Practical lesson N2

Lesson topic*: Determining the amount of extracted liquid and oil recovery factor by volumetric expansion drive*

Volumetric expansion drive (Compaction drive)

If pore volume contraction contributes prominently to overall oil expansion while the reservoir is saturated, then the reservoir drive is classified as a ***compaction drive.***

Compaction drive oil reservoirs are supplemented by solution gas drive if the reservoir pressure falls below the bubblepoint pressure; they may or may not be supplemented by a water or gas cap drive.

The condition for elastic drive implementetion - reservoir pressure must exceed bubblepoint pressure. Also bottomhole pressure must be higher than bubblepoint pressure. Oil is in a single-phase state. The influx of oil to the wells is due to elasticity energy (elastic expansion) of oil, connate water and related rocks. In the case of pressure reduction the amount of water and oil increases, pore volume reduces and the corresponding amount of oil flows to the well.

Basic formulas:

$$\boldsymbol{V_{prod.}} = \boldsymbol{V_0} \cdot \boldsymbol{\beta^*} \cdot \Delta \boldsymbol{P} \qquad (1)$$

where $V_{prod.}$- liquid production, m^3;

V_0-volume of field, m^3;

$$\mathbf{V_0 = F \cdot h} \qquad (2)$$

F – oil-drainage area, m^2;

h - formation thickness, m;

$$\boldsymbol{\kappa} = \frac{\mathbf{k}}{\boldsymbol{\mu \cdot \beta^*}} \qquad (3)$$

$$\mathbf{\Delta P = P_{init} - P_b} \qquad (4)$$

κ – piezoconductance coefficient, m^2/s;

β*-elasticity coefficient, Pa^{-1};

μ – oil dynamic viscosity coefficient, mPa· s;

k – reservoir of permeability, m^2;

ΔP – average reservoir pressure, Pa;

$P_{init.}$ – initial reservoir pressure, Pa;

P_b – bubble point pressure, Pa;

$$\beta^* = m_0 \cdot \beta_l + \beta_r, \qquad (5)$$

β_l - liquid elasticity coefficient, Pa^{-1};
β_r - rock elasticity coefficient, Pa^{-1};
m_0 - porosity coefficient;

$$\beta_l = \beta_{oil} \cdot S_{init.} + \beta_w \cdot (1 - S_{init.}), \quad (6)$$

β_{oil} - oil elasticity coefficient, Pa^{-1};
β_w - water elasticity coefficient, Pa^{-1};
$S_{init.}$ - initial oil saturation;

$$\eta_{oil} = \frac{V_{prod.}}{V_{oil\,init.}} \quad (7)$$

$$V_{oil\,init,} = F \cdot h \cdot m_o \cdot S_{init.} \quad (8)$$

η_{oil}- oil recovery factor

Task N1. Determine how many liquid will be produced by volumetric expansion drive for radial field development with initial oil-saturated reservoir radius R=2.5 km, if oil-saturated reservoir thickness is h=30 m, initial reservoir pressure – $P_{init.}$= 20 MPa, bubble point pressure – P_b= 15 MPa, oil dynamic viscosity coefficient – μ =2.5 mPa·s, reservoir of permeability –k= 0.2 D, piezoconductance coefficient – **κ**=0.2 m^2/s.

$$V_{prod.} = V_0 \cdot \beta^* \cdot \Delta P$$

$$\boldsymbol{\kappa} = \frac{k}{\mu \cdot \beta^*} \quad ==> \beta^* = \frac{k}{\mu \cdot \boldsymbol{\kappa}}$$

$$\beta^* = \frac{0,2 \cdot 10^{-12}}{2,5 \cdot 10^{-3} \cdot 0,2} = 4 \cdot 10^{-10} Pa^{-1}$$

$$\Delta P = P_{init.} - P_b = (20 - 15) \cdot 10^6 = 5 \cdot 10^6 \quad Pa$$

$$V_0 = \pi \cdot {R_к}^2 \cdot h = 3,14 \cdot 2500^2 \cdot 30 = 5,9 \cdot 10^8 m^3$$

$$V_{prod.} = 5,9 \cdot 10^8 \cdot 4 \cdot 10^{-10} \cdot 5 \cdot 10^6 = 118 \cdot 10^4 m^3$$

