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Open Hole Gravel Packing: New Trends and What We are Doing to Overcome the Challenges

Agostinho Calderon
Petrobras
Outline

- Main unconsolidated sandstone reservoirs in Brazil
- Review of the current Horizontal Open Hole Gravel Pack Technology – evaluation
- New trends and challenges in Open Hole Gravel Pack
- Conclusions
Main unconsolidated sandstone reservoirs in Brazil – Campos Basin

ALBACORA LESTE (1986)
ALBACORA (1984)
MARLIM (1985)
MARLIM LESTE (1987)
MARLIM SUL (1987)
RONCADOR (1996)
BARRACUDA (1989)
CARATINGA (1989)
ESPADARTE (1994)
1-RJS-539 – 1999
Main unconsolidated sandstone reservoirs in Brazil – Espirito Santo Basin

JUBARTE (2000)
CACHALOTE (2001)
GOLFINHO (2003)
PEROÁ/CANGOÁ (1996)
Review of the current Open Hole Gravel Pack (OHGP) technology

- Offshore reservoirs:
  - Unconsolidated Sandstones
  - $\uparrow \, \uparrow \, \uparrow$
  - $\Theta \, \uparrow \, K$

- OHGP $\rightarrow$ Good solution for sand control

- Horizontal Wells:
  - High Productivities
Review OHGP

285 wells - No sand control failure (sand production)
Total Screen length – Open Hole Gravel Pack

186 Km
OHGP – Evaluation (141 wells – 50%)

Average completion efficiency: 86 %

C.E. (Completion Efficiency) = 1/DR x 100

\[ DR = \frac{P_e - P_{wf}}{P_e - P_{wf} - \Delta P_{skin}} \]
Review of the current Open Hole Gravel Pack

Alpha and Beta Wave Technology – Water Pack

Cross section well with Open Hole Gravel Pack
Review of the current Open Hole Gravel Pack

The method “Alpha and Beta Wave Technology” – Water Pack
Alpha and Beta Wave Technology – Water Pack
(High Leakoff or Formation Fracture – Result Incomplete Pack)
Deep Water Challenges for OHGP Operations

**Deep and ultra deepwaters**

- **Short sediment layers**

  - **Rocks w/ low fracture resistance**

  - **Narrow operational window for OHGP operations**

**High productivity**

- **Long horizontal sections**

  - **High friction losses during GP op.**
Hydraulic Limits Definition

Upper Limit: High pump rates $\rightarrow$ pay zone fracture $\rightarrow$ premature screen out

Minimum pump rates $\rightarrow$ premature screen out in the rat hole
Simulator - Variable flow rate design

Alpha Wave

Beta Wave

Max pump rate

Min pump rate
Hydraulic limits extension - OHGP

Narrow operational window

Some strategies to overcome the limits

- Open BOP configuration
- Reducing the fluid weight
- Use of lightweight proppants
- Zero rat hole configuration
- Flow divergence valves
- Large diameter well
- Friction reducer
Hydraulic limits extension - OHGP

- Closed BOP configuration

BOP – Blow Out Preventer

Flowmeter (Choke Manifold)

Rig Tank

Completion Fluid

Work string (Water Pack)

Packer

Blank pipe

Screen
Hydraulic limits extension - OHGP

- Open BOP configuration

Diagram showing flow paths:
- Flowmeter (Flowline)
- Rig Tank
- Completion Fluid
- Work string (Water Pack)
- BOP
- Packer
- Blank pipe
- Screen
Hydraulic limits extension - OHGP

- Open BOP configuration – Flowmeter in the Flowline
Hydraulic limits extension - OHGP

➢ Open BOP configuration

![Graph showing hydraulic data with legend: BOP closed, BOP opened, and min. flow rate at Rat Hole.](chart)

- $Q$, bpn
- $t$, min.

0 50 100 150 200 250
Hydraulic limits extension - OHGP

- Reducing the fluid weight (Gravel pack carrier fluid)

Graph showing the relationship between fluid density and flow rate over time, with different densities and flow rates represented.
Use of lightweight proppants

- Sand (specific gravity=2.6)
- Lightweight proppant (spec. Gravity=1.25)
- Min. flow rate at Rat Hole (sand)
- Min. Flow rate at Rat Hole (LW)
Hydraulic limits extension - OHGP

- Zero Rat Hole Configuration

Zero Rat Hole: Liner

13 3/8"

WD = 1.554m

Well 12 ¾"

LINER 9 5/8” or 10 ¾” Flush
Hydraulic limits extension - OHGP

- Zero rat hole configuration

![Graph showing hydraulic limits with zero rat hole configuration](image_url)

- **Q (Q, bpm)**
- **t (t, min.)**

- **Line with dots** indicating zero rat hole configuration.
- **Blue line** indicating rat hole configuration.

