Buckman Jet Drilling

August 2013
ICoTA Lunch & Learn

Presented by
Dr. William G. Buckman
Dr. William C. Maurer
& Zach Pearl

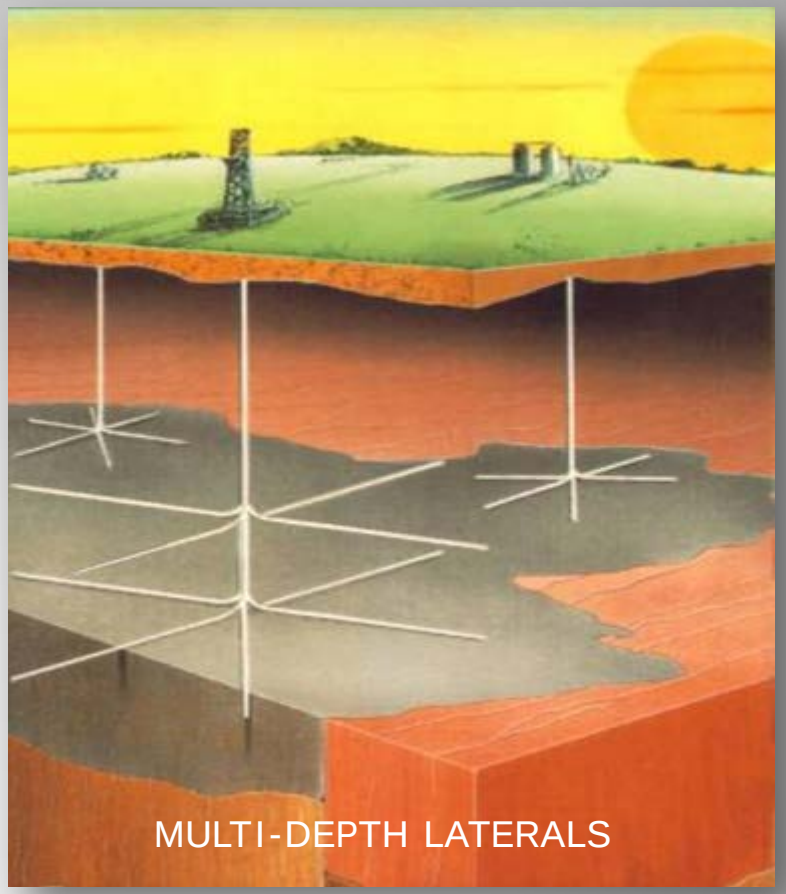
BJD

Company History

- **Dr. William G. Buckman Ph.D.**, Physics Professor Emeritus, founded BJD in 2000 .
- **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?

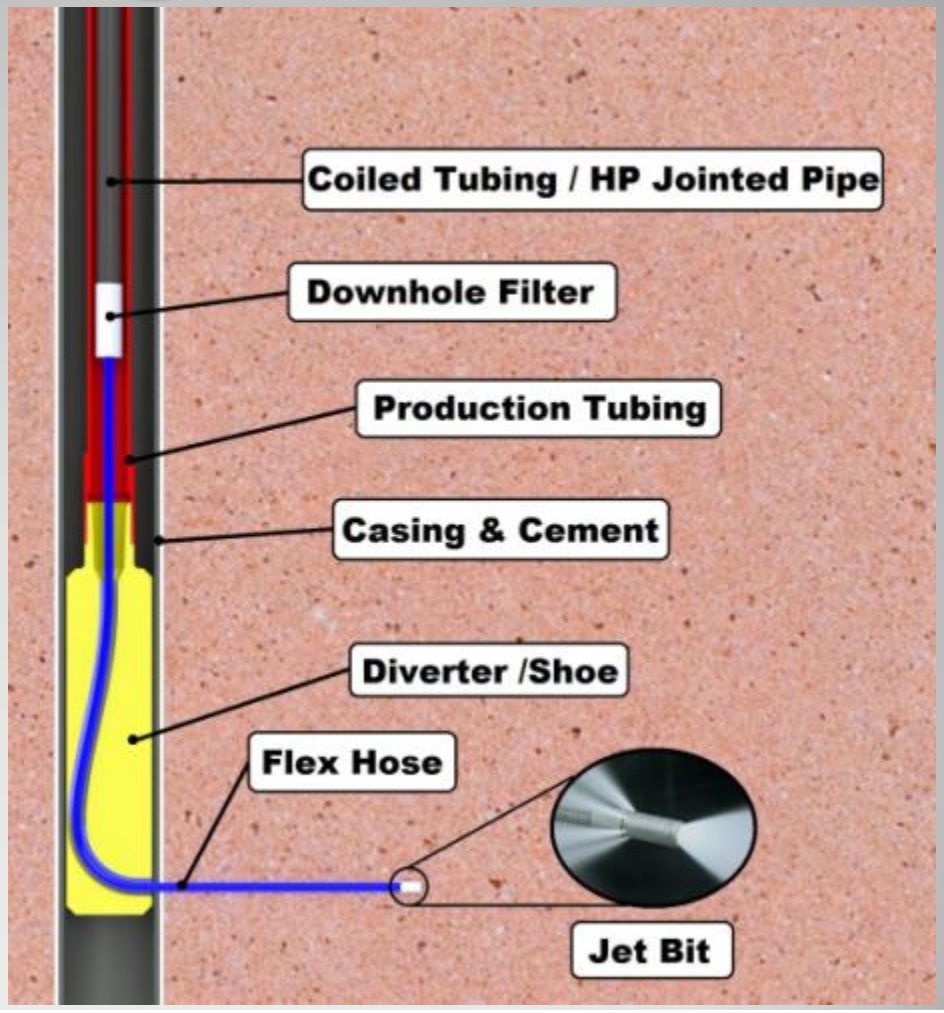
- Short radius laterals from vertical wellbores
- Lengths of 15’ to 100’
- Created by high pressure fluid
- Pretreatment for other services
  - Acidizing
  - Fracturing
  - And more



MULTI-DEPTH LATERALS

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,&

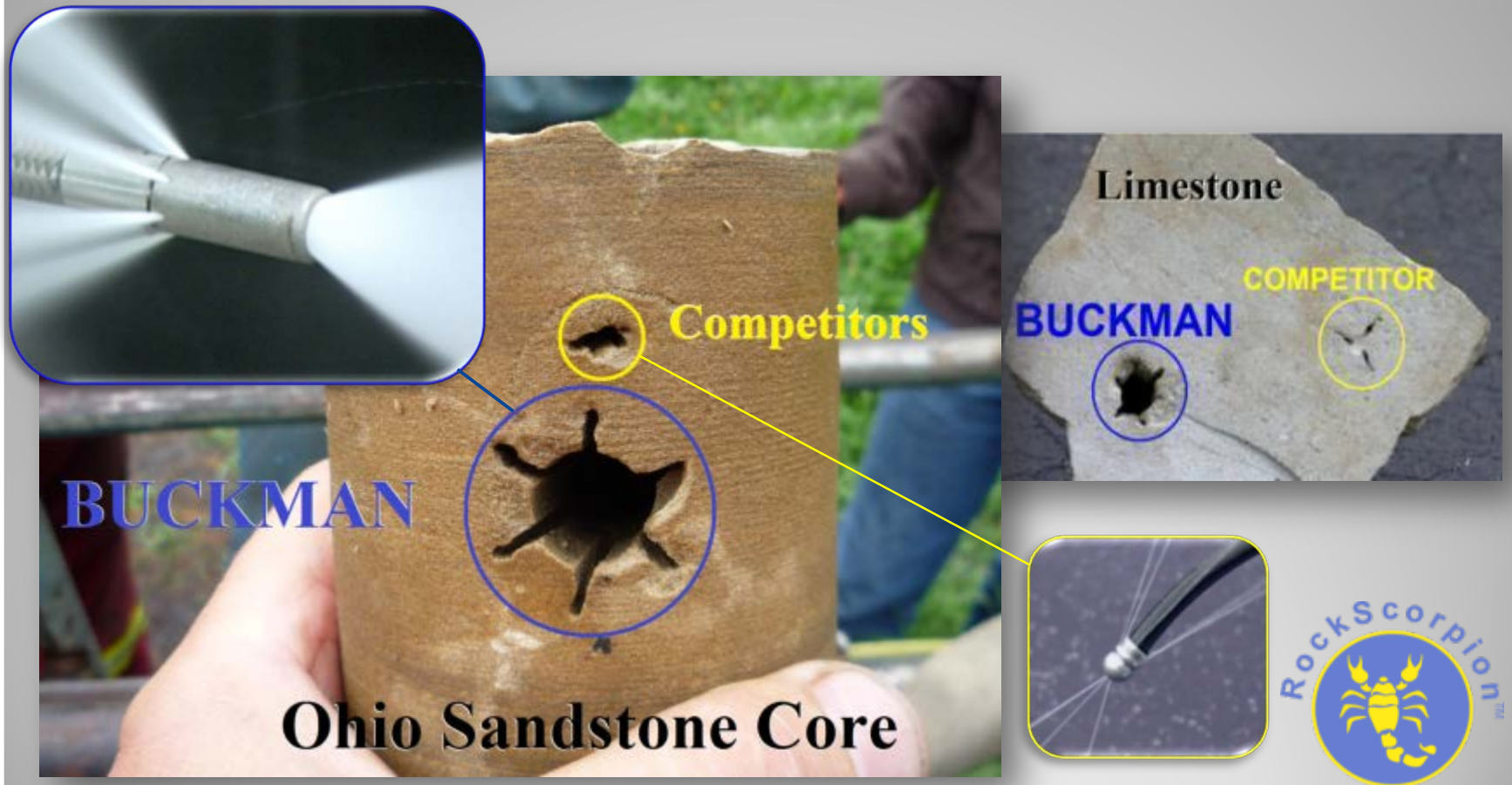
Window Section Milling
(10 Laterals per Depth)