Task N2. Determine the cumulative oil production from deposits to be achieved by elastic forces while reducing the average reservoir pressure on 9,8 MPa for the following data: oil productive area - $5 \cdot 10^6 m^2$, the effective thickness – 25 m, porosity coefficient - 0.15, oil elasticity coefficient – $1,53 \cdot 10^{-9}$ Pa^{-1}, water elasticity coefficient – $3,06 \cdot 10^{-10}$ Pa^{-1},initial oil saturation – 0,7. Oil layer is not deformed.

Data:
$F = 5 \cdot 10^6 \ m^2$
h= 25 m
$S_{init.} = 0.7$
$m_0 = 0.15$
$\Delta P = 9,8 \cdot 10^6$ Pa
$\beta_{oil} = 1,53 \cdot 10^{-9} \ Pa^{-1}$
$\beta_w = 3,06 \cdot 10^{-10} \ Pa^{-1}$
$\beta_r = 0$
Vprod. – ?

$$\boldsymbol{V_{prod.}} = \boldsymbol{V_0} \cdot \boldsymbol{\beta^*} \cdot \Delta \boldsymbol{P}$$

$V_0 = F \cdot h = 5 \cdot 10^6 \cdot 25 = 125 \cdot 10^6 \ m^3$

$\beta^* = m_0 \cdot \beta_l + \beta_r,$

$\beta_l = \beta_{oil} \cdot S_{init.} + \beta_w \cdot (1 - S_{init.}) = 15,3 \cdot 10^{-10} \cdot 0,7 + 3,06 \cdot 10^{-10} \cdot (1-0,7) =$
$= 11,63 \cdot 10^{-10} \ Pa^{-1}$

$\beta^* = 0,15 \cdot 11,63 \cdot 10^{-10} = 1,74 \cdot 10^{-10} \ Pa^{-1}$

$V_{prod.} = 125 \cdot 10^6 \cdot 1,74 \cdot 10^{-10} \cdot 9,8 \cdot 10^6 = 2,132 \cdot 10^5 \ m^3$

Task N3.

Determine oil recovery factor to be achieved by elastic forces while reducing the average reservoir pressure on 5 MPa for the following data: the effective thickness - 12 m, porosity coefficient - 0.12, liquid elasticity coefficient - $3 \cdot 10^{-10}$ Pa^{-1}, rock elasticity coefficient – $2 \cdot 10^{-10}$ Pa^{-1}, initial oil saturation – 0,75, the radius of the initial oil saturation -10000m.

Data:
R= 10000 m
h= 12 m
$S_{init.}$ = 0.75
m_0= 0.12
$\Delta P = 5 \cdot 10^6$ Pa
$\beta_l = 3 \cdot 10^{-10}$ Pa^{-1}
$\beta_r = 2 \cdot 10^{-10}$ Pa^{-1}
η_{oil} – ?

$$\eta_{oil} = \frac{V_{prod.}}{V_{oil\ init.}}$$

$$\boldsymbol{V_{prod.}} = \boldsymbol{V_0} \cdot \boldsymbol{\beta^*} \cdot \Delta \boldsymbol{P}$$

$V_0 = F \cdot h = \mathbf{3,14} \cdot 10^8 \cdot \mathbf{12} = 37,68 \cdot 10^8$ m^3

$\beta^* = m_0 \cdot \beta_l + \beta_r = 0,12 \cdot 3 \cdot 10^{-10} + 2 \cdot 10^{-10} = 2,36 \cdot 10^{-10}$ Pa^{-1}

$V_{prod.} = 37,68 \cdot 10000^2 \cdot 2,36 \cdot 10^{-10} \cdot 5 \cdot 10^6 = 4,45 \cdot 10^6$

