PVT

KAPPA

FOUNDATION
PRODUCTION LOG
INTERPRETATION
COURSE

Module #3 PVT

PVT

PVT: Properties of Reservoir Fluids as function of

P ressure

V olume

T emperature

Use of PVT in Emeraude

1. **PVT properties are used as inputs to the calculation process, in generating the downhole solution. e.g.**
   - Reynolds number (Flowmeter VPCF & Gradio frictions)
   - Correlations (Flow regime & Slippage velocity)

2. **PVT properties are also used to convert the calculated downhole rates to standard conditions. (Bo, Bg, Bw)**

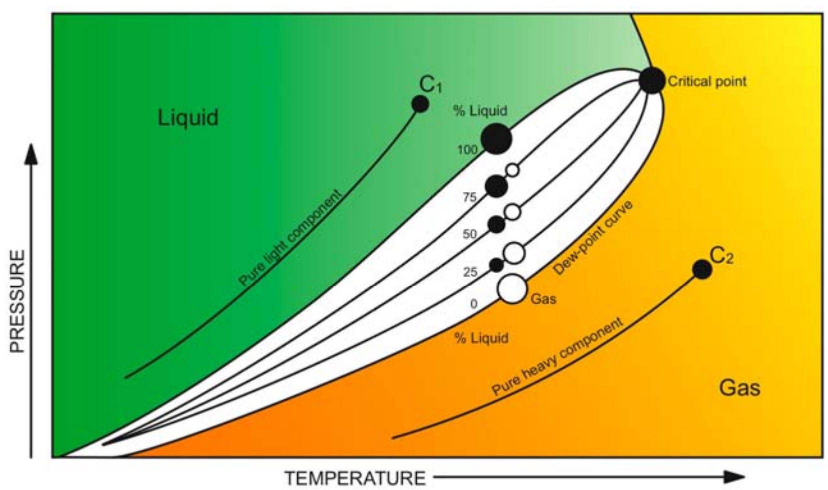
OBJECTIVE

We need the best PVT parameters that suit the uses described above.

NOTE: Errors in the PVT can introduce significant errors in the computed EMERAUDE results!

Two Component System:

Pressure vs. Temperature



PVT: Curve Definitions

Dew-Point Curve

Pressure – Temperature trajectory at which the saturated vapour starts to condense.

Bubble-Point Curve

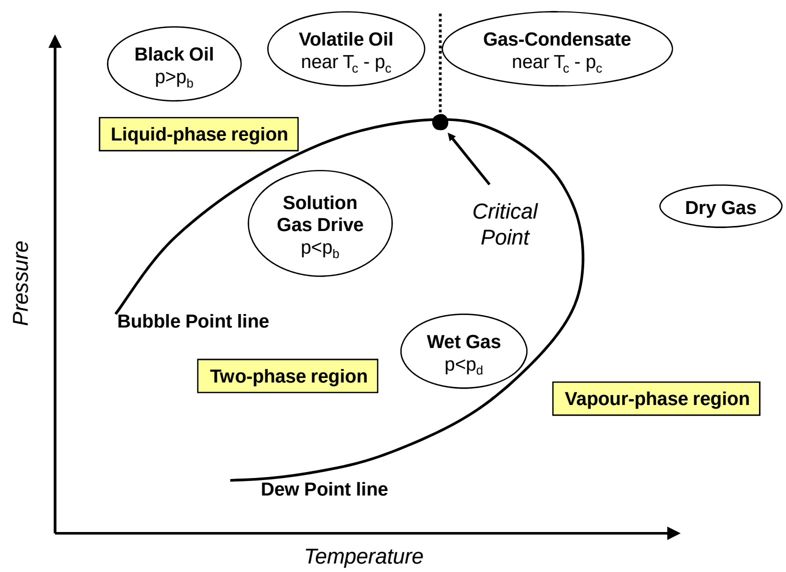
Pressure – Temperature trajectory at which the liquid starts to boil.

Critical Point

point where the ***bubble point and dew point curves meet***.

