Field-wide reservoir characterization based on a new technique of production data analysis: verification under controlled environment

Mata D., Gaskari R., Mohaghegh S.

Eastern Regional Meeting.
Lexington, Kentucky
October 2007
Agenda

1. Problem Statement
2. Methodology Employed
3. Model Configuration
4. Application of IPDA technique
5. Results
An Effective revitalization on mature fields in a time when price of oil & gas is high requires a reliable reservoir characterization.

Most common type of data that may be found in many of the mature fields is monthly Production rate data.

Recently a new methodology was introduced for characterization of mature fields based on monthly production rate data. This methodology integrates conventional production data analysis with several new techniques based on intelligent systems in order to map fluid flow in the reservoir as a function of time.
Problem Statement

Intelligent Production Data Analysis (IPDA)

Principles of the Technique

Monthly Production Rate Data

Intelligent Systems

DCA, TCM, HM

Predict Entire Field Behavior!
Validating the applicability of IPDA technique in reservoirs with heterogeneous characteristics, including single and multi-layered formations.

Verifying the potential of this technique to recognize new opportunities in Mature Fields.

Identifying those circumstances under which the technique might result in incorrect recommendations.
Methodology

Controlled Environment

Model the reservoir using a Simulator → Run the model and generate Production Data

Perform an IPDA

Characterize the Reservoir employing IPDA

Measure Accuracy of results
Methodology

Models Developed

**Single Layer Models** $(\phi, k)$
- 100 wells (SLM – 100)

**Two-Layer Models** 100 wells
- TLM–1 $(\phi, k)$

- Initial Gas in Place
- Estimated Ultimate Recovery (EUR)
- Remaining Reserve
- Permeability
- Fracture Half-length
- Drainage Area
- Well performance evaluation
Methodology

Models Developed

Single Layer Model
Methodology

Models Developed

Single Layer Models
Methodology

Models Developed

Single Layer Model

Porosity %

12 10 8
Methodology

Models Developed

Single Layer Model

Well Distribution 100 Wells
Methodology

Models Developed

Two-Layer Model

Isopermeability
Methodology

Models Developed

Two-Layer Model

Isoporosity
Production Strategy

Drilled in Groups of 10 wells, taking intervals of 3 months

Under Production for 30 years @ constant BHP
IPDA Technique

1. Data Acquisition
2. Decline Curve Analysis
3. Type Curve Matching
4. History Matching
5. Field-wide Pattern Recognition
IPDA Technique

Data Acquisition

Well Name
Latitude
Longitude
Monthly Production Rate Data
Date

Initial Reservoir Pressure
Average Reservoir Temperature
Gas Specific Gravity
Isotropy
Drainage Shape factor

Average Porosity
Average Pay Thickness
Average Gas Saturation
Average Flowing BHP
IPDA Technique

Decline Curve Analysis

Arps Approach

Type Curve Matching

Cox Approach

History Matching

Single-well Radial Simulation
Decline Curve Analysis is a method used for forecasting future behavior of a well by fitting previous records of Production Data with a mathematical model.

**Arps Equation**

\[ q_t = \frac{q_i}{(1 + bD_i t)^{1/b}} \]

- **Qi** = Initial Flow Rate.
- **Di** = Initial Decline Rate.
- **b** = Hyperbolic Exponent

- **b = 0** – Exponential
- **0 < b < 1** – Hyperbolic
- **b = 1** – Harmonic
Cox approach uses Constant Pressure (a.k.a. Rate) Type Curves developed specifically for low permeability reservoirs with hydraulically fractured wells.

For a specific "b"
IPDA Technique

Type Curve Matching
History Matching

The act of adjusting various parameters in a modeled reservoir until it reproduces past behavior of observed data.

K, Φ, P, A, T, Sg
IPDA Technique

History Matching

Single Well Radial Simulator
IPDA Technique

History Matching

Decline Curve Analysis

Type Curve Matching

EUR

EUR, K, DA

EUR, K, DA
IPDA Technique

Field-wide Pattern Recognition
IPDA Technique

Field-wide Pattern Recognition
Results
SLM - 100

Heterogeneous Porosity
Heterogeneous Permeability
Actual Porosity Distribution

Actual Permeability Distribution

Thickness

Initial Gas Distribution

Results SLM-100
Remaining Gas Distribution after 30 years
Estimated Ultimate Recovery

EUR After 45 years of Production

Average Difference 8.44%
Permeability

Results SLM-100

Permeability (mD)

- 3.00
- 0.5

Permeability (mD)

- 1.50
- 0.50
- 1.00
- 0.75
Results TLM

Heterogeneous Porosity
Heterogeneous Permeability
Results TLM

Estimated Ultimate Recovery @ 45 years

Average % error 3.74
What is an Under Performer Well?

- Bottom 25% of its own RRQI
- Below the average of next RRQI

Model SLM 100

<table>
<thead>
<tr>
<th>Category</th>
<th>Average Value / Well</th>
</tr>
</thead>
<tbody>
<tr>
<td>High 1</td>
<td>20</td>
</tr>
<tr>
<td>High-Mid 2</td>
<td>15</td>
</tr>
<tr>
<td>Mid-Mid 3</td>
<td>10</td>
</tr>
<tr>
<td>High-Low 3</td>
<td>5</td>
</tr>
<tr>
<td>Mid-Low 4</td>
<td>2</td>
</tr>
<tr>
<td>Low 5</td>
<td>1</td>
</tr>
</tbody>
</table>

Under Performer Wells
Select 10 wells in the reservoir and added positive skin (+4)

Model SLM 100

Under Performer Wells
Predicting Behavior of Future Wells

Model SLM 100

Verification Process
Model SLM 100

Verification Process

Close to the boundaries

Well #5 (Green Zone)

NPV between IPDA and Eclipse had up to 26% difference

Away from the boundaries

Well #8 (Red Zone)

NPV between IPDA and Eclipse had less than 5% difference
IPDA does not recognize boundaries.

*case (a)* 100% Effective Drainage Area

*case (b)* 35% Effective Drainage Area
1. Identifies sweet spots in a reservoir at any given time.
2. Provides a unified set of reservoir characteristics (Initial gas distribution, permeability, etc.)
3. May be applied in both single and multi-layered formations.
4. Accurately estimates the distribution of the remaining reserve at any time.
CONCLUSIONS

5. Is capable of forecasting Estimated Ultimate Recovery EUR
6. Provides reliable information regarding well parameters (drainage area, fracture half length, etc)
7. Identifies under-performer wells.
8. Assesses potential locations for infill drilling.
CONCLUSIONS

THE FOLLOWING LIMITATIONS WERE FOUND

1. The accuracy of the predictions depends on the quality of the conventional analysis performed (*decline curve analysis, type curve matching and history matching*) Therefore, the technique provides better results once the *pseudo-steady state* condition has been reached.

2. Intelligent Production Data Analysis stands for a qualitative analysis of the reservoir. Therefore, the estimated figures are not necessarily correct.
CONCLUSIONS

The following limitations were found

3. The proximity of the well to the reservoir boundaries might affect the accuracy of the predictions.

4. In some cases, it is not possible to find an appropriate partitioning that delineates the Relative Reservoir Quality Index (RRQI Map) and this situation affects the visualization of the results.