Крім того швидкість висхідного потоку визначає час перебування пере-сиченого розчину в об'ємі контактного середовища і, отже, час кристалізації сульфата кальцію з розчину.

Таким чином, параметри харак-теризують гідродинамічні закони існуван-ня завислого шару, є визначальним і в процесі кристалізації сульфату кальцію.

ЛІТЕРАТУРА:

1. Запольський А.К. Водопостачання, водовідведення та якість води: Підручник – К.: Вища шк., 2005.- 671с.
2. Айрапетян Т.С. Водне господарство промислових підприємств; Навчальний посібник. Харківська нац.іональна академія міського господарства. - Харків: ХНАМГ, 2010. - 280 с.
3. Хамский Е.В. Перенасыщение раствора.- Л.: Наука , 1975. - 100 с.
4. Николадзе Г. И.Технология очистки природных вод. - М.: Высш. шк. – 1987. -327с.
5. Шарков В.И. и др. Технология гидролизных производств. - М.: Лесная промышленность, 1975.-407с.
6. Эпоян С.М., Сташук В.А., Лукашенко С.В., Дехтярюк Л.В. Повышение эффективности работы систем водоснабжения и водоотведения предприятий машиностроения и металлургии // Науковий вісник будівництва.- Харків: ХДТУБА, ХОТВ АБУ.- 2011, Вип.. 66.- С . 332-336.
7. Соколов В.М. Кристализация солей из намагниченных растворов.- Новоси-бирск, 1964. - 357с.
8. Аксенов В.И. и др. Травильно –регенерационные комплексы .- М.: Теплотехник, 2006. - 240с.
9. Запольський А.К., Мєшкова- Кліменко Н.А., Астрелін І.М.та ін. Фізико –хімічні основи технологічного очищення стічних вод: Підручник – К.; Лібра, 2000. – 352с.
10. Аксенов В.И. Водное хозяйство промышленных предприятий. Справ. пособие.- М.:Теплотехник , 2005.- 640 с.

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SYSTEM ANALYSISOF «MATURE» FIELDS GAS PRODUCTIONDYNAMIC

Background. Ukraine has the world's foremost strategic gas transmission systemaimedto transport natural gas from main supplier Russian Federation to European Countries.However, Ukraine is not only reliable transportation partner of Europe, but also country is powerful oil and gas producer with a long history of oil and gas field development, primary descriptions of which can be found in the 40-ies of the last century. In those times Ukraine started active development of the Western region at the foothills of the Carpathian Mountains.Proven gas reserves of 600 billion m^3ensures total gas production required for domestic consumers and maintained constant in recent years (about 20 billion cubic meters per year).This wasachieved despite the fact that the average period of development for most of the fields reaches 40 years; they are classified as «mature» and are at the final stage of development.

This stage of oil and gas field development is characterized by great value of operating pressure drop for volumetric reservoir field, decreasing of well flow-rates and appropriate decreasing of the gathering system capacity in condition of low pressures, waterflooding, emergence ofsalt, clay and other hard deposits in the internal cavity of both surface and underground equipment, wear and tear (for example: tees-valves, processes and products of erosive and corrosive wear of the «mature» separation equipment etc.).

In spite of all the problems that accompany the process of developmentat the final stages, the main key to energy independence is laid inincreasing the total volume of hydrocarbons production from «mature» field or at least in its stabilization.

To stabilize or increase the natural gas production means to accomplish some known enhanced hydrocarbon recovery methods for volumetric reservoirs, such as:

- decreasingwells operating pressure which is leading to increasing of the flow rates due to the much greater gradient between reservoir, wellbore and wellhead pressures;

-change the depth of production wells up to the lower or above lying not depleted or previously bypassing reservoirs;

-drilling of new production wells and reconstruction of abandoned ones, that eventually leads to compaction of their grid;

- inclined drilling to existing casing of low-production wells [1];

- hydrofracturing the tight packed reservoirs.

