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Implementation of State of the Art Coiled Tubing Technologies in Challenging Completions

Thomas Dotson and
Eric Gagen

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Eric Gagen
Petroleum Engineer
Schlumberger

Eric Gagen is a Petroleum Engineer at Schlumberger with 20 years of experience in the oilfield, serving in a variety of technical and engineering management functions. His primary expertise is in reliably melding developing technologies with existing operations.

With Coil Tubing Services he was involved in organizing and expanding one of the largest independent coiled tubing companies in North America prior to their purchase by Smith. His primary expertise is in reliably melding developing technologies with existing operations.

Eric earned a Bachelor's Degree in Petroleum Engineering from Berkeley.

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Thomas Dotson founded TD Tools, Inc. in 2007. He is a design engineer and inventor with twenty years of experience in pumping services, tool design, research and development, and consulting.

He holds eight U.S. patents and has published three papers on sand jet perforating and cutting with the S.P.E.

Thomas earned a Bachelor of Science degree in Physics from Western Kentucky University.

Thomas Dotson
President
TD Tools, Inc.

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Paper No 184753

Overcoming Challenges of Stimulating a Deepwater, Frac-Pack-Completed Well in the Gulf of Mexico Using Coiled Tubing with Real-Time Downhole Measurements

Eric J. Gagen, Schlumberger, Alex D. Menkhaus, Technical consultant

Schlumberger

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Remedial and Stimulation Operations

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Land

- Thorough studies of basin and regional geology and lithography usually available
- Available comparisons
- Iterative approach possible; operational changes can occur
- More options for water production solutions

Deepwater

- Detailed well or reservoir information not as readily available as on land
- Uniqueness of each well
- Water production often costly or prohibited by regulations
- **High cost of failed stimulations**

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Well Situation

Well on a deepwater spar showed clear inflow impairment

- Several bullhead treatments were attempted with no improvement in performance or very short-term results.
- Thick frac-packed zones offer many fluid paths. Where did the acid go?
- Total depth is greater than 23,000 ft.
- Fish or debris was in the hole located near the lower portion of perforations.

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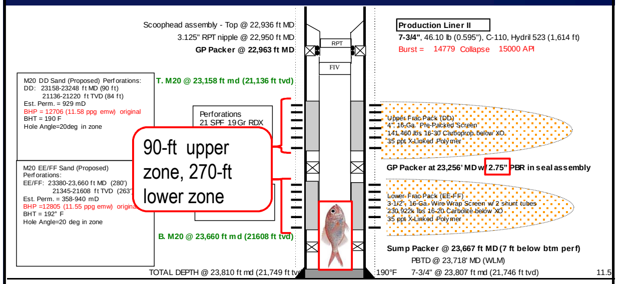
Well Situation



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Downhole Measurement with Fiber Optics

Key real-time CT measurements

- Distributed temperature sensing
  – Optimization of treatment fluid placement
- Gamma ray and CCL (depth)
  – Accrued depth control in deep wells
- Axial load on bottomhole assembly
  – Reduced risk of damage from fish or debris
- Downhole pressure inside and outside of tool
  – Enhanced control of screen jetting process

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Reservoir Information

Formation	
Formation	Sandstone
Perforated Section	23,158 – 23,248 ft MD 23,380 – 23,660 ft MD
Porosity	20 – 25 %
Permeability	100 – 800 mD
Average Reservoir Pressure @ Reference Depth	11,900 – 12,100 psi
Reference Depth	23,158 ft
Static Temperature @ Reference Depth	196 °F
Average Temperature Gradient	0.78996 °F/100 ft

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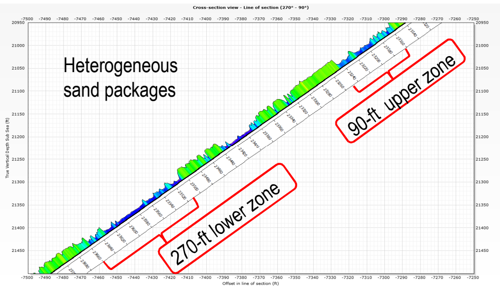
Gamma Ray



