The Thermal Treatment of Bottom-Hole Formation Zone of Gas Condensate Well

E S Kostina, V V Inyakin, R G Bochkov

Department of Oil and Gas Field Development and Operation, Industrial University of Tyumen, 38 Volodarskogo Str., Tyumen, 625000, Russia

E-mail: kostina_nice@mail.ru

Abstract. In the process of gas condensate field development and operation there is a decrease in the production well bottom-hole flow pressure. When the bottom-hole pressure drops below the dew point pressure condensate accumulates in the bottom-hole zone of the well, which leads to a formation of the condensate front. As a result, the productivity of the well is reduced both by gas and condensate.

With an increase in temperature the liquid condensate becomes versatile and enters the gas phase; so the accumulation of retrograde condensate can be reduced by increasing the temperature in the bottom-hole zone. Vaporization of condensate and its transfer into the gas phase can be carried out by electrothermic treatment of the bottom-hole zone. In this case it is necessary to use special equipment – a bottom hole electrical heater.

1. Introduction

If reservoir pressure is below the condensation start pressure, the development of oil and gas condensate fields is accompanied by phase changes. In other words there is a release of liquid from the gas phase. This process occurs prior to the dew-point pressure (the pressure at which retrograde condensation stops and with further decrease in the formation pressure the process of direct evaporation of unstable gas condensate dropped out in place occurs [1].

Simulation of the gas condensate system phase behavior is carried out in a phase equilibrium unit with isothermal pressure reduction by a constant volume depletion method (CVD). The method implies the following: at each stage the reduction is firstly achieved by increasing the volume of the working chamber, establishing phase equilibrium and further releasing the gas phase at a fixed pressure until the volume of the working chamber becomes equal to the initial volume [2-6]. After carrying out the experiment, we obtain a condensate formation loss curve (Figure 1), and thus, we have an understanding of the changes in the formation gas-condensate system.

In the PVT cell, there is a description of the phase behavior of the formation system without taking its motion into account. However, under real conditions, filtration is accompanied by qualitative and quantitative changes in the fluid moving from high pressure zones (external reservoir boundaries) to low-pressure zones (recovery zones).
A description of various models of gas-condensate mixture flow is given in papers [7-9, 23]. In the current paper, a model (Figure 2) with a significant decrease in reservoir pressure corresponding to a 4-zone filtration model (the description is made from right to left) has been considered. In zone 1 marked in white, single-phase filtration occurs, because the formation pressure in this zone is higher than the dew-point pressure. In zone 2, single-phase filtration also occurs, but the pressure in this zone is lower than the dew-point pressure and the dropped-out condensate is in a drop form. In zone 3, due to a significant decrease in the formation pressure, two-phase gas and condensate filtration occurs. This is due to the fact that the condensate in this zone is in a film-type state and not retained by capillary forces. Zone 4 is usually located in the bottom-hole zone of the formation, and similarly to zone 3, two-phase filtration occurs, but the retrograde condensate saturation is lower, due to a high-rate motion of the formation fluid.

The release of high-boiling components from the vapor-gas phase leads to an increase in retrograde condensate saturation and a decrease in phase permeability for gas (Figure 3), which in turn affects the well production capabilities and leads to a decrease in production rates.
Thus, consideration of the issue on an example of unique fields such as Urengoy (Achim deposits) is of practical interest.

The Urengoy oil and gas condensate field is one of the largest by gas reserves in Russian Federation. The aggregate mineral resource of Achim deposits put on books are 3 trillion m³ of gas and 0.9 billion tons of condensate [10]. Achim deposits are characterized by significant occurrence depth (3500 – 4000 m); anomalously high formation pressure (AHP) (55.0 - 62.5 MPa, with anomaly ratio of 1,55 - 1,60 according to [11, 12]) and low permeability, usually less than 1 mlD. An important factor is occurrence of paraffin in the gas condensate system which complicates the production process.

There is a wide range of methods to control retrograde condensate accumulation in place. A significant portion of them has only a theoretical description or a singular introduction into field experience. Apart from positive aspects the below methods have a significant number of disadvantages, the efficiency of which is strongly dependent on both the pay zone and the fluid saturating it.

- Gas cycling (cycling process [21];
- Injection of non-hydrocarbon gases [19, 20];
- Injection of hydrocarbon solvents [19, 20];
- Waterflooding [22];
- Integrated injection of gas and water [22];
- Acoustic treatment [26];
- Change in reservoir wettability [18];
- Acid treatment [14];
- Hydraulic fracturing [17];
- Thermal treatment [15].

Use of horizontal wellbore (HW) with hydraulic fracturing method is the most commonly applied integrated technology to control the retrograde condensate accumulation; although the effect of its use is temporary like with other applied methods, [13].

Our work focuses on the thermal treatment method due to the above issue – occurrence of paraffin. Distribution of thermic field is described by the following equation system [14]:

\[
\frac{\delta^2 T}{\delta r^2} + \left(1 - \frac{q c_r \delta(z)}{2 \pi h \lambda_n}\right) \frac{1}{r} \frac{\delta T}{\delta r} + \frac{\delta^2 T}{\delta r^2} = \frac{c_n}{\lambda_n} \frac{\delta T}{\delta t}
\]

boundary conditions:
\[ T = T_{pl}, \quad t = 0, \quad \Delta T - \Delta T_c = \frac{2\pi h \lambda R_c}{\rho c_g} \left( \frac{\delta T}{\delta r} \right), \quad r = R_c, \]
\[ \frac{\delta T}{\delta r} = 0, \quad r = R_k, \]
\[ \frac{\delta T}{\delta z} = 0, \quad z = 3h, \quad z = 0 \]
\[ \frac{h}{2} \geq z, \delta (z) = 1, \]
\[ \frac{h}{2} < z, \delta (z) = 0, \]

\( T, T_{pl} \) – current and initial formation temperatures;
\( \Delta T, \Delta T_c \) – difference of temperatures: current and bottom-hole;
\( R_c, R_k \) – well and formation radii;
\( h \) – formation thickness;
\( \lambda \) – thermal conductivity or the formation and surrounding rock;
\( c_p \) – gas specific heat;
\( q \) – mass flow.

Many of the proposed methods are costly and short-term by their efficiency. The method consisting in periodic heat treatment of bottom-hole well zones will allow increasing the duration of well operation till its complete retirement from the production well stock.

Vaporization of condensate and its transfer into the gas phase can be carried out by electrothermic treatment of the bottom-hole zone. In this case it is necessary to use special equipment – a bottom hole electrical heater which heats near-well zone in the perforation interval.

![Figure 4. Change in the temperature field.](image)

The time of heating the near-well zone (Figure 4) amounts to 30 days. For calculation the heaters of different power – 10 kW and 20 kW – were used. The depth of heating is 2.5 m. The significant difference between the heaters of different power ends at the depth of heating equal to 1.5 m.
The initial maximal saturation, i.e. before the treatment, was 0.37 and significantly decreased while the distance from the well increased amounting to 0.21 at the distance of 8 m. The comparison of the time of bottom-hole zone heating shows that there is no significant difference between the fourteen days’ and thirty days’ treatment.

2. Conclusion
- Basic regularities of dynamic condensation in the bottom-hole zone have been established;
- The effectiveness of the proposed electric heating effect on the bottom-hole zone has been evaluated;
- Basic ideas of the technology of bottom-hole zone treatment with heaters to control the condensate bank have been developed.

3. References
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