Practice lesson N6

Lesson topic: Determining initial reserves of reservoir gas, dry gas and hydrocarbon condensate in gas condensate field.

Most gas fields are confined to reservoir water drive systems and are developed under the conditions of ingressing edge or bottom water into gas saturated part of the reservoir. Development of gas fields under water pressure drive is characterized by incomplete displacement of gas by water from the porous medium and uneven (selective) movement of gas-water contact.

Gas recovery factor calculation under water drive

The basis of the calculation of the ultimate gas recovery factor is material balance equation for gas field under the water drive, which can be represented as:

$$\frac{\alpha_{in}\Omega_{in}P_{in}T_{st}}{Z_{in}P_{at}T_{res}} = \frac{\alpha_{in}\Omega(t)P_{res}(t)T_{st}}{Z(P_{res})P_{at}T_{res}} + \frac{\alpha_{res}\Omega_{w}(t)P_{w}(t)T_{at}}{Z(P_{w})P_{at}T_{res}} + Q_{cum}(t)$$

$$Q_{in.res.}=Q_{res}(t)+Q_{trappes}(t)+Q_{cum}(t), \qquad (1)$$

where $Q_{res}(t)$, $Q_{trapped}(t)$ – residual gas reserves in gas and watered zones at time t.

Substituting expressions for the initial and residual gas reserves in the gas-saturated and water-cut reservoir zones from equation (1) to equation (2):

$$\beta_{g} = \frac{Q_{in.res} - Q_{res.}}{Q_{in.res}} = 1 - \frac{Q_{res}}{Q_{in.res.}}, \qquad (2)$$

The following dependences can be obtained for determining the ultimate gas recovery factor at water drive:

In case of full watering:

$$\beta_{g.ul} = 1 - \frac{\alpha_{\text{res}} P_{w.final} Z(P_{in})}{\alpha_{\text{init}} P_{in} Z(P_{w.final})}; \tag{3}$$

In case of partial watering

$$\beta_{g.ul} = 1 - \frac{\alpha_{res} \Omega_{w} P_{w.f} Z(P_{поч})}{\alpha_{in} \Omega_{in} P_{in} Z(P_{w.f})} - \frac{\Omega_{g} P_{g.f} Z(P_{in})}{\Omega_{in} P_{in} Z(P_{g.f})}, \tag{4}$$

Where $P_{g.f}$, $P_{w.f}$ – final reservoir pressure in gas and water zones; $Z(P_{g.f})$, $Z(P_{w.f})$ – gas compressibility coefficients at Tres temperature and pressure respectively $P_{g.f}$ i $P_{w.f}$.

Equation (4) can be written as follows:

$$\beta_{g.ul} = \beta_{g.w} \frac{\Omega_{w}}{\Omega_{in}} + \beta_{g.g} \frac{\Omega_{g}}{\Omega_{in}}, \tag{5}$$

where $\beta_{g.w.}$, $\beta_{g.g}$ - the coefficients of the final gas ultimate gas recovery of the respectively water and gas saturated part of the formation. In most cases $\beta_{g.w} < \beta_{g.g}$.

Task N1.

Determine current gas recovery factor for gas fields, which is developing under conditions of water drive for the following data: the initial gas saturated radius - 10500 m, current gas saturated radius - 4000 m, initial reservoir pressure - 37 MPa, current reservoir pressure in flooded zone - 20 MPa, the current reservoir pressure in gas-saturated zone - 13 MPa, initial gas saturation - 0.8, residual gas saturation - 0.22, efficient gas-saturated reservoir thickness - 24 m, open porosity coefficient - 0.14, inition gas compressibility factor is 0,97, gas compressibility factor of current reservoir pressure in gas zone is 0,86 and in flooded zone -0,9.

Data:

$R_{init} = 10500$ m;

$R(t) = 4000$ m;

$p_{init} = 37$ MPa;

$\tilde{p}_w(t) = 20$ MPa;

$\tilde{p}_{res}(t) = 13$ MPa;

$h = 24$ m;

$m_o = 0{,}14$;

$\alpha_{init} = 0{,}8$;

$\alpha_{resid} = 0{,}22$;

$z_{init} = 0{,}97$;

$z(p_w) = 0{,}9$;

$z(\tilde{p}_{res}) = 0{,}86$.

$$\beta(t) = 1 - \frac{\Omega(t)\tilde{p}_{res}(t)z_{init}}{\Omega_{init}p_{init}z(\tilde{p}_{res})} - \frac{\alpha_{resid}\Omega_w(t)\tilde{p}_w(t)z_{init}}{\alpha_{init}\Omega_{init}p_{поч}z(\tilde{p}_w)}.$$

$$\Omega_{init} = \pi R_{init}^2 hm_o = 3{,}14 \cdot 10500^2 \cdot 24 \cdot 0{,}14 = 1{,}163 \cdot 10^9 \text{ m}$$

$$\Omega(t) = \pi R(t)^2 hm_o = 3{,}14 \cdot 4000^2 \cdot 24 \cdot 0{,}14 = 1{,}688 \cdot 10^8 \text{ m}^3.$$

$$\Omega_w(t) = \Omega_{init} - \Omega(t) = 1{,}163 \cdot 10^9 - 1{,}688 \cdot 10^8 = 9{,}942 \cdot 10^8 m^3$$

$$\beta(t) = 1 - \frac{1{,}688 \cdot 10^8 \cdot 13 \cdot 0{,}97}{1{,}163 \cdot 10^9 \cdot 37 \cdot 0{,}86} - \frac{0{,}22 \cdot 9{,}942 \cdot 10^8 \cdot 20 \cdot 0{,}97}{0{,}8 \cdot 1{,}163 \cdot 10^9 \cdot 37 \cdot 0{,}9} = 0{,}806.$$

Determining initial reserves of reservoir gas, dry gas and hydrocarbon condensate in gas condensate field.

