Example 1: The Virginia Hills Beaverhill Lake field is a volumetric undersaturated reservoir. Volumetric calculations indicate the reservoir contains 270.6 MMSTB of oil ini-tially in place. The initial reservoir pressure is 3685 psi. The following additional data are available:

Swi = 24%   Cw = $3.62*10^{-6}$ psi^{-1} Cf = 4.95 $*10^{-6}$ psi^{-1}

Bw = 1.0 bbl/STB   Pb = 1500 psi

The field production and PVT data are summarized below:

Volumetric Average Pressure	No. of producing wells	B_o (bbl/STB)	N_p (MSTB)	W_p (MSTB)
3685	1	1.3102	0	0
3680	2	1.3104	20.481	0
3676	2	1.3104	34.750	0
3667	3	1.3105	78.557	0
3664	4	1.3105	101.846	0
3640	19	1.3109	215.681	0
3605	25	1.3116	364.613	0
3567	36	1.3122	542.985	0.159
3515	48	1.3128	841.591	0.805
3448	59	1.3130	1273.530	2.579
3360	59	1.3150	1691.887	5.008
3275	61	1.3160	2127.077	6.500
3188	61	1.3170	2575.330	8.000

Calculate the initial oil in place by using the MBE and compare with the volumetric estimate of N.

Solution:

Step 1. Calculate the initial water and rock expansion term $E_{w,f}$ from:

$$E_{w,f} = B_{oi}\left[\frac{C_w S_{wi} + C_f}{1 - S_{wi}}\right]\Delta\bar{p}$$

$$E_{w,f} = 1.3102\left[\frac{3.62 * 10^{-6}(0.24) + 4.95 * 10^{-6}}{1 - 0.24}\right]\Delta\bar{p}$$

$$E_{w,f} = 10 * 10^{-6}(3685 - \bar{p}_r)$$

Step 2: Use the equations below to construct the following table:

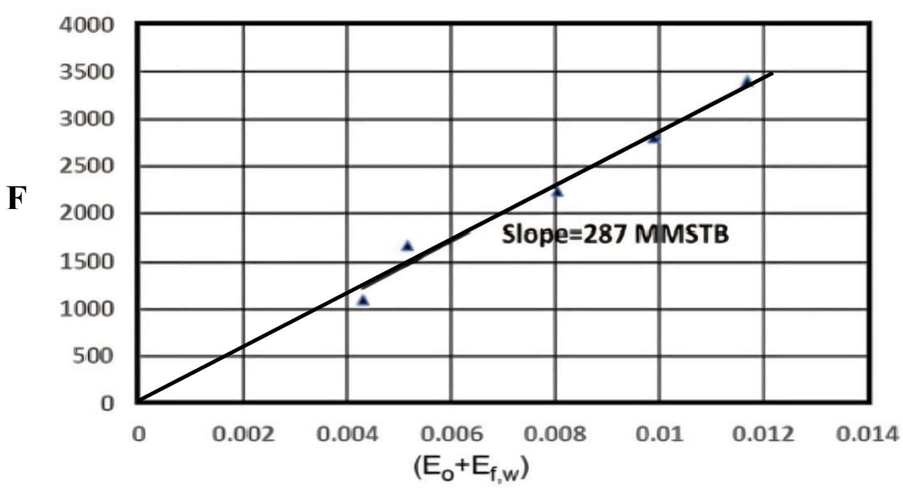
$F = NpBo + BwWp$

$Eo = Bo - Boi$

$\Delta p = Pi - Pr$

$\bar{p}_r$ (psi)	F (Mbbl) $eq.(3.53)$	E_o (bbl/STB) $eq.(3.54)$	$\Delta\bar{p}$	$E_{w,f}$	$E_o + E_{w,f}$
3685	—	—	0	0	—
3680	26.84	0.0002	5	50×10^{-6}	0.00025
3676	45.54	0.0002	9	90×10^{-6}	0.00029
3667	102.95	0.0003	18	180×10^{-6}	0.00048
3664	133.47	0.0003	21	210×10^{-6}	0.00051
3640	282.74	0.0007	45	450×10^{-6}	0.00115
3605	478.23	0.0014	80	800×10^{-6}	0.00220
3567	712.66	0.0020	118	1180×10^{-6}	0.00318
3515	1105.65	0.0026	170	1700×10^{-6}	0.00430
3448	1674.72	0.0028	237	2370×10^{-6}	0.00517
3360	2229.84	0.0048	325	3250×10^{-6}	0.00805
3275	2805.73	0.0058	410	4100×10^{-6}	0.00990
3188	3399.71	0.0068	497	4970×10^{-6}	0.01170

Step 3: for this case → **F= N(Eo + Ew,f).** So, plot the underground withdrawal term F against the expansion term (Eo + Ew,f) on a Cartesian scale, as shown in figure:



Slope = N= 287000 MSTB = 287 MMSTB

H.W

A volumetric saturated reservoir with a depletion drive has an initial pressure of 4000 psi an Swi= 30% , from the following PVT data,
calculate the initial oil in place.

