Cold Heavy Oil Production with Sand Workshop

Calgary
September 21, 2011

For More information

- Visit The OTS (Oilfield Technical Society) Heavy Oil Science Center
  - Lloydminster
- Visit [www.lloydminsterheavyoil.com](http://www.lloydminsterheavyoil.com)
- References are on the CD
- Visit [www.kirbyhayes.com](http://www.kirbyhayes.com)
Kirby Hayes

- runs his own company, Kirby Hayes Incorporated (KHI), which represents several corporations offering services and productions primarily involved in heavy oil production
- extensive background in cased hole wireline
- has co-authored several technical papers, patent applications, conducted seminars, short courses, workshops and presentations on wide-ranging topics of interest to heavy oil producers
Thank you

Presentation contributions:

- Ron Sawatzky, ARC
- Bob Mottram, Weatherford
- Rob Morgan, Harvest
- Murray Tluchak, Bonavista
- Ryan Rueve, Nexen
- Floyd Isley, CNRL
- Rick Walker, Devon
- Jerry Schoenroth, Husky
- Mike Kremer, Husky
- Cedric Gal, CAG Consulting
- Dave Love
- John Newman
- Janelle Irwin
- Maurice Dusseauult, U of W
- Ace Oilfeild
- Schlumberger
- G-Chem
- IPS
- Wavefront
- And others
Outline

- CHOPS – an overview
- Perforating for heavy oil – the issues
- Break
- Alternate completions
- Interventions examples
- Lunch
- Next steps prior to thermal or solvent EOR processes
- Interesting log examples
- Discussion

Cold Production

“Other things being equal, the maximum recovery of oil from an unconsolidated sand is directly dependent upon the maximum recovery of the sand itself”

February, 1917 (New York)
How Big Is It?

- Canada & US consume ~ 20 MBOD
- ~ 2,600,000,000,000 barrels in place (heavy oil and oil sands) in Canada
- If we achieve 30% recovery…
- 100% of current consumption for 100 years
- So…
  - why fight over Middle East Oil?
  - production problems are being solved

Operating Costs

<table>
<thead>
<tr>
<th>Cost per Barrel ($)</th>
<th>Before 1990</th>
<th>CHOPS</th>
<th>CSS</th>
<th>SAGD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cold</td>
<td>+ steam</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Recon CHOPS Workshop Calgary Sept 21, 2011
Recovery Efficiency

Could we get there?
**Technology is the Key**

- What are the technologies?
  - Thermal Processes
    - steam, SAGD, electrical heating
    - need to manage energy equation
  - Chemical Processes
    - solvent, upgrading
    - full value chain enhancement
  - Displacement Processes
    - enhanced floods → water, polymer, chemical
  - Pink Smoke and Marbles???

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**35 Billion Barrel Resource**

The industry needs to improve recovery factors

- 73.8%
- 17.6%
- 6.5%
- 2.1%

Slides courtesy of Rob Morgan, Harvest
**Heavy Oil & Bitumen Production**

Western Canadian Crude Oil Production

<table>
<thead>
<tr>
<th>Source</th>
<th>Production (bbl/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Sands Mining</td>
<td>760,000</td>
</tr>
<tr>
<td>Oil Sands In Situ</td>
<td>330,000</td>
</tr>
<tr>
<td>Conventional Heavy (Cold Production)</td>
<td>(230,000)</td>
</tr>
<tr>
<td>Conventional Light</td>
<td>500,000</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>2,190,000</strong></td>
</tr>
</tbody>
</table>

Production statistics at December, 2006
Sources: Alberta Dept. of Energy, NEB

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**Deltaic Depositional Environment**

The Mississippi Delta

A satellite photo of the Ganges Delta in India
**Exploration**

- In general exploration for CHOPS is easy in Lloydminster
- Best tool is offset mapping and production – high existing well density lends itself to good mapping
- 3D seismic is the norm
- Success rate is high (> 85%)
- Large regional sands are dependable and predictable
- Channels are a bit more tricky in terms of traps and water content – but big prizes

**Heavy Oil Leases**

- There are three basic configurations for a CHOPS well
  - Vertical
  - Slant
  - Directional
Cold Production