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Screen Cleaning

- High-pressure engineered rotary jetting nozzle
- Pump down CT at maximum rate
  - Actual 1.25 bbl/min
  - Dual injection bullhead through CT x production tubing annulus
- Minimum 1,500-psi pressure drop for optimum effect
- Monitoring of downhole pressure differential for real-time control of tool

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Downhole Technical Challenges and Solutions

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- BHA will see 13,600-psi minimum + injection pressure:
  - BHP 12,100 psi
  - Required pressure drop for effective screen jetting:1,500 psi
- Slack management of fiber optic carrier inside CT is difficult if pipe is worked at maximum depth.
- 2.875-in fiber optic tools rated for 15,000 psi cannot pass a 2.75-in restriction
- 2.125-in fiber optic tools are rated for 12,500 psi.
- Re-rated 2.125-in tool for 15,000 psi under these well conditions.
- CT string with new fiber 5,000' longer than needed for the well was used
  - Reduced risk of overdisplacing fiber.

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Sticky Tag at 23,700 ft on Downhole Item

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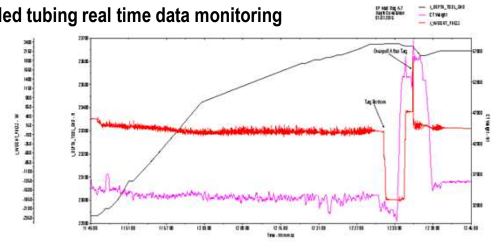
Coiled tubing real time data monitoring



Stuck pipe situation avoided with timely data

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Downhole Injection Pressure vs. Surface Pressure

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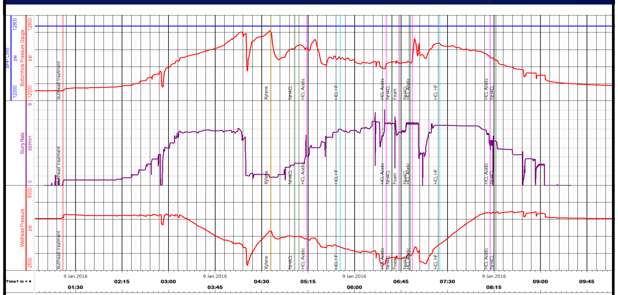

Surface pressure, and bottomhole pressure correspond poorly

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Acid Treatment Data Gathering

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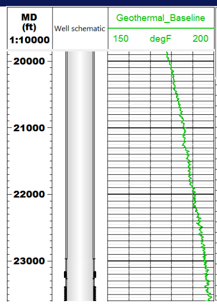
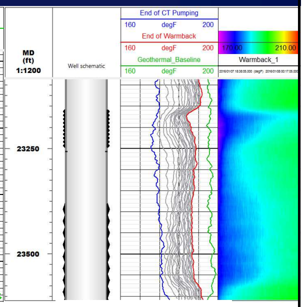


Pre injection thermal baseline



Post injection cooling

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171 bbl Ammonium Preflush Bullheaded Down CT

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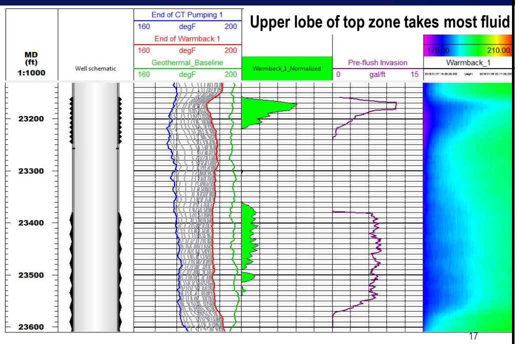
Upper lobe of top zone takes most fluid



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After First Acid Treatment

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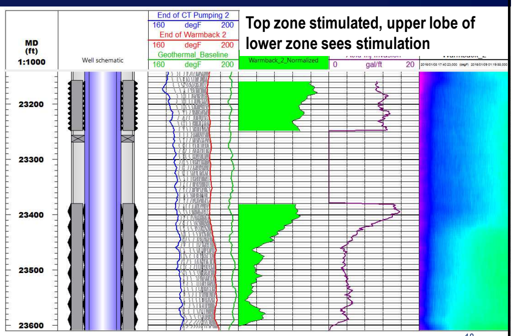
Top zone stimulated, upper lobe of lower zone sees stimulation



