Outline

• Overview of plug technology

• Introduction to the project
  – String and well specs
  – Downhole environment

• Initial success

• Unique problems encountered throughout the project

• Conclusions and recommendations
Permanent Plugs – The Reasoning

Composite frac plugs

Tried and true method

Relatively consistent application

Mill out operation required

Effort to reduce costs, eliminate milling process
Permanent Plugs – The Reasoning

Stop milling, start producing

- Large flow through ID, no mill out operation required
- Very similar application to composite plugs
- Not limited by coiled tubing reach

Permanent frac plug installations
Permanent Plugs – The Issue

- Stop milling. Start producing
- Refrac opportunity

- Large reductions in production as plugs restrict the wellbore and prevent flow from zones deep in the well.

- Material of permanent plug
- Very difficult to remove with standard procedures
60.3mm Coiled Tubing Tapered String
0.224”-0.156” WT

Average MD: 5436 m
Average TVD: 3250 m

114.3 mm casing

28.21 plugs per well

• Average Circ Pressure 44 MPa
• Average WHP 24 Mpa
Milling Operations Begin

Average downhole temperature: 124 °C
Initial Outlook = Positive

Target was as many plugs as possible with each mill/motor.

- Average mill time: **249 minutes/plug (4.15 hrs)**
- Average plugs per tool: **3.17**
- Average time milling on debris: **29.16 min**
- **Six plugs with one tool string**
- Total well time: **247 hrs (10.29 days 0.54 days per plug)**

- 649 plugs completed in 350 total rig days
- 5 rigs = 70 days required
Initial Practices

- 400 L/min pump rate
- 450 L/min return rate
- Infrequent wiper trips
- No Venturi runs
- 8.50 stalls per/plug

Frequently lost ground when recovering from a stall
Pattern Developing

- Frequent stalls
- Little action with similar weights and depths
- Another round of stalls
- Ground continues to be lost

- 246 minute plug (4.1 hrs)
- Sixth plug with current tool
- 13 stalls
Initial plugs

- Over all three pads 426 mins (7.1 hrs) for first eight plugs
- Average time spent milling on debris 53 minutes
Problems Start to Arise

- Very minimal debris brought back with each gel sweep or regular return rates
- Issues with sand production and pressures if pump/return rate increased
- Large debris pieces left downhole
- Large, flow through ID. No way to grind up
Plugs 9-16, Trend Continues

• Over all three pads the average time per plug increased to 761 minutes (12.7 hrs)
• Average time spent milling on debris also increased to 81 minutes

First well plug average of 249 min (4.15 hrs)
Frequent Stalls

Little action with similar weights and depths

Another round of stalls

Ground continues to be lost

• Debris issues amplifying the initial pattern noticed
Downhole Analysis – Weight on Bit Sub

Frequent stalls

High compression on surface not transmitted downhole – debris above tool?

High compression on surface and downhole – no action from motor
Debris Management - Venturi

- Program changed, three plugs then a Venturi run
- Brought back significantly more debris than initial program
- However large amounts of time lost
- Average time to perform a Venturi was 13 hours
- Issues arose when Venturi encountered too many obstructions/the plug
- Number of fishing runs conducted
Debris Management - Venturi

- Total time on final plugs = **410 hrs**
- Average time spent was **17 hrs**
Debris Management - Magnet

- Another method trialed was magnet runs to try and grab all the debris left down hole

- Fine shavings from the plug coated magnet before any large chunks could be obtained

- Very little success, not a lot of time attributed to magnet runs: 12.7 hrs

- Smaller magnets run on most Venturi BHAs however

- This issues with the fine shavings also highlighted another issue that was occurring with the fluid system
The constant introduction of steel into the fluid system caused a number of issues that were not predicted.

- Dissolved iron in the system caused:
  - Motors to be destroyed
  - Settled in the coil, required acid pickles
  - Chemical incompatibility
  - Damage to pumping equipment
Debris Management – Fluid Issues

Compatibility issues with different chemical systems

Fluid friction reducers

- High circulating pressures
- Reduced coiled tubing life and pump damage
- Less weight on bit and difficulty moving downhole

Metal to metal lubricants
Debris Management – Tapered Mill

- Tapered mills were also run in an effort to trap debris and remove it.
- Limited success was exhibited.
- If the mill encountered a plug could compromise slips, cause it to spin.
- Difficult to determine when this occurs = time lost.
Fatigue Management

- Fatigue management became a very large issue
- Had to try and keep a level profile from the highest spike
Final plugs in well

Over all three pads the average time per plug increased to 1570.24 minutes (26 hrs)

Average time spent milling on debris also increased to 184.8 minutes (3.1 hrs)
Could not break the trend

- Increases in all three areas:
  - Time milling
  - Time milling on debris
  - Percentage unsuccessful (could not fully remove plug with tool)
Could not break the trend

- Initial target 649 plugs in 350 working days
- Final result: 277 plugs in 330 working days
Conclusions and Recommendations

Permanent flow through plugs, eliminate the need for a mill out operation.

Incredibly costly and time consuming operation to remove these plugs, however there are ways to reduce the length and price of the operation by controlling:

• The actual milling of the plugs
• Debris management
• Fluid management
• Fatigue management
Conclusions and Recommendations

Milling of plugs:
- Proper weight application
- Recognize and address pattern

Debris management:
- Grind up debris downhole
- Get past the mill and headed up hole

Fluid management:
- Treat fluid to reduce iron content
- Understand and control the reaction with chemical systems

Fatigue management:
- Typical milling practices do not apply
- Attempt to maintain a consistent level

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Thanks very much to all the field professionals that participated in this challenging project

Questions?