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

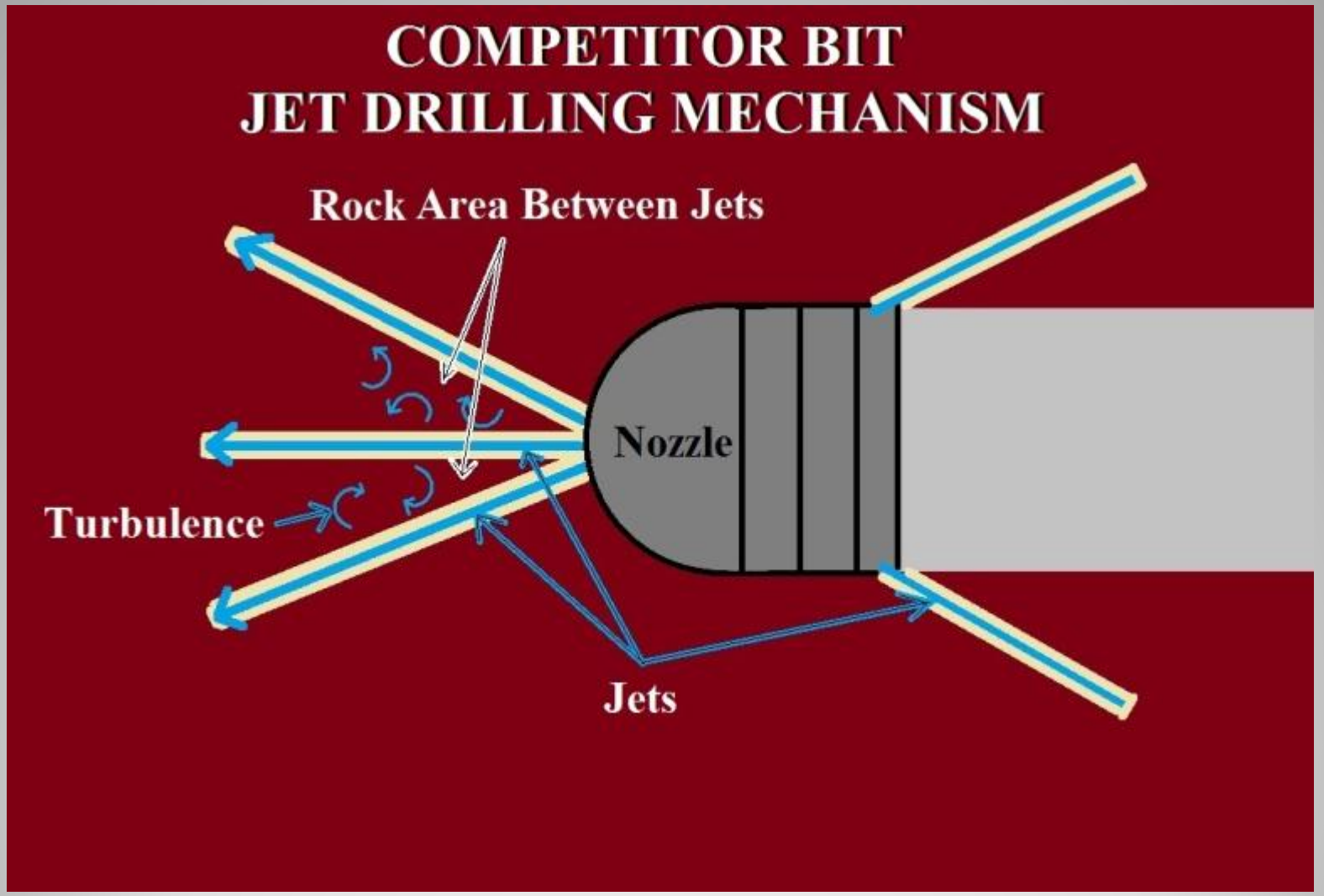
Patented Jet Drilling Nozzle

Patented Jet Drilling Nozzle



- Superior Drilling Performance!

COMPETITOR BIT
JET DRILLING MECHANISM



BJD

Nozzle Patents

CA 2480249 2004-10-06

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 October 2003 (23.10.2003)

PCT

(10) International Publication Number
WO 03/087522 A2

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Un organisme d'Industrie Canada

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(12) DEMANDE DE BREVET CA

(86) Date de dépôt PCT/PCT Filing Date: 2003/04/09

(12) STANDARD PATENT
(19) AUSTRALIAN PATENT OFFICE

(11) Application No. AU 20

(54) Title
Nozzle for jet drilling and associated method

(51) International Patent Classification(s)
E21B 7/08 (2006.01) *E21B 7/18* (2006.01)

(21) Application No: 2003226330 (22) Date of Filing: 200

(87) WIPO No: WO03/087522

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(43) Publication Journal Date: 2003.12.04
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(74) Agent / Attorney
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(56) Related Art
US 4787465 A
US 6293684 B1
US 5862871 A
US 5853056 A

US006668948B2

(12) **United States Patent**
Buckman, Sr. et al.

(10) **Patent No.: US 6,668,948 B2**
(45) **Date of Patent: Dec. 30, 2003**

(54) **NOZZLE FOR JET DRILLING AND ASSOCIATED METHOD**

(75) Inventors: **William G. Buckman, Sr.**, Bowling Green, KY (US); **Thomas L. Dotson**, Bowling Green, KY (US); **Michael D. McDaniels**, Glasgow, KY (US); **Wendell S. Bell**, Glasgow, KY (US)

(73) Assignee: **Buckman Jet Drilling, Inc.**, Bowling Green, KY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/119,790**

(22) Filed: **Apr. 10, 2002**

(65) **Prior Publication Data**

US 2003/0192718 A1 Oct. 16, 2003

(51) **Int. Cl.**[7] **E21B 7/08**; E21B 43/114

(52) **U.S. Cl.** **175/61**; 175/61; 175/424; 175/393; 299/17; 239/464; 239/463; 239/497

(58) **Field of Search** 175/67, 424, 61, 175/393, 340, 45; 239/463, 498, 494, 492, 490, 483, 497; 299/17

