DEEPWATER RIGLESS MATRIX STIMULATION OFFSHORE NIGERIA

- Successful Well Lifting of Depleting Reservoir with Nitrified Diesel Displacement After The Matrix Stimulation
- Cost Savings Achieved

OWI, WEST AFRICA
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Matrix acidizing is basically the act of injecting acid at matrix pressure (below formation fracturing pressure) intended to remove or dissolve acid-removable damage or plugging in the perforations and in the formation pore network near the wellbore thus increasing the Productivity Index (P.I) of the well.

The history of acidizing dates back to 1895 when Herman Frasch the Chief Chemist of The Standard Oil Company used concentrated hydrochloric acid (HCL) to stimulate oil wells producing from carbonate formations in Lima, Ohio. Acidizing is certainly also the oldest stimulation technique still in modern use.

History has shown repeatedly that acidizing cannot be and should not be subject to cookbook procedures. Only certain steps in the design decision process may be treated as such. With acidizing, there are many more expectations to the rules than there are rules. In fact, true success in acidizing is associated with a better understanding of the exceptions.
In our own case the particular exceptions we have are:

❖ That the Reservoir is tending towards depletion
❖ Horizontal XMT design that permits direct access to the well only with a rig.
❖ Acid treatment to be executed from FPSO which is around 2000m away from the wellhead (long flow line)

Thus less energy to lift well naturally after acid treatment job. This led to displacement of the well with nitrified diesel to have lighter hydrostatic column in the well & flow line from FPSO to ensure easy natural well lift after the acid stimulation job hence this presentation to showcase the details and advantages.
The Well’s PI dropped from a peak of 13bbl/d/psi to 2.9bbl/d/psi. The drop in productivity was suspected to be near wellbore formation damage as a result of fines migration.

Sandstone matrix acid stimulation treatment was performed on the well to stimulate the near wellbore and remove formation damage from the 3 pay zones (reservoirs) Zone (22m), Zone B (5.5m); Zone C (3m). A total combine net interval of 30.5m.

The job was performed as designed with no HSE issue from the FPSO

Post treatment result indicates a successful treatment as PI increased from 2.9bbl/d/psi to 10bbl/d/psi.
SCOPE

- Perform Well’s Xmas Tree preservation by injecting methanol to mitigate the risk of hydrates formation during the stimulation treatment.

- Fill up flowline and wellbore with diesel to displace flowline content into the Well.

- Perform Well matrix sandstone acid stimulation by bullhead treatment from FPSO on all the three levels A, B & C.

- Displace acid treatment with nitrified diesel to ensure at least 500psi underbalance on well.

- Flow back Well immediately after treatment through dedicated choke manifold on FPSO to test separator.
DESIGN OVERVIEW

❖ The Well is producing from a turbiditic sandstone formation with poor productivity and depleting reservoir. Likely damage mechanism is suspected to be fines migration into near wellbore region.

❖ Formulation of Sandstone acid system to provide maximum fines and clay dissolving power while maintaining compatibility with formation mineralogy.

❖ Sandstone acidizing system comprising 4% NH4Cl Brine Preflush, 15% HCl Acid Preflush, 12% HCl – 1.5% HF acid, 15% HCl Acid Afterflush and 4% NH4Cl Brine Afterflush was recommended to treat the near wellbore damage due to suspected fines migration.

❖ Formation conditioning systems used include - NH4Cl brine preflush to prevent clay swelling through ion exchange mechanism and the 15% HCl acid preflush to remove any carbonate in the near wellbore region to mitigate the risk of precipitate formation due to reaction between carbonates and live HF acid.
The HF acid treatment stage was over-displaced into the formation by 15% HCl acid, 4% NH4Cl afterflush and diesel displacement to mitigate risk of precipitate formation in the near wellbore region due to reaction between formation minerals and spent HF acid.

Nitrified diesel displacement was recommended to create at least 500 psi underbalance and mitigate the risk of the well unable to sustain flowback due to the depleted nature of the reservoirs being treated.
❖ simulation software was used to develop a job model. The model was then calibrated using historic data from previous jobs.

❖ The calibrated model was then used to estimate anticipated placement rates and pressures during the job with maximum allowable surface pressure estimated at 1,480 psi at a liquid rate of 5 bpm and nitrogen rate of 2,346 SCF.

❖ The results of the calibrated model indicates that the treatment can be successfully placed below the maximum allowable flow line pressure of 3,300 psi and maximum allowable surface pressure based on formation fracture pressure of 3,000 psi.
Three zones Smart completion deployed on the well:
- Upper zone ‘A’ flow and controlled by Upper FCV
- Middle zone ‘B’ flow and controlled by middle FCV
- Lower zone ‘C’ flow and controlled by Lower FCV

Cased hole frac pack performed on all the three zones.

Stimulation design was done considering the three zones.