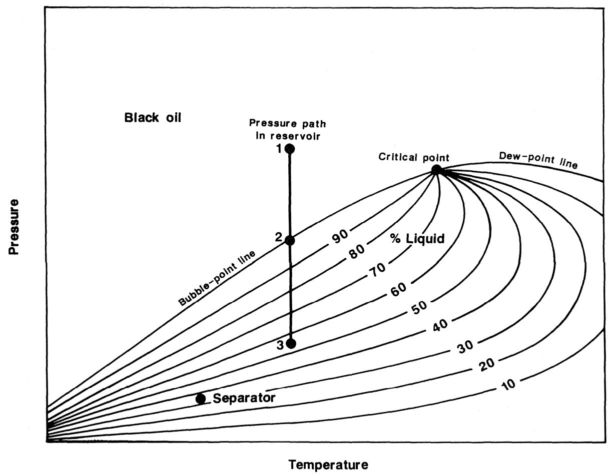
It is the point at which vapour and liquid phases become indistinguishable.

Reservoir Types



Black Oil *p-T* Diagram

Black Oil



Typical values:

γ_o < 45ºAPI

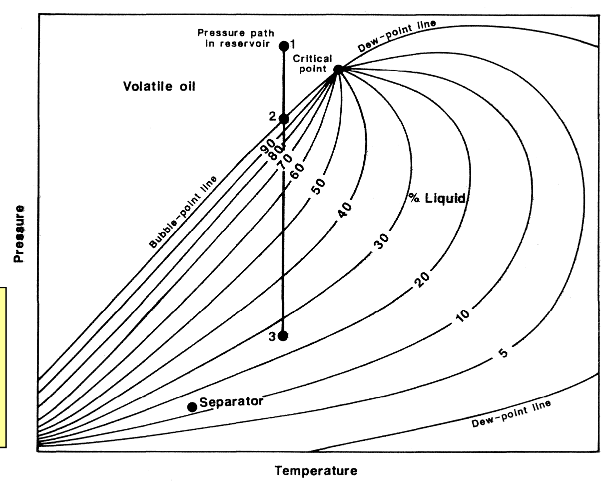
GOR_i < 1,000 scf/stb

B_{oi} < 2.0 rb/stb

C_{7+} > 30 %

Volatile Oil *p-T* Diagram

Volatile Oil



Typical values

45º<γ_o<60ºAPI

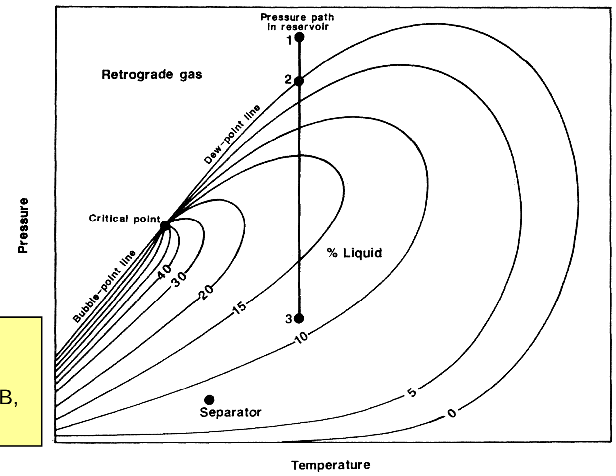
1000 < GOR_i < 8000 scf/stb

B_{oi} >2.0 v/v

C_{7+}>12.5%

Gas: Condensate *p-T* Diagram

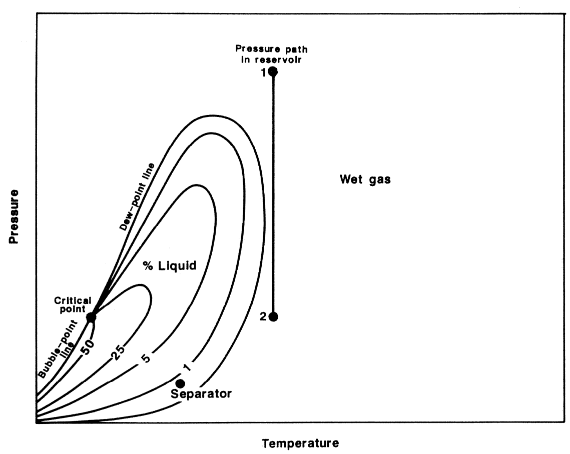
Retrograde Gas



Typical values
γ_o>60º API,
70K < GOR_i < 150K scf/STB,
C_{7+} < 12.5 %.

