KHAZAR UNIVERSITY

School: **Engineering and Applied Science**
Department: **Petroleum Engineering**
Major: **Petroleum and Gas Engineering**

MS THESIS

Theme: Complications occurring in the exploitation of oil wells with sucker-rodpumps and struggling measures

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Abstract

Various factors negatively impacting the work of the sucker-rod pump have been studied and methods applied in the oil fields for preventing these obstacles have been clarified in the graduation thesis.

The First Chapter is about the investigation of hazardous effect of associated gas penetrated into well bottom together with oil through the layer, and about the importance of use of gas anchors for carrying out the separation process of gas in the well bottom. Besides, scope of application of every anchor structure, that is, their effective use condition is defined.

In the Second Chapter, the negative impact of sand penetrating into the wells together with oil or ground water has been comprehensively explained.

In the Third Chapter, there are talking about the cleaning and saving pumps from bad impact of sand and protect them from all other struggles. The chapter highlights the negative impact of sand on work of the plunger pumps.

To prevent the mentioned complications occurred in the result of investigations, analysis and studies, certain measures have been worked-out and presented as a result of the thesis. These measures are of great practical importance and their application will stimulate the increase of oil and gas production in the fields.

XÜLASƏ

Mövzunun aktuallığı. Hazırda neft mədənlərində ən geniş tətbiq olunan istismar üsulu ştanqlı dərinlik nasos üsuludur ki, bu da neft yataqlarının işlənməsinin sonuna qədər tətbiq edilir. Dünyada hasil edilən neftin 45%-dən çoxu bu istismar üsulu ilə cıxarılır.

Ştanqli dərinlik nasos istismar üsulu ən kiçik debitli və həm də ən böyük əmək həcmli üsul olduğuna baxmayaraq, onun geniş miqyasda tətbiq edilməsi (məsələn, keçmiş SSR-də 1990-cı ildə 65%-dən cox olmuşdur) onunla izah edilir ki, kiçik debitli quyuların sayı çoxdur və bunlar üçün ştanqli dərinlik nasosları ilə istismar digər üsullara nisbətən hələ də teniki cəhətdən özünü doğruldur və iqtisadi cəhətdən səmərəlidir.

Qeyd etmək lazımdır ki, bu üsulla 4000 m-ə qədər dərilikdən nefti hasil etmək olur və müəyyən şəraitlərdə bu üsulun koməyliyilə bir quyudan 450t/gün-ə qədər maye debitlərini almaq olur.

Ştanqli dərinliknasos qurğusunun konstruksiyasının sadəliyi, ona xidmətin mürəkkəb olmaması və kifayət qədər geniş diapozonda həmin quyulardan depitlərin alinmasının mümkünlüyü bu istismar üsulunun geniş tətbiqinə gətirib çıxartmışdır.

Keçmiş SSR-də neft mədənlərində işləyən istismar neft quyularının yarısından çoxunu, Azərbaycanda isə 70%-dən çoxunu belə quyular təşkil edir.

Neft quyularının başqa üsullarla istismarında olduğu kimi ştanqlı dərinliknasos quyularının istismarında da bir çox əngəlliklər və mürəkkəbləşmələr müşahidə olunur.

Azərbaycanın neft mədənlərində onlar əsasən aşağıdakılardır:

1) Intensiv qum təzahürləri;
2) Səmt qazının plunjerli dırinliknasosunun işinə mənfi təsiri;
3) Quyuların məhuslunun vaxtından qabaq sulaşması;
4) Yeraltı avadanlıqda duzun çökməsi;
5) Quyu məhsulunun qazlaşması və.s

Bu magistr işinin məqsədi həmin yeni tərtibatları və texnologiyaları yığcam şəkildə şərh etmək və konkret şəraitlər ücün onların seçilməsi üsullarını göstərmək ve tətbiq dairələrini mümkün qədər genişləndirməkdir.

Magistr işində əsasən aşağıdakı mübarizə məsələləri şərh edilmişdir:

1) ştanqli dərinliknasos quyularında qazın mənfi təsirini almaq üçün quyudibi separasiya tərtibatlarının – qaz lövbərlərinin tətbiqi məsələləri;

2) həmin quyularda qumun mənfi təsirinin qarşısını almaq üçün quyudibi seperasiya tərtibatlarının – qum lövbərlərinin tətbiqi məsələləri;

Magistr işinin məzmunu.

Magistrişi girişdən, üç fəsildən, nəticədən və ədəbiyyat siyahısından ibarətdir.

Girişdə mövzunun aktuallığı əsaslandırılmış, işin məqsədi və məsələləri şərh edilmişdir.

Birinci fəsildə ştanqlı dərinlik nasosunun işinə qazın təsirilə əlaqədər əngəlliklər və mübarizə tədbirləri izah edilmişdir;yəni neftlə birlikdə hasil edilən səmt qazının plunjerli dərinlik nasosunun işinə mənfi təsiri ətraflı aydınlaşdırılmışdır.Bu xoşagəlməz hadisə ilə mübarizə aparmaq üçün müxtəlif konstruksiyalı qaz lövbərlərinin tətbiqi məsləhət görülmüşdür.Burada həm də qaz lövbərlərinin hesabı təqdim edilmiş və onların seçilməsi üsulu göstərilmişdir.Bundan başqa səmt qazının nasosların işinə mənfi təsirinin dərəcəsi qiymətləndirilmişdir.

İkinci fəsildə ştanqlı dərinliknasosunun işinə qumun təsirilə əlaqədar əngəlliklər və mürəkkəbləşmələr göstərilmiş və onlarla mübarizə etmək üçün tədbirlər göstərilmişdir.

İkinci fəslin əsas mövzusu qumun plunjerli dərinliknasosa mənfi təsiri və bu mənfi təsiri aradan qaldırmaq üçün istifadə olunan müxtəlif növ avadanlıqlar və onların iş prinsipi araşdırılmışdır. Bu istifadə olunan avadanlıqlara:

1) Süzgəclər
2) Qum lövbərləri
3) Boru içi boş ştanqların tətbiqi
4) Ərsinlər və burulğan yaradanlar

Üçüncü fəsildə isə qumun plunjerli nasosda ümumiyyətlə yaratdıqı mənfi təsirlər və onlara qarşı aparılan mübarizə usullarından danışılmışdır. Bunun üçün istifadə olunan kapron süzgəclər və onların istifadəsinin səmərliliyi geniş muzakirə edilmişdir.

Bütün bu araşdırmalar, təhlillər və tədqiqatlar nəticəsində qeyd edilmiş mürəkkəbləşmələrin qarşısını almaq üçün müvafiq tədbirlər işlənib hazırlanmış və dissertasiyanın nəticəsi kimi təqdim edilmişdir.Bu tədbirlərin böyük praktiki əhəmiyyəti vardır və onların tətbiqi mədənlərdə neft ve qaz hasilatının artırılmasına təkan verəcəkdir.

INTRODUCTION

Theme actuality. At present the exploitation method widely used in the oil fields is sucker-rod pumps which is applied till the completion of oil deposits.

More than 45% of produced oil is extracted by this exploitation method in the world. Though exploitation method with sucker-rod pumps has less output and requires much work, its wide usage (for example, in 1990 it was more than 65% in USSR) is explained with fact that the number of small output wells is high and application of exploitation method with sucker-rod pumps is still applicable for these wells and is effective from financial point view.

It should be noted that it is possible to extract oil from 4000m depth by this method and 450 t/day liquid outputs may be extracted from a well by this method under certain conditions.

The simplicity of the structure of the sucker-rod pumps, its uncomplicated maintenance and the possibility of extracting broad range of outputs from these wells (from m3/day to hundreds m3/day) caused to the wide use of this exploitation method.

More than half of the oil well bores in the oil fields of the former USSR, and more than 70% of oil wells in Azerbaijan are of this kind.

Russian scientist such as L.S. Leybenzo, V.I. Churshanov, A.S. Virnovski, A.G. Babikov and I.A. Charny, and Azerbaijan Institute of Mechanical Engineering, especially S.K. Aliverdizade, V.M. Rabinovich, A.N. Adoni and others have greatly contributed to the development and improvement of sucker-rod pump devices.

As in any other exploitation method applied in oil wells, there are also many obstacles and complexity in the exploitation of sucker-rod pumps.

In Azerbaijan oil fields, there obstacles are as follow:

6) Intensive sand appearance;

7) Negative impact of associated gas on the work of plunger pumps;

8) Water of well products beforehand;

To combat all these unpleasant cases, the scientist and expert-engineers worked out new layouts and new technologies which are widely applied in the oil fields.

The **purpose of this Master Thesis** is to analyze these new layouts and technologies in brief, to define their selection method for concrete conditions and to expand their application scope.

Mainly, the following struggle issues are stated in the thesis:

1) Application of well bottom separation works, that is use of gas anchors for preventing the negative impact of gas in the sucker-rod pump wells;

2) Application of well bottom separation works, that is use of sand anchors for preventing the negative impact of sand in the sucker-rod pump wells;

3) Combat salt precipitation at those watered wells;

4) Combat the paraffin precipitation in these wells, etc.

Content of the thesis

Master Thesis consists of Introduction, Three Chapters, Conclusion and Literature.

The Introduction section is about the theme actuality, the purpose and issues of the thesis.

In the First Chapter, the obstacles related with the gas impact on work of sucker-rod pumps and struggle measures have been set out, on other words, the negative impact of associated gas produced together with oil on the work of plunger pump has been clarified in detail. To combat this unpleasant case, the use of gas anchors with various designs was recommended. Moreover, the negative impact degree of associated gas on the work of pumps has been assessed.

The obstacles and complications related with impact of sand on the work of sucker-rod pumps are cleared and the struggle measures are recommended in the Second Chapter.

In the Second Chapter, there are talking about the cleaning and saving pumps from bad impact of sand and protect them from all other struggles.

The chapter highlights the negative impact of sand on work of the plunger pumps. Besides, the application of the following struggle methods is recommended:

1) Use of filter;
2) Use of sand anchors;
3) Use of empty (pipe) rods;
4) Use of scrapers and whirl forming devices;

In the Third Chapter, the main idea is around using the several measures for protecting pumps from harmful impact of sand.

Generally there are different measure tools which used in oilfield for protecting pumps such as scraper-vortex generator, the method adding liquid to annular space and the device for these operations. To protect pumps from all kind of harmful sand content using of this applications is recommended:

1. Application of method for easy operation of the well;
2. Application of method for adding liquid to the annular space;
3. Use of capron sand filter in sucker-rod pumps;

Application of method on control of the changes in the height of the sand plug formed in the operative sucker-rod pumps.

The proposals given in the Conclusion Section of the Thesis for concrete conditions are absolute and their application will be productive.

CONTENTS

CHAPTER I

OBSTACLES RELATED WITH THE IMPACT OF GAS TO THE WORK OF SUCKER-ROD PUMPS, AND STRUGGLE MEASURES

1.1. Negative Impact of Associated Gas to the Plunger Pump's Work

If layer pressure is less than saturation pressure of gas in oil, then free gas separates from liquid phase in layer and two phase leakage toward the bottom of wells occurs. In this case, the amount terms of liquid and gas phases depend on value of saturation pressure and condition of dynamic liquid level in the well during the exploitation process (that is, value of well bottom pressure). It may happen that, one-phase leakage may occur in the drainage zone (that is, gas may be solved in oil), but while penetrating into well, gas may be separated as the bottom pressure decreases than the saturation pressure. Free gas inflows to the pump inlet together with oil, and captures the part of useful capacity of the pump cylinder and decreases the pump efficiency. In certain cases, work of valves is completely paralyzed due to the gas impact and the pump practically does not produce liquid.

Oil and gas inflows to the pump cylinder at the upstroke of the plunger, and their $R = V_q / V_n$ capacity ratio remains on any fixed value. In case of greater flexibility of gas (squeeze) and greater value in comparison with oil, part of gas may be exhaled from compound at the beginning of down stroke of the plunger and may gathered over liquid under the injection valve. V full capacity of cylinder under the plunger will fill with oil and gas at the end of the upstroke of plunger. This capacity consists of V_s volume emitted by plunger and $V_{зяр}$volume of harmful area, that is [7; 13]:

$$V = V_s + V_{зяр} = V_n + V_q \qquad (1.1)$$

$V_q = RV_n$:

$V_s + V_{зяр} = V_n + RV_n$

Then

$$V_n = \frac{V_s + V_{зяр}}{1+R} \qquad (1.2)$$

is concluded.

Volume under plunger defined by the distance between the traveling and standing valve in the down stroke position of the plunger is called harmful space of pump.

The total volume of oil under plunger at the end of the upstroke of plunger is equal to the sum of oil in the harmful space and volume of oil penetrating into pump in upstroke. If not taking into account the oil volume after the separation of gas, this last volume [8] is expressed as follows:

$$V_n' = V_n - V_{зяр} = \frac{V_s + V_{зяр}}{1+R} - V_{зяр} \qquad (1.3)$$

The correlation volume of oil penetrating under the plunger in one stroke to the volume of plunger's drawn capacity is called filling ratio and is defined with following formula:

$$\beta = \frac{V_n'}{V_s} = \frac{V_s + V_{зяр}}{V_s(1+R)} - \frac{V_{зяр}}{V_s} \qquad (1.4)$$

If showing the comparison of harmful space $V_{зяр}$ volumewith plunger's drawn capacity, (1.4) formula will be as follow:

$$\beta = \frac{k+1}{1+R} - k = \frac{1-kR}{1+kR} = 1 - R'(k+1) \qquad (1.5)$$

Here R' - is amount of gas in oil (concentration), that is:

$$R' = \frac{V_q}{V_q + V_n}.$$

In this case, following may be concluded:

1) As $k = V_{зяр}/V_s$ amount decreases, that is, the volume of harmful spacedecreases and plunger's S_{pl} movement length increases, filling ratio of pump β rises.

2) As the ratio of spilled gas volume to oil volume decreases, that is, as $R = V_q / V_n$ decreases, the filling ratio of pump increases.