Of course, the implementation of each above mentionedmethods requires laborious, scientific and technical approach, since the error may lead to a waste of manpower, time and material resources. From other point of view the untimely put into the operation equipment (such as implementation of compression for pressure decreasing in gathering system while it can be accomplished by simple pigging) leads to the excess energy and fuel gas consumption.

Actually, taking into account the fact that most oil producing countries in the have their own “mature” field, the experience of Ukrainian specialists in this matter should come in handy.

The main aim. Increasing and stabilization of natural gas production involves finding reserves of wells operating pressure, variations of which will further reduce the size of the difference between reservoir pressure and the pressure at the wellhead pressure, resulting in an additional extraction of natural gas. This method was named as compression in the list of enhanced hydrocarbons recovery methods and in most cases the great value of pressure reserves can be provided by the installation of gas booster compressor stations in the certain point of gathering system. The second method of pressure decreasing at the wellhead of «mature» field suggest the building of new gas pipeline aimed to increase the total capacity of the gathering system.And the last one is hydraulic resistance decreasing by implementation of pigging, changing the wearing valve, reconstruction of GOSP. All three methods are complement each other forming one complex method – «compression».

This article is dedicated to problems of slugs and deposits both in surface and underground system, cause they create an additional pressure loses between booster compressor station and wellhead, since increase the value of wellhead pressure. Here we will try to assess the influence of different factors on total production of mature field.

Project concept. First of all the minimum list of need data from well testing can be collected by oil and gas engineer using controlled automatic parameters at the each GOSP:

-the annulus pressure;

-operating wellhead pressure;

-maximum wellhead pressure (the maximum pressure that can be achieved by the stopped well);

-GOSP inlet and outlet pressure;

-the same above mentioned control point temperature parameters;

-individual well flow-rates and total flow-rate through the gathering system between GOSP and booster compressor station.

Additional parameters, such as natural or associated gas composition, gas-oil or gas-condensate ratio, water cut and amount of sand accumulated in slug-catcher of separators, water and hydrocarbons dew points are subsidiary to obtain a holistic view of deposit creation, but at the same time they are routinely controlled.The bottom hole (wellbore) pressure, pressure gradient associated withgas lifting though production casing (extraction) and its gathering-processing, hydrates formation temperature, etc. are calculated by well-known formulas and allow engineer quickly to take an decisionconcerning complications during the extraction and transportation of natural gas.

So the pressure loss is the difference between bottom hole pressure and booster compressor station and they can be nominally associated with natural gas lifting upstream and transported downstream.These losses are known to be a reaction to the hydraulic resistance systemand considered to be that cannot be reduced in low pressure condition. Excessive pressure loss is additional pressure gradient arising as the result of increased hydraulic resistance of by-pass products deposits: water, condensate, sand etc. The sum of excessive and nominal pressure losses forms pressure gradient of underground and surface system. Naturally, that excessive pressure increases the pressure drop, since their estimation and evaluation of deposits volume is required to reduce the wellhead pressure and stabilized the production.

Primary and secondary production of natural gas volumetric reservoir is based on two main aspects:

- first: it is enough todecrease theoperating pressure in order to achieve increasing or at least stabilizing gas production;

- second: the wells flow-lines are designed so that all of the liquid that came to the wellhead must be sent by the reservoir power to GOSP. It is meant that any flowline designed in that way to provide gas velocity enough to transport the gas in single-phase condition.

The practice of productionat the final stages is being far from o these allegations. Researchers often make a mistake, considering production system (well) and gas gathering system separately. Look at deposit localization, having considered the parts of the system as a whole (Fig. 1).

As you can see from the picture, the liquid is localized not only in the well casing, but, due to its mass redistribution processes and as much dense part of gas-liquid mixture, formedslugs in the lowestzone of flow-line. The process of liquid accumulation in that zones is affected by two factors: great heights difference in relief that forms natural liquid traps and low gas velocities characterized the gathering process from mature fields wells.

We shall try to determine to which, the most influential factor on the volume of gas production from wells is hydraulic resistance of casing, and when hydraulic resistance of gathering system becomes determinative one. It will the best of put into the operation of booster compressor station.