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,047,380	A *	9/1977	Hellerman	60/39.461
4,570,860	A *	2/1986	Aprea et al.	239/478
4,664,314	A *	5/1987	O'Brien et al.	239/469
4,715,538	A	12/1987	Longnot	239/268
4,787,465	A *	11/1988	Dickinson et al.	175/67
4,790,394	A	12/1988	Dickinson, II et al.	175/61
4,842,197	A *	6/1989	Simon et al.	239/5
4,852,668	A	8/1989	Dickinson, II et al.	175/67
4,869,602	A *	11/1990	Schell	239/298
5,067,657	A *	11/1991	Young et al.	239/403
5,072,796	A	12/1991	Shea et al.	175/340
5,170,946	A	12/1992	Rankin	239/590
5,255,750	A *	10/1993	Wilkes et al.	175/61
5,294,057	A	3/1994	Corlett	175/67
5,353,599	A *	10/1994	Johnson et al.	60/748
5,542,486	A *	8/1996	Corlett	175/424
5,626,508	A	5/1997	Rankin et al.	451/102
5,769,164	A	6/1998	Archer	166/222
5,782,414	A	7/1998	Nathanson	239/589
5,799,258	A	7/1998	Akin et al.	239/590
5,853,056	A *	12/1998	Landers	175/424
5,862,871	A	1/1999	Corlett	175/340
5,897,062	A *	4/1999	Ennemo et al.	239/590
6,065,683	A	5/2000	Akin et al.	239/5
6,189,629	B1	2/2001	McLeod et al.	175/67
6,206,112	B1	3/2001	Dickinson, III et al.	175/67
6,263,984	B1	7/2001	Buckman, Sr.	175/67
6,551,095	B2 *	4/2003	Tielken et al.	431/8

OTHER PUBLICATIONS

"Horizontal Radial Drilling with a Swirling Water Jet"; *Water Jet Technology in Petroleum Engineering*, Shen Zhonghou, Pet. Univ. Press, 1997, Chap. Six, pp. 115–149).
Aqua–Dyne brochures "Nozzles", 2001.
"Clonical Water Jet Drilling," Dickinson, W., Wilkes, R.D., and Dickinson, R.W. Proceeding of the Fourth U.S. Water Jet Conference, Aug. 26–28, 1987 at the University of California, Berkeley. Water Jet Technology Association. www.wjta.org.
"The Ultrashort–Radius Radial System," Dickinson, W., Anderson, R.R., Dickinson, R.W. Society of Petroleum Engineers paper 14804 (1989).

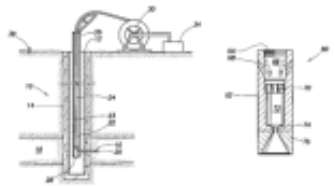
* cited by examiner

Primary Examiner—David Bagnell
Assistant Examiner—T Shane Bomar
(74) *Attorney, Agent, or Firm*—Baker Botts L.L.P.