Graph legend:
- **Blue line** for rat hole.
- **Red line** for Zero rat hole.
Hydraulic limits extension - OHGP

- Flow Divergence Valves
Hydraulic limits extension - OHGP

- Flow divergence valves

![Graph showing pressure vs. elapsed time with markers for Formation Fracture Pressure, Bottomhole Pressure, and Surface Pressure.](image-url)
Hydraulic limits extension - OHGP

- Large diameter well

![Graph showing flow rate over time for different bore sizes](image)

- Normal Bore (8.5 in)
- Large Bore (9.8 in)
- Min. flow rate at Rat Hole
Hydraulic limits extension - OHGP

- Case Study using 3 Strategies: Open BOP configuration / Duo density Proppants / Reducing the fluid weight (Gravel pack carrier fluid)

Well data (Golfinho Field):

- Horizontal Extension: 1150m
- Water Depth: 1581m
- Fluid weight: 9.6 ppg
- Gravel Pack Carrier fluid: 9.1 ppg
- Frac Gradient: 0.56 psi/ft
- Rat Hole: 14.75”
Hydraulic limits extension - OHGP

- Output of Simulator

Graph showing:
- Ceramic $d = 2.7$
- Lightweight Proppant $d = 1.75$
Hydraulic limits extension - OHGP

- Output of Simulator
Hydraulic limits extension - OHGP

- **Golfinho Field**: Open BOP configuration / Duo density Proppants / Reducing the fluid weight (Gravel pack carrier fluid)

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![Graph showing hydraulic limits extension](image-url)
Hydraulic limits extension - OHGP

Test with friction reducer

**HOHGP 10/03/09**

- Proppant Pumped: 109,653 lbm
- Proppant Placed: 102,165 lbm

- Screen out at 1514 psi
- Alfa Wave
- Beta Wave
- Canai + FRW-14 1gpt + Proppant
- Canai + FRW-14 1gpt + Proppant (Top of Pack) + Proppant (Bottom of Wash Pipe)
- Carboite 20:40

**Graph:**
- Pressure (psi)
- Rate (bpm)
- Return Rate (bpm)
- Proppant Conc. (psa)

**X-axis:** Elapsed Time (min)

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Filter Cake Removal - The Producer Well

Screens  Gravel  F. C.  Formation
The Injector’s Problem

- No mechanical filter cake removal mechanism
- Injection impairment
- Costs: clean up (flow back) vs acidizing
- Poor results without treatments
- Always treated → Mud acid → Drill solids
Dedicated Acidizing Tool

- Tool schematic

Zone 1 Isolated
Position to Treat Zone 2

Polished Seal Bore & Inverted Couplings
Isolate Zones for Individual Treatment
New Trends and Challenges in OHGP

Non-aqueous fluid for OHGP - alfa and beta wave mode

In 2007

- Drilled horizontal section with SBM and OHGP with non-aqueous fluid (alpha and beta wave mode)
New trends and challenges in OHGP

Non aqueous fluid for OHGP – Newtonian behavior

- Focus
  - Make the formulation of inverted solids-free emulsion with carrier fluid for horizontal gravel pack operations feasible
  - Evaluate if the alpha and beta waves occur
  - Keep the use of regular premium screens without any kind of extra paths
Physical testing simulation - results

- After fluid development: Physical simulation (flow loop): 3 kind of proppants (sand, ceramic and bauxite) and new gravel pack carrier fluid
- Alpha and Beta wave was detected with all proppants
- Excellent packing

SPE 102295
1st STEP – Field application – Marlim
SPE 110440

Well Design

Basic Data:

- Water depth: 665m
- Horizontal Section: 380m
- 8 ½” Well ; 5 ½” 250 µ screen
- Proppant: 16/20 mesh (Ceramic)
- Frac gradient = 0.60 psi/ft
Field application – OHGP design

OHGP – Operational window

- Maximum Flow rate - Fracture
- Minimum Flow rate – Rat Hole

Flow rate, bpm vs Time, min

- Alpha: 16 bpm
- Beta: 6 bpm
- 4 bpm
Gravel pack execution – Marlim field

- Bottom above the packer P1 (psi)
- Bottom below the packer P2 (psi)
- Bottom ext P3 (psi)
- Surface pressure (psi)

Flow rate (BPM)

Surface conc (lb/gal)
Gravel pack execution – Marlim field

Relevant observations – Marlim field application

- Low contamination of GP carrier fluid with DIF
- Effective mud cake DIF x GP carrier fluid – no losses
- The measured and the simulated pressures were found similar
- Excellent ceramic packing (> 100%)
- Proper filter cake clean up with production flow
Results - Marlim field application

✓ PI = 70.7 m³/day / kgf/cm²

✓ DR = 1 (zero skin)