Thus, following measures shall be taken to combat the harmful impact of gas while the sucker-rod pump works:

1) To decrease the volume of the harmful spaceby placing the traveling valve in the under part of the plunger, that is, to bring together traveling and standing valves in maximum in the down stroke position of the plunger;

2) To increase the stroke length of plunger;

3) To increase immersion depth of the pump, in this case, the immersion pressure increases and absolute volume of free gas inflowing the pump decreases in this regard, that is, amount of R decreases;

4) To apply special equipment, that is, to use gas anchor to transfer part of free gas in the inlet from pump to well (annular space): this is V_q and thus, decreases the ratio of $R = V_q / V_n$.

When there is no free gas in oil, i.e. when it is $V_q = 0$ and $R = 0$, the amount of filling ration of the pump β calculated with (1.5) formula will be equal to the unit not depending on the volume of harmful space; this will be achieved if other factors do not decrease its amount. If there is much gas in the composition of oil and if the volume of harmful spaceis greater, the sum of $R \cdot k$ may be closer to the unit, and consequently, β ratio will be equal to zero. In this case, gas gathered between the valves during the upstroke and down stoke of the plunger may change by pressing or expanding, this prevents the opening of valves, i.e. pump stops working.

The terms of this cut off according to the (1.5) formula are as follows: if $\beta = 0$, it is $1 - kR = 0$ or $R \geq 1/k$. Thus, if the volume of harmful spaceis equal to plunger's drawn volume, then if k = 1, the term of cut off of products starts when $R \geq 1$, i.e., cut off starts when inflowing oil and gas volume is equal.

If oil completely separated from gas in the pump (full degassing of oil), harmful space under plunger does not become more harmful, as there is no gas in the composition of oil in this space, then, gas is not solved in the down stroke of the plunger and no gas separates from oil in the upstroke. In this case, the exhaled capacity of plunger does not suffer from the gas expansion. Thus, filling of cylinder may be decreased on the account of gas portion with spilled oil in the cylinder. In this regard, no harmful spaceexists, and (1.5) formula became as follows:

$$\beta = \frac{1}{1+R} \tag{1.6}$$

That is, filling ratio of pump, especially, depends on regard to the volume of gas and oil in the pump.The work of pump will not be cut off completely, as oil will go into pump in certain degree. The sufficient work of sucker-rod pumps in wells with relatively greater harmful space may be explained by partly or complete separation of gas from oil in pump. In this case, gas is produced considerably less.

In case of complete termination of the pump work, the renewal (restoration) of product starts after this or other intervals. This happens due to the increase of liquid level in the well (as in the increase of immersion depth of the pump) and on the account of oil gathered under the plunger by leaking from the circular gap between the plunger and cylinder from PSP. As internal leakages increase, the product of pump is restored more quick on other equal conditions. The restoration period of products may be very short, as a whole, the work of pump remains unsatisfactory. So, if there is gas in the pump well bores, the precautions shall be taken to prevent their negative impact.

In some cases, intermittent fountain jumps in the pump wells are observed in the fields and this occurs as a result of free gas penetrating through the layers when the valves do not work, or due to the impact of gas got out from the product in the upper part of PSP piping. Sometimes it seems that the value of pump yield coefficient has increased more than the unit.

However, this event has nothing to do with work of borehole pumps. In all cases, the filling coefficient of the pump decreases as the oil temperature increases, and this occurs as a result of decrease of oil viscosity and increase of leakage in this regard.

1.2. Gas anchor installed to the sucker-rod pump suction

Gas anchors installed to the sucker-rod pump suction is for separation of oil in the well bottom from the free and solution gas [3; 4].

There are many gas anchors with different structure, but notwithstanding their differences in structure, their work principle is identical and based on the formation of differential pressure, change of the direction of gas-liquid flow and its separation into several parts. It should be noted that great part of gas separated from gas and oil mixture passing through filter of the anchor enters to the annular space. The separation of gas mainly occurs in the filter of the anchor, that is, in annular space between production string and the body of gas anchor.

The effectiveness of the separation of gas from oil in the gas anchor depends on the relation between rise speed of the gas bubbles in liquid and flow speed of the mixture in the cover of the anchor. The size of bubbles becomes large as the viscosity of liquid increases. As it is seen, the flow speed of the mixture in the body of the anchor in the productivity of the pump depends on the cross-section area of the anchor body.

It follows that effectiveness of the separation will increase as the flow speed of liquid decreases, that is, it will increase as the area of anchor section will increase under all conditions. However, practically, diameter of body of gas anchor is limited to the diameter of the production string. So, the flow speed of liquid in the anchor does not always provide complete separation of oil from gas.

To get better results it is necessary to change gas flow in the anchor many times, that is, flow turnover is realized. In this case, gas bubbles in the turns of liquid track in the horizontal short ways on cross-section of the pipe (during laminar flow) fall into space near interior walls of the pipe and then rise up freely as the speed is very low there.

For the greatest effective separation of gas in bottom hole, the measures of gas anchors may be defined according to the following estimations:

Rise speed (m/sec) of small gas bubbles in viscose liquid can be calculated either with Stokes formula given below:

$$w = \frac{gd^2}{18\nu} \qquad (1.7)$$

or with Allen formula as given below:

$$w = 0{,}261 \cdot 10^2 \sqrt[3]{\frac{g^2}{\nu}} \qquad (1.8)$$

Where g is speed of force of gravity, m/cec2; d - diameter of gas bubbles, m; ν - kinematic viscosity of liquid, m2/sec.

First formula is correct for values of Reynolds unit not greater than 1, the second formula is for values of Reynolds unit between 10 and 300.

The average speed of liquid flow (m/sec) in the body of gas anchor during the whole cycle of pump may be expressed by the following formula by taking into account tightening of access and egress hole for liquid and by knowing the unequal distribution of speed on sections (speed is low near the anchor walls):

$$v_{or} = \frac{F_{pl} S_{pl} n}{\alpha F_{люв} 60} \qquad (1.9)$$

Where F_{pl} is radius of plunger's cross-section, m^2; S_{pl} is length of plunger's movement, m; n is swing number in a minute; α - is coefficient used from the volume of anchor taking into account the inequality of flow speed on narrowing of flow on turns and section of anchor body of liquid particles $(\alpha < 1)$; F_{anc} is radius of spherical section of anchor's body, m^2.

It is apparent that the separated gas bubbles are those having higher rise speed than the speed of liquid flow in the anchor. Thus, maximum size of the bubbles (entering the pump) should be defined by the following equality:

$v_{or} - w = 0$.

Grounding on this, it is possible to find the optimal measures of gas anchor by using the formulas (1.7), or (1.8) and (1.9). Thus, we will get the following result after simple mathematical transformation for application terms of Stokes formula:

$$F_{люв} = 0{,}0306 \frac{F_{pl} S_{pl} n \nu}{\alpha d^2} \quad (1.10)$$

Analogically, for Allen formula, we will get:

$$F_{люв} = 3{,}10 \cdot 10^{-2} \frac{F_{pl} S_{pl} n \sqrt[3]{\nu}}{\alpha d} \quad (1.10^{a})$$

As the rated diameter of gas bubbles decreases, effectiveness of anchor work will increase; however, this will require considerable increase of cross-section of the anchor. Besides the required section of the anchor body, it is necessary to provide sufficient length in order to achieve effective work of anchor. This length is considered only if any gas bubble entering to the body of anchor has completed its flow in the body during one complete movement cycle of the pump (during upstroke and down stroke). As the complete cycle duration is 60/*n sec,* the maximum hydraulic length of the anchor will be:

$$l_{h.maks} = \frac{60 \cdot v_{or}}{n} = \frac{F_{pl} S_{pl}}{\alpha F_{люв}} \quad (1.11)$$

If $\alpha = 1$:

$$l_{h.maks} = \frac{F_{pl} S_{pl}}{F_{люв}} \quad (1.12)$$

Where $l_{h.maks}$ is the maximum hydraulic length of the anchor, m; F_{pl} is radius of plunger section, m^2; F_{anch} - is radius of spherical section of anchor's body, m^2; S_{pl} is length of plunger's movement, m.

The length of the anchor's filter is defined by the following formula subject to keep the radius of section of gas-liquid mixture flow in turns:

$$l_{сцз} = \frac{F_k - F_{люв}}{\pi D_{люв} k_{люв}} \qquad (1.13)$$

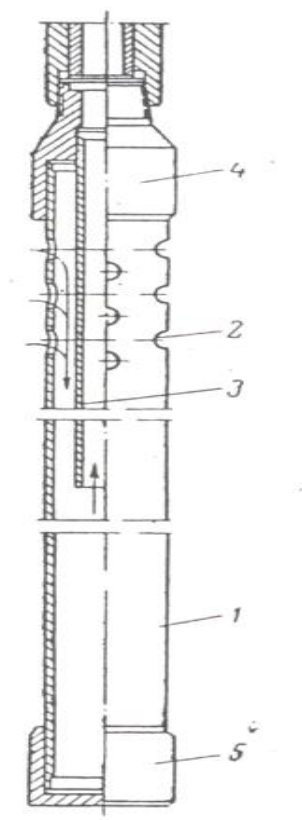
Where F_k and $F_{люв}$ is, accordingly, radius on external diameter of string gap and section of anchor body, m^2; D_{anch} is diameter of anchor body on average linear of thickness of the pipes, m; k_{anch} is openness ratio of the anchor filter, which is equal to the quotient of total radius of holes in the filter to the radius of full surface of the pipe.

Multi-sectional, submersible gas anchors and screen anchors are applied in the oil fields. The work of simple gas anchor of SG-1 type is based on the principle of changing the direction of flow of gas-liquid flow to 180°. You can find the picture of SG-1 gas anchor in Pic. 1.1.

While the pump is working, part of gas flowing with liquid twice changes its flow direction until penetrating into pump: it flows on spherical space between anchor body and suction pipe and then flows from the spherical space to the suction pipe and pump; and other part of gas flows on spherical space between body and suction pipe and then gathered at the upper part of the anchor filter and forms gas pad. While the volume of gas pad increases, part of gas is separated in the form of big bubbles and passing through upper holes of the filter increases to annular space without falling to pump suction. [14; 15]

1.3. Single cylinder gas anchor

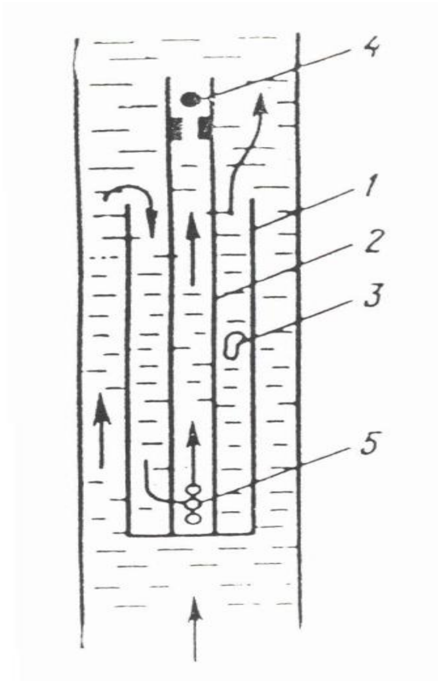
Working principle of the single cylinder gas anchor of SG-1 type which is widely applied in the oil fields is based on changing the flow of gas and liquid mixture for 180°.



Pic.1.1. SG-1 gas anchor

1 –Anchor body; 2 –slots in anchor body;

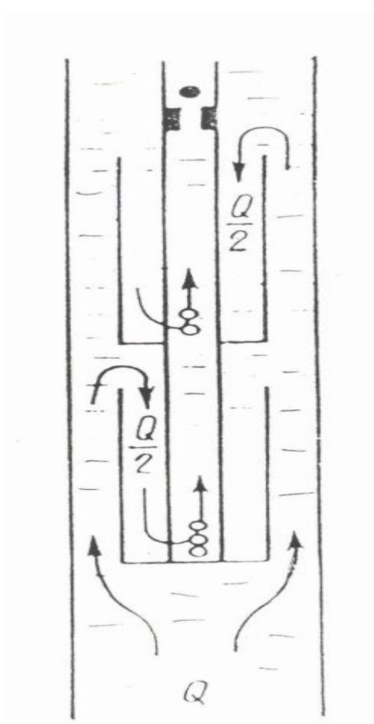
3 –suction pipe; 4 - adapter; 5 - tap



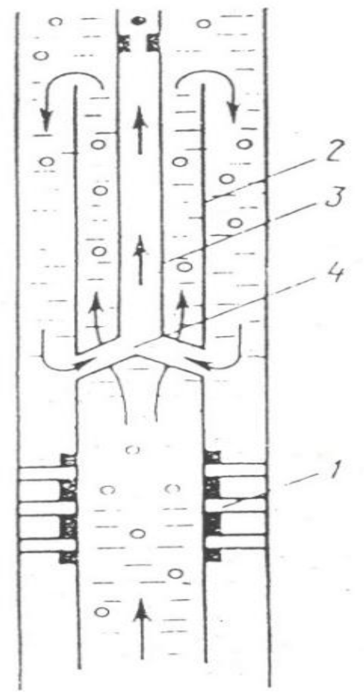
Pic.1.2. Single cylinder gas anchor

1 –Anchor body; 2 –Central pipe; 3 –Gas bubble;

4 –Suction valve of pump; 5 - Slots



Pic.1.3. Principle layout of two-cylindered gas anchor



Pic.1.4. “Umbrella” like gas anchor
1- elastic packer; 2 –anchor body;
3 –suction pipe; 4 –channel

Gas and liquid mixture in this anchor changes its flow direction twice until penetrating into pump while the pump is working; this flow concerns to the part of gas extracting from bed; firstly, flow occurs in the spherical space between anchor body and suction pipe, then from the spherical space to suction pipe and pump; other part of gas lows on spherical space between body and suction pipe and then gathered at the upper part of the anchor filter and forms gas pad. While the volume of gas pad increases, part of gas is separated in the form of big bubbles and passing through upper holes of the filter increases to annular space without falling to pump suction. Thus, bottom hole partial separation process is realized in the well.

