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Field Cases: Nonisothermal Behavior Due to Joule-Thomson and Transient Fluid Expansion/Compression Effects

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Abstract

Field cases illustrating nonisothermal behavior due to Joule-Thomson expansion and transient fluid expansion/compression effects are presented in this paper. Nonisothermal effects are particularly noticeable in high drawdown completions due to Joule-Thomson expansion of the reservoir fluids. Depending upon the pressure range and hydrocarbon composition, Joule-Thomson expansion can result in either a heating or cooling effect. At high pressures, Joule-Thomson expansion normally results in an increase in temperature for oil and gas reservoir fluids compared to a temperature reduction for low pressure gas. Field cases of high drawdown completions are presented; the first is a high pressure oil production test in which a temperature increase of 10ºF was observed for a 6,000 psi drawdown and the second is a low pressure gas production test in which a temperature reduction of 38ºF was recorded for a drawdown of 3,080 psi. The pressure and temperature profiles for each case were simulated with a 1D radial thermal simulator capable of modeling thermal effects due to Joule-Thomson expansion and viscous dissipation. Nonisothermal behavior is also observed after rate changes due to the rate of fluid expansion or compression. These nonisothermal effects, or temperature "jumps", are transient in nature and the direction of the temperature change depends on whether the fluid is expanding or being compressed. The most noticeable illustration of a temperature jump is at the commencement of a buildup. A field case is presented and modeled with a thermal simulator to illustrate this nonisothermal behavior.

Introduction

Modeling Joule-Thomson expansion within the reservoir is rarely performed as drawdowns are generally not high enough and a thermal simulator is required to represent Joule-Thomson thermal effects. Under conditions of high drawdown Joule-Thomson expansion effects can be significant. These conditions generally occur in low permeability reservoirs that require large drawdowns to achieve commercial production rates. Several authors have documented Joule-Thomson expansion effects at large drawdown but have not modeled the temperature and pressure responses. Hermanrud et al. (1991), based on an evaluation of 81 drill stem tests performed in the North Sea, state that Joule-Thomson expansion of reservoir fluids is one reason why measured flowing bottom-hole temperatures do not necessarily represent initial reservoir temperatures. Baker and Price (1990) documented an observed temperature increase of nearly 15ºF for a drawdown of 7,000 psi during a high pressure gas drill stem test in the North Sea. They attributed the observed temperature increase to Joule-Thomson expansion of the gas. Recently, coupled wellbore and reservoir thermal models representing Joule-Thomson expansion have been developed by Sui et al. (2008) and Duru and Horne (2008). The principal objective of these studies was improved estimation of reservoir properties through coupling the pressure and temperature behavior. As part of a horizontal wellbore modeling study, Yoshioka et al. (2007) developed a transient coupled reservoir and wellbore model to predict the temperature changes caused by water entry into the wellbore. Drawdowns considered were low, ranging from 100 to 500 psi, which are representative of horizontal well operating conditions.

Inspection of wellbore bottom-hole temperature profiles often indicates a temperature change immediately after a rate change. This thermal behavior is due to the rate of compression or expansion of the reservoir/wellbore fluid. An increase in rate represents an expansion process that results in a temperature reduction and a decrease in rate, such as a pressure buildup, represents a compression process that results in a temperature increase. These thermal effects are transient in nature and decay as the pressure changes become less significant. Bahrami and Siavoshi (2007) documented the observed temperature increase at the beginning of a pressure buildup and claim this can be used as a diagnostic tool in well test analysis.