Maximizing gas recovery in the SNS sector by gas well deliquification and produced water re-injection


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Principal Production Technologist – ONEgas/NAM
Agenda

- ONEgas – Past, present and future
- Deliquification methods in ONEgas - Southern North Sea (SNS)
- Velocity string experiences SNS
- Continuous Foam (CF) experiences
- Gas Well Deliquification (GWD) Challenges
- Conclusions

**LL** when \( Q < Q_{\text{min}} \), liquid loading cycle starts and production drops sharply

1. \( Q > Q_{\text{min}} \) \( \Leftrightarrow \) Gas and liquid are both produced to surface
2. \( Q < Q_{\text{min}} \) \( \Leftrightarrow \) Liquid accumulates in wellbore
3. \( Q < Q_{\text{min}} \) \( \Leftrightarrow \) Bottom hole pressure increases, hence \( Q \) decreases until gas flow stops
4. \( Q = 0 \) \( \Leftrightarrow \) Liquid drains away and near-wellbore pressure re-charges
5. \( Q > Q_{\text{min}} \) \( \Leftrightarrow \) Well starts flowing again
More than 30% of total gas wells are currently liquid loading. GWD (gas well deliquification) can increase ultimate recovery by 1-10%.

GWD Done

GWD candidates

- Wells ~ 300 wells
- CIW ~100 wells
- PRWI 4 wells operational

GWD = gas well deliquification, CIW = closed in wells, PRWI = produced water reinjection
Main Deliquification Methods in SNS

- **Inflow:**
  - Stimulation (perforating, acidizing, fracturing),
  - Water shut-off (WSO),
  - Fresh water soak/squeeze (salt),
  - Note: inflow optimization in 7 wells in offshore-NL delayed LL by 2-3 years (2015)

- **Outflow:**
  - Intermittent production IP (well cycling)
  - Reduce FTHP (compression, surface debottlenecking)
  - Reduce tubing size (velocity string)
  - Increase water carrying capacity (batch Foam or CF + PWRI well)
  - Cleanout (CT, bailing)

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**Gas production vs Time**

<table>
<thead>
<tr>
<th>Time (yrs)</th>
<th>Gas Rate (1e3 m³/d)</th>
<th>Gas Volume (1e6 m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>300</td>
<td>400</td>
</tr>
<tr>
<td>6</td>
<td>500</td>
<td>700</td>
</tr>
<tr>
<td>8</td>
<td>700</td>
<td>1000</td>
</tr>
<tr>
<td>10</td>
<td>700</td>
<td>1000</td>
</tr>
</tbody>
</table>

- **Base Case:** 63%
- **Compression:** 18%
- **Velocity string:** 4%
- **Foam:** 3%
Main Deliquification Methods in SNS Cont.

Velocity String
- OD 2 3/8” / 2 7/8” VS hung off below the SSSV to top of perfs
- LL rate reduced from ~4 to 1.5 mmscf/d, < WGR 50 bbl/MMscf (5” tubing)
- Candidates have ‘high=not good’ Darcy inflow factor A= (>~40 bar2/e3 m3/d)
- To date 21 VS installations in Leman, Barque and K14, K15, L13

Capillary & batch Foam
- Capillary string installed inside the tubing down to above the perforations
- LL rate as low as 0.9 MMscf/d, < WGR 100 bbl/MMscf, low CGR
- Candidates have ‘low=good’ Darcy inflow factor A= (<~20 bar2/e3 m3/d), vel. ~100 ft/sec
- Since early 2006, batch foaming to unload/kick of wells
- Since 2012, 12 wells on CF on 4 manned installations, 3.5 BCF gains (till 2015)

<table>
<thead>
<tr>
<th></th>
<th>SNS UK</th>
<th>SNS NL</th>
<th>ONEGas Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual to date 2016</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velocity strings (#)</td>
<td>8</td>
<td>13</td>
<td>21</td>
</tr>
<tr>
<td>Continuous Foam (#)</td>
<td>5</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>Plan – next 5 year plan</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velocity strings (#)</td>
<td>5</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Foam (#)</td>
<td>10</td>
<td>12</td>
<td>22</td>
</tr>
</tbody>
</table>
Deliqification Technology in Development

- Future Technology in development
  - SURPRISE (surface pressure is excellent) software - Use Surface PBU Records to Calculate WGR and Darcy Coefficient in determining GWD selection (Shell software)
  - Automated Intermittent production – Use Flowing Wellhead Temperature as Proxy for Gas Rate to optimize well cycle

Other:
- Enhanced Gas Recovery EGR project - maximize recovery of mature fields by N2 injection (De Wijk Onshore) - Ongoing
- Deep gaslift Annerveen NL – Ongoing NAM Onshore
- Water lift downhole pump Coevorden NL – Successfully tested Q3 2014 in NAM Onshore
De Wijk (Onshore NL) - Maximize recovery of mature fields

- EGR schematic:

- EGR in DeWijk
  - Injection: 2013-2028
  - Status
    - N2 inj.: ~20% of total planned, 4 inj. wells
    - EGR prod.: ~10% of planned (time lag effect)
    - Incremental 1.0 Bcm

- De Wijk observations
  - Liquid loaded well revived
  - Response in nearby wells: as modelled (rate & N2 cut)
  - Response in distance wells: as modelled (none yet or weak)
Annerveen Gas Field (Onshore NL) - Gas-Lift Dip Stick

- Initial field Pressure: 349 bara, year 1967
- OGIP: 73.3 Bcm
- Gp: 71.1 Bcm (01.01.2014)
- Reservoir pressure: ~10 bar, 3 stage compression
- Developed by 15 wells in 3 clusters
- Wells in liquid loading region

Annerveen Deep gas lift project:
- Dry gas-lift in 6 wells was selected as most attractive and feasible
- Retrofit dip-stick was developed in-house to achieve deep injection (no retrofit solutions on the market)
- Incremental ~0.5 Bcm
- Gas-lift cost was reduced by (re-)using existing surface infrastructure
- Gas-Lift is applied to reduce abandonment pressure of gas field with <=10 bar

Status: Dip stick designed internally, feasibility confirmed by C&WI, patent filed (B. Lugtmeier 2014)
**Velocity String Experience SNS**

Since 2008, installed 17 coiled tubing velocity strings to date on 6 platforms.