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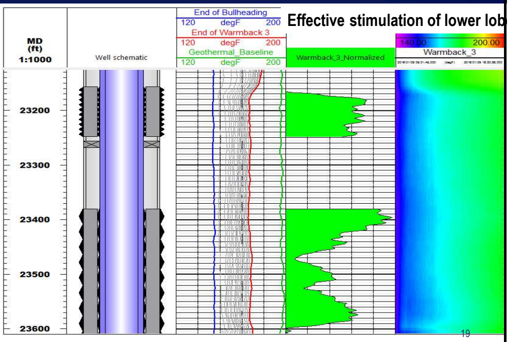
After Second and Final Acid Treatment



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Results

Successful acid treatment

- Production increased by 75% with increased choke pressure (4,000 to 7,000 BOPD)
- Injection profile was obtained from distributed measurements (unavailable from surface pressure data only).
- Treatment schedule was adjusted “on the fly” to optimize fluid placement based on profiling results.
- Higher tool pressure qualification proved reliable
- Neither the CT nor the BHA got stuck.

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Conclusions

- Tremendous effort by all field and operations staff
- Timely data interpretation
- Thank you for listening
- **Questions?**

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Sand Jetting Applications Throughout the Life of a Well-
From Drilling to Plug & Abandonment

Thomas Dotson
Founder and President, TD Tools, Inc.

Poll Question

How much experience do you have with abrasive jet perforating or cutting?

Poll Question

What geographic region are you from?

Background of Abrasive Jetting

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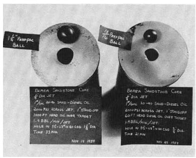
- Sand laden fluids were first used to perforate casing in 1939.
- Technical papers began to appear in the early 1960's.
- By the middle of 1961:
  - Between 1940 and 1961, over 5,000 perforating jobs were performed with a success rate of over 90%
  - Life of tooling during perforating was measured in minutes.
  - Fluid pressures high enough to cut casing were difficult to maintain with available pumps.
  - Explosive/shape charge perforators were emerging.



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Background of Abrasive Jetting

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- Interest in Sand Jet Perforating (SJP) renewed in the 1990's.
- More abrasive resistant materials and coatings are available today for tool construction and tool life is measured in hours and days.
- High pressure pumps that can withstand extended abrasive fluid run time are available.
- Advent of coiled tubing for reduced run time at greater depth.

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Technology Evolves

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- The Sand Does the Work
  - Once adequate pressure at the orifice is achieved, the amount of cutting performed is directly related to the quantity of sand.
  - Delivering a known quantity of sand to the orifice will produce predictable results.
  - Most sand jet jobs use too much sand.
  - Jobs need to be designed based on sand delivery.

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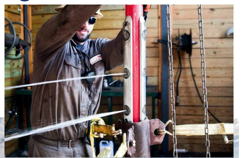
Technology Evolves

- Sand Size Matters
  - Larger, more massive sand cuts faster and farther.
  - Angular sand grains cut faster.
- Greater Acceleration Means Greater Cutting Force
  - Cutting with nitrogen foam
  - Decreased sand quantity
  - Decreased cutting time
  - Better circulation to surface

Technology Evolves

- Abrasive Jet Cutting with Nitrogen Foam



Technology Evolves

- Abrasive Jet Cutting with Nitrogen Foam

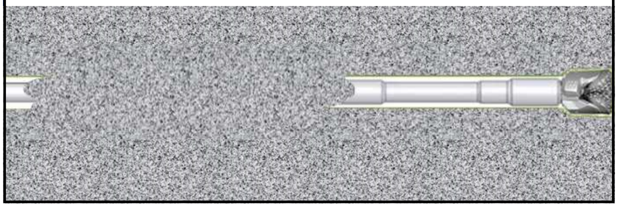
	Test 1	Test 2	Test 3
Sand Type	20/40	20/40	20/40
Fluid Pressure (psi)	2,500	2,500	2,500
N_2 Flow (cfm)	0	300	300
N_2 Foaming Agent	No	No	Yes
Fluid Flow (bbl/min)	1.5	1.3	1.3
Breakthrough time (min)	4:00	2:30	2:00
Total Pump Time	6:30	6:00	6:00
Sand Used at Breakthrough	75 pounds	50 pounds	50 pounds
Total Sand Used	100 pounds	100 pounds	100 pounds
Holes cut in casing	2	2	2

Technology Evolves

- Combine abrasive jetting with other technologies to achieve greater efficiency.
  – Manipulate flow through the tools to allow them to "piggyback" with the bottom hole assembly (BHA).
  – Use non-traditional fluid conveyance methods like drill pipe, resident production tubing, or small coil.
  – Build job specific tools to perform in difficult environments.
  – Design surface equipment to allow for reduced cost, smaller footprint well spreads.

