Unlocking the Value of Marginal Assets:
“Production Optimisation through Effective
Integrated Production System Modelling”

by
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Production Performance Optimisation – Marginal Fields

• Marginal fields are essentially those that can be produced at economic flow rates to recover small accumulations which are either the bulk of what is left tied up of a mature field or smaller reserves in the order of 20 millions barrels or less.

• Marginal fields are one of the world’s growing sources of oil, specially in mature oil producing regions like UK North Sea where the development of these smaller accumulations has significantly reduced the speed of production decline.
Production Performance Optimisation – Marginal Fields

- North Sea oil production is now declining and the only way to stem that decline appears to be in extracting new oil from smaller new fields.

- UKOOA estimates there are some 25 billions barrels of oil equivalent (oil & gas combined) in the North Sea yet to be exploited in addition to the 31 billions already produced.
• The commercial development of these small accumulations become possible with the development of new technologies with special reservoir engineering tools, formation evaluation methods, horizontal and multi-branched wellbores and advanced drilling techniques.

• The North Sea and other mature oil producing regions in the world are entering a new phase in oil production best practices, where much of the challenge in increasing output is to chase every barrel and optimise production performance.
• Integrated production system modelling can be defined as the measure of operational health which provides an effective understanding of actual wells and field performance

• The objective of integrated modelling is to improve production efficiency by cycling through the process loop to assess the wells performances, evaluate the results and review the options
• The well is only a component of the production network, we cannot analyse the well performance without considering the reservoir, the flowline and the processing facility, as each component of the system affects the operation of the entire network
Production Performance Optimisation – Optimisation Process Criteria

- Reservoir Potential
- Flowline Capacity
- Well Performance
The modelling of the entire production system is targeted to optimising the well productivity and maximising the field performance today and tomorrow.

It is a process about predicting the effects of changes through a systematic analysis of individual components (reservoir response, well and flowline behaviour) and the impact of their interaction on field performance.
Production Performance Optimisation – Integrated Modelling Process loop

- Reservoir model
- Well model
- Network model
• The rate at which a fluid flows towards the wellbore depends on the driving force which is the difference in pressure between the reservoir and the wellbore, otherwise called drawdown ($\Delta P_{DD}$).

• The inflow performance relationship quantifies the flowrate from a well as a function of the drawdown.
• The ability to pass reservoir fluids through the tubulars (Tubing) is termed the “vertical flow performance”

• The vertical flow is totally dependent on the tubing size and fluid properties.

• Though the vertical flow of fluid in a tube is completely independent of the inflow performance of the reservoir, the two phenomenon are closely related because the end condition of inflow performance is the initial condition of vertical flow.
The capacity of the reservoir to pass fluid into the wellbore and the capacity of the tubing to pass fluid to the surface have to be matched and be operating in equilibrium, this occurs at the conditions defined by the intersection of the two curves, and that is the stabilized and optimum production rate that the system will maintain.
Production Performance Optimisation – IPR/VLP Curves

- A matched well (VLP/IPR) model with measured well tests data can be used to:
  - estimate the reservoir pressure, in the absence or failed downhole gauges data,
  - save the costs of frequent pressure surveys to monitor reservoir behaviour (depletion)
  - which in turn can be used to tune the reservoir simulation model for a better reservoir management and production optimisation (e.g. pressure support with water or gas injection)
• An example of a single well model, note the reservoir depletion and decreasing production rate with time, and again an increase in production because of pressure support due to gas injection (welltest #4 and welltest #6 results)
An example well model (inflow vs outflow curves), based on a matched reservoir pressure, the production rates are generated for given flowing tubing head pressure (FTHP’s)

If this well has a productivity index (PI) of 7 bbls/d/psi and a water cut of 20%, an effective inflow performance optimisation could generate an incremental 250 bbls/d net oil, if the wellhead pressure was adjusted to 885 psi (61 bar) instead of 930 psi (64 bar)
• One key aspect of a gas lift system is the interaction between wells in the gathering network as back-pressure from additional gas in the flowline adversely affects production from all the other connected wells.

• The ‘optimal’ gas lift injection rate generally determined from a single-well analysis method has limited validity in analysing a production network of gas lifted wells.

• Therefore the need for a system approach to gas lift allocation optimisation based on a model that would optimise field-wide gas lift allocation.
Production Performance Optimisation – Network Modelling (Gas Lift)
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Production Performance Optimisation – Network Modelling (Gas Lift)

System type: Production
Optimisation Method: Production
Pipeline prediction: Pressure and temperature
Gas Available: 28.00 MMscf/day
Gas injected: 24.88 MMscf/day
Oil produced: 7924.46 STB/day
Gas produced: 3.47 MMscf/day
Water produced: 44432.25 STB/day
Liquid produced: 52356.72 STB/day

- Name       Oil
- Produced
- STB/day

-----------------------
- W#57       3184.35
- W#28       1367.95
- W#31       703.44
- W#24       666.84
- W#40       78.20
- W#27       1189.83
- W#32       0.47
- W#25       733.40