1.4. Multi-sectional gas anchors of Azerbaijan Scientific Research Institute on oil recovery

Multi-sectional gas anchors are used when the productivity of the pumps is great and oil viscosity is high, and when the diameter of production string does not allow using the gas anchors with rated diameter. The layout of four sectional gas anchor used in the field is given in the Pic.1.5. This anchor consists of the following parts: 1-adapter; 2 – anchor cover; 3 – suction nipple; 4- nipple with sand cone. This multi-sectional anchor consists of four simple anchors and they work in parallel**.**

General consumption of liquid passing through the anchor is separated unequal on the sections. In order to achieve this, various numbers of holes are opened in the sections of the suction pipe and the number of these holes increases from top to bottom. The total length of the anchor is 2330mm, the length of each section is 530mm, and the length of each simple anchor (entering into system) is 200mm. The sections are joined to each other with help of nipples. Ends of these sections enter to these holes through small intermediate gap, and these are for small amount leakage of liquid. Thus, hydraulic compaction for separating sections from each other is created. There are sand cones in the first three sections which make better the extraction of solid particles (sand) from the suction pipe holes.

1.5. Gas anchors of New Grozny type

The work principle of this anchor is based on changing the flow direction of gas and liquid for 180° and using the pressure fall formed by liquid column between the anchor input and pump suction. The pump is installed 5-10m away from the end plug for gathering mechanical mixtures in the bottom of the anchor body.

Different structures of this anchor are applied in the oil fields; the layout of one of them is given on Pic. 1.6.

There are perforated areas in the anchor's body. There are slots with 10-12 diameter installed in the form of chess in the lower part of the anchor in order to let degassed oil enter from the spherical space to the pipe and then to the pump. The upper part of the anchor has wider slots due to its section and they are installed in chess form in parallel across the anchor axis. For effective work of the anchor, it is necessary to install the upper slots of the anchor above liquid level, and the lower slots below that level.

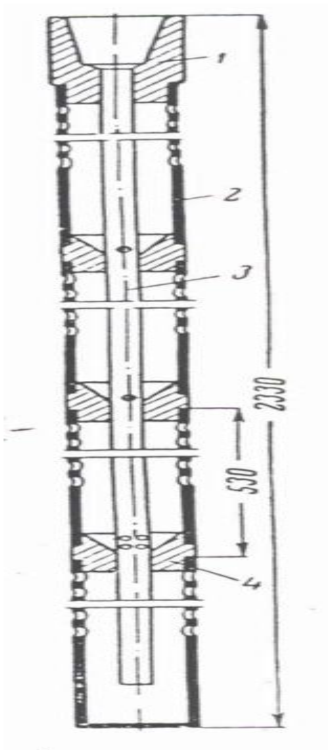
Depending on the dynamic level and immersion depth of the pump in this level, the length of the anchor pipe and distance between perforated areas can be defined. The length of the anchor pipe may be 80 thru 150m.

Before penetrating into pump, immersiondepth of pump into dynamic level during complete solution of free gas in oil is expressed by the following formula:

$$h_x = \frac{10Q_q}{Q_n \beta \gamma_n} = \frac{10}{\beta \gamma_n} G_0 \qquad (1.14)$$

Where h_x is immersion depth of the pump to the dynamic level (brought to the degassed oil column), m (this is required for complete solution of gas); Q_q is amount of gas entering to the gas anchor, m^3/day; Q_n is oil rate of the well, m^3/day; γ_n is relative specific gravity of oil; β - solution ratio of gas in oil m^3/m$^3 \cdot$at; G_0 - gas oil ratio, m^3/m^3.

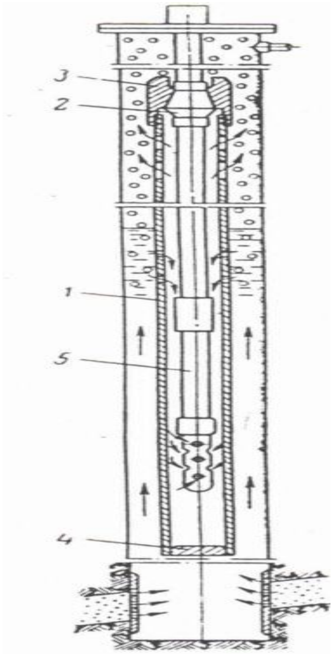
If there is water in the well product, gas oil ratio is accepted as $Q_q/(Q_n + Q_s)$ and instead of γ_n , γ_{qar} is taken.



Pic. 1.5. Four-sectional gasanchor

1 - adapter; 2 –anchor cover; 3 –suction pipe;

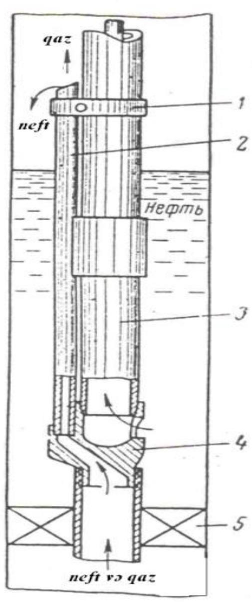
4 –cone like sand nipple



Pic.1.6. New Grozny gasanchor

1 –Anchorbody; 2 –Cone likespecialclutch; 3 – hangerclutch;

4 –end plug; 5 –subsurface pump



Pic. 1.7. Anchor-trap

1- Clamp; 2 –Leakage nipple; 3 - pump;

4 - nipple-adapter; 5 - packer

While inserting submersible anchor to the well, part of free gas will be separated in the annular space. Thus, immersion depth of the pump suction will be less than required in order to completely solve free gas in $1-k_s$ amount (where, k_s is separation ratio). It is apparent that immersion depth of the anchor is equal to h_{anc} and hydraulic length of the anchor is equal to l_{anc} and will be expressed by the following formula:

$$h_{люв}=l_{люв}=\frac{10(1-k_s)}{\gamma_n\beta}G_0 \qquad (1.15)$$

Thus, as it is seen from the (1.15) formula, hydraulic formula of submersible gas anchor not only depends on the solution ratio and gas factor, but also separation ratio: the length of the submersible gas anchor will be less as it increases:

We get it by dividing (1.15) formula to (1.14):

$$\frac{l_{люв}}{h_x}=1-k_s \quad (1.16)$$

Where we get:

$$l_{люв}=h_x(1-k_s) \qquad (1.17)$$

As $(1-k_s)<1$, to get that effect, the length of the gas anchor always will be less than amount required for immersion depth of the pump to the dynamic level without anchor and depends only the separation ratio.

The layout of the anchor-trap installed above the packer in the production string is given in Pic.1.7. The work principle of this anchor based on gas-liquid flow in the production string is directed to the annular space before getting to the pump suction; the upper end of the pipe is above the dynamic liquid level.

As a result of strict decrease of the speed of gas-liquid flow and the scattering of hole, gas separates, the production string rises up, and gas is produced from the annular space, and the degassed liquid entered to the pump suction [1,2,11,12,16].

1.6. Calculation and selection of gas anchor

Separation of gas (separation from the well product) in the well bottom, that is, in the gas anchor installed in the subsurface pump suction is called bottom hole separation and is considered more reasonable measure as the amount of gas penetrating into the subsurface pump decreases. Gas separated in bottom hole is directed to the annular space and then extracted. As a result, the recovery ratio of pump and actual productivity increases.

For example: Select the gas anchor required for specific condition given below and calculate the area of cross-section and length.

Gas anchor consists of two concentric pipes. 57mm pump works in the well. Plunger's stroke S=1,2 m, number of strokes is $n=9$ stroke/sec. conditional viscosity of oil extracted in well temperature, conditional viscosity = 2,5°, amount of water in well product is less than 80%. It is required to separate gas bubbles with diameter $d>0{,}15$sm.

Diameter of the production string d_k=8″; area of cross-section of the plunger of 57mm pump is F_{pl}=0,00255 m^2=25,5 sm^2; kinematic viscosity of oil is ν= 0,1575 cm^2/sec; application ratio of anchor is a=0,6

Solution of problem:

For low liquid flow, the cross-section area of the anchor is calculated as follow:

$$\Phi=0{,}00065\frac{F_{pl}Sn\sqrt[3]{\nu}}{ad} \quad (1.18)$$

$$F=\frac{0{,}00065\cdot 25{,}5\cdot 9\cdot 120\cdot \sqrt[3]{0{,}2575}}{0{,}6\cdot 0{,}15}=109{,}8\ \text{cm}^2$$

$$F=109{,}8\ \text{cm}^2$$

Diameter of the anchor body shall be big as possible (if there is not complexity with sand), then 2″ x 5″ and 2,5″ x 6″ pipes are taken to get the required cross-section area in the pipe combination.

2″ x 5″ diameters do not meet the condition of (1.18) formula, as spherical section area is 96,5 cm^2<109,8 cm^2 for this pipes.Thus, 6″ pipe is selected for body, and $d=2^1/_2$″ (as diameter of pump pipes) is selected for suction pipe. If there is not sand in well, then d_k=8″ protective production string allows the running of such anchor.

In this case, transitory cross-section area of the anchor:

$$F = F_{люв} - F_b = \frac{\pi}{4}\left(15{,}24^2 - 7{,}3^2\right) = 144{,}4\ \text{cm}^2$$

This result is more than enough.

The production string requires running the anchor consisting of two bodies with small diameter, but pipes with diameter less than above accepted.

The length of anchor is calculated below and following result is achieved:

$$l = \frac{F_{pl} S}{aF} \qquad (1.19)$$

$$l = \frac{25{,}5 \cdot 120}{0{,}6 \cdot 144{,}4} = 35{,}3\ \text{cm};\ l = 35{,}3\ \text{cm}.$$

In this case, anchor’s length l is calculated less than minimum allowed amount of $l_{\min} = 20D = 20 \cdot 12{,}24 = 304 \cdot 8$ cm. Thus, the anchor’s length is taken as $l = 305$ cm =3050 mm.

Now, let’s calculate the up flow speed of the gas bubble with diameter $d_{qab} = 0{,}15$ cm in liquid. Following formula is used in this regard:

$$C = 0{,}261 d \sqrt[3]{\frac{g^2}{\nu}} \qquad (1.20)$$

Values shall be put on place and calculated as follow:

$$C = 0{,}261 \cdot 0{,}15 \sqrt[3]{\frac{9{,}81^2}{0{,}1575}} = 15{,}37 \text{ Cm/sec}; \quad C = 15{,}37 \text{ cm/sec.}$$

The value of Reynolds parameter is as follow:

$$\mathrm{Re} = \frac{cd}{\nu} = \frac{15{,}37 \cdot 0{,}15}{0{,}15751} \cong 15$$

It may be concluded that, Allen formula is applicable.

Movement speed of liquid flow in cross-section of the anchor is calculated in the following way:

$$C_{лц} = \frac{F_{pl} Sn}{aF \cdot 60} \qquad (1.21)$$

$$C_{лц} = \frac{25{,}5 \cdot 120 \cdot 9}{0{,}6 \cdot 144{,}4 \cdot 60} = 5{,}3 \text{ cm/sec}; \; C_{лц} = 5{,}3 \text{ cm/sec}$$

As it is seen, this speed is lower than speed of $d = 1{,}5$ mm sized gas bubble.So, the anchor will be functioned well in more suitable conditions.

1.7. Determination of affect of gas on pump work

The solution of questions related with this subject is presented below.

Question.

According to the below information, the approximate completion ratio of the subsurface pump shall be defined: gas factor is G_0=20 m^3/m^3, solution ratio of gas in oil is $\alpha = 0{,}7$ m^3/m^3·at, pressure in pump inlet at the immersion depth is P=2 at, relative specific gravity of oil is $\gamma_n = 0{,}9$. Oil enters well without water.

Solution.

If the volume of the harmful space is V_{harm}=0, completion ratio of the pump as a result of gas affect is expressed by the following formula:

$$\eta = \frac{1}{1+V_{s.q.}}$$

Where, $V_{s.q}$ is the volume of free gas in produced liquid in the pump suction and is calculated with following formula:

$$V_{s.q.} = \frac{(G_0 - \alpha P V_n) K_{щяъ}}{P+1}$$

Where, G_0 is gas factor, m^3/m^3 (taken according to the amount of gas running with oil in the cross line of the pump); α is solution ratio of gas in oil, $m^3/m^3 \cdot at$; P is the pressure in the pump suction, at; in denominator (P+1) at; V_n is oil volume equal to $1m^3$; $K_{щяъ}$ radio taking into account the amount of oil volume in the produced liquid, per unit; in this question $K_{щяъ}$ =1.

By putting the defined number of their place in the formula, we get the following:

$$V_{s.q} = \frac{20 - 0{,}7 \cdot 2 \cdot 1}{3} = 6{,}2\,м^3/м^3; \eta = \frac{1}{1+6{,}2} \cong 0{,}14\,.$$

As it is seen, the coefficient of pump admission is very less. Thus, it is necessary to take measures, to install anchor and increase the pressure in order to reduce the harmful impact of gas.

If new Grozny type gas anchor is to be installed, then, gas dynamic is separated on liquid level and the separation reaches to 80%, and in this case, 20m3/m3 gas will enter to pump with 1m3 oil in the amount of $V'_{s.q} = \frac{20 \cdot 20}{100} = 4\,m^3/m^3$ (in atmospheric pressure); there will be P =2 atm free gas in the pump suction:

$$V'_{s.q} = \frac{4 - 0{,}7 \cdot 2 \cdot 1}{3} = 0{,}87\,m^3/m^3.$$

The coefficient of pump admission will be as follows:

$$\eta' = \frac{1}{1+0{,}87} = 0{,}53\,.$$

However, this amount is also not high enough and does not meet the exploiters requirements.

Let's see to which depth we shall lower the pump in order to have whole gas in the product, that is $V_{s.q}$ will be equal to zero:

$$V_{s.q} = \frac{4 \cdot 0{,}7 \cdot P}{P+1} = 0\,.$$

Where we get the immersion depth of pump into dynamic level in order to have pressure in the pump suction as P=5.7ati:

$$h = \frac{5{,}7 \cdot 10}{0{,}9} \cong 63\text{m}.$$

If the dynamic liquid level is above 63m of bottom hole, then this measure shall be applied. In this case, we can bring impact of gas on coefficient of admission to zero.

