LECTURE №7-8-9
BASIC HYDRODYNAMIC CALCULATIONS IN THE ELASTIC-WATER DRIVE

Condition elastic-water drive - excess reservoir pressure above the saturation pressure. Drive appears in early development and is characterized in descending reservoir pressure. In solving elastic-water drive the important task is to develop a definition of conversion put the solution gas drive. Knowledge of the time of development is necessary to determine the time that is given to the resettlement area of the building maintain reservoir pressure.

Condition elastic fluid and reservoir porosity depending on the pressure described by the following equations

$$\rho = \rho_0 \left[1 + \beta_{fl} \left(P - P_0 \right) \right]; \quad (1)$$

$$m = m_0 + \beta_r (P - P_0), \quad (2)$$

where m_0, ρ_0 - porosity and density at the initial pressure;

β_{fl} - compressibility factor of the fluid, 1/Pa;

β_r - compressibility factor of the porous medium, 1/Pa. These factors are determined in the laboratory.

With the reservoir when the pressure due to the elastic expansion of the fluid and rocks will be released a volume of fluid

$$\Delta V_{fl} = \beta_{fl} V_p \Delta P + \beta_r V_0 \Delta P, \quad (3)$$

but $V_p = mV_0$, and substituting in the equation (3)

$$\Delta V_{fl} = \beta_{fl} m V_0 \Delta P + \beta_r V_0 \Delta P = (\beta_{fl} m + \beta_r) V_0 \Delta P,$$

We introduce the notation $\beta_{fl} m + \beta_r = \beta *$. $\beta *$ - elastic capacity factor of the reservoir rock, 1/Pa. It shows the change in the stock of elastic fluid per unit volume when the pressure of 1 MPa.

Elastic reserve reservoir

$$\Delta V_{fl} = \beta * V_0 \Delta P, \qquad (4)$$

where V_0 - reservoir volume, m^3; ΔP - change in pressure, Pa.

The disadvantage of the formula (5) is that it is not related to time. Therefore advisable to determine the development of indicators will be formula

$$P(r,t) = P_{pl} - \frac{Q\mu}{4\pi kh}\left[E_i\left(-\frac{r^2}{4\chi \cdot t}\right)\right]$$ or $$P(r,t) = P_{пл} - \frac{Q\mu}{4\pi kh}\int_{u^2}^{\infty}\frac{e^{-u}}{u}du$$, where

$$u = \frac{r}{2\sqrt{\chi t}}.$$

Ei - exponential function.

After mathematical transformations we obtain the basic formula elastic drive

$$P(r,t)=P_{pl}-\frac{Q\mu}{4\pi kh}\ln\frac{2{,}25\chi t}{r^2}, \qquad (5)$$

where $P(r, t)$ - pressure at a distance r through time t, Pa;

P_{pl} – formation pressure, Pa;

Q – performance (or flow-rate), m^3/s;

μ – dynamic viscosity of the fluid, Pa·s;

k – permeability coefficient of the reservoir rock, m^2;

h – thickness, m;

χ – piezoconductivity factor, m^2/s.

Piezoconductivity factor characterises the rate of transmission of pressure in the formation and determines by the formula

$$\chi=\frac{k}{\mu\beta*}, \qquad (6)$$

it varies from 0.1 to 5.0 m^2/s.

Bottom-hole pressure is determined by the formula

$$P(r_{wr},t)=P_{pl}-\frac{Q\mu}{4\pi kh}\ln\frac{2{,}25\chi t}{r_{wr}^{\ 2}}, \qquad (7)$$

where r_{wr} – reduce radius, m. Reduce radius - is a radius, which should be well, so that it was perfect.

Formula (5) in the oilfield practices used to assess pressure changes over time, depending on the selection in the initial stage of development of oil when the deposit on a small number of wells. It is assumed that the selection is centered in the heart lay, and the change in pressure is determined by the distance from the center.

Figure 1 shows the change in pressure over time, performed for different values of Q, which are set constant. Graphic dependences shown in figure 1 can be concluded that the selection of fluid must agree with the period of time development and completion of construction of reservoir pressure maintenance. Unregulated in terms of selection of liquid elastic-water drive can result, which will take place in the deposit solution gas drive. The higher the Q wonder, the faster the pressure reaches the saturation pressure.

