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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

RESEARCH AND APPLICATION OF MECHANICAL OPERATING METHODS WITH THE AIM OF OIL PRODUCTION INTENSIFICATION

Speciality: 2525.01 – "Development and exploitation of oil and gas fields"

Field of science: Technical science

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Bakı – 2021

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GENERAL DESCRIPTION OF WORK

The actuality and study degree of the topic.

Compared to new explored fields, old fields developed in depletion mode have a number of their own characteristics. These features are listed below:

– In most of the production wells, the downhole pumping method is used, and the production of most of the wells is characterized by a high water cut;

– The oil flow rate in such wells is significantly lower than the water flow rate;

– Most wells are flooded ahead of time, and either isolation of formation water is required, or limitation of water flows entering the well along with oil;

– Watering of wells increases the intensity of sand production in them;

– Sand plugs are often formed, and the number of repairs associated with this is increasing;

– In this case, it is required to determine the effective frequency of repair work;

– After the expiration of time, the oil flow rate decreases, the water flow rate increases, and, as a result, the cost of oil increases.

Timely identification of the listed undesirable phenomena and the implementation of the necessary technical and technological measures in order to increase the efficiency of the development processes of such fields are considered as one of the most urgent scientific and practical tasks.

When such situations arise, in order to intensify the production of oil fields, the impact on the bottom–hole zone is applied in various ways, measures are taken to prevent flooding, and each time it becomes necessary to designate a new optimal technological mode of the well. When assigning the optimal technological mode of downhole pumping wells, they are mainly investigated in a steady state and indicator diagrams and control curves are taken. In accordance with this, from the point of view of increasing the efficiency of field research methods, during the study of the wells operating mode, the main exploitation indicators are not changed, and it is considered the most expedient to carry them out by adding a constant flow rate of fluid into the annulus, based on a new approach; because changing the well mode requires stopping the pumping unit, which leads to the fact that the exploitation indicators after the survey period are not restored to the values before the study. In the dissertation research methods based on this improved approach are developed and prepared.

Along with this, with the aim of intensifying oil production in fields developed in the depletion mode for a long time and operated by a mechanized method, by increasing the efficiency of research methods technical and technological methods that represent scientific novelty are also developed in the work.

Object and subject of research.

The object of research is to determine the technical, technological and reservoir features of the "reservoir-well" system, corresponding to the last stage of development; the subject of research is the achievement of intensification of oil production by increasing the efficiency of field research methods.

The purpose and main objectives of the study.

The main purpose of the implementation of the study in this thesis is to increase the operational efficiency of sucker-rod pumping wells in old oil fields. With this purpose in work the following tasks have been resolved:

– determination of reservoir pressure without stop in the work of downhole sucker-rod pump units;

– determination of reservoir pressure by bilateral buildup of bottomhole pressure in the wells that produce a highly viscous newtonian oil and viscous-plastic oil;

– change the mode of operation of the well without changing the "S" and "n" parameters;

– determination of the optimum depth of immersion of the plunger pump in the watered well and optimal bridle of the string of lift pipes;

– isolation of formation waters in drowned sucker-rod pumping wells by the use of hydrodynamic periodic method;

– determining the optimal flushing frequency of sand plugs in oil wells.

– a new method for determining reservoir pressure in deep sucker-rod pumping wells;

– determination of the friction force acting on the horsehead in deep sucker-rod pumping wells.

Methods for solving the tasks.

The tasks set in the dissertation were solved by conducting laboratory experimental and field studies, and the interpretation of the results was carried out by mathematical methods.

The main positions to be defended.

1. An effective approach to determining the nature of oil in reservoir conditions by constructing two-sided bottomhole pressure build-up curves, as well as performance indicators and reservoir properties, taking into account the possibility of reducing the time of research;

2. An effective approach that allows you to change the operating mode of wells operated by sucker rod pumps without stopping their operation and does not adversely affect the performance;

3. Effective methods for determining the operational parameters of the reservoir and reservoir properties without shutting down the deep-well pumping oil wells;

4. An effective approach to choosing the depth of the wellbore pump suspension, avoiding getting into the wellbore zone with the greatest water accumulation, and determining the pump submersion depth below the dynamic liquid level, depending on the value of the gas factor;

5. Hydrodynamic method of periodic isolation of formation waters in flooded deep pumping oil wells;

6. Method for determining the speed of propagation of sound waves for accurate measurement of the liquid level in pumping wells;

7. Method for determining the frequency of flushing sand plugs in sand-producing wells;

8. Method for determining the value of the friction force acting

on the mulehead.

The scientific recency of the research.

1. An effective approach has been developed and prepared for determining the nature of oil in reservoir conditions by constructing two-sided downhole pressure build-up curves, as well as performance indicators and reservoir properties, taking into account the possibility of reducing the research time.

2. A method for changing the operating mode of an oil deep-well pumping well, which is determined by adding a constant flow rate of liquid, which makes up a certain part of its flow rate is proposed.

3. Methods for the effective determination of reservoir performance and reservoir properties parameters without stopping the operation of downhole pumping wells are proposed.

4. A method for determining the speed of propagation of sound waves for accurate measurement of the liquid level in pumping wells is proposed.

5. A method for determining the frequency of flushing sand plugs in sand-producing wells has been developed and prepared.

6. A hydrodynamic method for isolation of formation waters in flooded wells, based on the use of degassed "dead" oil as an isolating agent is proposed.

7. A method for determining the value of the friction force acting on the mulehead, taking into account the removal of an additional dynamometer chart has been developed.

Theoretical and practical value of work.

In the dissertation, the application of the recommended new research methods in sucker rod-pumping oil wells does not require a lot of time, the work of wells does not stop, the loss of oil production is much reduced and other faults are not occurs, thus it finds a favour and wide use in the activity of field engineers.

Approbation of the work.

