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THE PROBLEM OF FLOODING OF NEDIELNE GAZ-CONDENSATE FIELD AND THE WAYS TO SOLVE IT

In the process of Nedielnegas-condensate field development flooding of the productive horizon M-4 is observed, which negatively effects reaching the maximum hydrocarbonex traction factor. Experts of Yuliyevskeoil, gas and condensate workshop conducted exploration study of well 3. On the results of this study such mode of the well operation was chosen, which provides periodical gas take-off. During subsequent operation the well stopped. In order to restore its operation, development of the well was carried out and then it was operated again. Due to the growth of the water factor, well operation did not last long.

To solve this well flooding problem, works on selective water-isolation were carried out according to the technology developed by Ukrainian Research Institute for Natural Gases. Its essence lies in the formation of impermeable layer of blocking material in reservoir conditions, which provides isolation of the stratum water inflow. The institute experts elaborated the plan according to which the work was conducted in several stages, in particular, supplying foam into the internal cavity of the lift tubes for washing out the sand, pumping blocking solution, pumping chemical reactants and study of the well. On the results of the conducted water-isolation works reduction of the stratum water content in the well was achieved. Individual measurements of the well operation parameters were conducted. Thus, the conducted water-isolation works made it possible to restore the well operation. Technological mode of the well operation that was limited due to the installation of a washer at the wellhead was proposed. In order to prevent premature flooding of the water horizons, an important measure is selection and adherence to the optimal technological mode of the well operation. In the conditions of the water factor growth it is necessary to conduct geophysical studies in order to detect the source of water inflow to the well.

Keywords: *well, productive horizon, stratum water, technological mode of operation, flooding, water intake isolation.*

Introduction

The problem of flooding gas and gas-condensate wells is extremely relevant at present. It is associated with a number of factors: special features of the field geological structure and the amount of hydrocarbon reserves, operation modes and technical condition of the wells, etc.

Analysis of the latest research and publications

During development of gas and gas-condensate fields for depletion, reduction of the reservoir and working pressures occurs with respective decrease of the well yield. Taking this into account, measures should be taken to stabilize extraction of hydrocarbons.

In [1, 2, 3, 4] ways for effective extraction of hydrocarbons are considered by the examples of Yuliyivske, Skvortsivske, Nariznianske and Nedielne fields. During development of the fields a number of problematic issues and complication arise, which negatively affect provision of the required level of raw hydrocarbon extraction. Thus, to stabilize extraction from the fields, respective measures are elaborated and implemented as well as prospective development programs.

During operation of the well 53 of Yuliyivske oil and gas-condensate field (OGCF) growth of the water factor was observed, which affected negatively the level of hydrocarbon extraction. To overcome this complication, Ukrainian Research Institute for Natural Gases developed a technology of water-isolation works with the application of cements on hydrocarbon base. The technology consists in creation of a cement screen on the way of stratum water upcoming to the well. In productive layers oil-cement solution does not stiffen and does not reduce its filtration properties.

Positive effect from application of the given technology was achieved in well 53 of Yuliyivske OGCF. The operation object was represented by two productive horizons C-5б and C-6 (perforation

intervals – 3134-3128 m, 3112-3097 m). In the process of the well operation, the lower horizon was flooded first and later the upper horizon was flooded as well. According to the data of MPD-control (MPD-maximum permissible discharge), gas-water contact rose to 3103 m. During water-isolation works cement ring was formed outside the operating column in the water-producing interval and in the same interval a cement glass was installed. As a result, water inflow was isolated.

During the years of 2005 – 2006 repair and isolation works were carried out in order to liquidate water inflow at other wells of Yuliyivske OGCF, using the described Ukrainian Research Institute for Natural Gases technology, which had proved its effectiveness. Application of the developed technologies and formulations of the insulation materials in the wells made it possible to increase the efficiency of wells operation in the flooding conditions [5].

Formulation of the paper aims

The aim of the paper is to determine measures for optimizing operation of the gas-condensate wells in the conditions of stratum water inflow from the productive horizon.

Coverage of the main material

Most of the wells of PJSC «Ukgasvydobuvania» are exhausted and are at the last development stage. In this regard relevant is the problem of ensuring optimal hydrocarbon extraction from the wells in the conditions of flooding of the productive horizons.

