WIERTNICTWO NAFTA GAZ • TOM 28 • ZESZYT 4 • 2011

S. Kabdulov*, K. Jiyembayeva*, B. Kaliev*, A. Mankhanova*

PRODUCTION LOGGING TEST IN HORIZONTAL WELLS

1. OUTLOOK

Production logging is the measurement of fluid parameters and flow contributions on a zone-by-zone basis to yield information about the type and movement of fluids within and near the wellbore. This well-established production-logging technique provides vital information about well performance and can help engineers to identify potential problems and take remedial action before production is interrupted. Production logging also helps production and reservoir engineers to understand where the various fluids enter the well. This enables them to identify optimal solutions, such as selecting which unwanted fluid entry zones should be shut off or which poorly producing layers require perforation and/or stimulation.

The principal aim of production logging is to measure the performance of producing and injecting wells by gathering diagnostic data, for example, information indicating the efficiency of perforation. When extensive production-logging campaigns are conducted as part of a reservoir monitoring or surveillance program, operating companies can use the data to assess the individual reservoir compartments and establish their contributions to oil and gas production or water cut. The information gained from production logging can be used to help companies in defining field economics and thus to make the most appropriate decisions for field development and reservoir management.

However, traditional production-logging methods have limitations in many of today's wells, wellbore conditions, and fluid types. Wellbore conditions have a large effect on the quality of the data obtained. In vertical wells with high fluid flow rates, the data acquired are accurate and reliable. However, multiphase flow conditions exist in many deviated and horizontal wells. In these wells, conventional production-logging tools are often inadequate and may give misleading results. In the 1990s, the industry began to drill large numbers of

* Kazakh-British Technical University, S.Kabdulov@kbtu.kz

deviated and horizontal wells, and so the need to understand and measure fluid flow within complex flow regimes became increasingly important and necessitated the development of new tools and techniques.

2. MAKING SENSE OF MULTIPHASE CONDITIONS

Interpreting production-logging data and determining downhole flow profiles in single-phase flow conditions are, usually, straightforward processes. Flow profile determination in multiphase conditions is much more complicated. Factors including holdup, slippage velocity, and phase segregation combine to greatly complicate flow behavior. The holdup, for example, is defined as the percentage by volume of the borehole contents (i.e., gas, oil, and water) measured over a cross-sectional area. This cross-sectional area is typically the inner diameter of the production string (casing or tubing). Holdup can be measured at different places throughout the production string and can vary dramatically with borehole deviation and fluid flow rate. Under multiphase conditions, light phases move faster than heavier phases by an amount known as the slippage (slip) velocity. Engineers must therefore determine the downhole holdup when attempting to interpret production logs obtained under multiphase flow conditions.

The main objective for production logging in three-phase-flow wells is usually to establish the flow rates for oil, water, and gas. However, characteristics such as stratification, misting, annular flow, and recirculation can make accurate quantification extremely difficult. Flow rate is a function of holdup and velocity. Engineers who want to evaluate the flow rate of each phase at every depth level along the survey interval must map fluid velocities and holdups inside the wellbore [1–4].

3. FLOW STRUCTURE IN DEVIATED AND HORIZONTAL WELLS

In vertical wells, oil and water are mixed across the entire wellbore. The velocity profile is smooth, and the water holdup profile varies gradually across the borehole. Averaged measurements across the wellbore, such as those obtained using conventional production-logging tools, are generally adequate to determine the velocity and the holdup in this type of flow regime.

However, once the wellbore deviation exceeds more than a few degrees (say 20^{o}), the centrally positioned sensors of conventional production-logging tools become much less reliable. Phase segregation and small changes in well inclination and flow regimes all influence the flow profile.

Logging problems typically occur when conventional tools run in deviated wells encounter topside bubbly flow, heavy phase recirculation, or stratified layers flowing at different speeds.

Flow-loop laboratory experiments that simulate conditions in the wellbore have shown that the flow regimes that develop in highly deviated wells can be extremely complicated (Fig. 1). These flow regimes are controlled by factors including the borehole size and deviation, the fluid holdup, and the velocity, density, and viscosity of each phase. Tests have also shown that even a 1° variation in well deviation can have a dramatic effect on fluid distribution, holdup, and velocity [5, 6].

