Outline

- Timeline 2010-2011
- Timeline 1999-2010
- Specific Cases (1999-2010)
- Additional Information
3M™ Glass Bubbles Drilling Fluids/WO

Indonesia (Tambun field)

Canada

Vietnam

China

India (Offshore)

Norway (Offshore)

Canada

3M Energy and Advanced Materials Division
ENI Dual Gradient Drilling (Project*)

(*) Project considered innovative but not pursued for lack of funding
Technological Challenge
- Depleted wells: need to drill near balance

Solution
- Reduce mud density by adding HGS4000 to drill at pressure slightly above the formation pressure

Key Parameters
- Add 6-8 vol% to WBM
- Mud tank capacity 360 bbl
- Shallow well inland

Conclusion
- No lost circulation
- Very good density control
- Less than 5% bubble breakage
- Project economics satisfactory for the customer
Technical Challenge
- Depleted wells: heavy fluid losses
- Remote location: cost/logistics cost prohibitive for aerated fluids

Solution
- Reduce mud weight to near balance conditions using HGS6000

Key Parameters
- Max depth 2,600 m
- Deviation 55° and 725 m
- Target density 8 to 8.2 ppg
- Used 48,000 lbs of HGS6000 (5 to 10 vol%)

Conclusion
- Fluid loss issues addressed
- Mud density maintained within acceptable limits (8 to 8.7 ppg)
Venezuela 2002

- **Technical Challenge**
  - Low pressure reservoir, depleted zones, logistics issues with aerated fluids
  - Reactive shale and highly fractured formation

- **Solution**
  - Add HGS4000 to OBM at 12 vol% to achieve 7.1 ppg

- **Key Parameters**
  - 8 ½” section, TVD 8,362 to 10,000 and 280 °F BHT
  - Used 17,000 lb of HGS4000

- **Conclusion**
  - OBM/GB system was stable, homogeneous with good rheological and filtration properties.
  - System stable at 330 °F
Technical Challenge
- Depleted reservoir
- Achieve completion at underbalance conditions

Solution
- Light Weight Completion Fluid (LWCF)
- Add HGS6000 (10 w/w%) to oil based completion fluid

Key Parameters
- Well 2,058m and 2,600 psi (HP)
- Target ΔP 200 psi
- 72 bbl of LWCF pumped at 0.5 to 1.0 bbl/min

Conclusion
- Successful completion
- Avoided perforation damage
- 3,000 bpd achieved, 30% higher than neighboring wells
China 2007 (HGS6000)

- **Technical Challenge**
  - Low porosity/low permeability and low pressure sandstone reservoir

- **Solution**
  - XC, WBM with a target density of 0.95 g/cc
  - Use HGS6000

- **Key Parameters**
  - TVD 3216 m
  - Long horizontal portion (2000 m)
  - 250 m$^3$ of mud, 6 MT of HGS6000
  - Complete solids control line (shakers, cyclones and centrifuges)

- **Conclusion**
  - Target density successfully managed although with high consumption of glass bubbles.
  - Two wells drilled
China 2007 (HGS5000)

- **Technical Challenge**
  - Very low permeability reservoir, hard/dense sandstone
  - Wellbore stability & clean-up, differential sticking, high torques and friction

- **Solution**
  - Underbalance drilling using WBM
  - Lower density 0.85 g/cc adding HGS5000

- **Key Parameters**
  - TVD 4055 m
  - Long horizontal portion (2000 m)
  - 240 m$^3$ of mud, 60 MT of HGS5000
  - Complete solids control line (shakers, cyclones and centrifuges)

- **Conclusion**
  - Mud density maintained under 1.0 g/cc
  - Production rate 3x compared to neighboring wells drilled overbalance.
  - Solids control needs to be optimized.
  - Five wells drilled
3M Energy and Advanced Materials Division

Russia 2008 - 2009

- **Technical Challenge**
  - Depleted field, high fluid losses

- **Solution**
  - Under balance drilling using WBM
  - Add HGS4000 to lower density to 0.95 - 0.97 g/cc

- **Key Parameters**
  - Horizontal section drilled. TVD 2840 m, MD 3710 m
  - WBM with 6 vol% HGS4000 (about 7 MT for the first well)
  - PDC 143 mm bit

- **Conclusion**
  - Mud density maintained within acceptable limits
  - Five wells drilled
  - Project still at experimental level (new lab tests under way)
India 2008

- **Technical Challenge**
  - Offshore
  - Limestone/shale low pressure reservoir
  - Important fluid loss, lost circulation and formation damage

- **Solution**
  - MPD using WBM
  - Add HGS4000 to reduce density to 6.8 ppg

- **Key Parameters**
  - TVD 1400 m, 300-500 m horizontal sections
  - 15-20 vol% HGS4000 (100,000 lb/well)

- **Conclusion**
  - 2 wells drilled
  - Fluid Loss reduced from 100+ bbl/hr to 0-8 bbl/h
  - Prevention of lost circulation and formation damage resulted in higher total liquid production than expected for both well.
India 2008