All the three zones were stimulated at once.
EQUIPMENT SPECIFICATION AND LAYOUT

50bbl Batch Mixer:
- In built Centrifugal Pump
- Boast rate of 15bpm

Panther Pump:
- 750HHP
  - Maximum pump pressure: 11,000
  - Maximum Pump Rate: 7 bpm

V-16 High Pressure Pump:
- 650hhp
  - Maximum pump pressure: 11,000
  - Maximum Pump Rate: 7 bpm

50bbl Holding compartment with paddle
- In built Centrifugal Pump
- Boast rate of 15bpm
**Data Acquisition System: DAS**
- 2 each Site pack
- Monitor job parameters real time
- Serve as a Technical Command Centre

**Nitrogen Converter:**
- Maximum pump pressure: 15,000psi
- Zone 2 rated
- Maximum Pump Rate: 180,000SCF/hr

**Stainless Steel Storage Tanks:**
- 220bbl tank; 120bbl tanks (3ea)
- 4” Suction outlet
- Guard rails on top
EQUIPMENT RIG UP

[Diagram of equipment rig up with various components and connections.]
EQUIPMENT RIG UP
Operational Overview / Execution

**Operations Sequence**

- Complete pumping equipment Rig up and testing.
- Perform Well Xmas Tree preservation by injecting methanol to mitigate the risk of hydrates formation.
- Close Horizontal Xmas Tree (HXT) valves (PMV & PWV) to Shut in Well.
- Fill up flowline and wellbore with diesel.
- Re-open HXT valves
- Displace flowline contents into Well pumping diesel.
- Perform Well matrix stimulation by bull heading acid treatment from FPSO on all the three Reservoir zones (all the 3 FCVs kept open).
  - Perform Injectivity Test
  - Perform main Acid treatment (Pre-flush, Main Acid, Post-flush)
- Displace acid treatment with nitrified diesel to ensure at least 500 psi underbalance on well.
- Flow back well immediately after treatment.
  - Soda ash injection at surface to neutralize flow back acid
Required quantity of Diesel was bullheaded into Well to flush the flowline and wellbore before injectivity test

Injectivity test performed indicated that the acid treatment can be pumped and displaced to perforations
The treatment was pumped as designed

QA/QC of mixed fluid was performed before pumping
Operational Overview / Execution – Nitrified Diesel Displacement

❖ Average nitrogen pump rate was ~ 1,300 scf/min to ensure maximum allowable surface pressure was not exceeded.
❖ Well was successfully put back on production after treatment.
❖ No indication of acid break down was observed on surface pressure due to nitrified diesel as displacement fluid.
❖ However, the downhole gauges as monitored from the FPSO Control room indicated significant acid breakdown in the 3 Reservoir zones: A, B & C treated
OPERATIONAL OVERVIEW / EXECUTION – DHPT Gauges Response
Operational Overview / Execution – Treating Pressure & Rate Summary

- Treatment was safely pumped with no injury to personnel
- No environmental spill of any of the treatment fluid on FPSO Deck or Overboard
- Primary pump failed during treatment but contingency back up pump was able to deliver job as planned
- Job was performed under stipulated timeline
  - Rig up & Tests: 2 days
  - Fill-up, Injectivity test & Treatment: 1 day
  - Rig down and load on vessel: 2 days
RESULTS AND LESSONS LEARNT

▪ Stimulation operations was successfully executed and favorable results achieved
  ❖ Successfully completed as designed without HSE issues
  ❖ Well was successfully flowed back using nitrified diesel displacement for the sandstone acid treatment.
  ❖ Well hydrocarbon production was successfully restored and sustained.
  ❖ Well Productivity Index (PI) improved from 2.9 bbl/d/psi to 10 bbl/d/psi.

▪ Lesson Learnt
  ❖ QA/QC of equipment and chemicals to be sustained on future operations to minimize possibility of failure on site
  ❖ Ensure contingency back up to critical equipment is as good as primary equipment
  ❖ Check and double check equipment before mobilization and after equipment are spotted on deck. Have critical spare readily available on site
## COST SAVINGS

### RIG OPTION

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Rig Cost Plus Equipment Rentals (USD/DAY)</th>
<th>DAYS</th>
<th>TOTAL COST (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rig Mobilization, positioning and Equipment mobilization</td>
<td>426,000.00</td>
<td>1</td>
<td>426,000.00</td>
</tr>
<tr>
<td>BOP run, LS deployment and Well re-entry (pumping equipment rig up was done offline)</td>
<td>426,000.00</td>
<td>4</td>
<td>1,704,000.00</td>
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<tr>
<td>Nitrogen equipment + CT &amp; Lifting Frame Rig up</td>
<td>426,000.00</td>
<td>1</td>
<td>426,000.00</td>
</tr>
<tr>
<td>CT run and Pumping operation</td>
<td>426,000.00</td>
<td>2</td>
<td>852,000.00</td>
</tr>
<tr>
<td>Secure well, Recover LS, Recover BOP and Risers</td>
<td>426,000.00</td>
<td>3</td>
<td>1,278,000.00</td>
</tr>
<tr>
<td>Rig Demobilization</td>
<td>426,000.00</td>
<td>1</td>
<td>426,000.00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>5,112,000.00</strong></td>
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### FPSO OPTION

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Equipment Rental Cost Plus Vesssel (NO Rig /FPSO Cost) (USD/Day)</th>
<th>DAYS</th>
<th>TOTAL COST (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Mobilization with Vessel</td>
<td>26,000.00</td>
<td>1</td>
<td>26,000.00</td>
</tr>
<tr>
<td>Pumping Services (equipment Rig up, pumping job and equipment Rig down and load on vessel)</td>
<td>26,000.00</td>
<td>5</td>
<td>130,000.00</td>
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<tr>
<td>Equipment Demobilization</td>
<td>26,000.00</td>
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<td>52,000.00</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>208,000.00</strong></td>
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</table>

❖ Cost does not include product costs (chemicals and consumable which is same for both option)
❖ **HUGE COST SAVINGS TO THE TUNE OF 4,904,000.00 USD**
THANKS