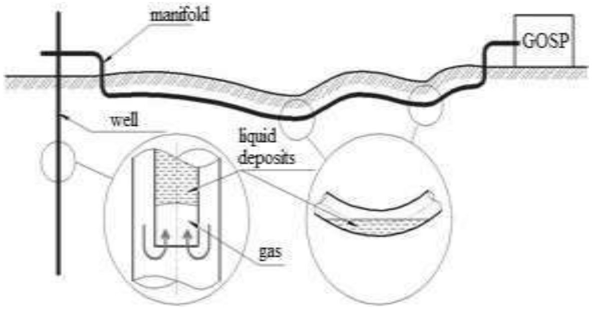

Fig. 1. Location of the liquid deposits in the underground and surface systems

First let's talk about the motion of 2 phase (gas-liquid) flow in production casing. In the final stages of development deposit water enters as free orcondensesdue toJ-T effect and environment temperature drop on the way frombottom hole to the well head. Natural depletion of reservoirs causes the pressure and flow-rates reductions which lead to gas velocity reduction. At the certain period of time the value of velocity becomes not enough to transfer the tiniest drop of water to the wellhead thus forming liquid accumulation in production casing. The total production is starting to reduce depending on hydraulic resistance formed by liquid and friction to the casing wall thickness. The wellhead pressure tends to the minimum possible and then under the pressure of gas from reservoir and annulus the liquid accumulation is removed from casing into flow-line.

So the production from mature field can be characterized by cyclic liquid accumulation and removing process [2]. Over time, the volume of accumulated liquid in the casing is changed accordingly to the effects of some variable parameters:

-gas flow velocity;

-bottom-hole (well bore) pressure;

-the volume of liquid entering as free or condensing in the casing.

All this parameters create the lifetime of liquid plugs as it is shown at the Fig. 2.

If at any time the volume of accumulated liquid reaches a critical value, the production will be stopped and the well is considered as water flooded one.Assuming that during isothermal process the liquid enters and condenses in casing permanently and if gasflow rate Q_g = const(respectively gas velocity alsoω_g = const),the volume of the accumulation will depend on pressure changes $V_{num}^{свр} = f(P)$.

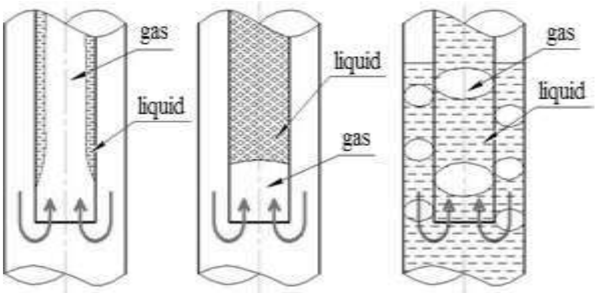

Fig. 2. The liquid accumulation lifetime from early to the final stage of field development

The minimal difference between the annulus pressure and wellhead pressure means that hydraulic resistance of casing is minimal and volume of accumulated liquid is close to zero. The greater the difference in pressure the more liquid is in the casing.

The amount of fluid formed in casing can be estimated by the formula:

$$V_{cr}^{well} = 9{,}8135 \cdot 10^4 \cdot \frac{\pi d^2}{4} \cdot \frac{|P_{wh} - P_{an}|}{\rho\, g} \quad (1)$$

where d – casing inner diameter,P_{an} – annulus pressure, bar; P_{wh} –wellhead pressure, bar; ρ – the density of the two-phase flow heaviestconstituent, кg/m^3; g – acceleration of gravity, m/sec^2.

Unlike the casing tubes the process of liquid accumulation in the flow line or trunk line is somewhat different because it never completely overlaps the pipe cross-section. Under the condition of reduces flow-rates and depending on the relief liquid is trappedat the lowestpoints of pipelines forming the volume corresponding to the state of its rest.This state of its rest in the pipeline can be characterized by the area of liquid mirror with certain length and width. The volume of liquid forms the different value of central angel 2φto the horizontal border of formation. This implies that during a sudden additional release of liquid from wells the volume of formation is tending to be greater increasing the central angle toliquid mirror. The growth of the central angle to liquid mirror is possible only up to a certain value (critical values) enough to transfer the excess amount of the liquid to another lowest point of the pipeline [3, 4]. Angle, respectively, reduced to a normal value that corresponds to the state of rest in this lowest point (Fig. 3).

