Gas Well Deliquification Workshop
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Update on NAM’s Experience and Strategy for Gas Well Deliquification

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NAM Background

• JV between Shell/Exxon
• Onshore & offshore production, mostly gas, some oil
• 3 Assets: Offshore, Groningen & Land
Tail-end production management

Aspiration

- Traditional production enhancement activities, e.g. re-perf, stimulations
- Improved diagnostics for detecting or predicting onset of liquid loading
- Non-traditional production enhancement activities, e.g. foam lifting, velocity/insert string, mobile wellhead compression, etc.

Optimise

Typical gas well production profile

Onset of liquid loading

Intermittent production

- LL affects ~155 E6scf/d in NAM on- and offshore
- Deliquification gains since 2003: 16 BCF (8.6 in 2007)
Our strategy & challenges ...

- **Do not re-invent the wheel**
  - Adapt existing deliquification technology to European operating conditions & HSE regulations

- **Technical**
  - Expand technology to wells with 2-barrier policy (use of SCSSV)

- **Regulatory**
  - Build safety case for 1-barrier policy in low pressure/capacity gas wells

- **Environmental**
  - Certification of chemicals, de-oiling and disposal of produced water offshore

- **Costs**
  - Development of (critical mass) European infrastructure to support deliquification technology
  - Share experiences to fast-track implementation and market development

- **“Sweating the asset” mentality**
  - Demands different approach than greenfield development
Combating Liquid Loading in NAM

• Velocity strings (last 10 years)
  – Producing 7 MMCF/d from 7 wells, 2 new installations planned for Q1 2008

• Batch foaming (last 4 years)
  – Producing 12 MMCF/d from ~15 wells – move offshore

• Continuous foaming (last 3 years)
  – Producing 20 MMCF/d from 7 wells, 3 more planned for Q1 2008

• Tailpipe extensions (2007)
  – 2 wells in 2007, 2.3 MMCF/d

• Plunger lifting below SCSSV (to be implemented in 2008)
  – Trials planned in 3 wells in April-June 2008

• Mobile wellhead compression (to be implemented end 2008)
Typical Well Information NAM

- Mostly 3½” tubing, some 5” or even 7”
- Liner size – 4½”, 7”, 9 5/8”
- Subsurface safety valve requirement
- Liquid loaded production range 0.3–7 MMscf/d
- Perforated interval length: 120 – 900 ft gross
- Sandstone and fractured carbonate formations
- Depths of 3,600 – 12,000 ft
- Some H₂S
- High-cost environment
NAM Historical Foam Gains

Yearly Gains from Batch & Continuous Foam

- Batch Foam
- Continuous Foam
- Cumulative Gains

<table>
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<tr>
<th>Year</th>
<th>Batch Foam</th>
<th>Continuous Foam</th>
<th>Cumulative Gains</th>
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<td>7.06</td>
<td></td>
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Batch Foam 2007 gains split: 4.56 BCF

- Most gains from kicking off big wells (>90%!)
- Big wells logical future continuous foam candidates
- Around 220 million scf gains from ‘regular’ batch foam wells
Batch Foam Example

- Tried stopping batch foam jobs...
- Decided to re-start as the well performance deteriorated
Continuous foam 2007 gains split: 4 BCF

- Top three wells with 7” completions
- Foam injection via SCSSV & injection valve below it
- Injection valve damage in some cases:
  - Requires pulling and repair twice/yr on average
- Alternative injection valves being considered
Continuous foam injection valve block

Continuous foam injection valve block

Foam

Shattered Tungsten-Carbide seat

Ball ‘wedged’ into seat

~1 inch

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Continuous foam installation: hang-off depth of capstring

- Capillary foam injection string could not be hung off just above the perforations, injection valve got stuck in ‘HUD’ while running in some 50 m above top perfs
- This can cause liquids to build up below the foam injection point
- Solution: Shut in well 2 hrs while injecting foamer
- Foamer drops into the stagnant liquid (like a batch foam job)
- When well is opened the well unloads the liquids
Continuous foam installation: hang-off depth of capstring