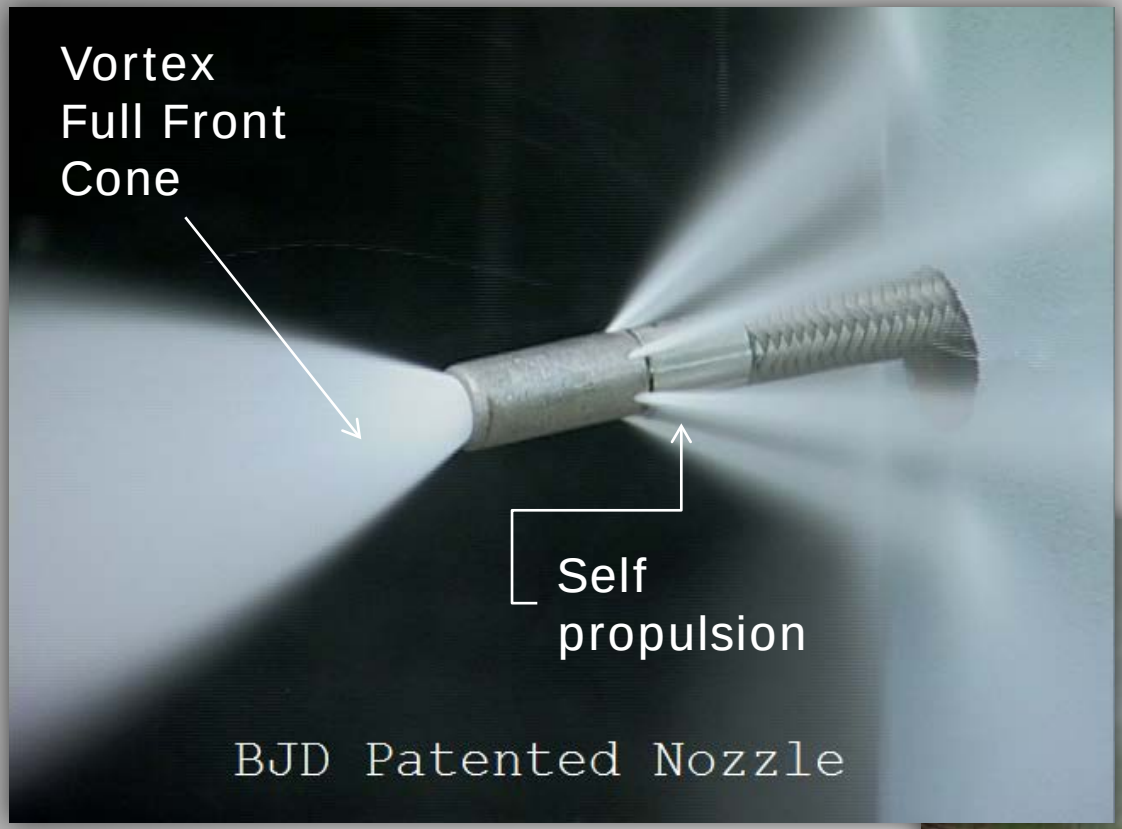
(57) **ABSTRACT**

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

23 Claims, 3 Drawing Sheets

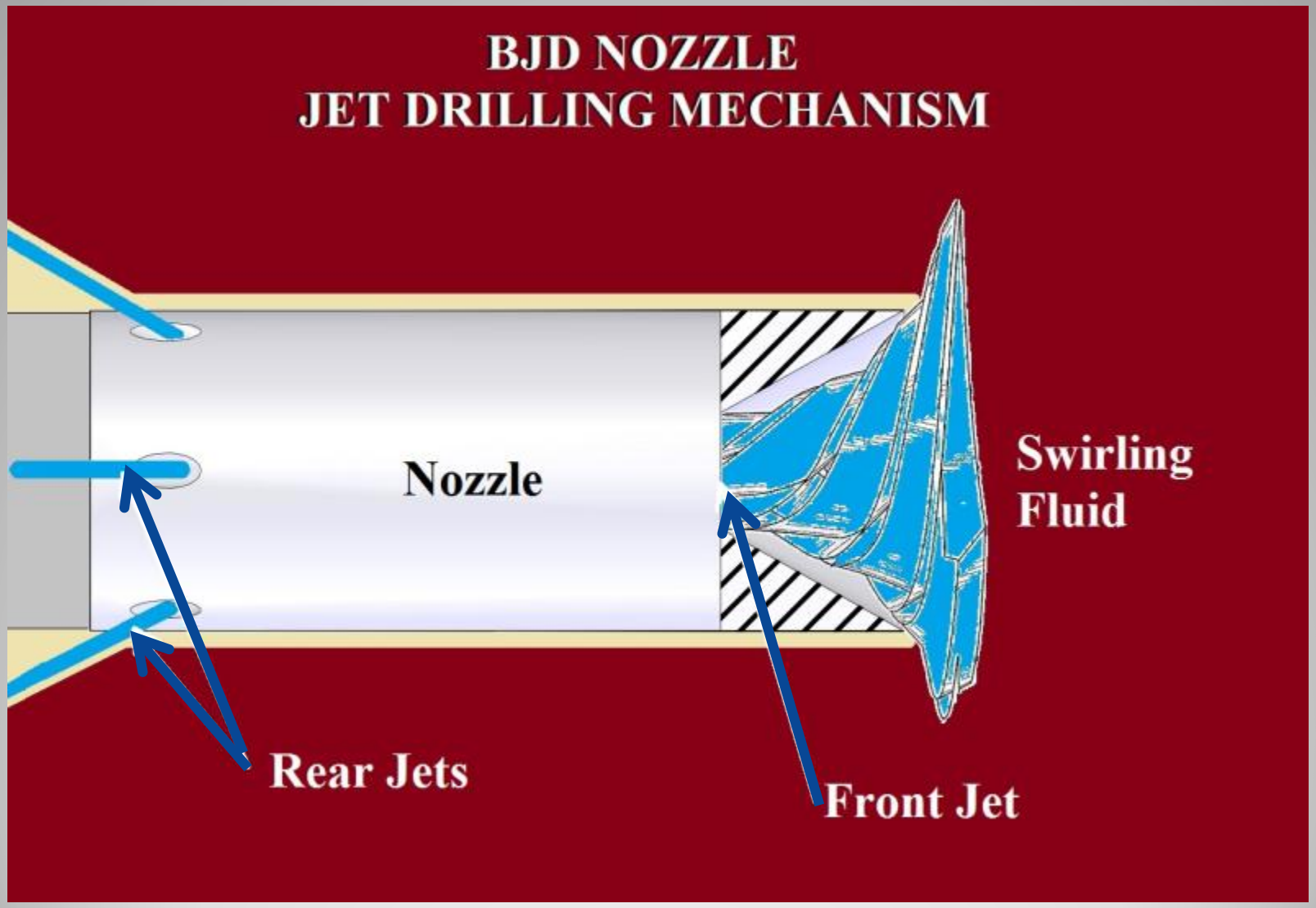


Patented Jet Drilling Nozzle



What Makes BJD Different from other Jet Drilling Companies?

The BJD Super Nozzle and BJD tooling.


BJD NOZZLE
JET DRILLING MECHANISM
Nozzle
Swirling
Fluid
Rear Jets
Front Jet

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

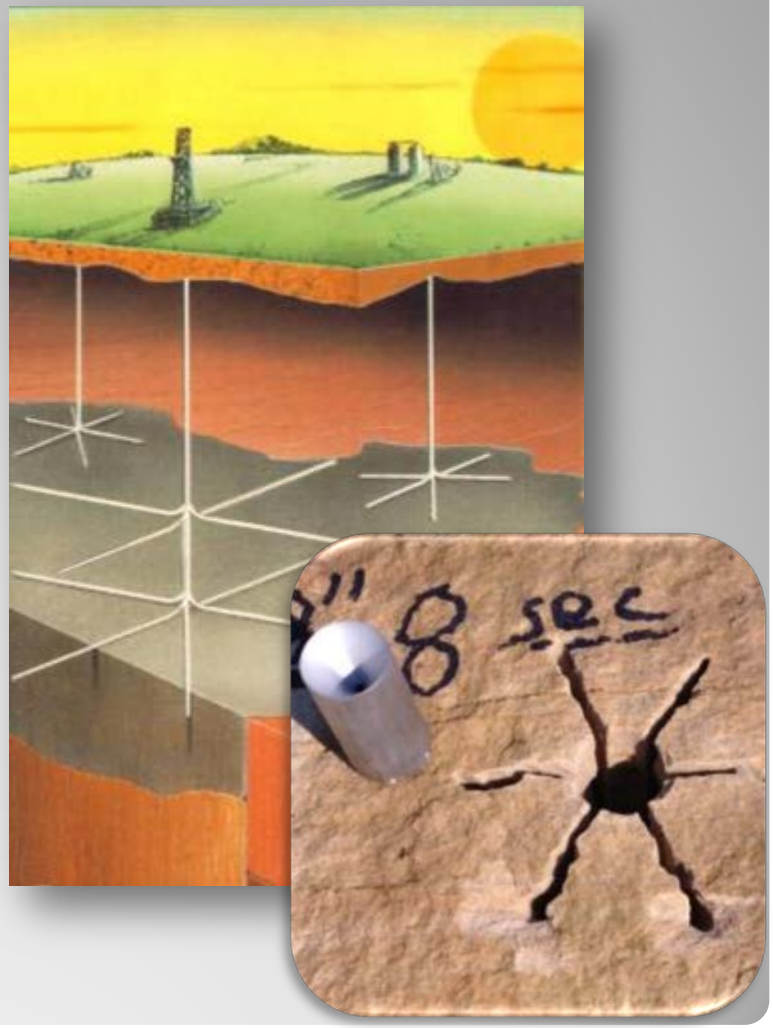
BJD High Horsepower Nozzle

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



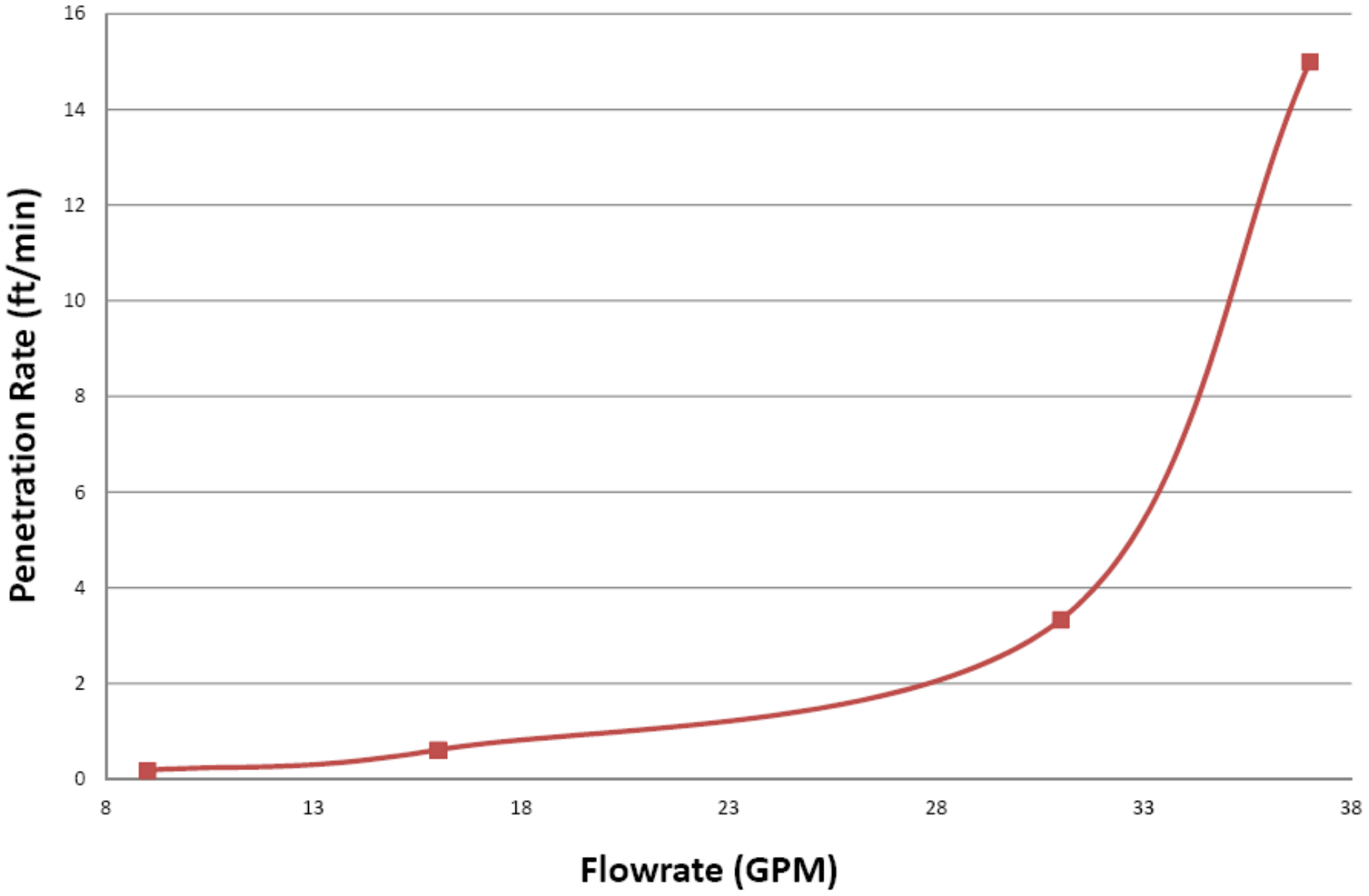
Jet Bit Penetration

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

BJD Jet Bits	Flow (GPM)	Penetration Rate (ft/hr)
834L	9	11
834C	16	37
High Flow (HF)	31	200
Xtreme Flow (XF)	37	900