Question. Grounding on the following data, approximately calculation of gas impact on coefficient of subsurface pump admission shall be made.

Maximum stroke length of plunger of PGP-1 pump with catch rod of 70mm diameter is S_1=0.9m, and stroke length of plunger of PGP-2 pump with catch lock (valve at the bottom of plunger) is $S_2' = 0{,}9$m and $S_2'' = 3$ m, gas factor is G_0=20m^3/m^3.

Solution ratio of gas in oil is α=0.7m^3/m^3, and pressure in immersion depth of the pump is P=2 atm. Oil is without water. There is not gas in annular space.

The solution of the question: taking into account the harmful space, gas effect on the coefficient of pump admission is calculated by the following formula:

$$\eta = \frac{V_s - RV_{зяр}}{V_s(1+R)}$$

Where, V_s is the drawn volume of plunger; R is the correlation of gas volume in the cylinder of pump suction to the volume of oil in the cylinder of top death point of the plunger; V_{harm} – is the volume of the harmful space relatively taking into account at the calculation.

Now, let’s calculate these quantities separately for each pump.

PGP-1 pump:

$$V_s' = FS_1 = \frac{3{,}14}{4} 0{,}070^2 \cdot 0{,}9 = 0{,}00346\,\text{m}^3$$

$$R' = \frac{V_{s.q}}{V_n} = \frac{G_0 - \alpha P V_n}{(P+1)V_n}$$

If $\mathbf{V_n}$=1m^3, $R' = \dfrac{20 - 0{,}7 \cdot 2 \cdot 1}{(2+1) \cdot 1} = 6{,}2\,\text{m}^3/\text{m}^3$, that is gas with P=2ati pressure will take 6.2 times more place in comparison to oil in submersible place of pump. V_{harm} is the volume of harmful space and consists of following:

1) Volume of internal space of the nipple under the travelling valve with 0.09m length:

$$V_1' = \frac{\pi}{4} \cdot 0{,}035^2 \cdot 0{,}09 = 0{,}000087\,\text{m}^3$$

2) Volume of internal space of plunger with 1,210-(0,022+0,013)=1,17m length (not including threads for connecting nipple with plunger end):

$$V_2' = \frac{\pi}{4} \cdot 0{,}056^2 \cdot 1{,}17 = 0{,}00288\,\text{m}^3$$

3) Volume of internal space of plunger end with 0.06m length:

$$V_3' = \frac{\pi}{4} \cdot 0{,}0452^2 \cdot 0{,}06 = 0{,}000095\,\text{m}^3$$

4) Volume between standing valve in 3” nipple-expansion and plunger end while the plunger is in the bottom death condition; we will take distance between the defined details as 0.05m approximately:

$$V_4' = \frac{\pi}{4} \cdot 0{,}075^2 \cdot 0{,}05 = 0{,}000221\,\text{m}^3$$

5) The volume of internal surface of nipple-expansion, external surface of plunger and volume between the cage is equal to 0.4m length of nipple-expansion, and 0.14m length of cage:

$$V_5' = \frac{\pi}{4}(0{,}075^2 - 0{,}070^2)\cdot 0{,}4 = 0{,}000228\,\text{m}^3$$

We can deduct the volume of rod $V_{шт} = \frac{\pi}{4}\cdot 0{,}0016^2 \cdot 1{,}115 = 0{,}000224\,\text{m}^3$ and volume of its head $V_b = 0{,}035\cdot 0{,}016\cdot 0{,}050 = 0{,}000028\ \text{m}^3$ from the total volume of $V_1' + V_2' + V_3' + V_4' + V_5' = 0{,}003511\text{m}^3$.

As a result, we get the volume of the harmful space:

$V_{зяр}' = 0{,}003259 \cong 0{,}0033\,\text{m}^3$.

The total length of cylinder seized by the harmful space:

$$l_1 = \frac{V_{зяр}}{F} = \frac{0б0033}{0б785\cdot 0б07^2} = 0{,}86\,\text{m}$$

NGN-2 pump:

$$V_s'' = FS_2' = \frac{3{,}14}{4}\cdot 0{,}07^2 \cdot 0{,}9 = 0{,}00346\,\text{m}^3$$

$$V_s''' = FS_2'' = \frac{3{,}14}{4}\cdot 0{,}07^2 \cdot 3 = 0{,}01154\,\text{м}^3,\ R'' = 6{,}2\ \text{m}^3/\ \text{m}^3$$

will be same as in NGH-4 pump.

Volume V''_{harm} of the harmful space is formed from the following:

1) Volume of internal space of catcher with 0.12m length:

$$V_1'' = \frac{\pi}{4}\cdot 0{,}035 \ \ \cdot 0{,}12 = 0{,}0001115\,\text{m}^3$$

2) The volume between catcher and cage of standing valve in the 3” nipple (the distance between the defined details will be same in the PGP-1 pump, 0.05m length) will be as follows:

$$V_2'' = \frac{\pi}{4} \cdot 0{,}075 \quad \cdot 0{,}05 = 0{,}000221\text{m}^3$$

3) The volume of circular space (cage of standing valve) between the internal surface of 3” nipple-expansion and the rod with 0.09m length of catcher:

$$V_3'' = \frac{\pi}{4} \cdot (0{,}075 \quad - 0{,}03^2) \cdot 0{,}09 = 0{,}000334\text{m}^3$$

4)The volume between internal surface of 3” nipple-expansion and the cage with 0.14m length:

$$V_4'' = \frac{\pi}{4} \cdot 0{,}035 \quad \cdot 0{,}14 = 0{,}000135\text{m}^3$$

The volume of harmful space is as follow:

$$V_{зяр}'' = V_1'' + V_2'' + V_3'' + V_4'' = 0{,}0008\,\text{m}^3$$

The total length of cylinder seized by the harmful space:

$$l_2 = \frac{V_{зяр}''}{F} = \frac{0{,}0008}{0{,}785 \cdot 0{,}07^2} = 0{,}21\text{m}$$

While comparing PGP-1 and NGN-2 pumps, we see that the volume of harmful space in first pump is 4.1 times more than in the second; accordingly, the harmful impact of gas on coefficient of admission of PGP-1 pump is more exact.

For PGP-1 pump with S_1=0,9m value, the coefficient of admission in P=2 atm immersion pressure will be as follow:

$$\eta_1 = \frac{0{,}00346 - 6{,}2 \cdot 0{,}0033}{0{,}00346(1 + 6{,}2)} = -\frac{0{,}017}{0{,}0249} = -0{,}7$$

NGN-2 pump:

If $S_2' = 0{,}9$ m

$$\eta_2 = \frac{0{,}00346 - 6{,}2 \cdot 0{,}0008}{0{,}00346(1 + 6{,}2)} = -\frac{0{,}00015}{0{,}0246} = -0{,}06$$

If $S_2'' = 3$m

$$\eta_3 = \frac{0{,}01154 - 6{,}2 \cdot 0{,}0008}{0{,}01154(1 + 6{,}2)} = \frac{0{,}00658}{0{,}0831} = 0{,}08$$

In both pump, there is not liquid product in amount of S=0.9m stroke length, as the work was spent for compressing and expanding fast in pump cylinders. Increasing the stroke way in NGN-2 pumps to maximum value $S_2'' = 3$m improves the coefficient of admission of pump; however, this improvement is realized in very low level.

Now, let's see change of coefficient of pump admission with separation value of 0.8 after installation of new Grozny type gas anchor.

On the above question, we have defined that as a result of installation of anchor to the pump suction, instead of 20 m^3/m^3 gas in the atmosphere pressure will reach 0.87m at the pressure P=2at in pump immersion.

For PGP-1 pump, we can get the coefficient of pump admission in S_1=0,9m:

$$\eta_1 = \frac{0{,}00346 - 0{,}87 \cdot 0{,}0033}{0{,}00346(1+0{,}87)} = \frac{0{,}00059}{0{,}00647} = 0{,}09$$

For NGN-2 pump:

If $S_2' = 0{,}9$ m

$$\eta_2' = \frac{0{,}00346 - 0{,}87 \cdot 0{,}0008}{0{,}00346(1+0{,}87)} = \frac{0{,}00276}{0{,}00647} = 0{,}43$$

If $S_2'' = 3$m

$$\eta_2'' = \frac{0{,}01154 - 0{,}87 \cdot 0{,}0008}{0{,}01154(1+0{,}87)} = \frac{0{,}01084}{0{,}02158} = 0{,}50$$

Thus, PGP-1 pump will extract liquid in $\eta_1' = 0{,}09$ coefficient of admission in the relation of gas and oil 0.87:1; NGN-2 pump will give $\eta_2' = 0{,}43$product, that is, pump will give tangible product. Decrease of volume of the harmful space will positively effect to the coefficient of pump admission from the point view of gas effect in comparison with increase of stroke length.

Thus, it is necessary to decrease volume of harmful space, to apply gas anchor, to increase stroke way, and to lower pump to the well under liquid level so that gas will run from pump completely solved in water and the harmful impact of gas is reduced to zero. If there is liquid column on required height in the well, the immersion depth of pump may be reached to 150-200m.

On the above question, the immersion depth is 63m.

40 of the 100 operative sucker-rod pump wells in the 1 NGC workshop of "ANSHAD Petroleum" JV produce degassed (dead) oil. Gas rate and gas factor is equal to zero in these wells; there is no need to take preventive measures against negative impact of the gas.

Gas factor in 24 wells is higher than $100 m^3/T$; besides, gas factor changes between $200 \div 300$ m^3/T in 5 wells (No 849, 1003, 1036, 1042, 1084), and in 6 wells (No. 825, 854, 875, 889, 1049, 1111) the gas factor is higher than 300 m^3/T. To eliminate the negative impact of gas to the work of sucker-rod pump wells and to increase their product ratio, it is necessary to implement abovementioned measures.

CHAPTERII

OBSTACLES REGARDING SAND IMPACT ON WORK OF SUCKER-ROD PUMP AND STRUGGLE MEASURES

2.1. Negative impact of sand on the sucker-rod pumps with plunger

While working with sucker-rod pump in the well, sand enters to cylinder together with oil and damages the plunger and valves. Especially, fine sand particles enter between annular space between plunger and cylinder and damage the pump.

One of the frequently met problems of low productivity of the pump is that sand in the oil damages the valves. Oil jet having sand in its composition is obliged to change its direction strictly while passing through valve and runs to up from the narrow circular section by washing the sphere of the valve. Valve sphere and seating are being rubbed by sand and thus, the valves change their direction and as a result, normal work order of the valves is deteriorated.

As a result of formed non-tightness, part of liquid in upper stroke of PSP leaks to the bottom of cylinder from the travelling valve and its admission degree lowers, other part of liquid is pressed to well through standing valve from cylinder in the downstroke of plunger and as a result, the production of pump is decreased.

If there is much sand in liquid, it is gathered in all defective places of pump, especially, in expanded places of the valves, and thus, running speed of liquid decreases (in the valve outlet, in pipes on plungers). Sand precipitates intensively in water produced wells. Sand precipitated in pump hampers the work of valves, sometimes it blocks the valves completely and this requires to stop the work in well and conduct maintenance.

The struggle methods against sand may be separated into following directions:

1) establishment of barriers in front of sand penetrating into well through layer by application of bottom hole filters with different structure and by strengthening bottom hole zones with the chemical reagents;

2) limitation of sand amount penetrating into well through the layers by regulating amount of liquid;

3) exploitation of wells by extracting sand in the well through production string and pump pipes;

4) extracting sand gathered in the bottom hole with intervals;

5) Decreasing the amount of sand in pump suction by installing different protection equipment, filters, sand anchors and separators.

2.2.Filters

Filters separating different types of sand may be used in the pump suction. Downhole filters in the production string, that is, pump filters are installed to the metal net in the cracked or perforated suction pipe. Circular Grozny type filters are also used for this purpose.

Gravelled filters usage term is longer than grid filters. The main shortcoming of gravelled filters is that they are quickly become dirty and prevent oil to enter to pump. To restore its work, these filters are taken out from the well and cleaned. These types of filters are mainly used in shallow, low rated wells with less sand not depending on the required size and form of gravel.

If there is much sand in liquid, the sand anchors are best to get the desired results in their separation.

2.3. Sand anchors

The purpose of the sand anchor is based on separating oil from sand by decreasing the flow speed of oil to the pump suction and by changing its movement direction. The simplest type of sand anchor is any structured gas anchors: here, the partial separation of sand is realized in the inlet of suction pipe of pump where the jet turns. Thus, there are pockets for gathering sand which is precipitated in the bottom of gas anchor. The work effectiveness of flat anchors is low because of sand separation, and this is related with increase of flow speed in the suction pipe. Therefore, it is not recommended to use them in the wells with more sand. The more effective work is achieved by use of turned type of sand anchors where liquid flow is realized in the cross-section of the pipes.

Picture 2.1 describes the scheme of the turned type sand anchor. Here flat and directing sand anchors are applied (Picture 2.2).

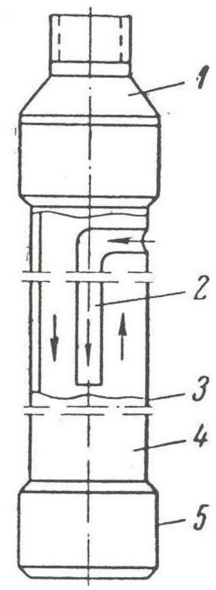
2.4. Gas-sand anchors

Gas-sand anchors made from the combination of gas and sand anchors are used in the beam wells, the product of which consists from liquid, gas and sand.

SSP-1 and SSP-2 type gas-sand anchors are applied in the oil fields. Picture 2.3 describes the scheme ofSSP-1 type gas-sand anchor. This anchor consists of two strings: top string is for gas separation and bottom string is for sand precipitation. These strings are connected to each other by means of 5 clutches. The anchor is installed to the pump suction with two pup subs, and the body of the anchor is connected to three suction pipes.