Field Examples

<table>
<thead>
<tr>
<th>Producer</th>
<th>PanCanadian</th>
<th>Mobil</th>
<th>Suncor</th>
<th>Amoco</th>
<th>Texaco</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formation</td>
<td>Mannville</td>
<td>Mannville</td>
<td>Clearwater</td>
<td>Clearwater</td>
<td>Mannville</td>
</tr>
<tr>
<td>Field</td>
<td>Lindbergh, Frog Lake</td>
<td>Celtic</td>
<td>Burnt Lake</td>
<td>Elk Point</td>
<td>Frog Lake</td>
</tr>
<tr>
<td>Oil Saturation (%)</td>
<td>80</td>
<td>87</td>
<td>70-80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas/Oil Ratio (std m³/m³)</td>
<td>10</td>
<td>5-11</td>
<td>11-15.2</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Live Oil Viscosity (mPa-s)</td>
<td>3,000 to 10,000</td>
<td>1,200 to 3,000</td>
<td>40,000 (dead)</td>
<td>2,000 to 55,000</td>
<td>20,000 to 50,000</td>
</tr>
<tr>
<td>Pressure (MPa)</td>
<td>4</td>
<td>3.3</td>
<td>3.3</td>
<td>3.8</td>
<td>2.8-3.4</td>
</tr>
<tr>
<td>Permeability (darcy)</td>
<td>1.5-2.5</td>
<td>0.5-4.0</td>
<td>2.0</td>
<td>1.0-5.0</td>
<td></td>
</tr>
<tr>
<td>API gravity</td>
<td>12-14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Net pay (m)</td>
<td>14</td>
<td>3-5</td>
<td>20</td>
<td>11-14</td>
<td>4-11</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>32</td>
<td>33</td>
<td>34</td>
<td>34</td>
<td>33</td>
</tr>
</tbody>
</table>

- Typical field oil production rates ⇒ 5 – 25 m³/day

Cold Production

Lloydminster-Area Cold Production Blocks

<table>
<thead>
<tr>
<th>Block</th>
<th>Producing Well Count</th>
<th>Oil Production (m³/day)</th>
<th>Avg Rate per Well (m³/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lloyd</td>
<td>3,667</td>
<td>21,757</td>
<td>5.9</td>
</tr>
<tr>
<td>Lindbergh</td>
<td>1,322</td>
<td>8,348</td>
<td>6.3</td>
</tr>
<tr>
<td>Cold Lake</td>
<td>600</td>
<td>4,486</td>
<td>7.5</td>
</tr>
<tr>
<td>5H Sank</td>
<td>306</td>
<td>2,220</td>
<td>7.3</td>
</tr>
<tr>
<td>TOTALS</td>
<td>5,895</td>
<td>36,811</td>
<td>6.2</td>
</tr>
</tbody>
</table>

Production statistics at December, 2001
Cold Production

Oil Production Rate Estimates

Effective Permeability

- without sand
- with sand

- typical for cold production

Oil Viscosity (mPa.s)

Oil Rate (m$^3$/day)

- 1 darcy
- 3 darcy
- 10 darcy
- 30 darcy
- 100 darcy
- 300 darcy

5 m net pay
2,500 kPa draw down
7 in wellbore diameter
200 m far-field radius

Cold Production

Oil Production Rate Estimates

- Development of high permeability channels – “wormholes”
  - much greater reservoir access
- Large, local drawdowns at ends of channels
  - high pressure gradients – gas exsolution
- Substantial increase in oil rates
- Successful commercial process

CHOPS

- depth ~ 400 - 600 m
- thickness ~ 2 - 7 m

continued sand production at cuts ≥ 0.5%
Example of a Wormhole on Surface

Far Field Reservoir Drainage

Andrew Squires and Earl Jensen
Stimulating Sand Production

- Where does new failure occur?
  - In reservoir ⇒ at tip of wormhole network
    - enhances drainage
  - Near well ⇒ at edge of cavity
    - neutral or negative impact on inflow

Completion Objectives

- To initiate sanding: Initial sand production history of a well affects its long term productivity
**Cold Production**