Nedielne GCF was opened in 2008 by an exploratory well 1, which was drilled in order to find gas deposits in Bashkir, Serpukhov, Visean fields and in the crust of weathering the crystalline basement rocks. As a result of the industrial-geophysical research and testing of the wells in Bashkir and Moscow levels, productive horizons Б-3-4, Б-2в, Б-1н, М-5-6 and М-4 were detected. According to the test data, productive gas content was found only in the three of them: – hor. Б-3-4 (well 1), hor. Б-2в (well 3) and hor. М-4 (well 3).

Productive collectors are sandstones and siltstones with a porosity of 15-24%. The gas structures of the deposits are vaulted, but lithologically limited [6].

At present gas-condensate deposits of Б-3-4 and М-4 horizons are at the development stage. Total fund of Nedielne GCF is 2 wells – well 1 and well 2.

Gas-condensate deposits of Б-3-4 and М-4 horizons of Nedielne GCF are floating structures. Thus, the field development involves solving the problem of premature flooding of the wells. One of the options to optimize development of the floating deposits is periodic stopping of the wells for water cone settling. This causes reduction of hydrocarbon extraction. An optimal measure to prevent flooding of the wells is limiting the draw-down pressure, which was proposed by the authors of DPR project [7].

Horizon Б – 3 - 4 of Nedielne GCF was opened by well 1 by perforating the interval of 2292 – 2302 m. When testing the well on the choke with a diameter of 5.0 mm, gas yield of 73.5 thousand m^3/day at Ptub –18.12 MPa, Pan – 18.36 MPa was achieved. Static pressure was 18.74 MPa.

Well 1 was put into operation in 2009 with gas yield of 60 thousand $м^3$/day at Pp – 17.05 MPa, Pop – 18.14 MPa. The flow-line length was 7794 m. At the beginning of 2011 the well yield was 67 thousand m^3/day, water factor – 60 cm^3/m^3.

Horizon М-4 of Nedielne GCF was opened by well 3 by perforating the interval of 1970 –1974 m. When testing the well on the choke with a diameter of 5.0 mm, gas yield was 81.6 thousand m^3/day with Ptub – 15.80 MPa, Pan – 15.79 MPa. Static pressure was 16.09 MPa.

Well 3 was put into operation in 2010 with gas yield of 60 thousand m^3/day with Pp –15.29 MPa, Pop – 15.49 MPa. Flow-line length was 12323 м. At the beginning of 2011 gas yield was 60 thousand m^3/day, water factor – 75 cm^3/m^3. In the first and second quarters of 2011 water yield in the well production gradually increased and reached 14.5 m^3/day and gas yield reduced to 40 thousand m^3/day. Therefore, certain corrections had to be introduced into the technological mode of operation. To optimize conditions of the well operation, periodical work was proposed to be carried out and a schedule of the well periodical operation was compiled. Thus, the well worked

periodically with gas yield of 5 thousand m^3/day and water yield 5.1 m^3/day. In June of 2011 the well stopped (self-extinguished by its own water). So, the well was developed by means of successive replacement of the reservoir water with a liquid of lower density, i. e. water was pumped into the well with periodic supply of gas-nitrogen mixture from the mobile nitrogen compressor station (ПАКС-250). In the process of pumping, hydrostatic pressure reduction was observed due to replacement of the liquid column by the water-gas mixture. In addition, a 10% solution of surfactants was pumped into the annulus space by means of cementing unit with further blowing of the tubing space. After the well had been developed, its operation did not last long as a result of the water factor growth. In October of 2011 static pressure increased to 14.70 MPa and the well was put into operation. However, in 7 days the well stopped its operation.

In December of 2011 a set of industrial-geophysical studies was conducted in order to determine the source of water inflow to the well. According to the data of LM, the device stopped at the depth of 1772 m. Probably, this happened as a of result of sand carry-over and creation of the sand plug. In the process of research, water was taken for investigation. According to laboratory tests, it is stratum water with the density of 1.12 g/cm, chemical content of Ca^{2+} – 12024 mg/l, Mg^{2+} – 1824 mg/l.

Based on the given research, in order to reduce carry-over of the stratum water and to increase extraction capacity of the well, it was proposed to conduct selective isolation according to the standard СТП 320. 00158764. 058-2003 "Technology of selective isolation of the mineralized stratum water cone of calcium chloride-magnesium chloride type, flowing into the wells, with preliminary flushing the well with foam. Its essence lies in the formation of an impermeable layer of blocking material in the reservoir conditions, which ensures isolation of the stratum water inflow over a large area of the stratum water-gas or stratum water-oil contacts.

Specialists of Ukrainian Research Institute for Natural Gases developed a plan of water isolation in well 3 of Nedielne gas field. It contains basic geologic-industrial data on the well, the required equipment and materials, preparation works, technology of their realization and labor protection measures.

