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MATERIALS AND CHEMICAL REAGENTS IN OIL AND GAS PRODUCTION

PRACTICE MANUAL

Ivano-Frankivsk
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Ivano-Frankivsk National Technical University of
Oil and Gas

Department of Petroleum Production

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Workbook is developed in accordance with the work program of the discipline "Materials and chemical reagents in oil and gas production". It is intended for preparation of bachelors in specialty 185 – "Oil and gas engineering and technologies".

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CONTENT

INTRODUCTION

Materials and chemical reagents in oil and gas production is a discipline that studies the physicochemical properties and parameters of formation fluids, gases and gas condensate mixtures and reagents used in drilling and operation of wells, to intensify production and industrial preparation of hydrocarbons, oil and gas applications. and their filtration in reservoir rocks, wells and pipelines.

Knowledge of the discipline is necessary and contributes to better mastering of materials necessary for a specialist in oil and gas (researcher) in such disciplines as "Technology and technology of oil and gas", "Technology of oil, gas and gas condensate fields", "Technology and techniques of oil gas condensate extraction ",“ Collection and preparation of oil and gas in the fields ”.

The processes of development and operation of oil, gas and gas condensate fields are closely related to the laws of filtration of hydrocarbons, water, various solutions of reagents in rocks, of which the productive strata are composed. Therefore, knowledge of the properties of rocks and formation fluids, as well as reagents used in the development and operation of productive formations, the laws of their interaction determines the rational technology of oil and gas development, as well as economic indicators of their extraction and further transportation to consumers.

When studying the discipline, important provisions of geology, physics, chemistry, physicochemistry of oil and gas reservoir, underground hydrogas mechanics, oil and gas mechanics and thermodynamics of rocks, technology of drilling and operation of wells and production systems are comprehensively used.

1. MATERIALS AND CHEMICALS USED IN DRILLING, DEVELOPMENT AND OPERATION OF RESERVOIRS

1.1 The main technological parameters and values that characterize the materials and chemicals used in the drilling process

Problem № 1

Determine the mass and volume of bentonitic clay and the volume of waste water which are needed for preparing 1 m^3 of drilling mud. Moisture content of bentonitic clay is 7.5 %, the density of waste water is 1060 kg/m^3, the density of drilling mud is 1250 kg/m^3. Instruction: the magnitude of the density of bentonitic clay should be taken within the range 2200 – 2700 kg/m^3.

Solution

The mass of bentonitic clay which is needed for preparing 1 m^3 of drilling mud is determined by formula:

$$G_{b.c.} = \frac{\rho_{b.c.} \cdot (\rho_{d.m.} - \rho_{w.w.})}{\rho_{b.c.} - \rho_{w.w.} \cdot (1 - n_{b.c.} + 10^{-3} \cdot n_{b.c.} \cdot \rho_{b.c.})} \quad (1.1)$$

where $G_{b.c.}$ is the mass of bentonitic clay which is needed for preparing 1 m^3 of drilling mud, kg/m^3;

$\rho_{b.c.}$ is the density of bentonitic clay, kg/m^3;

$n_{b.c.}$ is moisture content of bentonitic clay, fractions;

$\rho_{d.m.}$ is the density of drilling mud, kg/m^3;

$\rho_{w.w.}$ is the density of waste water, kg/m^3.

According to the instruction for the solution of problem take the magnitude of the density of bentonitic clay: $\rho_{b.c.} = 2450\ \text{kg/m}^3$.

So

$$G_{b.c.} = \frac{2450 \cdot (1250 - 1060)}{2450 - 1060 \cdot (1 - 0.075 + 10^{-3} \cdot 0.075 \cdot 2450)} =$$

365.2 kg/m^3

2. The volume of bentonitic clay which is needed for preparing 1 m^3 of drilling mud (m^3/m^3):

$$V_{b.c.} = \frac{G_{b.c.}}{\rho_{b.c.}} = \frac{365.2}{2450} = 0.15\ \text{m}^3/\text{m}^3 \qquad (1.2)$$

3. The volume of waste water which is needed for preparing 1 m^3 of drilling mud:

$$V_{w.w} = 1 - V_{b.c.} = 1 - 0.15 = 0.85\ \text{m}^3/\text{m}^3 \qquad (1.3)$$

Problem № 2

Determine the mass and volume of bentonitic clay and the volume of waste water which are needed for preparing 1 m^3 of drilling mud. Moisture content of bentonitic clay is 9.5 %, the density of waste water is 1085 kg/m^3, the density of drilling mud is 1270 kg/m^3. Instruction: the magnitude of the density of bentonitic clay should be taken within the range 2200 – 2700 kg/m^3.

Problem № 3

Determine the density of washing liquid if the depth of productive formation is 2160 m. Formation pressure in it is 20.8 MPa. Coefficient of safety changes within the range 1.05 – 1.15. Instruction: take the magnitude of coefficient of safety depending on the depth of the well (by the vertical) to the middle of perforation interval.

Determine the back pressure of each of the three liquids (drilling mud, formation water and gas condensate) and draw the conclusion at which of these liquids there will be the inflow of formation fluid to the bottom of the well. The depth of the well is 2000 m; density of drilling mud is 1340 kg/m^3; density of formation water is 1040 kg/m^3; density of gas condensate taken for the washing is 770 kg/m^3. Estimated formation pressure is 16.1 MPa. Draw the conclusion.

1. The density of washing liquid is determined by formula:

$$\rho_{w.l.} = k_s \cdot \frac{P_f}{g \cdot H} \qquad (1.4)$$

where $\rho_{w.l.}$ is the density of washing liquid, kg/m^3;

P_f is formation pressure, Pa;

H is the depth of productive formation (the depth of the well to the middle of perforation interval), m;

k_s is coefficient of safety.

The magnitude of coefficient of safety is taken depending on the well depth.

If $H > 1200$ m coefficient of safety k_s should be taken within the range 1.05 – 1.1.

So finally we take $k_s = 1.07$.

So the density of washing liquid is:

$$\rho_{w.l.} = 1.07 \cdot \frac{20.8 \cdot 10^6}{9.81 \cdot 2160} = 1050.3 \text{ kg/m}^3.$$

2. The condition of inflow of the fluid from the formation is:

$$P_b = \rho_l \cdot g \cdot H < P_f. \qquad (1.5)$$

For drilling mud:

$P_{b.1} = \rho_{d.m.} \cdot g \cdot H =$

$=1340 \cdot 9.81 \cdot 2000 = 26.291 \cdot 10^6$ Pa $= 26.291$ MPa.

26.291 MPa > 16.1 MPa - no inflow of the fluid from the formation.

For formation water:

$P_{b.2} = \rho_{f.w.} \cdot g \cdot H =$

$=1040 \cdot 9.81 \cdot 2000 = 20.405 \cdot 10^6$ Pa $= 20.405$ MPa.

20.405 MPa > 16.1 MPa - no inflow of the fluid from the formation.

For gas condensate:

$P_{b.3} = \rho_{g.c.} \cdot g \cdot H =$

$= 770 \cdot 9.81 \cdot 2000 = 15.107 \cdot 10^6$ Pa $= 15.107$ MPa.

15.107 MPa < 16.1 MPa - there is inflow of the fluid from the formation.

Conclusion. Only for gas condensate there will be the inflow of formation fluid to the bottom of the well.

Problem № 4

Determine the density of washing liquid if the depth of productive formation is 1770 m. Formation pressure in it is 19.3 MPa. Coefficient of safety changes within the range 1.05 – 1.15. Instruction: take the magnitude of coefficient of safety depending on the depth of the well (by the vertical) to the middle of perforation interval.

Problem № 5

Determine the back pressure of each of the three liquids (drilling mud, formation water and gas condensate) and draw the conclusion at which of these liquids there will be the inflow of formation fluid to the bottom of the well. The depth of the well is 2150 m; density of drilling mud is 1360 kg/m^3; density of formation water is 1085 kg/m^3; density of gas condensate taken for the washing is 760 kg/m^3. Estimated formation pressure is 16.8 MPa. **Draw the conclusion.**

1.2 Determination of the required number of reagents for the preparation of clay solutions under different geological and industrial conditions

Problem № 6

Determine the mass and volume of weighting agent (barite) for weighting 1 m^3 of the drilling mud from 1240 kg/m^3 to 1750 kg/m^3. Moisture content of weighting agent is 8 %, the density of weighting agent (barite) is 4512 kg/m^3.

Solution

1. The mass of weighting agent (barite) for weighting 1 m^3 of the drilling mud is determined by formula:

$$G_{w.a.} = \frac{\rho_{w.a.} \cdot (\rho_{d.m.2} - \rho_{d.m.1}) \cdot (1 - n_{w.a.})}{\rho_{w.a.} - \rho_{d.m.2} \cdot (1 - n_{w.a.} + 10^{-3} \cdot n_{w.a.} \cdot \rho_{w.a.})} \qquad (1.6)$$

where $G_{w.a.}$ is the mass of weighting agent (barite) for weighting 1 m^3 of the drilling mud, kg/m^3; $\rho_{w.a.}$ is the density of weighting agent, kg/m^3; $\rho_{d.m.1}$ is the density of drilling mud before the weighting, kg/m^3; $\rho_{d.m.2}$ is the density of drilling mud after the weighting, kg/m^3; $n_{w.a.}$ is moisture content of weighting agent (barite), fractions.

$$G_{w.a.} = \frac{4512 \cdot (1750 - 1240) \cdot (1 - 0.08)}{4512 - 1750 \cdot (1 - 0.08 + 10^{-3} \cdot 0.08 \cdot 4512)} = 932.481 \text{ kg/m}^3$$

2. The volume of weighting agent (barite) for weighting 1 m^3 of the drilling mud is determined by formula:

$$V_{w.a.} = \frac{G_{w.a.}}{\rho_{w.a.}} = \frac{932.481}{4512} = 0.207 \text{ m}^3/\text{m}^3 \qquad (1.7)$$

Problem № 7

Determine the density of reagent (fluid for killing oil well); the volume of reagent (fluid for killing oil well); the mass of reagent which is necessary for preparing the needed volume of it and the volume of solvent (waste water).

Conduct the comparing calculation for wet and dry reagent (determine the mass of dry reagent and the difference of masses of dry and wet reagent in %).

The depth of the well to the bottom is 1935 m, the depth of the well to the middle of perforation interval is 1870 m, coefficient of safety is 1.07, coefficient of losses is 1.09, the inner diameter of casing is 150.5 mm, formation pressure is 22.3 MPa, density of reagent is 2130 kg/m^3, density of solvent (waste water) is 1120 kg/m^3, density of moisture is 1060 kg/m^3; moisture content of reagent is 15 %.