Wet Gas *p-T* Diagram

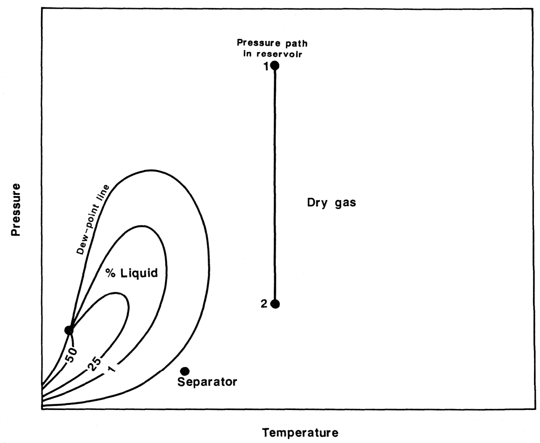
Wet Gas



Typical values
GOR_i > 100,000 scf/STB.

Dry Gas *p-T* Diagram

Dry Gas

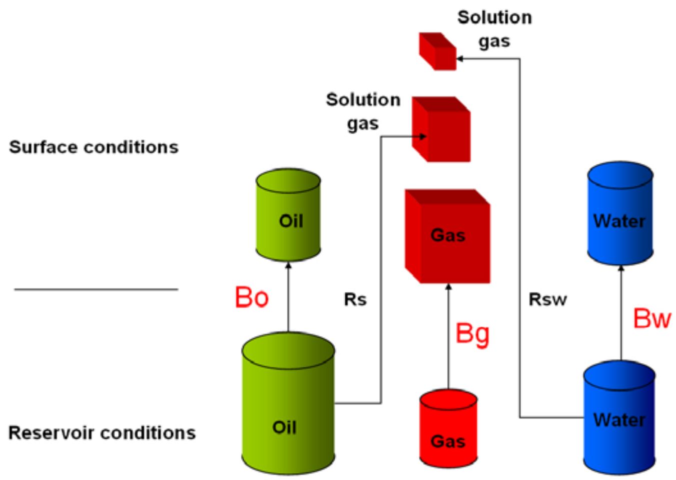


Summary of Classifications

	Oil		Gas		
	Black	**Volatile**	**Condensate**	**Wet**	**Dry**
GOR [kscf/b] **CGR [kstb/MMscf]**	**< 1.75**	**1 – 8**	**70 – 100** **14.3 - 10**	**>100** **< 10**	
API Gravity	**< 45**	**45 - 60**	**> 60**		
Bo	**< 2**	**>2**			
Color	**dark green - black**	**light brown – green**	**light**	**clear**	
Mole % C7+	**> 30**	**>12.5**	**< 12.5**		

After Barrufet's: Classification of the Hydrocarbon Stream (Texas A&M)

Formation Volume factors



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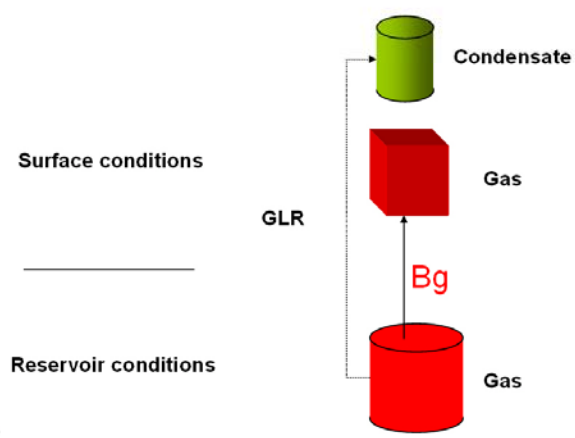
Retrograde Gas Condensate