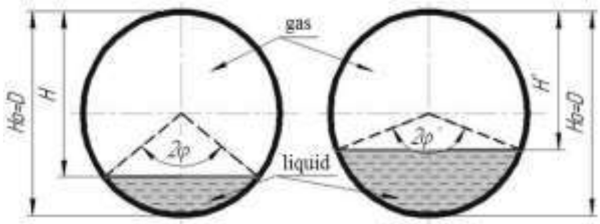

Fig. 3. Geometry and dynamics of liquid plugs in the pipeline lowest point

It is clear that the geometry of liquid formation can be estimated sing the technological parameters of two-phase flow in gathering system and the physical modeling.

Simulation of different critical values of the central angle to a liquid mirror which was formed under certain pressures, temperatures and flow rates for different two-phase system: «water – gas», «condensate- gas», «oil – gas» systems, helped researcher to bond the geometry of formation with 3 main technological parameters and 2-phase flow composition (see Fig. 4 and formula 2).

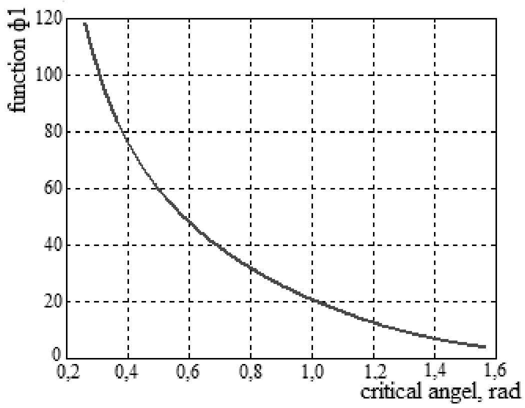

Fig. 4. Functional conditions Φ1(φ_{cr}) curve

$$\Phi_1(\varphi_{cr}) = \frac{2\beta \cdot \frac{2\pi^2\omega^2\gamma_{г}}{D\, g}}{\Delta\rho \cdot cos\alpha} = \quad (2)$$
$$= \frac{4\pi^2\beta\omega^2 P}{zRTD\, g\, cos\alpha\left(\rho_l - \frac{P}{zRT}\right)}$$

where β = 1,045-1,1 – Carioles factor (correction factor for the uneven distribution of speeds); ω – the linear gas velocity,m/sec;P – pipelines average gas pressure, Pa; z – gas compressibility factor, for uncompressed gas extracted from Ukrainian oil and gas field it is acceptable as 0,96; R – universal gas constant,J/kg·K; T –pipeline average gas temperature K; D – pipes inner diameter, m; g –acceleration ofthe gravity, m/sec; α– the angle of the pipeline incline,rad; ρ_l– liquid density, кg/m^3.

At the Fig. 5 below the mathematic model of functional condition for the certain 100-mm pipeline system gathering gas from gas-condensate wells with operating pressure 10 bar is presented.

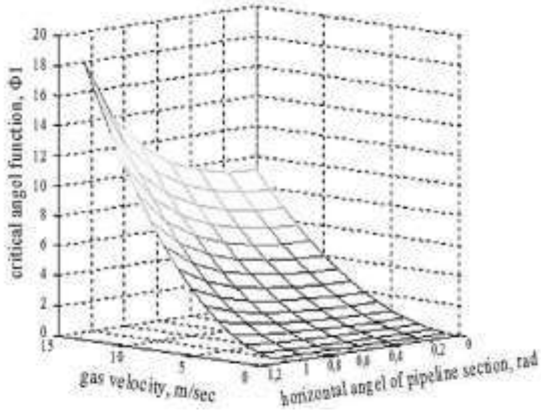

Fig. 5. 3-D implementation of mathematical

Using the area of liquid accumulation-inside the gas pipeline:

$$F = \frac{D^2}{4} \cdot \left(2\varphi_{\text{кр}} - sin2\varphi_{\text{кр}}\right) \qquad (3)$$

One can findthe critical volume of liquid impeded the production of natural gas (Fig. 6):

$$V_{cr}^{pipe} = \frac{D^2}{4} \cdot \left(2\varphi_{\text{кр}} - sin2\varphi_{\text{кр}}\right) \cdot s \quad (4)$$

where s – the length of the liquid mirror, m.