Assume that the rock and water expansion term is negligible.
Also assume that the secondary gas cap is still small (i.e., m=0).

P	N_P	R_P	B_o	B_g	r_s		N
4000	— x10⁶	718	1.492	0.001041	718	Solution	— x10⁶
3800	3.87	674	1.423	0.001273	614		91.50
3600	5.26	1937	1.355	0.001627	510		96.02
3400	6.44	3077	1.286	0.002200	400		96.01

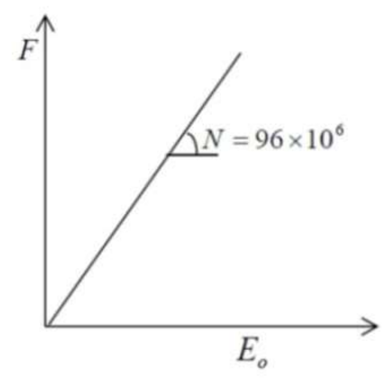
As shown N ≠ const., so rearrange MBE as a straight line

$$N_p\left[B_o + (R_p - r_s)B_g\right] = N\left[B_o - B_{oi} + (r_{si} - r_s)B_g\right]$$

$$F \quad = N \quad E_o$$

$$R.F = \frac{N_p}{N} = \frac{B_o - B_{oi} + (r_{si} - r_s)B_g}{B_o + (R_p - r_s)B_g}$$

P	F	Eo
4000	0x10⁶	0
3800	5.802	0.0634
3600	19.339	0.2014
3400	46.124	0.4804



229 From Fig: $N = 96\times10^6$ STB

Example 2: The production history and the PVT data of a gas-cap-drive reservoir are given below:

Date	$\bar{p}$ (psi)	N_p (MSTB)	G_p (MMscf)	B_t (bbl/STB)	B_g (bbl/scf)
5/1/89	4415	–	–	1.6291	0.00077
1/1/91	3875	492.5	751.3	1.6839	0.00079
1/1/92	3315	1015.7	2409.6	1.7835	0.00087
1/1/93	2845	1322.5	3901.6	1.9110	0.00099

The initial gas solubility Rsi is 975 scf/STB. Estimate the initial oil and gas-in-place.

Solution:

Step 1. Calculate the cumulative produced gas–oil ratio R_p

$\bar{p}$ (psi)	G_p (MMscf)	N_p (MSTB)	$R_p = G_p/N_p$ (scf/STB)
4415	–	–	–
3875	751.3	492.5	1525
3315	2409.6	1015.7	2372
2845	3901.6	1322.5	2950

Step 2:

$$F = N\left[E_o + mE_g\right]$$

$$\frac{F}{Eo} = N + mN\left(\frac{Eg}{Eo}\right)$$

A plot of $\frac{F}{Eo}$ versus $\frac{Eg}{Eo}$ should then be linear with intercept N and slope mN.

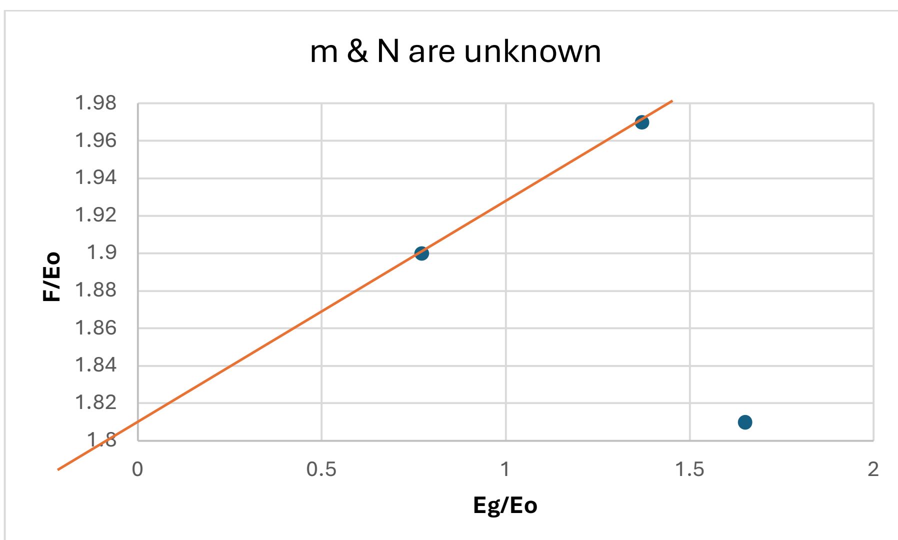
Step 3. Calculate **F, Eo, and Eg** from:

$$F = N_p[B_t + (R_p - R_{si})B_g] + B_w W_p$$

$$E_o = B_t - B_{ti}$$

$$E_g = B_{ti}\left[\left(\frac{B_g}{B_{gi}}\right) - 1\right]$$

P (psi)	F (bbl)	Eo	Eg	F/Eo	Eg/Eo
3875	$1.043 * 10^6$	0.0548	0.0423	$1.90 * 10^7$	0.772
3315	$3.046 * 10^6$	0.1544	0.2116	$1.97 * 10^7$	1.370
2845	$5.113 * 10^6$	0.2819	0.4655	$1.81 * 10^7$	1.651



