperature condensate gas reservoirs.

**CONCLUSION**

1) For high-pressure and high-temperature condensate gas reservoirs, the gas deviation factor can be obtained by the HY method and DAK method. The BB method and DPR method are not appropriate.

2) For gas viscosity calculation, the Lee model has a lower error than the Dempsey model under high-pressure and high-temperature conditions. However, some modification for Lee model is needed to make the error lower than 1%.

3) Under high-pressure and high-temperature conditions, in order to obtain more accurate bottom hole flow pressure, the temperature–pressure coupling model can be applied. The average temperature-coefficient of deviation method and Cullender–Smith method are not suitable.

**AUTHOR CONTRIBUTIONS**

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.
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Conflict of Interest: RC, WH, BX, XS, DY, and CW were employed by No.1 Gas Production Plant of Xinjiang Oilfield Company, CNPC.

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