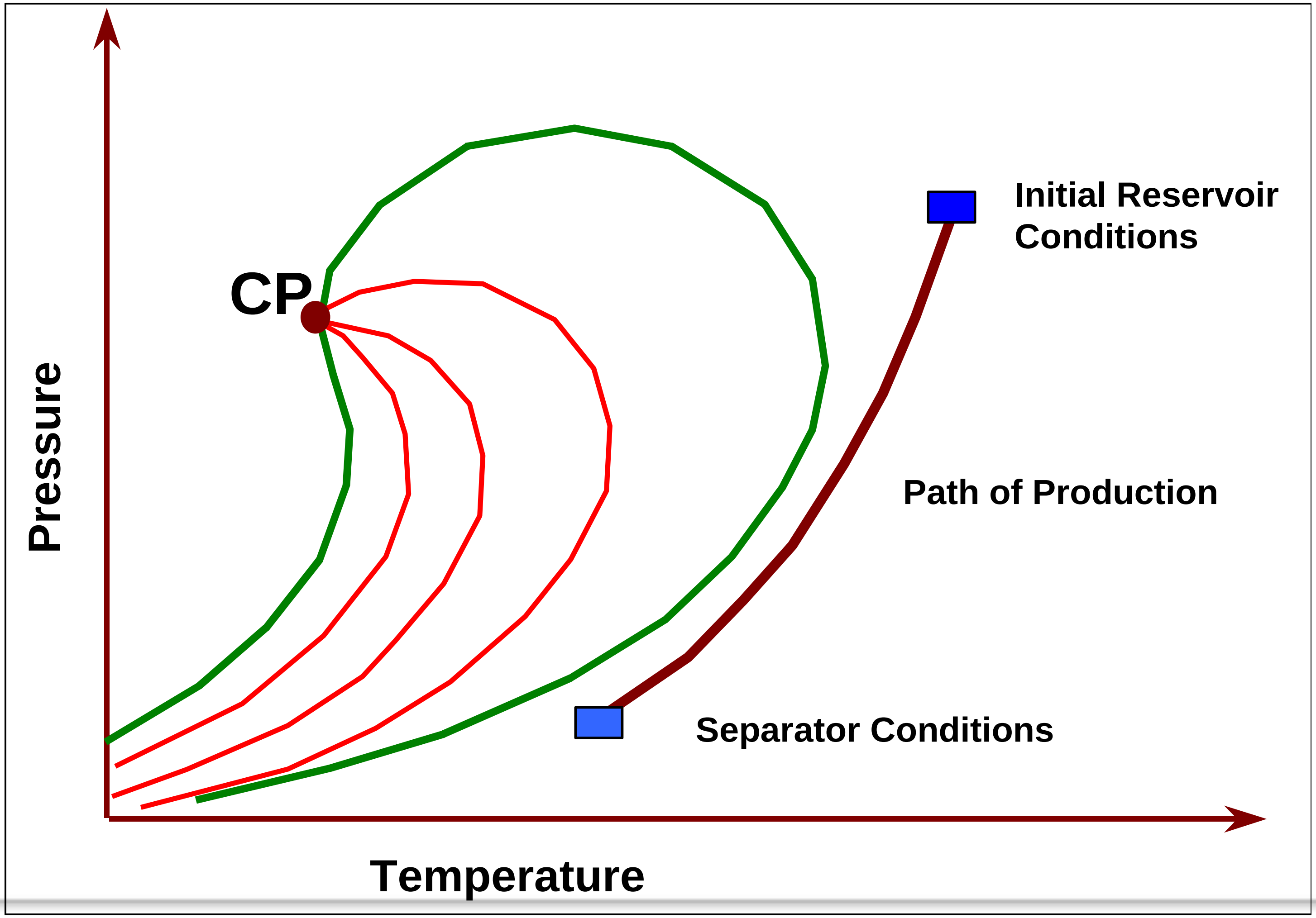
PETE 310

Lecture # 12

Properties of Dry Gases

(Chapter 6 - pages 165-178)