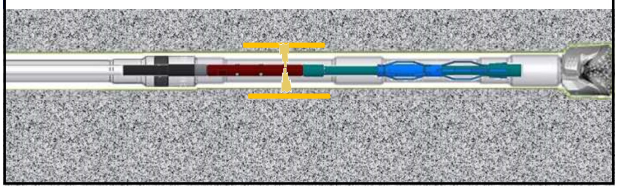
Drilling Opportunities

•When the drilling BHA becomes stuck as a result of:
•Differential Pressure
•Wall Sticking
•Stuck in the low side of the hole (improper cleaning)



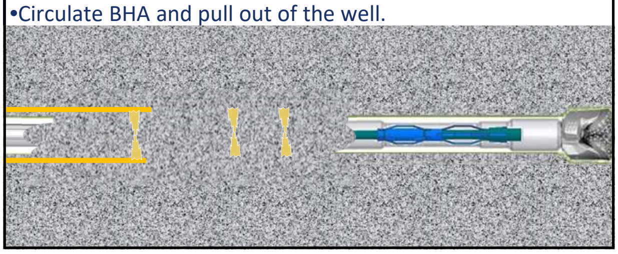
Drilling Opportunities

•Run in with abrasive jetting tool on small (1-1/4") coil
•Pump sand slurry.
•Cut perforations in drill pipe or drill collar.
•Circulate stuck drill pipe lubricant through perforations in drill pipe.



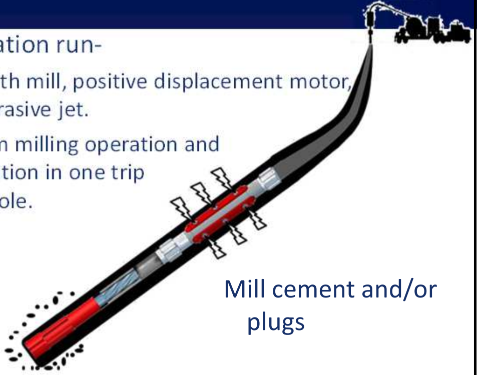
Drilling Opportunities

- Cut multiple sets of perforations in drill pipe.
- Circulate stuck pipe lubricant through holes in drill pipe to free the drill pipe.
- Circulate BHA and pull out of the well.



Completion Opportunities

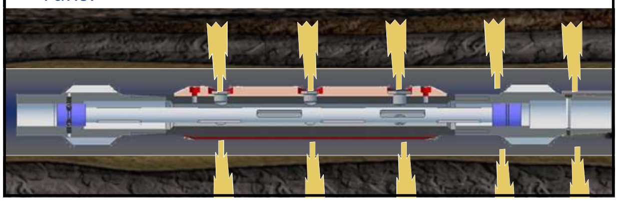
- Confirmation run-
  - BHA with mill, positive displacement motor, and abrasive jet.
  - Perform milling operation and perforation in one trip downhole.



Mill cement and/or plugs

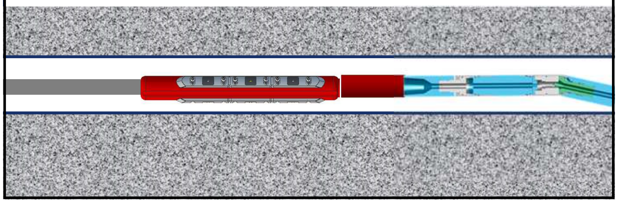
Completion Opportunities

- Use flow isolation to perform multiple tasks.
- Can be used with PDM and motor or plug setting tool.
- Save time and money with fewer coiled tubing runs.