- Cap string hung off 50 m above perfs
- Well unloads from here
- Foam goes straight up with gas/liq flow
Expanding Foam application: NAM Offshore

- Around 30 MMCF/d production lost due to liquid loading
- Challenges:
  - Environmental permits for both foamer and defoamer
  - Dependency on water disposal wells (WOB quality)
  - Logistics
- First batch foam trials summer 2007:
  - LL diagnostics using acoustic surveillance, liquid sampling, lab testing
  - 9 trials done
  - Managed to unload 1st well
- Expanding scope to 2 offshore blocks
Examples of successful Velocity string applications
Example of Tail-end Extensions

- In/Outflow modeling
- Severe (7”) liner loading evident from surveillance data (acoustic, FPG)
- No batch foam success
- 3.5” tubing still OK
- Solution: 2” tail-pipe extension, to be followed by full velocity string when tubing starts loading later in well life
Tail-end Extensions: First Application

600 ft Tailend extension

Gas production [scf/d]

THP [psig]

TE installed

~64 MMCF

WBT??

Automatic Intermittent Production

- Operations are resource constrained
- Unmanned locations, daily visit at best
- Wells need multiple shut-ins per day
- Result: Low uptime
- AIP on 3 wells installed
- Uptime improved
- Gains: 1.5E6 scf/d
Plunger-lifting with SCSSV

- Worldwide used to EFFICIENTLY unload LL wells, new in NAM
- Travelling piston (plunger) through tubing
- More gains than normal PBU due to automatic cycle and efficient unloading
- Major challenge: SCSSV is ID obstruction
  - Plunger will be hung-off below flapper
  - Gas has to unload liquids from SCSSV depth to surface
  - Difficult fish if plunger gets stuck

Way forward:
- Design adjusted system (SCSSV requirements) by contractor [next presentation]
- Pilot in 3 wells by end 2007
- More wells if successful
- Unlock tail-end potential beyond foam and VS!
Mobile wellhead compression: Lower FTHP to 30 psia

- Shut in due to liquid loading
- Gas wells
- Gas well location/satellite
- Central compression
- Back pressure 86-150 psia
- To pipeline/central facilities

- THP down to 30 psia
- Low cost movable booster compression
- Producing at low FTHP
- Gas wells
- Gas well location/satellite
- Including wellhead compression
- Central compression
- Back pressure 86-150 psia
- To pipeline/central facilities

- 6 locations selected for MWHC
- 12 wells in sequence
- Backup sequence
- MWHC On-stream in Q4 2008

Gas Production Rate [mln m³/d]
Tubing Head Pressure [bar]
Liq Load
Production
Gas Production Rate [mln m³/d]
Mobile wellhead compression: Lower FTHP to 30 psia

Mobile Wellhead Compressor Curve & Well PQ Curve

Flow rate natural gas [E6scf/d] vs Pressure [psia]

- MWHC operating curve (max), 145 psia DP
- MWHC operating curve, 174 psia DP
- Well PQ curve

liquid loading

producing
Summary

- Continuous foam application in large completions can ‘save’ a tubing size over the life of the well by lowering critical rates up to 50%
- Batch foam kick-off wells form logical future continuous foam candidates
- Automatic intermittent production improves well uptimes considerably in a resource-constrained environment
Annual European Gas Well Deliquification Conference

- To stimulate & fast track the implementation of deliquification technologies in Europe
- Organised & hosted by NAM in 2006 & 2007 and will continue on an annual basis
- 200 attendees in 2007, representing:
  - 23 operating companies
  - 22 vendor companies
  - 3 R&D
  - 2 Regulatory Bodies
- First established and now maintains active (European) network, close links with Denver Deliquification Workshop
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