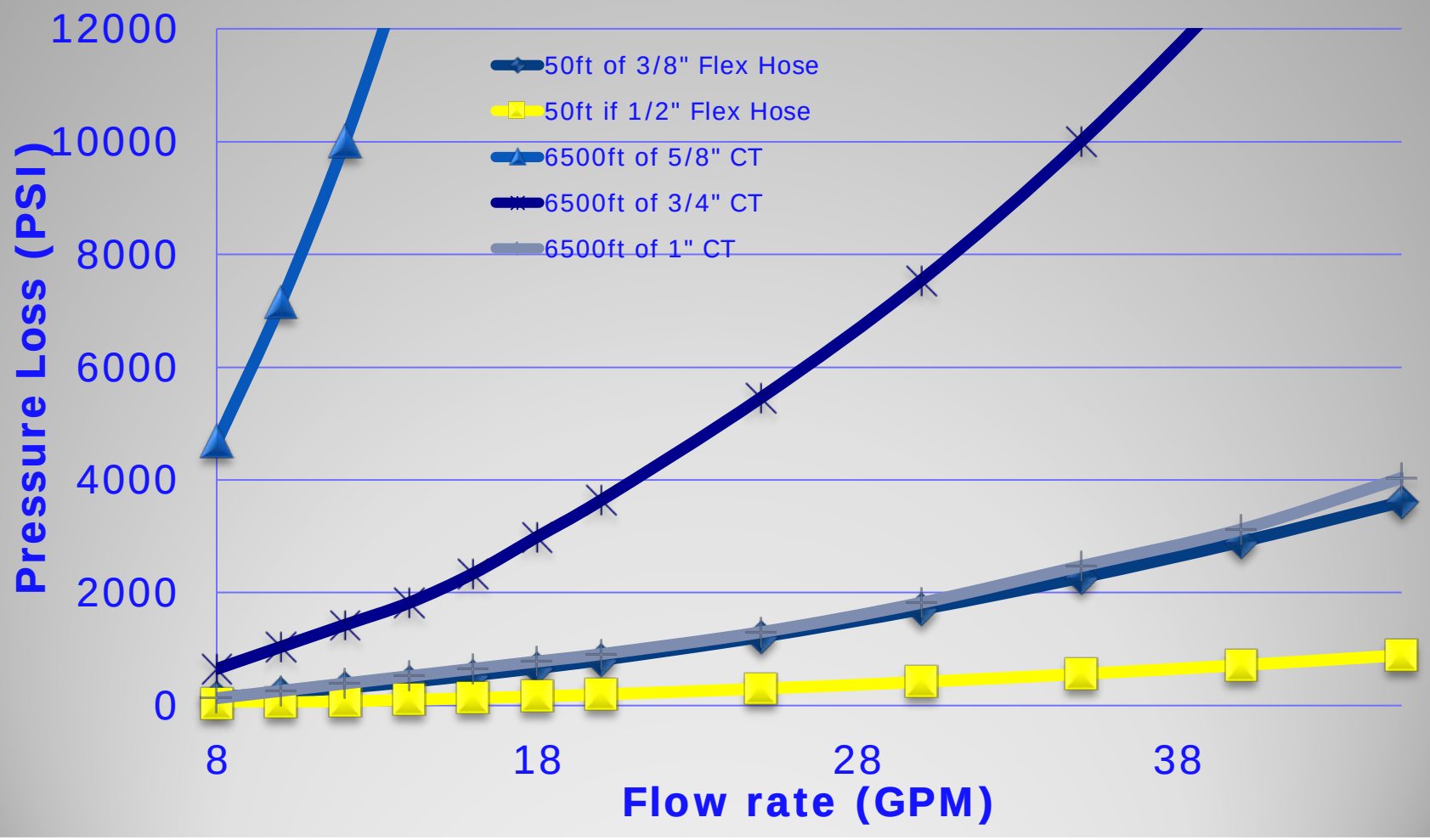
TABLE 1

Flowrate vs. Penetration Rate




RockScorpion™
10 GPM
834L [½" OD]
[10GPM – 47HP]
BJD
13 GPM
834C [½" OD]
[13GPM – 60HP]
BJD
24 GPM
HF Nozzle [9/16" OD]
[23.5GPM – 110HP]
BJD
32 GPM
XL Nozzle [5/8" OD]
[32GPM – 175HP]
BJD
Pick the Right Nozzle for Your Application!

Pressure Loss Across Tubulars



Nozzle Pressure Calculation

$Flow_{rate} := 28.5 \cdot gpm$

$Velocity_{water} := \frac{Flow_{rate}}{Nozzle_{area}}$

$D := 0.308in$

Water density is 1000 kg/m^3

$\rho := 1000 \frac{kg}{m^3}$

Water viscosity at 70 F is 6.556 x 10 ^ -4 lb/ft*S

$\mu := 6.556 \cdot 10^{-4} \frac{lb}{ft \cdot s}$

$V_{avg} := \frac{Flow_{rate}}{\pi \cdot \left(\frac{D}{2}\right)^2}$

$V_{avg} = 37.407 \cdot \frac{m}{s}$

Re < 2300 laminar flow

2300 < Re < 4000 transitional flow

Re > 4000 turbulent flow

Reynolds Number

$C_d := .76$

$Re_{num} := \frac{\rho \cdot V_{avg} \cdot D}{\mu}$

$Re_{num} = 299946$

$Pressure_{nozzle} := \left(\frac{Flow_{rate}}{Nozzle_{area} \cdot C_d}\right)^2 \cdot \frac{\rho \cdot \left(1 - \beta^4\right)}{2}$

$Pressure_{nozzle} = 10000 \cdot psi$

Medium Flow Nozzle

Buckman Jet Drilling

Shale Cores

Dual Coil Applications

Acid Jet Drilling

US 20090107678A1

(19) **United States**

(12) **Patent Application Publication**
Buckman, SR.

(10) **Pub. No.: US 2009/0107678 A1**

(43) **Pub. Date: Apr. 30, 2009**

(54) **CHEMICALLY ENHANCED STIMULATION OF OIL/GAS FORMATIONS**

(76) Inventor: **William G. Buckman, SR.**, Bowling Green, KY (US)

Correspondence Address:
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CONROE, TX 77304 (US)

(21) Appl. No.: **12/259,806**

(22) Filed: **Oct. 28, 2008**

Related U.S. Application Data

(60) Provisional application No. 61/001,183, filed on Oct. 31, 2007.

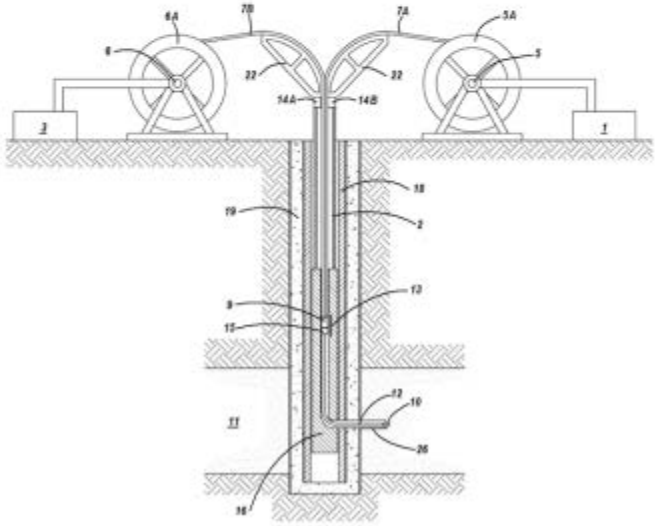
Publication Classification

(51) **Int. Cl.**
E21B 43/114 (2006.01)

(52) **U.S. Cl.** **166/297**; 166/55

(57) **ABSTRACT**

Method is provided for drilling of formations containing carbonate minerals with flexible tubing capable of being turned in a very short radius. The very flexible tubing may be placed inside a work string in a well with coiled tubing and a micro-jet bit on the tubing be diverted to a selected direction and depth. Acidic drilling fluid pumped through the micro-jet bit allows high rates of drilling with hydrochloric acid. A slip joint between coiled tubing and the flexible tubing may be used to allow jet drilling without movement of the coiled tubing and use of a jet bit with forward-facing jets. Mixing of acid and base solutions downhole may be used to provide hotter acid solutions for 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.earthbornclean.com