The basic suppositions of dissertation are reported in:

– Scientific-practical conference «Azerbaijan – 2020: Perspectives of Oil and Gas Industry Development» dedicated to the 90th anniversary of Nationwide Leader Geydar Aliyev, Baku, 2013, pp. 55-56;

– XIX Republic scientific conference of doctoral students and young researchers. Baku 2015, pp. 93-95;

– XIX Republic scientific conference of doctoral students and young researchers. Baku 2015, pp. 101-103;

– XX Republic scientific conference of doctoral students and young researchers. Baku 2016, pp. 153-154;

– II International scientific-practical conference, Krasnodar, Russia, 31/03/2018, Volume 3, pp. 289-294;

– II International scientific-practical conference, Krasnodar, Russia, 31/03/2018, Volume 3, pp. 321-323;

– IV International scientific-practical conference, Krasnodar, Russia, 31/03/2020, Volume 2, pp. 337 – 343.

The new ways of studies and proposals showed in thesis have been successfully applied at "A.D.Amirov" OGPD oil fields, at "Bibiheybat" OGPD in the pumping wells, at "Absheronneft" OGPD in sucker-rod pumping wells.

On the topic of the dissertation published 18 publications

The name of the organization where the work was performed. Azerbaijan State Oil and Industry University.

The total volume of the thesis with a separate indication of the individual structural parts of the thesis.

The dissertation work consists of introduction, four chapters, 15 sections, conclusions and recommendations, the list of references, consisting of 144 titles and applications. The volume of work is 189 computer printed text including 24 diagrams, 9 figures and 10 tables. Total volume of dissertation is 223867 symbols.

Brief content of the work.

In the introduction justified the actuality of the dissertation, its general positions, solutions to the tasks, scientific recency and practical value are reflected.

The first chapter provides a brief overview of the research work carried out so far in oil wells operated by sucker rod pumping units. Based on the information provided in the review of literary sources on the topic, it is noted that for oil fields that have been in development for a long time and have entered the last stage, according to certain technical and technological solutions at the level of sustainable management, information on the necessary operational and reservoir features, directly for the well and the reservoir, depending on ensuring the degree of reliability, efficiency and effectiveness of various technological cases can be received. Thus, only in these cases the actual reliability of the applied technical and technological solutions can be ensured.

A brief review of the scientific and technical literature on the topic of the dissertation work simultaneously showed that in order to make a decision on the effective management of the completion of the oil fields development that have been in operation for a long time, in first order, taking into account the current production levels achievement of the improving the efficiency of well operation and, for this purpose, studying the issues of increasing the effectiveness of the technical and technological measures are considered as scientifically and technically significant problems, which, first of all, creates the need to improve the existing field research methods, in particular, methods for stimulating well production, as well as determining the performance of wells and reservoir parameters based on support continuous well operation. It is considered that only thanks to such improvements it becomes possible to increase the time between repair work and minimize possible arising oil losses due to the influence of certain technological factors, which ultimately creates the opportunity to somewhat intensify oil production and keep it at a profitable level for a long time for the fields at the last stage of development.

Referring to the above, in the dissertation work, the need to improve the exploitation characteristics of wells operated by a mechanized method to identify, study and, first of all, to implement important tasks aimed at increasing the efficiency of the application of field research methods in accordance with obtaining adequate information corresponding to the current state of the "reservoir -well" system is noted.

In the second chapter of the dissertation new methods of study of sucker-rod pumping wells by means of the liquid adding are presented.

In the first paragraph of the chapter, the results of the determination of reservoir pressure without stopping the operation of the pump-jack are described.

The essence of this method is as follows: liquid (pure oil or water) is poured into the annulus of a working well in a certain volume or is pumped in by a unit, the liquid level in the well rises several meters above its static position, with using of the echometer of "Quantor-4micro" complex the level drop in the well is observing and the dynamic fluid level build-up curve is taken. Conjoined, a graph of characteristics of a plunger pump operating in well is plotted in the same coordinate system.

It is advised to plot these features on base of the following formula:

$$h = \frac{Q}{F} \cdot t$$

h is the height of the column of fluid injected during time t;

Q is the actual volumetric productivity of the pumping well;

F is the cross section of the annulus $F = \frac{\pi}{4}(D^2 - d^2)$;

D is the inner diameter of the production string;

d is the outer diameter of the tubing.

Taking into account the value of these parameters for some time t, the value of h is calculated using this formula and point B is constructed, and through points 1 and B an inclined straight line is drawn in the same coordinate system where the restoration curve for the dynamic level was built.

Diagram 1 shows the study diagrams of the sucker-rod pumping oil well No. 289 of the Lokbatan field are presented. In the figure, a tangent straight line to the curve (graph II) is drawn parallel to the characteristic of the pump (graph I); the ordinate of the obtained point C gives the depth of the static fluid level in the well (H^{st}).

The height of the static liquid column in the well can be found accordingly to the formula:

$$H_s = H_t - H^s$$

Where H is the depth of the midpoint of the filter interval. Taken into account the value of the specific gravity of the fluid (γ) reservoir pressure is calculated by the formula:

