Consideration of Gas Hydrate Production Well Technology

August 17, 2005
Gas Hydrate Production Well Technology

- Drilling & completion issues

- Well performance issues
  - Flowing pressures
  - Water production
  - Other flow assurance issues

- Field development review based on Mallik
Typical Well Completion

Permafrost ~ 1800 ft TVD

Tubing accessories:
- Artificial lift
- Electronic pressure gauge
- Heating system
- Methanol injection sub

Sand screen shroud will incorporate fibre optic loops with distributed temperature and several discrete pressure sensors
Typical HZ Well Profile

- KOP 500 ft
- 8.5" OH w/Screen
- Surface Casing
- Fault
- Intermediate Casing
- 30/100 ft

Horizontal Displacement, ft

depth, ft TVD

0 1000 2000 3000 4000 5000 6000 7000 8000
Well Performance - Pressure

Conventional Gas Reservoir
- Typically normal or higher initial reservoir pressure
- FBHP controlled by:
  - Drawdown limitation (borehole stability, water production etc.)
  - Surface pressure constraint
  - Rate constraint
- Compression typically staged later in life of field

Gas Hydrate Reservoir
- Initially normally pressured (water phase pore pressure)
- FBHP controlled by dissociation (say 350-500 psi)
- Production rate must equal dissociation rate
- FWHP controlled by FBHP and production rate (gas & water)
- Compression required throughout life of project
**Well Performance - Water**

### Conventional Gas Reservoir
- **Water sources:**
  - 1-2 bbls/MMscf condensation
  - Coning & cusping
  - Active aquifer
- **Historical controls (low cost):**
  - Cyclic operation
  - FWHP reduction
  - Water shut-off re-completions
  - Lift assist
- **Other controls (high cost):**
  - Sidetrack/horizontal well
  - Artificial lift (gaslift, PD pumps, jet pumps)

### Gas Hydrate Reservoir
- 1 ft³ of gas hydrate = 164 scf of gas & 0.9 ft³ of water:
  - ~ 978 bbls/MMscf
  - Actual water production function of well geometry, reservoir drainage
- Low FBHP conditions provides stable tubing performance with relatively high watercuts
- **Artificial lift required:**
  - Well start-up
  - Continuous and/or intermittent basis
- **Disposal or resource (low salinity)**
Water Production

- No Free water
- Gravity effect dominate gas/water segregation
- Gas will accumulate along top of dissociated zone, expansion due to low pressure will drive gas towards wellbore
- No driving energy in free water phase – gas velocity only???
2 3/8” Tubing Performance

Fluid Properties:
- Gas Gs = 0.50
- Water Gh = 1.06
- WGR = 10.0 Bbl/MM

Wellbore Data:
- MMP = 260.0 psig
- TVD = 2465.5 ft
- CIP = 69.8
- Tdp/2.375/3300
- Cag/7.00/3400
- Cag/4.50/3450
- Cag/4.50/3725
2 3/8” Tubing Performance
Well Performance – Flow Assurance

**Conventional Gas Reservoir**
- Hydrate formation prevention:
  - FWHT > 75 F depending upon gas analyses & pressure
  - Temporary heating or chemical injection
- Liquid loading
- Others:
  - CO$_2$ & H$_2$S (corrosion)
  - Scale (produced water)
  - Asphaltenes & paraffins (gas condensate)
  - Extreme high temperatures and pressures

**Gas Hydrate Reservoir**
- Hydrate formation prevention:
  - Low FBHP
  - Heat and/or chemical injection
- Freezing:
  - Geothermal < 32 F
  - Heat and/or chemical injection
- Water production
- Others:
  - No significant corrosion
  - No condensate liquids
  - No significant scaling
Gas hydrate wells will have a relatively benign operating environment – long life and few interventions.

Technologies required to produce gas hydrate wells are currently used in conventional gas field operations.

Capital & operating cost impacts:
- Compression requirement for gas hydrate wells represents additional costs compared to conventional gas wells.
- Artificial lift requirement and water disposal for gas hydrate wells represent additional costs compared to conventional gas wells.
- Must consider the above in context of field life and reserves recovery per well.
Mallik 5L-38 Hydrate Deposit
Case 1 – Gas Hydrate Over Free Gas
Case 1 – Free Water Established
Case 1 – Cont’d Gas Hydrate Dissociation
Case 2 – Gas Hydrate Over Water
Case 2 – Onset of Gas Production
Case 2 – Continued Hydrate Dissociation
Production Comparison
Production Comparison

- **Case 1**
- **Case 2**

**Graph Details:**
- **Y-axis:** Total Gas (BCF)
- **X-axis:** Time (Years)
- **Legend:**
  - Red line: Case 1
  - Blue line: Case 2
STARS Reservoir Model

Single well
1 sq mile drainage area

Over Burden
Hydrate Zone
Free Gas Zone
Under Burden

80 grid blocks high x
100 grid block radial
STARS Temperature Profile

Pwf = 5 MPa
TOUGH-Fx/Hydrate Temperature Profile

Additional JT effects in near wellbore area require heat addition.
## Cost Summary - $CDN 2004 MM

5 Wells, ~1 TCF GIP

### Capital Costs

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<thead>
<tr>
<th></th>
<th>Case 1</th>
<th>Case 2</th>
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<tbody>
<tr>
<td>Drilling &amp; Completions</td>
<td>$82</td>
<td>$87</td>
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<tr>
<td>Facilities &amp; Pipeline</td>
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<td>$198</td>
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<td><strong>Sub-total</strong></td>
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<td>$285</td>
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### Operating Costs

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<tr>
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<td>Local Pipeline</td>
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<td>Local Facilities</td>
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<td>Gas Plant Process</td>
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<td>Water Handling</td>
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<td>Workovers</td>
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<td>Pipeline Tariff</td>
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<tr>
<td><strong>Sub-total</strong></td>
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<td>$1,838</td>
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### Total Capital & Operating

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<th>Case 1</th>
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<tbody>
<tr>
<td><strong>Total Capital &amp; Operating</strong></td>
<td>$2,937</td>
<td>$2,123</td>
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## Economic Evaluation - Unit Technical Cost

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<th>Case 2</th>
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<tr>
<td><strong>Total Capital &amp; Operating, $ MM</strong></td>
<td>$2,937</td>
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<td><strong>Sales Gas, BCF</strong></td>
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<td><strong>$CDN/Mscf</strong></td>
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<tr>
<td>0% Discount</td>
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<td>20% Discount</td>
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