Re-designing EOR through Integration:
Fast Track Approaches

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Issues with Deployment of EOR

- **Long lead times** for pilot delivery and excessive time to full field FID
- **Inconclusive Pilot results** due to lack of data or design (cost cutting?)
- **Success case economic drivers** not properly understood (pilot objective?)
- **Lack of implementation experience** and **lack of continuity** of project team
- **Lack of integration**: facilities-subsurface-operations
- Internal service providers (drilling, facilities, production, surveillance) **slow to adapt to EOR** requirements

*AS MANY AS 80% OF PILOTS FAIL TO LEAD TO FULL IMPLEMENTATION (YET)*
Change Approaches: re-design EOR for fast track implementation

Positioning of NAM/LAM Heavy Oil Operators, 2010

Focus on Design

Time to Production

High

Low

Maximim Value Aspiration
Reducing EOR Cycle Time

- Develop a common EOR Workflow
- Reduce EOR cycle time to proof of concept and EOR FID thru:
  - One stop shop: Services and Project Management.
  - Continuity: Same team to stay with the project, maintaining knowledge and minimizing handover delays
  - Contracting: up front and not tendering at each stage
  - Integrated approach: for lab, studies, design, implementation, operation, surveillance, proof of concept, EOR FDP
  - Phasing: Lab and studies in parallel with design, not sequential
  - Design for Proof of concept: leads to full field EOR FDP in parallel with early pilot expansion
  - Comoditizing pilot equipment: standardize on modular steam boilers, chemical units, gas supply
  - Confirmation: Best in class surveillance technology to confirm benefits are achieved by **closing the production loop in the shortest time**
EOR Project Roadmap (excl Decision Delays)

Key Message:
• Feasible to have Pilots online within 18 months
• Proof of Concept for full field feasible within 36 months
• Key is to minimize tendering at each stage – one stop shop
RIDER: Rapid Integrated Deployment of Enhanced Recovery

<table>
<thead>
<tr>
<th>Step</th>
<th>Industry Average</th>
<th>Rapid Execution thru Customer and Service Co Collaboration</th>
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</thead>
<tbody>
<tr>
<td>Preliminary Screening</td>
<td>Red</td>
<td>Blue</td>
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<tr>
<td>Laboratory Testing &amp; Studies</td>
<td>Red</td>
<td></td>
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<tr>
<td>Pilot Design</td>
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<td>Pilot Tendering</td>
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<td>Pilot Construction and Installation</td>
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<tr>
<td>Pilot Operation &amp; Evaluation</td>
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<tr>
<td>Full Field EOR Development Planning</td>
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EOR Reserves Quantified

Earliest Proof of Concept
Fast Track in SPM Portfolio by Recovery Themes

- **NAM Assets**
  - Barnett/Bakken
  - Eagleford Shales

- **Panuco & Carrizo**
  - Onshore
  - Brownfield
  - Heavy oil/EOR

- **Casabe**
  - Onshore
  - Brownfield
  - Waterflood/cEOR

- **SSFD & Libertador**
  - Onshore
  - Brownfield
  - Infill/Waterflood

- **Laslau Mare**
  - Onshore Gas
  - Brownfield

- **Bokor**
  - Offshore Oilfield
  - iWAG/EOR

- **Samarang**
  - Offshore Oilfield
  - mWAG/EOR

- **SLB CoPower, Ordos Basin**
  - Tight Gas

- **140GWA**

Paper # • Paper Title • Presenter’s Name
Is the Fast Track EOR Roadmap Achievable in Practice?

- Casabe (Colombia) Polymer Pilot
- Panuco Fractured Carbonate (Mexico) Thermal Pilot
Colombia: Casabe Polymer Pilot

- Layered sand/shale sequence
  – as many as 17 zones/producers
- 50-300mD
- 30-80cP oil
- RF<30% pattern WF

Vertical and Horizontal Heterogeneity

Relative Preservation Of The Channel Sandstones Under Low And High A/S Conditions

Modifed from Ramon Y Cross, 1997
Polymer Injection for Mobility Control

- Two pilot patterns selected
  - Better ResQ and below average ResQ
  - Covers range of effectiveness
  - Two layers comprising >40% of OIP
  - Two suppliers – SNF and MI/BH


Where:
Ev = Volumetric Efficiency
Ea = Areal Efficiency
Ei = Vertical Efficiency

\[ M = \frac{k_{rd} \mu_D}{k_{rd} / \mu_d} \]

FIGURE 2. MOBILITY RATIO

Two (2) SP Flooding Pilots for mobility control and \( S_{of} \) Reduction EOR; variation in chemical make up for different K/V shale
- One in Average Rock Quality, swept.
- One in Best Rock Quality, swept
Casabe Fast Track Timeline: Parallel Activities + Focus Team

- Project Manager
- Reservoir Engineer
- G&G
- Production Technologist
- Well Construction Engineer
- Facilities Engineer
- Production Optimization
- Economic Analyst
- Supply Chain Support

**EOR Project Implementation Process**

- Screening
- Conceptual Design
- Pilot Design
- Pilot Well Construction
- Pilot Operation

- Lab Studies
- EOR Preferred Vendor Selection
- EOR Contract
- Product & Facilities Delivery

- Monitoring
- Tech. Installation
- Baseline Construction

- InterWell Tracers Contract
- Well Intervention
- InterWell Tracers
- Tracer Analysis

