Practical lesson N3

Lesson topic*: <u>Determining the amount of extracted liquid and oil recovery factor by natural water drive</u>*

Natural Water Drive Mechanism

The principle of natural water drive is that an aquifer provides the energy for hydrocarbon production. Both water expansion, as a result of pressure reduction, and inflow are involved.

Natural water drive ia associated with high recovery rates; oil from 35-75% OIIP; gas from 60-80% GIIP.

It is not uncommon for flow from the surface to supply the energy for natural water drive. When a pressure drop occurs, both the oil and water liquid phases expand resulting in production. Additionally, water inflow radially and vertically displaces the oil towards the producers. Oil fields that have an active water drive mechanism are developed the most efficiently. It results in achieving high oil yields and the highest economic performance.

Basic formulas:

$$\eta_{oil} = \eta_{sw} \cdot \eta_{disp}$$

η_{oil}-oil recovery factor;

η_{sw}-vertical sweep efficiency;

η_{disp}-displacement factor;

$$\eta_{disp.} = \frac{S_{init.} - S_{resid.}}{S_{init.}}$$

$S_{init.}$-initial oil saturation;

$S_{resid.}$-residual oil saturation;

$$k = \frac{Q_W}{Q_{init.}}$$

k- flushing multiplicity (multiplicity cleaning);

$$n_w = \frac{Q_w}{Q_{liq.}}$$

n_w – average water cut;

Q_w-water production;

$Q_{liq.}$-liquid production;

Displacement characteristic:

Q_{oil}=a+b·$Q_{liq.}$

a,b-coefficient of displacement characteristic;

Task N1. Determine the average water cut at which oil recovery factor of 0.3 will be achieved if the initial oil reserves in the deposit equal 8,5·10^6 tons and displacement characteristic has the form :

$$\sum Q_{oil} = -9{,}092 \cdot 10^6 + 0{,}718 \cdot 10^6 \cdot \ln \sum Q_{liq}.$$

Data:

η = 0,3

$Q_{init.oil}$ = 8,5·10^6 t

$\sum Q_{oil} = -9{,}092 \cdot 10^6 + 0{,}718 \cdot 10^6 \cdot \ln \sum Q_{liq}.$ – displacement characteristic

n_w– ?

Determine the cumulative oil production:

$$\sum Q_{oil} = Q_{init.oil} \cdot \eta_{oil}$$

$$\sum Q_{oil} = 8{,}5 \cdot 10^6 \cdot 0{,}3 = 2{,}55 \cdot 10^6 \quad t$$

Determine the cumulative liquid production:

$$\sum Q_{oil} = -9{,}092 \cdot 10^6 + 0{,}718 \cdot 10^6 \cdot \ln \sum Q_{liq}$$

$$0{,}718 \cdot 10^6 \cdot \ln \sum Q_{liq} = 2{,}55 \cdot 10^6 + 9{,}092 \cdot 10^6$$

$$\sum Q_{liq} = e^{\frac{2{,}55 \cdot 10^6 + 9{,}092 \cdot 10^6}{0{,}718 \cdot 10^6}} = 10{,}434 \cdot 10^6 \quad t$$

Determine the average water cut:

$$n_w = \frac{Q_w}{Q_{liq}} = \frac{Q_{liq} - Q_{oil}}{Q_{liq}}$$

$$n_w = \frac{10{,}434 \cdot 10^6 - 2{,}55 \cdot 10^6}{10{,}434 \cdot 10^6} = 0{,}756$$

Task N2. Calculate the ultimate oil recovery coefficient of oil field in case of oil-water displacement. The initial oil reserves in the field – $0{,}5\cdot10^6$ t, average water cut equal 95 %. Oil displacement characteristics of water looks:

$$\frac{Q_{liq.cum.}}{Q_{oil.cum.}} = 0{,}02 + 0{,}1 \cdot 10^{-4} \cdot (Q_{liq.cum.} - Q_{oil.cum.})$$

$Q_{liq.cum.}$ i $Q_{oil.cum.}$ – liquid and oil cumulative production (t)

Data:

$Q_{init.oil} = 0{,}5\cdot10^6$ t

$n_w = 95\%$

$$\frac{Q_{liq.cum.}}{Q_{oil.cum.}} = 0{,}02 + 0{,}1 \cdot 10^{-4} \cdot (Q_{liq.cum.} - Q_{oil.cum.})$$

η_{oil} – ?

