Company History


- **Dr. William Maurer** recipient of the SPE “Legends of Drilling”, advises BJD and has contributed greatly to the further refinement of BJD systems.

- **Zach Pearl**, Mechanical Engineer & Certified SolidWorks Associate, has been heading the additional technology developments in the recent years.

- **Dr. Claude Cooke** recipient of the SPE “Legends of Hydraulic Fracturing”, has been a major assistance in the development of BJD’s intellectual property portfolio.
What is Jet Drilling?

- Short radius laterals from vertical wellbores
- Lengths of 15’ to 100’
- Created by high pressure fluid
- Pretreatment for other services
  - Acidizing
  - Fracturing
  - And more
Jet Drilling Process

- Low cost enhancement technique
- Small footprint
- Higher production rates
- Decreased decline rates
Issues Hindering Jet Drilling Commercialization

- Jet Drilling Hard Rock
- Difficulty Cutting Casing
- Fluid Friction Losses in Coiled Tubing
- Inadequate Jet Power & Jet Bits
Patented Casing Cutting Systems

C-5 Ballcutter, C-5 Abrasive, & Window Section Milling (10 Laterals per Depth)
Key Design Points for Ball Cutter System (1” Milled Holes)

- Faster Cutting
- No Operator Finesse Needed
- Torque Monitoring
- Superior Flex Shaft
- Improved Cutter
- Multiple Job Conformation Techniques
- Tool Designs For 4.5”, 5.5”, & 7” Casings
- Wide Casing Grade Coverage
  - J-55 to P-110
Patented Jet Drilling Nozzle
Patented Jet Drilling Nozzle

Superior Drilling Performance!
(12) UNITED STATES PATENT

Buckman, Sr. et al.

(15) Patent No. US 6,668,948 B2
(14) Date of Patent: Dec. 30, 2003

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6,508,029 B2 12 2002 Dardick et al. 343-400
6,495,550 B1 10 2002 Luu 343-400

(57) ABSTRACT

A jet nozzle is provided for drilling holes through the earth, such as those bored around a well. The nozzle may include an orifice for discharging fluid to drive the nozzle forward and include a disk or other device having a plurality of slots to produce a swirling motion to fluid at the body of the nozzle. Swirling fluid is discharged from a front orifice and an orifice is placed forward of the front orifice to confine the swirling fluid in a radial direction.

23 Claims, 3 Drawing Sheets
Patented Jet Drilling Nozzle

What Makes BJD Different from other Jet Drilling Companies?

The BJD Super Nozzle and BJD tooling.

Vortex Full Front Cone

Self propulsion

BJD Patented Nozzle
BJD NOZZLE
JET DRILLING MECHANISM

Nozzle

Rear Jets

Front Jet

Swirling Fluid
BJD Nozzle Characteristics

- Full cone vortex

- Vortex cutting nozzles use effective shearing action to cut rock

- Rear thrusters create thrust and more contact area
Patented Jet Drilling Nozzle

Rear Jets Make a Large Star Pattern Increasing Surface Area 10 Fold!!
BJD Nozzle Advantages

- No Moving Parts
- Higher Consistency & Reliability
- Effective Shearing Action
- Larger Hole Diameters
- Drills Harder Rock in Deeper Wells
- Improved Economics
- Self-Propelled Rear Jet Cuts Larger Channels
BJD High Horsepower Nozzle

Increases hydraulic power 3 to 4 fold

Increases drilling rates 30 to 80 fold

Able to Drill Harder & Lower Permeability Rocks

Larger Diameter Holes and Larger Slots
# Jet Bit Penetration

in 16% Porosity, 69mD, 3500 psi Berea Sandstone

<table>
<thead>
<tr>
<th>BJD Jet Bits</th>
<th>Flow (GPM)</th>
<th>Penetration Rate (ft/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>834L</td>
<td>9</td>
<td>11</td>
</tr>
<tr>
<td>834C</td>
<td>16</td>
<td>37</td>
</tr>
<tr>
<td>High Flow (HF)</td>
<td>31</td>
<td>200</td>
</tr>
<tr>
<td>Xtreme Flow (XF)</td>
<td>37</td>
<td>900</td>
</tr>
</tbody>
</table>

**TABLE 1**
Pick the Right Nozzle for Your Application!
Pressure Loss Across Tubulars

Flow rate (GPM)

Pressure Loss (PSI)

- 50ft of 3/8" Flex Hose
- 50ft of 1/2" Flex Hose
- 6500ft of 5/8" CT
- 6500ft of 3/4" CT
- 6500ft of 1" CT
Nozzle Pressure Calculation

Medium Flow Nozzle

Flow rate := 28.5 · gpm

\[ D := 0.308 \text{in} \]
\[ \rho := 1000 \frac{\text{kg}}{\text{m}^3} \]
\[ \mu := 6.556 \times 10^{-4} \frac{\text{lb}}{\text{ft} \cdot \text{s}} \]

Velocity of water := \( \frac{\text{Flow rate}}{\text{Nozzle area}} \)