$$P_r = \rho g \quad l$$

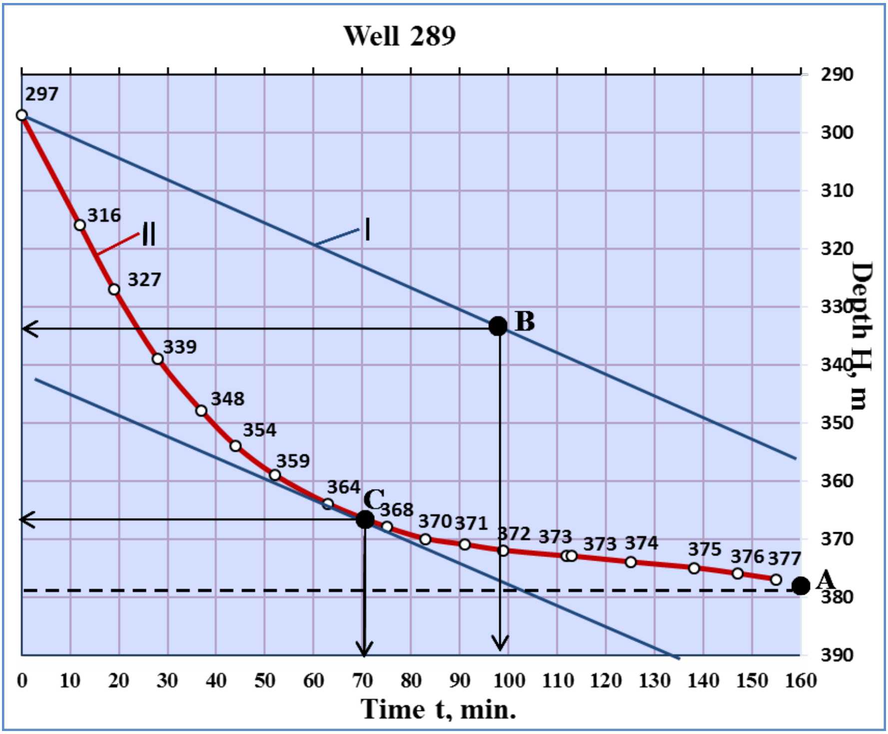

Diagram 1. Diagrams of the study of sucker rod pumping oil well 289 of the Lokbatan field:

I – characteristic of the sucker rod pump; II – liquid dynamic level build-up curve.

The results obtained for well No. 289 are given below:

$$H_s = H_t - H^s = 4 \quad - 3 \quad 9 = 1 \quad 6m$$

$$P_r = \rho g \quad _s = 0{,}9_t \quad H \cdot 9{,}8 \quad \cdot 12 \quad = 1{,}21\, M26a$$

This method was applied in the well No. 2153 of the Puta field and in the sucker-rod pumping well No. 495 of the Lokbatan field and positive results were obtained.

The second paragraph of the chapter describes a method for bilateral buildup of bottomhole pressure of wells producing highly viscous newtonian oil and viscous-plastic oil and comprehensively describes the results of the application of this method in deep-pumping oil wells of the A.D.Amirov OGPD.

It is known that, to characterize the movement of abnormal oils, the choice of a mechanical model is associated with a specific task. For example, to determine reservoir pressure, the use of a viscous-plastic model is effective, which is a two-parametric model, one of which is the structural viscosity of oil η, and the other is the initial shear stress of oil τ_0. This can be seen from the Bingam-Shvedov law of friction.

This method, firstly, makes it possible to identify the nature of oil in reservoir conditions (oil can be Newtonian or viscous-plastic fluid). That is, the presence or absence of the occurrence of the initial pressure gradient (IPG) is established this parameter occurs only during movement (filtration), secondly, the values of reservoir pressure, lower and upper limits of static bottom-hole pressures are determined.

The essence of the method is as follows, at the beginning, the depth of the dynamic liquid level is measured with an echometer in its technological mode of well operation, then the well operation is stopped and the increase in the liquid level is monitored by the echometer until it stabilizes: the depth of the lower static position of the level H 'is determined after that through this well into the formation liquid is injected in a certain volume and without delay, the level drop in the well is observed until it stabilizes, and the depth of the upper limit level H" is determined. Based on these parameters, all required indicators are determined (P_r, ΔP_0, G and other reservoir parameters).

This method was used in many oil fields in Azerbaijan and the former Soviet Union.

The method is called a two-way build-up method because here the reservoir pressure is approached from two sides, that is, both from below and from above.

We used this method for the first time in the wells of oil and gas production department named after A.D.Amirov and obtained interesting results.

In the wells of the A.D. Amirov OGPD, this method was used by us for the first time and interesting results were obtained.

On diagram 2, on December 25, 2014, at Kalmas Square in OGPS No. 4, this method was used to investigate the deep sucker-rod pumping well No. 423 (operating the IV PS horizon of the productive section). Figure 2 shows the curves of bilateral buildup of the oil level taken in this well, as can be seen as a result of the study, the following values are determined:

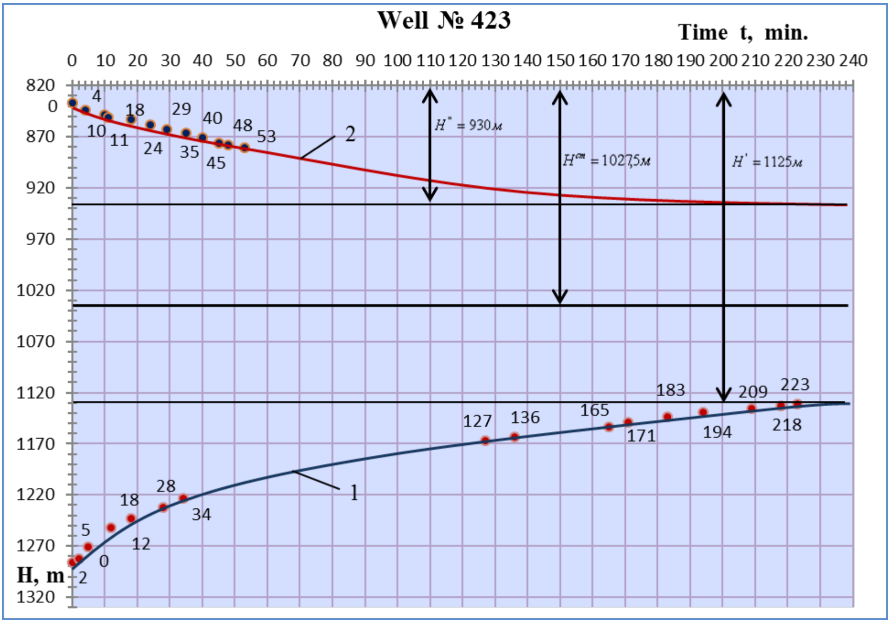

Diagram 2. Curves of the bilateral oil level for well 423 of the Kalmas field

1 and 2 – the lower and upper levels of build-up in the well, respectively

$$H' = 1 \quad 1m ; \quad H'' = 9 \quad m3$$

According to these values the depth of the static level is calculated:

$$H^s \; =^t \frac{1}{2}(H' + H'') = \frac{1}{2}(1 \quad + 91 \quad) = 132 \quad ,5m0$$

