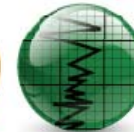




Weatherford[®]



Drilling



Evaluation



Completion



Production



Intervention

Modeling and Testing of Sand Jet Perforation as a Safer Alternative to Conventional Tubing-conveyed or E-line Explosives Techniques (IPS-12-19)

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Sand Jet Perforator System

- Introduction
- Product Development
- Prototype Perforator
- Laboratory Testing
- Advantages
- Applications
- Conclusion
- Questions



Introduction to Sand Jet Perforators (SJPs)

- **SJPs are down hole tools that utilize:**
 - High pressure abrasive laden fluids
 - Perforate casing, cement, and extend cavity into reservoir
- **SJPs are safer**
 - Tubing conveyed perforating
 - E-line perforating
- **SJPs run on jointed tubing or coiled tubing**
 - Depth
 - Temperature
- **SJPs can be customized for specific phasing**
 - Jet nozzle quantity
 - Orifice diameter



Product Development

Sand Jet Perforator CFD Erosion Modeling

- **CFD fluid simulation**
 - Sand particle motion analysis
 - Erosion modeling with dynamic mesh
- **Erosion is dependent on**
 - Fluid conditions
 - Sand particle, casing & cement properties
- **No structural analysis is required**



Product Development

CFD Erosion Modeling Configuration

Geometry

Nozzle Diameter (D_n)	0.125in & 0.188 in.
Nozzle length (L_n)	1.25in
Standoff distance from nozzle exit to casing (S_d)	0.08-0.35in
Casing OD/ID	4.5/3.5in

Flow Conditions

Flow Rate	26 - 43gpm
Perforation pressure	2500psi
Reference conditions	75degF & 14.5psi

Concrete Property

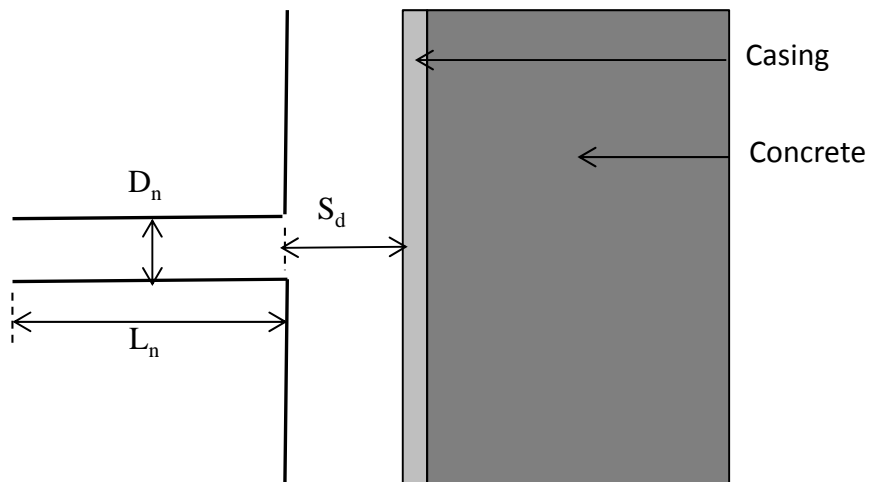
Compressive strength	7500psi
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Sand Properties

Concentration	1ppg
Size	20/40 Ottawa

Casing Material Properties

Weight	2.87lbm/in ³
Young's modulus	30M psi
Poisson's ratio	0.3
Yield stress	110ksi