$N = 1.81 * 10^7$ STB = $18.1 * 10^6$ STB

slope= mN = 0.117

m= 0.117/ 1.81 = 0.064

G = mN Bti / Bgi = 2.45 MMM scf

Example 3:

The material balance parameters, the underground withdrawal F, and the oil expansion E_o of a saturated oil reservoir (i.e., m = 0) are given below:

$\bar{p}$	F	E_o
3500	–	–
3488	2.04×10^6	0.0548
3162	8.77×10^6	0.1540
2782	17.05×10^6	0.2820

Assuming that the rock and water compressibilities are negligible, calculate the initial oil-in-place?

Solution:

Step 1. The most important step in applying the MBE is to verify that no water influx exists. Assuming that the reservoir is volumetric, calculate the initial oil in-place N by using every individual production data point in Equation 4.4.15, or:

$$N = F/E_o$$

F	E_o	$N = F/E_o$
2.04×10^6	0.0548	37 MMSTB
8.77×10^6	0.1540	57 MMSTB
17.05×10^6	0.2820	60 MMSTB

Step 2. The above calculations show that the calculated values of the initial oil in-place are increasing, as shown graphically in Figure (3.14), which indicates a water encroachment, i.e., water drive reservoir.

Step 3. For simplicity, select the pot aquifer model to represent the water encroachment calculations in the MBE as given by $eq.$ (3.65), or:

$$\frac{F}{E_o} = N + K\left(\frac{\Delta p}{E_o}\right)$$

Step 4. Calculate the terms F/E_o and $\Delta p/E_o$ of $eq.$ (3.65):

$\bar{p}$	Δp	F	E_o	F/E_o	$\Delta p/E_o$
3500	0	–	–	–	–
3488	12	2.04×10^6	0.0548	37.23×10^6	219.0
3162	338	8.77×10^6	0.1540	56.95×10^6	2194.8
2782	718	17.05×10^6	0.2820	60.46×10^6	2546

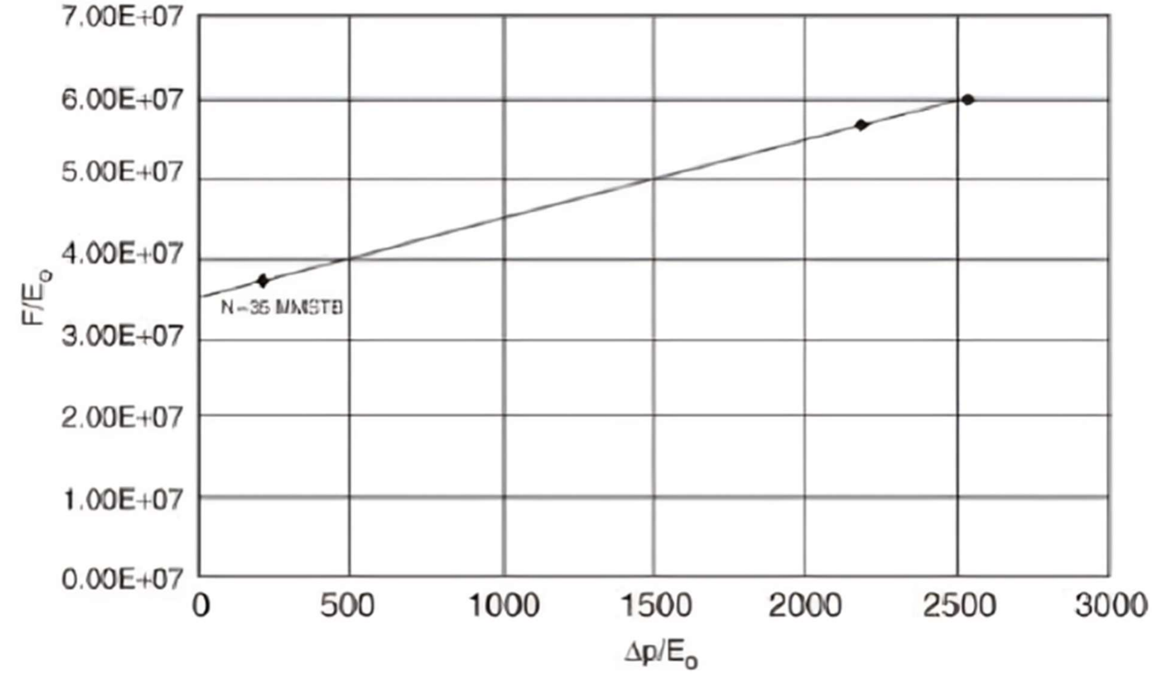


Figure (3.15) F/E_o vs $\Delta p/E_o$

Step 5. Plot F/E_o vs $\Delta p/E_o$, as shown in Figure (3.15) and determine the intercept and the slope:

Intercept = N = 35 MMSTB

Slope = K = 9983