- Facilities Design
- Facilities Contract
- Facilities Construction

*Facilities = Contracted Equipment, Installation & Connection*
Casabe Polymer

- Polymer injection commenced in first pilot pattern on October 28 2014
- 21 Months from kick off (due to equipment delay)
- Four polymer injector wells.
- Total injection capacity is 3,000 B/D of 500 ppm polymer solution at 2,000 psi
- Short term response shows decrease in water cut across all wells and central producer has increased oil rate.
- Second pilot pattern on hold due to ECP cash constraints. However, pilot expansion to multiple layers is under design for second stage pilot.
Mexico: Panuco Thermal Pilot

- Cyclic steam stimulation (CSS) pilot
- Fractured carbonate with heavy oil >300cP
- Two horizontal I/P wells penetrating the fracture corridors
- One deviated well for monitoring microseismic events
Panuco Thermal Pilot Objectives & Risks

• Introduce thermal operations without HSE or social incidents.
• Designing the Pilot to give a conclusive proof of concept, proving:
  – Sufficient steam injectivity.
  – Sufficient incremental production associated to the thermal process.
  – Technical and economic feasibility of full-field implementation (if possible).
• Collecting sufficient data and measurements to confirm proof of concept.
• Delivering the project on time and within budget, and with a proper management of risks.
• Demonstrating SPM capability in EOR implementation for future collaborations

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>Hazard or worst consequence</th>
<th>Initial Risk</th>
<th>Control Measure</th>
<th>Residual Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seal rock integrity</td>
<td>Steam leaks or breakthrough at surface, with environmental consequences</td>
<td>High</td>
<td>Geomechanical study, injection pressure control, monitoring system (microseismic)</td>
<td>Low</td>
</tr>
<tr>
<td>Permitting</td>
<td>Delays in Project start</td>
<td>High</td>
<td>Pemex, PetroSPM support Expedite thorough support</td>
<td>Mid</td>
</tr>
<tr>
<td>Social</td>
<td>Delinquency, robbery</td>
<td>High</td>
<td>Support from External Affairs. Explain risks of project.</td>
<td>Mid</td>
</tr>
<tr>
<td></td>
<td>Manifestations and protests</td>
<td>High</td>
<td>Avoid areas close to towns, reduce use of noisy trucks, logistics for transportation, support from External Affairs to inform about the project, what is and what it is not.</td>
<td>Mid</td>
</tr>
<tr>
<td>Operational</td>
<td>Steam generation failure, procedures for measuring and handling hot fluids at Surface</td>
<td>High</td>
<td>Hired experienced contractors, apply PSIM, train operators</td>
<td>High</td>
</tr>
<tr>
<td>Water supply</td>
<td>No supply source found</td>
<td>High</td>
<td>Local providers Softeners, water treatment plant, water quality monitoring plan</td>
<td>Mid</td>
</tr>
<tr>
<td>Hot fluid production</td>
<td>H2S, difficult separation and measurement of fluids.</td>
<td>High</td>
<td>Operations plan</td>
<td>Mid</td>
</tr>
<tr>
<td>Poor cement job, poor well design</td>
<td>Casing growth with temperature, heat losses, steam leaks, well loss, casing collapse</td>
<td>Mid</td>
<td>Cement to surface, test quality and repair if necessary, proper casing and wellhead design program</td>
<td>Low</td>
</tr>
<tr>
<td>Integrity of old wells</td>
<td>Old neighboring wells affected by steam injection, steam flow to Surface with environmental consequences</td>
<td>Mid</td>
<td>Area selection. Wells shut in at bottom. Monitoring during injection.</td>
<td>Low</td>
</tr>
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</table>
Panuco Pilot

Panoramic view of the surface facilities installed in the pilot pad

Plan view of the steam generation equipment
Panuco: Surveillance Intensive

Microseismic events during the injection, soaking and hot production periods
Panuco Pilot Outcomes

Came on line some ten months after SLB took over the asset, demonstrating:

- Delivery according to the scope, in record time and within budget.
- Most risks were managed successfully.
- Proved injecting steam is feasible without social or HSE incidents.
- Sufficient measurements were collected to confirm concept applicability.
- Injecting steam at 1,600 psi gave no compromise cap rock integrity over the pilot area. Geomechanics vital to minimize the risk of failure of the layer.
- Steam injectivity was low, yet cumulative injection achieved expected volume.

- **Productivity increased three to five times after steam stimulation.**
- A mechanical restriction near the top of one well did not allow installation of the artificial lift and production of stimulated intervals (620-630 m, 700-710 m).
- Two nearby wells were influenced by steam injection: Pemex_1127 in which the fluid production rate increased by 50%, and Cacalilao_1192, in which the water cut was increased to 100% and after injection stopped, the water cut fell back to 5%.
Integration has confirmed Fast Track EOR

- Successful Implementation by Casabe and Panuco Pilot Teams
  - Fast Track EOR is not only feasible but achievable
    - With the right integration of Operator and Service Provider(s):
      - 18 months to pilot online
      - 36 months to proof of concept

- Critical success factors are:
  - Standard equipment – Boilers/Wtu; Polymer Skids; N2 Gas/Compressors
  - One Stop Shop to minimized tender, decision and handovers delays
  - Design, Operation & Surveillance must still be best in class and focus on earliest proof of concept
  - Close the production loop: Tie lab work to simulation to surveillance to predictions

- Over-riding Objective:
  
  Prove full field follow up is economically viable in shortest time
Thank You