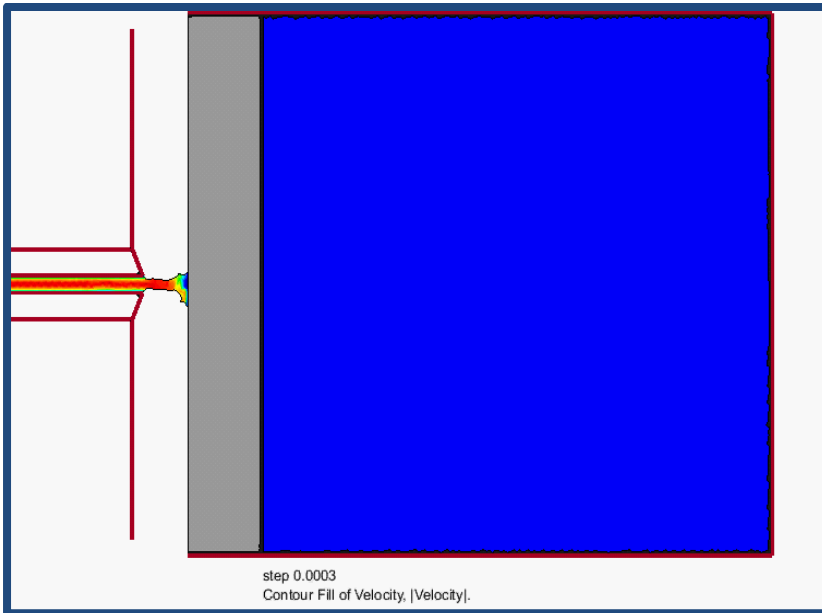
Schematic of the SJP model



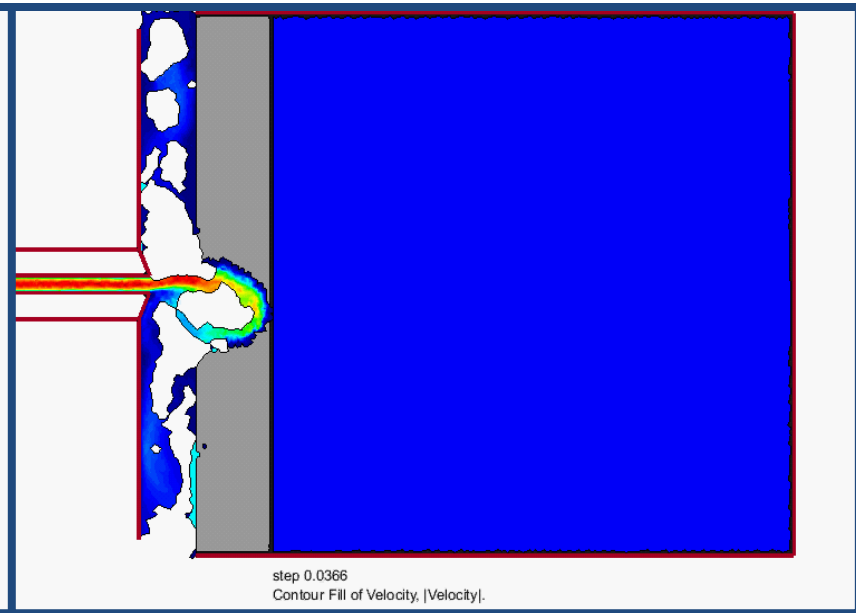
Product Development

CFD Erosion Modeling

1st Cut Through Casing



2nd Cut Through Cement



Prototype Perforator

- **Contains a flow actuated valve**
 - Allows function of hydraulic tools below when open
 - Allows high pressure abrasive perforating when closed
 - Switch flow is adjustable from 40–185gpm (1–4.5 bpm)
- **Enables multiple operations during a single trip**
 - Operates a motor for milling operations then perforates
 - Reactivates motor for well cleanout
 - Sets a plug then perforates



Laboratory Testing

- **Cutting fluid of density 9 lbs./gal**
 - Gel, water and 20/40 sand at 1ppg concentration
- **Minimum cutting pressure (2500 psi)**
- **Cutting time ranges from 15 to 30 min**
- **Two and Four nozzle patterns per respective orifice diameter**
 - 0.125" (3.175 mm)
 - 0.188" (4.763 mm)
- **Jet stand-off 3 times orifice diameter**
- **4.5 in. OD casing of P110 material (0.50" thickness)**



Laboratory Testing Results



OUTPUT DATA 4-1/2" OD WITH 1/8" NOZZLES	CUT # 1	CUT # 2	CUT # 3	CUT # 4
Cutting Time (min)	15	20	25	30
Avg. Flow Rate (gpm)	84	84	84	84
Avg. Perf. Pressure (psi)	2500	2500	2500	2500
Avg. Perf. depth (inches)	2.63	2.90	3.23	3.5