- **initial reserves of reservoir gas:**

$$Q_{gas\,res.} = \frac{\alpha_{init} \cdot \Omega_{init} \cdot P_{init} \cdot T_{st}}{Z_{init} \cdot P_{at} \cdot T_{res}}$$

- **initial reserves of dry gas:**

$$Q_{dryg.} = \frac{Q_{gasres}}{\beta(p_{init})}.$$

-initial reserves of hydrocarbon condensate:

$$M_{rescond.} = Q_{resgas} \cdot q_{initcond},$$

$$\Omega_{init} = F \cdot h \cdot m_o,$$

Task N2.

Determine initial reserves of reservoir gas, dry gas and hydrocarbon condensate in gas condensate field if initial reservoir pressure is 40 MPa, reservoir temperature - 70°C, gas productive area - $7{\cdot}10^8$ m^2, initial gas saturation - 0.81, open porosity coefficient - 0.15, gas gravity - 0.85, dry gas conversion factor - 1.05, the initial condensate yield - 230 g / m^3, effective gas-saturated reservoir thickness - 24 m.

Data:

$F = 7 \cdot 10^8$ m^2;

h =24 m;

m_o =0,15;

$\alpha_{поч}$ =0,81;

$p_{поч} = 40$ MPa;

$\beta(p_{init})$ =1,05;

$t_{res} = 70$ °C;

$\overline{\rho}_g$ =0,85

$q_{initcond}$ =230 g/m^3.

$T_{res} = 70 + 273 = 343$ К

$p_{cr} = 4{,}892 - 0{,}4048 \cdot \overline{\rho}_g = 4{,}892 - 0{,}4048 \cdot 0{,}85 = 4{,}548$ MPa,

$T_{cr} = 94{,}717 + 170{,}8 \cdot \overline{\rho}_g = 94{,}717 + 170{,}8 \cdot 0{,}85 = 239{,}897$ К.

$$p_{red} = \frac{p_{init}}{p_{cr}} = \frac{40}{4,548} = 8,795,$$

$$T_{red} = \frac{T_{init}}{T_{cr}} = \frac{343}{239,897} = 1,43,$$

$$z_{init} = (0,4\lg(T_{red}) + 0,73)^{p_{red}} + 0,1 \cdot p_{red} =$$
$$= (0,4\lg(1,43) + 0,73)^{8,795} + 0,1 \cdot 8,795 = 1,008.$$

$$Q_{initres} = \alpha_{init} F \cdot h \cdot m_o \frac{p_{init} T_{st}}{z_{init} p_{at} T_{res}}$$

$$Q_{initres} = 0,81 \cdot 7 \cdot 10^8 \cdot 24 \cdot 0,15 \frac{40 \cdot 293}{1,008 \cdot 0,1013 \cdot 343} = 6,83 \cdot 10^{11} \text{ m}^3$$

$$Q_{drygas} = \frac{Q_{initres}}{\beta(p_{init})} = \frac{6,83 \cdot 10^{11}}{1,05} = 6,505 \cdot 10^{11} \text{ м}^3$$

$$M_{rescon} = Q_{initres} \cdot q_{initcon} = 6,83 \cdot 10^{11} \cdot 230 = 1,571 \cdot 10^{14} \text{g} =$$
$$= 1,571 \cdot 10^8 \ t.$$

Task N3.

Determine current gas recovery factor of gas field watered zone, which is developing under conditions of water drive for the following data: initial reservoir pressure 40 MPa, current reservoir pressure in the flooded area - 20 MPa, initial gas saturation - 0.8, residual gas saturation - 0.22, reservoir temperature of - 70 °C, gas gravity - 0.85.

Data:
T_{res}=70+273=343K
ρ_g=0.85
P_{init}=40 MPa;
$\tilde{p}_w(t) = 20$ MPa;
$\alpha_{init} = 0,8$;
$\alpha_{resid} = 0,22$;

You must determine inition gas compressibility factor and gas compressibility factor of current reservoir pressure (dy analogy with the previous task).

Z_{init}=1.008
Z_{cur}=0.79

$$\beta = 1 - \frac{\alpha_{res} P_{w.final} Z(P_{in})}{\alpha_{init} P_{in} Z(P_{w.final})};$$

$$\beta = 1 - (0{,}22 * 20 * 1{,}008 / (0{,}8 * 40 * 0{,}79) = 1 - 0{,}18 = 0{,}82.$$