SIMPLE FIELD
SOLUTIONS
FOR HEAVY OIL
About Fractal Systems

Fractal Systems Inc. is a private Canadian corporation with offices in Calgary, Alberta and Sherbrooke, Quebec.

Fractal Systems Inc. is a heavy oil technology company who develops, patents, and deploys innovative, cost-effective solutions to improve producer margins, de-bottle infrastructure and provide flexibility associated with the transportation of heavy oil.
Experienced Team

WITH PROVEN TRACK RECORD

Joe Gasca, Executive Director
• 30+ years of industry experience, most recently serving as CEO of Ivanhoe Energy
• 20+ years in major leadership positions at Texaco & BG Group

Michel Chornet, VP Technology Development & Engineering
• Co-founder of Fractal Systems, Inc. and 20 years of engineering and technology development experience in energy sector
• Shell and H-Power

Ed Veith, COO, Fractal USA
• 30+ years of oil company and engineering company experience
• 14 years at Ivanhoe Energy most recently as EVP Upstream/SVP Canada Projects

Dr. Esteban Chornet, Founder
• Inventor of JetShear™ technology & Professor of Chemical Engineering at Université de Sherbrooke (Québec, Canada)
• Founder of Enerkem and Fractal Systems, Inc.

Committed investors with energy domain experience
• Rho Ventures
• Braemar Energy Ventures
JetShear

Enhanced JetShear + ARP

TECHNOLOGIES ENHANCE PRODUCER ECONOMICS BY

• Decreasing viscosity
• Reducing diluent volumes
• Lowering transportation costs
• Increasing infrastructure utilization
• Reducing acid number
• Improving product value
• Reducing GHG emissions
Fractal Technologies
TECHNOLOGIES ENHANCE ECONOMICS

JetShear™
- Reduce diluent by 40-50%
- Successful commercial field demonstration
- Product and process patents in place
- 15-20% more bitumen in pipeline

Enhanced JetShear™
- Reduce diluent by 50-60%
- Improve product value through upgrading
- Eliminate olefins
- Commercial field demonstration in 2016
- Patent application filed
- 20-25% more bitumen in pipeline

ARP™
- Reduce TAN by ~ 80% or < 1.0 mgKOH/g
- Commercial field demonstration in 2016
- Patent application filed
Pipeline Transportation

- Once the heavy oil is to the surface, it cools and high viscosity makes transportation difficult

- Producers use costly **diluent** to blend with the heavy oil to meet pipeline specifications

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Diluent is a light hydrocarbon (i.e. typically condensate or naphtha) that is used to “dilute” the heavy oil in order to improve its transportation characteristics (e.g. lower viscosity and density)
JetShear on **Canadian Bitumen**

**VISCOSITY SPECIFICATION MET WITH SUBSTANTIALLY LESS DILUENT**

![Graph showing the relationship between Viscosity (cSt) at 15° and % Diluent Content. The graph compares JetShear Product and Canadian Cold Lake Dilbit, indicating that JetShear Product meets viscosity specifications with substantially less diluent.](image)

Results from Fractal - Sherbrooke labs
## JetShear vs. Canadian Bitumen/Dilbit

### Typical Results Using a Generic Bitumen

<table>
<thead>
<tr>
<th>Properties</th>
<th>Raw Bitumen</th>
<th>Dilbit</th>
<th>JetShear</th>
<th>Enhanced JetShear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (°API)</td>
<td>7.5</td>
<td>19-20</td>
<td>19-20</td>
<td>19-20</td>
</tr>
<tr>
<td>Viscosity (cSt) @ 12° C</td>
<td>200,000-1,500,000</td>
<td>≤350</td>
<td>≤350</td>
<td>≤350</td>
</tr>
<tr>
<td>Diluent content (%)</td>
<td>n/a</td>
<td>+30</td>
<td>~17</td>
<td>~13</td>
</tr>
<tr>
<td>Diluent displacement (%)</td>
<td>n/a</td>
<td>n/a</td>
<td>~42</td>
<td>~55</td>
</tr>
<tr>
<td>Olefin content (wt %)</td>
<td>0</td>
<td>0</td>
<td>&lt;1%</td>
<td>~0</td>
</tr>
<tr>
<td>Acid Number (mgKOH/g)</td>
<td>2.5</td>
<td>1.75</td>
<td>1.25</td>
<td>&lt;1.0 w/ARP</td>
</tr>
<tr>
<td>Sulphur content (wt %)</td>
<td>4.75</td>
<td>3.33</td>
<td>4.28</td>
<td>3.8</td>
</tr>
</tbody>
</table>
JetShear Frees Up Take-Away Capacity

