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Successful Application of a New Oil Production Optimization System at the Kokdumalak Field in Uzbekistan

Vladimir Shaposhnikov, Simon Tseytlin, Geliy Mirzoev, Isaak Golbraykh, Josef Gaportsin, GMG International, Houston, TX; Vladislav Sokolov, Parda Khaydarov and Alimakhmud Karimov, Uzgeoneftegasdobycha, Tashkent, Uzbekistan.

ABSTRACT

Kokdumalak is a major oil and gas field in Uzbekistan with an annual oil production of 29 MMB/year. The reservoir is formed by an Upper Jurassic pinnacle reef with high average porosity (17-25%) and permeability of 200–500 mD.

After 15 years of production, the output of certain wells has declined 50% from a level of 1500 bpd, and the water cut is as high as 20%. The field's SE part has gas breakthroughs from the gas cap. The GOR has risen from 1000 to 4500-18000 scf/bbl. A demonstration of a new oil production optimization system (POS) that began at Well 289 produced the following results: daily oil production up from 780 to 920 bpd (+18%), GOR down from 6000 to 4500 scf/bbl (-15%), and the water cut has fallen to zero and stayed there. These results were achieved by installing a downhole POS device in the tubing that generates additional variable hydrodynamic drag, which automatically maintains an optimal bottomhole pressure and stabilizes the well's performance. This made it possible to reduce the skin effect in the bottomhole zone and eliminate gas and water cones from perforations. The use of the POS at Well 289 yielded approximately 37,500 additional barrels of oil over a nine-month period.

INTRODUCTION

The POS technology was developed for oil fields with a high gas-oil ratio (> 600 cft/bbl) whose development is usually accompanied by a rapid decline in reservoir pressures. This results in the oil's degassing and loss of mobility and volumetric shrinkage in the pore space. This causes a dramatic decline in the reservoir's oil saturation and relative oil permeability. At the same time the reservoir's relative gas permeability rises. This is accompanied by the so-called skin effect in the bottom-hole zone, which partially blocks the oil and allows the gas to escape the reservoir prematurely, contributing to an even faster decline in reservoir pressure, oil flow, and oil recovery.

The problems described above have taken place at the Kokdumalak Field. Because oil withdrawal greatly exceeded water injection, there was an imbalance between the pressures of the oil and gas parts of the field, which caused the release of more solution gas from the oil and the lowering of the gas-oil contact. This caused breakthroughs of free gas in the form of gas cones from the gas cap and water cones from the water-oil contact, resulting in a decline in oil flow, a higher gas-oil ratio, a higher condensate content in the liquid hydrocarbons, a higher water cut, and a decline in current oil recovery.

The purpose of this paper is to consider the results of the application of a new oil production optimization system (POS), which in addition to its former advantages (skin effect control and so forth) can enhance the oil production of an oil-gas-condensate field by reducing gas and water cones and maintaining production at an optimum level.

DESCRIPTION OF THE FIELD

The Kokdumalak oil-gas-condensate field is a world-class. It contained in-place reserves of
oil and condensate conservatively total 195 million tons (approximately 1.4 BBO). Recoverable reserves have been estimated by Uzbekneftegas as 54.3 million tons of oil, using a recovery factor of 0.55, 67.4 million tons of condensate, using a recovery factor of 0.7 and approximately 128 billion cub.m of gas (4.5 tcf). The Kokdumalak field lies in Western Uzbekistan in north-eastern part of Amudarya Basin. It is located within $38^0$42'40'' - $38^0$46'30'' North Latitude and $64^0$35'45'' - $64^0$42'40'' East Longitude. Kokdumalak field was discovered by well # 3 in 1979 and evaluated by twenty-well exploration phase in 1989.