Jet Perf&Drill™

Jet Drilling Units
(Coiled Tubing)

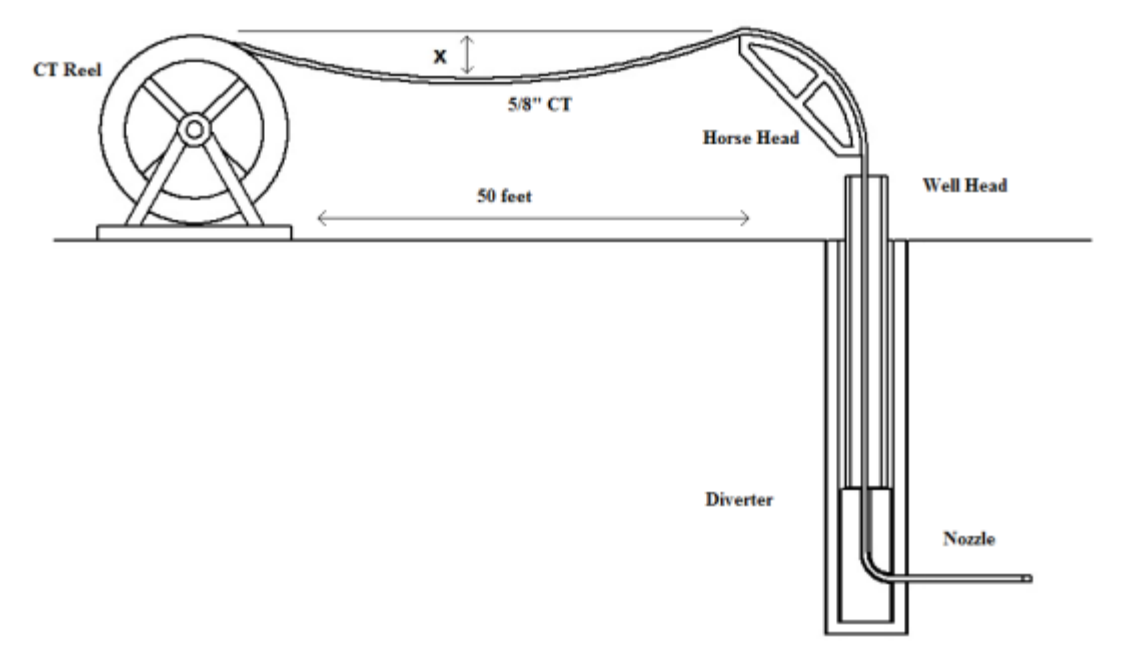
High Pressure Jointed Pipe

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

BJD Jet Drilling Pump

Jet Drilling Enhancements

Flow Increase

RADIAL FLOW EQUATION

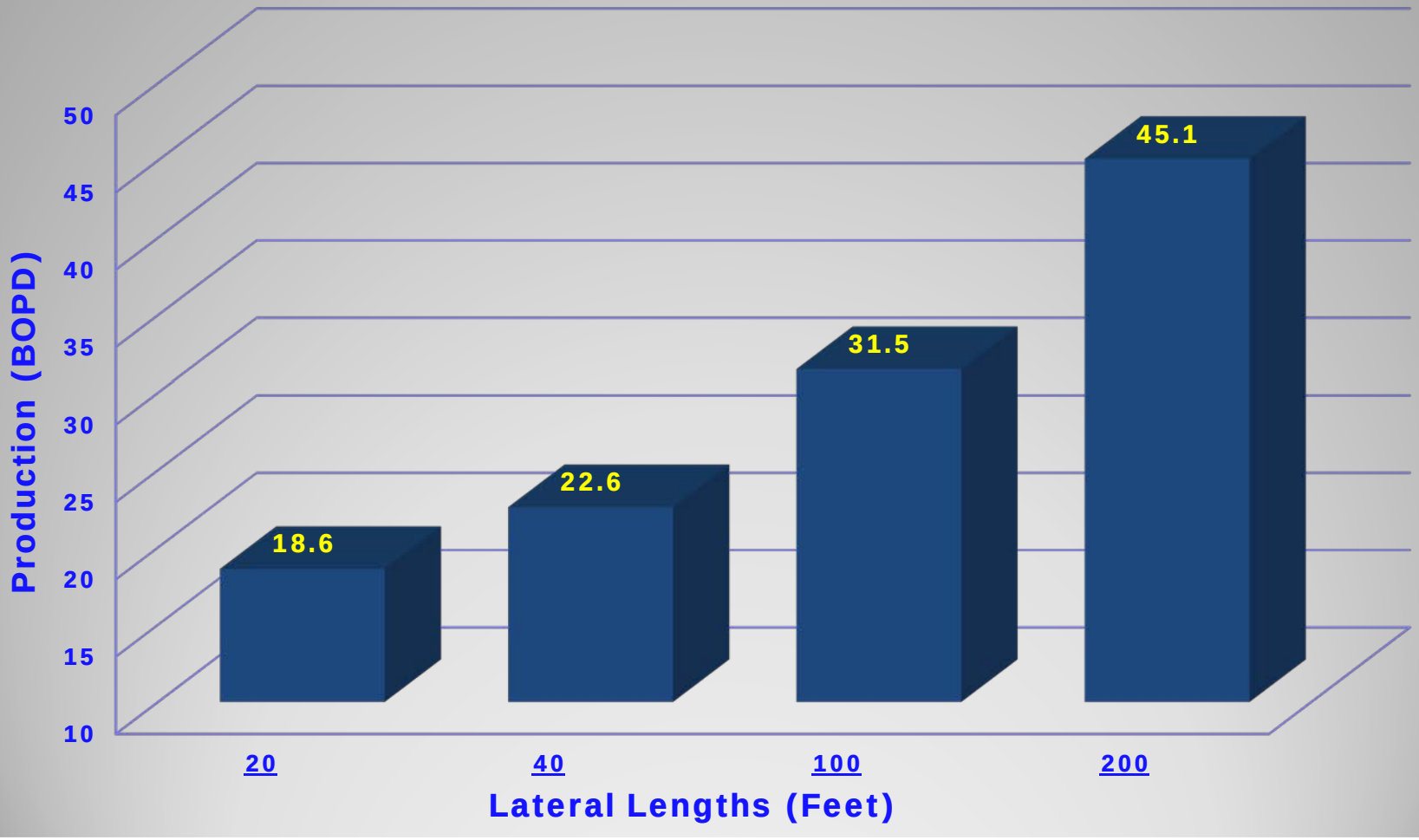
$$\text{FlowRate}_{BOPD} := \frac{2k \cdot h \cdot (pe - pw)}{"\mu " \cdot \ln\left(\frac{re}{rw}\right)}$$

k = rock permeability
h = formation thickness
pe = fluid pressure at outer boundary
pw = fluid pressure in wellbore
μ = fluid viscosity
re = effective drainage radius
rw = wellbore radius
BOPD = barrels of oil per day

CALCULATED FLOWRATE INCREASE (1000 FT DRAINAGE RADIUS)