Phase Diagram of a Dry Gas Reservoir



Dry Gas Reservoir Characteristics

- No hydrocarbon liquids produced at surface or minimal production (or GOR > 100,000 SCF/STB)
- May produce water
- Mostly methane

Standard Conditions

- Unify volumes to common grounds for sales and regulatory purposes
  - $T = 60\ ^0F$
  - $P = 14.65 – 15.025$ (State dependent see Table 6-1)

  Practice evaluating V_M For TX

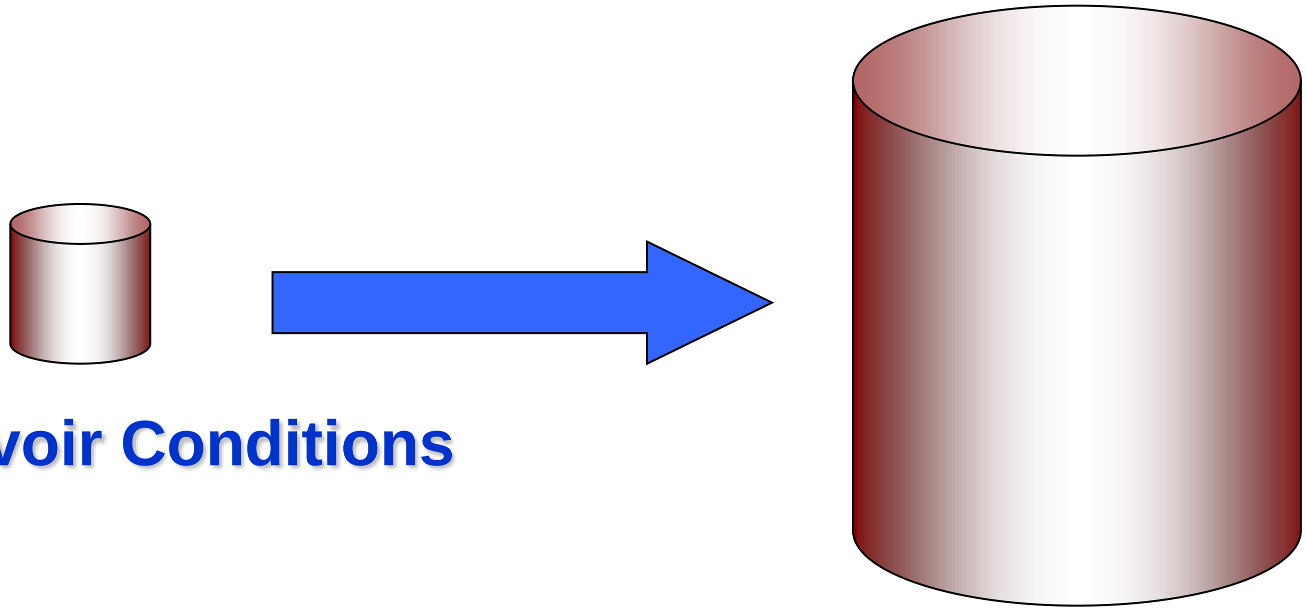
  $V_M = RT_{sc}/P_{sc}$

More Practice Problems

- A dry gas well with a SG = 0.56 in Aggie-field is producing 70,000 SCF/day
  - How many lb-moles are being produced daily?
  - How many pounds?
  - If the gas is made of just C1 and C2, what is the gas composition?

Reservoir Engineering Properties of Dry Gases

- Gas formation volume factor Bg



Reservoir Conditions

Standard Conditions

Gas Formation Volume Factor

[res bbl/SCF] or [ft^3/SCF]

Volume of an arbitrary amount of gas at reservoir T & P

Volume of SAME amount at standard T & P

$$B_g = \frac{V_R}{V_{SC}}$$

Gas Formation Volume Factor

[res bbl/SCF] or [ft^3/SCF]

$$Bg = \frac{\dfrac{ZnRT}{P}}{\dfrac{Z_{SC}\, nRT_{SC}}{P_{SC}}}$$

Gas Formation Volume Factor

Since in this book $T_{sc} = 520°R$, $p_{sc} = 14.65$ psia, and for all practical purposes $z_{sc} = 1$, then