The height of the static liquid column will be:

$$H_s \; = H_t - H^s \; = 2^t \quad -1 \quad 05 = 1 \; 0 \; ,58m$$

The height of the dynamic oil column in its technological mode of operation of the well will be:

$$H_d \; =_y 2 \quad _n -10 \quad = 38 \quad m$$

The dynamic bottomhole pressure of the well in its technological mode of operation will be:

$$P_c = \rho g \quad _d \quad = 0,9_y \; H \quad \cdot {}_n 9,8 \; \cdot 74 \quad = 7,11 \; M6 \; a$$

The impressed depression in its technological mode of operation of the well will be:

$$\Delta P = 9,7 \quad -7,1 \quad 8 \; 2,6 \; 4M \quad a$$

The initial pressure drop is:

$$\Delta H_0 = \frac{H' - H''}{2} = \frac{1 \quad -19}{2} = 9 \; 23 \; ,5m \; 5$$

$$\Delta P_0 = \rho g \Delta H_0 = 0,9 \quad \cdot 9,8 \; \cdot 9 \, 4,5 = 0,91 M 7 \, 7$$

The initial pressure gradient will be:

$$G = \frac{\Delta P_0}{R_c - r_w} = \frac{0,91}{100 - 0,0625} = 0,0091 \frac{MPa}{m}$$

This method was applied in deep sucker-rod pumping well No. 54, 427 field Calmas and No. 1854 field of Kushhana and positive results are obtained.

In 1968, a method for determining reservoir pressure in deep sucker-rod pumping wells without stopping the operation of the pump-jack was proposed.

The new proposed method of determination set forth ***in the third paragraph of the second chapter of the dissertation*** is simpler and is carried out in a relatively short time. The significance of this is that it makes it possible to increase the number of determined reservoir pressures. Most of the sucker-rod pumping oil wells were drowned and in this state, the buildup of reservoir pressure occurs in a relatively short time. This also makes it possible for widespread use of the proposed method.

In the fourth paragraph of the second chapter described rules of construction of indicator diagrams in sucker rod-pumping oil wells using a new method of changing the mode of operation.

The dissertation is moving away from these traditional methods and proposes a new method.

In the drowned sucker-rod pumping oil wells when changing the mode of operation under the new method, at every time in their annulus are added or pumped by the unit fixed consumption as both pure oil and water, though their values are taken equal to the parts of each output per day of oil and water to its operation mode of the well.

This new proposed method has been applied in drowned wells (wells 1125, 152, 1546 and 46) and positive results are obtained.

In the fifth paragraph of the second chapter**,** with the aim of increasing the efficiency of operation of sucker-rod pumping oil wells (non-drowned and drowned wells) detailed information about the use of multifunctional measure are described.

This multifunctional measure is the adding or the pump-in the pure liquid (oil or water) into the annular space by the unit and this is done during the implementation of various technological processes.

Adding of the pure fluid into the annular space in sucker-rod pumping oil wells with intensive sand production has many years of field experience and is designed to improve the conditions of lifting of sand particles to the surface.

The constant adding of the pure liquid into the well in the upward flow of well products increases the amount of liquid and decreases the concentration of particles of sand. This is one function of a multifunctional measure that prevents the formation of sand plug in the well and reduces intensity of this process.

It should be noted, that the use of multifunctional measure carried out in the form of the adding of the liquid in the annular spase to be conducted in the following different ways:

– dynamic fluid level in the well rises a few meters above its static position by the adding of the liquid in the annulus;

– dynamic level of a liquid rises, but it does not reach its static position.

In the third chapter of the dissertation the problem of drowned deep sucker-rod pumping wells is considered, the analysis and synthesis of these processes are carried out.

Here in ***the first paragraph*** the method of determining of the optimal bridle of lifting pipes string in drowned sucker-rod pumping wells is proposed.

The third paragraph of the second chapter, the results of the study of the drowned deep sucker-rod pumping oil well No. 1254 operated in OGPS, No. 3 of the A.D.Amirov OGPD are given.

This method was used in well No. 411 of Lokbatan field, in wells No. 1795 and 1797, in well No. 521 of Garadag field and the following results were obtained.

The third paragraph of the third chapter describes the positive results of isolating of formation water in the drowned deep sucker-rod pumping wells at “Janub gyryshygy” (“South Fold”) oil field of the Absheronneft oil and gas production department.

Currently, this old oil field is being depleted and its wells have been drowned and required isolation of formation water.

Until 2014 year in the drowned wells of this field for isolation of formation waters as the agent the cement solution was used. The negative side of this agent is that, after injecting it into the formation it becomes solid and turns into stone creating a solid barrier in front of as both of the reservoir oil and the reservoir water. After the implementation of measures for isolation to create a flow of the reservoir oil to the well the downhole filter in front of upper oilbearing part is perforated repeatedly 4-5 times, or the filtration flow from the reservoir to the well is created, and if it does not take place bottomhole filter fall out.

In 2001 year the method of the periodic isolation of formation waters in drowned gaslift wells is proposed and a PATENT 2001 0112 is got. This method was used in gaslift wells of the "Gum Adasy" OGPD and by means of the isolation of the formation water in mass quantity of oil was produced. After several years on the basis of this method the "Method of isolation of wells" is proposed and PATENT 2008-0027 was got. Later, this second patent was used in drilling well No. 124 with a depth of 6000 m and a powerful gas showing was prevented.

In 2012 year this method of water isolation was first applied in drowned sucker-rod pumping wells of A.D.Amirov OGPD and were obtained positive results.

The graphs showing the dynamics of changes in the production rates of oil and water of sucker-rod pumping oil well No. 460 at "Janub gyryshygy" ("South Fold") oil field of "Absheronneft" OGPD after isolation of the reservoir water by means of hydro-dynamic way. As can be seen, the water production rate of this well has decreased from 11.51 m^3/day to 7.31 m^3/day, and oil production rate increased from 2 m^3/day to 3.3 m^3/day. Similar positive results were also in wells No. 370 and 431.

In the fourth chapter, the measures for the management of operation of sucker-rod pumping wells in old fields and fields developed in the depletion mode are proposed as well as the widespread use of positive results obtained with their thoroughly analysis are described.