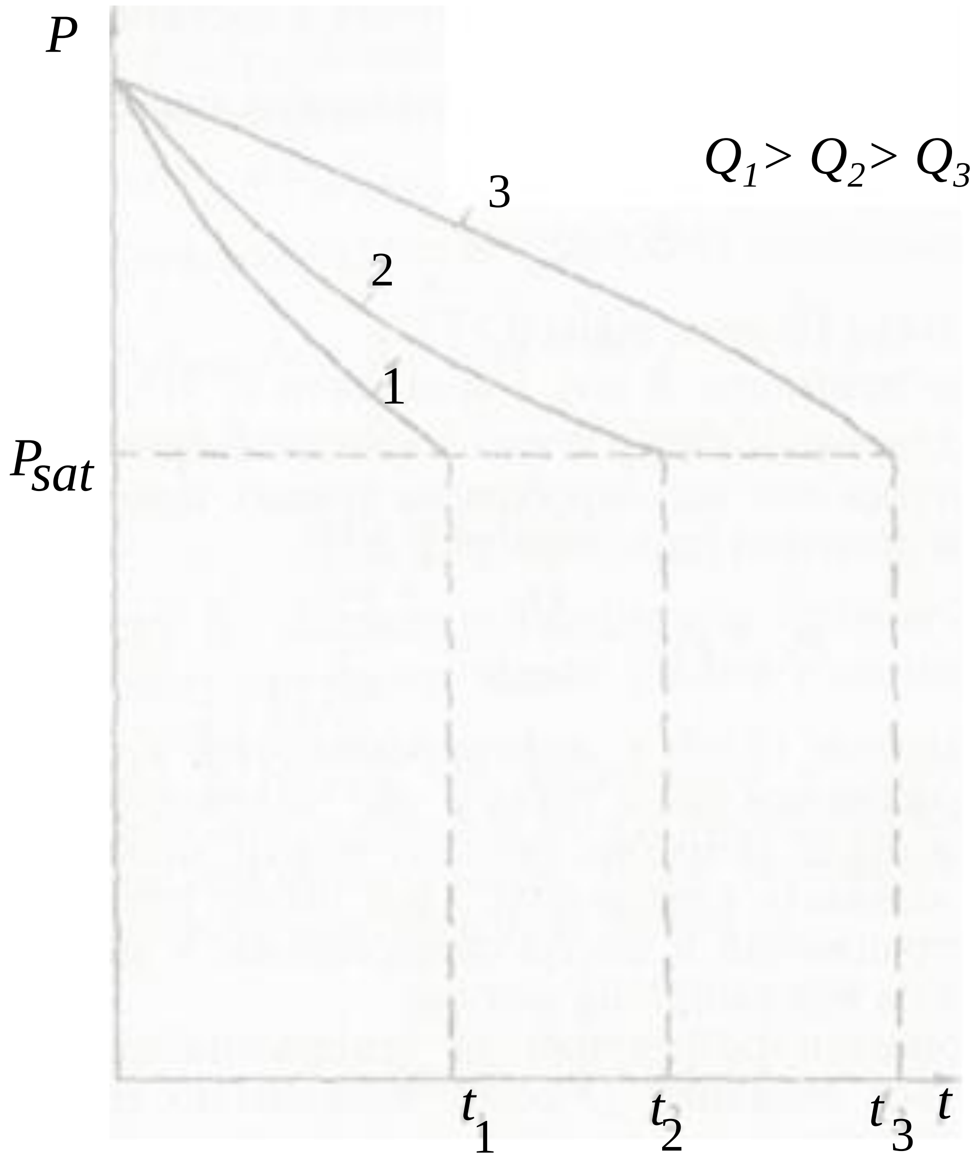


Figure 1 - Change formation pressure at the time of selection for different values of Q_1, Q_2, Q_3

As a result of trial operation are put actual pressure change over time. Often it does not coincide with the theoretical, the projected change in pressure over time. The difference may be due to an error of the mean values of parameters taken reservoir, installed within the studied tend oil-bearing part of the reservoir and the water shortage area or put isolation, the presence of the active zone of water flow. Theoretical calculations performed depending on the basic formula elastic drive. For the coordination of theoretical and actual dependencies in formula (5) is introduced coefficients z1 and z2 for harmonization of the reservoir and formation fluid (adaptive coefficients). So, we have

$$P(r,t) = P_{pl} - \frac{Q\mu}{4\pi kh} z_1 \left[E_i \left(-\frac{r^2}{4\chi \cdot t} \cdot z_2 \right) \right], \qquad (8)$$

where $z_1 = \frac{\left(\frac{kh}{\mu}\right)_{theor}}{\left(\frac{kh}{\mu}\right)_{act}}, \quad z_2 = \frac{\chi_{theor}}{\chi_{act}}.$

To find the unknown coefficients z1 and z2 rewrite equation (8) at time t1 and t2

$$\begin{cases} P\left(r,t_1\right)=P_{pl}-\frac{Q\mu}{4\pi kh}z_1\left[E_i\left(-\frac{r^2}{4\chi\cdot t_1}\cdot z_2\right)\right], \\ P\left(r,t_2\right)=P_{pl}-\frac{Q\mu}{4\pi kh}z_1\left[E_i\left(-\frac{r^2}{4\chi\cdot t_2}\cdot z_2\right)\right]. \end{cases} \quad (9)$$

In general, the task of determining the change in pressure is solved for two cases:

1) $Q\ (t) = const$;

2) $Q\ (t) \neq const$.