Field Oil Production Rates

- Oil Rate (m³/day)
- Production Time (days)
- With sand
- Without sand

**Field Behavior**

Typical Good Well

- Field Oil Rates
- Field Water Rates
- Field Sand Rates
Achieved during a stable foam operation on a new completion
In 40 hours produced:
117m³ sand
222m³ oil
90m³ water

Aggressive Sand Production

Stages of Development

- Sand Matrix Failure
- Wormhole Growth
- Sand and Fluid Transport

matrix failure when: $\nabla p \geq \nabla p_c$

inflow

Imposed $\nabla p$

wormholes partially filled with sand

wormholes filled with sand
Sand and Fluid Transport

- Tip of wormhole network to well
- EITHER: Plug flow in filled wormholes
  - high produced sand cut
    - ~ 20-40%

Sand and Fluid Transport

- OR: Stratified flow in open wormholes
  - low produced sand cut
    - ~ 1-2%
Wormhole Growth

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Wormhole Growth

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Field Predictions

Dynamic Wormhole Growth

Wormhole Growth

Wormhole Structure

- Wormhole cast after removal
- Imprint left when cast was removed
- Tensile failure bands

Dimensions:
- 20 cm
- 10 cm
Wormhole Growth

Wormhole Configuration

Top Orifice

Bottom Orifice

Sand Pack

36 cm

80 cm

30 cm

24 cm

80 cm

30 cm

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Wormhole Growth

Wormhole Configuration

- 44 cm
- 80 cm
- 30 cm

Top Orifice

Bottom Orifice

Sand Pack

Wormhole Growth

- Critical Pressure Gradient
  - reduced by foamy oil → expansion of gas bubbles
- Growth Rate
  - increases with pressure gradient
- Diameter
  - increases with drained region
  - open (sand-free) area likely less than 10 cm in diameter
Wormhole Growth

- Interaction
  - wormholes compete for drainage
  - Darwinian behaviour $\Rightarrow$ some grow, some wither

Sand Matrix Failure

- Formation Strength
  - unconsolidated sand $\Rightarrow$ low cohesive strength $\sim 5$ – $20$ kPa
  - fines content $\Rightarrow$ increases strength
  - capillary pressure $\Rightarrow$ capillary cohesion
  - high oil viscosity $\Rightarrow$ dynamic strengthening
  - slight cementation $\Rightarrow$ substantial strength increase
Field Implications

- Operate wells at low enough pressure to allow continuing sand production
- Wormholes tend to grow first and predominantly in weakest sand and toward highest pressure gradient
- Wormholes don’t necessarily grow from each perforation – dependant on sand strength
- Wormholes usually stable
**Foamy Oil**

- Large numbers of persistent gas bubbles in oil
- Generated by depressurization of live heavy oils

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**Bubble Growth and Gas Transport**

**Dynamic Partitioning**

- **Oil Phase**
  - Dissolved Gas
  - Small Bubbles

- **Immobile**
  - Large Bubbles

- **Gas Phase**
  - Connected Bubbles
Bubble Growth and Gas Transport

Increasing time, and/or expansion

- Microbubbles
- Small bubbles ($<$ pore throat) → Flow with oil
- Large bubbles ($\geq$ pore throat) → Immobile
- Interconnected bubble clusters → Free gas flow

Field Implications

- Operate wells at low enough pressure to obtain rapid local gas exsolution
- Surprisingly high ultimate recoveries, due to high apparent critical gas saturations
- Large blasts of gas when growing wormhole network and growing zones of interconnected bubble clusters connect
Conclusions Courtesy of Ron Sawatzky AITF

Gas Production
- dissolved gas likely only source of produced gas for 2 wells
- additional external gas source may exist in 2 wells
  (petrophysics indicates source present, flow path uncertain)

Oil Production
- reasonable rates can be maintained at fairly high producing GOR:
  i.e. ~ 10-20 × initial GOR

Draw Down
- oil production rates and recovery enhanced by rapid draw down

When Cold Production Fails

- Well
  - well bore sands off
- Near well
  - perforation plugging
  - shale / coal failure ⇒ collapse or blockage
  - casing failure
- Reservoir
  - wormholes plug, collapse, stop growing
  - watering out
  - gas breakthrough
  - permeability reduction from fines, formation debris, wax precipitation and wasted solution gas

- Important to understand for diagnosis
Complex Flow

- Phases - gas, water, oil, sand and solids
- Variables
  - Mobility
  - Cuts - time
  - Viscosity (oil) – time – depth
  - Sources of water and gas in the drainage geometry
  - Sources (gas) – free or solution?

