CT Operations in Extended Reach Laterals

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Coiled Tubing – Global Product Manager
Why develop – Unconventional Shale Oil & Gas Plays

Challenges – self sufficient
- Energy crisis
- Energy shortages
- Declines in domestic production
- Need for R & D
- Political instability
- Conflicts

Key US gas plays: Haynesville; Barnett; Marcellus
- 665 tcf of recoverable shale gas
- Net gas exporter of Liquified Natural Gas (LNG)

Key US oil plays: Bakken; Eagleford; Permian
- 58 billion barrels recoverable oil US shales
- Net exporter of petroleum products: diesel, gasoline & heating oil
Well Drilling and Completion

- Early 90’s shale developments
  - Largely Vertical limited entry
  - Massive Hydraulic Fracturing (MHF)
    - 1500 ft+ frac length/120+ BPM
  - Economics borderline at best

- Technological and management advances in 10 years make plays economic
  - Multiple Well pads drilling
  - Drilling extended-reach horizontals
  - Horizontal laterals doubled in last 5 years
  - 10,000 -12,000 ft laterals (22,000 ft TD)
  - Optimized multi-stage hydraulic fracturing
  - 40 fracturing stages plus
Completion Methods

- Plug and Perf
- Ball/Sliding Sleeves
- Coiled Tubing Stimulation
Plug ‘n’ perf

- Allows rapid perforating, stimulation and production of multiple stages
- Accounts for 70 - 80 % of unconventional wells
- Communication established with TCP & toe section stimulated
- Perforating guns with a composite plug are circulated on wireline to bottom
- First section perforated and stimulated
- Process repeated 300 - 400 ft intervals (40 stages)
- Plugs milled out with coiled tubing
Plug and Perf (PNP) Technique

Advantages
- Considered reliable
- Best placement of fractures
- Best overall recoveries
- Flexibility - treat individual stages - can change design on fly
- With micro-seismic fracture mapping can avoid geo-hazards or offset wells
- Advanced fracturing techniques
- Full bore after plug mill out

Disadvantages
- Multiple trips into well
- Has higher intervention costs when compared to other techniques sleeves
- Depending on number of stages technique can take several days or more
Interventionless Toe Sleeve

- Interventionless means of establishing initial flow path
- Run as part of the casing string
- Can be run with both plug and perf and sliding sleeve completion
- Removes need for TCP perforating guns on coiled tubing
- Toe sleeve enabling casing pressure test prior to frac
- Pressure activated
- Can be run with both plug and perf and sliding sleeve completions
Ball Activated Sliding Sleeves

- Allows stimulation and production of multiple stages
- Can be cemented or open hole
- Uses a ball drop system to manipulate sleeves
- Requires little or no intervention
- Communication established stage stimulated
- Process repeated 300 - 400 ft intervals (30-40 stages)
- Sleeves-balls can be milled out
Sliding Sleeves

**Advantages**
- More efficient – reduced field operating time
- Reduced cost due to field time
- Several stages can be stimulated in a single day.

**Disadvantages**
- May have to pull completion if can’t get to depth
- Swellable packers can be activated causing difficulty in round tripping
- Completion may be landed at less than optimum position
- In-flexible – changes cannot be made in stage depths
- Risk of poor isolation due to enlarged boreholes or wash outs
- Unless milled loss of full bore
- Harder to clean out if you get a premature screen out-drill out baffles
- May need to drill out baffles if bad sleeve
Ball Activated Sliding Sleeves

- Comprises ball operated frac and stage sleeves
- Single or multiple entry points per stage
- Openhole or cement isolation
- Can be run with a liner hanger or on a long-string
- Can use dissolveable frac balls
- Millable baffle if full access needed
Self-Removing Ball Technology (Dissolveable)

- Generally Magnesium, Aluminum & other alloys
- Last for the duration of the fracturing treatment
- Designed to degrade with time and temperature
- Quickly degrade post stimulation
- Different ball options depending on well conditions
- Resist differential pressures during fracturing operations
- Hold up to down hole temperatures
- Last for the duration of the fracturing treatment
Coiled Tubing Stimulation

- Simple Multi-stage technology.
- Enables perforating fracturing and fluid diversion in a single trip.
- No perforating guns
- Uses hydra-jetting to create the perforations
- No pumpdown plugs
- Proppant plug set during hydrajetting
Annular Fracs with CT and Casing Sleeves

Advantages
• Perforating, fracturing and diversion in single trip
• No need for perforating guns
• No need to set mechanical plugs
• Less horsepower required on location
• Flexible can carry out treatment modification on the fly
• CT readily available for premature screen outs
• Can reverse circulate screen premature screen outs
• Less fluids required
• Less chance of over-flushing NWB