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Formation Volume Factor

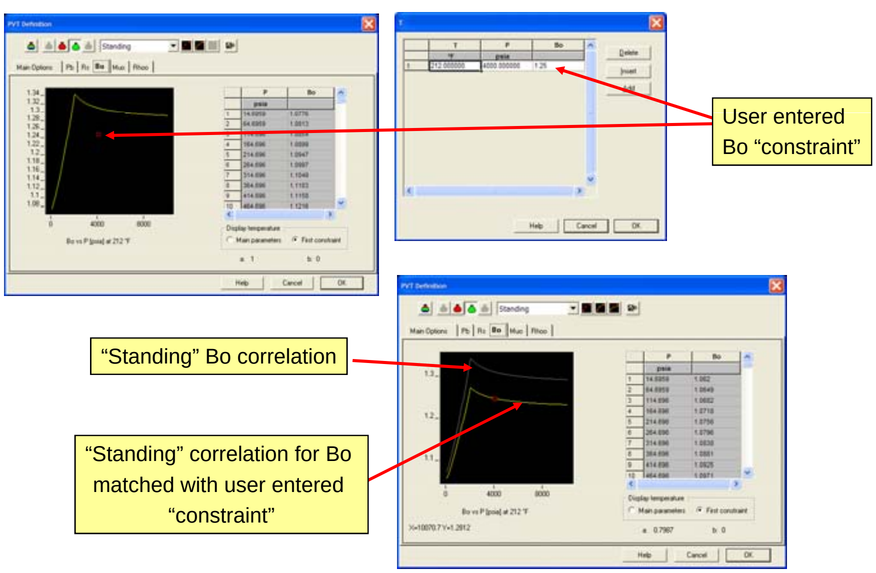
Formation Volume Factor: $B_{o,g,w}$

$$B_{o,g,w} = \frac{\text{Fluid volume at reservoir conditions}}{\text{Fluid volume at standard conditions}}$$

The *Formation Volume Factor* "converts" surface volumes to downhole conditions.

Typical values:				
Oil:	1.2	to	2.4	RB/STB
Gas:	0.003	to	0.01	rcf/scf
	100	*to*	*333*	*scf/rcf (=expansion factor)*

Oil Volume factor - Constrained

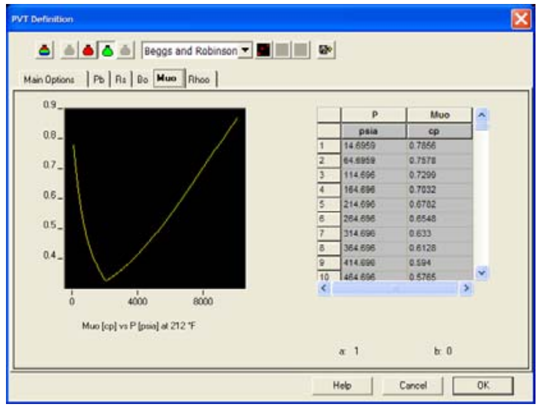


Viscosity

Fluid viscosity depends on pressure, temperature and composition.

Typical values:

Oil: 0.2 - 30 cp
Gas: 0.01 - 0.05 cp
Water: 0.5 - 1 cp



Fluid Correlations

Oil PVT Correlations used in Emeraude

	R_s/p_b	B_o	μ_o	c_o
Standing	☑	☑	-	-
Lasater	☐	-	-	-
Vasquez and Beggs	☐	☐	-	☑
Glaso	☐	☐	☐	-
Lasater- Standing	☐	-	-	-
Petrosky and Farshad	☐	☐	-	☐
Beggs and Robinson	☐	-	☑	-
Beal	-	-	☐	-

☑ generally used as default

Gas

In order to keep the liquid flow equations linear, the variations in gas properties are accounted for by the real gas pseudo-pressure function

$$m(p) = \int_{p_0}^{p} \frac{2p.dp}{\mu(p).z(p)}$$

Pseudo-pressure available as a scaling option in Emeraude SIP plot

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Gas Correlations

Gas PVT Correlations used in Emeraude

	z-factor	μ_g
Dranchuk, et al.	☐	-
Beggs and Brill	☑	-
Hall and Yarborough	☐	-
Lee, et al.	-	☑
Carr, et al.	-	☐

☑ generally used as default

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Condensates

Two methods to define Condensates in Emeraude:

"Dry Gas" and Condensate.

"Dry gas" Condensate is added to the dry gas stream to get downhole properties.