Where Blockage Can Happen
Debris Causing Blockage Material

- Formation
  - Pyrite
  - Shale
  - Coal
  - Chert
  - Asphaltenes
  - Waxes
  - Complex sands, silts and clays
  - Will probably re-occur

- Other
  - Drilling mud
  - Cement
  - Perf debris
  - Possible to remedy with workover/s

Example of Debris
Sand plugging, bridging and arching

- From gravel pack literature:
  - Tendency for bridging = $k \frac{D_{\text{sand grain}}}{D_{\text{gravel}}}$
  - Capacity for unrestricted flow = $k' \frac{D_{\text{perf}}}{D_{\text{sand grain}}}$

- Studies concluded ratios from 3:1 to 16:1 hole size to flowing solid size

Dr. Tariq Schlumberger

Coal

Can Be a water source, check offsets
Carbonate Example

Note SP and Pe response
**Gamma Ray (GR)**

- Can be useful to identify shale collapse
- Warning: GR is statistical… don’t read too much into subtleties if the logs show different character - the borehole has changed (casing & cement)
Compensated Neutron Log (CNL) Diagnostic Log
Note GR and N Porosity Differences

- Can be useful to identify coal shifts
- Warning: N is statistical… don’t read too much into subtleties if the logs show different character - the borehole has changed (casing & cement)
50/50 Deep Penetrator (DP) / Big Hole (BH) or eXtra Big Hole (XBH)

- Politically correct – why didn’t you use …?
- How thick is the cement sheath? – use manufacturer’s model to determine penetration through the sheath – usually the cement sheath is not that thick
- Can you shoot through drilling fluid loss damage?
- Increased volume of traumatized zone?
- Sacrifice of flow area

Traumatized zone DP vs. XBH
A New (Better) Configuration Than 50/50

- 26 Shots Per Meter (SPM) – 20 XBHs and 6 DPs
  - 1/3 DP by 2/3 XBH 26spm
  - Or
  - 2:1

- Less sacrifice of flow area
- Consistent with production performance data
- New - suppliers need lead time

Penetration versus compressive strength

<table>
<thead>
<tr>
<th>Charge</th>
<th>Target</th>
<th>Penetration increases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>Steel</td>
<td></td>
</tr>
<tr>
<td>Rock</td>
<td>Rock</td>
<td></td>
</tr>
<tr>
<td>Unconsolidated sand</td>
<td>Unconsolidated sand</td>
<td></td>
</tr>
</tbody>
</table>

Jet dispersion increases - penetration decreases
Casing and Cement Issues

- Un-supported casing and cement is more likely to fail
- Do you perforate through collars?
  - Not recommended for thermal operations
  - Depends on how thick the zone is
    - many don’t

Current Trend Is Not To Shoot Through Collars

Probable casing failures

Overburden

Completely failed region

Do not perforate on the same horizontal plane in environments where this occurs
Example of perforation damage to unsupported casing

Before

After

No severe damage from perforating
**Re-perforating Trends**

- Not popular ’70s Bob Hayes “Do we need more holes or are we just shaking things up?”
- Early ’80s + - 10% successful
- Mid ’90s optimizations with PCPs – 90% successful
- 2000 – casing and cement damage!!
- 2005 – missed pay and stimulation

**Perforating Debris**

- Perforating debris from a 127mm 6 meter 26 spm DP / XBH gun
- Debris magnets are recommended
Questions and Discussions

Extending Cold Production Applications

- Stepping out from core heavy oil region
  - NW ~ sands weaker, oil more viscous
  - SE ~ sands stronger, oil less viscous
  - Kuwait, Alaska, Venezuela, Columbia, Albania, Argentina
- Broader variation in reservoirs
  - heavy oil sands are not uniform
  - differences occur over many scales
    - field to field
    - pool to pool
    - zone to zone
      - interval to interval
    - well to well
Heavy Oil Completions

Can we throw out the cookie cutters?