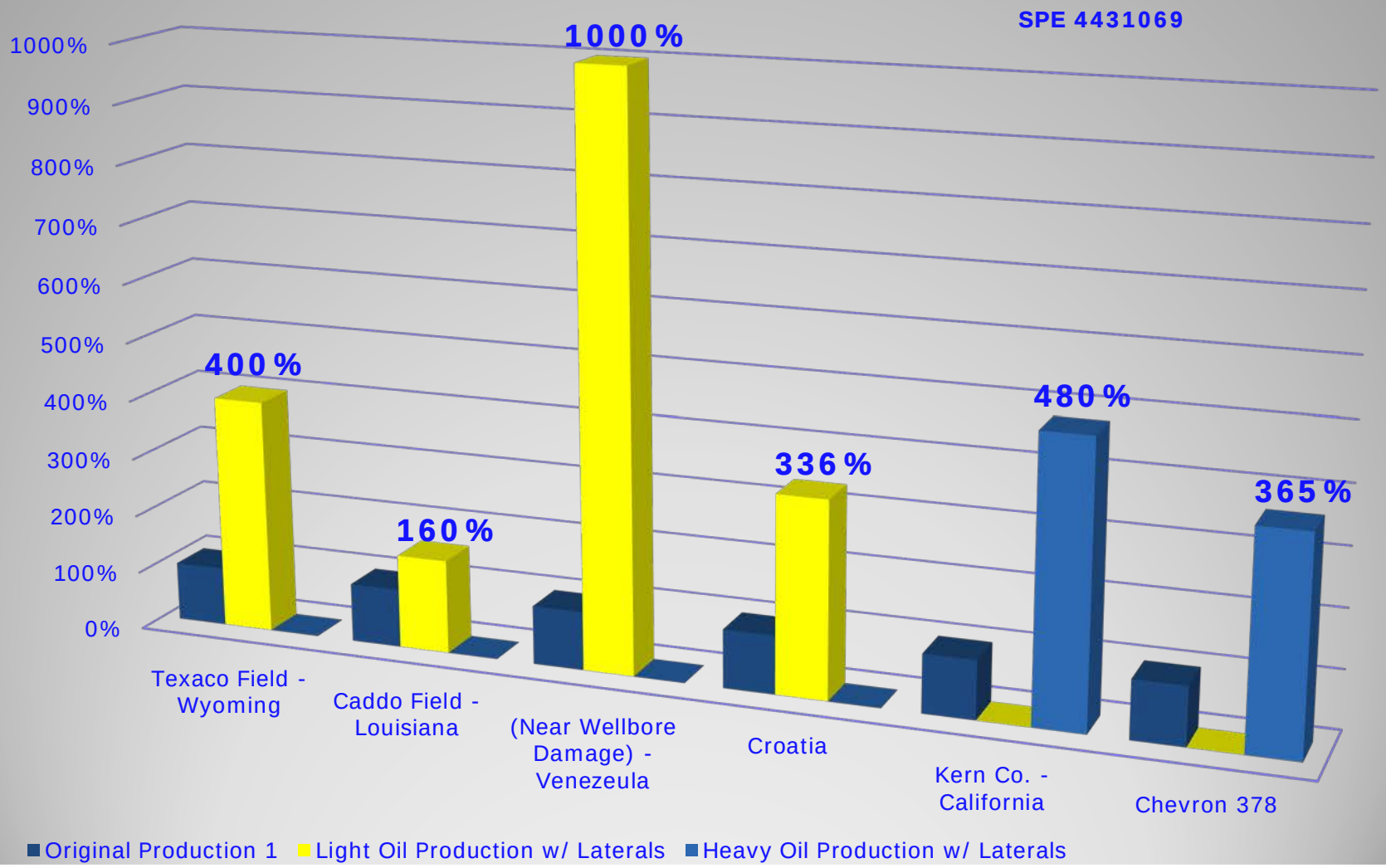
LATERAL WELL LENGTH (FT)	STIMULATION RATIO
0	1.00
5	1.37
10	1.58
20	1.86
40	**2.26**
60	2.58
100	**3.15**
150	3.83
200	**4.51**
300	6.03

Modified Radial Flow Equation Example for Enhancing a Well by Jet Drilling

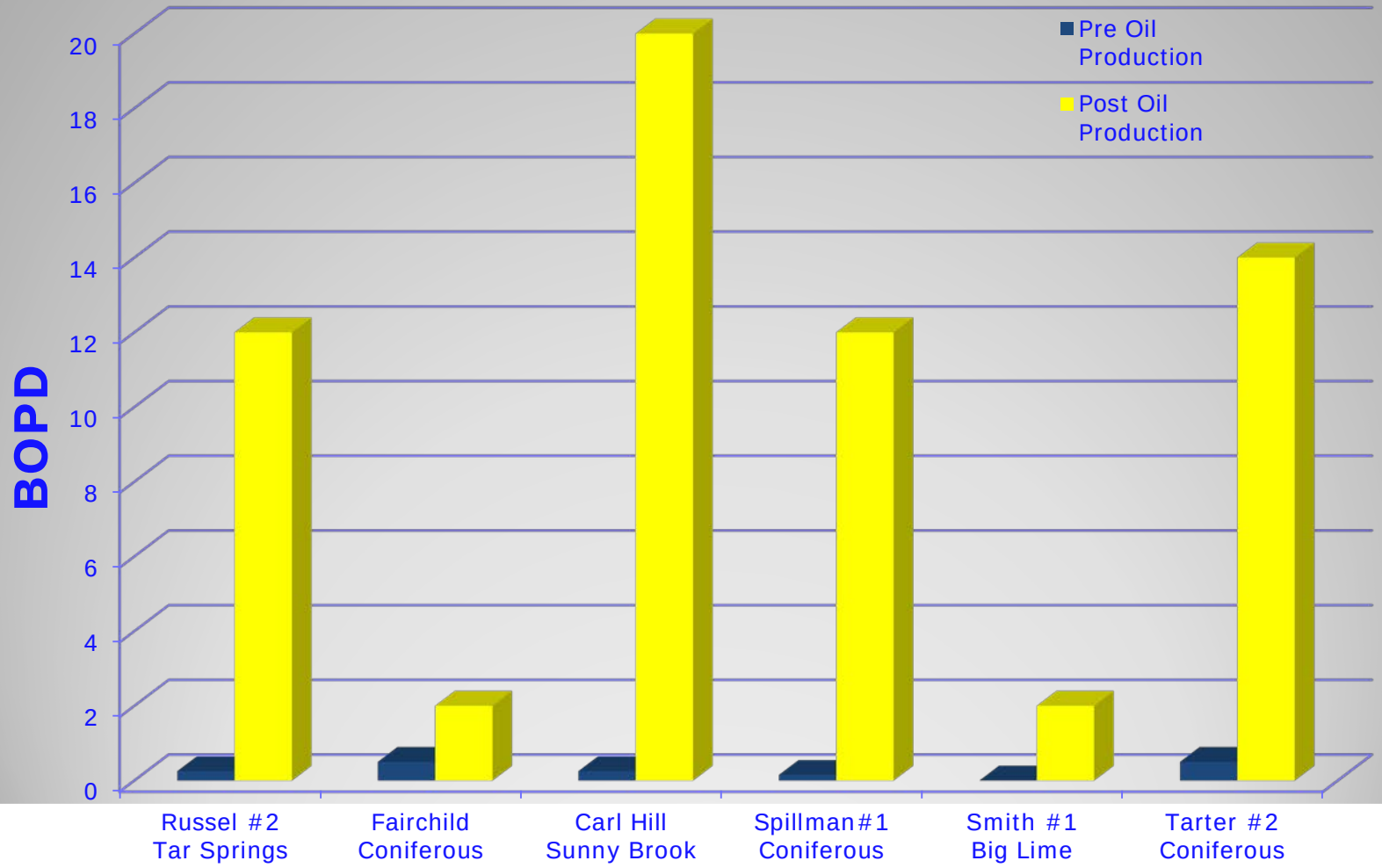


Original Production without laterals is 10 BOPD.

Dickinson Published Results



Some KY Enhancements



Articles Published on Jet Drilling

SPE 26348, 68th SPE/ATCE 1993

"Coiled-Tubing Radials Placed by Water-Jet Drilling"

Dickinson,W.
Dykstra, H.
Nordlund,R
Dickinson, R.

Field Results, theory, and Practice, SPE 26348, 68th SPE/ATCE, Houston, Texas. October 3-6, 1993.

WORLD OIL 2011 Article

"Radial drilling can increase production and access hydrocarbons in a cost-effective and time-efficient manner."

Steve Elliott
Project Development Manager
Tethys Petroleum

Elliott, Steve. "Coiled-tubing method drills radial laterals to improve oil production from a depleted reservoir." WORLD OIL October 2011: 57-64.

E&P Magazine 2011 Article

"Hydrajetting advances improve Saudi Aramco's gas well performance."

Mark Thomas

Thomas, Mark. "Jetting Technology Improves Production." E&P Magazine September 2011

Drilling Contractor
June 2013 Article

"Low-cost radial jet drilling helps drilling revitalize 40-year-old oilfield."