Solution

1. Determine the density of reagent (fluid for killing oil well) by formula:

$$\rho_{f.k.} = k_S \cdot \frac{P_f}{g \cdot H} \qquad (1.8)$$

where $\rho_{f.k.}$ is the density of reagent (fluid for killing oil well), kg/m^3; P_f is formation pressure, Pa; H is the depth of the well to the middle of perforation interval, m; k_S is coefficient of safety which takes into account the possibility of increase of formation pressure in the well zone during work-over.

$$\rho_{f.k.} = 1.07 \cdot \frac{22.3 \cdot 10^6}{9.81 \cdot 1870} = 1300.703 \text{ kg/m}^3$$

2. Determine the volume of reagent by formula:

$$V_{f.k.} = 0.785 \cdot D^2_{in.c.} \cdot L_w \cdot \psi =$$

$$= 0.785 \cdot 0.1505^2 \cdot 1935 \cdot 1.09 = 37.502\ m^3 \qquad (1.9)$$

3. Determine the mass of reagent which is necessary for preparing the needed volume of it by formula:

$$M_r = \frac{(\rho_{f.k.} - \rho_{w.w.}) \cdot V_{f.k.}}{1 - \dfrac{\rho_{w.w.}}{\rho_r - (\rho_r - \rho_m) \cdot b_r}} =$$

$$= \frac{(1300.703 - 1120) \cdot 37.502}{1 - \dfrac{1120}{2130 - (2130 - 1060) \cdot 0.15}} = 15711.31\,kg$$

Determine the volume of solvent (waste water) by formula:

$$V_{solv} = \frac{V_{f.k.} \cdot \rho_{f.k.} - M_r}{\rho_{w.w.}} =$$

$$= \frac{37.502 \cdot 1300.703 - 15711.31}{1120} = 29.525\ m^3 \qquad (1.10)$$

4. Determine the mass of dry reagent ($b_r = 0$):

$$M_{d.r.} = \frac{(\rho_{f.k.} - \rho_{w.w.}) \cdot V_{f.k.}}{1 - \dfrac{\rho_{w.w.}}{\rho_r}} =$$

$$= \frac{(1300.703 - 1120) \cdot 37.502}{1 - \dfrac{1120}{2130}} = 14291.507\ kg \qquad (1.11)$$

5. The comparing calculation for wet and dry reagent (determination of the difference of masses of dry and wet reagent in %):

$$\frac{\Delta M_r}{M_r} = \frac{M_r - M_{d.r.}}{M_r} \cdot 100,\%$$

$$\frac{\Delta M_r}{M_r} = \frac{15711.31 - 14291.5}{15711.31} \cdot 100 = 9,04\ \% \cdot$$

Problem № 8

Determine the density of reagent (fluid for killing oil well); the volume of reagent (fluid for killing oil well); the mass of reagent which is necessary for preparing the needed volume of it and the volume of solvent (waste water).

Conduct the comparing calculation for wet and dry reagent (determine the mass of dry reagent and the difference of masses of dry and wet reagent in %).

The depth of the well to the bottom is 1840 m, the depth of the well to the middle of perforation interval is 1780 m, coefficient of safety is 1.1, coefficient of losses is 1.08, the inner diameter of casing is 132.1 mm, formation pressure is 19.6 MPa, density of reagent is 2050 kg/m^3, density of solvent (waste water) is 1090 kg/m^3, density of moisture is 1065 kg/m^3; moisture content of reagent is 12.5 %.

1.3 Selection of fluids for the opening of productive strata and their development

Problem № 9

Determine the back pressure of each of the three liquids (drilling mud, formation water and oil) and draw the conclusion at which of these liquids there will be the inflow of formation fluid to the bottom of the well. The depth of the well is 2520 m; density of drilling mud is 1330 kg/m^3; density of formation water is 1055 kg/m^3; density of oil taken for the washing is 820 kg/m^3. Estimated formation pressure is 21.5 MPa.

Solution

The condition of inflow of the fluid from the formation is:

$$P_b = \rho_l \cdot g \cdot H < P_{f.} \qquad (1.12)$$

For drilling mud:

$$P_{b.1} = \rho_{d.m.} \cdot g \cdot H =$$

$$1330 \cdot 9.81 \cdot 2520 = 32.879 \cdot 10^6 \text{ Pa} = 32.879 \text{ MPa}.$$

$32.879 \text{ MPa} > 21.5 \text{ MPa}$ - no inflow of the fluid from the formation.

For formation water:

$$P_{b.2} = \rho_{f.w.} \cdot g \cdot H =$$

$$1055 \cdot 9.81 \cdot 2520 = 26.081 \cdot 10^6 \text{ Pa} = 26.081 \text{ MPa}.$$

$26.081 \text{ MPa} > 21.5 \text{ MPa}$ - no inflow of the fluid from the formation.

For oil taken for the washing:

$$P_{b.3} = \rho_{g.c.} \cdot g \cdot H =$$

$$820 \cdot 9.81 \cdot 2520 = 20.271 \cdot 10^6 \text{ Pa} = 20.271 \text{ MPa}.$$

$20.271 \text{ MPa} < 21.5 \text{ MPa}$ - there is inflow of the fluid from the formation.

Conclusion. Only for oil taken for the washing there will be the inflow of formation fluid to the bottom of the well.

Problem № 10

Determine the back pressure of each of the three liquids (drilling mud, formation water and oil) and draw the conclusion at which of these liquids there will be the inflow of formation fluid to the bottom of the well. The depth of the well is 2680 m; density of drilling mud is 1350 kg/m^3; density of formation water is 1090 kg/m^3; density of oil taken for the washing is 800 kg/m^3. Estimated formation pressure is 22.4 MPa.

Problem № 11

Determine the wellhead pressure during the completion of gas well (completion by the method of replacing the liquid that is replacing the drilling mud by gas condensate).

Density of drilling mud is 1350 kg/m^3; density of gas condensate is 780 kg/m^3; the depth of the well to the bottom is 2160 m, the depth of the well to the middle of perforation interval (the depth of tubing) is 2070 m.

Solution

The formula for determination of the formation pressure for the first case that is when the bore hole is occupied by drilling mud (figure 1.1) :

$$P_f = \rho_{d.m.} \cdot g \cdot L \qquad (1.13)$$

$$P_f = \rho_{g.c.} \cdot g \cdot H + \rho_{d.m.} \cdot g \cdot (L - H) + P_{wh} \qquad (1.14)$$

The formula for determination of the formation pressure for the second case that is when the bore hole is occupied by gas condensate (figure 1.1)

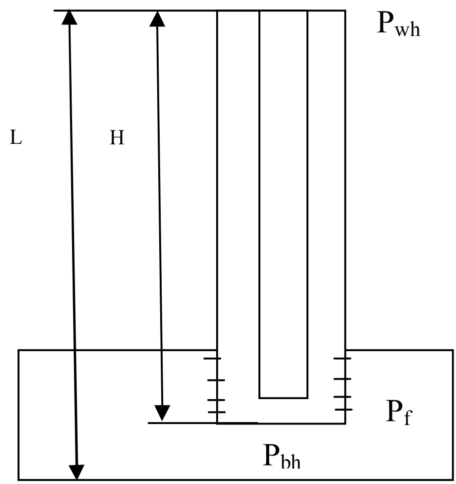


Figure 1.1 – Figure for determination of the wellhead pressure during the completion of gas well (completion by the method of replacing the liquid that is replacing the drilling mud by gas condensate).

Since the left parts of the formulas (1.13) and (1.14) are equal then equal the right parts of them and determine the wellhead pressure during the completion of gas well :

$$\rho_{d.m.} \cdot g \cdot L =$$
$$\rho_{g.c.} \cdot g \cdot H + \rho_{d.m.} \cdot g \cdot (L - H) + P_{wh}$$

$$P_{wh} = g \cdot H \cdot (\rho_{d.m.} - \rho_{g.c.})$$

$$P_{wh} = 9.81 \cdot 20160 \cdot (1350 - 780) = 11.52 \cdot 10^6 \text{ Pa} =$$
$= 11.52$ MPa.

So the wellhead pressure during the completion of gas well (completion by the method of replacing the liquid that is replacing the drilling mud by gas condensate) is 11.52 MPa.

Problem № 12

For killing the oil well water-air foam was used. Determine density of water-air foam with aeration stage a = 40 for three cases : 1) downward flow; 2) upward flow; 3) in the case of the absence of relative motion of phases. Data: pressure and temperature in the calculation point of the well are 5.3 MPa and 71°C accordingly. Coefficient of slippage k_{sl} is 0.05. Consider that gas is ideal (that is gas compressibility factor Z_g = 1). Draw the conclusion.

Solution

1. Determine density of water-air foam in the case of downward flow by means of formula:

$$\rho_{\text{f.d.f.}} = \frac{\rho_l \cdot (1 - k_{sl} \cdot a \cdot \dfrac{Z_g \cdot P_{atm} \cdot T}{P \cdot T_{st}}) + \rho_{g\,st.c.} \cdot a \cdot (1 + k_{sl})}{1 + a \cdot \dfrac{Z_g \cdot P_{atm} \cdot T}{P \cdot T_{st}}}$$

$$\rho_{\text{f.d.f.}} = \frac{1000 \cdot (1 - 0.05 \cdot 40 \cdot \dfrac{0.1013 \cdot 344}{5.3 \cdot 293}) + 1.205 \cdot 40 \cdot (1 + 0.05)}{1 + 40 \cdot \dfrac{0.1013 \cdot 344}{5.3 \cdot 293}} =$$

$= 530$ kg/m^3.

2. Determine density of water-air foam in the case of upward flow by means of formula:

$$\rho_{\text{f.u.f.}} = \frac{\rho_l \cdot (1 + k_{sl} \cdot a \cdot \dfrac{Z_g \cdot P_{atm} \cdot T}{P \cdot T_{st}}) + \rho_{g\,st.c.} \cdot a \cdot (1 - k_{sl})}{1 + a \cdot \dfrac{Z_g \cdot P_{atm} \cdot T}{P \cdot T_{st}}}$$

$$\rho_{\text{f.d.f.}} = \frac{1000 \cdot (1 - 0.05 \cdot 40 \cdot \dfrac{0.1013 \cdot 344}{5.3 \cdot 293}) + 1.205 \cdot 40 \cdot (1 + 0.05)}{1 + 40 \cdot \dfrac{0.1013 \cdot 344}{5.3 \cdot 293}} =$$

$= 574.762$ kg/m^3.

3. Determine density of water-air foam in the case of the absence of relative motion of phases ($k_{sl} = 0$):

$$\rho_{\text{f.a.r.m.}} = \frac{\rho_l + \rho_{g\,st.c.} \cdot a}{1 + a \cdot \dfrac{Z_g \cdot P_{atm} \cdot T}{P \cdot T_{st}}}$$

$$\rho_{\text{f.a.r.m.}} = \frac{1000 + 1.205 \cdot 40}{1 + 40 \cdot \dfrac{0.1013 \cdot 344}{5.3 \cdot 293}} = 552.381 \text{ kg/m}^3.$$

$$\frac{\rho_{f.d.f.}}{\rho_{f.a.r.m}} = \frac{530}{552.381} = 0.959 \qquad \frac{\rho_{f.u.f.}}{\rho_{f.a.r.m}} = \frac{574.762}{552.381} = 1.04.$$

Conclusion

The neglect of relative slippage of phases results in negligible error (4 − 4.1 %).

For killing the oil well water-air foam was used. Determine density of water-air foam with aeration stage a = 40 for three cases : 1) downward flow; 2) upward flow; 3) in the case of the absence of relative motion of phases. Data: pressure and temperature in the calculation point of the well are 6.9 MPa and 85 ^{o}C accordingly. Coefficient of slippage k_{sl} is 0.05. Consider that gas is ideal (that is gas compressibility factor Z_g = 1).