The reservoir is formed by an exceptionally high quality Upper Jurassic (Oxfordian-Callovian) pinnacle reef, one of the best among 40 others in the reefal barrier. It is over-lapped by salt-anhydrite formation (Tithonian – Kimmeridgian) with thickness 525-878 m. The Kokdumalak reef is kidney-shaped with its longer axis trending northwest-southeast. The reef outline covers an area about 30 sq. km. The reef is 310 m thick. Toward the top of the reef complex, a layered unit of less porous carbonate appears to occupy the interior portion of the reef and is interpreted as a lagoon deposits (thickness 120 m) within an atoll form. Cavern porous reservoir is excellent because high porosity ranging up to 25% and permeability up to 500 mD. The reservoir is isolated by salt formation and has pressure that is more than twice normal hydrostatic gradient (drilling mud used
1.9 g/sm^3).

Oil pool dimensions are 8,000 m x 3,200 m x 59 m. Gas pool dimensions are 7,800 m x 3,000 m x 216 m. Initial parameters are as fellow: formation pressure 57.3 – 56.2 mPa, saturation pressure 53.5 mPa, formation temperature 114^0C, GOR 101-230 m^3/m^3, specific gravity 30.4 API(oil) and 43.2 API (condensate), oil viscosity at temperature 20^0 in layer is 1.4 mPa s, oil saturation 0.8751, gas saturation 0.7-0.9, condensate factor 720 – 670 g/m^3. OWC was on the absolute depth - 2830 m, OGC was on absolute depth - 2771 m.

THE PROBLEMS OF RECOVERY STRATEGY

Before 1996 the field was developed by depletion drive with an almost concurrent decline in oil and gas reservoir pressure. In 1996 there was a sharp decline in reservoir pressure (by 6.5 MPa). Waterflooding began the same year, and cycling was implemented in 1997. But the imbalance between water injection and oil withdrawal from the oil reservoir, on one hand, and gas withdrawal from the gas cap, on the other hand, led to problems, the most noticeable of which was a gas breakthrough from the gas cap in the form of a gas cone into the oil reservoir, which expelled oil from the casing perforations. As a result, oil flow in certain wells has declined from 1500 bpd by approximately half to two thirds, and in places the water cut is as high as 20%. These problems were especially severe in the SE part of the field, where the GOR rose from 1000 to 4500-18000 scf/bbl, the height of the gas cones reached 25-30 meters, and condensate precipitated in the liquid phase in the bottom-hole zones of several reservoirs. All these problems accelerated the decline in reservoir pressure and oil production, which in turn reduced ultimate oil recovery from 55% to 30%.

THE NEW OIL PRODUCTION OPTIMIZATION SYSTEM (POS)

The POS basically re-distributes pressure in the reservoir-well system and maintains bottom-hole pressure at an optimum level. This is accomplished by installing a special downhole device consisting of a multi-parametric system of Venturi tubes of different lengths, diameters, and nozzles in the well. The geometric dimensions of the tubes are calculated individually for each well so as to generate the required hydrodynamic resistance and thus maintain bottomhole pressure at an optimal level within a certain range of reservoir pressures. These improved conditions allow the POS to reduce or completely eliminate the gas and/or water cones that accompany the development of an oil reservoir. Even though drawdown is reduced in the process, the wells' oil production is normally improved by the redistribution of phase flows near the perforations and the removal of gas cones from certain perforations in favor of the oil phase.

There exists a certain current bottomhole pressure that depends on reservoir properties and fluid PVT and which if maintained over the life of a project will make it possible to maximize current oil production and achieve a maximum ultimate oil recovery. This bottomhole pressure is called **the optimal bottomhole pressure**. It can be determined from a mathematical model of multi-phase flow in a system of elements matched in terms of pressure and flow rates: reservoir – bottomhole POS device – tubing – wellhead choke. This simulator and a large number of computer simulators developed for this technology enables quick assessments of:

1. the possibility of the effective use of the POS at a given field
2. anticipated fluid production parameters from wells with the POS:
   - enhancement of current well production
   - reduction in current GOR and WC
   - enhancement of the oil recovery factor
   - longer natural flow production

We should mention that known downhole chokes served as the prototype for the POS. The POS is more efficient than the chokes because of its:

1. use of a unique multi-parametric downhole device with greater flexibility and self-control capabilities
2. use of complex simulators

We should emphasize that the downhole device makes it easier to control wellhead pressure, which becomes smoother and more stable and stabilizes well performance. The downhole device can be installed and replaced by adapting it to the mandrels in a few hours without killing the well.