20-25% MORE HEAVY OIL BLEND CAN BE TRANSPORTED IN EXISTING PIPELINES (> 400 KBPD at 2 MBPD*)

DilBit
- Diluent content = 30%

JetShear
- Diluent content = 17%
- 42% Diluent Displacement

Enhanced JetShear
- Diluent content = 12%
- 60% diluent displacement

Diluent volumes are reduced lessening the need for imported diluent and improving infrastructure utilization**

* In July 2015 CAPP estimated that oilsands insitu production was 1.24 million bpd in 2014 and is expected to grow to 2.38 million bpd by 2030
** In 2014 250 kbpd of additional diluent was imported to supplement insitu Canadian supply
JetShear Location is Flexible

TRANSPORTATION OPTIONS ENHANCE PRODUCER ECONOMICS

SAGD Project → Diluent Return → Terminal (JetShear) → Dilbit → Pipeline or Rail → Refinery

Oilsands Mine → Dilbit → JetShear → Dilbit → Pipeline → Refinery
JetShear Technology Background

JetShear™ | Enhanced JetShear™ | ARP™
The Science

THE PROCESS

• JetShear uses low severity, hydrodynamic cavitation and heat to structurally modify asphaltene molecules by separating resin groups attached to the asphaltene core.

• The rapid change in pressure, below cracking temperature allow microbubbles to form around nucleation sites.

• Kinetic energy from cavitation, converts to chemical energy and modifies heavy oil microstructures and the state of aggregation.

• The resulting de-structuring lowers viscosity and bulk density with essentially no change in the chemical composition or volumetric yield.
The Science

Heavy Oil

JetShear™ - Destructured Heavy Oil

Solvation

Heat
Facilitates molecular mobility

Cavitation
Liberates kinetic energy to chemical energy

Cyclic Saturates
Linear Saturates
Aromatics
Ashphaltene Core
Resins
JetShear
THE PROCESS

• Heavy oil blend is delivered from the production facility or terminal.
• The initial processing step separates the light ends using simple fractionation.
• Light ends are routed around the plant to be recycled back to the production facility or to become part of the final sales blend.
• The stripped heavy oil is sent to the core JetShear module, heated to just below thermal cracking temperatures and pumped through proprietary jet-nozzles where cavitation and mechanical shearing occurs.
• The upgraded product is then cooled and sent to the sales tank or to blending prior to sales.
JetShear Process Flow Diagram

Process utilizes heat + cavitation + off the shelf technologies.
Enhanced JetShear

THE PROCESS

• Higher severity treating conditions within the core JetShear module result in higher viscosity reduction and diluent avoidance.

• Enhanced JetShear adds a processing step to remove olefins with the naphtha cut.

• The naphtha cut is processed in a low pressure catalytic hydrogen polishing unit before being cooled and then blended with the final product.

• Higher diluent displacement is achieved when olefins content no longer limits the aggressiveness of the JetShear treatment conditions.
Enhanced JetShear Process Flow Diagram

PROCESS ADDS HYDROPOLISHING TO NAPHTHA CUT
Acid Reduction Process (ARP)

THE PROCESS

- The ARP process consists of a simple configuration of pre-fractionation and a soaker drum with a heater.
- Acids, primarily concentrated in the heavier cuts, are thermally destroyed at temperatures below the onset of cracking thereby reducing the Total Acid Number or TAN.
- In combination with Enhanced JetShear’s hydro-polishing step any olefins generated with ARP can be addressed.
Enhanced JetShear + ARP Process Flow

PROCESS UTILIZES FRACTIONATION + HEAT + OFF THE SHELF TECHNOLOGIES
JetShear Commercialization
Commercializing JetShear

DEMONSTRATED TECHNOLOGY DEVELOPMENT

Pre-2009
1-30 bopd Bench Scale

2009-2010
300 bopd Pilot Facility

2012-2015
1,000 bopd Commercial Demonstration Plant
- Class 4+ engineering designs with major EPC firm
- Canadian and USGC capital cost studies

August 2014
- Patents filed: Heavy oils having reduced total acid number and olefin content

2016
- Enhanced JetShear + ARP Commercial Demonstration

2016
- FEED on first commercial facility
- Expand business development internationally

September 2008
- Patent granted: Process for treating heavy oils

December 2008
- Patent granted: Treated oils having reduced densities and viscosities