- The recombination ratios are based on the total measured surface rates and densities.
- The analysis assumes single phase production (no oil phase)
- Can be used in low-medium CGR wells (mist flow, check your correlation)

Remark mist flow assumes no slippage

Condensates

Condensate Fluid is split into two components: gas and liquid

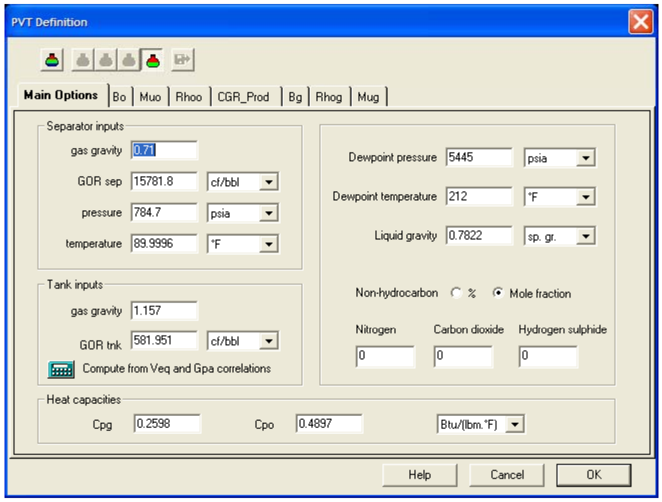
- Can distinguish between oil and gas downhole

Caution Split into two downhole phases is often difficult:

- Requires more detailed surface data and PVT properties are critical
- Holdups are often difficult to determine:
  - Uncertainties in densities gives wrong split (for instance the friction in gradio measurements)
  - GHOST: max fluid velocity is 9 m/s. And measurements are affected by presence of (small) water droplets)
  - In condensate wells part of the liquid flow is along the pipe: not measured

It is recommended to use the "Dry Gas" option where possible

Condensates



PVT Parameter Source

Source of the PVT parameter values:

Laboratory

Accurate, Expensive

Time delay.

Laboratory PVT results present a problem as they are often isothermal, derived at a single reservoir temperature.

NOTE: **EMERAUDE** requires a non-isothermal PVT

Correlations

Fast

Built in to **EMERAUDE**

Less accurate

Oil viscosity often problematic.

The best solution is to use PVT Correlations, and constrained by Laboratory measurements (or in some cases density readings from the PL tool)

PVT: Lab Measurements

Examples of PVT Lab analysis:

******Flash Vaporization*:** in equilibrium during T&P traverse (tubing and separator)

***Differential Vaporization*:** Gas is removed at every step (reservoir)

Hydrocarbon Analysis of reservoir fluids

Additional and Special Analysis, such as detailed liquid drop-outs and accurate phase envelopes for volatile oils and gas-condensate reservoirs (LNG).

Essential PVT Inputs

Minimum PVT parameters required for EMERAUDE

WATER

- **Salinity ppm**

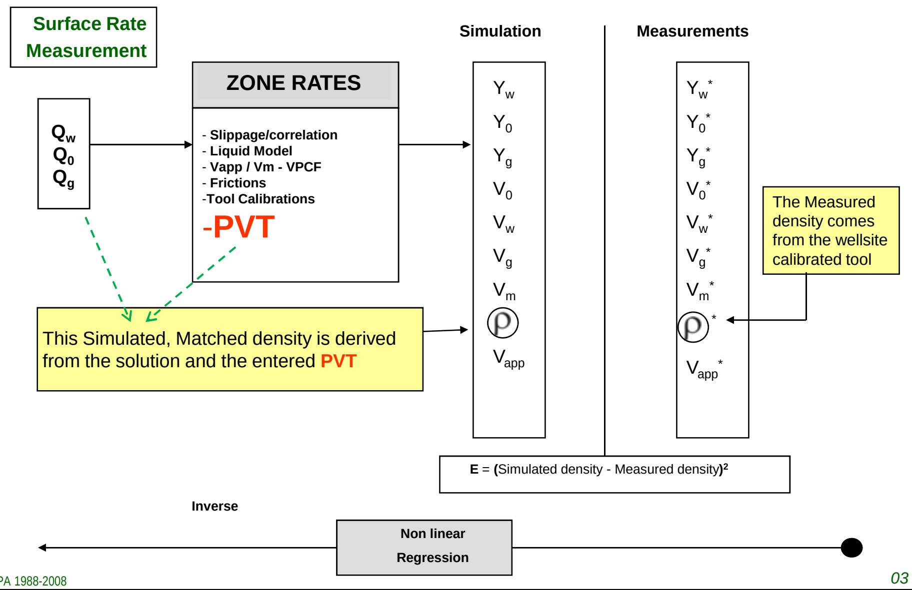
OIL

- **Gravity API**
- **Rs (Solution Gas-Oil Ratio)..**
- **NOTE: Rs is not necessarily the produced GOR!!!**