2 MATERIALS AND CHEMICALS USED TO INCREASE WELL PRODUCTIVITY

2.1 Determination of the required amount of reagents for the preparation of acid solutions during acid action

Problem № 13

Determine the volume of acid solution and the radius of acid treatment of well bottom-hole formation zone. Well radius is 0.15 m, thickness of productive formation is 23 m, formation porosity is 18 %. The norm of acid solution discharge is 0.7 m^3/m (that is for carrying out acid treatment it is necessary to inject 0.8 m^3 of acid solution for 1 m of productive formation thickness).

Solution

1. Determine the volume of acid solution which is necessary for acid treatment

$$V_{ac.s} = V_{n.ac.s} \cdot h = 0.8 \cdot 31 = 24.8 \, m^3 \quad (2.1)$$

2. Determine the radius of acid treatment of well bottom-hole formation zone

$$R_{ac.tr} = \sqrt{\frac{V_{ac.s}}{\pi \cdot h \cdot m} + r_w^2} = \sqrt{\frac{24.8}{3.14 \cdot 31 \cdot 0.16} + 0.16^2} = 1.272 \, m \quad (2.2)$$

Answer: the volume of acid solution is 24.8 m^3, the radius of acid treatment of well bottom-hole formation zone is 1.272 m.

Problem № 14

Determine the volume of acid solution and the radius of acid treatment of well bottom-hole formation zone. Well radius is 0.18 m, thickness of productive formation is 25 m, formation porosity is 17.5 %. The norm of acid solution discharge is 0.8 m^3/m (that is for carrying out acid treatment it is necessary to inject 0.8 m^3 of acid solution for 1 m of productive formation thickness).

Problem № 15

Determine the volume of acid solution and the technological effect of acid treatment of well bottom-hole formation zone if the radius of external reservoir boundary is 850 m. As a result of acid treatment coefficient of permeability of bottom-hole formation zone increased for 4 times. The radius of acid treatment of well bottom-hole formation zone is 1.25 m. Well radius is 0.16 m. The norm of acid solution discharge is 0.7 m^3/m (that is for carrying out acid treatment it is necessary to inject 0.7 m^3 of acid solution for 1 m of productive formation thickness).

Solution

1. Determine the volume of acid solution which is necessary for acid treatment

$$V_{ac.s} = V_{n.ac.s} \cdot h = 0.7 \cdot 27 = 18.9 \text{ m}^3$$

2. Determine the technological effect of acid treatment of well bottom-hole formation zone

$$E = \frac{\ln\left(\frac{R_{e.r.b.}}{r_w}\right)}{\frac{1}{n}\cdot\ln\left(\frac{R_{ac.tr.}}{r_w}\right)+\ln\left(\frac{R_{e.r.b.}}{R_{ac.tr.}}\right)} = \frac{\ln\left(\frac{850}{0.16}\right)}{\frac{1}{4}\cdot\ln\left(\frac{1.25}{0.16}\right)+\ln\left(\frac{850}{1.25}\right)} = 1.219 \quad (2.3)$$

Answer : the volume of acid solution is 18.9 m^3, the technological effect of acid treatment of well bottom-hole formation zone is 1.219.

Problem № 16

Determine the volume of acid solution and the technological effect of acid treatment of well bottom-hole formation zone if the radius of external reservoir boundary is 750 m. As a result of acid treatment coefficient of permeability of bottom-hole formation zone increased for 5 times. The radius of acid treatment of well bottom-hole formation zone is 1.3 m. Well radius is 0.13 m. The norm of acid solution discharge is 0.6 m^3/m (that is for carrying out acid treatment it is necessary to inject 0.6 m^3 of acid solution for 1 m of productive formation thickness).

Problem № 17

Determine the volume of acid solution and the radius of acid treatment of well bottom-hole formation zone. Well radius is 0.19 m, thickness of productive formation is 21 m, formation porosity is 25 %. The norm of acid solution discharge is 0.7 m^3/m. Determine the technological effect of acid treatment of well bottom-hole formation zone if the radius of external reservoir boundary is 500 m. As a result of acid treatment coefficient of permeability of bottom-hole formation zone increased for 4 times.

1. Determine the volume of acid solution which is necessary for acid treatment

$$\mathrm{V_{ac.s}} = \mathrm{V_{n.ac.s}} \cdot \mathrm{h} = 0.7 \cdot 21 = 14.7\,\mathrm{m}^3.$$

2. Determine the radius of acid treatment of well bottom-hole formation zone

$$\mathrm{R_{ac.tr}} = \sqrt{\frac{V_{ac.s}}{\pi \cdot h \cdot m} + r_w^2} = \sqrt{\frac{14.7}{3.14 \cdot 21 \cdot 0.25} + 0.19^2} = 0.963 \text{ m.}$$

3. Determine the technological effect of acid treatment of well bottom-hole formation zone

$$\mathrm{E} = \frac{\ln\left(\dfrac{\mathrm{R_{e.r.b.}}}{\mathrm{r_w}}\right)}{\dfrac{1}{n} \cdot \ln\left(\dfrac{R_{ac.tr.}}{r_w}\right) + \ln\left(\dfrac{R_{e.r.b.}}{R_{ac.tr.}}\right)} = \frac{\ln\left(\dfrac{500}{0.19}\right)}{\dfrac{1}{4} \cdot \ln\left(\dfrac{0.963}{0.19}\right) + \ln\left(\dfrac{500}{0.963}\right)} = 1.183$$

Answer: the volume of acid solution is 14.7 m^3, the radius of acid treatment of well bottom-hole formation zone is 0.963 m, the technological effect of acid treatment of well bottom-hole formation zone is 1.183.

Problem № 18

Determine the volume of acid solution and the radius of acid treatment of well bottom-hole formation zone. Well radius is 0.15 m, thickness of productive formation is 31 m, formation porosity is 23 %. The norm of acid solution discharge is 0.8 m^3/m (that is for carrying out acid treatment it is necessary to inject 0.8 m^3 of acid solution for 1 m of productive formation thickness). Determine the technological effect of acid treatment of well bottom-hole formation zone if the radius of external reservoir boundary is 600 m. As a result of acid treatment coefficient of permeability of bottom-hole formation zone increased for 5 times.

Problem № 19

Determine the volume of acid solution which is necessary for acid solution which is necessary for acid bath. Well radius is 0.17 m, thickness of productive formation is 24 m.

Solution

Volume of acid solution which is necessary for acid bath:

$$V_{ac.s.b} = \pi \cdot r_w^2 \cdot h = 3.14 \cdot 0.17^2 \cdot 24 = 2.179 \text{ m}^3.$$

Problem № 20

Calculate the quantity (the mass) of magnesium for carrying out the thermal acid treatment of productive formation of the thickness 16.5 m. For this purpose acid solution of concentration 15 % should be used. The temperature of acid solution in the interval of the treatment has to be increased up to 90 °C. The norm of acid solution flow rate is 0.8 m^3 per 1 m of formation thickness (0.8 m^3/m). Determine also the residual concentration of acid solution after reaction with the rock.

Solution

1. Calculate the volume of acid solution:

$$V_{a.s.} = V_{n.a.s.} \cdot h = 0.8 \cdot 16.5 = 13.2 \text{ m}^3. \quad (2.4)$$

2. Put the given temperature (90 °C) on the figure and draw the horizontal line to the intersection with the curve 1 (point A) (figure 2.1). Draw the vertical line from the point A to the

intersection with the curve 2 (point B). Draw the horizontal line from the point B to the right axis (axis $V'_{n.a.s.}$). Determine the norm of flow rate of acid (15 % concentration) per 1 kg of magnesium (in dm^3/kg) $V'_{n.a.s.}$ by the right axis (axis $V'_{n.a.s.}$). In this case we have : $V'_{n.a.s.} = 65\ dm^3/kg = 0.065\ m^3/kg$.

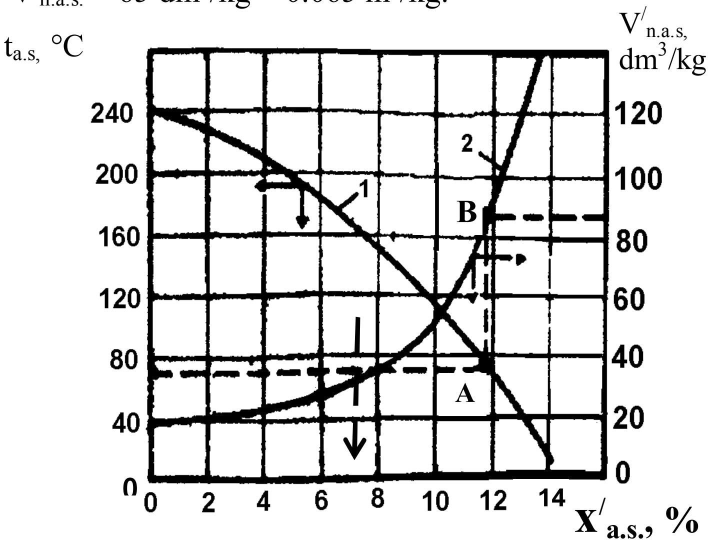


Figure 2.1 – The figure for determination of the increase of the temperature of acid solution and the norm of flow rate of acid (15 % concentration) per 1 kg of magnesium

The curves:

$1 - t_{a.s.} = f(X'_{a.s.})$; $2 - V'_{a.s.} = f(X'_{a.s.})$.

$t_{a.c.}$ is the temperature of acid solution, °C ;

$V'_{n.a.s.}$ is the norm of flow rate of acid (15 % concentration) per 1 kg of magnesium, dm^3/kg ;

$X'_{a.s.}$ is the residual concentration of acid solution after reaction with the rock, %.

Calculate the mass of magnesium which is necessary for carrying out the thermal acid treatment of productive formation by means of the formula:

$$Q_{magn} = \frac{V_{a.c.}}{V'_{n.a.c.}} = \frac{13.2}{0.065} = 203.1 \text{ kg} \quad (2.5)$$

Determine the residual concentration of acid solution after reaction with the rock from the figure.

Draw the vertical line from the point B to the axis $x'_{a.c.}$

So $x'_{a.c.} = 11$ %.

Answer: the mass of magnesium which is necessary for carrying out the thermal acid treatment of productive formation $Q_{magn} = 203.1$ kg; the residual concentration of acid solution after reaction with the rock $x'_{a.s.} = 11$ %.

Problem № 21

Calculate the quantity (the mass) of magnesium for carrying out the thermal acid treatment of productive formation of the thickness 23 m. For this purpose acid solution of concentration 15 % should be used. The temperature of acid solution in the interval of the treatment has to be increased up to 105 °C. The norm of acid solution flow rate is 0.7 m^3 per 1 m of formation thickness (0.7 m^3/m). Determine also the residual concentration of acid solution after reaction with the rock.

Problem № 22

Determine the carbonate content of the rock if as a result of reaction of hydrochloric acid with the rock (the weight of tested rock is 4.62 g) carbon dioxide CO_2 of the volume 24 cm^3 has released. The density of carbon dioxide CO_2 is 1.81 kg/m^3 (under conditions of reaction).