Water density is 1000 kg/m^3
Water viscosity at 70 F is 6.556 x 10^{-4} lb/ft^2*S

\[ V_{\text{avg}} := \frac{\text{Flow rate}}{\pi \left( \frac{D}{2} \right)^2} \]
\[ V_{\text{avg}} = 37.407 \frac{\text{m}}{\text{s}} \]

Reynolds Number

\[ C_d := 0.76 \]
\[ \text{Re}_{\text{num}} := \frac{\rho \cdot V_{\text{avg}} \cdot D}{\mu} \]

Re < 2300 laminar flow
2300 < Re < 4000 transitional flow
Re > 4000 turbulent flow

\[ \text{Re}_{\text{num}} = 299946 \]

Pressure of nozzle := \( \left( \frac{\text{Flow rate}}{\text{Nozzle area} \cdot C_d} \right)^2 \cdot \rho \cdot \left( 1 - \beta^4 \right) \frac{2}{2} \)

Pressure of nozzle = 10000 · psi
Buckman Jet Drilling
Dual Coil Applications

Acid Jet Drilling
New Jetting Fluids

EARTHBORN CLEAN “UltraSeries”

- Replaces HCL Acid
- Safe and non reactive to equipment
- Better Permeability Result than HCL
  - Core Flood Tested at University of Kansas by Dr. Barati

www.earthbornnclean.com
Jet Drilling Units
(Coiled Tubing)

High Pressure Jointed Pipe

SHALLOW UNIT

CAPILLARY UNIT

STANDARD CT UNIT
Catenary Drilling Method

- As the jet nozzle progresses, the coil tubing between the CT reel and the horse head will tighten and increase in height. (x is less)

- The operator controls the CT reel at a rate that keeps slack between the CT reel and the horse head.

- When CT reel rate exceeds the nozzle drilling rate the slack in the coil increases and the CT operator should slow the CT reel’s rate.
Shallow Unit

½” ID High Pressure Hose
2,000 Ft & Less

37,000 PSI Rupture Pressure
Capillary Coiled Tubing Unit

5/8” Stainless Steel Tubing

6,500 ft & Less
Standard Coiled Tubing Unit

1 ¼” Steel Tubing

12,000 ft & Less
Jet Drilling Enhancements
### Flow Increase

**Radial Flow Equation**

\[
\text{FlowRate}_{\text{BOPD}} = \frac{2k \cdot h \cdot (p_e - p_w)}{\mu} \cdot \ln \left( \frac{r_e}{r_w} \right)
\]

- \(k\) = rock permeability
- \(h\) = formation thickness
- \(p_e\) = fluid pressure at outer boundary
- \(p_w\) = fluid pressure in wellbore
- \(\mu\) = fluid viscosity
- \(r_e\) = effective drainage radius
- \(r_w\) = wellbore radius
- BOPD = barrels of oil per day

**Calculated Flowrate Increase (1000 FT Drainage Radius)**

<table>
<thead>
<tr>
<th>Lateral Well Length (FT)</th>
<th>Stimulation Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>5</td>
<td>1.37</td>
</tr>
<tr>
<td>10</td>
<td>1.58</td>
</tr>
<tr>
<td>20</td>
<td>1.86</td>
</tr>
<tr>
<td><strong>40</strong></td>
<td><strong>2.26</strong></td>
</tr>
<tr>
<td>60</td>
<td>2.58</td>
</tr>
<tr>
<td><strong>100</strong></td>
<td><strong>3.15</strong></td>
</tr>
<tr>
<td>150</td>
<td>3.83</td>
</tr>
<tr>
<td><strong>200</strong></td>
<td><strong>4.51</strong></td>
</tr>
<tr>
<td>300</td>
<td>6.03</td>
</tr>
</tbody>
</table>
Original Production without laterals is 10 BOPD.
Dickinson Published Results

SPE 4431069

Texaco Field - Wyoming
Caddo Field - Louisiana
(Near Wellbore Damage) - Venezuela
Croatia
Kern Co. - California
Chevron 378

Original Production 1  Light Oil Production w/ Laterals  Heavy Oil Production w/ Laterals
Some KY Enhancements

BOPD

Pre Oil Production
Post Oil Production

Russel #2
Tar Springs
Fairchild
Coniferous
Carl Hill
Sunny Brook
Spillman #1
Coniferous
Smith #1
Big Lime
Tarter #2
Coniferous
Articles Published on Jet Drilling
“Coiled-Tubing Radials Placed by Water-Jet Drilling”

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Dykstra, H.
Nordlund, R
Dickinson, R.

Field Results, theory, and Practice, SPE 26348, 68th SPE/ATCE, Houston, Texas. October 3-6, 1993.
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Steve Elliott
Project Development Manager
Tethys Petroleum

“Hydrajetting advances improve Saudi Aramco’s gas well performance.”

Mark Thomas

Thomas, Mark. “Jetting Technology Improves Production.” E&P Magazine September 2011
“Low-cost radial jet drilling helps drilling revitalize 40-year-old oilfield.”

