9. Frac Candidate Selection

Tight Gas 19<sup>th</sup> Sept 06
Sami Haidar
Fracture Technologies Ltd.
Hydraulic fracturing was implemented in the USA as early as the 1940’s without sand – hence production enhancement was limited.

In the late 50’s and 60’s proppant was introduced (natural sand).

In the sixties the technique became well established for production enhancement of tight reservoirs. Analytical techniques (Cinco-Ley et al) were developed to estimate negative skin.

In the 80’s Mini Frac analysis (Nolte et al) was developed, which made fracturing into a science rather than an art.

In the mid 80’s tip screen out was developed (by Paul Martins in BP) which was valuable in medium-high permeability reservoirs.

In 2000 reservoir and fracture numerical modeling (Stimplan a and WellWhiz) were introduced for fracture production optimisation and design.

Currently 80% of the production from the USA is from hydraulically fractured wells.
Fracturing History in USA

Figure 1: Fracturing’s Importance Has Increased for Gas Wells

Number of Wells Treated (1000) vs. % Frac Treated

- Oil
- Gas

Year: 1945 to 1993

Graph shows the increase in the number of wells treated and the percentage offrac treatment over time for oil and gas wells.
North Sea Fracturing

- Under utilized. Historically we tend to develop the better reservoir and leave behind marginal ones.
- Costly to apply, and hence carries a high risk.
- Proppant flow back was a threat in the past in some Companies still believe that is a deterrent.
- Current oil prices suggest lots of opportunity to develop marginal reservoirs.
- Better tools, products and experience has evolved in the last 10 years that does improve results.
Fracturing and Stresses

Fracturing Technologies

S_v
S_t
S_r
Vertical stress
Max horiz. stress
Min. horiz. stress
Fracture Dimensions
Simplistic View

P3D Fracture
Laminated pay zone with sand-shale sequences. The sand laminae may be connected to the wellbore by short, wide fractures.
Analytical Methods
PI increase in Vertical Wells

North Sea Range!
Frac Design ‘Old’
In ‘Frac Models’ we Trust!
Or Do We?! (Same input/same software Two answers)

Analytical Solution

Numerical Solution
New Ways

- New tools are now available for better design
  - In depth Fracture design – field data collection
  - Numerical Reservoir Simulation
  - Sensitivities and field calibration of models
  - Etc……..
# Candidate Selection-A Field Example

## Mechanical Screening

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<tr>
<th>Well</th>
<th>Well Type</th>
<th>Indication</th>
<th>Azimuth</th>
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Basis of Selection

- GIIP in model obtained from P/Z
- KH obtained from PBU (a challenge in tight gas where the well might not flow)
- Layer permeability obtained from PLT
- Model is initially history matched with prod data
- Well trajectory and CBL, etc..
- Frac modeling includes multi-phase flow (condensate banking) and non Darcy effects numerical techniques used
- Fracture placement
Inputs to Numerical Reservoir Simulator (WellWhiz)

**Fracture Geometry**
- Multiple fractures
- Width/Height/Length
- Conductivity, non-Darcy $\beta$

**Reservoir Parameters**
- Perm, $\Phi$
- Multiple Rel perm regions
- Multiple shale/sand units
- Condensate drop-out

**Sensitivities**
- Tunnel Permeability
- non-Darcy $\beta$
- # of Effective
- Frac Fluid
- Annular Pack “D”
- Early Screen-out
- Flow thru’ frac/ non-frac perfs
- Zonal contribution

**Perforation**
- Diameter
- Tunnel Permeability
- non-Darcy $\beta$
- # of Effective

**Wellbore Hydraulics**
- Prosper generated VLP

**Screen Effects**
- Screen selection
- Annular pack perm
- “D” non-Darcy coefficient
Inputs to Frac Simulator (WellWhiz)

Wellbore Hydraulics
- Prosper generated VLP

Perforation
- Diameter
- Tunnel Permeability
- non-Darcy $\beta$
- # of Effective

Screen Effects
- Screen selection
- Annular pack perm
- “D” non-Darcy coefficient

Fracture
- Multiple fractures
- Width/Height/Length
- Conductivity, non-Darcy $\beta$

Reservoir WellWhiz
- Perm, $\Phi$
- Multiple Rel perm regions
- Multiple shale/sand units
- Condensate drop-out

StimPlan
- Tunnel Permeability
- non-Darcy $\beta$
- # of Effective

Lab Work
- Fracture
- WellWhiz

Tests
- Screen Effects
- Perforation

StimPlan
- Wellbore Hydraulics
Rate A (24.50 MMscf/D) flow profile and differential.

Flowrate mmscf
P/Z Plot
PBU- June 1999
Log Log (kh=740 mD-ft)
Horner Plot (kh=720 mD·ft, S=9)
WellWhiz Reservoir Modeling
GIIP=62 BCF from P/Z
# Layers Model
Calibrated to PLT and PBU (sort of)

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**Total KH m(mD-ft): 1,239.90**
Gas-Condensate Rel Perm
(all models)
Frac Performance

To Frac or Not to Frac

4.5 BCF Prize

Gas Rate - Do Nothing
Gas Rate - Frac March 05
Cum Prod- Do Nothing
Cum Prod-Frac March 05
Extra Reserves with fracturing!

- IPR Un fractured well
- IPR for a fractured well
- Tubing lift curve

BHFP

Rate (MMscf/d)
# Summary of Data

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<th>Well</th>
<th>Pre Frac Gas Rate</th>
<th>SIBHP</th>
<th>Cum Prod</th>
<th>P/Z GIIP</th>
<th>Transient pressure testing</th>
<th>Post Frac Rate</th>
<th>Frac Incremental GIIP</th>
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Conclusions

- Hydraulic fracturing like any other technology will work when selecting the right well and conducting the correct design.

- Statistics from the last 15 wells (over the last few years) indicate a success ratio of over 95%.

- Fracturing should be considered an a completion strategy (during field development studies), and not an after thought when production does not meet expectations.

- Finally, for success consider expertise, up to date tools and good data when selecting a well for fracturing, and of course post frac evaluation.
One Slide on Post Frac Evaluation

- Post frac net pressure match using frac models to assess fracture geometry and proppant concentration
- Post frac PBU tests to detect Bi-Liner flow period
- Post frac production history match
- Learn and re design next job