Patent granted: Treated oils having reduced densities and viscosities

Fractal Systems, Inc. – Creators of JetShear™ / Enhanced JetShear™ / ARP™
Commercial Demonstration Facility
PARTNERED WITH LARGE OILSANDS PRODUCER

Near Provost, Alberta

Adjacent heavy oil production facility

Thermal Oxidizer

H2S Removal

JetShear building

Glycol Cooler

Heater
COMMERCIAL DEMONSTRATION RESULTS
SUCCESSFUL FIELD APPLICATION CONFIRMED

- Processed over 100,000 barrels of diluted bitumen over 1 year
- Met all milestones established with our partner, a large oilsands producer

<table>
<thead>
<tr>
<th>Category</th>
<th>Measure</th>
<th>Target</th>
<th>Actual</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSE</td>
<td>Lost time injuries</td>
<td>0</td>
<td>0</td>
<td>✔</td>
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<tr>
<td>Performance</td>
<td>Yield</td>
<td>≥ 98 wt%</td>
<td>&gt;98 wt% ✔</td>
<td>✔</td>
</tr>
<tr>
<td></td>
<td>Material balance closure</td>
<td>≤ 1%</td>
<td>≤ 1%</td>
<td>✔</td>
</tr>
<tr>
<td></td>
<td>Throughput</td>
<td>1,000 bpd</td>
<td>930 bpd* ✔</td>
<td>✔</td>
</tr>
<tr>
<td></td>
<td>Nozzle life</td>
<td>≥ 4,000 hrs</td>
<td>&gt; 4,100 hrs</td>
<td>✔</td>
</tr>
<tr>
<td>Product quality</td>
<td>Diluent displacement</td>
<td>≥ 40%</td>
<td>~ 42%</td>
<td>✔</td>
</tr>
<tr>
<td></td>
<td>H₂S content</td>
<td>≤ 20 ppm</td>
<td>&lt; 20 ppm</td>
<td>✔</td>
</tr>
<tr>
<td></td>
<td>TAN reduction</td>
<td>≥ 15%</td>
<td>&gt;25%</td>
<td>✔</td>
</tr>
<tr>
<td></td>
<td>Stability (P-Value)</td>
<td>≥ 1.5</td>
<td>&gt;2.2</td>
<td>✔</td>
</tr>
</tbody>
</table>

* Reduced target due to hydraulic limitation in peripheral equipment.
Scale-Up Risk is Minimal
FIELD PROVEN, MAJORITY OF EQUIPMENT IS OFF-THE-SHELF

- Scale-up risk has been effectively addressed
- Two commercial size nozzles successfully demonstrated in the field with over 100,000 bbls of bitumen blend
- Commercial design utilizes parallel banks of 500 bpd nozzles
- Commercial runtime > 6 months

SCALE-UP SEQUENCE

1 bpd/nozzle
3 bpd/nozzle
30 bpd/nozzle
150 bpd/nozzle
500 bpd/nozzle

27,000 BPD
COMMERCIAL
CONFIGURATION

6 BANKS OF 9 NOZZLES
(500 BPD / NOZZLE)
Commercial Demonstration

DEMONSTRATING ENHANCED JETSHEAR AND ARP

Fractal and partner, a large oilsands producer, have undertaken a commercial demonstration of Enhanced JetShear plus ARP

- Diluent displacement up to 60%
- TAN levels less than 1 mgKOH/g
- Olefin content below the detection limit
- Achieve all other pipeline specifications

Project Status

- Project partially funded via a grant from SDTC*
- Facility modified (i.e. blue process units) to allow JetShear and ARP (Q2 2016)
- Commissioning completed, operations initiated
- Results over the remainder of the year
- Performance objectives established with partner

* Sustainable Development Technology Canada (SDTC) is a Government of Canada agency that helps bring Canadian clean technologies closer to market, readying them for growth and export markets.
Demonstration Facility **Enhanced JetShear + ARP**

OPERATIONS INITIATED WITH RESULTS OVER REMAINDER OF 2016
JetShear
Economics
Value Add from **Enhanced JetShear**

2015 CANADIAN BITUMEN EXAMPLE – AT 55% DILUENT REDUCTION

- 7 bbls Bitumen
  - 1.35 bbls diluent ($2.98 / bitumen bbl)
  - Pipeline tariffs ($0.68 / bitumen bbl)
  - JetShear™ OPEX ($0.82 / bbl)

- 3 bbls diluent ($6.63 / bitumen bbl)
- Pipeline tariffs ($1.50 / bitumen bbl)