Determine also the amount of limestone dissolved by hydrochloric acid if after 2.5 minutes of the laboratory experiment on studying the kinetics of reaction of hydrochloric acid with carbonate rock the volume of carbon dioxide CO_2 of 90 cm^3 has released.

Instruction: to determine the amount of limestone dissolved by hydrochloric acid use the formula:

$$G_{dis.\,lim.} = 4.468 \cdot V'_{CO2},$$

where $G_{dis.\,lim.}$ is the amount of limestone dissolved by acid for the given moment of time, g; V'_{CO2} is the volume of carbon dioxide which has released by the given moment of time, *l*.

Solution

1. Determine the rock carbonate content (in %) by the formula:

$$K = \frac{V_{CO2} \cdot \rho_{CO2}}{4.4 \cdot G}, \qquad (2.6)$$

where

V_{CO2} is the volume of CO_2 which released in the result of reaction of the acid with rock, cm^3;

G is the weight of tested rock sample, g;

ρ_{CO2} is the density of CO_2 under conditions of the laboratory experiment, mg/cm^3 (kg/m^3).

$$K = \frac{24 \cdot 1.81}{4.4 \cdot 4.62} = 2.14\ \%.$$

2. Determine the amount of limestone dissolved by hydrochloric acid by means of the formula:

$$G_{dis.\,lim.} = 4.468 \cdot V'_{CO2},$$

where

$G_{dis.\,lim.}$ is the amount of limestone dissolved by acid for the given moment of time, g;

V'_{CO2} is the volume of carbon dioxide which has released for the given moment of time, *l*.

$$G_{\text{dis. lim.}} = 4.468 \cdot V'_{CO2} = 4.468 \cdot 90 \cdot 10^{-3} = 0.402\ \text{g}.$$

Problem № 23

Determine the carbonate content of the rock if as a result of reaction of hydrochloric acid with the rock (the weight of tested rock is 4.17 g) carbon dioxide CO_2 of the volume 16 cm^3 has released. The density of carbon dioxide CO_2 is 1.83 кг/м^3 (under conditions of reaction).

Determine also the amount of limestone dissolved by hydrochloric acid if after 2 minutes of the laboratory experiment on studying the kinetics of reaction of hydrochloric acid with carbonate rock the volume of carbon dioxide CO_2 of 72 cm^3 has released.

Instruction: to determine the amount of limestone dissolved by hydrochloric acid use the formula:

$$G_{\text{dis. lim.}} = 4.468 \cdot V'_{CO2},$$

where $G_{\text{dis. lim.}}$ is the amount of limestone dissolved by acid for the given moment of time, g; V'_{CO2} is the volume of carbon dioxide which has released by the given moment of time, *l*.

Problem № 24

Determine the volume of acid solution which is necessary for carrying out acid treatment and volumes of reagents for preparing asid solution (hydrochloric acid, chloride barium, inhibitor of corrosion, intensifier, stabilizer and water), if the opened up thickness of formation is 34 m, the norm of acid solution discharge is 0.7 m^3/m, the concentration of hydrochloric acid is 27 % mass, the concentration of acid solution is 18 % mass. The norm of adding the intensifier (surfactant) is 0.25 % mass.

The norm of adding inhibitor of corrosion is 0.2 % mass.
The norm of adding acetic acid of 100 % 2.5 % mass.
The volumetric fraction of sulfuric acid in the hydrochloric acid is 0.4 %.
The density of chloride barium is 4000 kg/m^3.
The volumetric fraction of inhibitor of corrosion is 100 %.
The volumetric fraction of acetic acid 80 %.
The volumetric fraction of intensifier (surfactant) is 100 %.

Solution

1. The norm of acid solution discharge is 0.4 – 0.6 m^3 per 1 m of productive formation thickness of porous of rocks of low permeability and 0.6 – 1 m^3 per 1 m of productive formation thickness of porous of rocks of high permeability.

2. The volume of acid solution which is necessary for carry out acid treatment is:

$$V_{a.s.} = V_{n.ac.s} \cdot h_{op.f.}$$

$$V_{a.s} = 0.7 \cdot 34 = 23.8 \text{ m}^3.$$

3. The volume of hydrochloric acid (in m^3) :

$$V_a = \frac{V_{a.s} \cdot X_{a.s.} \cdot (5.09 \cdot X_{a.s.} + 999)}{X_{a.} \cdot (5.09 \cdot X_{a.} + 999)} \tag{2.7}$$

$$V_a = \frac{23.8 \cdot 18 \cdot (5.09 \cdot 18 + 999)}{27 \cdot (5.09 \cdot 27 + 999)} = 15.23 \text{ m}^3$$

4. The mass of chloride barium

$$G_{chl.b} = 21.3 \cdot V_{a.s} \cdot \left(a \cdot \frac{X_{a.s}}{X_a} - 0.02 \right) \tag{2.8}$$

where a is the volumetric fraction of sulfuric acid in the hydrochloric acid, % mass.

$$G_{chl.b} = 21.3 \cdot 23.8 \cdot \left(a \cdot \frac{18}{27} - 0.02 \right) = 125.045 \text{ kg}$$

5. The volume of chloride barium

$$V_{\mathrm{chl.b}} = \frac{G_{\mathrm{chl.b}}}{\rho_{\mathrm{chl.b}}} \tag{2.9}$$

$$V_{\mathrm{chl.b}} = \frac{125.045}{4000} = 0.031 \ \mathrm{m}^3$$

6. The volume of stabilizer (acetic acid)

$$V_{\mathrm{a.a.}} = b_{a.a.} \cdot \frac{V_{a.s}}{C_{a.a.}} \tag{2.10}$$

$$V_{\mathrm{a.a.}} = 2.5 \cdot \frac{23.8}{80} = 0.744 \ \mathrm{m}^3$$

7. The volume of inhibitor of corrosion:

$$V_{\mathrm{inh.c.}} = b_{inh.c.} \cdot \frac{V_{a.s}}{C_{inh.c.}} \tag{2.11}$$

$$V_{\mathrm{inh.c.}} = 0.2 \cdot \frac{23.8}{100} = 0.048 \ \mathrm{m}^3$$

As inhibitor of corrosion the reagent katapin-K (катапін-К) will be used.

8. The volume of intensifier (surfactant).

$$V_{\mathrm{int}} = b_{\mathrm{int}.} \cdot \frac{V_{a.s}}{C_{\mathrm{int}}} \tag{2.12}$$

$$V_{\mathrm{int}} = 0.25 \cdot \frac{23.8}{100} = 0.06 \ \mathrm{m}^3$$

As the intensifier the surfactant sulphonol (сульфонол) will be used.

9. The volume of water which is necessary for preparing the acid solution

$$V_{\mathrm{w}} = V_{a.s.} - V_a - V_{chl.b.} - V_{inh.c.} - V_{a.a} - V_{\mathrm{int}} \tag{2.13}$$

$$V_{\mathrm{w}} = 23.8 - 15.23 - 0.031 - 0.048 - 0.744 - 0.06 = 7.69 \ \mathrm{m}^3$$

Problem № 25

Determine the volume of acid solution which is necessary for carrying out acid treatment and volumes of reagents for preparing asid solution (hydrochloric acid, chloride barium, inhibitor of corrosion, intensifier, stabilizer and water), if the opened up thickness of formation is 26 m, the norm of acid solution discharge is 0.8 m^3/m, the concentration of hydrochloric acid is 29 % mass, the concentration of acid solution is 17 % mass

The norm of adding the intensifier (surfactant) is 0.3 % mass

The norm of adding inhibitor of corrosion is 0.2 % mass

The norm of adding acetic acid of 100 % 3 % mass

The volumetric fraction of sulfuric acid in the hydrochloric acid is 0.4 %.

The density of chloride barium is 4000 kg/m^3

The volumetric fraction of inhibitor of corrosion is 100 %

The volumetric fraction of acetic acid 80 %

The volumetric fraction of intensifier (surfactant) is 90 %

2.2 Determination of the required number of reagents during hydro-sand jet perforation

Problem № 26

Calculate the necessary amount of chemical reagents for carrying out hydraulic jet perforating in oil well (that is calculate the total volume of the working liquid, the amount of sand which is necessary for carrying out hydraulic jet perforating and the flow rate of the working liquid). The depth of the well to the middle of productive formation (the depth of hydraulic jet perforating) 1840 m, mass concentration of sand in the liquid and sand mixture 150 kg/m^3, density of working liquid (water) 1020 kg/m^3, density of sand 2480 kg/m^3, the inner diameter of casing 150.5 mm, the quantity of nozzles in the hydroperforator is 4, coefficient of flow rate 0.82, diameter of the nozzle 3 mm.

Solution

1. The total volume of the working liquid (water) $V_{w.l.}$ (in m^3) is taken equal to approximately (2.3 – 2.5) volumes of the well:

$$V_{w.l.} = 2.4 \cdot \frac{\pi \cdot D^2_{in.cas.}}{4} \cdot H_w$$

$$V_{w.l.} = 2.4 \cdot 0.785 \cdot 0.1505^2 \cdot 1840 = 78.35 \quad m^3 \qquad (2.14)$$

at this $0.4 \cdot V_{w.l.}$=31.34 m^3 is used to carry sand to the well bottom;

$0.4 \cdot V_{w.l.}$ = 31.34 m^3 is used for washing the well after carrying out the process of hydraulic jet perforating;

$0.2 \cdot V_{w.l}$ = 15.67 m^3 is used for preventing the loss of circulation of liquid because of intake (absorption) of liquid by formation

2. The total amount of sand which is necessary for carrying out hydraulic jet perforating Q_s (in kg) should be calculated for the volume $0.6 \cdot V_{w.l}$:

$$Q_s = 0.6 \cdot V_{w.l.} \cdot C_s = 0.6 \cdot 78.35 \cdot 150 = 7051.5 \text{ kg} \quad (2.15)$$

3. Determine the flow rate of the working liquid $Q_{w.l}$, m^3/s (as the working liquid as a rule water is used) by means of the formula:

$$Q_{w.l.} = 1.414 \cdot \mu \cdot n_n \cdot f_n \cdot \sqrt{\frac{\Delta P_n}{\rho_{l.s.m}}} \qquad (2.16)$$

where

μ is coefficient of flow rate. It is taken equal to 0.82 ;

n_n is the quantity of nozzles in the hydroperforator (as a rule

$n_n = 4$);

f_n is cross-sectional area of the nozzle at the exit, m^2

$$f_n = \frac{\pi}{4} \cdot d_n^2 = 0.785 \cdot 0.03^2 = 1.59 \cdot 10^{-5} \text{ m}^2$$

ΔP_n are the losses of pressure in the nozzles, MPa.

For the nozzles of diameter d_n = (3 – 4.5) mm the magnitude of ΔP_n should be taken within the interval ΔP_n = 18 – 20 MPa.

So we take ΔP_n = 20 MPa.