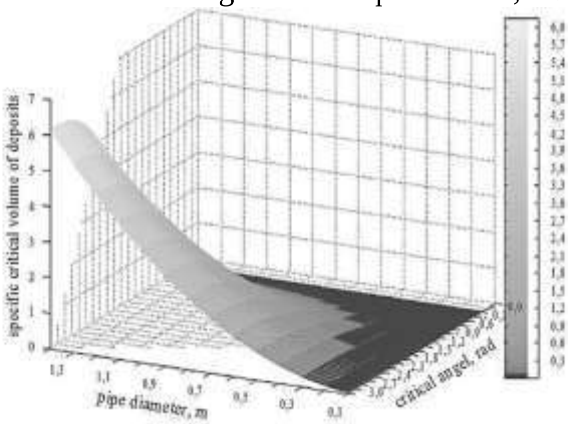

Fig. 6. Dependence of the liquid accumulation critical volumeon critical angel φ and the pipeline diameter

So on the basis of the above theoretical approach, using even the smallest set of operating data: well flow rate, velocity and pressure changes, and, operator can obtain two values:

– the critical volume of accumulated liquid in gas well casing V_{cr}^{well};
– critical volume of liquid formed in the gathering systemV_{cr}^{pipe}.

A comparison of these values enables the estimation of the impact on the flow-rate from certain well:

– the main determining factor is casing hydraulic resistance ($V_{cr}^{well} > V_{cr}^{pipe}$);
– liquid accumulation in gathering system impeding the flow rate ($V_{cr}^{well} < V_{cr}^{pipe}$);
– -the combined effect of both parameters on the total production($V_{cr}^{well} \approx V_{cr}^{pipe}$).

The presented above algorithm was used as the basis for software development «Hydraulic resistance control» (Fig. 7) [5].

Fig. 7. Windows of the software

The software analyzes and systematizesthe operating data in control points of «mature» field in real-time mode. A mathematical model describes the change in well flow-rate in time under the influence of the change of operating pressure and casing – flow line hydraulic resistance. Equation was studied by mathematical statistics methods on error (3.2%), significance of impacts and model adequacy.

Depending on the distribution of liquid formations in underground and surface system field 3-D models of production was obtained for each specific gas. These 3-D models are the classic representation of regression equation associated the response function with main factors [6, 7]: operating pressure, temperature, volume of the liquid accumulation.An example of such a model obtained from its regression equation for one of the gas-condensate field of Western production region is shown below:

$$\Delta q = -0{,}2105 \cdot \Delta V_{cr}^{pipe^4} - 0{,}421 \times \Delta V_{cr}^{well^3} + 0{,}3684 \cdot \Delta V_{cr}^{pipe} \cdot \Delta V_{cr}^{well} \quad (5)$$

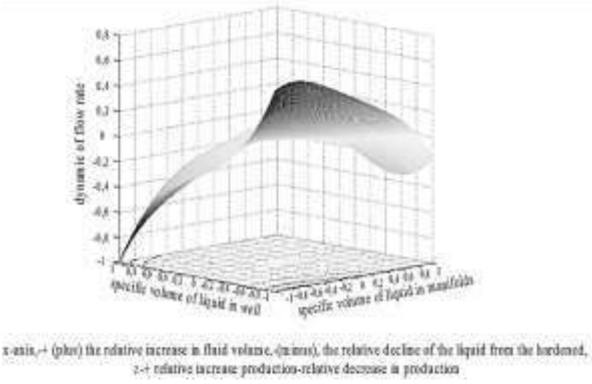

Fig. 8. Dynamics Model of gas production

Changing one value relative to another can be written as:

$$\Delta V = \frac{V - V^{/}}{V} = 1 - \frac{V^{/}}{V} \quad (6)$$

where $V^{/}$– value changes.