Laboratory Testing Results

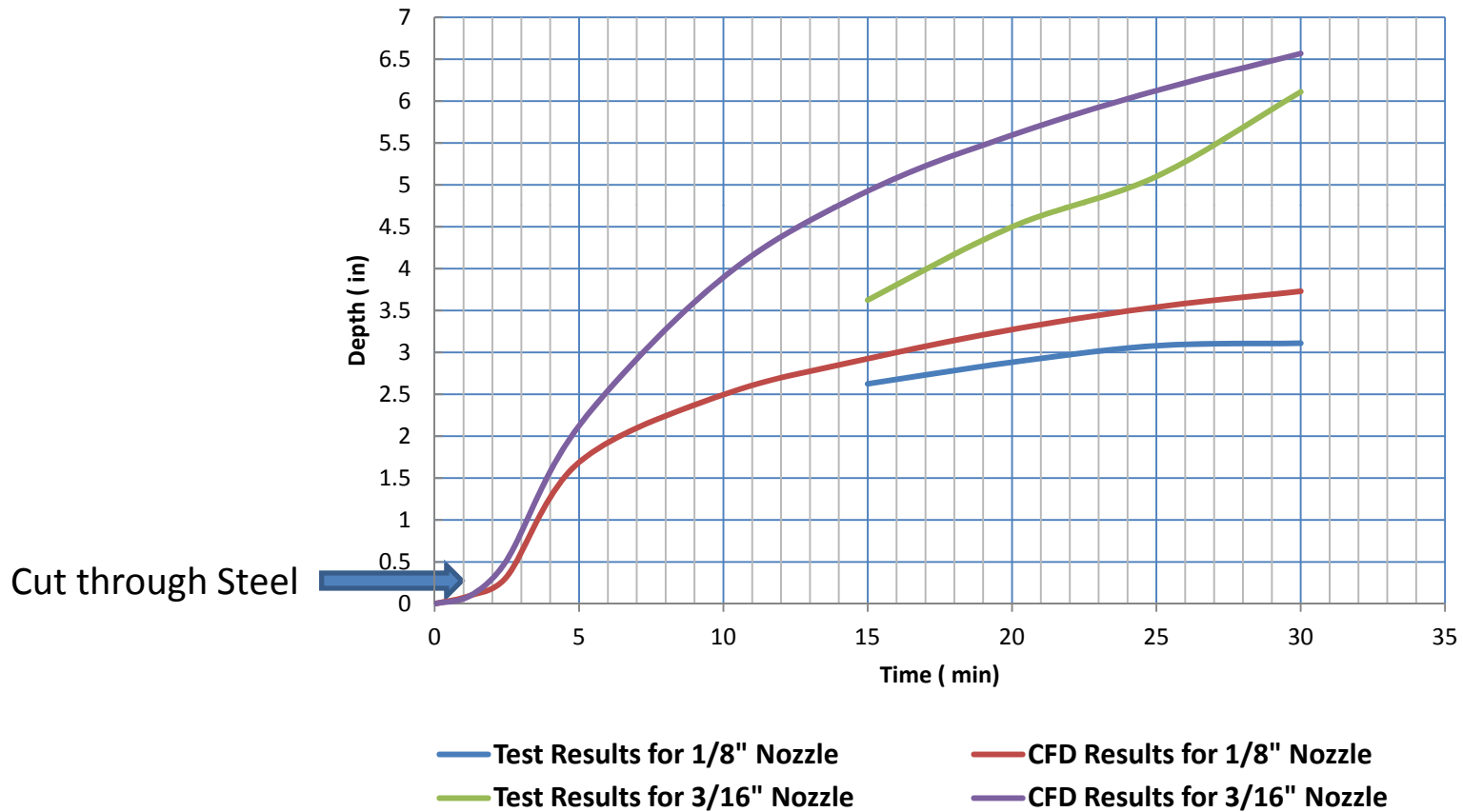


OUTPUT DATA 4-1/2" OD WITH 3/16" NOZZLES	CUT # 1	CUT # 2	CUT # 3	CUT # 4
Cutting Time (min)	15	20	25	30
Avg. Flow Rate (gpm)	84	84	84	84
Avg. Perf. Pressure (psi)	2500	2500	2500	2500
Avg. Perf. depth (inches)	3.5	3.75	4.25	6.25



Comparison of CFD & Test Results

CFD & Test Results of Cutting Depth vs. Time



Job Modeling Capabilities

Calculation Notes Imperial Metric

Surface

Gas: No Gas

Gas Flow: 0 scfm

Liquid Flow: 57 gpm

Choke: 0 psi

Loss Calibration: 100 %

Flows At Pump

Gas: 0.0 gpm

Total: 57.0 gpm

% Gas: 0 %

Pump Pressure: 4278 psi

Over Off-Bottom: 0 psi

Downhole

Output Torque: 1 ft-lbs

Annulus Pressure at Motor: 5345 psi

Pressure Loss in String: 2341 psi

dP over Motor: 0 psi

Total Flow into Motor: 57 gpm

% Gas into Motor: 0 %

Motor & BHA MacJet Sand Jet Fluid Well String Capillary

Sand Jet (Sand Mesh Size and Concentration affect Fluid tab)

Nozzle Count: 8

SJP OD: 3.125 in

Nozzle Diameter: 0.125 in

Formation Strength: 5500 psi

Sand Mesh Size: 40

Nozzle Velocity: 497 ft/s

Nozzle Losses: 2538.2 psi

Wall Perf Time: 53 seconds

Total Perf Time: 11 minutes

Pipe Grade: N-80

Pipe Thickness: 0.25 in

Perf Depth: 7 in

Sand Conc: 1 ppg

Impact Pressures

At Steel: 2642 psi

At Depth: 1749 psi

Power Curve Jetting Annular Velocities

perforation depth (inches)

