NDR @model

Natural Oil Depletion

The STOIIP V_O is related to reservoir oil volume V_o as:

(1) $$V_O = V_o / B_o$$

while the latter is related to the reservoir pore volume V_ϕ as:

(2) $$V_o = s_o\, V_\phi = (1 - s_{wi})\, V_\phi$$

so that

(3) $$V_o = B_o\, V_O = (1 - s_{wi})\, V_\phi \quad \Rightarrow \quad V_\phi = \frac{B_o\, V_O}{1 - s_{wi}}$$

The pore volume reduction due to cumulative offtakes Q_O is:

(4) $$\delta V_\phi = B_o\, Q_O$$

and this can be related to total compressibility c_t as:

(5) $$c_t = \frac{1}{V_\phi}\frac{\partial V_\phi}{\partial p} = \frac{1 - s_{wi}}{B_o\, V_O}\frac{B_o\, Q_O}{\delta p} = \frac{1 - s_{wi}}{\delta p}\frac{Q_O}{V_O} = \frac{1 - s_{wi}}{\delta p} \cdot \mathrm{EUR_O}$$

where

(6) $$c_t = c_r + s_{wi} c_w + (1 - s_{wi}) c_o$$

is total compressibility of oil saturated formation .

The pressure reduction δp due to pore volume reduction caused by offtakes is going to be a difference between initial formation pressure p_i and minimal bottom-hole flowing pressure $p_{wf,\,\mathrm{min}}$:

(7) $$\delta p = p_i - p_{wf}$$

For low compressible oil, the total compressibility can be assumed constant $c_t = \mathrm{const}$ and (5) becomes:

(8) $$\frac{1 - s_{wi}}{(p_i - p_{wf\,min})} \cdot \mathrm{EUR_O} = c_t = \mathrm{const}$$

and

(9) $$\mathrm{EUR}_O = \frac{(p_i - p_{wf\,min})\, c_t}{(1 - s_{wi})}$$

For the naturally flowing wells the bottom hole pressure under flowing conditions can be roughly assed by homogeneous multiphase pipe flow model assessed as:

(10) $$p_{wf} = p_s + \rho_g\, g\, h + \left(1 - \frac{\rho_g}{\rho_o}\right) p_b$$

where p_s – tubing-head pressure defined by the production gathering system, h – is the true vertical depth at formation top, $\{\rho_o, \rho_g\}$ – oil and gas densities, p_b – bubble-point pressure.

Natural Gas Depletion

The Expected Ultimate Recovery during the natural gas depletion can be assessed with the following formula:

(11) $$EUR_{GD} = \frac{Q_g}{V_g} = 1 - \frac{p_{wf}}{p_i}$$

See also

Petroleum Industry / Upstream / Production / Field Development Plan / Recovery Methods / Natural Depletion Recovery