In the first paragraph of this chapter the method of determining the velocity of sound waves to accurately measure the depth of fluid level in sucker-rod pumping wells is proposed.

When measuring by means of the float in the working well it with its measuring cable rope (steel cable rope) lowers down in the annulus, during this process the wire wound around the lifting pipes and gets broren. To avoid this problem, the eccentric bace plate is used.

This method leads to higher material costs and in different wells gives error. The echogram obtained in the well №805 with measured level by means of the “Quantor-T” is shown - the speed of sound has changed.

When the pressure in the annulus is from 0 to 100 atm the speed of sound is determined automatically, and when it increases to 100 atm, the measurements with use of the complex "Quantor-4micro" occur error and as this is against the safety rules, measurements are prohibited.

When the pressure in the annular space is equal to atmospheric, then the device automatically for the speed of sound takes the value of 300 m/sec and in most cases is error. Therefore, in wells awaiting repairs and in the observation wells after measuring the static level by means of the float such level is also measured by use of the “Quantor-4 micro” complex.

If the instrument's reading differs from the measured by the float, the echogram obtained by the complex entered into a programme “Quantor-T” available in the computer and as both of the speed of sound and the speed of sound corresponding to a value measured by the float are changing, and the speed of sound is switched on manualy.

In the subsequent measurements for the same well determined values of the speed to enter the complex to obtain right results.

In the “Quantor-T” changing of the speed of sound is permitted to change in the range of 200-700 m/sec, but the complex it is allowed to change this value up to 100-999 м/sec.

When the sound speed is entered into the device manualy in the range of 100-200 m/sec or 700-999 m/sec, in the program “Quantor-T” if it is needed to change this parameter, the program automatically replaces this value of the speed in the interval of 200-700 m/sec.

This method was used in the well of Lokbatan-Puta-Gushhana field of A.D. Amirov OGPD and correct results are obtained.

In the second section of the chapter ways of field studies of sucker-rod pumping wells improvement with “Quantor-4micro” complex are reviewed.

In the third section of the chapter the methods of carrying out monitoring of the downhole pump unit with the help of hardware-software complex "Quantor-4micro" are outlined. Here the purpose, the construction, the principle of work and range of application the complex are described.

Figure 1. Hardware and software complex "Quantor-4micro"
1–"Quantor-4micro"; 2–dynamometer; 3–impact vessel; 4–echometer; 5–impact generator; 6–interconnection cable; 7–battery.

In the operation of sucker-rod pumping wells based on the shape of the shooting dynamic card the type of accident occurring in the well is determined. In addition by means of the instrument "Amp-pincers" the state of the pump jack is determining and with use of the device

Figure 2 (a). Installed echometer

Figure 2 (b). Installed dynamometer

called "radio-extender" the results of the measurements are transmitted over long distances.

When measuring dynamic fluid level in the well to the annular flange is connectig the additional flange and the sensor is attached to the complex. The distance between the level measuring tool (echometer) fitted in the annular and the well should not be more than 5 m. This flange and the sensor should not be dirty otherwise defined data do not give valid values.

Installation, operation and taking down of the level measuring tool should seriously be performed by employees receiving instruction got acquainted with the rules of use of the device and safety methods.

For continuous and efficient operation of the device should be systematically carried out its technical inspection.

Figure 2 shows a photograph of the hardware-software complex "Quantor-4micro", and Figure 4 shows a) echometer and b) dynamometer.

In the absence of the ability to get closer to the well the complex sensor should be connected with the radio-sensor to transmit the results of measurement over long distances.

The echometric activities are carried out by means of the sensor called echometer. In the annulus if there is atmospheric pressure, impact cylinder is connected to echometer and field studies are conducted.

If the annular space has a pressure from 0.1 atm to 100 atm echometer need to connect with the impact generator.

To record a dynamic card the special sensor device to be attached to the polished rod and the walking beam of the pump jack performs one swing, i.e. one movement up and down.

In the forth paragraph of the fourth chapter the rules and ways of measuring of dynamic fluid level in sucker-rod pumping wells are explained.

Each sucker-rod pumping oil wells (SRPW) has its optimal technological mode of operation, that is the result of hydrodynamic studies of wells in stationary modes of inflow, i.e. the recording of indicator diagram and regulating curves. For normal operation, the depth of the optimal level of fluid is required to maintain constant.

In the operation of wells with intensive sand production the sand plugs that create local hydraulic resistance are often formed, under the sand plug increases the dynamic bottom-hole pressure, reduce the enclosing depression in the well and output per day of oil from the well. Deep pump continues to pump fluid from the well. Therefore, the dynamic level of liquid above the sand plug drops down from its optimum value.

Return the level to its optimal position is possible only after flushing the sand plug. This flushing is a great technological process carried out by the underground repair brigade using the respective equipment and unit. As can be seen here regulation of dynamic liquid level (i.e. the return to its optimal mode) is carried out not automatically but manually, because currently there is no any universal automatic regulator to solve this problem.

As in the cases of origin of different residue in the wells a similar situation is occured .

For example, in "Gum adasy" OGPD in one well of the various formation waters of two layers shifted to each other, and as a result solid salt precipitate was that formed, thus pipes for cleaning were brought to the surface and the inner walls of these pipes was difficult to clean even with using of the mill operation.

From the above examples it is clear that to return the level to its optimum value each time it is necessary to regulate this parameter and better to carry out this regulation automatically, i.e. by means of the automatic regulator. However, currently this auto-regulator is be out, therefore, the regulation is executed manualy.

In the fifth paragraph of the chapter in the dissertation**,** a method for determining the exact value of the friction force acting on the horsehead is proposed. In this method, by known methods, the values of all the forces acting on the horsehead are determined. In addition, with the help of a dynamometer, a dynamic card is removed from which the maximum load acting on the horsehead is also graphically determined. The ordinate of the upper horizontal straight dynamogram gives the maximum load on the horsehead, which also includes friction force. The difference between maximum force on the dynamogram and in a certain calculation way gives the value of friction.