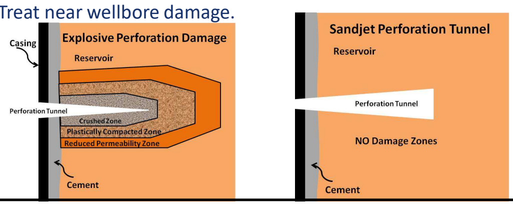
Multi-Lateral Completion

- Flow through tool to use hydraulic knuckle joint to locate specific lateral
- Drop ball to isolate perforator
- Increase pressure to open jets
- Perforate or acid treat with slimhole abrasive jetting tool

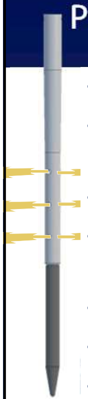


Reperforation Opportunities

- Extends efficiently into the reservoir by eroding the perforation channel. Lower temperature, lower pressure.
- Washes out a tunnel with a larger inner diameter for increased contact with the formation- 1 inch to 2 inch diameter tunnel.
- Eliminates compressive stresses on source rock.
- Better reservoir drain area. Use fewer shots per foot than explosive
- Treat near wellbore damage.



Production Opportunities



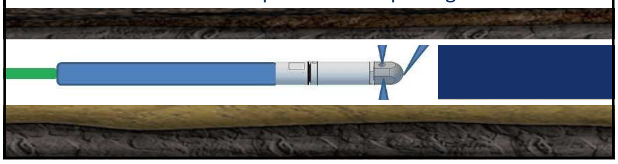
- For use in completed wells under rod pump
- Use resident production tubing to convey fluid
- Inject acid directly into perforation tunnels
- Significantly shorten time to perforate producing wells.
- Reperforate zones
- Complete new zones
- Slickline conveyed sand jet perforator

Production Opportunities

- Reperforation with slimhole tools on coiled tubing.
- Pass through restrictions or resident tubing.
- Pressure actuated jets can be opened from the surface.

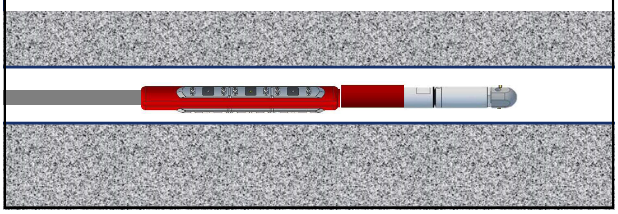
Production Opportunities

- Descaling of casing and production tubing.
- Rotating tool run with a very low concentration of sand to clean production tubing and casing
- Remove hard deposits accumulated over years of production
- Clear obstructions from perforation openings



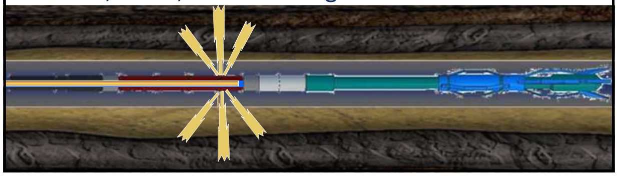
Descaling, Re-perforation, Treatment

- Flow through tool to use rotating abrasive jetting nozzle to descale tubing and casing
- Drop ball to isolate perforator
- Increase pressure to open jets



Intervention Opportunities

- Completely sever production tubing and drill pipe
- Run on coil or jointed pipe
- One trip
- Both rotating and indexing tools are available
- Smooth, clean, cut on tubing for easier retrieval



Intervention Opportunities

- Casing cutters
  - Fixed position jets- run on jointed pipe with power swivel.
  - Rotating- run on coiled tubing or jointed pipe
  - Indexing- run on coiled tubing or jointed pipe
  - Single or multiple strings

Plug & Abandonment Opportunities

- Cut holes to evaluate cement bond
  - Perforate casing and inject to determine bond
- Perforate and place cement through tubing or casing
- Single or multiple strings
- Perforate in multiple places and pump cement in one run downhole
- Cut tubing and/or casing for removal

Greater Efficiency & Safety

- Removal of explosives from the well location.
- Faster perforating or cutting availability.
  - No transportation restrictions
  - No licenses
  - No escorts in international locations.

Where do we go from here?

- Longer cutting time in one run
  - Harder tool materials- saphire, diamond
- Greater penetration length
  - Harder abrasive media- bauxite
  - Heavier abrasive media
  - Would allow more strings of casing to be cut at a single time
- Combination with more technologies

Thank you for your time!

Any questions?