PCL
Production Performance Optimisation – Network Modelling (Gas Lift)

System type: Production
Optimisation Method: Production
Pipeline prediction: Pressure and temperature
Gas Available: 28.00 MMscf/day
Gas injected: 28.00 MMscf/day
Oil produced: 8481.35 STB/day
Gas produced: 3.57 MMscf/day
Water produced: 45987.56 STB/day
Liquid produced: 54468.90 STB/day

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<td>W#25</td>
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System type: Production
Optimisation Method: Production
Pipeline prediction: Pressure and temperature

Gas Available: 28.00 MMscf/day
Gas injected: 28.00 MMscf/day
Oil produced: 8836.45 STB/day
Gas produced: 3.67 MMscf/day
Water produced: 44688.90 STB/day
Liquid produced: 53525.36 STB/day

- Name  Oil
  - Produced
  - STB/day

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Modelling the gas lift network production system on a field-wide basis has allowed us to:

- better understand and reduce the adverse effect of back-pressure within the flowlines
- accelerate cash flow and generate direct profit estimated at US $ 3 millions for the year

The incremental net oil production due to gas lift gas allocation optimisation was estimated 500 bbls/d, approximately at 6% of the field total production.
Production Performance Optimisation – Production Allocation

• Daily production allocation can be done using nodal analysis (IPR/VLP curves) and network modelling. Production rates are allocated to individual well based on measured FTHP’s data.

• Production allocation is required for accurate production history matching or material balance to assess, and if required, to tune the reservoir simulation model for better reservoir performance monitoring, reserves estimates and future development planning, all that so crucial for smaller and often complex accumulations (marginal fields).
Production Performance Optimisation – Production Allocation

- Onshore field (Main field + satellites)
- Total production limited by MER rate
Production Performance Optimisation – Production Allocation
Production Performance Optimisation – Production Allocation
### Production Performance Optimisation – Production Allocation

#### Gap Well Model vs Procount Data

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<tr>
<th>Well</th>
<th>VBP (psig)</th>
<th>WAP (%)</th>
<th>GOR (STB/MMscf)</th>
<th>Gap pres (psig)</th>
<th>Gap PL (STB/MMscf)</th>
<th>Procount (STB/MMscf)</th>
<th>Gap (STB/MMscf)</th>
<th>Error (%)</th>
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<td>2,572</td>
<td>3,031</td>
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**Number of Wells:** 14  
**Total:** 31,440  
**Procount:** 31,002  
**Gap:** 1  
**Maximum Error Tolerance:** 2%

#### Gap Model vs Matched Parameters

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<tr>
<th>Productivity Index</th>
<th>Reservoir Pressure</th>
<th>Gap vs Procount Rates (STB/MMscf)</th>
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#### Gap vs. Procount Rates (STB/MMscf)

- **Procount**  
- **Gap**

#### Allocation Process:

1. **Enter Allocation Date:** 03/11/04  
2. **Open Gap Model**  
3. **Transfer Reservoir & Save Gap Model**  
4. **Refresh Procount Query**  
5. **Transfer Procount Only**  
6. **Close Gap Model**  
7. **Visit Production Allocation**
Production Performance Optimisation – Production Allocation

Well#1 Production History

Oil production (bbls/d)

Oil Rate (WTest)

WHP

PCL

PCL
Production Performance Optimisation – Production Allocation
Production Performance Optimisation – Production Allocation
Production Performance Optimisation – Typical Cycle Overview

Measured Data
- WHP
- WHT
- BHP
- BHT
- WC
- GOR
- Q

Central Database

Well Model ↔ Network Model ↔ Reservoir Model

Production Performance Optimisation

Production Targets

Short Term Production Forecasts

Material Balance (Production History Match)

PCL
Production Performance Optimisation – Successful Optimisation

• The production system analysis requires tools to be effective and for the production optimisation to be efficient. The key to successful performance modelling is predicting the effects of changes in order to optimise production today and tomorrow, it is a proactive and continuing process to improve effectiveness and efficiency.

**Effectiveness** being to do the right thing, that is to build a reliable model that represents the entire production system.

• Once the model is effective, predictable and reliable as a production optimisation tool, it should improve efficiency.

**Efficiency** being to do better, that is to predict the effects of changes through a systematic analysis of field performance.
Production Performance Optimisation – Integrated Modelling is Cost-effective Solution To:

- Provide effective understanding of reservoir response, wells and flowlines behaviour and the impact of their interaction on field performance

- Optimise field production performance and maximise recovery, set production targets based on potential well performance and generate short term production forecasts

- Achieve significant savings by reducing well tests frequency, if wells and network models are used as virtual flow meter and stand alone production allocation tool for well surveillance and reservoir performance monitoring

- Extend life of the reservoir and minimise potential costs of well interventions, e.g. gas lift re-completion, re-perforations and other stimulations