Material Balance Summary

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Compiled by Yohanes Nuwara (Source from Brian F. Towler (2001) SPE Textbook *Fundamental Principles of Reservoir Engineering*)

0.1 Material balance parameters - reservoir voidage (F) and total FVFs (B_t)

Reservoir Fluid	F	B_{tg}	B_{to}
Dry-gas	G_pB_g	B_g	no condensate component
Gas-condensate	$N_p(\frac{B_o-R_sB_g}{1-R_vR_s})+(G_p-G_i)(\frac{B_g-R_vB_o}{1-R_vR_s})$	$\frac{B_g(1-R_vR_{vi})+(R_{vi}-R_v)B_o}{1-R_vR_s}$	$\frac{B_o(1-R_vR_{si})+(R_{si}-R_s)B_g}{1-R_vR_s}$
Undersaturated non-volatile oil ($R_s=R_{si}, R_v=0$)	N_pB_o	no vapor component	B_o
Undersaturated volatile oil($R_s=R_{si}, R_v\neq 0$)	$N_p(\frac{B_o-R_sB_g}{1-R_vR_s})+(G_p-G_i)(\frac{B_g-R_vB_o}{1-R_vR_s})$	no vapor component	B_o
Saturated non-volatile oil($R_s\neq R_{si}, R_v=0$)	$N_p(B_o-R_sB_g)+G_pB_g\mathrm{OR}N_p(B_{to}-R_{si}B_g)+G_pB_g$	B_g	$B_o+(R_{si}-R_s)B_g\mathrm{OR}B_{to}$
Saturated volatile oil($R_s\neq R_{si}, R_v\neq 0$)	$N_p(\frac{B_o-R_sB_g}{1-R_vR_s})+(G_p-G_i)(\frac{B_g-R_vB_o}{1-R_vR_s})$	$\frac{B_g(1-R_vR_{vi})+(R_{vi}-R_v)B_o}{1-R_vR_s}$	$\frac{B_o(1-R_vR_{si})+(R_{si}-R_s)B_g}{1-R_vR_s}$

*) In Tarek Ahmed, F (defined as the "underground withdrawal") is expressed differently. The F from the above table is added with water production term; B_wW_p

0.2 Basic Plots - to identify volumetricity, waterdrive, and formation drive

Reservoir	x-axis var.	y-axis var.	G_{fgi}	N_{foi}	Volumetric	Waterdrive	Formation Drive
Dry-gas	E_g	F	slope	-	straight lineslope -	curves upward	curves downward
Dry-gas	G_p	$\frac{p}{z}$	x-intercept	-	straight lineslope +	curves upward	curves downward
Dry-gas	G_p	$\frac{F}{E_g}$	y-intercept	-	horizontal lineslope 0	straight lineslope +	
Gas-condensate *)	E_g	F	slope	-	straight lineslope -	curves upward	curves downward
Gas-condensate *)	G_p	$\frac{p}{z}$	x-intercept	-	straight lineslope +	curves upward	curves downward
Gas-condensate	G_p	$\frac{F}{E_g}$	y-intercept	-	horizontal lineslope 0	straight lineslope +	
Undersaturated Oil	$E_o+B_{oi}E_{fw}$	F	-	slope	straight lineslope +	curves upward	curves downward
Undersaturated Oil	N_p	$\frac{F}{E_o + B_{oi}E_{fw}}$	-	y-intercept	horizontal lineslope 0	straight lineslope +	
Saturated Oil	$\frac{E_g}{E_o}$	$\frac{F}{E_o}$	slope	y-intercept	straight lineslope 0		

Reservoir	x-axis var.	y-axis var.	G_{fgi}	N_{foi}	Volumetric	Waterdrive	Formation Drive
Saturated Oil	$\frac{E_o}{E_g}$	$\frac{F}{E_g}$	y-intercept	slope	straight lineslope 0		

*) These plots apply only for gas-condensate above dewpoint (Towler, 2001)

0.3 Waterdrive Plots - MB plot for waterdrive reservoirs

After identifying the waterdrive from the basic plots, we proceed with these plots. We calculate $\Sigma(\Delta p W_{eD})$ using van-Everdingen Hurst method. Then, there are new terms introduced; the **combined formation/gas/aquifer expansion factor** (E_c) and the **total fluid expansion** (E_t)

Reservoir	x-axis	y-axis	G_{fgi}	N_{foi}
Dry-gas	$\frac{\Sigma(\Delta p W_{eD})}{E_g}$	$\frac{F}{E_g}$	slope	-
Dry-gas	E_c	F	slope	-
Gas-condensate	$\frac{\Sigma(\Delta p W_{eD})}{E_g}$	$\frac{F}{E_g}$	slope	-
Gas-condensate	E_c	F	slope	-
Undersaturated Oil	$\frac{\Sigma(\Delta p W_{eD})}{E_o}$	$\frac{F}{E_g}$	-	slope
Undersaturated Oil	E_c	F	-	slope
Saturated Oil	E_t	$F - \Delta W$	-	slope

E_c is used in dry-gas and gas-condensate reservoirs

$$E_c = E_g + B_{gi}E_{fw} + \frac{2(c_f + c_w)B_{gi}\Sigma(\Delta p W_{eD})}{1 - S_{wi}}(\frac{h_{aq}}{h_R})$$

And E_c for undersaturated-oil reservoir is

$$E_c = E_o + B_{oi}E_{fw} + \frac{2(c_f + c_w)B_{gi}\Sigma(\Delta p W_{eD})}{1 - S_{wi}}(\frac{h_{aq}}{h_R})$$

E_t is used in saturated oil reservoirs

$$E_t = E_o + mE_g\frac{B_{oi}}{B_{gi}} + B_{oi}(1+m)E_{fw}$$

Where m is the gas-cap volume ratio

$$m = \frac{G_{fgi}B_{gi}}{N_{foi}B_{oi}}$$

0.4 Formation drive plots - plot to correct the compressibility effect

This plot is relevant to gas reservoirs (dry-gas and gas-condensate). After, identifying that the basic plots make a downward curving, we use these plots. The plots will now look straight.

Reservoir	x-axis	y-axis	G_{fgi}	N_{foi}
Dry-gas			slope	-
	$E_g + B_{gi}E_{fw}$	F		
Dry-gas	G_p	$\frac{p}{z}(1 - E_{fw})$	slope	-
Gas-condensate			x-intercept	-
	$\frac{\Sigma(\Delta p W_{eD})}{E_g}$	$\frac{F}{E_g}$		