Lecture № 2

(continuation of lecture № 1)

WELL DRILLING AND REAGENTS USED FOR PREPARATION OF DRILLING MUDS

Drilling muds are classified depending on:

1) the composition of the dispersed phase: clayless muds, thin clay drilling muds, clay muds, bitumen muds;

2) the type of dispersed environment: water-base drilling muds and oil-base drilling muds;

3) the composition of fillers: aerated muds (foamed), emulsion muds, weighted muds and carbonate (chalk) muds;

4) the chemical treatment: inhibited muds and untreated muds.

To supply necessary favorable drilling conditions and provide further inflow of oil and gas from production layers, drilling muds must have such basic properties, which define their quality:

– density;

– viscosity;

– water loss;

– mud-cake thickness;

– shearing strength;

– stability;

– the content of solid particles in the clay mud;

– the concentration of hydrogen ions pH.

1. Density

The greater is the density of the drilling mud, the higher pressure it creates on the head and the wall of the well. The pressure of the mud column in the well during drilling must exceeded the reservoir pressure.

$$\rho_{w.l.} = k_s \cdot \frac{P_{res}}{g \cdot H} \qquad (1)$$

If $H > 1200$ m coefficient of safety $k_s = 1.05 \ldots 1.1$.

If $H < 1200$ m coefficient of safety $k_s = 1.1 \ldots 1.15$.

where $\rho_{w.l.}$ is the density of washing liquid, kg/m^3; P_{res} is formation (reservoir) 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.

Coefficient of safety

Coefficient of safety is the coefficient which takes into account the possibility of increase of formation pressure in the well zone during the work-over (repairing of the well).

H, m	≤ 1200	> 1200
k_s	1.1 – 1.15	1.05 – 1.1

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

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

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.

The magnitude of the density of bentonitic clay should be taken within the range 2200 − 2700 kg/m^3.

Moisture content of bentonitic clay as a rule for practical calculations is taken within the range 5 – 10 % (0.05 – 0.1).

The mass of weighting agent (barite) for weighting 1 m^3 of the drilling mud:

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

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.

2. Viscosity :

– dynamic viscosity;

– kinematic viscosity;

– plastic viscosity – the ability of the solution to retain solid particles in the suspended state when the circulation of liquid is finished.

For drilling in porous, fractured rocks with low reservoir pressures, which are absorbing the washing liquid, *high viscosity drilling mud* should be used (clogs pores and channels of the reservoir).

For drilling in layers containing gas, *low viscosity drilling mud* is better to allow passing of gas bubbles through the fluid column.

3. Water loss

Water loss is measured in cm^3/30 min. This is an ability to give away water to porous rocks. Water losses is a measured amount of liquid (in *ml*) that is filtrated through the pores and channels under 0.1 MPa pressure drop at normal temperature (293 K).

4. Shearing strength

Is determined by the resistance of the force, which should be applied to the solution so that it begins to flow.

5. Stability.

The stability of the mud is determined after 1 day of rest by comparing the difference in densities of lower and upper halves of the liquid column inside a standard cylinder. The solution is considered to be good when there is no sludge and density difference does not exceed 20 kg/m^3 for nonweighted mud and 40-60 kg/m^3 for weighted mud.

6. The content of solid particles in the clay mud.

This value is a ratio of the solid particles amount to the total volume of the drilling solution (in %).

7. The concentration of hydrogen ions pH

This concentration defines if the drilling mud is alkaline (for pH>7), neutral (for pH=7) or acid-cut (for pH<7).

Properties of drilling muds are determined by:

1. Pycnometers and areometers

2. Fluidimeters

3. Merasuring filtrated volume of water in 30 min by means of Vicat apparatus (containing a special needle).

The main materials, used for preparation of drilling muds are *clay powders* and *weighting*. Also, lowering viscosity reagents, lowering water loss reagents and reagents of special purpose can be used for stabilization, inhibition and intensification.

***Clays* are the mineral field, polydisperse, alumina compounds that are capable of coming into plastic state when in contact with water. Clay is used to prepare the basis of drilling muds – colloidal suspensions.**

To prepare drilling mud different types of clay powders can be used:

montmorillonite 

kaolinite 

hydromica 

palygorskite 

Depending on the composition, clay powders are divided into: bentonite, kaolinite, hydromica and palygorskite. To improve the quality of powders, various reagents are used for treatment (sodium carbonate, sodium tri polyphosphate, surface active agent).

Bentonite powder is added to drilling fluids to improve the cleaning out from bit cuttings, to restrict water filtration into production layers, to provide the presence of a thin filter cake with low permeability to preserve the stability of the wellbore when drilling poorly cemented rocks and to prevent absorption.