Disadvantages
• Available WOB at depth for setting tools (typical min 2000lb 20 lb/ft casing
• Slower than sliding sleeves
• Increased pump time vs plug n perf
Coiled Tubing Interventions
Completions and Coiled Tubing Intervention

All completion methods have a requirement for intervention whether planned or contingency

Benefits vs Work Over Rigs
- Efficient - Faster
- Work on live wells
- Continuous circulation RIH/POOH
- Small footprint

Challenges
- Extended reach challenges getting out to 22,000 ft
- Circulating rates
- Weight on bit
- Logistical challenges (transport)
Efficient CT Operations in extended laterals
Job Modelling - Coiled Tubing

- Typically modeling
  - Milling operations
  - Sand cleanouts

- Well Parameters
  - 22,000 ft MD wellbore
  - 9,800 ft TVD
  - 0 - 6500 ft 5.5  23.0 lb/ft
  - 6500 ft - 22,000 ft 20 lb/ft

- Note: Toe up configurations or tortuous well paths can significantly affect CT reach
Job Modeling & Simulation Software

Design of Coiled Tubing String
- Tubing OD
- Reach & friction coefficients
- Set down weight
- Collapse/burst pressure
- Strength/grade of string

Fluid System design
- Bottom Hole pressure
- Circulating pressures
- Fluid volumes

Bottom Hole Assembly Design
- Motor Flow Rate
- Agitator/water hammer tool flow rate
## Coiled Tubing String Design

<table>
<thead>
<tr>
<th>String</th>
<th>Length (ft)</th>
<th>Diameter (in)</th>
<th>Wall Thicknesses</th>
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<tbody>
<tr>
<td>22,700 ft 2 in QT-1000 true taper</td>
<td>5,000</td>
<td>0.203” wall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>760</td>
<td>0.203” x 0.188” wall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5,000</td>
<td>0.188” wall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>640</td>
<td>0.188” x 0.175” wall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11,300</td>
<td>0.175” wall</td>
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<tr>
<td></td>
<td>Total road weight</td>
<td>81,335 lb</td>
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<tr>
<td>22,700 ft 2 3/8 in QT-1000 true taper</td>
<td>5,000</td>
<td>0.203” wall</td>
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<td>760</td>
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<td></td>
<td>640</td>
<td>0.188” x 0.175” wall</td>
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<tr>
<td></td>
<td>11,300</td>
<td>0.175” wall</td>
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<tr>
<td></td>
<td>Total road weight</td>
<td>98,582 lb</td>
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</table>
Reach comparison 2 in vs 2 3/8 in

- 2 in
- 2 3/8 in

- Lock up occurs at 21,200 ft
- No Lock Up
CT Forces

- Max Set down

- Max Pick Up

![Graph showing Max Set down and Max Pick up forces.](image-url)
Friction Matching
Bottom Hole Assemblies

Typical Mill Out BHA
- TEC
- Back Pressure Valve
- Bi-Directional Jar
- Hydraulic Disconnect
- Agitator
- Motor
- Tri-cone bit

BHA's - 30 ft long; 4.5 in OD bit
Extended reach tools

- Oscillatory tool
- Variable pressure pulses
- Improved weight transfer
- Reduces Friction
- Reduces helical buckling/lock-up
- 2 7/8” OD
- 1 bpm - 3.33 bpm
- Typical frequency 8-10 Hz
- Can extend reach by 10%
Fluid Systems

Considerations
- Chemical composition & concentrations
- Compatibility with formation/wellbore fluids
- Mixing capability

Fluid Friction Reducer
- Reduced circulating pressure
- Reduced string fatigue

Metal to metal friction reducer
- Reduce normal force between string and completion
- Maximize weight transfer to bit
- Mitigate helical buckling

Gel Sweep
- Excellent hole cleaning
- Excellent suspension/transport properties
Effect of Friction Reducers

2 3/8 in 0.26 FF

Lock up occurs at 19,259 ft

2 3/8 in 0.23 FF

No Lock Up
Road Laws

- State & County variations
- No of axles
- Tire contact area
- Axle weight limits
- Axle spacing limits
- Bridge loading limits
- Width limits
- Height limits
- Divisible loads
## COMPARISON OF STATE TRANSPORT REGULATIONS AND PERMITS
**TEXAS Vs. COLORADO Vs. NORTH DAKOTA**