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"A new approach to drilling......"

Buckman, William G.
Maurer, William C.
Pearl, Zachary
Addressed Issues Hindering Jet Drilling Commercialization

- Not Having a Effective Jet Nozzle
  - BJD Nozzles are the Most Effective in the Market

- Non Reliable Casing Cutting
  - BJD Has a Refined Case Cutting System

- Fluid Friction Loss in Coiled Tubing
  - BJD Utilizes Larger Diameter CT

- Too Low Horsepower for Harder Rock
  - BJD has High Horsepower Jet Nozzles
CONCLUSION

BJD has Developed Valuable Patented Jetting Technologies.
Economically Enhancing Oil/Gas Production
Short Radius Lateral Jet Drilling with Environmentally Responsible Technology

Licenses are still available for many regions
- Self use • Non-exclusive license • Exclusive license

www.buckmanjetdrilling.com
William G. Buckman, Sr., Ph.D. • (270) 975-4233
e-mail: bbuckman@buckmanjetdrilling.net

The heart of the BJD system is the patented jet bit Rock Scorpion™ which swirls the fluid ahead of the bit allowing the bit to drill much harder rock at rates up to 10 times faster than competitor jet bits.

The Rock Scorpion™ has the potential to revolutionize lateral jet-drilled completions. Our jet bit has an economic impact in the drilling and well-services industry similar to that of the roller cone bits in the 1930s and PDC bits in the 1980s.
H.P. Pipe

- Use workover rigs in shallow wells, CT in deeper wells
- Simplifies drilling operation
- Lower cost in shallow wells (200 to 1500 meters)
- CT rig better in deeper wells (1500 to 3000 meters) due to longer trip time

1” or 1 ¼” Macaroni Tubing
# Pipe Data

**Connection:** CS®
**Casing/Tubing:** TUB

## Pipe Body Data

<table>
<thead>
<tr>
<th>Geometry</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal OD</td>
<td>1.315 in.</td>
<td>Nominal Weight</td>
<td>2.25 lbs/ft</td>
<td>Standard Drift Diameter</td>
</tr>
<tr>
<td>Nominal ID</td>
<td>0.957 in.</td>
<td>Wall Thickness</td>
<td>0.179 in.</td>
<td>Special Drift Diameter</td>
</tr>
<tr>
<td>Plain End Weight</td>
<td>2.17 lbs/ft</td>
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<td></td>
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</tbody>
</table>

## Performance

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Body Yield Strength</td>
<td>70 x 1000 lbs</td>
<td>Internal Yield</td>
<td>26200 psi</td>
<td>SMYS</td>
</tr>
<tr>
<td>Collapse</td>
<td>25860 psi</td>
<td></td>
<td></td>
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</table>

## CS® Connection Data

<table>
<thead>
<tr>
<th>Geometry</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Connection OD</td>
<td>1.600 in.</td>
<td>Connection ID</td>
<td>0.864 in.</td>
<td>Threads per in.</td>
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<tr>
<td>Make-Up Loss</td>
<td>2.220 in.</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

## Performance

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tension Efficiency</td>
<td>100 %</td>
<td>Joint Yield Strength</td>
<td>70 x 1000 lbs</td>
<td>Internal Pressure Capacity</td>
</tr>
<tr>
<td>Compression Efficiency</td>
<td>80.0 %</td>
<td>Compression Strength</td>
<td>56 x 1000 lbs</td>
<td>Bending</td>
</tr>
<tr>
<td>External Pressure Capacity</td>
<td>25860 psi</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Make-Up Torques

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>400 ft-lbs</td>
<td>Target</td>
<td>450 ft-lbs</td>
</tr>
<tr>
<td>Maximum</td>
<td></td>
<td>Maximum</td>
<td>500 ft-lbs</td>
</tr>
</tbody>
</table>

**Size:** 1.315 in.
**Wall:** 0.179 in.
**Weight:** 2.25 lbs/ft
**Grade:** P110
**Min. Wall Thickness:** 87.5 %
Casing Cutting With High Pressure Tubing

- Run diverter to bottom on production tubing
- Run PDM motor and Ball Cutter to bottom on HP tubing
- Cut hole in casing with ball cutter and PDM motor (500 psi)
- Rotate diverter in 90 degree increments until four holes cut in casing
- Pull PDM and Ball Cutter from the well
Jet Drilling With High Pressure Tubing

- Run HP tubing is to bottom with a 30 to 60 feet HP hose and nozzle on bottom.
- Pump water through nozzle at 10,000 to 12,000 psi.
- Drilling by lowering HP tubing at a controlled drilling rate.
- Drill the lateral to the desired distance.
- Use a downhole filter to prevent plugging nozzles.
Jet Drilling With High Pressure Tubing

- Rotate diverter in 90 degree increments to drill four laterals
- Pull diverter or move to another kickoff point and drill four more laterals
- Repeat process until all laterals are drilled