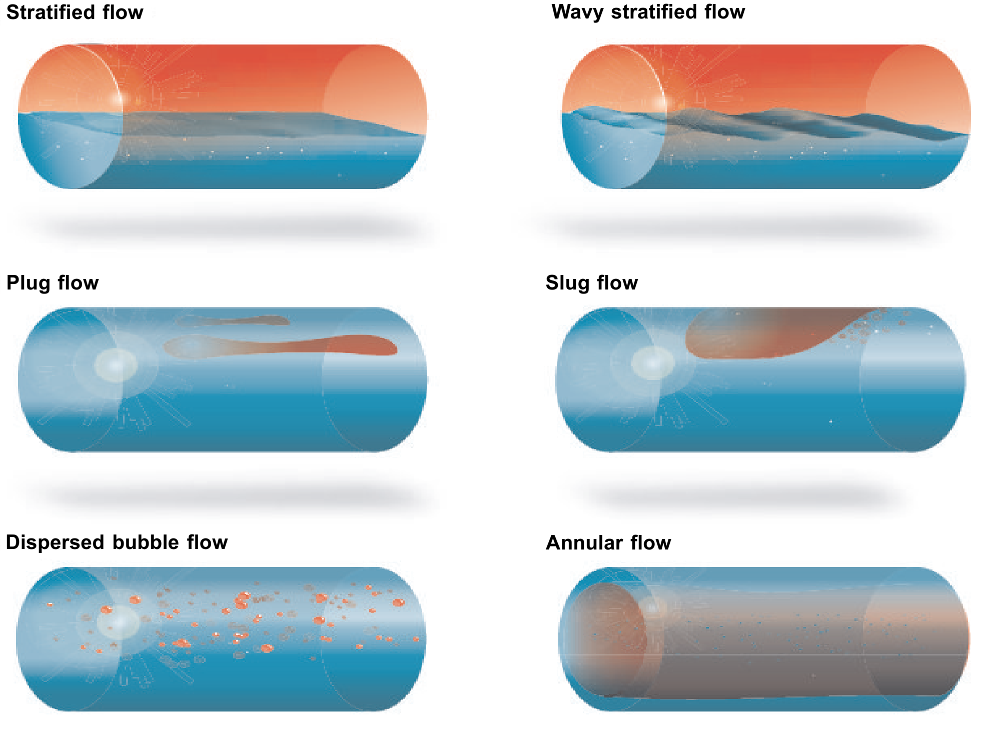

Fig. 1. The flow regimes that develop in highly deviated wells can be extremely complex

Flow-loop studies have also revealed the ineffectiveness of conventional logging tools in multiphase flows once there is strong phase segregation. The measurements made are inadequate for describing complicated flow regimes. In addition, conventional tool sensors are usually spread over a long tool string, which makes the measurements even more difficult to make.

4. MAPPING FLUID VELOCITIES

Two of the most significant challenges in developing a new generation of production-logging tools were extending measurement coverage across the diameter of the borehole and making measurements in a shorter depth interval over the wellbore.

One solution was to develop a tool with a range of small sensors that covered the full width of the wellbore and could be placed close together to improve depth resolution.

In wells containing two or more immiscible fluid phases, wellbore deviation causes phases with different densities to separate out with a mixing layer of dispersed bubbles between them. In two-phase systems, the flow structures are characterized by the width of the mixing layer. One of the key factors influencing flow structure is well deviation. The thickness of the mixing layer is fixed for a given borehole diameter and deviation. The composition of the produced fluids determines the position of the mixing layer. As the overall fractional volume of water in the wellbore (i.e., the water holdup) changes, the mixing layer moves across the borehole's diameter.

The effect of borehole deviation on mixing and flow structure is complicated, even in relatively simple two-phase systems such as those containing only water and oil. Three principal types of flow structures can be defined on the basis of well deviation (Fig. 2).

a) b) c)