$\rho_{l.s.m}$ is the density of liquid and sand mixture, kg/m^3

$$\rho_{l.s.m.} = \rho_{w.l.} \cdot (1 - b_s) + \rho_s \cdot b_s \qquad (2.17)$$

where b_s is volumetric concentration of sand in the liquid and sand mixture

$$b_s = \frac{C_s}{C_s + \rho_s} \qquad (2.18)$$

where C_s is the mass concentration of sand in the liquid and sand mixture, kg/m^3

ρ_s is density of sand, kg/m^3

$$b_s = \frac{150}{150 + 2480} = 0.057$$

Determine the density of liquid and sand mixture:

$$\rho_{l.s.m.} = 1020 \cdot (1 - 0.057) + 2480 \cdot 0.057 = 1103.2 \text{ kg/m}^3$$

Put all ciphers into formula (3) and we will get:

$$Q_{w.l.} = 1.414 \cdot 0.82 \cdot 4 \cdot 1.59 \cdot 10^{-5} \cdot \sqrt{\frac{20 \cdot 10^6}{1103.2}} = 0.0099 \text{ m}^3\text{/s.}$$

Answer:

the total volume of the working liquid is 78.35 m^3

the total amount of sand which is necessary for carrying out hydraulic jet perforating is 7064.2 kg

the flow rate of the working liquid is 0.0099 m^3/s

Problem № 27

Calculate the necessary amount of chemical reagents for carrying out hydraulic jet perforating in oil well (that is calculate the total volume of the working liquid, the amount of sand which is necessary for carrying out hydraulic jet perforating and the flow rate of the working liquid). The depth of the well to the middle of productive formation (the depth of hydraulic jet perforating) 2500 m, mass concentration of sand in the liquid and sand mixture 280 kg/m^3, density of working liquid (water) 1030 kg/m^3, density of sand 2500 kg/m^3, the inner diameter of casing 150.5 mm, the quantity of nozzles in the hydroperforator is 4, coefficient of flow rate 0.82, diameter of the nozzle 4 mm.

3. MATERIALS AND CHEMICALS USED TO DEAL WITH COMPLICATIONS DURING WELL OPERATION

3.1 Determination of the required number of reagents to protect oil and gas equipment from corrosion

Problem № 28

Determine the relative rate of corrosion of the equipment of gas well. Data: the total content of ions of iron in the liquid (formation water) is 75 mg/*l*, productivity of well is 50 th m^3/day, water-gas ratio is 35 cm^3/m^3, the length of tubing column is 2150 m, the inner diameter of tubing is 62 mm.

Solution

The relative rate of corrosion of the equipment of gas well could be determined by means of the formula:

$$K_r = \frac{C_{i.i.} \cdot Q_l}{A_{s.k.}} \tag{3.1}$$

where K_r is the relative rate of corrosion of the equipment of gas well, g/m^2·hour

$C_{i.i.}$ is the total content of ions of iron in the liquid (formation water), g/*l*.

Q_l is the flow rate of liquid (formation water), *l*/hour.

$A_{s.k.}$ is the area of the surface of contact of metal with analyzed liquid, m^2.

The flow rate of liquid (formation water) could be determined by means of the formula:

$$Q_l = Q_g \cdot R_{w.g.} \tag{3.2}$$

$$Q_l = 50 \cdot 1000 \cdot 35 \cdot 10^{-6} = 1.75 \text{ m}^3/\text{day}$$

Transform Q_l to l/hour:

$$Q_l = \frac{1.75 \cdot 1000}{24} = 72.9 \text{ l/hour}$$

The area of the surface of contact of metal with analised liquid (formation water):

$$A_{s.k.} = \pi \cdot d_{i.t.} \cdot L_s \qquad (3.3)$$

Where L_s is the length of the section of well equipment which has to be prevented of corrosion, m.

$$A_{s.k.} = \pi \cdot 0.062 \cdot 2150 = 418.774 \quad m^2.$$

So $K_r = \dfrac{75 \cdot 10^{-3} \cdot 72.9}{418.774} = 0.0131$ g/m^2·hour.

Answer:

The relative rate of corrosion of the equipment of gas well is K_r=0.0131 g/(m^2· hour).

Problem № 29

Determine the relative rate of corrosion of the equipment of gas well. Data: the total content of ions of iron in the liquid (formation water) is 126 mg/*l*, productivity of well is 140 th. m^3/ day, water-gas ratio is 84 cm^3/m^3, the length of tubing column is 2390 m, the inner diameter of tubing is 62 mm.

Problem № 30

Determine the necessary daily discharge of corrosion inhibitor CT-1 for prevention of corrosion of downhole equipment of gas condensate well.

The daily productivity of the well for gas condensate is 3.42 m^3/day.

Recommended discharge of concentrated corrosion inhibitor (in mg per 1 *l* of hydrocarbonic condensate recovered from the well − mg/*l*) $C_{inh.}$ = 1000 mg/l. The quantity of parts (volumetric or mass) of the hydrocarbonic condensate per 1 part of the concentrated inhibitor 1:4 (that is the inhibitor before injection into the well is diluted by condensate with the ratio 1:4 − so n = 4).

Solution

Since the inhibitor CT-1 is soluble in the hydrocarbonic condensate, its discharge is calculated per the unit of the volume of the hydrocarbonic condensate produced in the well.

The necessary daily discharge of corrosion inhibitor CT-1 for prevention of corrosion of downhole equipment of gas condensate well:

$$Q_{\text{inh. cor.}} = \frac{C_{inh.} \cdot Q_{g.c.} \cdot (1+n)}{1000} \qquad (3.4)$$

$$Q_{\text{inh. cor.}} = \frac{1000 \cdot 3.42 \cdot (1+4)}{1000} = 17.1 \ \frac{1}{\text{day}}$$

The discharge of corrosion inhibitor which is continuously injected into the well is determined at first during laboratory researches and then during the field injection into the well.

Problem № 31

Determine the necessary daily discharge of corrosion inhibitor KMA for prevention of corrosion of downhole equipment of gas condensate well. The daily productivity of the well for gas condensate is 18.6 m^3/day. Recommended discharge of concentrated corrosion inhibitor (in mg per 1 *l* of hydrocarbonic condensate recovered from the well − mg/*l*) $C_{inh.}$ = 750 mg/l. The quantity of parts (volumetric or mass) of the hydrocarbonic condensate per 1 part of the concentrated inhibitor 1:3 (that is the inhibitor before injection into the well is diluted by condensate with the ratio 1:3 − so n = 3).

3.2 Determination of the required number of reagents to protect gas equipment from hydrate formation

Problem № 32

Determine the daily discharge of the hydrating inhibitor for prevention hydrating in the bore hole of gas (gas condensate) well.

The working (factual) temperature on the well head is 12 ^{O}C, hydrating equilibrium temperature on the well head is 16 ^{O}C, productivity of gas well (gas flow rate) is 185 thm^3/day, moisture content on the bottom of the well is 3.4 kg/th. m^3, moisture content on the well head is 0.9 kg/th. m^3, the mass concentration of added (fresh) hydrating inhibitor is 97 % mass.

Solution

The choice of the type of hydrating inhibitor.

Let's choose methanol because methanol is the most efficient and it is not difficult-to-obtain.

The daily discharge of the hydrating inhibitor methanol for prevention hydrating in the bore hole of gas (gas condensate) well:

$$Q_{h.inh.} = \frac{(W_1 - W_2) \cdot C_2}{C_1 - C_2} \cdot Q_g \qquad (3.5)$$

where $Q_{h.inh.}$ is the daily discharge of the hydrating inhibitor, kg/day,

Q_g is gas flow rate under the standard conditions, th. m^3/day,

W_1, W_2 are moisture contents on the bottom of the well and on the well head respectively, kg/th.m^3

C_1, C_2 are mass concentrations of added (fresh) hydrating inhibitor and worked out hydrating inhibitor (hydrating inhibitor saturated by the moisture), % mass

The mass concentration of hydrating inhibitor saturated by the moisture C_2 could be determined by means of Hammershmidt's formula:

$$C_2 = \frac{M \cdot \Delta t}{M \cdot \Delta t + K} \qquad (3.6)$$

where M is the molecular mass of hydrating inhibitor ;

K is the constant;

Δt is the difference between the hydrating equilibrium temperature and the working (factual) temperature in the point of adding hydrating inhibitor, ^{O}C.

M and K should be taken from the table [1].

For methanol we have the constant K=1295;

The molecular mass of methanol is 32.04 g/mole or kg/kmole

The difference between the hydrating equilibrium temperature and the working (factual) temperature in the point of adding hydrating inhibitor:

$\Delta t = |t_{h.e.} - t_{w.h.}| = 16 - 12 = 4\ ^{O}C$.

The mass concentration of hydrating inhibitor saturated by the moisture:

$$C_2 = \frac{32.04 \cdot 4}{32.04 \cdot 4 + 1295} \cdot 100 = 9\ \%$$

So the daily discharge of the hydrating inhibitor (methanol) for prevention hydrating in the bore hole of gas (gas condensate) well:

$$Q_{h.inh.} = \frac{(3.4 - 0.9) \cdot 9}{97 - 9} \cdot 185 = 47.3$$

Answer:

The necessary daily discharge of the hydrating inhibitor methanol for prevention hydrating in the bore hole of gas (gas condensate) well is 47.3 kg/day.

Problem № 33

Determine the daily discharge of the hydrating inhibitor for prevention hydrating in the bore hole of gas (gas condensate) well. The working (factual) temperature on the well head is 10 ^{O}C, hydrating equilibrium temperature on the well head is 18 ^{O}C, productivity of gas well (gas flow rate) is 240 thm^3/day, moisture content on the bottom of the well is 3.1 kg/th. m^3, moisture content on the well head is 0.8 kg/th. m^3, the mass concentration of added (fresh) hydrating inhibitor is 98 % mass.

3.3 Determination of the amount of salt inhibitor to protect downhole equipment from salt deposits and prevent salt deposits

Problem № 34

Determine the necessary amount (mass) of scaling inhibitor СНПХ-5314 for scaling control of oil well by means of periodical injection of the inhibitor into the annular space of oil well without displacing it to the bottom-hole formation zone. The mass daily production rate of oil well for water is 28.5 t/day; the specific discharge of scaling inhibitor is180 g/m^3, the density of formation water is 1060 kg/m^3; the foreseeable time of scaling control is 60 days.

Solution

The volumetric daily production rate of oil well for water:

$$Q_W = \frac{M_w}{\rho_{f.w.}} = \frac{28.5 \cdot 10^3}{1060} = 26.89 \text{ m}^3\text{/day} \qquad (3.7)$$

The amount (mass) of scaling inhibitor СНПХ-5314 for scaling control of oil well by means of periodical injection of the inhibitor into the annular space of oil well without displacing it to the bottom-hole formation zone:

$$Q_{s.i.} = Q_{v.w.} \cdot q_{s.s.i.} \cdot T_{s.c.} \qquad (3.8)$$

where $q_{s.s.i.}$ is the specific discharge of scaling inhibitor, g/m^3. It is recommended to take specific discharge of scaling inhibitor within the range from 70 to 200 g/m^3.

$T_{s.c.}$ is the foreseeable time of scaling control, days. The foreseeable time of scaling control is determined by means of laboratory experiment and field experiments and should be from 30 to 90 days)

$Q_{v.w.}$ is the volumetric daily production rate of oil well for water, m^3/day.

$$Q_{s.i.} = 26.89 \cdot \frac{180}{1000} \cdot 60 = 290.412 \text{ kg.}$$

Problem № 35

Determine the necessary amount (mass) of scaling inhibitor СНПХ-5314 for scaling control of oil well by means of periodical injection of the inhibitor into the annular space of oil well without displacing it to the bottom-hole formation zone. The mass daily production rate of oil well for water is 32.3 t/day; the specific discharge of scaling inhibitor is165 g/m^3, the density of formation water is 1085 kg/m^3; the foreseeable time of scaling control is 45 days.

