An Integrated Scientific Workflow Enables Successful Perforating Operations in Offshore Southeast Asia

NAPS-2018
Agenda

- Background
- Description of the Field
- Objectives

Scientific Analysis
- Flow Laboratory Testing
- Flow Modeling (Productivity / Clean-up)
- Job-Design & Modeling

Scientific Workflow to Job Execution

Conclusions
Background

- Integrated technology solutions are key to improving operational efficiency and maximizing hydrocarbon recovery
  - State-of-the-art downhole equipment
  - Laboratory Testing
  - Digital Analysis

- “Perforating Solutions engineered for optimized completions”
  - Disciplined and systematic process for job design
  - Integrated testing & modeling workflows
  - Fit-for-purpose equipment (advanced live-well deployment)
Description of the Field

- Maharaja Lela Jamalulalam (MLJ) field situated 50km offshore from Brunei’s coast and in approximately 65m of water depth.

- New wellhead platform MLJ3 was installed in 2015, approximately 6km south of the two existing platforms.

- Two types of completion in MLJ south wells: 10Kpsi wells with a 5-1/2” Liner 23# and 15Kpsi wells (HP) with a 4-1/2” Liner 18.9#.

- Tight rock gas formation (Compressive strength ~ 15,000psi, Permeability < 10mD).

- Drilling and completion campaign involving six wells.
Evaluate and optimize the perforating strategy for MLJ3 wells

**Objectives of the Study**

- Physical Connection (Charge Penetration) Testing
- Perforation Conductivity (Debris, Clean-up) Testing & Modeling
- Perforation Flow (Productivity) Testing & Modeling
- Operational Risk Vs Reward Modeling & Operational Expertise
- Job Planning & Execution

**Testing:** Flow Laboratory  
**Modeling:** CFD (Computational Fluid Dynamics), Job planning, Dynamic event  
**Operations:** Quality plan, crew competency & training, execution

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Flow Laboratory Testing

- Comprehensive testing program (API RP-19B Section 2 & 4) undertaken to provide insight into perforating strategies

- Testing
  - Analog rock (Nugget sandstone)
  - Single/dual/triple casing string
  - Deep penetrating vs Reservoir-driven charges
  - Special HT cement cured at well conditions

- Design factors
  - Shaped charge performance
  - Underbalance and clean-up
  - Influence of wellbore fluids
  - Influence of post-perforating flow time-scales

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Flow Laboratory Testing

- Transient pressures, tunnel characteristics using CT scanning, productivity and debris mechanisms were analyzed.

- Both shaped charges penetrated through all the casing, cement sheath and into the core.

- Reservoir-driven charges
  - Improved performance with reservoir-driven charges compared to standard charges.
  - Improved core penetration (>50%) and tunnel surface area (~120%)
  - Larger hole sizes (casing/core) with reservoir-driven charges

- Minimal influence of wellbore fluids on charge or flow performance.

- Ability to flow was not affected by post-perforating flow time-scales.
Flow Laboratory Testing

- Tunnel clean-up / debris
  - Tunnel debris analysis provided 14gm of debris at 8000psi underbalance compared to 27.0gm at 1200psi underbalance.
  - CT scan analysis of perforated cores demonstrates the reduction of debris as underbalance is increased.

- Why computational modeling?
  - Core heterogeneity
  - Fracture initiation around tunnels
  - Complement experimental analysis

<table>
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<tr>
<th>Test #</th>
<th>Static Underbalance (psi)</th>
<th>Weight of Debris (gms)</th>
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<tr>
<td>6</td>
<td>1200</td>
<td>27.0</td>
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<tr>
<td>5</td>
<td>4562</td>
<td>21.4</td>
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<tr>
<td>9</td>
<td>8000</td>
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Advanced Computational Modeling

- Smart-CFD approach that utilizes the true perforation tunnel geometry to better predict the flow characteristics around perforations

- Isolate the effects of core heterogeneity / fractures and understand flow characteristics around perforation tunnels only.

- Influence of static underbalance on debris mechanisms (clean-up) and productivity.
Advanced Computational Modeling (Productivity)

The casing adds significant resistance to flow, productivity ratio, PR=0.50 (casing only).

Adding the tunnel leads to slightly higher productivity compared to pre-shot productivity, PR=1.02 (tunnel).

Damage at 50%/3mm did not significantly reduce productivity, PR=0.99 (tunnel+damage).

Debris reduces productivity by a noticeable amount, PR=0.91 (tunnel+damage+debris, 50%/3mm).

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Experimental analysis showed that higher static underbalance provides reduced debris, which indicates better clean-up of the tunnel.

Unique approach where the tunnel geometry was kept constant and debris patterns from tests at different static underbalances were digitally incorporated into the tunnel.

Consistent and quantitative analysis of debris and showed the overall effect static underbalance has on productivity.

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Advanced Computational Modeling

- Modeling software to conduct force analysis and wellbore hydraulics modeling for coiled tubing deployment.

- Dynamic event modeling
  - Gun shock physics due to perforating event
  - Risk evaluation and mitigation
  - Underbalance and clean-up optimization

- Upscale from laboratory to well-scale job design
Six wells delivered safely and within timeframe and budget.
Four well interventions successfully completed with enhanced production.
Advanced live-well deployment system successfully used for deploying ~300 guns
Continuous improvement process that led to improved operational efficiency with each well.
MLJ3-05 well
- Execution of an optimized perforating strategy led to the well delivering excellent productivity (more than expected). Well is currently flowing ~40% above its planned production capacity.
- **Highest underbalance of 5,600psi** achieved due to the insight from in-depth scientific testing and modeling efforts.
- **Shortest and fastest completion** duration of 22 days.
- **Lowest NPT Completion** since beginning of the campaign, 0.7 days throughout the entire completion duration (3.4%)

MLJ3-06 well
- Reservoir-driven charges used for the entire perforation interval.
- Well currently flowing as per expectations.
Conclusions

- Comprehensive testing and modeling program provided insight into the perforating strategies for the MLJ3 well campaign.

- All MLJ south wells were successfully perforated, establishing communication between wellbore and targeted reservoir.

- The productivity on the wells was determined to be as expected or exceeded expectations (in particular, MLJ3-05).

- Significant operational benefits like reduced NPT, faster deployment of guns etc. were also accomplished through comprehensive planning and collaboration between the operator and service provider.

- Reference: OTC-28693 for more details

<table>
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<th>Parameter</th>
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<th>Job-Model</th>
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<td>Shaped charge Performance</td>
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Acknowledgements / Thank You / Questions

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QUESTIONS? THANK YOU