GAS

- **Specific gravity**

Importance of PVT - Density



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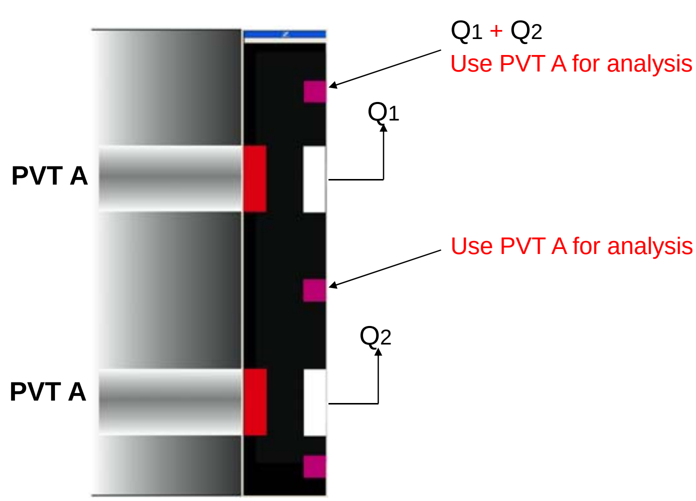
Zoned PVT



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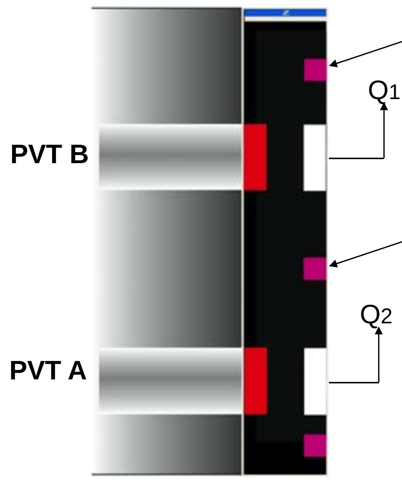
Zoned PVT



$Q_1 + Q_2$

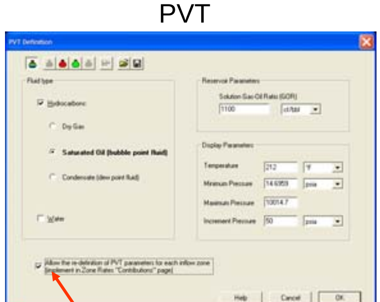
Use combined PVT A + PVT B for analysis

(Since this combined PVT requires knowledge of Q2, a **Global Solution** must be used – See Zone Rates)

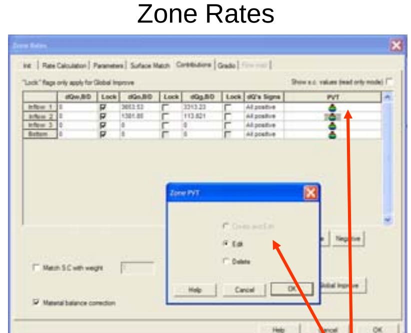
Use PVT A for analysis

Zoned PVT

PVT



Zone Rates



Enable “Zoned PVT” option in the PVT dialogue

Initialise PVT for each inflow zone prior to Global Improve for simultaneous optimisation

PVT References

- Fundamentals of Reservoir Engineering — Calhoun (1953).
- Properties of Petroleum Fluids — McCain (1990).
- Reservoir classification Based on Fluid Types, Barrufet,
  PETE 323 Texas A&M
- Hydrocarbon Liquid Phase Definition, Determination and Allocation in
  Two-Phase Hydrocarbon Reservoir, A.N. Hamoodi et. al.,
  SPE 78363 (2002)
- Fundamentals of Reservoir Engineering – L.P. Dake
  ISBN 0-444-41380-X Elsevier

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