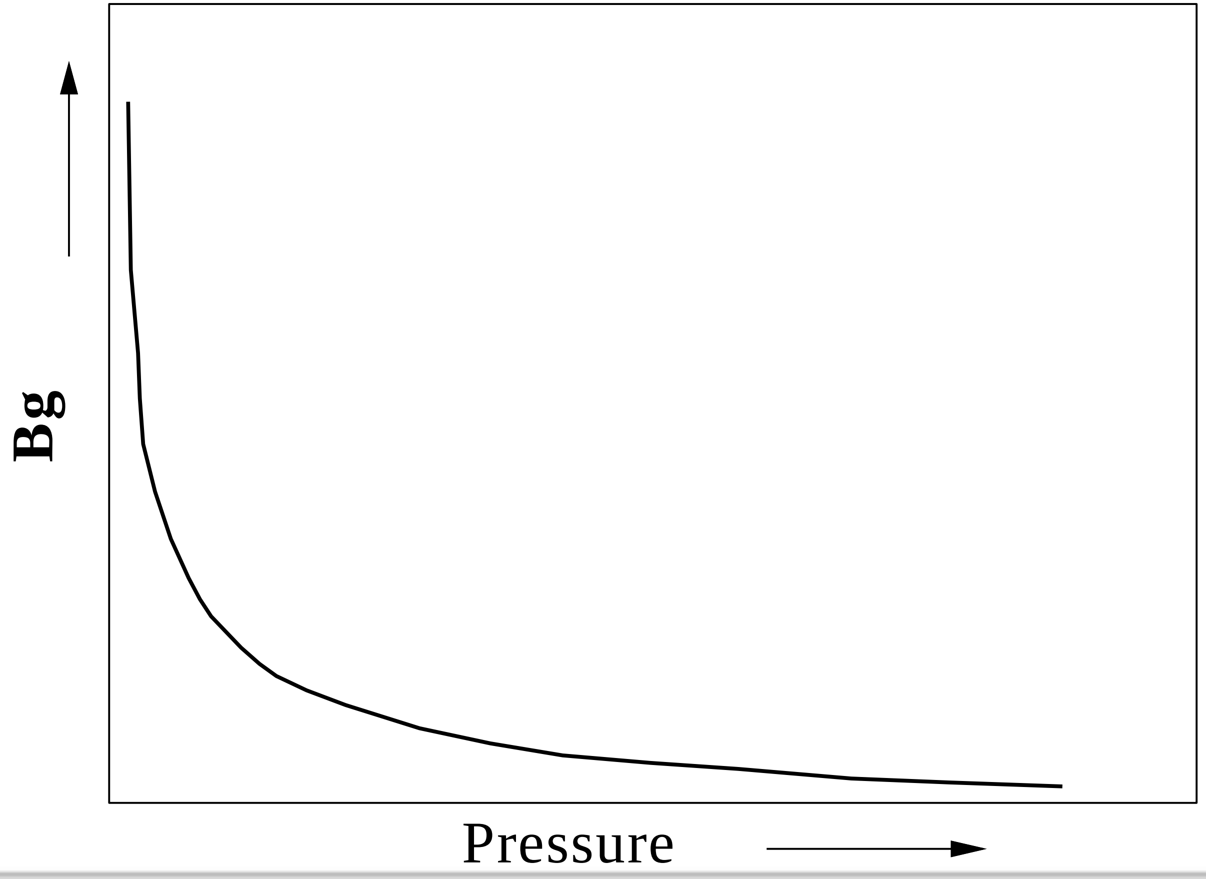
$$B_g = \frac{zT(14.65)}{(1.0)(520)p} = 0.0282 \frac{zT}{p} \frac{\text{cu ft}}{\text{scf}} . \qquad (6\text{–}2)$$

Also,

$$B_g = \left(0.0282 \frac{zT}{p} \frac{\text{cu ft}}{\text{scf}}\right)\left(\frac{\text{bbl}}{5.615 \text{ cu ft}}\right) = 0.00502 \frac{zT}{p} \frac{\text{res bbl}}{\text{scf}} , \quad (6\text{–}3)$$