In accordance with this plan, the works were conducted in several stages:

I stage (25.04.2012):

– checking technical condition of X-tree, well-killing assembly as well as tightness of the latches;

– checking the well operation parameters (Pp, Pop) and position of the latches on X-tree and well-killing assembly; installation of manometers in the tubing and annulus space;

– before the work started, the pressures were Pp – 12.25 MPa, Pop – 12.25 MPa;

– cementing unit was connected to the tubing space at the killing assembly, ejector and ПАКС-250 with check valve were installed in the pumping line for supplying foam to the internal chamber of the lift tubes for washing out the sand. Pumping line was pressurized for 1.5 times expected operating pressure – 20.10 MPa;

– preparing 10 m^3 of the solution of 1% KCl with 2% surfactant for washing out the well;

– pumping the prepared 1% KCl with 2% surfactant into the tubing space through the ejector and washing out the well from the sand deposits by foam, without creating depression on the layer, with the foam release to the pit via the annulus;

– closing the well at pressures Pp – 7.84 MPa, Pop –16.18 MPa.

II stage (26.04.2012):

– before the work started, the pressures were Pp – 7.84 MPa, Pop – 15.69 MPa;

– cementing unit was connected to the tubing space at the killing assembly, ejector and ПАКС-250 with check valve were installed in the pressure line for pumping and pushing of the blocking solution into the layer. Pumping line was pressurized for 1.5 times expected operating pressure – 20.10 MPa;

– blocking solution was prepared on the basis of ammonium bicarbonate in the volume of 8 m^3;

– blocking solution was pumped into the tubing space and pushed into the layer, using ПАКС-250, with gas-nitrogen mixture supply at pressures Pp – 7.35 MPa, Pop – 15.29 MPa;

– tubing and annulus spaces were connected via bypass at the X-tree and the well was left at the maximum permissible pressure to provide blocking reaction (for 10 days) and recovering of the static pressure.

III stage(08.05.2012):

– before he work was started, the pressures Pp – 10.29 MPa, Pop – 10.29 MPa;

– cementing unit was connected to the tubing space at the killing assembly with installation of a check valve in the pressure line for pumping methanol with solution of surfactants. Pumping line was pressurized for 1.5 times expected operating pressure – 20.10 MPa;

– 2 m^3 of methanol was prepared from 0,1 m^3 of 0. 5 % solution of surfactants;

– the prepared mixture was pumped into the tubing space with closed annulus space. Pressures at the wellhead remained unchanged;

– tubing and annulus spaces were connected via bypass at the X-tree and the well was left until the liquid was absorbed and the static pressure recovered.

Stage IV (16.05.2012):

– before the work started, the pressures were Pp – 10.29 MPa, Pop – 10.29 MPa;

– the well was blown with the annulus space to the pit through a washer of 4 mm diameter with gas-nitrogen mixture supplied into the tubing space at a pressure of 13.73 Mpa. After 25 minutes of the well blowing at pressures Pp – 11.23 MPa, Pop – 5.69 MPa, condensate pressures increased from Pp – 10.78 MPa and Pop – 13.43 MPa to Pp – 12.94 MPa and Pop – 13.43 MPa respectively. After that the well was closed for static pressure growth and subsequent research to be carried out five days later.

In May of 2012, after water-isolation works and investigations, the well was put into operation with the following parameters: Pp – 13.73 MPa, Pop – 14.90 MPa, Pin – 12.75 MPa, Ty – 16 °C, Tin – 12 °C. According to the conducted separate measurement of the extraction capacities for such operating mode, the following results were achieved: yield of gas – 24 thousand m^3/day, of condensate – 1 t/day, stratum water – 1.5 m^3/day. Technological mode of the well operation is limited due to the washer of 4 mm diameter installed at the wellhead. Thus, works on the water inflow isolation gave positive results.

Conclusions

1. In the process of Nedielne GCF development a number of problematic issues arise, which require an integrated approach for their solution. One of them is flooding of the productive layer in the well 3. To overcome this complication, water-isolation works were carried out according to the technology of Ukrainian Research Institute for Natural Gases. As a result, positive effect was achieved, namely, reduction of stratum water content in the well production, which made it possible to renew the well operation.

2. To prevent flooding of the productive layers of Nedielne GCF, it is necessary to establish optimal mode of the well operation, which involves limiting the depression. Although this causes productivity reduction, it provides stable operation of the wells and extraction of the hydrocarbon reserves, which, ultimately, increases extraction capacity of the operational fund.

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