While subsurface pump operates, liquid with gas and sand in composition enters to top string where gas is separated from liquid. Later, degassed liquid passing through B hole (which is in 5 clutches) enters to the sand anchor. Liquid separated from the sand runs up to circular space of sand anchor and enters, first, to suction pump by passing through special clutch hole and then enters to pump inlet.

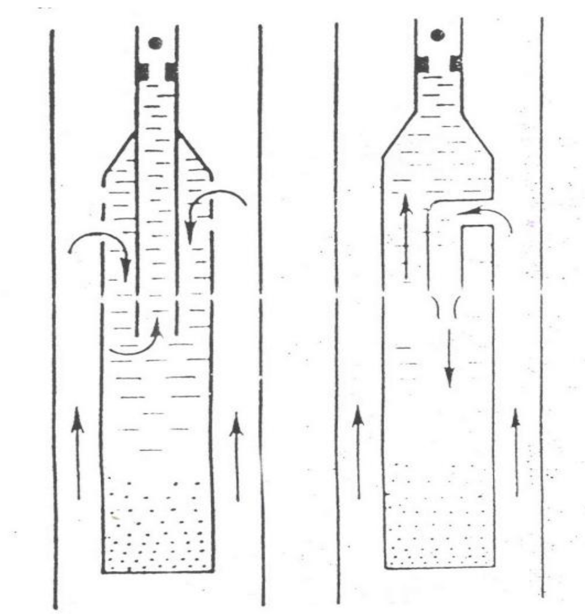
To provide the best separation of gas and sand, measures of cross-section of anchor bodies which are proper to the productivity of pump and liquid quality, diameters of suction and internal pumps, diameter of outlets, working length of anchor sections shall be correctly selected. The measures of gas elements are selected by formula appropriate for calculation of gas anchors. For the diameter of body of sand anchor may be accepted as the biggest diameter of the well.



Pic.2.1. Turned sand anchor

1-pup sub; 2-pipe for liquid inlet;

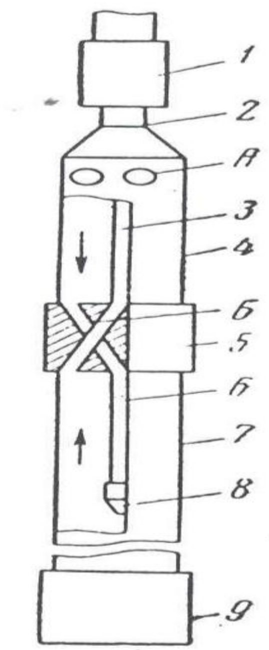
3- body of anchor; 4-sand pipe; 5-plug



a b

Pic. 2.2. Principle schemes of sand anchor:

a- flat anchor; б-directing anchor.



Pic.2.3. SSP-1 gas-sand anchor.

1-clutch of subsurface pump; 2-pup sub; 3-suction pipe;

4-gas string body; 5-special clutch; 6-working pipe;

7-sand string body; 8-conic outlet; 9-plug; A and B-holes.

During the work of sand and gas-sand anchors with high separation ratio and during the inlet of sand from the well without break, there shall be big capacity for gathering separated sand in the anchor. After certain time, the pocket is filled with sand, and anchor is blocked with sand and pump stops to function in normal order.

Thus, at present pocket is installed to the last pipe in order to unload gathered sand to the ground rarely and to expand the work period of gas-sand anchor during the maintenance (to decrease the maintenance frequency). During preventive maintenance of pump and well, sand pipe is taken out and cleared from sand.

Depending on the characteristics of the well, following protection equipment may be selected to connect to the subsurface pump suction:

1) When there is less sand and less gas –filters
2) When there is less sand and much gas –gas anchor
3) When there is much sand and less gas –sand anchor
4) When there is much sand and much gas – gas and sand anchor

IIICHAPTER

Alternative measures for protecting pump from harmful impact of sand

3.1. General information about alternative measures for protecting pump from harmful impact of sand

Beside different type of sand filters, sand and gas-sand anchors, there are also technical and technological measures applied to protect pump from harmful impact of sand. The positive results gave those measures which consider exploiting wells by extracting sand in the bottom hole to the surface.

Extracting sand to the surface completely is realized by creating certain running speed for liquid flow with sand in production string, pump pipes. The speed shall be 2.5 times more than free precipitation speed of liquid with sand[5]. That is:

$$u = \frac{Q_m}{\omega F} = \frac{v_m}{\omega} \geq 2{,}5 \qquad (3.1)$$

Where Q_m is rate of liquid; F is cross-section area of pipeline, or cross-section area of annular space between pump pipes and rods; v_m is the flow speed of liquid running up; ω is free precipitation speed of sand in liquid.

While not following this condition and common consumption concentration of sand is $0.5 \div 1\%$, concentration of sand volume increases and this leads to the gathering of sand in filter and prevent liquid to enter to the well.

Value of consumption concentration is defined as correlation of amount of sand in liquid and total exploitation of sand, that is:

$$\alpha_0 = \frac{q_{qum}}{Q_m + q_{qum}} \qquad (3.2)$$

Where, q_{sand} is amount of sand.

If u=2,5, the minimum liquid consumption (rate of well) for pump pipes with any size (with sandy liquid running up) will be defined by the following formulas:

$$\Gamma_{м.мин}=0,216\cdot 10^{6} F\omega \quad (3.3)$$

Where $Q_{m.min}$, m^3/day; F, m^2 and ω, m/sec.

Free precipitation speed of sand will be expressed by the following formula:

$$\omega = \frac{1}{18} g \frac{\rho_2 - \rho_1}{\nu \rho_1} d_q^2 \qquad (3.4)$$

Where, ω is required precipitation speed, m/sec; $э$ is acceleration of gravity force, m/sec^2; ρ_1 is density of liquid, kg/m^3; ρ_2 is density of sand, kg/m^3; ν is kinematic viscosity of liquid, m^2/sec; d_q– diameter of sand particle, m.

Hollow rod (pipe-rod) equipment and small sized pumps are applied, these equipment are lowered to pump with PSP with 48 and 60mm conditional diameter. The rotating scrapers and subsurface outlets are used as well. Besides, in order to protect pump from the harmful impact of sand, the beam wells are operated in level place, and the process of adding liquid to annular space is regulated.

3.2. Application of pipe rods (hollow)

Pipe rods are used in the wells where sand enters to the pump in great amount.

Liquid runs through cylinder of subsurface pump and enters to pipe rods moving up and down in PSP and is raised to the earth surface. As pipe rod, plain PSP with conditional diameter of 48mm is used, and its end with diameter 33 and 42mm is extracted out, and they play the main role in upstroke and down stroke of pump plunger and in raising liquid from well to the surface. Hollow rods are connected to plunger of pump to prevent liquid to enter into PSP and to separate pump cylinder, and in order to connect mounting pump to them, rod plunger is replaced with nipples connected to adapter sub. As a result of separation of liquid from the cylinder, sand is prevented to fall to space between cylinder and plunger, plunger is not riveted, and jamming of plunger is decreased. While applying hollow rods, as the correlation of cross-section areas of pipes and valves is reduced, conditions for providing flow of liquid with equal speed are created; and the reduction of section area of hollow rods relatively increases the speed of liquid to run up, and as a result, the condition for extracting sand to the surface is improved.

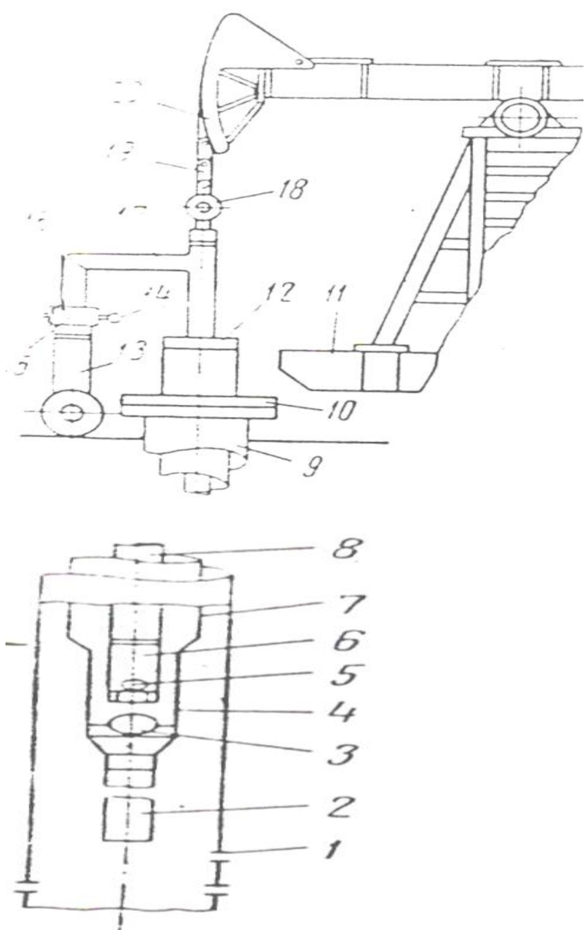
While exploiting small rated wells with much sand in the product, small sized pumps with diameter 28 and 32mm are used to prevent sand plug in the bottom hole and to increase the raise speed of liquid flow, these pumps are lowered till bottom hole filters in 48mm PSP and it is operated with rods having rings of 15mm diameter. In this case, liquid speed in 60mm pipes increases 1.5 times more than in 19mm rods, and it provides liquid to run through pump cylinder without any obstacles and reach to well head.

In Pic.2.4, we can see scheme of hollow sucker-rod pumps, and in Pic.2.5 scheme of connection of hollow rod to the pump plunger.

Hollow rod string (thick 1” pipes or PSP with 1 ¼, 1 ½ diameters) is hanged to balance beam of the pumping unit. Hollow rods are connected to 1 prompt hose on 4 surfaces, and due to this, well product is directed to the separator. The hose gives vibration to rod strings; that is why, it is replaced with three barrel extension pipe which moved up and down in the metallic tank used for storing liquid; this tank is installed near the well base.

Subsurface pump may have different types; generally, TB typed subsurface pumps, telescopic pumps or mobile cylindrical P typed pumps are used. While working with hollow rods, the plunger of subsurface pump differs from those which are used to in pump rods. Direct coupling of internal space of plunger with internal space of pipes are provided by 5 transient clutches.

The subsurface pumps are lowered to well in 2 ½", or 3" PSP, or are fixed to production string with anchor. In the last case, the hollow rods realize the functions of PSP and pump rods. This method is economic, as it eliminates the use of PSP.
However, its area of application is not extensive as the anchor may be plugged with sand. The pump is lowered to well in the hollow rod equipment to 6 PSP. 4 hollow rods actually mean the expansion of 7 mobile cylinders to the earth surface. The hollow rods moved to up and down in 3 packing boxes on the surface; they are covered with reverse clutch fusion which provides correct movement of rod string and prevents the hollow rods to displace to sides.

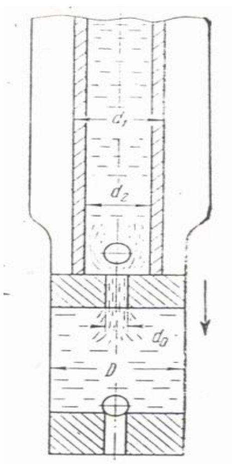


Pic.2.4. Installation scheme of the subsurface pumps in hollow rods

1-production string; 2- pump shank; 3- standing valve of pump; 4- pump cylinder; 5- travelling valve; 6- plunger; 7- pipes; 8- hollow rods; 9- production string;10- tubing head adapter; 11- pumping unit; 12- ring for closing annular space; 13- traverse line; 14- supports for fastening the packing box;

15-packing box; 16- nipple; 17-outlet; 18- swivel; 19- roller chain;

20- balance beam trunk.



Pic. 2.5. Scheme on connection of hollow rods to the pump plunger

Setting 8 is for fastening the pump in PSP and allows taking out the pump with hollow rods from the well without lifting the PSP.

The pump rods are hanged to the head of balance beam with help of 2 joints same as in the normal pump rods. The annular space between thePSP string and rods may be filled with liquid or may be left hollow.

Internal diameter of the hollow rods is calculated on the following basis: v_m ascent speed of liquid shall be more than v_{sand} lowering speed of sand in liquid. For laminar flow, the precipitation speed of sand in liquid is calculated by Stock formula and for turbulent flow, it is calculated with Rettinger formula. Flow regime mainly will be laminar, so Stock formula will be used:

$$v_{qum} = \frac{d_q^2 g(\gamma_q - \gamma_m)}{18\mu} \qquad (3.5)$$

Ascent speed of liquid in hollow pump rods will be:

$$v_m = \frac{10^6 Q}{86400\gamma_m \frac{\pi d^2_{и.б.ш.}}{4}} \qquad (3.6)$$

On conditions of $v_m \geq v_{sand}$, it will be solved taking into account (3.5) and (3.6) formulas:

$$d_{и.б.ш.} < \frac{16,5}{d_{qum}} \sqrt{\frac{Q\mu}{g(\gamma_{qum} - \gamma_m)}}$$

Where, $d_{h.rod}$ is internal diameter of the hollow rods, cm; d_q is diameter of sand particle accepted in the form of sphere, cm; Q is the rate of liquid in well, T/day; μ is dynamic viscosity of liquid, pz; g- is gravity force, cm/sec^2; γ_{sand} and γ_m is weight of sand (γ_{sand}=2.6) and liquid, G/cm^3.

Unlike common rods, the hollow rods are operated in more severe conditions, as pressure balance impacting the plunger is disturbed, and the pressing forces are formed as a result of side pressures in the hollow rods.

Side pressures in vertical hollow rods with open bottom may create longwise bending as a result of pressing loads along the axis, and its value will be defined by the following formula:

$F_{pres.} = P_{Sh.rod}$(3.7)

Where, P is internal pressure of the hollow rods; $S_{.h.rod}$ is area of internal section of the hollow rods.

