Case Study:
Tripling Well Productivity by applying new perforating job design & Combined perforation technologies

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Outlines

- Objective
- Introduction
- Perforation Selection
- DUB Perforation Theory
- Rock Model Charges
- Results
Objective

New Perforation Technology

- Maximize Production
- Minimize Cost
- Short Term Solutions
Gulf of Suez Petroleum Company - GUPCO - (EGPC & BP Joint Venture) is one of The Largest Oil Producers in Gulf of Suez Basin (EGYPT) Since 1960s.

The main activity of the company is the production of crude oil and gas from offshore wells and to maintain the continuity of the production by a set of processes and activities in a row.

The average daily production for the Gulf of Suez area of 80,000 barrels of oil from a total of about 400 wells in Gulf of Suez area
Background

- The well was completed in Kareem formation to the west of a depleted well
- Calculated net pay found is 30 ft
- Only 17’ was perforated to avoid initial gas production
- Estimated initial production was 2000 BOPD
Perforation

Rock Model Charges

DUB Technique

Results
Perforation Selection
**Productivity Ratio (PR)** - is defined as the ratio of the expected production rate of the "perforated well" to the "ideal" openhole flow rate. The "ideal" well is assumed to have no damage and to be fully open to flow. For a vertical or deviated well, the performance is measured against an openhole vertical well. For a horizontal well, the performance is measured against an openhole horizontal well. Turbulent, non-Darcy, flow effects are not included in the Productivity Ratio calculation.

\[
PR = \frac{q_{\text{perforated}}}{q_{\text{openhole}}} = \frac{\text{Perforated Well Flow}}{\text{Undamaged Open Hole Flow}}
\]
Perforation

Rock Model Charges

DUB Technique

Results
DUB perforation technique

Pore fluid: GAS (Dry N2)

Static UB

DUB

Pore fluid: LIQUID (brine)

Static UB

DUB

Diagram showing the effects of different pore fluids on the DUB perforation technique.
Perforation & DUB Timescale

1: Gun positioned on depth

- Shape Charge Detonation
- Gun Pressure: \( P_g \)
- \( P_w > P_g \)

Perforation Tunnel
- & Reservoir Pressure: \( P_r \)

DUB Condition: YES
- \( P_r > P_w > P_g \)

Pressure

Wellbore pressure: \( P_w \)

Cement

Virgin Reservoir:
- \( P_r, K \)

Formation damage

Comments:
- \( P_w \) is below \( P_r \) and corresponds to a desired initial underbalance pressure
- \( P_g \) below \( P_w \) since \( P_g \) is at atmospheric pressure
Perforation & DUB Timescale

2 : Fire guns

<table>
<thead>
<tr>
<th>Shape Charge Detonation</th>
<th>Perforation Tunnel &amp; Reservoir Pressure: ( P_r )</th>
<th>DUB Condition: NO ( P_r &gt; P_w &lt; P_g )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gun Pressure: ( P_g )</td>
<td>Pr &gt; Pw &lt; Pg</td>
<td>Wellbore pressure: ( P_w )</td>
</tr>
<tr>
<td>Pw &lt; Pg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments:
* Gun Pressure \( P_g \) is building up inside the Gun because of gas pressure generated by explosive (detonation, shaped charge) combustion.
* Gun starts to swell.
Perforation & DUB Timescale

3: Gun pressure released

**Shape Charge Detonation**
- Gun Pressure: $P_g$
- $P_w < P_g$

**Perforation Tunnel & Reservoir Pressure**
- Reservoir Pressure: $P_r$

**DUB Condition:** NO
- $P_r < P_w < P_g$

Comments:
- High gas pressure generated by explosives exits from gun and gas expends creating a large spike in pressure in the wellbore.
4: Creation of perforation tunnel

**Shape Charge Detonation**
- Gun Pressure: \( P_g \)
- \( P_w < P_g \)

**Perforation Tunnel**
- Reservoir Pressure: \( P_r \)

**Comments**:
- High impact jet on reservoir pulverizes formation rock grains causing a change in the matrix rock that results in a low-permeability crushed zone immediately surrounding the perforation tunnels and creating potential for migration of fine particles.
- The process also leaves some residual charge debris inside the perforations.
- Gas fully expanded in wellbore.
### Perforation & DUB Timescale

#### 5: Wellbore fluid rushes in gun

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<tr>
<th>Shape Charge Detonation</th>
<th>Perforation Tunnel &amp; Reservoir Pressure: ( \text{Pr} )</th>
<th>DUB Condition: NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gun Pressure: ( \text{Pg} )</td>
<td>( \text{Pw} &gt; \text{Pg} )</td>
<td>( \text{Pr} &lt; \text{Pw} &gt; \text{Pg} )</td>
</tr>
</tbody>
</table>

**Diagram:**
- **Virgin Reservoir:** \( \text{Pr} \)
- **Loose sand**
- **Reduced Permeability Crushed Zone:** \( \text{Kc} \)
- **Damaged Zone:** \( \text{Kd} \)
Perforation & DUB Timescale

6: Dynamic UB occurs

Shape Charge Detonation
Gun Pressure: $P_g$
$P_w > P_g$

Virgin Reservoir:
$Pr, K$

Perforation Tunnel

DUB Condition: YES
$Pr > P_w > P_g$

Comments:
- Tensile failure is caused by exposure to the high differential pressure between reservoir and wellbore. When the peak strength of the flow exceeds the strength of the rock damaged by perforating, tensile failure will cause the weakened rock to be removed.
7: Transport of failed material

- **Shape Charge Detonation**
  - Gun Pressure: \( P_g \)
  - \( P_w = P_g \)

- **Perforation Tunnel & Reservoir Pressure**: \( P_r \)

- **DUB Condition**: YES
  - \( P_r > P_w \)

**Comments**:
- Fines and perforation debris are removed from the perforation tunnel by the subsequent flow into the wellbore caused by the dynamic underbalance.
Perforation & DUB Timescale

8 : Reservoir response

Shape Charge Detonation
Gun Pressure : \( P_g \)
\( P_w = P_g \)

Perforation Tunnel
&
Reservoir Pressure : \( P_r \)

Comments :
- After perforating and DUB events, perforation tunnels are free of damages.
- Reservoir is flowing with increased permeability around perforation tunnel and thus enhanced well productivity.
DUB environment

DUB pressure environment as predicted by the model during job design (Run # 9)

DUB pressure environment as measured using fast pressure gauge (Run # 9)
Rock Model Shaped Charges

Changing the standards by building the perforating models on actual rock lab tests instead of normal concrete block
Several lab tests showed:
• 27% increase in stressed-sandstone penetration
• 33% increase in stressed-limestone penetration
• 50% more formation contact for more effective stimulation treatments and increased drainage contact for greater productivity
Job Results

Estimated

Actual
Thank You