Gas Formation Volume Factor

[res bbl/SCF] or [ft^3/SCF]



Example of Use of Dry Gas Properties in Material Balance Equation

Much more of these in PETE 323

Classical Reservoir Engineering Analysis

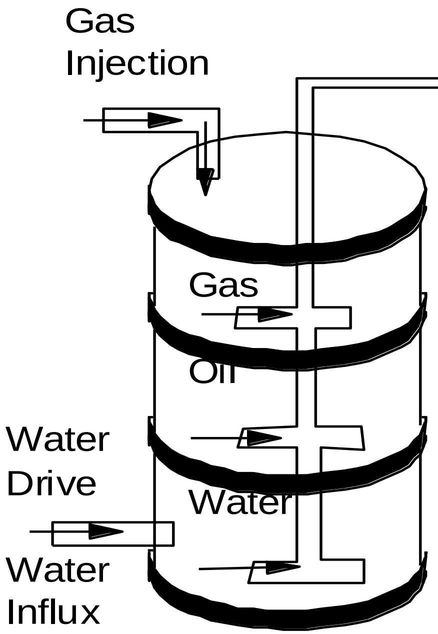
- Volumetric
  - Isomaps
  - Structural maps
  - Geological wisdom
- Material Balance
  - Production data
  - PVT data
- Fluid Displacement
  - Fractional Flow theory
  - Waterflooding

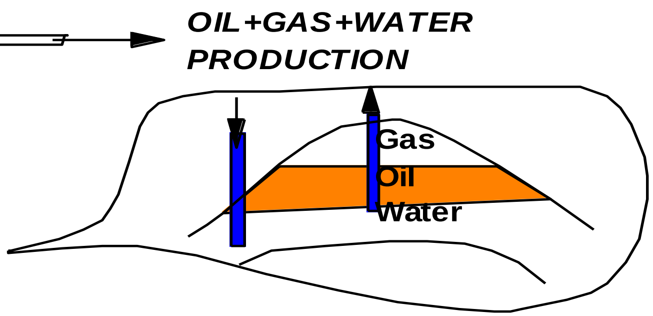
Limitations of Material Balance Methods

- No spatial distribution of pressures and saturations
- No Indication of Unswept or Uncontacted Areas
- Does Not Use Spatial Information
- Reservoir properties are average properties
- Reservoir is a tank

Processes Included in GMBE

GENERAL MATERIAL BALANCE EQUATION (GMBE)





- Approximates reservoir as a tank with given boundaries and uniform T and P.
- MB Calculation is a very gross approximation of the reservoir performance, but one that is very useful in practice