In the sixth paragraph of this chapter the method of determining of the optimum flushing frequency of the sand plugs is proposed.

Figure 3 shows a scheme of a deep pumping well at the bottom of which a sand plug is being formed. On this scheme, the following parameter designations are adopted; Pc – dynamic bottom-hole pressure; P_1 pressure at the upper end of the sand plug; P_0 oil pressure in the dynamic level of the well; P is the plug pressure at the current height; D is the inner diameter of the production casing of the well; H is the height of the dynamic column of oil in the well; h (t) is the current height of the formed plug in the well; t is the recorded time at the beginning of the plug formation; ρ is the oil density; g is the acceleration of gravity; K_1 – plug permeability; μ is the dynamic viscosity of oil.

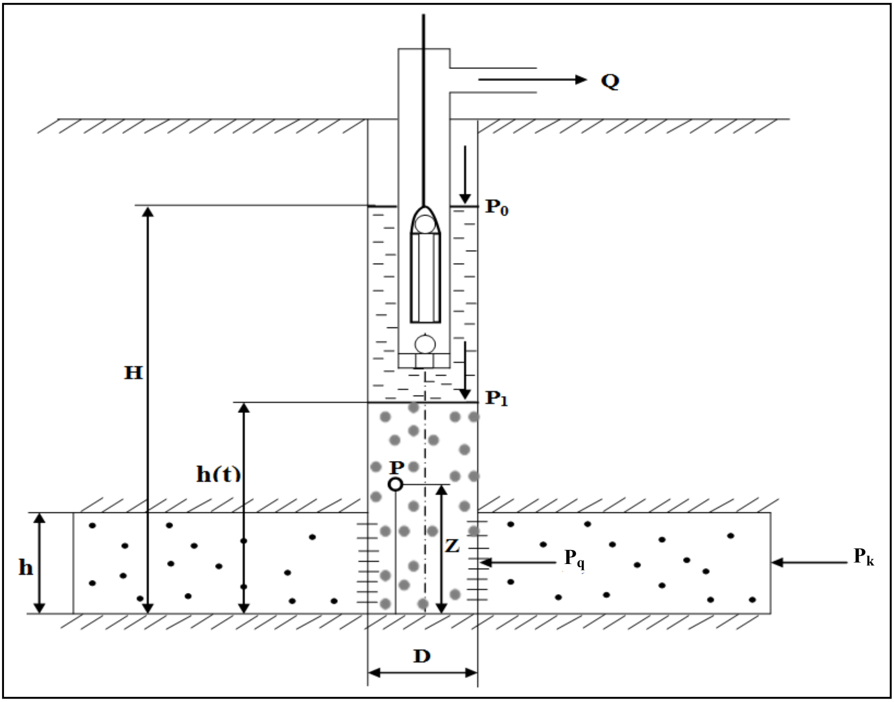

Figure 3. Scheme of a sucker rod pumping oil well with a sand plug

It is known, that the continuation of the sand plug formation process in the well results with the decreasing of oil and water production per day. For large reductions of these indicators sand plug is washed. However, such work does not meet the scientific approach to solve this problems.

Here the main task lies in the right choise of the height needed to carry out the most effective flushing of the sand plug.

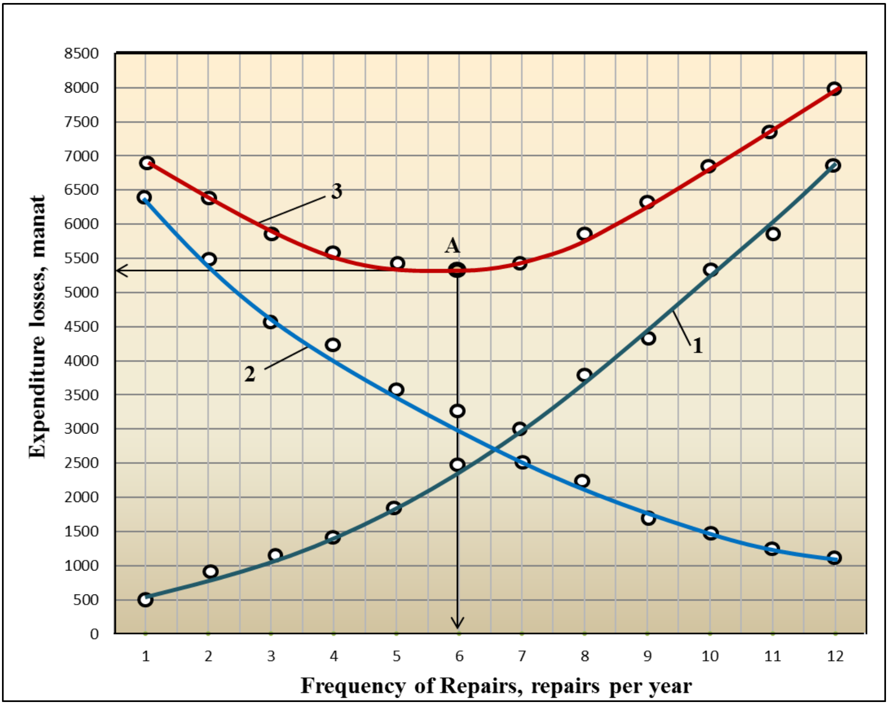

Diagram 3. Dependencies of financial expenditures associated with washing sand plugs in well 308 of the Gushkhana field

1–graph of the dependence of the costs of washing sand plugs on the frequency of repairs; 2–graph of the dependence of the loss of oil production on the frequency of repairs; 3–graph of the dependence of the total monetary loss from both factors on the frequency of repairs.

To determine this effective parameter the hydrodynamic task is solved and the formula for the pressure P_1 at the upper end of the sand plug for the production per day of oil filtrating through the sand plug and for the production per day of oil flowing from the formation into the well P_c is deduced .

In a working well, for the dependence h = h(t), the following formula is adopted:

$$h(t) = \frac{H}{T} \cdot t$$

where T is the duration of complete formation of a sand plug.

The value of H and T are different in different wells: therefore, for each well, the frequency of repair associated with flushing of the sand plug are different. For this reason, the optimal frequency of repair of each well must be determined correctly

The following is one example.