Two wells (7” Liner at 1899 m)
WOB 6-8 ton RPM 40 GPM 250 ROP 10-15 m/hr

<table>
<thead>
<tr>
<th></th>
<th>Well A</th>
<th>Well B</th>
</tr>
</thead>
<tbody>
<tr>
<td>TVD, m</td>
<td>1350</td>
<td>1335</td>
</tr>
<tr>
<td>6” drain hole drilled, m</td>
<td>500</td>
<td>600</td>
</tr>
<tr>
<td>Density, ppg</td>
<td>7.2-7.9</td>
<td>7.3-8.0</td>
</tr>
<tr>
<td>Loss rate, bbl/hr</td>
<td>6-8 bbl/hr</td>
<td>0</td>
</tr>
<tr>
<td>Total time, hr</td>
<td>70</td>
<td>77</td>
</tr>
<tr>
<td>HGC Consumption, MT</td>
<td>60</td>
<td>75</td>
</tr>
<tr>
<td>(Liquid) Production rate, bbl/day</td>
<td>800</td>
<td>2,200</td>
</tr>
</tbody>
</table>

**Equipment**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Number</th>
<th>Screen</th>
<th>GPM</th>
<th>RPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shale Shaker (derrick)</td>
<td>2</td>
<td>150 mesh</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>Centrifuge</td>
<td>1</td>
<td>50</td>
<td>1800-2000</td>
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</tbody>
</table>
Technical Challenge
- Need for ultra light OBM (< 7.5 ppg) when drilling depleted reservoir
- Pore pressure on G-8 was +/- 6.5 ppg
- 7 5/8” liner differentially stuck

Solution
- Ultra Low density fluid implemented as part of Fluids Technology Plan
- 3M™ Glass Bubbles HGS Series used as de-weighting agent
- HGS glass bubbles enabled low density (6.8 ppg) drilling fluid with acceptable drilling fluid properties
- Multiple lab tests conducted (including rheological properties, pressure testing, attrition)
- Onshore large scale testing performed (including logistical options, mixing procedures, shearing, shaker screen performance)

Key Parameters
- 7.8 ppg Carbosea OBM as drilling fluid.
- Incorporated HGS18000 mud to achieve 7.0 ppg fluid
- All HGS glass bubbles mixed onshore to avoid offshore handling

Results
- Displaced well from 7.8 ppg to 7.0 ppg to free stuck liner
- 2 liner sections were retrieved after displacing to 7.0 ppg HGS mud
Technical Challenge
- Fractured limestone, MTVD 1,800 m
- Lost circulation due to natural depletion
- Reservoir pressure has dropped from 2630 psi (1.03 SG) in 1993 to ~ 1970 psi (0.77 SG)
- Past practice was drilling with KCl Polymer mud (1.02-1.04 SG) to curb losses and pump LCM pills (Diaseal M, 40ppb)
- Time consuming and potential skin damage

Solution
- Add HGS8000X to XC/bentonite mud to drill pay zone (180-200m)
- Target density 0.9 g/cc

Key Parameters
- BHT ~200 °F (circulating), 250 °F (static)
- Total circulating Volume: 850 bbl/well
- Top Drive 750 HP
Conclusion

- Compatible with field conditions
- Similar application to traditional KCl polymer mud system
- Reusability with conditioning
- 9 wells to date have been successfully drilled.

First two wells

<table>
<thead>
<tr>
<th></th>
<th>w/o GB*</th>
<th>w/o GB*</th>
<th>Well 1</th>
<th>Well 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interval length</td>
<td>m</td>
<td>83</td>
<td>331</td>
<td>185</td>
</tr>
<tr>
<td>Drilling time</td>
<td>days</td>
<td>13</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>Total loss to formation</td>
<td>bbl</td>
<td>69,626</td>
<td>2,358</td>
<td>0</td>
</tr>
</tbody>
</table>

(*) GB glass bubbles
Technical Challenge
- New Field
- Lost circulation observed when drilling wells 4 and 5
- Well 5 temporarily abandoned

Solution
- WBM in combination with HGS8000X to achieve target density of 0.84 g/cc
- 0.75 - 0.79 g/cc would have been ideal

Results
- Reduced losses
- Well 6 successfully completed and flowing (400-500 bopd)
Technical Challenge

- Fine sandstone/sandy shale with thin beds of silstone
- Offset wells showed severe losses (i.e. 288 m³) despite using low density OBM. Most losses at 1,300 m depth
- Rig time: 2 days minimum
- Cement plugs 3

Solution

- Standard base oil in combination with HGS8000X with the potential for drilling straight through with reduced losses, no downtime, no cement plugs

Key Parameters

- 2275 m (7,464 ft) interval depth
- 222 mm (8.74 in) hole
- 150 m³ (943 bbl) total circulating volume
- OBM start/target density: 910/810 kg/m³ (7.59/6.76 ppg)
Performance

- One PDC bit used
- Total drilled section drilled with HGS8000X 1675 (5,495 ft)
- Approx. 150 cycles circulated in 10 days
- Total losses 60 m³ (377 bbl)
- Loss rate 3.5 m³/100m (considered average)
- Total volume recovered 133 m³ at a density of 810 kg/m³, which will be used again for next well (Q4 2010).

Conclusion

- Trial considered successful
- The combination of a base oil and HGS8000X lightened the mud as well as worked as a bridging agent to restrict losses to formation
- 9 wells have been successfully drilled to date and 3 more will be drilled by the end of 2011.
Thank you!
Publications on 3M Glass Bubble use in Drilling Fluids


SPE 75508 (2002) Field application of Glass Bubbles as a Density Reducing Agent in an Oil Base Drilling Fluid for Marginal / Low-Permeability / Low-Pressure Reservoirs.


