Thermal Enhanced Bitumen Recovery

**Conventional SAGD**
- Reduced Steam Pressure
  - Shallow depth, Caprock integrity, Outcrop proximity
- Geological Issues
  - Vertical Perm, Shale barriers, Lean zones

**Conventional CSS**
- Geological Issues
  - Bottom water, Caprock integrity, Top gas

**Single-Well SAGD**
- Engineer around Geology
  - High permeable propped vertical planes
  - Operate in SAGD mode
Weakly Cemented Formations

Hydraulic Fracturing
- Conventional
  - Strong, Hard Rocks – Brittle Fracture
- Frac & Pack
  - Weak, Soft Sediments – Ductile Process

Weakly Cemented Formations
- Minimal Cementation, Soft & Weak
- Stress State
  - Force Chains Fragile
    - Easily Destroyed
    - Minor Vibration or Shearing
    - Grain Contact Dissolution
    - Over-Pressurization
  - Minimal Formation Stress Contrast
    - Stress Contrast can not be maintained over geological time
- Constitutive Behavior
  - Ductile Frictional Behavior
  - Anelastic
Early Field Trials of Azimuth Control

[Images of field trials with labels: Plane Coalescence Beneath Surface and Plane Orientated Along Required Azimuth (String Line)]
Azimuth Control Initiation Devices

Single Azimuth Tools

<table>
<thead>
<tr>
<th>Prototype</th>
<th>1st Generation</th>
<th>2nd Generation</th>
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<tbody>
<tr>
<td><img src="image1.png" alt="Prototype 1991" /></td>
<td><img src="image2.png" alt="1996 Generation" /></td>
<td><img src="image3.png" alt="1997 Generation" /></td>
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Azimuth Control Iron Propped Planes

Corrected Horizontal Distance (ft)

Resistivity (Ohm)

Inclined Wall Thickness interpreted to be approximately 4.8-inches
Multi-Azimuth Vertical Planes

Each individual Plane Initiated & Propagated by Dedicated Tubing

Diametrically Opposite Cavities are Dilated to Initiate Azimuth Controlled Vertical Planes
Milk River Tight Gas Field Trials

- 100km
- Alberta, Saskatchewan
- Four (4) propped wings
- 4-1/2” J55 Casing
- Shoreline Anisotropy
Single-Well SAGD System

Operated in SAGD Mode
- no startup
- shallow or deep

Top Pay
Bottom Pay
Sump
Injector
Producer
Single-Well SAGD Completion

**Legend**
- X-Drain Casing
- Orientating Mule Shoe
- Cementing Shoe
- Slotted Liner

**Casing**
- 9-5/8”

**Liner**
- 7”
- Blanket Gas
- Produced Liquids 2-7/8” or 3-1/2”
- Steam 4-1/2” VIT

**Composite**
- Epoxy
- Ceramic

**Completion**
- Slotted Liner
Thermal Simulation Model Idealization

TRS-Thermal Simulator
Athabasca Bitumen
Sp=1,750kPa and 1,200kPa
Gas saturation (vpp_22.5deg_1200_50_56)

Athabasca Bitumen
Sp=1,750kPa

Time = 1e-006 days
Single-Well SAGD in Channel Sand

Athabasca Bitumen
Sp=1,750kPa

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4x Single-Well vs Conventional SAGD

Athabasca Bitumen
Sp=1,750kPa

Slide 14
Single-Well SAGD Clean-Dirty Sands

Athabasca Bitumen
Sp=1,750kPa
Single-Well SAGD Shale Barrier

Oil Production Rate (bbl/day)

Cummulative Oil (MMbbl)

Cummulative SOR

Time (days)

Clean Sand
Kv=2D
Barrier Holes
K=200mD
Barrier Holes
K=20mD

Athabasca Bitumen
Sp=1,750kPa
Permeable Lean Zone

Water Saturation

Temperature 0.1 day

Temperature 1 day

Temperature 6 days

Temperature 30 days

Temperature 90 days

Permeable lean zone

Athabasca Bitumen
Sp=1,200 kPa
Reservoir temperature (vpp_30deg_1200_50_86_mackay_h=30a)

Athabasca Bitumen
Sp=1,200kPa
Conclusions

• Process not depth limited

• Reservoir simulations indicate performance almost invariant of geology

• As built issues
  – Skin between coalesced vertical planes
  – Permeability of planes needs to be high
    • In placed permeability
    • Maintain permeability over time
  – Steaming trials required to quantify issues

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