H=300 m, T=30 days=1 month, the frequency of repair n=12 repair per year.

To determine the optimal frequency of repairs for each of the n=1,2,3,4,5,6,7,8,9,10,11,12 repair per year the losses in oil production and the amount of expired costs are calculated. From them the option for which the expenditure has got minimal value is selected.

Diagram 3 for well №308 of the Gushhana oil field shows the graphs of the dependencies of the financial costs associated with cleaning of the sand plugs.

At A.D.Amirov OGPD average expired cost for flushing of one sand plug is 573 manat.

The dependence of the loss of oil from the frequency of repairs is monotonically decreasing; i.e. with the decreasing frequency of repairs, the loss of production increases.

To construct graph 3 the relevant current ordinates are summarized. The figure shows that graph 3 consists of two parts: the first part with increasing of repairs frequency total losses decreases, i.e. the dependency is monotonically decreasing, and the second part with increasing frequency of repairs the total cost is increased, i.e. the dependence is monotonically increasing.

The ordinate of the point A being the boundary of these two parts gives the minimum total cost and the absciss is the optimum frequency of repair.

In the seventh paragraph of the fourth chapter, the solution of the hydrodynamic problem of one-dimensional movement of a compressible viscous-plastic fluid in a compressible reservoir to a linear gallery under water drive mode was presented. As a result, equations that make it possible to determine the pressure on the gallery and the specific gravity of oil for the gallery, put into operation with a constant flow rate in dynamics over time t have been obtained.

Graph 4 shows the designations of the following parameters: P_i – initial reservoir pressure; γ_i is the specific gravity of oil; m_i – reservoir porosity coefficient; G (t) constant weight flow rate of oil produced from the gallery and filtered from a unit cross-section of the formation. It is required to determine the bottom-hole pressure P_0 subsequent after the expiration of time t after the gallery launched into operation and the specific gravity of oil is γ_0.

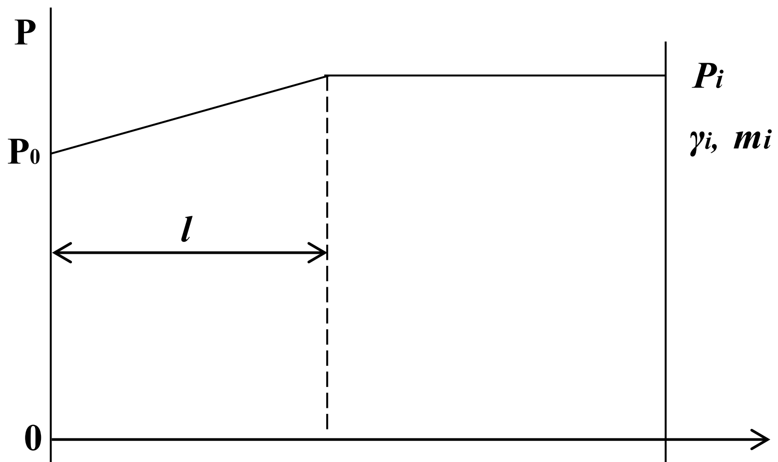

Diagram 4. Scheme of a strip-like oil reservoir

It is assumed that the length of the strip-like reservoir is L, and the distance at the boundary of the influence of the depression l, x is the spatial coordinate (abscissa).

To solve this task, the method of sequential change of stationary states was used and the following formula is deduced.

$$l = \sqrt{\frac{V(t)}{\frac{1}{2}\left(\frac{1}{k_r^*} + \frac{m_i}{k_l^*}\right)\left[\frac{\vartheta(t)\eta}{k} + \frac{\alpha_0 \tau}{\sqrt{k_1}}\right]}}$$

$$P_0 = P_i - \sqrt{\frac{\left[\frac{\vartheta(t)\eta}{k} + \frac{\alpha \tau_0}{\sqrt{k_1}}\right]V(t)}{\frac{1}{2}\left(\frac{1}{k_r^*} + \frac{m_i}{k_l^*}\right)}}$$

$$\gamma_0 = \gamma_i \left(1 - \frac{1}{k_l^*}\sqrt{\frac{\left[\frac{\vartheta(t)\eta}{k} + \frac{\alpha \tau_0}{\sqrt{k_1}}\right]V(t)}{\frac{1}{2}\left(\frac{1}{k_r^*} + \frac{m_i}{k_l^*}\right)}}\right)$$

The physical quantities involved in these expressions are as follows:

η – structural viscosity of oil in reservoir conditions;

α = 167 · 10^{-4} – coefficient;

τ_0 – the initial shear stress of oil in reservoir conditions;

k – permeability of the reservoir for oil;

k_1 – absolute permeability of the formation for the air;

k_r^* – modulus of elasticity of the rock;

k_l^* – modulus of elasticity of the rock of the oil.

Conclusions

1) The importance of determining the reservoir pressure in sand-producing deep pumping wells without stopping their operation and avoiding accidents and complications was noted, in addition, a method for determining the nature of oil for high-viscosity oils and viscous-plastic formations, as well as the operational parameters of the reservoir and reservoir parameters of wells by research two-sided bottomhole pressure build-up curves, which reduces the time spent on research was developed.

2) An effective method for changing the operating mode of an oil deep-well pumping well, determined by adding a constant flow rate of liquid, which makes up a certain part of its flow rate according to studies of continuous operation of the well for each new mode has been developed.

3) In order to improve the efficiency of field studies of water-cut deep-well oil wells, it was determined the need to determine the choice of the depth of the suspension of the submersible pump, avoiding entering the wellbore zone with the greatest water accumulation, and determining the depth of immersion of the pump below the dynamic level of the liquid, depending on the value of the gas factor

4) A hydrodynamic method of periodic isolation of formation waters in flooded deep pumping wells based on the use of degassed “dead” oil as an isolating agent is proposed.

5) A method for determining the frequency of flushing sand plugs in sand-producing wells has been developed and prepared.

6) Methods for the effective determination of reservoir performance and reservoir properties parameters without stopping the operation of downhole pumping wells have been proposed.