If the side pressure is violated, then the hollow rods are forced to the longwise bending; as in any pipes, they are also pulled with the following loads:

$F' = -P \cdot S_{pipe}$ (3.8)

Where, S_{pipe} is full section of the pipe.

Let's suppose that, the annular space between PSP and the hollow rods is not filled with liquid. In this case, the bottom end of the hollow rod will remain open during the downstroke of the plunger, and the rod string will be bend longwise as a result of impact of internal pressure in the rods (as F_{pres} pressing load along the axis). The value of this load is defined from the (3.7) expression. For point of the hollow rod strings in x level (elevation) from the plunger, P value will be:

$П = \gamma_m (Л - x)$(3.9)

Where, L is the length of the rod string.

On other side, as a result of different diameters of plunger and rod during the plunger's downstroke, the pressing Force F'_{pres} is formed, and it affects from bottom to top. This force is expressed by the following formula:

$F'_{зых} = \Delta P \cdot (C - C_{и.б.ш})$ (3.10)

Where, ΔP is difference between pressure in the pump cylinder and pressure in the space between the hollow rods and PSP. The pump is lowered to well with PSP. It is supposed that this annular space is not filled with liquid[13] .

$\Delta P = \gamma_m L$,

Where s, d is area of section of plunger space and its external diameter; S_b, $d_b$is area of section of pipe space and external diameter; $S_{h.\ rod.}$,$d_{h.rod}$ is area of internal section of the hollow rods and their internal diameter.

The weight of a single length of hollow rods

$г = \gamma_0 (S_b - S_{h.rod})$ (3.11)

Where γ_0 is a specific weight of materials made by the hollow rods.

The weight of the hollow rods below x point will be:

$G = qx = \gamma_0 (S_b - S_{и.б.ш.}) x$ (3.12)

Substitutive force along the axis affecting the pump on direction of axis in the level x will be as follows:

$$F_x = G - F_0 - F_{сых}.$$

Following is achieved by using expressions (3.8), (3.9), (3.10) and (3.11):

$$F_x = \gamma_0 (S_b - S_{и.б.ш.})x - \gamma_m L(S - S_{и.б.ш.}) - \gamma_m (L - x) S_{и.б.ш} \quad (3.12)$$

if

$$q' = \gamma_0 (S_b - S_{и.б.ш.}) + \gamma_m S_{и.б.ш} \text{ and } F'_{сых} = \gamma_m SL \quad (3.13)$$

Symbols are accepted, then (1.34) expression may be submitted as follows:

$$F_x = q'x - F'_{сых} \quad (3.14)$$

L length of string forced to pressing will be defined by $F_x=0$ value in the hollow rod string:

Using (3.14) expression for $x=l$ and $F_x=0$ values, we get:

$$l = \frac{F'_{сых}}{q'} = \frac{\gamma_m S}{\gamma_0 (S_b - S_{и.б.ш.}) + \gamma_m S_{и.б.ш.}} \quad (3.15)$$

Expressing S, S_b and $S_{h.rod.}$ values with d, d_b and $d_{h.rod}$ diameters, we get the following:

$$l = \frac{\gamma_m d^2}{\gamma_0 (d_b^2 - d_{и.б.ш.}^2) + \gamma_m d_{и.б.ш.}^2} L \quad (3.16)$$

Regarding to (3.16) formula, the length of hollow rods with longwise bending increases symmetrically to the L lowering depth of the pump. The maximum allowed depth for pump without longwise bending in the bottom of the hollow rod string will be defined according to the equality between general pressing force used in pump plunger and critical point of longwise bending. If it is hollow rod string with fastened ends and without side displacement, then critical length of longwise bending will be defined by the following formula:

$$l_{kr} = c\sqrt[3]{EI/q'} \qquad (3.17)$$

Where c=$f\,(l/L)$ ratio is defined from diagram or analytical expressions.

For application area of hollow sucker-rod pumps c=3,6;………..;3,8.

If putting l in (3.12) formula in l=L_{kr} equality, in *(*3.13) formula $l_{kr}$and in (3.14) formula q' to their places, then the value of polar inertia moment of the hollow rods will be defined, that is,

$$I = \frac{\pi}{64}(d_b^4 - d_{и.б.ш.}^4)$$

by taking into account this formula, we find the following:

$$L = \frac{c}{\gamma_m d^2}\sqrt[3]{\frac{E}{16}(d_b^4 - d_{и.б.ш.}^4)\left[\gamma_0(d_b^2 - d_{и.б.ш.}^2) + \gamma_m d_{и.б.ш.}^2\right]^2} \quad (3.18)$$

Where *L* is the depth allowed to lower pump without fear of longwise bending of the rod string, m; *E* is elasticity module of the material, kG/m^2; *d. $d_{b,}$ $d_{h.rod.}$*is internal and external diameters and diameter of hollow rod pipes, m; γ_0, γ_m is specific weight of material and liquid, kG/m^3.

Value of L defined by (3.15) formula is not generally high. Thus, it is necessary to eliminate the effect of the reasons causing the pressing force in the hollow rods in order to lower the pump to the great depth, or it is necessary to increase the critical length of longwise bending /kr.

According to the formula (3.15), the differential pressure is *ΔP=0* while filling the annular space between hollow rod and NKB with liquid (pump is lowered to the well with this PSP).In this case, p

ressing F_0 forces will not exist.Besides, taking into account the formulas (1.34) and (1.35), the value of internal and external pressures of hollow rods will be found: $F = F'_{pres} + F' = P(S_{h.rod} - S_b) < 0$ as $S_b > S_{h.rod}$.

Thus, substantive F force formed as a result of impact of external and internal side pressures is pulling force. In this case, longwise bending of string is eliminated. So, if the annular space is filled with liquid, then only the pulling forces affect the rod string.

The longwise bending may be cancelled by increasing l_{kr}. For this, polar inertia moment *I* of hollow rod shall be increased according to the (3.15) formula. In this case, heavy hollow rods are used and their external diameters are increased and internal diameter is kept in its previous value.

Generally, the hollow rods are used while appropriating the well charazterized with existence of sand with intervals. After cleaning the well from sand, common rods are used again.

To increase the lifting speed of sand in the well, oil is put to the annular space between PSP and the hollow rods. Oil runs to the hollow rods through the special holes in the top of the plunger.

The poured oil is lifted to the surface together with extracted oil by means of hollow rods. Thus, the oil rate increases and as a result, the sand extraction speed also increases.

Maximum lowering depth of the pumps is 800-100m as a drop of big loads to the plain rod.

3.3. Scraper - vortex generator

Riveting of plunger in the cylinder very often is due to the insufficient running speed of liquid in pump pipes to up and frequent cancellation of work in the wells. To prevent plunger rivet, the scraper and vortex generators are used; they are installed on pump rod strings and they create the vertex of liquid, and prevent the sand precipitation along the internal walls of the pump pipes. It is possible to raise sand to surface by installing enough scrapers and vortex generators. When pumping unit is stopped, sand lowered in liquid will be precipitated not on travelling valves, but on the surface of the scrapers.

3.4 Method on smooth operation of well

Stable working regime of sandy wells is established not only by limiting liquid, but also by method of smooth operation; in this case, first small liquid receiving regime is established, and it is proper to the small depression and no sand enters well in this depression, later, in order to increase liquid receiving, the parameters of subsurface pump is changed several times, that is, number of stroke and swing is increased. In every new regime, the well works without any interval for certain period and volume concentration of sand in liquid is observed. Thus, it is possible to increase the optimum liquid receiving to certain value by gradually increasing parameters of the subsurface pumps.

3.5. Method on adding liquid to the annular space

This method is applied during the exploitation of wells, the product of which has much sand in composition, to prevent the formation of sand plug in the bottom hole. After cleaning bottom hole from the sand plug, the subsurface pump or tail under the pump suction is lowered to the filter zone, or is installed in front of the upper holes of filters. While pump is working, sand-free oil or other liquid (water) is injected to the annular space of the well. Consumption concentration of sand is decreased by adding liquid to pump, and this occurs as a result of mixture of sand with high concentration and sand-free liquid which is added to the product or well.

By regulating the amount of sand-free liquid, the liquid capacity is formed and movement speed required in running way from the bottom hole to the well head is achieved; thus, extraction of sand to the surface is provided, and pumps or pipes are prevented to be plugged with sand. Following liquid adding methods are applied to the annular space in the oil fields: self-addition, coupling addition, centralized liquid addition and liquid addition with special dosing pumps.

The best method is the application of the dosing pumps to get the reliable regulation of the process. The dosing pumps allow achieving the required productivity and they may be changed, if required. As group dosing device, the device which may be used in six wells constructed on the basis of pumping unit with CKH2-615 type redactors.

Complex scheme of the device is given in the Pic. 2.6.

Whole device is installed on the base of the well center in the open air. The productivity of a pump may be changed between 2-26 m^3/day and number of swings may be changed between 5-15 swing/min, and length of plunger stroke can be changed between 30-600mm.

3.6. Device for adding liquid to the annular space

Adding pure liquid to the annular space of the sucker-rod pumps that form the sand plugs is one of the most effective methods in struggle against sand. The widest method among the different implementation forms of liquid addition is “coupled liquid addition» form. The essence of this form is that the product of well which is pure (sand-free) is directed to the annular space of the well where sand plug is formed; in this case, the productivity of the subsurface pump working in the second well shall be calculated by multiplying its own liquid to the added liquid.

The advantage of coupled liquid addition is that its implementation is very simple and there is no need for application of special coagulants for precipitation of sand in the added liquid. Only because of its simplicity, this method is widely used in comparison other method; notwithstanding that some of them, for instance, “self-addition” is the perfect form from the principle point of view.

However, there are serious shortcomings of coupled liquid addition form:

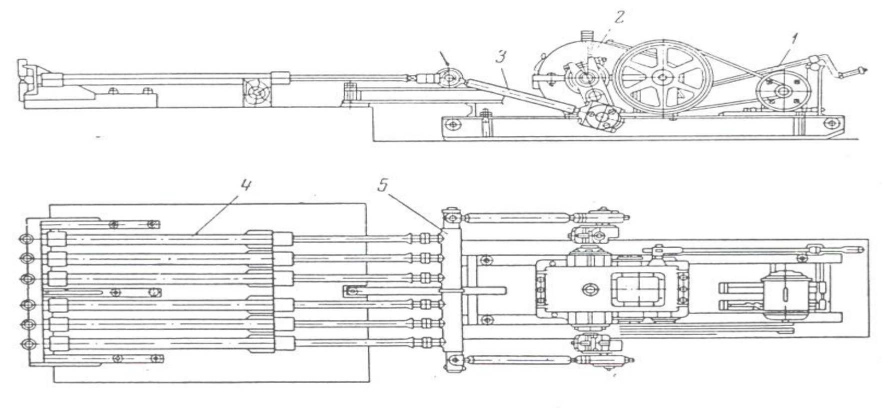
1. The difficulties while the measuring the amount of added liquid is that it is necessary to connect the annular space of well with pure liquid source in order to prevent complication with sand during the measurement. That is why, the amount of added liquid is rarely measured at the oil fields, and the measure is supposed according to the total production gained form the well that forms the sand plug.

2. When the work at the well, the pure product of which is used, is suddenly terminated, the pump in the sand plug forming wells is riveted and other complications are observed, and it cannot be prevented.

3. While the production of wells that form the sand plug is terminated, the added liquid continues to fill into the annular space. In best case, if the well is absorbing, the well will be filled with liquid and overflow and deteriorate the oil field. It is obvious that in both cases oil is wasted.

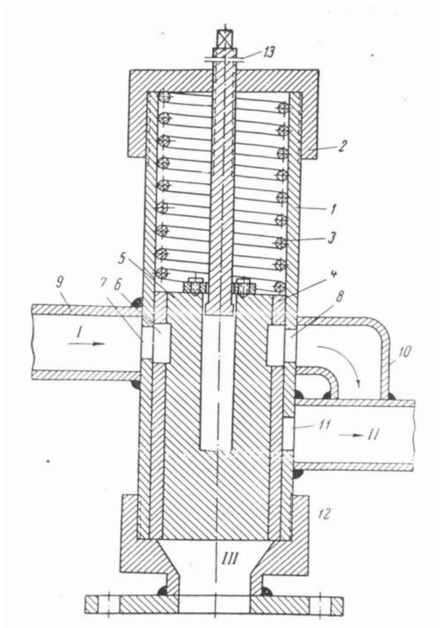
In order to prevent these shortcomings, the construction and work principle of the considered automatic setting is explained below (Pic 2.7).

On the top, spring (3) and plunger (4) is placed to the lagging (1) closed with head (2). Rod is pressed in the plunger, and this allows cutting the round waterways in plunger (6) in the level of holes (7 and 8).



Pic.2.6. Dosing pump for pouring liquid to the wells

1-engine; 2-reductor; 3-connecting rod; 4-pumps; 5-manifold.



Pic.2.7. Machine fastened to the annular space of wells

forming sand plug for adding liquid

1-lagging; 2-head; 3-spring; 4-plunger; 5-rod; 6- round waterway in plunger;

7,8-holes in lagging; 9-nipple; 10-outlet; 11-hole; 12-bottom valve; 13-screw

The hole (7) is coordinated with travers line of the well, that forms sand plug, with help of nipple (9). The hole (8) is connected to the annular space with outlet (10). This is coupled with hole (11), this hole is opened in certain distance with holes 7 and 8.