Problem № 36.

Determine the necessary amount (mass) of scaling inhibitor СНПХ-5314 for scaling control of gas well by means of periodical injection of the inhibitor into the annular space of gas well without displacing it to the bottom-hole formation zone. The daily productivity of gas well is 130 thm^3/day, water-gas ratio is 75 cm^3/m^3, the specific discharge of scaling inhibitor is 165 g/m^3, the foreseeable time of scaling control is 80 days.

Solution

The daily production rate of gas well for water :

$$Q_W = Q_g \cdot R_{wg} = 130 \cdot 10^3 \cdot 75 \cdot 10^{-6} = 9.75 \text{ m}^3\text{/day} \qquad (3.9)$$

The amount (mass) of scaling inhibitor СНПХ-5314 for scaling control of gas well by means of periodical injection of the inhibitor into the annular space of gas well without displacing it to the bottom-hole formation zone

$$Q_{s.i.} = Q_w \cdot q_{s.s.i.} \cdot T_{s.c.} = 9.75 \cdot 165 \cdot 10^{-3} \cdot 80 = 128.7 \text{ kg}$$

where

$q_{s.s.i.}$ is the specific discharge of scaling inhibitor, g/m^3. It is recommended to take specific discharge of scaling inhibitor within the range from 70 to 200 g/m^3·

$T_{s.c.}$ is the foreseeable time of scaling control, days. The foreseeable time of scaling control is determined by means of laboratory experiment and field experiments and should be from 30 to 90 days.

Mass of scaling inhibitor СНПХ-5314 for scaling control of gas well:

$Q_{s.i.}$=128.7 kg.

Problem № 37

Determine the necessary amount (mass) of scaling inhibitor СНПХ-5314 for scaling control of gas well by means of periodical injection of the inhibitor into the annular space of gas well without displacing it to the bottom-hole formation zone. The daily productivity of gas well is 160 thm^3/day, water-gas ratio is 120 cm^3/m^3, the specific discharge of scaling inhibitor is 130 g/m^3, the foreseeable time of scaling control is 85 days.

Problem № 38

Determine the necessary amount (mass) of scaling inhibitor СНПХ-5314 for scaling control of gas well by means of periodical injection of the inhibitor into the bottom-hole formation zone (at displacing the scaling inhibitor into the formation). Determine also the volume of displacing liquid.

The daily productivity of gas well is 350 th m^3/day, water-gas ratio is 105 cm^3/m^3, the specific discharge of scaling inhibitor is 150 g/m^3, the foreseeable time of scaling control is 84 days, the coefficient of increasing the discharge of scaling inhibitor which takes into account the no uniformity of its carrying out from the bottom-hole formation zone 1.8 (coefficient A should be within the range from 1.5 to 2); porosity factor of formation is 0.18 ; the foreseeable radius of penetration of scaling inhibitor into the formation 1.4 m ; the opened up thickness of formation is 15 m; the inner diameter of the casing is 132.1 mm; the outer diameter of the tubing is 73 mm; the depth of the well to the middle of productive formation is 2340 m.

Solution

1). The necessary amount (mass) of scaling inhibitor СНПХ-5314 for scaling control of gas well by means of periodical injection of the inhibitor into the bottom-hole formation zone (at displacing the scaling inhibitor into the formation) [$Q_{s.i.}$, in kg] could be determined by means of the formula:

$$Q_{s.i.} = A \cdot q_{s.s.i.} \cdot Q_w \cdot T_{s.c.} \tag{3.10}$$

where $q_{s.s.i.}$ is the specific discharge of scaling inhibitor, g/m^3· It is recommended to take the specific discharge of scaling inhibitor within the range from 70 to 200 g/m^3·

$T_{s.c}$ is the foreseeable time of scaling control, days. The foreseeable time of scaling control is determined by means of laboratory experiment and field experiments and should be from 30 to 90 days).

Q_w is the daily production rate of gas well for water, m^3/day

The daily production rate of gas well for water (in m^3/day):

$$Q_w = Q_g \cdot R_{wg} = 350 \cdot 10^3 \cdot 105 \cdot 10^{-6} = 36.75 \text{ m}^3\text{/day}$$

$$Q_{s.i.} = 1.8 \cdot \frac{150}{1000} \cdot 36.75 \cdot 84 = 833.49 \text{ kg}$$

2). The volume of displacing liquid (water) could be determined by means of the formula:

$$V_{d.l.} = m \cdot \pi \cdot R_p^{\ 2} \cdot h + V_{an.s.} \tag{3.11}$$

where $V_{an.s.}$ is the volume of annular space of the well, m^3;

porosity factor of formation should be within the range from 0.18 to 0.2.

$$V_{an.s.} = \frac{\pi}{4} \cdot (D_{in.c.}{}^2 - d_{o.t.}{}^2) \cdot H_{m.pr.f.}.$$

$$V_{an.s.} = \frac{\pi}{4} \cdot (0{,}1321^2 - 0{,}073^2) \cdot 2340 = 22.28 \quad m^3 \tag{3.12}$$

So the volume of displacing liquid (water) is:

$V_{d.l.} = 0.18 \cdot \pi \cdot 1.4^2 \cdot 15 + 22.28 = 38.91$ m^3.

Problem № 39

Determine the necessary amount (mass) of scaling inhibitor СНПХ-5314 for scaling control of gas well by means of periodical injection of the inhibitor into the bottom-hole formation zone (at displacing the scaling inhibitor into the formation). Determine also the volume of displacing liquid.

The daily productivity of gas well is 210 th m^3/day, water-gas ratio is 135 cm^3/m^3, the specific discharge of scaling inhibitor is 190 g/m^3, the foreseeable time of scaling control is 90 days, the coefficient of increasing the discharge of scaling inhibitor which takes into account the no uniformity of its carrying out from the bottom-hole formation zone 1.5 (coefficient A should be within the range from 1.5 to 2); porosity factor of formation is 0.2 ; the foreseeable radius of penetration of scaling inhibitor into the formation 1.15 m; the opened up thickness of formation is 19.5 m; the inner diameter of the casing is 129.1 mm; the outer diameter of the tubing is 73 mm; the depth of the well to the middle of productive formation is 3250 m.

Problem № 40

Determine the necessary amount (mass) of scaling inhibitor СНПХ-5314 for scaling control of oil well by means of periodical injection of the inhibitor into the bottom-hole formation zone (at displacing the scaling inhibitor into the formation). Determine also the volume of displacing liquid.

The mass daily production rate of oil well for water is 25.8 t/day, the density of formation water is 1045 kg/m^3, the specific discharge of scaling inhibitor is 140 g/m^3, the foreseeable time of scaling control is 85 days, the coefficient of increasing the discharge of scaling inhibitor which takes into account the no uniformity of its carrying out from the bottom-hole formation zone 1.7 (coefficient A should be within the range from 1.5 to 2); porosity factor of formation is 0.2 ; the foreseeable radius of penetration of scaling inhibitor into the formation 1.25 m ; the opened up thickness of formation is 18.5 m; the inner diameter of the casing is 150.5 mm; the outer diameter of the tubing is 73 mm; the depth of the well to the middle of productive formation is 2450 m.

Solution

1). The necessary amount (mass) of scaling inhibitor СНПХ-5314 for scaling control of oil well by means of periodical injection of the inhibitor into the bottom-hole formation zone (at displacing the scaling inhibitor into the formation) [$Q_{s.i.}$, in kg] could be determined by means of the formula:

$$Q_{s.i.} = A \cdot q_{s.s.i.} \cdot Q_w \cdot T_{s.c.} \tag{3.13}$$

where $q_{s.s.i.}$ is the specific discharge of scaling inhibitor, g/m^3. It is recommended to take the specific discharge of scaling inhibitor within the range from 70 to 200 g/m^3.

$T_{s.c}$ is the foreseeable time of scaling control, days. The foreseeable time of scaling control is determined by means of laboratory experiment and field experiments and should be from 30 to 90 days).

Q_w is the daily production rate of oil well for water, m^3/day.

The volumetric daily production rate of oil well for water (in m^3/day):

$$Q_W = \frac{M_w}{\rho_{f.w.}} = \frac{25.8 \cdot 10^3}{1045} = 24.689 \ m^3/day.$$

$$Q_{s.i.} = 1.7 \cdot \frac{140}{1000} \cdot 24.689 \cdot 85 = 499.458 \ kg.$$

2). The volume of displacing liquid (water) could be determined by means of the formula:

$$V_{d.l.} = m \cdot \pi \cdot R_p^{\ 2} \cdot h + V_{an.s.} \qquad (3.14)$$

where $V_{an.s.}$ is the volume of annular space of the well, m^3;

porosity factor of formation should be within the range from 0.18 to 0.2.

$$V_{an.s.} = \frac{\pi}{4} \cdot (D_{in.c.}^{\ 2} - d_{o.t.}^{\ 2}) \cdot H_{m.pr.f.}.$$

$$V_{an.s.} = \frac{\pi}{4} \cdot (0{,}1505^2 - 0{,}073^2) \cdot 2450 = 33.33 \quad m^3 \quad (3)$$

So the volume of displacing liquid (water) is:

$$V_{d.l.} = 0.2 \cdot \pi \cdot 1.25^2 \cdot 18.5 + 33.33 = 51.492 \ m^3.$$

Problem № 41

Determine the necessary amount (mass) of scaling inhibitor СНПХ-5314 for scaling control of oil well by means of periodical injection of the inhibitor into the bottom-hole formation zone (at displacing the scaling inhibitor into the formation). Determine also the volume of displacing liquid.

The mass daily production rate of oil well for water is 29.4 t/day, the density of formation water is 1085 kg/m^3, the specific discharge of scaling inhibitor is 200 g/m^3, the foreseeable time of scaling control is 72 days, the coefficient of increasing the discharge of scaling inhibitor which takes into account the no uniformity of its carrying out from the bottom-hole formation zone 1.9 (coefficient A should be within the range from 1.5 to 2); porosity factor of formation is 0.2 ; the foreseeable radius of penetration of scaling inhibitor into the formation 1.4 m ; the opened up thickness of formation is 26 m; the inner diameter of the casing is 124.7 mm; the outer diameter of the tubing is 73 mm; the depth of the well to the middle of productive formation is 2100 m.

Problem № 42

Calculate the necessary daily discharge of scaling inhibitor СНПХ-5314 for scaling control of gas by means of continuous injection of the inhibitor into the well and productivity of the pump. The daily productivity of gas well is 430 th m^3/day, water-gas ratio is 140 cm^3/m^3, the concentration of the working solution of scaling inhibitor is 10 %, the specific discharge of scaling inhibitor is 185 g/m^3, the density of the working solution of scaling inhibitor is 1020 kg/m^3.