7) A method for determining the value of the friction force acting on themulehead, taking into account the removal of an additional dynamometer chart has been developed.

Main content of dissertation reflected in the following works:

1. Guliyev, R.A., Khanaliyev, V.B. The selection of optimum depth for submergence of pump into the liquid in drowned sucker rod-pumping wells // – Baku: Azerbaijan Oil Industry Journal, – 2015. №2, – pp. 30-35.

2. Khanaliyev, V.B. For the control of operation of the downhole sucker rod pumping the tool "Quantor-4micro" and improvement research // Materials of the XIX Republican Scientific Conference for the Doctorates and Young Researchers dedicated to the 70th anniversary of ANAS, − Bakı: − 3 fevral, − 2015, − pp. 101-103.

3. Guliyev, R.A., Khanaliyev, V.B. The method of reservoir pressure determination without stopping of downhole pumping unit // – Moscow: Oilfield Engineering Scientific-technical journal, VNIIOENG, – 2015. №9, – pp. 41-44.

4. Samadov, T.A. Static pressure determination of the reservoirs containing high-viscous newtonian and viscous-plastic oils by bilateral pressure recovery / T.A.Samedov, S.D.Mustafayev, R.A.Guliyev [and oth.] // Oilfield Engineering Scientific-technical journal, VNIIOENG, − Москва: − 2016. №1, − pp. 44-48.

5. Mustafayev, S.D., Guliyev, R.A., Khanaliyev, V.B. Control of operation of the well pump unit on the device “Quantor-4micro” //, − Yekaterinburg: International Research Journal, − 2016. №1 (43), − pp. 118-122.

6. Mustafayev, S.D. Simultaneous motion of a compressible viscous-plastic oil with a compressible layer with water drive to the rectilinear gallery / S.D.Mustafayev, F.A.Samedov, N.S.Sadygova [and oth.] // “Azerbaijan Science” International scientific-theoretical journal, – 2016. February, – pp. 23-26

7. Khanaliyev, V.B. Study of deep sucker-rod pumping wells with “Quantor-4micro” device // Materials of the XX Republican Scientific Conference for the Doctorates and Young Researchers dedicated to the "Year of Multiculturalism" in Azerbaijan, − Baku: − 24-25 may, − 2016, – pp. 153-154.

8. Khanaliyev, V.B. Determination of the velocity propagation

of sound in the wellbore for accurate measurement fluid levels in pumping wells // – Baku: Transactions of Azerbaijan Institutes of Technology journal, – 2017. №1, – pp. 69-77.

9. Huseynov, Sh.Sh., Guliyev, R.A., Khanaliyev, V.B. Isolation of reservoir water in sucker-rod pum wells of "South wrinkle" field in Absheronneft OGPD // – Baku: Azerbaijan Oil Industry Journal, − 2017, №7-8, − pp. 35-38

10. Khanaliyev, V.B. On regulations of dynamic level of liquid in sucker rod downhole pump oil wells // − Baku: “Eco-Energetics” Scientific-technical journal, − 2017. №3, − pp. 30-36.

11. Samadov, T.A., Mustafayev, S.D., Khanaliyev, V.B. Multifunctional action, the efficiency of maintenance of sucker rod pump oil wells applied to increase // − Baku: “Eco-Energetics” Scientific-technical journal, − 2017. №3, − pp. 90-95.

12. Mustafayev, S.D., Guliyev, R.A., Khanaliyev, V.B. A method of operation mode change in sucker-rod pump oil production wells // – Baku: Azerbaijan Oil Industry Journal, –2017. №12, – pp. 21-25.

13. Khanaliyev, V.B. Definition of optimum suspension for underground pipes column in flooded sucker rod pump oil wells // – Baku: Azerbaijan Oil Industry Journal, – 2018. №2, – pp. 27-31.

14. Samadov, T.A., Mustafayev, S.D., Khanaliyev, V.B. Multlfunctional action, the efficiency of maintenance of sucker rod pump oil wells applied to increase // Materials of IInd International Scientific-practical conference “Bulatov’s Readings”, – Krasnodar: «Publishing House – Yug», Chapter 3, 31 March, − 2018, pp. 289-294

15. Khanaliyev, V.B. On regulations of dynamic level of liquid in sucker rod downhole pump oil wells // Materials of IInd International Scientific-practical conference “Bulatov’s Readings”, – Krasnodar: «Publishing House – Yug», Chapter 3, 31 March, − 2018, pp. 321-323

16. Mustafayev, S.D., Guliyev, R.A., Khanaliyev, V.B. A new method for determining reservoir pressure in rod deep-pumping wells // − Yekaterinburg: International Research Journal, − 2020. №2 (92), − pp. 98-104.

17. Khanaliyev, V.B. Determination of the friction force acting on the balancer head in rod deep-pumping wells // – Baku: Azerbaijan Oil Industry Journal, – 2020. №2, – pp. 30-33.
18. Mustafayev, S.D., Guliyev, R.A., Khanaliyev, V.B. A new method for determining reservoir pressure in rod deep-pumping wells // Materials of IV International Scientific-practical conference “Bulatov’s Readings”, – Krasnodar: «Publishing House – Yug», Chapter 2, 31 March, − 2020, pp. 337-343

In the works carried out with co-authors, the personal work of the author:

[2], [7], [8], [10], [13], [15], [17] - performed independently.

[1], [5], [9], [12] - statement of the problem, research work and analysis of the results.

[3], [4], [6], [11], [14], [16], [18] - the shares of the authors are the same.

The defense will be held on 30 June, 2021 at 11:00 at the meeting of the Dissertation council ED 2.03 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at Azerbaijan State Oil and Industry University.

Address: AZ1010, Baku, D. Aliyeva str., 227

Dissertation is accessible at the Library of Azerbaijan State Oil and Industry University.

Electronic versions of dissertation and its abstract are available on the official website of the Azerbaijan State Oil and Industry University.

Abstract was sent to the required addresses on "08" may 2021.

Signed for print: 07 May, 2021

Paper format: A5

Volume: 38224

Number of hard copies: 30