$3.65 savings per bbl of bitumen

Based on average 2015 pricing

WTI = US$ 49.35/bbl  WCS = C$44.82/bbl  DilBit = WCS – C$2.50/bbl  Diluent = C$60.28/bbl  Dilbit tariff to Hardisty = C$2.00/bbl  Diluent tariff f/Edmonton = C$1.50/bbl
Historical Benefit of Enhanced JetShear

BENEFIT DERIVED PRIMARILY FROM DILUENT AVOIDANCE – NO UPGRADING BENEFIT

Enhanced JetShear Net Value Add

C$/BBL

Jan-04 Jan-05 Jan-06 Jan-07 Jan-08 Jan-09 Jan-10 Jan-11 Jan-12 Jan-13 Jan-14 Jan-15 Jan-16

30% Blend Ratio-Typical S. Athabasca
Value from **Upgrading**

**UPGRADING WITH JETSHEAR RESULTS IN IMPROVED DISTILLATION PROFILE**

- JetShear converts resid to higher value products
- JetShear products have improved distillation profile
  - Resid is higher quality requiring less light cycle oil to meet the high sulfur fuel oil (HSFO) spec
  - VGO + resid cut roughly equivalent to WCS
  - Major consulting firm deemed value equivalent to WCS in a cracking configuration
- Enhanced JetShear results in further improvements
  - Resid decrease
  - VGO increase
  - Diesel increase
  - Higher refinery yields of transportation fuels
- Acid Reduction Process (ARP)
  - Reduces penalties due to high TAN
Major International EPC firm developed a Class 4+ engineering study at 50,000 bpd

- Adjacent to a new or existing SAGD facility
- Assumes utilities and other off-sites are available

Significantly lower capital intensity than competing technologies

Smaller footprint than competing technologies

- Approximately 3 acres for a 50,000 bpd Enhanced JetShear facility
Robust Economics Over Historical Range

DECENT RETURNS IN CURRENT ENVIRONMENT

- End-user conceptual returns for a 50 kbpsd size facility at 55% diluent avoidance
- Business model assumed: License
- Ten year value of diluent avoidance ranges from a low of $3 / bbl during the financial crisis to up to $14 / bbl
- Exposure to monthly/seasonal volatility in market prices introduce additional risks
- Decent returns are achieved in an environment of “lower for longer”
- Significant upside as oil prices rebound
JetShear Environmental Benefit

SIGNIFICANT GHG REDUCTIONS ARE POSSIBLE FOR PRODUCERS WHO USE JETSHEAR IN THEIR OPERATIONS

- A life cycle GHG assessment was completed by ClimateCHECK in May 2016*
  - The assessment compared a typical Canadian SAGD sourced dilbit with a SAGD project integrated with JetShear to determine the wells-to-refinery GHG impacts
    - Reduced greenhouse gas (GHG) emissions on a wells-to-refinery basis
    - Less diluent is being transported from the site to the refinery, and back to site
    - Less diluent is required to be produced
    - Less diluent is being processed at the refinery
- Two transportation modes were investigated
  - Pipeline to / from USGC (diluent via pipeline)
  - Rail to / from USGC (diluent via rail)
- Wells-to-refinery basis reductions possible
  - 5.4 to 9.8% for Enhanced JetShear
  - 6.7 to 11% for Base JetShear
- Majority of GHG footprint is from SAGD and refining. Point-source JetShear emissions are minimal (approx. 2% of total footprint)

JetShear

Summary
Fractal’s JetShear Technology Platform

ADDS VALUE BY:

- Improving viscosity
- Reducing density
- Reducing acid number
- Improving take-away capacity
- Reducing diluent
- Reducing GHG

R&D program adding value

- Enhanced JetShear and ARP field demo (2016)
- Patent applications filed
  - Enhanced JetShear™
  - Acid Removal Process (ARP™)
- R&D continues for Total Diluent Displacement (TDD™)

JetShear™ is viable today

- Successful commercial field demonstration
- Engineering completed with major EPC
- Focused on commercial deployment
- Process and product patents in place
- GHG benefits improve oil sands sustainability
PROTECTING + ENHANCING VALUE

Three (3) JetShear patents/applications:
    o Process for treating heavy oils
    o Treated oils having reduced densities and viscosities
    o Treatment of Heavy Oils to Reduce Olefin Content

One (1) Acid Removal (ARP) patent application:
    o Heavy oils having reduced total acid number and olefin content

Filing countries:
  • Canada and USA
  • National Filings
    o Brazil, Ecuador, Colombia, Mexico, EU, Oman, China
  • PCT application

Work underway for new patents adding further upgrading & quality