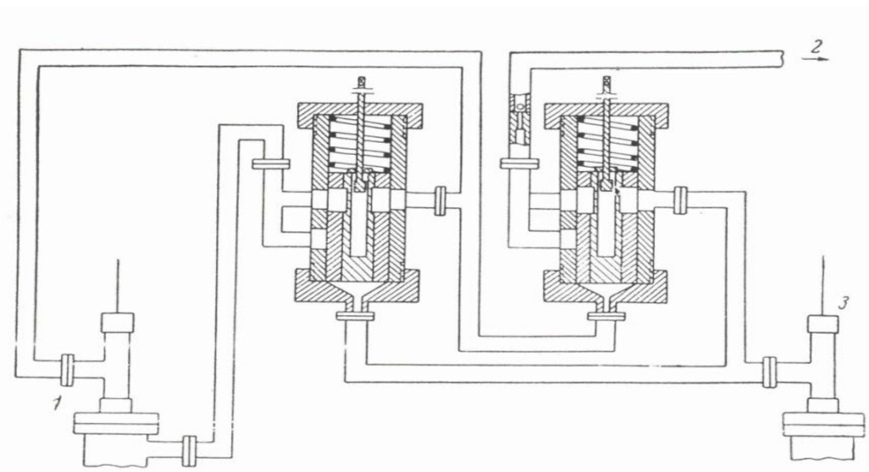
In the extra time, liquid runs to machine through lower 12 head and pushes the plunger, thus raises it up, and then by running through the hole (11), liquid enters to annular space of the well that forms sand plug. At this moment, the travers line of the well that forms sand plug and the annular space is separated from each other as a result of displacement of the round waterway (6) in comparison with windows (7 and 8).

After termination of liquid addition, the spring brings the plunger to down, the waterway (6) coincides with holes (7 and 8), and liquid produced in the well, where sand plug is formed, enters to the annular space and this eliminates complication of sand plugs until new liquid is added.

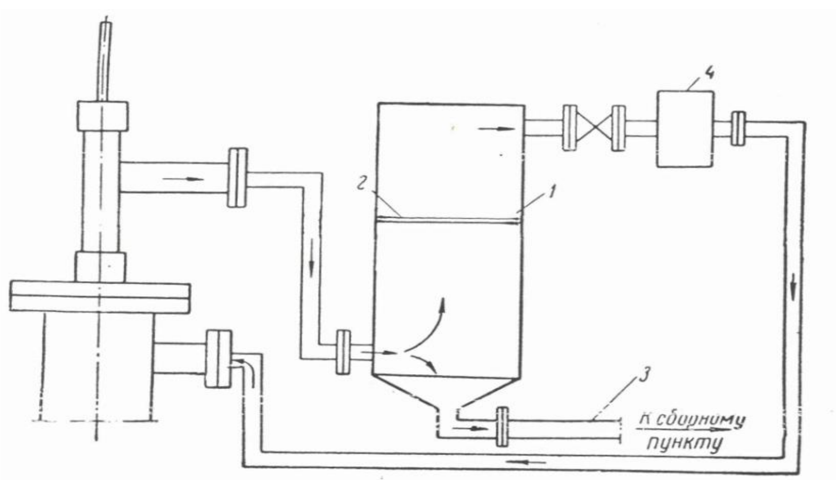
Analogical turnover of liquid extracted from the well that forms the sand plug is realized when the adding liquid is intentionally terminated to measure the rate of well which add liquid to other well. Screw (13) is for carrying out the well measurement, and it is also for coupling the machines and for taking out the plunger to control its condition. During the termination of work in the well which forms sand plugs, such machine is installed in its travers line in order to prevent the oil loss. Dressing scheme of the machines installed on the frame near the head of the well which forms the sand plugs is given in the Pic. 2.8.

The plunger of the right machine is pulled up with help of screw in order to launch the coupled machines and it closes the way of added liquid to gathering station. After some hour passes, liquid runs to the annular space of the well that forms sand plugs by pressing the spring of left machine and with the product of the well, liquid runs to the gathering station by pressing the spring of right machine; the screw of the right machine lowers again.

As the recovery of the well which forms sand plug is terminated, the plunger of the right machine comes down with impact of the spring, and the added liquid is directed to the gathering station. In order to know the amount of added liquid during the work of machines, the plunger of the left machine is kept in low condition with help of screw.



Pic.2.8. Machine dressing for adding coupled liquid to the annular space in the wells that form the sand plug



Pic.2.9. Self-cleaning device for self-adding liquid
1-hermetical tank; 2-net; 3-travers line of well;
4- “kama” type small-sized centrifugal pump

As the pressure in the annular space of the well forming the sand plug is the pressure for pressing the right string of machine, then the product of this well will enter to the annular space, and added liquid will enter to the measuring trap. After measuring, the machines will be launched.

It is easy to prepare these machines in the workshops at the oil field. For this purpose, plungers of the used sucker-rod pumps and lagging may be used. It is not difficult to select spring. However, the pressure required for its pressing shall be above 12kG/cm^2 from the pressure in the measuring trap.

Addition of liquid to the annular space of the wells, where sand plugged, is one of the effective and developed methods. It is main point is that liquid injected with the subsurface pump and which is equal to the well rate is directed to the travers line, and other part of liquid is added to the annular space by passing through the coagulant. It is obvious that the productivity of the pump shall provide the speed of liquid flow rising up in order to extract the sand in the well to the surface.

The main technological priority of the self-addition of liquid is that the process is realized automatically and serves to the well.

However, there are some difficulties in the implementation of this method as well:

1. Practically, the sand separation is weak in the small-sized coagulants which may be installed near the well head. As a result of this, as a rule, liquid with different amount of mechanical mixture in the composition enters to the annular space and this reduces the effectiveness of the process.

2. It is necessary to clean the coagulant from sand frequently, and as a result the field area is polluted.

3. The difficulty in the regulation of the amount of liquid directed to the annular space and the travers line is mainly met in the extraction of oil in field and in its transportation (airtight) and this, as a rule, is observed in the instability of the pressure in the collectors.

Let’s see the structure and work principle of the self-regulating device for self-adding of liquid (Pic. 2.9). The weight of the device in portative version is 40 kg.

Liquid injected with the subsurface pump is directed to the hermetical tank (1); this is made of 8” or 10” pipe. This tank is divided into two sections with its two capron nets with three or four layers. The end of the tank is connected to three travers lines of the well; the top of the tank is connected either with annular space of the well, or with 4 small sized centrifugal pump suctions of Kama type depending on oil collection and its transportation. The travers line of this pump is connected with the annular space (here, small-sized sprocket pumps may be used as well). Pure liquid is entered to the annular space with such structure of the device, and sand is directed to the travers line.

It should be noted that the necessity in the application of liquid addition in the field practice is arisen when the well is operated after the maintenance, and this is related with cleaning or wash of the sand plug. After the set of usual working regime of the well, the addition of liquid is stopped, and this regime usually lasts for several days [3, 4,6,10,13,14,15,and 16].

3.7. Method of defining the height of the sand plug formed in the operative sucker-rod pumps

It is known that the exploitation of oil wells with sands results with precipitation of sand in the bottom hole and the formation of sand plug and as time passes, the height of this plug increases. As the sand plug forms in the recovery wells, the rate of well decreases; if the well’s product is watery, then oil and water rate of the well decreases as the days pass, because the height of the sand plug formed in the well increases; it may happen that the well productivity may be terminated after the height of sand plug exceeds. It is not reasonable to wait complete termination of rate of well with sand, and after several days or months to clean the sand plug; in this case the oil production may be lost. So, the sand plug shall be washed out in intervals on effective time.

In order to select correct time for cleaning of sand plugs in such sucker-rod pumps, the height of sand plug shall be controlled depending on the exploitation period. So, it is necessary to measure or define the depth of well bottom hole at various times. The measurement of the well bottom is realized by lowering the steel wire load to the bottom hole in the field. If the well is not deep and is vertical, this operation will be successful. However, if the well is deep and inclined or bended, the measuring rope is hitched to the pipes and creates the obstacles.

Thus, it is required to control the sand plug formed in the bottom hole if the sucker-rod pump wells in other way.

I.I. Aliyev suggested an effective method with following main points.

This method is based to the formulas achieved as a result of the solution of the hydrodynamic problem related with the filtering flow of Newton liquid in non-homogeneous layer on one hand, and on other hand is related with the meaning of well rate and condition of liquid level.

To solve the problem on work of exploitation well with sand plug, the formula of the plain and radial filtering flow of the Newton liquid in the non-homogeneous layer with two zones of different conductivity is used; and the conductivity of these two zones must be completely different from each other. The filtering flow in the concentric round areas with different conductivity will not be parallel but consecutive.

While solving analogical problem for the wells with sand plug, sand plug formed in the bottom hole is accepted instead of zone around the well in the non-homogeneous layer, as in this case the drainage zone of the well will have two different conductivities. Thus, there will be flat-parallel filtering flow toward the top of the well with sand plug in the bottom hole, and flat-radial filtering flow toward the bottom hole in the drainage zone.

The hydrodynamic problems were solved for Newton and anomaly (non-Newton and viscous-plastic) liquid for consecutive simple filtering flow of liquid in the system consisting of sand plug and drainage zone (20). In these problems, we used the formulas for defining the rate of the well with sand plug, laws of division of pressure both in drainage zone and sand plug in the well (in the form of analytic expressions), and formulas for calculating gradient of pressure in these zones, filtering speed and pressure under the sand plug etc.

For defining the height of the sand plug in the sucker-rod pump wells operating with Newton oil, the author is used rate formula and found out the following formula:

$$L = \frac{k_2 r_q^2 \left[2\pi k_1 b(P_k - P_a) - Q\mu \ln \frac{R_k}{r_q} \right]}{2k_1 b(Q\mu + \pi k_2 r_q^2 \rho g)} \quad (3.19)$$

Where, k_1, k_2 is the conductivity of the layer and sand plug, mkm2; r_q is the radius of the well, m; R_k is the radius of the feeding contour, m; b is the force of the layer, m; Q is the rate of the well with sand plug, T/day; μ is the dynamic viscosity of the oil in layer, MPa·s; P_k is the pressure of the layer, MPa; pg is the specific weight of the oil, G/cm3.

The pressure over the sand plug in the well is expressed by the following formula:

$$P_a = hpg \quad (3.20)$$

Where, *h* is the height of the liquid column over the sand plug in the well. On other side, the height of the san plug is expressed by the following formula:

$$L = H - H^{din} - h \quad (3.21)$$

Where, *H* is the depth of the well; $H^{din}$is the level of liquid in the well and is defined by measuring.

As it is seen, value of *h* in (3.17) and (3.18) formulas is unknown.

According to the law of stability of liquid consumption, the rates for drainage zone of the layer and sand plug are same, and is equal to the rate of well.

The debit formula sand plug is as follows:

$$Q = \frac{\pi k_2 r_q^2 (P_q - P_a \rho g L)}{\mu L} \qquad (3.22)$$

First of all, using (3.19) formula, we get the formula for P_a, and is written for the value of L in (3.16) formula; the gained formula (3.17) is used in the equality of the formula and following equation is achieved for defining the h:

$$h = (H - H^{din})\left(1 + \frac{\pi \rho g k_2 r_q^2}{Q\mu}\right) - \frac{\pi k_2 r_q^2 P_q}{Q\mu} \qquad (3.23)$$

h found in the equation (3.20) will be written in (3.18 formula) and is following formula is defined to find out the height of the sand plug in the well:

$$L = \frac{\pi k_2 r_q^2}{Q\mu}\left[P_q - \rho g (H - H^{din})\right] \qquad (3.24)$$

As it is seen from (3.21) formula, as the rate of the well with sand plug decreases, the height of the plug increases; this means that as the height of the plug increases, the well rate decreases. As a result, pressure on the plug decreases, as the hydraulic resistance and differential pressure increases while liquid is filtered from the plug. Besides, (3.16) formula is the analytical expression of the functional dependence between L, Q, and P_a values; other quantities in the formula are stable and their values may be defined as a result of experiments and field researches.

Calculation scheme of the sucker-rod pump wells with sand plug is given in In Pic, 2.10.

The rate of the well is measured in the measurement trap; the layer pressure P_k and layer's conductivity k_1 is defined as a result of research if there is not sand plug; the oil viscosity μ and specific weight *p*g is defined in the oil laboratories; to define the conductivity of the sand plug k_2, an experimental research shall be carried out in the layer model at the laboratory by taking the sample from the sand plug in the well.

Thus, the height of the sand plug in the sucker-rod pump wells is defined consecutively by the suggested method:

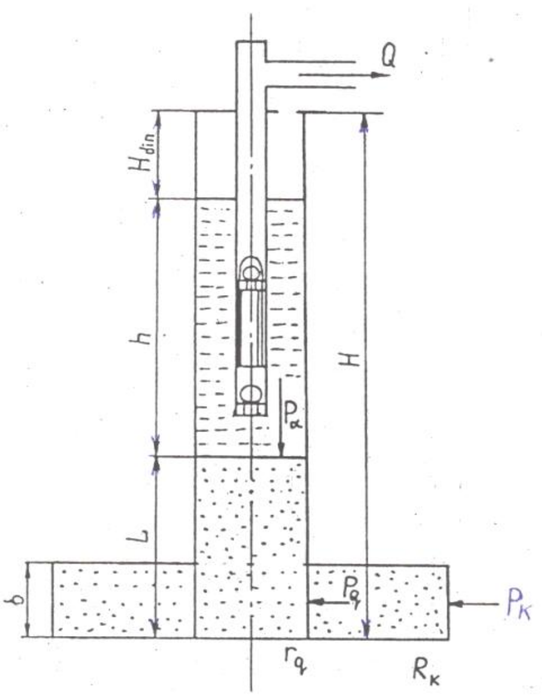
First, Q well rate in the measurement trap is defined:

1) Later, pressure under the sand plug is calculated with the known $P_q = P_k - \frac{Q\mu}{2\pi kb} \ln \frac{R_k}{r_q}$ formula;

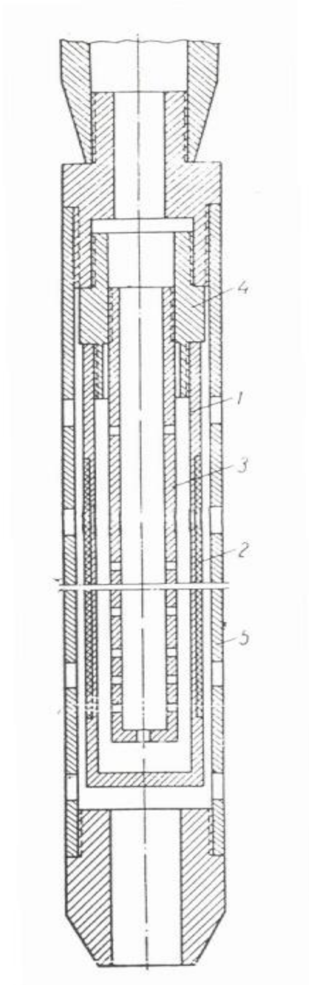
2) H^{din} - the depth of dynamic level of liquid in the well is measured by echo sounder;

3) Finally, L - the height of sand plug in the well is defined by the (2.25) formula.