We should also mention that the POS can be used with different field development systems and has been adapted to different kinds of production. It can be used in combination with gas lift after natural flow has stopped.

The performance of the technology and device at Well 289 at the Kokdumalak Field provide A clear example of the effectiveness of the POS.

THE USE OF THE POS IN KOKDUMALAK WELL No. 289

In early January 2001, a POS bottomhole device was installed at a depth of 3078 meters 18 meters above the perforation interval in Pilot Well 289 at the Kokdumalak Field. Well 289 is located in the gassy southeast part of the field in the immediate vicinity (300 meters) of the OWC. The oil production prospects of this well without the POS were exactly the same as the nearby Wells 95, 286, 56, 284, and 288, which since 1998 have been plagued by gas breakthroughs (gas cones) and where average oil production has declined from 949-1168 bpd to 282-584 bpd, i.e. a rate of decline of 15.3-20.4 bbl per month, and the gravity of the liquid hydrocarbons has declined sharply from 31.1 API to 41.7 API (and even to 49.9 API). The GOR rose from 2300-2800 scf/bbl to 5600 – 16000 scf/bbl, and the WC is up to 12- 22%. According to the Mubarekneftegaz Upstream Division's forecasts, oil production in Well 289 without the POS should have fallen to 584-620 bpd in July 2001, the oil's specific gravity should have declined to 37.0 API, while the GOR and WC should have risen to 8000 scf/bbl and 20% respectively. But now Well 289 with its POS device has been performing more and more efficiently for more than 10 months and its production has remained at an optimal level. This has been shown by 13 well flow tests (Table 1) and is illustrated in Figure 1. During this time, if we factor in the natural decline in reservoir pressure, additional daily liquid hydrocarbons output has risen from 102 to 234 bpd and oil accounts for up to 80% of the liquid hydrocarbons, as evidenced by the higher specific gravity of the oil (up to 32.8 API). The rate of decline of oil production has slowed by a factor of 2.5-3 to 6.6 bbl/mo, the GOR has declined from 6000 to 4500 scf/bbl, i.e. by 15%, and the WC has declined from 5.8% to 0%. The range of daily variations of liquid hydrocarbon gravity has narrowed by a factor of 5-6, which indicates that the position of the top of the gas cone has stabilized at the perforations.