Cinelli, Steven D
Kamel, Ahmed H.

Cinelli, Steven D; and Kamel, Ahmed H., "**Low-cost radial jet drilling** helps drilling revitalize 40-year-old oilfield," Drilling Contractor, June 12, 2013.

Oilfield Technology August2013 Article

"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.

BJD

XF Nozzle

BJD Buckman Jet Drilling, Inc.

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

Leading Innovator in Jet Drilling Technology

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

BJD

Pipe Data

July 30 2013

TenarisHydril

Size: 1.315 in.
Wall: 0.179 in.
Weight: 2.25 lbs/ft
Grade: P110
Min. Wall Thickness: 87.5 %

Connection: CS®
Casing/Tubing: TUB

PIPE BODY DATA

GEOMETRY

Nominal OD	**1.315** in.	Nominal Weight	**2.25** lbs/ft	Standard Drift Diameter	**0.863** in.
Nominal ID	**0.957** in.	Wall Thickness	**0.179** in.	Special Drift Diameter	**N/A**
Plain End Weight	**2.17** lbs/ft				

PERFORMANCE

Body Yield Strength	**70** x 1000 lbs	Internal Yield	**26200** psi	SMYS	**110000** psi
Collapse	**25860** psi				

CS® CONNECTION DATA

GEOMETRY

Connection OD	**1.600** in.	Connection ID	**0.864** in.	Threads per in.	**8.00**
Make-Up Loss	**2.220** in.				

PERFORMANCE

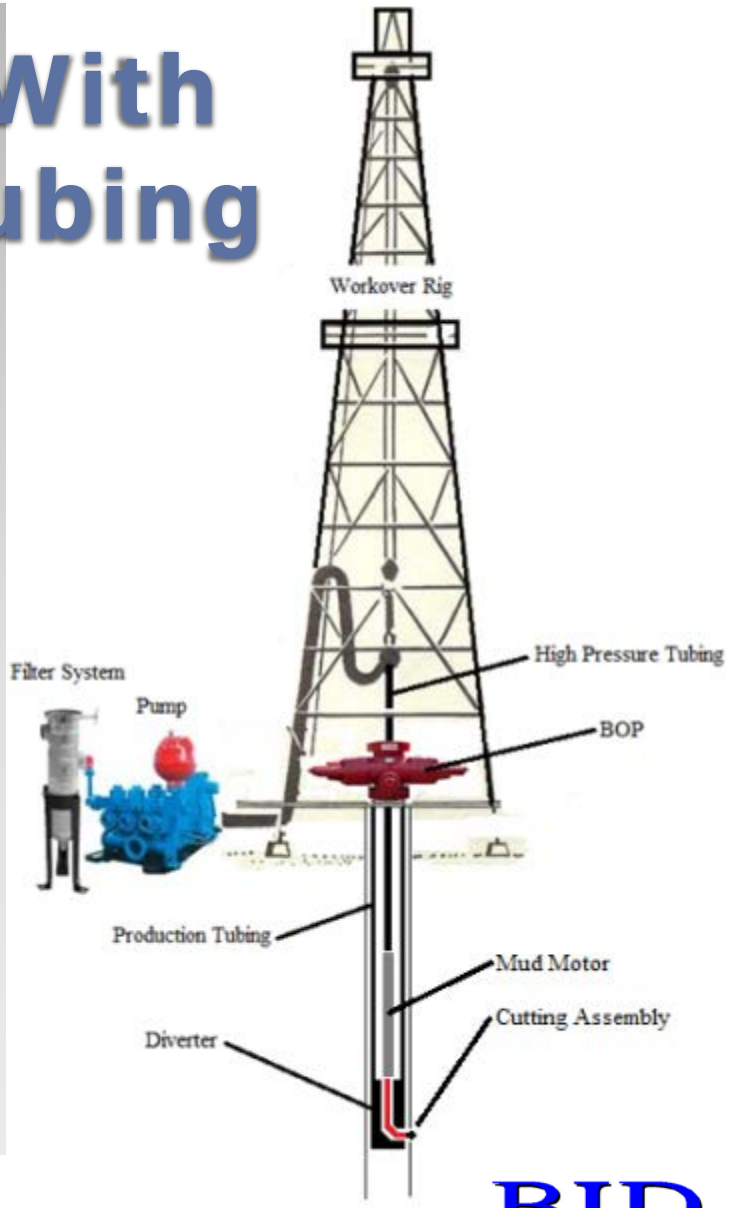
Tension Efficiency	**100** %	Joint Yield Strength	**70** x 1000 lbs	Internal Pressure Capacity	**26200** psi
Compression Efficiency	**80.0** %	Compression Strength	**56** x 1000 lbs	Bending	**306** °/100 ft
External Pressure Capacity	**25860** psi				

MAKE-UP TORQUES

Minimum	**400** ft-lbs	Target	**450** ft-lbs	Maximum	**500** ft-lbs

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



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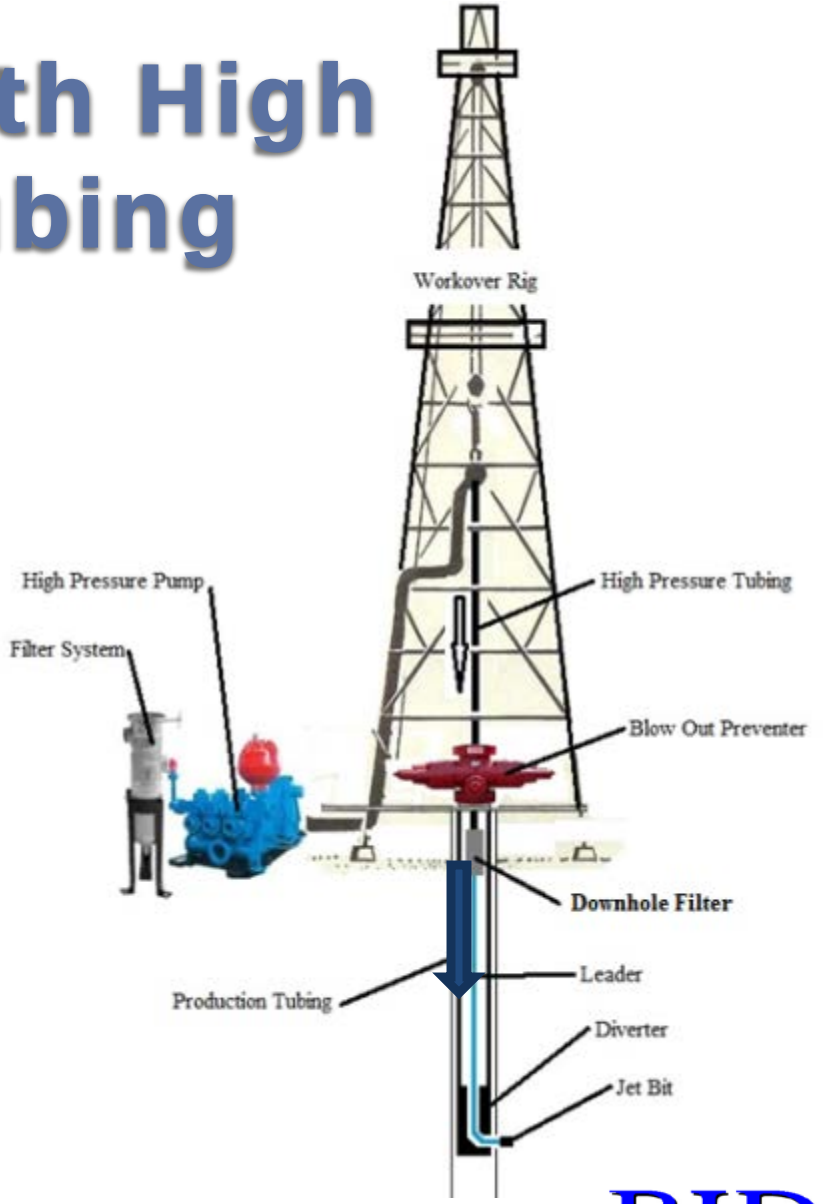
Jet Drilling With High Pressure Tubing

- 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



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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