Motor & BHA MacJet Sand Jet Fluid Well String Capillary

String OD: 2 in

String Section

	Length (ft)	Thickness (in)
1	6000	0.151
2	4075	0.129
3	4930	0.104
4		
5		

Volume: 1856.3 gals

Total Length: 15005 ft

Charge Time: 22 mins

Hydrostatic Pressure in String: 6389 psi

Motor & BHA MacJet Sand Jet Fluid Well String Capillary

Well Profile

	Angle (deg)	Vert Depth (ft)	Measured (ft)	TVD Total (ft)
1	0	12320	12320	14135.0
2	25	1815	2000	14320.0
3				

Live Well or Lost Circulation

Completion/Tubing

	Length (ft)	Bore (in)
1	14320	4
2		
3		
4		

Surface Temp: 80 F

Temp At Motor: 350 F

Current Measured Depth: 13200 ft

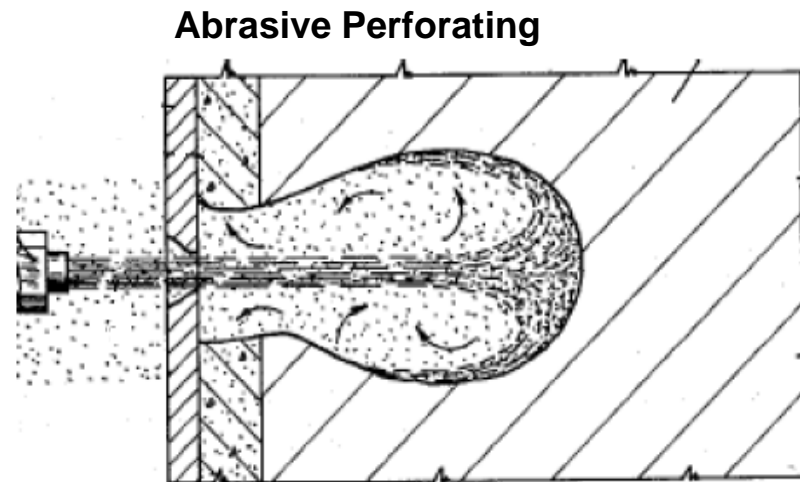
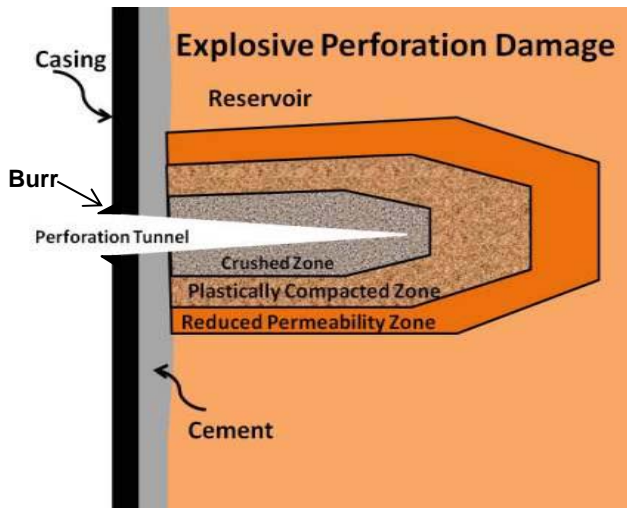
Current V. Depth: 13119 ft

Total Length: 14320 ft



Abrasive Perforating Advantages

- Reduces near wellbore friction effects → Better Frac
- Does not require explosives → Safer operations
- Does not induce formation damage → Lower breakdown pressures & increased permeability



Applications

- **Perforating new vertical and horizontal completions**
- **Re-perforating trouble zones**
 - Substantial formation damage
 - Production reduced due to the sediment build-up
- **Perforation and treatment of coal bed methane wells**
- **Integrated one-trip applications that utilize**
 - Bridge plugs for zonal isolation
 - Motors for well cleanout prior to perforating
- **Cut tubing or slotting**



Conclusions

- **CFD Erosion Modeling**
 - Pure CFD erosion modeling
 - P110 material and 7500 psi C.S.
- **Laboratory Testing**
 - CFD results correlates well with test results
 - Perforation depth of up to 6.25"
 - ½" thick P110 material and 7,500 psi C S. Concrete
- **Perforator Versatility**
 - Bridge plugs for zonal isolation
 - Motors for well cleanout prior to perforating
- **Safer because no explosives is required**
 - Eliminate concerns of misfiring or unexploded ordnance returning to surface
 - Reduce transportation cost
 - Eliminate military escort for international locations



Questions?

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