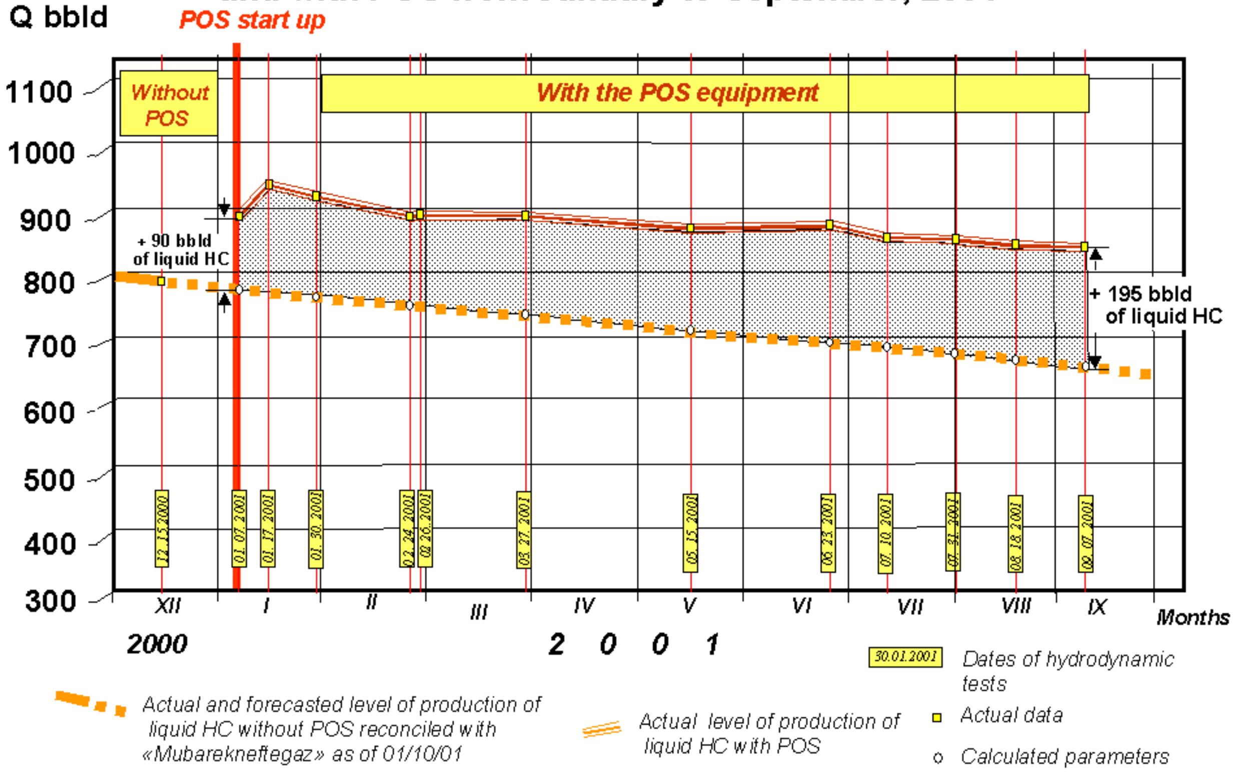
The redistribution of pressure losses in the reservoir-well system has led to its more efficient use by reducing the stress on the wellhead, where wellhead pressure declined from 19.5 to 14.6 MPa. In the first nine months of operation of the POS, Well 289 produced more than an additional 44,000 barrels of liquid hydrocarbons, including an additional 35,500 barrels of oil.

CONCLUSIONS

The performance of Pilot Well 289 at the Kokdumalak Field have demonstrated the effectiveness of the POS system:

- Production was up and the rate of decline slowed;
- The GOR and WC were reduced;
- Wellhead pressure was reduced and well performance was stabilized;
- The rate of decline of reservoir pressure was slowed, which led to a longer period of natural flow and a higher oil recovery factor.

Production of liquid Hydrocarbons from well No289 without POS in December, 2000, and with POS from January to September, 2001



HYDRODUNAMIC TESTING RESULTS OF LIQUID HYDROCARBONS INFLOW IN WELL No 289 OF KOKDUMALAK FIELD CONDUCTED BY "MUBAREKNEFTEGAZ"

Parameters/ Measurements	Without POS, in 2000	With the POS equipment, in 2001											
	1	2	3	4	5	6	7	8	9	10	11	12	13
Test date	*12.16*	*01.07*	*01.17*	*01.30*	*02.24*	*02.26*	*03.27*	*05.15*	*06.23*	*07.10*	*07.31*	*08.08*	*09.07*
Testing period, hours	24	24	24	24	24	24	24	24	24	24	24	24	24
P_{wh} psig	2,864	2,135	2,111	2,140	2,183	2,183	2,184	2,187	2,164	2,164	2,154	2,140	2,136
T^o F at bottom hole	235.4	235.4											
Q_{liquid} bbld	842	885	931	909	887	889	888	861	873	851	848	839	832
$Q_{oil+cond}$ bbld	793	883	928	908	884	885	883	859	872	848	842	835	829
Q_{gas} Mscfd	3,865	4,836	5,111	5,065	4,818	4,841	3,805	3,653	3,842	3,795	3,790	3,497	3,593
GOR scf/bbl	4,876	5,507	5,513	5,596	5,475	5,488	4,333	4,160	4,462	4,475	4,501	4,208	4,371
Water cut, %	5.80	0.20	0.30	0.10	0.40	0.40	0.60	0.20	0.06	0.28	0.70	0.50	0.30
Density of blended liquid hydrocarbons, ^{o}API	34.4	33.4	33.2	31.5	33.4	32.3	32.5	33.0	33.0	32.8	32.8	32.8	33.0