Sequence of Stirred Tanks Model

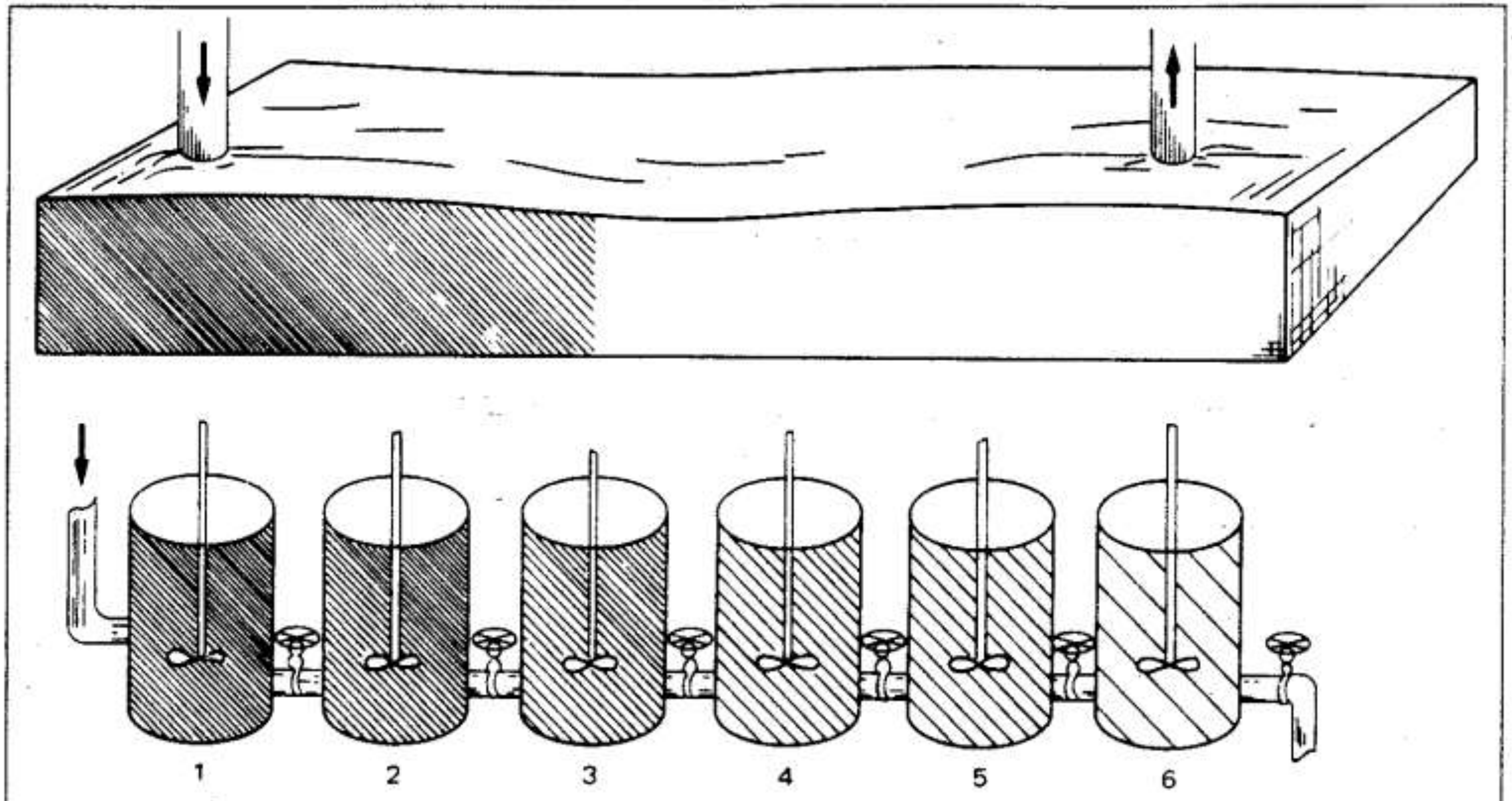


Fig. 2.1—A well-stirred tank analog of a simulator grid system.

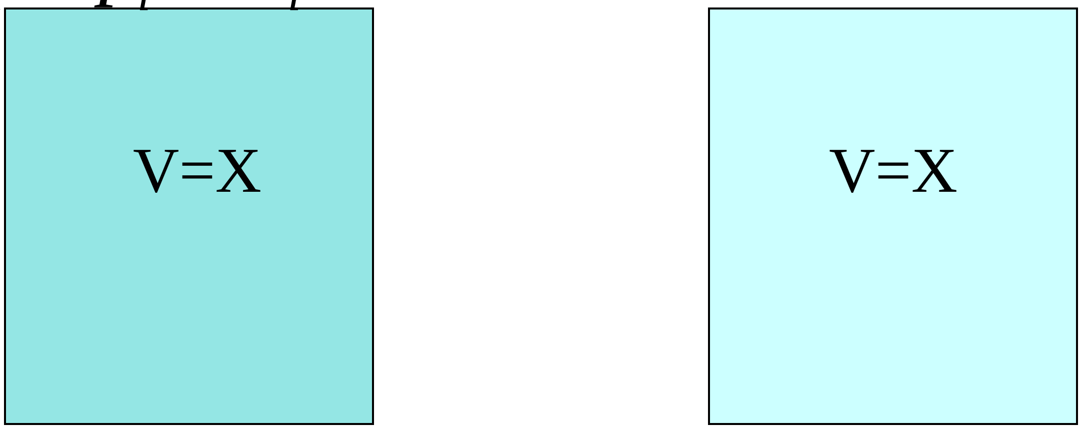
Sources of Reservoir Energy

- Liquid and rock compressibility,
- Gas in solution,
- Gas in the gas cap,
- Water influx,
- Gravity Segregation