Velocity strings are a proven GWD deliquification method, ‘maintenance free’ and well understood in modelling. Overall good results, however candidate selection is critical:

- **Sand:** 3 x VS stopped producing due to HUD sand build up in liner (NL side).
- **Mechanical:** 1 x VS hang off in TR-SSSV damaged the seal bore area and installation was cancelled (UK side).
- **Failure:** Accidental drop of VS with HWU (NL side).
- **Timing:** Two premature installations which constraint production (UK side).
Case UK SNS: Velocity Strings (after ~3 yrs)

Well Details
- Pre VS Rate: 38 Ksm$^3$/d (intermittent)
- Initial VS Rate: 125 Ksm$^3$/d
- Current Pot: 70 Ksm$^3$/d @ FTHP: 18 barg
- CITHP: 84 barg
- WGR: 120 m$^3$/MMm$^3$
- A factor: 150 bar$^2$/1000m$^3$/d)

Completion Details
- No top string
- VS hanger at 340 m AHD in SSSV profile
- SSD @ 343 m AHD (ran closed)
- 2 7/8" CT @ 2440 m AHD – 40 deg incl
- 16Cr
- Installed in Jan 2013, Startup March 2013

Reducing LL and stabilizing production by velocity string
ONEgas Continuous Foam System (CF)
**UK SNS CF foamer case study - Uptime**

**Case-study:**
- 3 wells on a manned production facility
- Drilled in 1990 and started liquid loading after 15-20 years of production
- CF installed in 2013, successfully increased reserves recovery
- Uptime decreased after 1 year, due to operational challenges

<table>
<thead>
<tr>
<th>Well</th>
<th>Can produce intermittently</th>
<th>Incremental capacity [MMscf/d]</th>
<th>CF recovery vs total well recovery*</th>
<th>Average foamer uptime*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>Yes</td>
<td>4</td>
<td>5%</td>
<td>88%</td>
</tr>
<tr>
<td>R</td>
<td>No</td>
<td>2</td>
<td>2.5%</td>
<td>36%</td>
</tr>
<tr>
<td>B</td>
<td>No</td>
<td>2</td>
<td>10%</td>
<td>50%</td>
</tr>
</tbody>
</table>

SPE-180031 • Four Years of Continuous Foamer Application in SNS Offshore Gas Wells
# Continuous Foam failures

<table>
<thead>
<tr>
<th>Issue:</th>
<th>Impact:</th>
<th>Mitigation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downhole Blockages</td>
<td>Stops foamer injection, reduces uptime, increases OPEX</td>
<td>Improve BHA, use downhole siphon, seamless capillary, sample foamer quality, filtering</td>
</tr>
<tr>
<td>Sand Erosion</td>
<td>Causes capillary string leaks and possible fish, increases OPEX</td>
<td>High grade materials, avoid high flow velocities, well selection</td>
</tr>
<tr>
<td>Poor Foam Separation</td>
<td>Need PRWI well, Causes separator trips</td>
<td>Anti-foamer, adopt bean-up strategy</td>
</tr>
</tbody>
</table>

SPE-180031 • Four Years of Continuous Foamer Application in SNS Offshore Gas Wells
Continuous Foam – Meantime between failure

Data:

- Average Meantime >2012 = 374 Days
- Average Meantime 2012-2014 = 667 Days
- Design criteria = 2 years

Increase Meantime to Repair

1. Increase reliability components
2. Investigation failures
3. Update surfactant quality
4. Well selection
Challenges GWD

- Though knowledge and screening tools are improving i.e Deliq factory, Prosper, SURPRISE, choosing the optimum well deliquification method is challenging.

- Deliquification methods are costly depending access location (and SSSV!). Average costs 1.5 – 2 mln Euro offshore. Emphasis on reducing costs.

- VS challenges: proven technology and ‘keep it simple!’ - best practice is to install VS below SSSV

- Foam challenges:
  - Foamer type compatibility issues (Cl resistant)
  - Erosional velocities - sand
  - OIW > 30 ppm – PRWI injection wells dependent - 500 – 2500 ppm,
  - Operational Excellence and reliability - MTTR
  - CF Uptime
Brown Field GWD in SNS/ONEgas

- Permanent deliquification methods are costly and not without risk. Only install GWD in wells which are actually LL! Timing is important.

- Optimum well inflow i.e. stimulation, clean out, soaks, WSO delayed GWD in various cases and pays off.

- IP and subsequent VS and/or foam is the preferred well GWD method in ONEgas off-shore. Foam installations on unmanned platform are on hold due to cost level.

- Based on inflow/out flow modeling, indicate foam applications to be the best option to enhance gas recovery from the various fields in SNS.

- Sand producers are risky candidates for GWD and require close controlled operation and/or downhole repair i.e. retrofit sand screens before any GWD.

- PRWI wells allow foam applications offshore. However, foam affect corrosion inhibitors and OIW content. PRWI dependency increasing offshore.