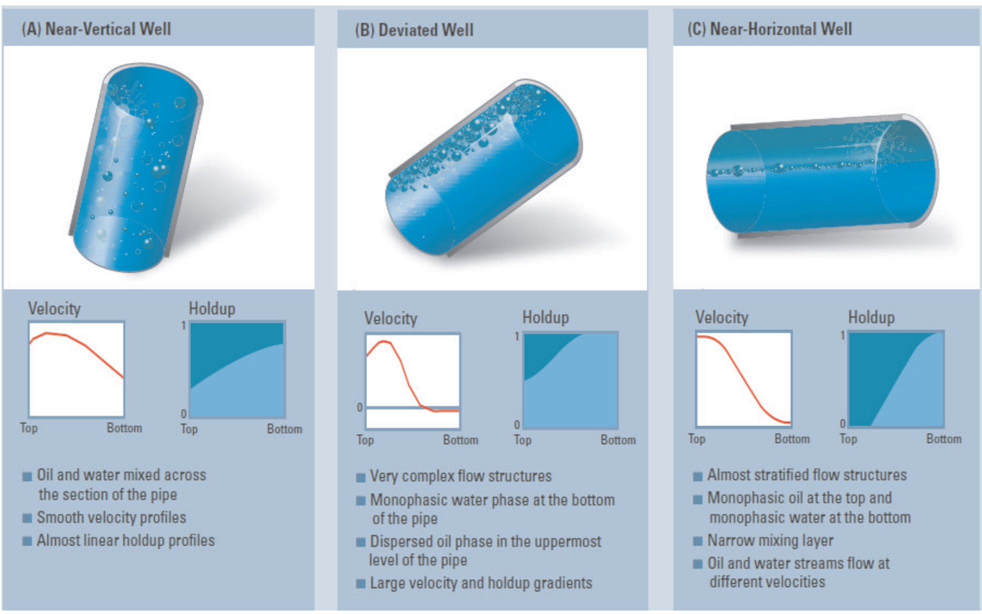

Fig. 2. Three main types of flow structure can occur in a two-phase (water-oil) system: a) near-vertical well; b) deviated well; c) near-horizontal well

4.1. Near-vertical wells

In near-vertical wells, the oil and water phases are fully mixed across the entire wellbore cross section. Even for wells with a deviation of less than 20^o, the mixing layer is large and the two phases are mixed across the borehole with a smooth velocity profile.

However, as soon as the wellbore deviates further, gravity creates a higher concentration of oil in the upper section of the borehole. The profile of the local water holdup begins to vary across the wellbore.

4.2. Deviated wells

In wells deviated at angles between 20^o and 85^o, portions of the wellbore cross section have monophasic flow but the overall flow structure is more complex. Heavy phases, typically water, segregate at the bottom of the borehole because of gravity, and the mixing layer is located in the upper part of the wellbore and contains dispersed bubbles of oil or gas. In mixed gas-liquid flow, the structure can be more complex. The gas can flow in slugs instead of small bubbles. This flow structure has large velocity gradients and local holdup distributions. At low flow rates, water is frequently water velocity at the bottom of the borehole may be negative.

At high flow rates, differential acceleration of the phases caused by the shear forces between the different fluid phases can lead to Kelvin–Helmholtz instabilities; these almost cause breakdown in stratification. Under these conditions, production-logging sensors that yield average answers are unsuitable for understanding flow structure. Local measurements made across the borehole's diameter are needed to clarify the velocity and holdup profiles.

4.3. Near-horizontal wells

For horizontal and near-horizontal wells (deviations between 85^o and 95^o), the flow structure is completely stratified, with the water flowing at the bottom and the oil or gas phase at the top with little or no mixing. At low flow rates, well deviation has a strong influence on flow behavior. The slightest deviation from 90^o causes the monophasic oil and water streams to flow at different velocities.

5. OVERVIEW

The methodology of production logging analysis is essentially some from one interpretation package to the other. The interpretation packages are however much more rigorous to generate a more accurate analysis and allow the interpreter to spend more time on analysis and less time on the data manipulating.

By single phase flow we mean a single fluid type – oil, gas and water. Because there is only one fluid type, there is no slip velocity.

By two phase flow we mean two fluid types this can be gas and oil, gas and water, oil and gas or oil and water. Conventional multi-phase production log interpretation follows the same generic pattern however we have to consider phase holdup's and slip velocities.

In three phase flow oil, gas and water are following at the same time. For three phase flow it is necessary to have two fluid identification tools.

The first tool capacitance water holdup determines the water holdup and the next one measures fluid density to determine the remaining oil and gas holdup.

REFERENCES

[1] Sondex – "Field Engineers Production Logging Course", London 2003.

[2] Halliburton Logging Services – "Production Logging Training Notes", 1994.

[3] Gearhart Industries, Inc. – "Production Logging", 1985.

[4] Smoleń J. James – "Cased hole and production log evaluation", Oklahoma 1996.

[5] Geofizyka Toruń Sp. z o. o. – „Zastosowanie geofizyki wiertniczej w górnictwie naftowym, sejsmice i geologii", Szymbark 2002.

[6] Mężyk W.: *Zagadnienia Holdup w interpretacji pomiarów geofizycznych wykonywanych w produkcyjnych otworach wiertniczych*. Nafta-Gaz, nr 9, 1994.