Substituting $V_{cr}^{well} = 9{,}8135 \cdot 10^4 \cdot \frac{\pi d^2}{4} \cdot \frac{|P_{wh} - P_{annulus}|}{\rho\, g}$ and $V_{cr}^{pipe} = \frac{D^2}{4} \cdot (2\varphi_{cr} - sin2\varphi_{cr}) \cdot s$, and considering that for a particular point in time values of the liquid density, casing and pipe diameter, length of liquid mirror will be constant the formula 5 is modified to:

$$\Delta q = 0{,}3684(1-b)(1-a) - 0{,}421(1-a)^3 - 0{,}2105(1-b)^4 \quad (7)$$

where a– gathering system resistance factor ($a = \frac{2\varphi_{cr}^{/} - sin2\varphi_{cr}^{/}}{2\varphi_{cr} - sin2\varphi_{cr}}$); b – casing resistance factor ($b = \left|\frac{P_{wh}^{/} - P_{annulus}^{/}}{P_{wh} - P_{annulus}}\right|$).

Conclusions. The results of experimental data obtained for this gas-condensate field shows that near 40 % of reservoir power will be wasted on gathering system hydraulic resistance overcoming. But if enough volume of liquid was formed in casing it is no matter how «clean» flow-line is used the well will be shut off.

The absolute advantage of the model implementation is possibility of estimation of exact time and place for booster compressor station installation in the gathering system depending on resistance of gathering system, because first engineer can estimate the «operating pressure reserves to be reduced», second the lower value of resistance you will deal with the far from well head station can be installed.

REFERENCES:

1. Galko T.M., AksenovV.V. Osobennosti proektirovaniya razrabotki gazokondensatnyih mestorozhdeniy na zavershayuschey stadia promyishlennoy ekspluatatsii. – Nauchno-proizvodstvennyiy zhurnal: «Neftyanaya i gazovaya promyishlennost» Kiev «NAK «NeftegazUkrainyi» - №2, 2009 – S.26-28.
2. Boyko V.S., Kondrat R.M., Yaremiychuk R.S. Spravochnik po neftegazovomu delu. – K.: Lvov, 1996. –620s.
3. Bratah M.I., Toporov V.G., Ruzina I.M., Soboleva A.V. Matematicheskaya model zalpovogo vyibrosa zhidkosti iz pustotyi gazoprovoda. XVIII (ezhegodnaya) mezhdunarodnaya nauchno-tehnicheskaya konferentsiya «Ekologicheskaya i tehnogennaya bezopasnost, ohrana vodnogo i vozdushnogo basseynov, utilizatsiya othodov», 07-11 iyunya 2010 g., g. Berdyansk, sb. nauchn. trudov, S. 444-452.
4. Charnyiy I.A. Vliyanie relefa mestnosti i nepodvizhnyih vklyucheniy zhidkosti ili gaza na propusknuyu sposobnost truboprovodov / I.A. Charnyiy// Neftyanoe hozyaystvo – 1965: № 6. – S.51-55.
5. Bratah M.I., Toporov V.G., Ruzina I.M., Hay V.V., Homenko G.O. Kompyuterizatsiya protsessa kontrolyu gidratoobrazovaniya i kvazistatsionarnyih rezhimov rabotyi gazoprovodov sistemy i dobyichi is boragaza. – «Vopros razvitiya gazovoy promyishlennosti». Zb. nauch. pr., vyip. XXXVIII Harkov: UkrNIIgaz, – 2010 g., S. 201-207.
6. Buslenko N.P. Modelirovanie slozhnyih sistem. – Moskva, Nedra. 1978. –. 399s.
7. Doroshenko V.M. Osnovy naukovykh doslidzhen. Navchalnyi posibnyk. // K.: ISDO; 1998. –128 s.