Solution

1). The necessary daily discharge of scaling inhibitor for scaling control of gas well by means of continuous injection of the inhibitor into the well could be calculated by means of the formula:

$$Q_{s.i.\,c.i.} = q_{s.s.i.} \cdot Q_w \tag{3.15}$$

where $q_{s.s.i}$ is the specific discharge of scaling inhibitor, g/m^3.

It is recommended to take the specific discharge of scaling inhibitor within the range from 70 to 200 g/m^3.

Q_w is the daily production rate of gas well for water, m^3/day.

$$Q_w = Q_g \cdot R_{wg} = 430 \cdot 10^3 \cdot 140 \cdot 10^{-6} = 60.2 \quad m^3/day$$

So the necessary daily discharge of scaling inhibitor for scaling control of gas well by means of continuous injection of the inhibitor into the well is:

$$Q_{s.i.\,c.i.} = \frac{185}{1000} \cdot 60.2 = 11.137 \qquad kg/day$$

2). Productivity of the pump $q_{p.}$ (in *l*/hour) for injection of scaling inhibitor into the well could be calculated by means of the formula:

$$q_{p.} = \frac{q_{s.s.i.} \cdot Q_w}{C_{w.s.s.i.} \cdot \rho_{w.s.s.i.}} \qquad (3.16)$$

$$q_{p.} = \frac{185 \cdot 60.2 \cdot 100 \cdot 1000}{24 \cdot 1000 \cdot 10 \cdot 1020} = 4.549 \ l\text{/hour}$$

or $4.549 \cdot 10^{-3}$ m^3/hour = 0.109 m^3/day.

Problem № 42

Calculate the necessary daily discharge of scaling inhibitor СНПХ-5314 for scaling control of gas by means of continuous injection of the inhibitor into the well and productivity of the pump. The daily productivity of gas well is 500 th m^3/day, water-gas ratio is 185 cm^3/m^3, the concentration of the working solution of scaling inhibitor is 25 %, the specific discharge of scaling inhibitor is 170 g/m^3, the density of the working solution of scaling inhibitor is 1015 kg/m^3.

Problem № 43

Calculate the necessary daily discharge of scaling inhibitor СНПХ-5314 for scaling control of oil well by means of continuous injection of the inhibitor into the well and productivity of the pump. The mass daily production rate of oil well for water is 23.4 t/day, the density of formation water is 1035 kg/m^3, the specific discharge of scaling inhibitor is 170 g/m^3, the concentration of the working solution of scaling inhibitor is 5%, the density of the working solution of scaling inhibitor is 1015 kg/m^3.

Solution

1). The necessary daily discharge of scaling inhibitor for scaling control of gas well by means of continuous injection of the inhibitor into the well could be calculated by means of the formula:

$$Q_{s.i.\,c.i.} = q_{s.s.i.} \cdot Q_w$$

where $q_{s.s.i.}$ is the specific discharge of scaling inhibitor, g/m^3.

It is recommended to take the specific discharge of scaling inhibitor within the range from 70 to 200 g/m^3.

The volumetric daily production rate of oil well for water (in m^3/day):

$$Q_{v.w.} = \frac{M_w}{\rho_{f.w.}} = \frac{23.4 \cdot 10^3}{1035} = 22.609 \text{ m}^3/\text{ day}$$

So the necessary daily discharge of scaling inhibitor for scaling control of oil well by means of continuous injection of the inhibitor into the well is:

$$Q_{s.i.\,c.i.} = \frac{170}{1000} \cdot 22.609 = 3.844 \text{ kg/day.}$$

2). Productivity of the pump $q_{p.}$ (in *l*/hour) for injection of scaling inhibitor into the well could be calculated by means of the formula:

$$q_{p.} = \frac{q_{s.s.i.} \cdot Q_w}{C_{w.s.s.i.} \cdot \rho_{w.s.s.i.}}$$

$$q_{p.} = \frac{170 \cdot 3.844 \cdot 100 \cdot 1000}{24 \cdot 1000 \cdot 5 \cdot 1015} = 0.537 \text{ } l\text{/hour or}$$

$0.537 \cdot 10^{-3}$ m^3/hour = 0.013 m^3/day.

Problem № 44

Calculate the necessary daily discharge of scaling inhibitor СНПХ-5314 for scaling control of oil well by means of continuous injection of the inhibitor into the well and productivity of the pump. The mass daily production rate of oil well for water is 29.3 t/day, the density of formation water is 1060 kg/m^3, the specific discharge of scaling inhibitor is 145 g/m^3, the concentration of the working solution of scaling inhibitor is 8 %, the density of the working solution of scaling inhibitor is 1025 kg/m^3.

3.4 Use of surfactants for extraction of formation fluid from well bottom

Problem № 45

Determine the volume of liquid (formation water) which is on the bottom of gas well and the mass of surfactant which is necessary for removal of formation water from the bottom of the well.

Data: inner diameter of the tubing is 62 mm, density of formation liquid (formation water) is 1060 kg/m^3, the concentration of surfactant which is necessary for foaming the formation liquid is 200 g/*l* (kg/m^3), the active mass of surfactant is 80 %, wellhead tubing pressure (wellhead pressure) is 13.7 MPa, wellhead annulus pressure is 14.5 MPa.

Solution

1. The volume of liquid (formation water) which is on the bottom of gas well:

$$V_l = \frac{\left(P_{w.h.a.} - P_{w.h.t.}\right) \cdot F}{g \cdot \rho_l} \qquad (3.17)$$

were $P_{w.h.t}$ is wellhead tubing pressure (wellhead pressure), MPa

$P_{w.h.a.}$ is wellhead annulus pressure, MPa

2. F is the area of the section of tubing, m^2; ρ_l is density of formation water, kg/m^3

g - is acceleration of free falling, m/s^2

$$F = \frac{\pi \cdot d_{i.t.}^{\ 2}}{4}$$

$$F = \frac{\pi \cdot 0.062^2}{4} = 0.00302 \text{ m}^2$$

$$V_l = \frac{\left(16.1 \cdot 10^6 - 15.2 \cdot 10^6\right) \cdot 0.00302}{9.81 \cdot 1060} = 0.261\, m^3$$

3. The mass of surfactant which is necessary for removal of formation water from the bottom of the well:

$$m_{surf} = \frac{C_{surf} \cdot V_l}{a} \qquad (3.18)$$

were C_{surf} is the concentration of surfactant which is necessary for foaming

the formation liquid, g/*l* (kg/m^3); a is the active mass of surfactant, fractions.

$$m_{surf} = \frac{200 \cdot 0.261}{0.8} = 65.25 \ \ kg$$

Problem № 46

Determine the volume of liquid (formation water) which is on the bottom of gas well and the mass of surfactant which is necessary for removal of formation water from the bottom of the well. Data : inner diameter of the tubing is 59 mm, density of formation liquid (formation water) is 1100 kg/m^3, the concentration of surfactant which is necessary for foaming the formation liquid is 200 g/*l* (kg/m^3), the active mass of surfactant is 85 %, wellhead tubing pressure (wellhead pressure) is 16.3 MPa, wellhead annulus pressure is 16.8 MPa.

4 ENVIRONMENTAL PROTECTION DURING DRILLING, OPERATION OF WELLS, THEIR REPAIR AND DURING PREPARATION AND STORAGE OF INDUSTRIAL PRODUCTS

Problem № 47

Determine the bottom-hole pressure in the inclined oil well if the deviation off the vertical line is 360 m, the total length (depth) of the well is 3120 m. Wellhead pressure is 2.7 MPa. Production of well includes oil and water. Water cutting of well production is 61 %. Density of formation oil is 790 kg/m^3. Density of formation water is 1040 kg/m^3. Acceleration of free falling equals g = 9.81 m/s^2

Solution

The bottom-hole pressure in the inclined oil well could be determined by means of the formula:

$$P_{bh} = P_{wh} + \rho_l \cdot g \cdot H \quad (4.1)$$

Density of liquid (oil and water mixture):

$$\rho_l = n_w \cdot \rho_{w.} + (1 - n_w) \cdot \rho_{o.}$$

$$\rho_l = 0.61 \cdot 1040 + (1 - 0.61) \cdot 790 = 942.5 \text{ kg/m}^3 \quad (4.2)$$

Determine the vertical length of well (vertical component of well length)

$$H = \sqrt{L^2 - \Delta x^2} = \sqrt{3120^2 - 360^2} = 3099.161 \text{ m} \quad (4.3)$$

For determining the magnitude of hydrostatic pressure in the include oil well we use the formula (figure 1):

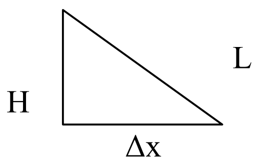


Figure 4.1 – Inclined well.

$$P_{bh} = 2.7 \cdot 10^6 + 942.5 \cdot 9.81 \cdot 3099.161 = 31.355 \cdot 10^6 \text{ Pa.}$$

Problem № 48

Determine the bottom-hole pressure in the inclined oil well if the deviation off the vertical line is 250 m, the total length (depth) of the well is 3440 m. Wellhead pressure is 3.1 MPa Production of well includes oil and water. Water cutting of well production is 58 %. Density of formation oil is 825 kg/m^3. Density of formation water is 1080 kg/m^3. Acceleration of free falling equals g = 9.81 m/s

Problem №49

Determine the bottom-hole pressure in the oil well (injection well) at the motion of the liquid in the tubing. Data: the depths of the tubing is equal to the middle of the perforation interval, the inner diameter of tubing is 75.9 mm, the flow rate of liquid is 130 m^3/day, the density of liquid is 1040 kg/m^3, perforation interval is 3180 − 3220 m, dynamic viscosity of liquid is 1.25 mPa·s, wellhead pressure is 5.4 MPa.

Solution

The bottom-hole pressure in the oil well at the motion of the liquid in the tubing could be determined by means of the formula:

$$P_{bh} = P_{wh} + \rho_l \cdot g \cdot H - \Delta P_{fr} \tag{4.4}$$

Friction pressure loss ΔP_{fr} could be determined by means of the Darcy – Veisbacha formula:

$$\Delta P_{fr} = \lambda \cdot \rho_l \cdot \frac{L}{d_{i.t}} \cdot \frac{\upsilon^2}{2} \tag{4.5}$$

The velocity of liquid:

$$\upsilon = \frac{4 \cdot Q}{\pi \cdot d_{i.t}{}^{2} \cdot 86400} = \frac{4 \cdot 130}{\pi \cdot 0.0759^{2} \cdot 86400} = 0.333 \text{ m/s}$$

Reynolds numder:

$$\mathrm{Re} = \frac{\upsilon \cdot d_{i.t} \cdot \rho_l}{\mu_l} = \frac{0.333 \cdot 0.0759 \cdot 1040}{1.25 \cdot 10^{-3}} = 21028.55$$

Coefficient of hydraulic resistance could be determined by means of Blasius formula

$$\lambda = \frac{0.3164}{\mathrm{Re}^{0.25}} = \frac{0.3164}{21028.55^{0.25}} = 0.026$$

So the friction pressure loss is

$$\Delta \mathrm{P_{fr}} = 0.026 \cdot 1040 \cdot \frac{3200}{0.0759} \cdot \frac{0.333^{2}}{2} = 6.321 \cdot 10^{4} \text{ Pa}$$

And finally the bottom-hole pressure in the oil well (injection well) at the motion of the liquid in the tubing is:

$$\mathrm{P_{bh}} = 5.4 \cdot 10^{6} + 1040 \cdot 9.81 \cdot 3220 - 6.321 \cdot 10^{4} = 38.19 \cdot 10^{6} \text{ Pa}$$

Problem №49

Determine the bottom-hole pressure in the oil well (injection well) at the motion of the liquid in the tubing. Data: the depths of the tubing is equal to the middle of the perforation interval, the inner diameter of tubing is 62 mm, the flow rate of liquid is 240 m^3/day, the density of liquid is 1030 kg/m^3, perforation interval is 3460 − 3494 m, dynamic viscosity of liquid is 1.18 mPa·s, wellhead pressure is 6.2 MPa.