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<thead>
<tr>
<th>Parameter</th>
<th>Texas</th>
<th>Colorado</th>
<th>North Dakota</th>
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<tbody>
<tr>
<td>Max gross weight (lbm)</td>
<td>80,000</td>
<td>85,000</td>
<td>80,000</td>
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<td></td>
<td>254,300</td>
<td>200,000</td>
<td>150,000</td>
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<tr>
<td>Steering axle (lbm)</td>
<td>13,000</td>
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<td></td>
<td>19,500</td>
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<td>21,600</td>
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<tr>
<td>Tri-axle group (lbm)</td>
<td>42,000</td>
<td>—</td>
<td>42,000</td>
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<tr>
<td></td>
<td>60,000</td>
<td>Case by case</td>
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<tr>
<td>Quad-axle group (lbm)</td>
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<td>70,000</td>
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<td></td>
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<td>50,000</td>
<td>68,000</td>
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<tr>
<td>Length (ft)</td>
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<td>70</td>
<td>75</td>
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<tr>
<td></td>
<td>125</td>
<td>110 to 130</td>
<td>120</td>
</tr>
<tr>
<td>Width (ft-in)</td>
<td>8’ 6”</td>
<td>8’ 6”</td>
<td>8’ 6”</td>
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<tr>
<td></td>
<td>16</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>Height (ft)</td>
<td>14</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>18’ 11”</td>
<td>16</td>
<td>18</td>
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</tbody>
</table>
Operational Challenges - Safety

Common Hazards

- Working Under Suspended Loads
- Dropped Objects
- Hand-finger safety
- Manual Handling
New CT Surface Equipment for extended laterals

- Large capacity reel trailers (BART)
  - 23,000 ft 2 3/8 “ CT String
- 125K injector
  - Increased capacity for larger pipe
- Enhanced Quick rig (EQR)
  - Quicker to rig up
  - Safer
- Additive Storage, Mixing & Pumping (AMP1600)
  - Purpose design and built
New Reel Trailer (BARTS)

BARTS MKII
- 23,000 ft 2 3/8 Coiled Tubing
- New CT operator house
- 125K injector
- Quad Drive Tractor
- 2 Axle Jeep
- GFW 246,000 lb
- 62 ft long reel trailer
- 92 ft 6 in long total length
- 12 Total Axles (including jeep)
- 12 ft wide
- 14 ft 8 in high
Enhanced QuikRig® (EQR) System

Unique Design

- Specifically developed for plug mill out operations

- 5 1/8 in 15K pressure control Equipment

- Quicker to rig up

- Safer to operate
Enhanced QuikRig® (EQR) System

- CTU hydraulic power pack
- Diesel storage tanks
- Generator set for reel trailer
- Hydraulic elevating mast
- PCE hoses and hose reels
- Riser support clamp
- Work platform
- Storage baskets
Enhanced QuikRig® (EQR) System

Unique Mast

- Docking trolley
- Locks in position

Pre-assembled WCE package:

- 4 1/16 in 15M dual stripper
- 30 ft 4 1/16 in 15M riser
- 4 1/16 in x 5 1/8 in 15M x-over
- 5 1/8 in 15M quad BOP
- 5 1/8 in 15M flow cross
- 5 1/8 in 15M dual BOP
Enhanced QuikRig® (EQR) System – Rig Up
EQR - Features and Benefits

Preassembled WCE, mast, and trolley system offers:

**FASTER** rig-up and rig-down of CT equipment
- Pre-assembled WCE
- Multi-coupler adapters
- Riser Clamping system

**SAFER** operations
- Reduction to number of crane lifts
- Reduction of working under suspended loads
- Reduction of dropped objects
- Reduction of pinch-crush points
- Reduction in manual handling
AMP™ 1600 Pumping Trailer

- Purpose Design and build for coiled tubing applications
- Combined LA storage/dosing, mixing and HHP pumping trailer
- Reduced footprint on location
- Reduced emissions
- Train Cat C-18/CX-35 P800/Eaton AT1202/ Hal HT400 @ 630 HHP ea
AMP™ 1600 Pumping Trailer

- Eliminates need for separate tote trailer
- Eliminates need for additional pump trailer
- Remote controlled dosing
- Reduces personnel on location
- 2 x 10 bbl mixing tanks with agitators
- 4 x 6x 5 centrifugal pumps
Conclusions

- Extended lateral wells are now reaching 22,000 ft
- Regardless of completion technique CT intervention is likely at some time
- Modeling is vital in predicting reach
- Post job matching will help validate models for future
- Significant improvements in reach can be gained by
  - Initial well design
  - Larger OD (stiffer) 2 3/8 “ strings
  - Use of friction reducing tools
  - Use of metal to metal friction reducers
Conclusions (continued)

- Significant improvements now made in surface equipment design
- Larger coil carrying capacity
  - 23,000 ft 2 3/8 in
- String carrying capacity now matching state rules
- New units are safer
- New units offer quicker rig up
- A paradigm shift will be required for future
THANK YOU
Who to Contact, Where to get more information

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