As it is seen, it is not difficult to carry out these works in the field.



Pic.2.10. Calculation scheme of the sucker-rod
Pump wells with sand plug



Pic.2.11. Capronsandfilter

1- perforated body; 2 - capron material with 3-4 layers;

3-suction pipe; 4-adapter sub; 5-cover

It should be noted that it is impossible to define the height of the sand plug formed in the sucker-rod pump wells by echo sounder, as there is liquid column of certain height in the annular space over the plug and most part of sound wave of the echo sounder returns to the well head being reflected in liquid level and few part reaches to the plug by spreading over the liquid column on the plug and is returned by reflecting, later penetrating through liquid level goes up diffusing in the gas environment. Sound waves weaken and turn out in such complex movement which occurs in various environments; on other side, it is impossible to define the diffusion speed of sound waves in liquid environment in the well. So, it is impossible to measure the sand plug by the echo sounder.

So, there is great practical importance of the suggested method in the solution of the problem. This method has great role in the sucker-rod pump wells with intensive sand plugs [18].

Sand plugs are cleaned by two methods in the “Binagadineft” Oil and Gas Production Department:

1) Soft and pseudo arc sand plugs are cleaned with specific constructed bailer;
2) Firm and pressed sand plugs are cleaned with cleaning liquid with impact of gravitational force.

The formation process of the sand plug (SP) is analyzed and the results are given in the Table 2.1. Oil rate of six wells changes between 0.5-4.5, water rate between 2.5-9.5 T/day; general liquid rates change between 3.0-14T/day. Drowning degree changes between 67.6-86.5%, i.e. these wells are very drown and produced water shall be extracted. The work period of these wells between the maintenance was 71-240 days. Their maintenance frequency (cleaning of plug), i.e., number of maintenances in a year changed in 0.7-8.1 maintenance/year intervals. Well No. 1568 was well with minimum sand and Well No. 2728 was well with maximum sand among six wells. The maintenance frequency of other four well is 1.9-5.1 maintenance/year. As it is seen from the table, the rate of fractions in the product during the formation of the sand plug in the well decreases; here decrease of water rate is undesirable as this means the decrease of oil and gas production in the fields.

If the analogical analysis is carried out on all sucker-rod pump wells in the Oil and Gas Production Department, then it will be possible to find out how much the sand plugs damages the annular oil production. In six wells, the height of the plug formed during the period between the cleaning of two consecutive sand plugs was 18-68m. If this formation period of sand plug is taken into account, then speed of plug formation changes between 0.16/0.67m/day internals. The maximum speed of plug formation (0.67m/day) in these wells group was seen in the well No. 2728; value of this parameter changes in 0.16-0.32 m/day in these five wells and these values are close to each other. Thus, the average value of this indicator on the wells is 0.24 m/day, and this shows that the height of sand plug formed in the well increases for 1 m during every 4 days.

Table 2.1

Indicators	**Number of wells**					
	2728	769	2375	2308	2668	1568
Formation date of sand plug (start date)	18.12.03	24.10.03	17.11.03	12.07.03	06.09.03	08.05.03
Complete elimination date of sand plug	02.02.04	16.02.04	29.02.04	29.01.04	22.01.04	08.01.04
Exploitation period with sand plug, day	45	112	71	195	130	240
Average rate during the formation of sand plug, P/day						
- oil	4,5	0,5	0,5	0,7	1,0	0,5
- water	9,5	3,2	2,5	2,5	4,6	3,2
- liquid	14,0	3,7	3,0	3,2	5,6	3,7
Average rate at the end of formation of sand plug, P/day						
- oil	3,4	0,2	0,3	0,4	0,7	0,2
- water	8,0	3,0	2,0	2,0	4,0	2,8
- liquid	11,4	3,2	2,3	2,4	4,7	3,0
Loss in rate as a result of sand plug, P/day						
- oil	1,1	0,3	0,2	0,3	0,3	0,3
- water	1,5	0,2	0,5	0,5	0,6	0,4
- liquid	2,6	0,5	0,7	0,8	0,9	0,7
Average watery during sand plug, %	67,6	86,5	83,3	78,1	82,1	86,5
Height of sand plug, m	30	18	15	63	27	68

Formation speed of sand plug, m/day	0,67	0,16	0,21	0,32	0,21	0,28
Frequency of cleaning of sand plug, maintenance/year	8,1	3,3	5,1	1,9	2,8	0,7

It should be noted that one of the main reasons intensifying the process of sand plug formation is drowning of the product. Thus, methods of extraction of produced water in the drowning wells shall be considered as struggling measures against sand.

On other side, the abovementioned loss in the annual oil production is not only related with negative impact of the sand plug on the rate, but also result of 100% of water extraction of the wells and then drowning of the wells after cleaning of the plugs with water. In such cases, water for cleaning the plug penetrates into the layer, and expands the water channels and makes the oil channels narrow. So, it is reasonable to clean the sand plug with pure oil. It should also be noted that after cleaning the sand plug with water and after giving wells into exploitation, the intensively of produced sand increases as the drowning percent of product increases distinctly; as the viscosity of water is less than oil in the layer, its filtering speed and ability to split the rock is higher than oil.

To prevent the negative effects, the sand plugs also cleaned with oil in "Binagadineft" Oil and Gas Production Department.

For instance, a sand plug with 35m height is formed in the well No. 2379. Its depth is 497m, and the filter interval is 470-319m. The productivity of the well was 1 T/day of oil and 0.2 T/day of water, and its drowning was 16.7%, i.e., drowning was not so high. It is natural that it is not allowed to clean the plug with water. The plug in this well after being washed with 7 ton of oil, the well produced 1.4 t/day of pure oil in 20 days, and then produced 1.2 T/day oil rate for several days.

3.8. Capron sand filter for subsurface pump suction

There are many wells with small rate of oil in the oil fields that struggling method against the sand does not give positive results. For instance, strengthening the bottom hole area of the wells with small layer pressure decreases the rate of oil. Besides, adding liquid to the annular space may decrease the rate of well or may cause to the drowning of the product. In such wells, we often see the riveting of the plunger with sand, the pollution of the valves or jamming of the rubbing surfaces.

To prevent the unpleasant events in the field, it is necessary to use different structured filters against sand in the pump suction, and this method prevents the penetrating of sand into pump partly or completely. It is obvious that the product filters in the pump suction and separated sand forms sand plug by precipitating into the bottom hole; it is necessary to clean the bottom hole with intervals and extract sand from the well. Thus, the application of such filters shall be considered as last measure and this measure proves itself when the main methods on struggling with sand do not give the positive effect.

There are different types of sand filters suction of subsurface pumps: metal-ceramic, cement dust and others; but all of them have the following shortcomings:

1) Running ability of the filters in the wells where dynamic liquid level is very deep is not sufficient;

2) To provide the firmness of the filters, the walls of the filter shall be very thick; and this causes to the siltation (plug) of the filters with fine clays;

3) Separation of sand and clay (penetrating to the pump) causes the formation of plugs with small conductivity in the bottom hole.

The value of these filters is high. “Qaradaghneft” Oil and Gas Production Department constructed capron sand filters and tested it.

It should be noted that idea of using materials as a filter in the wells where sand plugs are formed is not new. It is known from the literature and experience that in order to protect subsurface pumps from the sand, bag materials, felt and other materials may be used. However, it is natural that these efforts were useless, as these materials are not firm and self-restrained (especially, in water and oil mixtures). So, capron material is more effective.

The structure of the capron filter is given in Pic.2.11. The perforated body of the filter is wrapped with 2 capron materials of 3-4 layers, and then its ends are fatened to the body with Bakelite lacquer.

The narrow non-perforated strip is kept for fastening the material and wrapped layer is stacked to this strip. The diameter of the holes on the body is 3-4mm. the load part of each surface will be less and working period of the filter will be more if the number of the holes is more.

The density of the capron in the filter is very important. As the experience shows, the use of thin fibred capron materials (like stocks) gives the best results. Very dense materials are nondurable; it seems that the suction strength of the filter increases in the result of siltation. And this causes the deterioration of the material and the filter.

Suction pipe (3) is connected to thread to the body (1) with help of adapter sub (4); and holes with diameter of 3mm are opened in its side surface. The number of the holes on the pipes decreases from the top to bottom; and this provides the equal load of the filtered element and extracts the same liquid consumption from cross-section of pipes. The calculation of number of holes in the suction pipe and their location are defined by the method where the gas anchors are taken into account.

It should be noted that there must be the suction pipe in the capron filter. If there is not such pipe in the filter then only upper part of the filtering element works, and this is directly located near the standing valve of the subsurface pump and the rest surface does not have any load. As a result, the upper part of the filter is deteriorated very quickly. To prevent the plug of suction pipe with sand, hole with 3mm diameter shall be opened on the bottom.

To connect the body of filter with the suction pipe, there are threads in the adapter sub (4) except the external threads and the filter is connected to the cover (5) due to these threads. And this cover protects the filter from the deterioration while lowering the filter to the well. While applying this to the mounting pump (with diameter 28-32mm), a cover is prepared from the cover pipes of the pump. The body of the filter is made of 1" pipe and the suction pipe is made of ½". The length of the filter body is 400-500mm.

The described filter is characterized with the following positive features:

1. It has high conductivity which lets to apply it in the wells with very low dynamic liquid level.

2. The thickness of the filtering element is so small that it prevents the siltation.

3. It has ability to extract silt and clay particles, and their limit sizes are regulated with the number of the layer of material. As a result of extraction of these particles from the well, the formation of sand plug in the bottom hole is delayed and the conductivity of the plug is more than the conductivity of the plug formed during the complete separation of sand and clay in the subsurface pump suction.

4. The lower price and simplicity of the structure allows preparation of this filter in any field workshop.

The main disadvantage of this filter is that its application gives better results in the wells with 5-6 m^3/day of rate. The firmness of the material is not enough for the wells with more rates and the filter may be destructed as a result of changing load.

It should be noted that the theoretical views and practices show that the durability of filtering elements depends on the size of configuration of the holes on the body. Thus, these holes shall be in such size and form that it will be possible to use these filters widely.

The current period between the maintenance of 26 of the 100 efficient sucker-rod pump wells in “ANSHAD Petrol” LLC is less than 30 days. These are mainly wells with intensive sand appearance. The maintenance frequency for these wells, i.e., the number of current maintenance for a year changes between 365: 12 = 30.4 maintenance/year and 365: 31= 11.8 maintenance/year.

It is necessary to apply abovementioned struggle measures against sand in these wells: that is, to apply sand, gas-sand anchors, hollow rods, to add liquid to the annular space, to use wells smoothly after their maintenance, to clean the sand plugs with bailer, to apply the underground depression string (UDS) and other measures shall be carried out. On other hand, it is necessary to strengthen the sand in the bottom hole with cement. It should be noted that analogical measures were carried out in some of these wells and positive results were achieved. For instance, sand in the bottom hole of the well No. 177 was strengthened with cement solution; 1 ½” hollow rod in the wells No. 1220 and 1224 was used as a rod string; liquid was added to the annular space in the wells No. 1118, 819, 1159, 1040, 140; sand was cleaned in the wells No. 1058, 1088, 1077 and 849 where the underground depression string was applied and positive results were achieved.

CONCLUSION

After comprehensive and wide studies, analysis and researches, the following results are gained:

1. Associated gas impact negatively to the work of the subsurface pumps in the beam wells where gas factor is high and decreases its productivity significantly. Thus, it is necessary to connect the gas anchor to the pump suction and decrease the amount of gas injecting to the pump cylinder.

2. Proper constructive and technological consideration shall be implemented by taking into account the production parameters of the well in order to select correct gas anchor for every well.

3. Sand, coming with oil or from the layer in the beam wells with intensive sand, creates many obstacles. Thus, it is necessary to use sand, gas-sand anchors, capron filters and other protective equipment from sand. As the pockets of these anchors are filled with sand, they shall be taken out from time to time and after clearing the pockets, they shall be lowered to the well again. This shall be done on other maintenance works as well.

4. In some wells, it is necessary to use hollow rods, as their cross-section area is small; running speed of liquid in these rods is high and may easily extract sand out of the well.

5. To simplify the extraction of sand from the bottom of the well to the surface together with well products, the application of method on adding liquid to the annular space in the wells is necessary. In this case, amount of liquid increases because of pumped liquid and sand, and the amount of sand remains unchanged, and as a result, the concentration of sand in liquid space decreases. However, the consumption of liquid shall be less the amount of the product coming through the layer.

6. The height of the sand plug formed in the bottom of the beam wells shall be controlled with the echo sounder. Thus, it is advisable to apply I.I. Aliyev’s method.

7. After maintenance, the wells with sand shall be launched smoothly, that is, high depression shall not be applied suddenly, and it shall be increased gradually part by part.

8. If the productive layer consists of sand and fine sandstones, then method of strengthening the bottom hole area with cement shall be applied in order to prevent amount of sand penetrating into the well.

9. It is advisable to use mechanical methods of dewaxing in the beam wells, that is, application of different designed scrapers. Besides, thermal and electrical dewaxing methods shall be applied, if possible.

10. The best thermal dewaxing method is to apply hydrocarbon solvents (fine kerosene, condensate etc), as there is no need for their separation from the produced oil products.

11. Chemical reagents (for instance, sodium metaphosphate etc.) shall be used in struggling against the sand precipitation. Moreover, cleaning the precipitated sand with drinking water is also effective method.

12. To prevent liquid leakage in the wells, certain measures shall be applied; the pump details and PSP shall be replaced with new once.

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