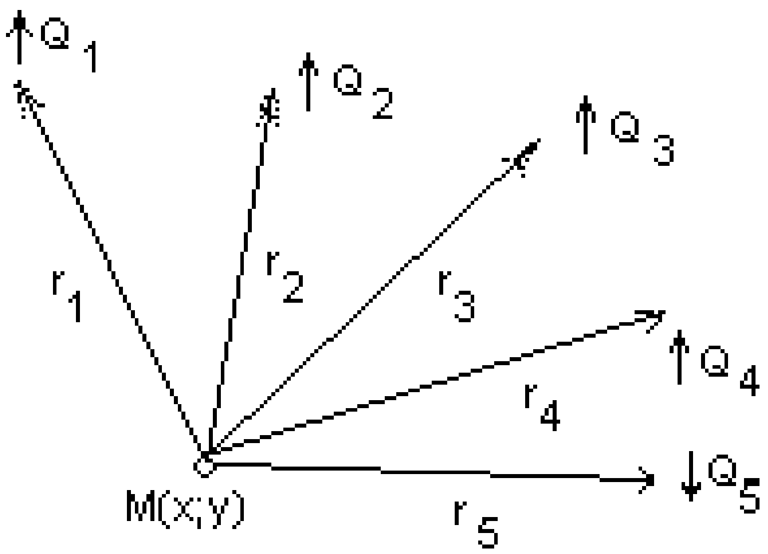
If the task is solved for $Q\ (t) = const$, then use the basic formula elastic drive

$$\Delta P=\frac{Q\mu}{4\pi kh}\ln\frac{2{,}25\chi t}{r^2}. \quad (10)$$

If the task is solved for *Q(t)* $\neq$ *const*, then use the **method of superposition.**

The method of superposition - a way of solving hydrodynamic tasks when their general solution defined as the sum of the solutions. In other words, changing the pressure in any point of the layer is determined by direct summation of depression caused by the work of single wells.

In the event that the deposit on working well with different flow rates (*Q*), and the need to find a change of pressure in any point of the layer (p. M), then come true.



↑ - production well;

↓ - injection well.

The task is solved using the method of superposition

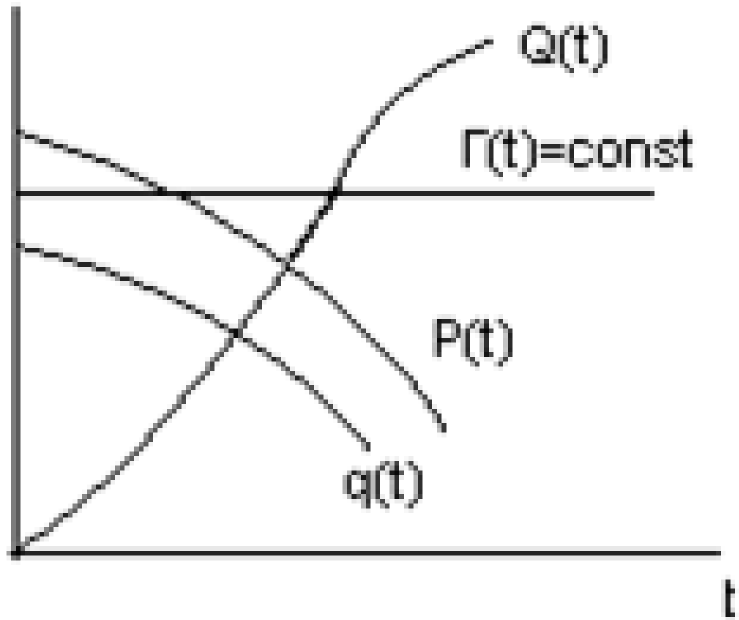
$$\Delta P_M(t) = \frac{Q_1\mu}{4\pi kh}\ln\frac{2{,}25\chi t_1}{r_1^2} + \frac{Q_2\mu}{4\pi kh}\ln\frac{2{,}25\chi t_2}{r_2^2} + \ldots + \frac{Q_3\mu}{4\pi kh}\ln\frac{2{,}25\chi t_3}{r_3^2} - \frac{Q_W\mu_B}{4\pi kh}\ln\frac{2{,}25\chi t_5}{r_5^2}. \qquad (11)$$

By changing the position of the M put on the area and each time hoping the pressure $\Delta P(t)$, can be traced to changes in pressure put on the area.

Then placing wells more convenient to set coordinates (*x1*, *y1*), (*x2*, *y2*), (*x3*, *y3*), etc., and the position of point M coordinates (*x*, *y*). Then the distance from the point M to be written through the coordinates of wells

$$r_1^2 = \left(x - x_1\right)^2 + \left(y - y_1\right)^2; \quad r_2^2 = \left(x - x_2\right)^2 + \left(y - y_2\right)^2.$$

For elastic-water drive of development dynamics of development depending on the time shown in fig.



Thus, analytical calculations of oil put options in respect to elastic drive based on the use of the basic formula elastic drive and method of superposition. They are appropriate for surgical use, approximate prediction of development indicators.