Volumetric gas material balance

Moles of gas

$$n_i = p_i V / z_i RT \qquad n_2 = p_2 V / z_2 RT$$



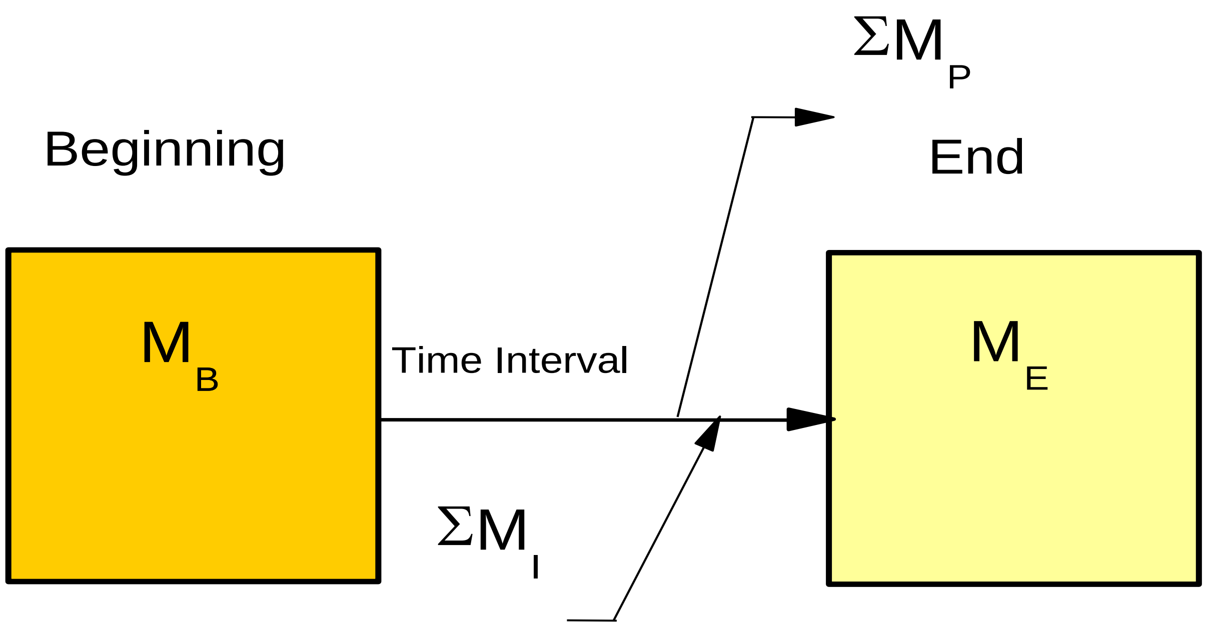
Original pressure at reservoir temperature

Time 1

New pressure at reservoir temperature

Time 2

A Simple Mass Balance



Mass Balance: $M_E - M_B = \Sigma M_I - \Sigma M_P$

On a volumetric basis

$$V_E - V_B = V_I - V_P$$

Volumetric gas material balance

Moles of gas produced = $n_i - n_2$

380.7 scf per lb mol of gas in Texas (@60 deg F and 14.65 psia)

Volume of gas produced = $380.7*(n_1-n_2)$ scf

Material Balance Derivation

Initial state
before production

$$p_i V = n_i z_i RT$$

After some
Production
Moles left in reservoir

$$pV = \left(n_i - n_p\right) zRT$$

Ratio Equations and rearrange

$$\left(\frac{pV}{zRT}\right)\left(\frac{z_i RT}{p_i V}\right) = \frac{n_i - n_p}{n_i}$$