Problem №50

Determine the magnitude of formation pressure in the oil well if the depth of the well is 1960 m; statical level is on the depth 840 m. Water cutting of the production of the well in the operation period was 52 %. Density of formation oil is 760 kg/ m^3; density of formation water is 1054 kg/m^3.

Solution

The magnitude of formation pressure in the oil well could be determined by means of the formula:

$$P_f = \rho_l \cdot g \cdot (H_w - h_{st}) \qquad (4.6)$$

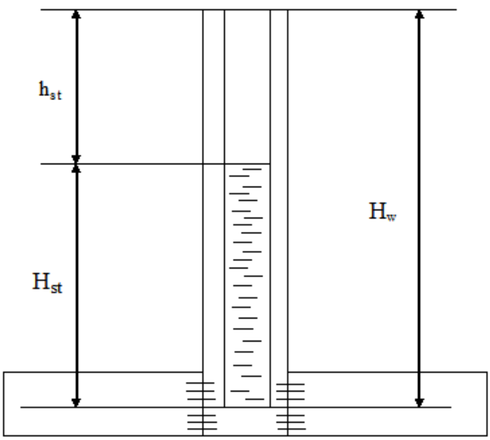
where $H_w = 1960$ m is the depth of the well, m; h_{st} is the statical level in the oil well from the surface, m; ρ_1 is density of liquid, kg/m^3 ; g is the acceleration of free falling, m/s^2.

Density of liquid (oil and water mixture):

$$\rho_l = n_w \cdot \rho_{w.} + (1 - n_w) \cdot \rho_{o.}$$

$$= 0.52 \cdot 1054 + (1 - 0.52) \cdot 760 = 912.88 \text{ kg/m}^3.$$

Figure



So, formation pressure in the oil well is:

$$P_f = 912.88 \cdot 9.81 \cdot (1960 - 840) = 10.03 \cdot 10^6 \text{ Pa} = 10.03 \text{ MPa}.$$

Problem № 51

Determine the magnitude of formation pressure in the oil well if the depth of the well is 2850 m; statical level is on the depth 1240 m. Water cutting of the production of the well in the operation period was 57 %. Density of formation oil is 810 kg/m^3; density of formation water is 1070 kg/m^3.

Problem № 52

Determine the magnitude of hydrostatic pressure in the inclined oil well. Depth (total length) of the well is 2350 m, deviation off the vertical line is 600 m. Production of well includes oil and water. Water cutting of well production is 45 %. Density of formation oil is 880 kg/m^3. Density of formation water is 1045 kg/m^3. Acceleration of free falling equals g = 9.81 m/s^2.

Express (put) hydrostatic pressure in MPa.

Solution

For determining the magnitude of hydrostatic pressure in the include oil well we use the formula:

$$P_{hydr} = \rho_l \cdot g \cdot H \qquad (4.7)$$

were P_{hydr} is hydrostatic pressure, Pa; H is vertical length of well (the vertical component), m; ρ_l is density of liquid, kg/m^3; g is the acceleration of free falling, m/s^2

Density of liquid (oil and water mixture):

$$\rho_l = n_w \cdot \rho_{w.} + (1 - n_w) \cdot \rho_{o.} =$$

$$= 0.45 \cdot 1045 + (1 - 0.45) \cdot 880 = 954.3 \text{ kg/m}^3$$

Determine the vertical length of well (vertical component of well length)

$$H = \sqrt{L^2 - \Delta x^2} = \sqrt{2350^2 - 600^2} = 2272.1 \text{ m.}$$

Determine the magnitude of hydrostatic pressure in the inclined oil well:

$$P_{hydr} = 954.3 \cdot 9.81 \cdot 2272.1 = 21.3 \cdot 10^6 \text{ Pa=21.3 MPa}$$

Problem № 53

Determine the magnitude of hydrostatic pressure in the inclined oil well. Depth (total length) of the well is 2840 m, deviation off the vertical line is 210 m. Production of well includes oil and water. Water cutting of well production is 62 %. Density of formation oil is 800 kg/m^3. Density of formation water is 1085 kg/m^3. Acceleration of free falling equals g = 9.81 m/s^2. Express (put) hydrostatic pressure in MPa.

4. THE TASK FOR HOME WORK ON THE DISCIPLINE "MATERIALS AND CHEMICAL REAGENTS IN OIL AND GAS PRODUCTION"

Problem № 1

Determine the mass and volume of bentonitic clay and the volume of waste water which are needed for preparing N m^3 of drilling mud. The moisture content of bentonitic clay is $n_{b.c.}$ %, the density of waste water is $\rho_{w.w.}$ kg/m^3, the density of drilling mud is $\rho_{d.m.}$ kg/m^3. The density of bentonitic clay is $\rho_{b.c.}$ kg/m^3.

Determine the mass and volume of weighting agent (barite) for weighting $N_{d.m.}$ m^3 of the drilling mud. The moisture content of weighting agent is $n_{w.a.}$ %; the density of weighting agent is $\rho_{w.a.}$ kg/m^3 ; the density of drilling mud before the weighting is $\rho_{d.m.1}$ kg/m^3 ; the density of drilling mud after the weighting is $\rho_{d.m.2}$ kg/m^3.

The data for calculations are given in table 5.1.

Besides the calculations students have to describe the materials and chemicals which are used for drilling wells, for drilling-in (exposing) productive formations and for completion of wells (recommended volume of theoretical part is 3 − 5 sheets).

Problem № 2

Calculate the required amount of reagents for hydraulic fracturing. Output data for calculation in table 5.2.

In addition to the implementation of the calculations it is necessary to describe the technology of hydraulic fracturing.

Problem № 3

Calculate the necessary amount of chemical reagents for carrying out hydraulic jet perforating in oil well (that is calculate the total volume of the working liquid, the amount of sand which is necessary for carrying out hydraulic jet perforating and the flow rate of the working liquid). Output data for calculation in table 5.3.

In addition to the implementation of the calculations it is necessary to briefly describe the technology of hydraulic jet perforating in oil well.

Table 5.1 – Data for Problem №1

Index, unit of measurement	Variant № (the last cipher of number in the teacher's register)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**
The density of waste water, $\rho_{w.w.}$, kg/m^3	1070	1040	1120	1100	1060	1090	1080	1110	1130	1050
The moisture content of bent. clay, $n_{b.c.}$, %	12	8	10	7.5	7	8.5	9	11	6	13
The volume of drilling mud, **N**, m^3	5	8	3	4	7	10	5	9	2	6
The density of drilling mud, $\rho_{d.m.}$, kg/m^3	2110	2160	2025	1950	2260	2210	2100	2080	2250	2135
The density of bentonitic clay, $\rho_{b.c.}$, kg/m^3.	2480	2250	2630	2500	2390	2420	2510	2360	2230	2670
The moisture content of weighting agent, $n_{w.a.}$,%	8.5	14	12	11	13	9	10	9.5	15	10
The density of drilling mud before the weighting, $\rho_{d.m.1}$, kg/m^3	1180	1250	1290	1320	1200	1230	1270	1310	1220	1240
The density of drilling mud after the weighting, $\rho_{d.m.2}$,kg/m^3.	1560	1600	1670	1700	1580	1620	1660	1730	1620	1650
the density of weighting agent, $\rho_{w.a.}$, kg/m^3	4502	4510	4505	4508	4512	4503	4500	4509	4504	4507
The volume of drilling mud, $\mathbf{N_{d.m.}}$, m^3	4	2	5	8	10	7	9	3	6	7

Table 5.2 – Data for Problem № 2

Index, unit of measurement	surname	Variant № (the last cipher of number in the teacher's register)									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**
Depth of the well to the middle of productive formation, m Hc,		2730	2154	2310	2170	2314	2822	1896	2060	2263	2191
Thickness of the formation,m		12	16	24	20	27	18	24	22	25	14
Coefficient of permeability of formation, mkm^2	A-L	50	28	23	110	70	160	180	65	95	40
	M-Z	34	20	90	52	40	200	45	57	36	84
Well productivity before the hydraulic fracturing, m^3/day		50	20	36	30	100	85	70	45	78	63
Well radius, m	A-L	0,12	0,14	0,15	0,18	0,17	0,18	0,13	0,2	0,18	0,14
	M-Z	0,15	0,11	0,16	0,19	0,12	0,16	0,19	0,14	0,13	0,11
Radius of external reservoir boundary, m		700	400	600	1000	500	800	900	750	500	850
Inner diameter of tubing, m		0,0503	0,062	0,076	0,059	0,062	0,0503	0,059	0,076	0,0503	0,062
Pump		УН1 - 630х700 (4АН-700)									
Liquid injection rate m^3/s		0,0025	0,0036	0,0025	0,0036	0,0025	0,0063	0,009	0,0063	0,009	0,0063
Mass concentration of sand in the sand-carrying liquid, kg/m^3		200	210	230	250	220	240	210	230	200	250
Volume of the fracturing liquid, m^3		10	9	8	12	15	14	11	9	13	10
Mass of sand, kg		4,5	4,2	4,0	5	6	5,4	4,8	4,3	5,2	4,6
Viscosity of the fracturing liquid, mPa·s		0,0020	0,0012	0,0015	0,0025	0,0016	0,003	0,0027	0,0035	0,0039	0,0025
Density of the fracturing liquid, kg/m^3		1100	1120	1130	1080	1120	1250	1270	1170	1120	1130
Density of sand, kg/m^3		2500									

Table 5.3 – Data for Problem № 3

Index, unit of measurement	surname	Variant № (the last cipher of number in the teacher's register)									
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**
Depth of the well, m	A-L	3130	3654	3380	4250	4840	3810	3690	3150	2963	4539
	M-Z	3370	2987	3120	3925	4345	3940	4080	2927	3560	3825
Mass concentration of sand in the liquid and sand mixture, kg/m^3 mass concentration of sand in the liquid and sand mixture 280 kg/m^3	A-L	100	120	130	150	100	140	170	100	120	180
	M-Z	150	170	120	160	110	120	110	150	140	130
The inner diameter of casing, mm	A-L	132,1	124,3	132,1	124,3	203,7	150,5	152,4	193,7	168,3	150,5
	M-Z	152,4	168,3	152,4	132,1	150,5	124,3	203,7	132,1	152,4	124,3
Conditional diameter of casing, mm	A-L	146	140	146	140	219	168	178	219	194	168
	M-Z	178	194	178	146	168	140	219	146	178	140

The quantity of nozzles in the hydroperforator 4, diameter of the nozzle – 4.5 mm.

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