DYNAMIC UNDERBALANCE PERFORATIONS BRING HIGHER PRODUCTIVITIES THAN CONVENTIONAL PERFORATIONS

A large scale comparative review from the Tunu Gas Field (Indonesia)

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What is the TUNU field (Indonesia, PSC Mahakam)?

- Tubingless completions
- Perforations are added by light intervention barges (electric lines)
- Annually: more than 2500 ms of perforations, 600 intervals

- Large activities and workload continue to increase as field become mature
- Sufficient data for developing comprehensive perforation analysis

Multilayer thin sandstone Reservoirs
Gas + condensate
Deltaic channels and mouth bars
10-20% Porosity
1-500md Permeability
WHAT IS “DYNAMIC UNDERBALANCE” (DUB)?

Dynamic Underbalance (DUB) Technology

- Generate a **large dynamic under balance** from **modest static under balanced or over balanced pressure**.

- DUB system needs set of charges and additional **void space inside the gun** (blank section, implosive chamber).
- DUB system required **liquid** (water / oil / mud) around the gun when shot.
- Fast gauge is run in tandem with the gun to measure actual dynamic underbalance (optional, record up to 100,000 samples/second)

Unload using coiled tubing

Result: pressure drop within perforation intervals by 1500 to 2500 psi during **a few milliseconds**

Objective: optimized clean up of the perforation cavity
DOES IT WORK?

Legend in this presentation:
Conventional perforations, without DUB
Perforations with Dynamic UnderBalance

Data from TUNU gas field (2005-2011), operated by TOTAL EP INDONESIE

Perforation results, by classes of gain
(mmscfd per job)

Perforation initial production rates 2005-2011
(one reservoir only per job)

Productivity by meter of perforation
(mmscfd / m)

Reservoir productivity
Virgin pressure reservoirs only

Perforation Gain per Meter of Net Pay
(mmscfd/m)
ARE WE SURE THERE IS NO BIAS?

There are always some classical bias

- Choice/selection of best reservoirs for application of DUB? “Quality bias”?
- ~30 DUB perforations only: “luck” effect?

**Example of petrophysical indicator: Porosity**

It is a fact that reservoirs perforated with DUB in Tunu tend to have better petrophysical properties on average.

The question becomes: “once we remove quality bias and adjust for the sample size, will DUB still make a difference?”
FIRST METHOD: A POLL (13 INNOCENT PAIRS OF EYES)!

1 question: “for each reservoir, which perf. gain (in mmscfd) do you expect?”

<table>
<thead>
<tr>
<th>Gain</th>
<th>&lt;2</th>
<th>2-5</th>
<th>5-10</th>
<th>10-15</th>
<th>15-20</th>
<th>&gt;20</th>
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<tbody>
<tr>
<td>Mark</td>
<td>1</td>
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<table>
<thead>
<tr>
<th>Participants’ guess (average)</th>
<th>Real result</th>
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<tbody>
<tr>
<td>Conv. perfos</td>
<td>2,0 / 6</td>
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<tr>
<td>Dynamic UB</td>
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Experts of their field
In “blind” test, DUB Good Results not predicted

A reservoir quality bias is perceived
SECOND METHOD: USING EPIDEMIOLOGICAL METHODS

Epidemiological methods = classically used to test new drugs or health issues

1. Which steps?
   • Validation of data quality is essential
   • Perforations without a clear outcome are not considered
     → No perforation job with multi reservoirs
     → Reservoirs diagnosed with technical problems or water problems are excluded
     → Need to have reliable pressure data (cf infill wells)
   • The statistical influence of each parameter on differences between results using the same perforation technique must be understood before any comparison
     – Degree of dependence between parameters
     – Influence of porosity, res. pressure, etc…
     – gun size, static underbalance, brand, etc…

   (cf. SPE paper 158083 for extensive details)
SECOND METHOD: USING EPIDEMIOLOGICAL METHODS

Epidemiological methods = classically used to test new drugs or health issues

• The challenge: Build “comparable samples”, free of size and quality bias
• More than 200 eligible conventional perforations
• 29 flowing DUB perforations

• Two possible approaches:
  • Our original approach →
    – Our group of 29 DUB perfo is the reference sample
    – Let’s downscale the 200 conv. perforations into random draws of 29 representatives, respecting same res. characteristics as DUB samples

To get an apple to apple comparison, let’s try a comparison between
“Basket filled with 29 apples” and “baskets with 29 apples”!
RANDOM GENERATION OF 150 COMBINATIONS OF 27-30 CONV.PERFOS, WITH SAME RESERVOIR PROPERTIES AS DUB SAMPLE

Percentiles of sub-samples distribution

Sub-samples randomly created, but “matching” DUB sample distributions of porosity, pressure, mobility, and thickness
RESULT: AN EXPLICIT INSIGHT IN THE PERFORATION RESULTS

Distribution of Results (in mmscfd/m) of the 150 randomly created sub-samples of conventional perforations

At 90% confidence level: Dynamic UB does bring better productivity results than conv. perfos

Explicit evaluation of benefit = +10 to +25% initial productivity (3.7-4.3 vs 3.4)
CONCLUSIONS

In Tunu gas sandstones, Dynamic UnderBalance makes a difference

→ +10 to +25% initial productivity per meter of perforation

→ after removing all possible statistical bias (reservoir quality & sample sizes)

10 additional jobs performed post-study reinforce the quantitative results
They still give 4.0mscf/d, with similar quality

Applicability?

- In gas wells, DUB is limited to wells with a liquid column (provider)
- Unlikely adapted for tightest reservoirs (operator’s observation)

• Why not having worked with evaluations of “skin”? 
  - Too little data to be analysed (see paper)
  - Skin data validity and quality are a major variable, with little control, as associated to well testing procedures

• Independent analysis, and more in SPE158083
Acknowledgements
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INPEX

BPMigas - MIGAS

Thank You / Questions
DYNAMIC UNDERBALANCE SUCCESS

Reservoir Data
- Porosity: 12.95%
- Pore Pressure: 5211 psi
- Mobility: 31.6
- Interval 3620.5-3623.5m (3m reservoir P131)

Technique
- Design gun to get optimum dynamic underbalance
- Design 100psi static UB and estimate the reservoir pressure is enough to lift up the fluid column
- Clean up the well right after perforation, CT ready to start up in case well unable to flow
- RIH fast gauge tandem with gun to measure the dynamic underbalance

Result
- Real DUB at bottom gauge: 1620 psi (fast gauge data)
- Well flow 15.9 MMscfd without unloading job