$$\frac{p}{z} = \frac{p_i}{z_i}\left(1 - \frac{n_p}{n_i}\right)$$

Material Balance Derivation

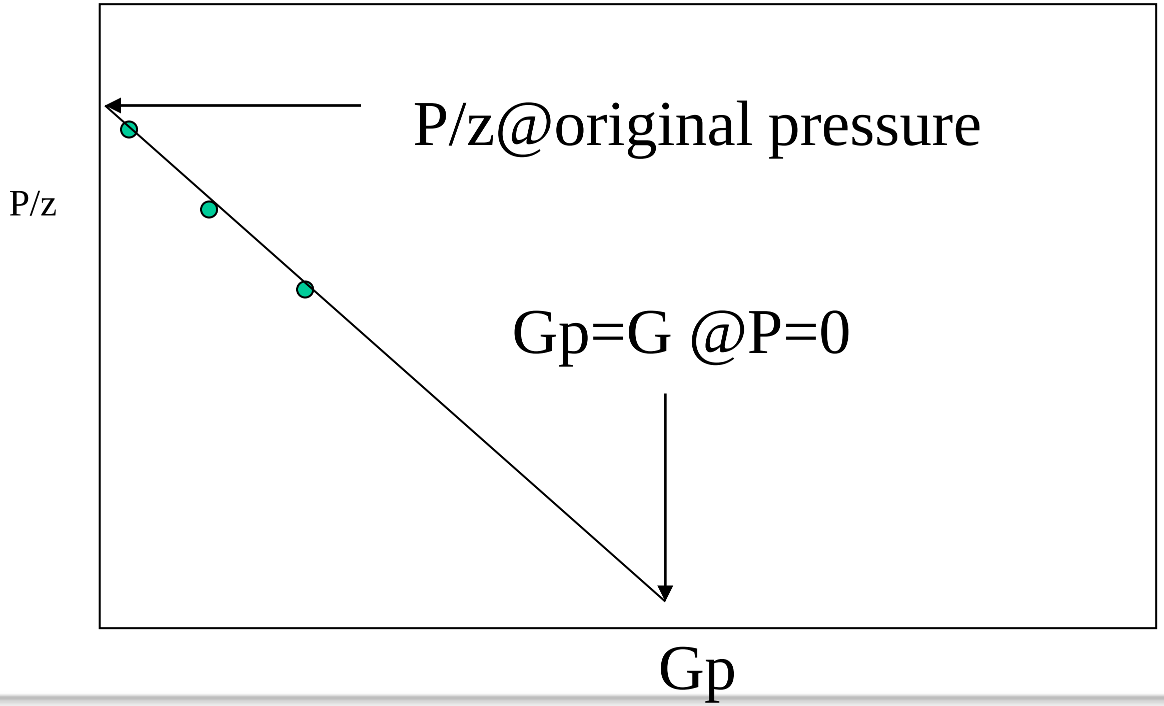
$$\frac{p}{z} = \frac{p_i}{z_i}\left(1 - \frac{n_p}{n_i}\right)$$