✓ Contribution from the whole horizontal extension (Production Log Tool)
Next Step → Infill drilling project (2010)

- Old Well
- Side-Track
New trends and challenges in OHGP

Manati Field – Northeast of Brazil

Block - BCAM 40
Water depth < 50m
9 Km from the coast
Environmental sensitive area (zero discharge)
Manati field – northeast of Brazil

Discovered - oct/2000, well 1-BAS-128

Gas Reservoir – Low vertical depth (1400m)

Thick reservoir - (100m to 350m)

High permeabilities (200 mD – 500 mD) and high porosities (21%)

High Productivity Index

High fluid density (up to 12.5 ppg)
Manati field – Initial well project (no sand control)

Completion; no sand control (7” liner)

- Água Grande Form.
- 9 5/8” casing
- 7” casing
- 8 ½” OH
- 300 m

Sergi Fm
Initial well project (no sand control)

Main restrictions observed during well completions:

- Liner top isolation (dry-test) – 52 hours / well
- 300m perforation (high costs)
- During well completions, new requirements (50% increase in flow rates)
- R&D Center (CENPES) → Sand production risks → Sand control requirement
Sand control options for Manati field

Main limitations for cased hole sand control (Fracpack) – Manati field:

- Liner top isolation (rig time and leak risks)
- Long perforation intervals
- Smaller screen diameter - 3 ½”
- Injection of high fluid volumes - calibration tests and fracpack (minimum 10000 bbl estimated)
- Longer rig time to flow back the well and environmental restrictions (zero discharge).
- High water volumes injection in gas reservoirs are not recommended
- Fracpack require stimulation boat: high power, pressures, gel and higher costs
Sand control with OHGP for Manati field:

- No liner, cement operations, logs for cement evaluation, dry-test.
- No guns and rig time
- No fluid injection and related problems with flow back, separation, environmental restrictions. The evaluation is fast;
- OHGP with low pump rate and pressure, low power, no gel, lower costs and risks.
- One operation for OHGP and up to 5 fracpack operations, for 300m thickness
- OHGP requires 5 ½” screen (8 1/2” OH) and fracpack 3 ½” screen (7” CSG).
Options for sand control – Manati field

Fracpack

OHGP Selected

5 Fracpacks

1 OHGP

50 m

300 m

Options for sand control – Manati field

Fracpack

OHGP Selected

5 Fracpacks

1 OHGP

50 m

300 m
Main challenges for OHGP in Manati field

- Higher pore pressure than the conventional OHGP;

- Drill in fluid requirements:

  - Completion fluid → Same weight D.I.F and compatible;

  - Usual D.I.F. (NaCl base) → More than 10 ppg (CaCl2) is usual, but is incompatible with polymers

  - Drill in Fluid (sodium formate) and completion fluid (sodium formate and potassium formate)

Good results (All requirements): Mud cake thickness (< 1mm), Break out pressure (< 10 psi), K return (90 %)
These 2 wells were drilled with water base D.I.F (Sodium Formate base)

The D.I.F. was displaced by filtered completion Fluid (Sodium Formate and Potassium Formate).

The premium screens was RIH and the OHGP performed
OHGP execution – Manati field (2 Wells)

OHGP Chart - Well 5 (100% packed)

- Treating pressure
- Slurry rate
- Propant concentration
- Return rate

Press (psi) vs. Time (min)
Well tests evaluation Manati field:

<table>
<thead>
<tr>
<th>Wells</th>
<th>Sand Control (Y/N)</th>
<th>Net Pay (m)</th>
<th>AOF (million m3/day)</th>
<th>K (mD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well-03</td>
<td>N</td>
<td>191</td>
<td>12.6</td>
<td>305</td>
</tr>
<tr>
<td>Well-04</td>
<td>N</td>
<td>194</td>
<td>11.5</td>
<td>295</td>
</tr>
<tr>
<td>Well-05</td>
<td>Y</td>
<td>243</td>
<td>15.8</td>
<td>220</td>
</tr>
<tr>
<td>Well-06</td>
<td>Y</td>
<td>142</td>
<td>19.7</td>
<td>482</td>
</tr>
</tbody>
</table>

The best productivity result in Manati field is OHGP (compared with wells without Sand Control)
Conclusions

- OHGP: Productivity and reliability;

- The oil base system as a gravel pack carrier fluid: sensitive reservoirs and mature fields;

- For higher pore pressure reservoirs → formates;

- OHGP is a good option for high permeability reservoirs (gas or oil): simplicity, productivity and economic advantages
Thank you!
Questions?
Your Feedback is Important

Enter your section in the DL Evaluation Contest by completing the evaluation form for this presentation or go online at:

http://www.spe.org/events/dl/dl_evaluation_contest.php
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