$$n_w = \frac{Q_{w.cum.}}{Q_{liq.cum.}} = \frac{Q_{liq.cum} - Q_{oil.cum.}}{Q_{liq.cum.}} = 1 - \frac{Q_{oil.cum.}}{Q_{liq.cum.}}$$

$$\frac{Q_{oil.cum.}}{Q_{liq.cum.}} = 1 - n_w$$

$$Q_{oil.cum.} = Q_{liq.cum.} \cdot (1 - n_w)$$

$$\frac{Q_{liq.cum.}}{Q_{liq.cum.} \cdot (1 - n_w)} = 0{,}02 + 0{,}1 \cdot 10^{-4} \cdot (Q_{liq.cum.} - Q_{liq.cum.} \cdot (1 - n_w))$$

$$\frac{1}{1 - n_w} = 0{,}02 + 0{,}1 \cdot 10^{-4} \cdot (Q_{liq.cum.} - Q_{liq.cum.} + n_w \cdot Q_{liq.cum.})$$

$$\frac{1}{1 - n_w} = 0{,}02 + 0{,}1 \cdot 10^{-4} \cdot n_w \cdot Q_{liq.cum.}$$

$$\frac{1}{1 - 0{,}95} = 0{,}02 + 0{,}1 \cdot 10^{-4} \cdot 0{,}95 \cdot Q_{liq.cum.}$$

$$Q_{liq.cum.} = 2{,}103 \cdot 10^6 \quad t$$

$$Q_{oil.cum.} = 2{,}103 \cdot 10^6 \cdot (1 - 0{,}95) = 0{,}105 \cdot 10^6 \quad t$$

$$\eta_{oil} = \frac{Q_{oil.cum.}}{Q_{init.oil.}} = \frac{0{,}105 \cdot 10^6}{0{,}5 \cdot 10^6} = 0{,}21$$

Task N3. Calculate the ultimate oil recovery coefficient of oil field in case of oil-water displacement. The initial oil reserves in the field in surfase conditions- $5 \cdot 10^6$ t, flushing multiplicity equal 2, oil formation volume factor – 1.15, degassed oil density - 840 kg / m^3. Oil displacement characteristics of water looks:

$$\sum Q_{oil} = 2{,}119 \cdot 10^6 + 0{,}0918 \cdot \sum Q_{liq.}$$

where $Q_{oil.}$, $Q_{liq.}$ – [m^3].

Data:

$Q_{init.oil\ surf.cond.}$= $5 \cdot 10^6$ t= $5 \cdot 10^9$kg

k= 2

b=1,15

$\rho_{oil.deg.}$= 840 kg / m^3

$$\sum Q_{oil} = 2{,}119 \cdot 10^6 + 0{,}0918 \cdot \sum Q_{liq.}$$

η_{oil}– ?

$$k = \frac{Q_W}{Q_{init.oil.res.cond.}} = \frac{Q_W}{Q_{init.oil.surf.cond.}} \cdot \frac{1}{b} \cdot \rho_{oil.deg.}$$

$$\sum Q_w = k \cdot Q_{init.oil.surf.cond.} \cdot b \cdot \frac{1}{\rho_{oil.deg.}}$$

$$\sum Q_w = \frac{2 \cdot 5 \cdot 10^9 \cdot 1{,}15}{840} = 1{,}37 \cdot 10^7 m^3$$

$$\sum Q_{oil} = 2{,}119 \cdot 10^6 + 0{,}0918 \cdot (1{,}37 \cdot 10^7 + \sum Q_{oil.})$$

$\sum Q_{oil}$-0,0918 $\cdot \sum Q_{oil}$=$2{,}119 \cdot 10^6 + 0{,}0918 \cdot 1{,}37 \cdot 10^7$

$0{,}9082 \cdot \sum Q_{oil}$=$3{,}377 \cdot 10^6$

$\sum Q_{oil}$=$3{,}72 \cdot 10^6 m^3$

$$\eta_{oil} = \frac{Q_{oil.cum.}}{Q_{init.oil.}} = \frac{3{,}72 \cdot 10^6 \cdot 840}{5 \cdot 10^9} = 0{,}62.$$

Task N4. Determine oil recovery factor and oil cumulative production in case of oil displacement by surfactant solution if the initial oil saturation is 0.78, residual oil saturation - 0.22, vertical sweep efficiency - 0.5, oil productive area – $2,3 \cdot 10^7$ m^2, effective oil-saturated thickness - 19m, open porosity coefficient - 0.15, oil formation volume factor- 1.2, degassed oil density - 825 kg/m^3.

Data:

$S_{init.} = 0,78$

$S_{resid.} = 0,22$

$\eta_{sw} = 0,5$

$F = 2,3 \cdot 10^7\ m^2$

h=19m

m=0,15

b=1,2

$\rho_{oil.deg.} = 825\ kg/m^3$

$\eta_{oil} - ?$

$Q_{oil.cum.} = ?$

$$\boldsymbol{\eta_{disp.} = \frac{S_{init.} - S_{resid.}}{S_{init.}}}$$

$$\eta_{disp.} = \frac{0,78 - 0,22}{0,78} = 0,72$$

$$\boldsymbol{\eta_{oil} = \eta_{sw} \cdot \eta_{disp}}$$

$\eta_{oil} = 0,72 \cdot 0,5 = 0,36$

$$Q_{oil.res} = \frac{F \cdot h \cdot m_o \cdot S_{in} \cdot \rho}{B}$$

$$Q_{oil.res.} = \frac{2,3 \cdot 10^7 \cdot 19 \cdot 0,15 \cdot 0,78 \cdot 825}{1,2} = 3,49 \cdot 10^{10} kg$$

$Q_{oil.cum.} = 3,49 \cdot 10^{10} \cdot 0,36 = 1,26 \cdot 10^{10} kg.$