Express moles produced and initial in terms of standard volumes

$$n_p = \frac{p_{sc} G_p}{R T_{sc}} \qquad n_i = \frac{p_{sc} G}{R T_{sc}}$$

P/z plot Volumetric reservoir graphic interpretation--

$$\frac{p}{z} = \frac{p_i}{z_i}\left(1 - \frac{G_p}{G}\right)$$

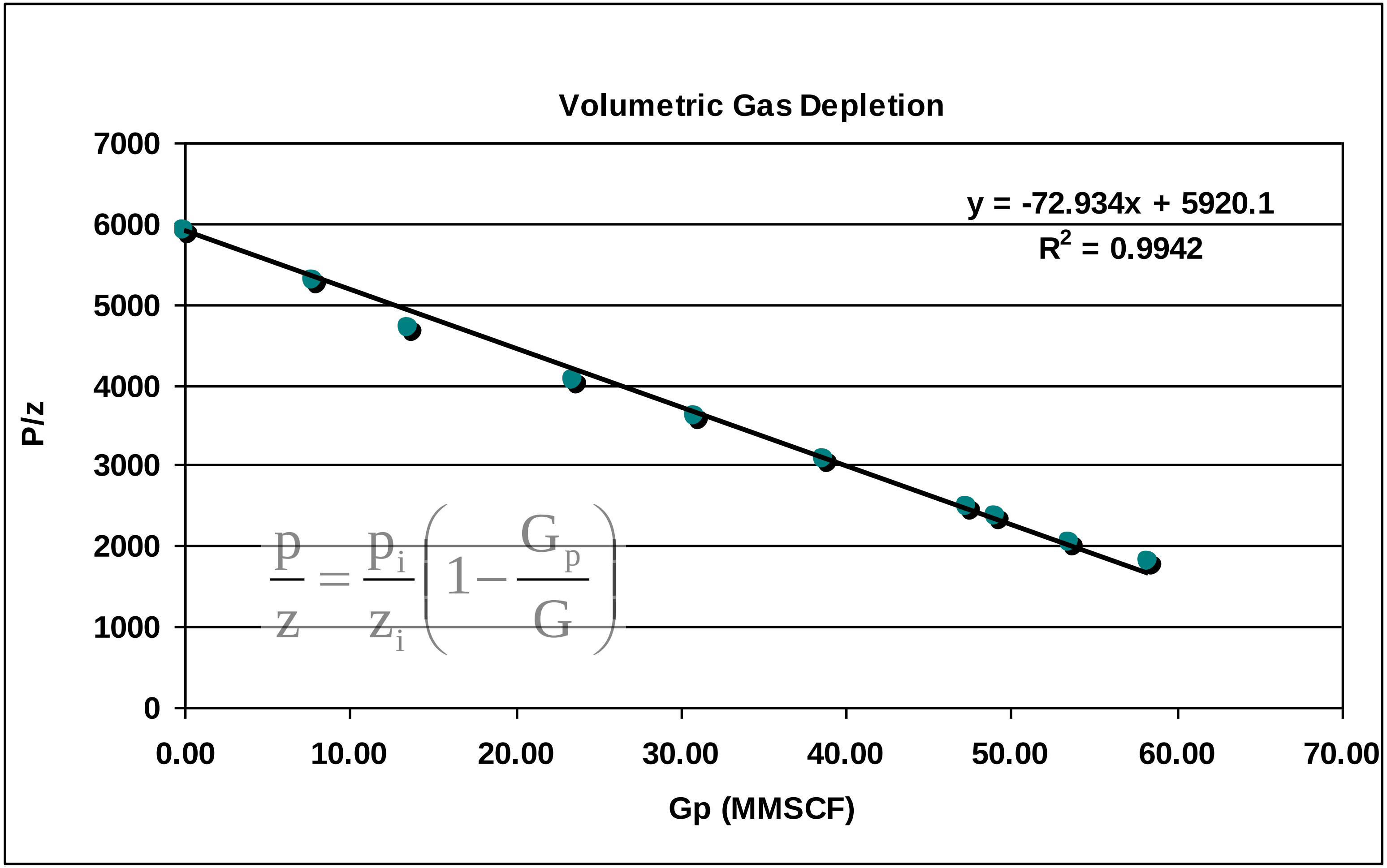


Material Balance Exercise

- Volumetric Depletion of a Dry Gas Reservoir

Pressure	Gp (SCF)	Z	Gp (MMSCF)	P/Z
6000	0	1.0135	0	5920.078934
5300	7737328.244	1.0006	7.7373282	5296.821907
4520	13536207.06	0.9627	13.536207	4695.128285
3640	23488811.39	0.8972	23.488811	4057.066429
3100	30905455.55	0.863	30.905456	3592.12051
2600	38671313.9	0.8502	38.671314	3058.103976
2120	47318522.34	0.8525	47.318522	2486.803519
2028	49122795.64	0.855	49.122796	2371.929825
1760	53512916.85	0.8617	53.512917	2042.474179
1570	58302139.98	0.8765	58.30214	1791.21506

Material Balance Exercise



$$\frac{p}{z} = \frac{p_i}{z_i}\left(1 - \frac{G_p}{G}\right)$$

Related Possible Exam Questions

- Find the gas in place
- Find recoverable gas at a certain abandonment pressure
- Determine initial reservoir pressure
- Determine reservoir pore volume

More Gas Properties

- Viscosity
- Heat of combustion
- …