$V_{oil\ init,} = F \cdot h \cdot m_o \cdot S_{init.}$

$V_{oil\ init.} = \mathbf{3,14} \cdot 10000^2 \cdot \mathbf{12} \cdot 0,12 \cdot 0,75 = 3,39 \cdot 10^8$ m^3

$$\eta_{oil} = \frac{4,45 \cdot 10^6}{3,39 \cdot 10^8} = 0,013$$

Task N4. Determine oil recovery factor which will be achieved by volumetric expansion drive for radial field development with initial oil-saturated reservoir radius -10000 m and aquifer zone radius -40 000 m if oil-saturated reservoir thickness is 12 m, open porosity coefficient- 0.15, initial oil saturation - 0.75, oil elasticity coefficient - $2\cdot10^{-9}$ Pa^{-1}, rock elasticity coefficient - $2\cdot10^{-10}$ Pa^{-1}, water elasticity coefficient – $4{,}1\cdot10^{-10}$ Pa^{-1}, initial reservoir pressure - 40 MPa, bubble point pressure - 37 MPa.

Data:
$R_{init.oil}$= 10 km
$R_{aq.z.}$= 40 km
h= 12 m
$S_{init.}$ = 0.75
m_0= 0.15
$P_{init.} = 40\cdot 10^6$ Pa
$P_b = 37\cdot 10^6$ Pa
$\beta_{oil} = 2\cdot10^{-9}$ Pa^{-1}
$\beta_w = 4{,}1\cdot10^{-10}$ Pa^{-1}
$\beta_r = 2\cdot10^{-10}$ Pa^{-1}
$\eta_н$ – ?

$$\eta_н = \frac{V_{prod.}}{V_{oil\ init.}}$$

$V_{oil\ init,} = \pi \cdot R_{init}^2 \cdot h \cdot m_o \cdot S_{init.}$
$V_{oil\ init.} = \mathbf{3,14}\cdot10^8\cdot \mathbf{12}\cdot0{,}15\cdot0{,}75=4{,}2\cdot10^8$ m^3

$V_{prod.}=V_{oil}+V_w$

$$\boldsymbol{V_{oil.}} = \boldsymbol{V_0} \cdot \boldsymbol{\beta^*} \cdot \Delta\boldsymbol{P}$$

$V_0=F\cdot h = \mathbf{3,14}\cdot10^8\cdot \mathbf{12} =3{,}77\cdot10^9$ m^3

$$\beta^* = m_0 \cdot \beta_l + \beta_r$$

$\beta_l = \beta_{oil} \cdot S_{init.} + \beta_w \cdot (1 - S_{init.}) =20\cdot10^{-10}\cdot0{,}75+4{,}1\cdot10^{-10}\cdot(1-0{,}75)=$
$= 16\cdot10^{-10}$ Pa^{-1}

$\beta^* = 0{,}15\cdot16\cdot10^{-10}+2\cdot10^{-10}=4{,}4\cdot10^{-10}$ Pa^{-1}

$V_{oil.}= 3{,}77\cdot10^9\cdot4{,}4\cdot10^{-10}\cdot3\cdot10^6=4{,}98\cdot10^6$ m^3

$$\boldsymbol{V_{w.}} = \boldsymbol{V_0} \cdot \boldsymbol{\beta^*} \cdot \Delta\boldsymbol{P}$$

$V_0=\pi \cdot(R_{aq,z,}^2 - R_{init}^2)\cdot h = \mathbf{3,14}\cdot(16\cdot10^8-10^8)\cdot \mathbf{12} =5{,}65\cdot10^{10}$ m^3

$$\beta^* = m_0 \cdot \beta_w + \beta_r$$

$\beta^* = 0{,}15 \cdot 4{,}1 \cdot 10^{-10} + 2 \cdot 10^{-10} = 2{,}6 \cdot 10^{-10}$ Pa^{-1}

$V_{w.} = 5{,}65 \cdot 10^{10} \cdot 2{,}6 \cdot 10^{-10} \cdot 3 \cdot 10^{6} = 44 \cdot 10^{6}$ m^3

$V_{prod.} = (4{,}98 + 44) \cdot 10^{6} = 48{,}98 \cdot 10^{6}$ m^3

$$\eta_{н} = \frac{48{,}98}{420} = 0{,}12$$