To increase the density of drilling mud, crushed powders of heavy inert weighing materials are used.

All weighing materials can be divided into 3 groups:

1) low density (2600 – 2900 kg/m^3) – marl, chalk, limestone, dolomite;

2) medium density (3800 – 5000 kg/m^3) – siderite, barite, iron compounds;

3) high density (6000 – 7000 kg/m^3) – concentrates of lead ore, iron-arsenic ore.

Densities of weighing materials:

Weighing material	**Density , kg/m^3**
Calcite ($CaCO_3$)	2600 – 2800
Dolomite ($CaMg(CO_3)_2$)	2800 – 2900
Celestite	3700 – 3900
Siderite ($FeCO_3$)	3700 – 3900
Barite ($BaSO_4$)	4200 – 4700
Ilmenite	4500 – 5100
Magnetite	4900 – 5200
Hematite (Fe_2O_3)	4900 – 5300
Galena	7400 – 7700

Weighing agent barite is obtained from flotation barite concentrate. Improving the quality of barite weighting is achieved by its additional processing before drying or during grinding (by adding phosphates, polymers, surface active agents). This contributes to hydrophilization of barite's particles, binding of calcium ions and prevents coagulation of the solution.

Using of iron-containing weightings (hematite, magnetite, ilmenite) is restricted as soon as their high abrasiveness and magnetic properties negatively affect on the life time of drilling tools and equipment.

Benefits from physical and chemical treatment of drilling muds:

1) decreased swelling of clay particles, reduces the amount of physically bound water in the pores of the reservoir;

2) reduces the surface tension on the filtration border fluid – reservoir;

3) minimizes differential pressure on the productive horizon for the same density and rheological characteristics.

LECTURE 2: Cementation of wells and reagents used for preparation of washing and plugging-back solutions

Main aim of cementation – separation of production layers, protection of casing from mineralized water and gas, prevention of rock caving and clogging of casing.

Possible methods of cementing: single-stage cementing, two-stage cementing, reverse cementing, collar cementing, liner cementing, cementing under pressure.

Plugging materials (cements) are classified depending on composition of main materials, application temperatures, densities, resistance to aggressive environments, types of clinker.

Plugging cements can be based on: artificial cement, blastfurnace slag, lime-sand mixtures.

Plugging solutions are obtained by mixing cement and adding to it with water in proportion 2:1 or 5:2.

Most commonly used reagents for plugging cements are aimed on increasing or decreasing the time of cement setting, reducing of filtration (fluid) losses, changing of its density.

For increasing the time of cement setting such reagents can be used: sulfuric iron (up to 1 % from mass of dry cement), carboxymethyl cellulose (0.5 … 0.8 %), distillery stillage sulphide (up to 1 %).

For decreasing the time of cement setting such reagents can be used: calcium chloride and sodium chloride.

Main calculations for cementation process:

1. Volume of plugging solution

$$V_{p.s.} = \frac{\pi}{4}\left[K_c\left(D_w^2 - D_{c.ext.}^2\right)H_{cem.} + D_{c.int.}^2 h\right]$$

2. Mass of dry cement for plugging solution.

$$G_{cem.} = \frac{1}{1+m} \cdot K_l \cdot V_{p.s.} \cdot \rho_{p.s.}$$

3. Volume of water for plugging solution :

$$V_w = \frac{m \cdot G_{cem.}}{K_l \cdot \rho_w}$$

4. Volume of squeezing liquid

$$V_{s.l.} = \frac{\pi}{4} K_s \cdot D^2_{c.\mathrm{int}.} \cdot \left(H_{c.l.} - h\right)$$

$$p_{max} = \left[\left(H_{c.l.} - H_{cem.}\right) \cdot \rho_{d.m.} + H_{cem.} \cdot \rho_{p.s.}\right] \cdot 10^{-4} -$$
$$- \left[\left(H_{c.l.} - h\right) \cdot \rho_{s.l.} + h \cdot \rho_{p.s.}\right] \cdot 10^{-4} + p_2$$

$$p_2 = 0.01 \cdot H_{c.l.} + 8$$

$$p_2 = 0.01 \cdot H_{c.l.} + 16$$

6. Number of cementing units :

$$n_{c.u.} = \frac{0{,}785 \cdot K_1 \cdot \left(D^2_w - D^2_{c.ext.}\right) \cdot v_{p.s.}}{Q_{cem.}} + 1$$

7. Cementing time for the case of 1 working unit

$$T_{cem} = T_4 + T_3 + T_2 + T_1 + T_p$$

$$T_i = \frac{V_{p.s._i} + V_{s.l._i}}{Q_i}$$

8. Necessary number of cementing units:

$$n = \frac{T_{cem}}{0,75 \cdot T_{set}} + 1$$