Alternate cookie cutters (methods)

Methods specific to the reservoir

The cookie cutter:

- Perforate aggressively under balanced
  - Tight phasing, big hole, high shot density
  - Most of the zone
- Rapidly clean out with Pump To Surface (PTS), bailer or put on production with a Progressive Cavity Pump (PCP)
- Produce aggressively with PCP with as low as possible fluid level

30% of CHOPS wells fail
Shale Spalling

- **De-pressurized shale from large draw down causes tiny particulate shale debris**

- Establish a buffer layer

Minimize shale spalling

- **Strategy for reducing risk**
  - identify a buffer layer below shale to be not perforated
  - thickness of buffer layer may depend on thickness of zone
  - maintain a conservative draw down and avoid well bore trauma
Shale Collapse

Casing Failure and Shale Collapse

Stable pillars
Casing Failure and Shale Collapse

- Strategy for reducing risk
  - perforate balanced or slightly under balanced
  - perforate less aggressively with no more than 120°, 180° or 0° phasing
  - slowly increase pressure draw down until production is initiated
  - produce at a constant draw down until risk of destabilizing near well region becomes small (i.e. wormhole network is growing away from well)
  - stable pillars harder to establish and maintain in thicker zones and are easy to establish between laminations
  - steady draw down propagates worm hole growth of the weakest sands

Laminate pay example

$400k in rubble workovers
Laminate Pay Collapse

4.0 m perforations - 104 shots

Laminate Pay Collapse

Fragmentation

Extraneous water path
Penetrators

- Mill a 25.4mm window in casing
- Drill a 25.4mm, 2 meter horizontal hole
- Tool is controlled and activated by changing circulation rates and pressures
- Minimizes cement and shale fragmentation
- Overcomes drilling and fluid loss damage
Example #2

Penetrated 8 x 1” holes at 90°

Example #2 Production

Well watered out
Discontinuous shale?
Penetrator conclusions

- Sustained production was achieved with a minimum of holes and flow area
- Proper clean up was achieved with chemicals and 24-36 hour PTS operations

Cost Comparison  Courtesy of Ryan Rueve, Nexen
Pump to Surface (PTS) (with Tubing Conveyed Perforating (TCP) vs Perforating While Foaming (PWF) (TCP)

- PTS (4 days with Rig)
  - Rig (38 hrs) $13,680
  - Consultant $3,000
  - PTS Tool $2,500
  - Pressure/Vac $1,500
  - Total PTS costs $20,680

- PWF (3 days with Rig)
  - Patented
  - Rig (29 hrs) $10,440
  - Consultant $2,250
  - Foam Unit $8,000
  - Pressure/Vac $2,200
  - Total PWF costs $22,890

- Extra cost to PWF is approx $2,200. This is saved by less workovers caused by sand in months after the completion.
- Costs not included above are: perforating, tubing, rods, pump, etc. These items are the same in both scenarios.
Reservoir Properties

- Bakken/Basal Mannville
- ~850 mKB (80m Sub Sea)
- Gravity: 16API
- Density @ 15°C = 965 kg/m³
- Viscosity @ 30°C = 500 cP
- Porosity: 30-33%
- Permeability: 2,000-4,000 md

Located 130 km South of Lloyd in SK

Sand Cut Comparison of PTS & PWF
Filtered data 3 vs 3 wells – first month

Average Monthly Oil Production for Fields By Completion

- Nexen PWF Wells
- Nexen PTS Wells
- Offset Wells

Cumulative Monthly Oil Production (m³)

Nexen PWF Wells
Nexen PTS Wells
Offset Wells

31/09 PTS
Economics of more aggressive completions:

- 3 wells verses 3 wells for the 8 months after the first month
- The aggressive competed wells produced 4850 m³ more oil
Observations From Data

- Take it with a grain of salt especially the filtered data
- Excellent period of production
- PWF wells are to the outside of the pool (good and bad)
- PTS well 3.1 meters of perforations did quite well

Perturbation

- Definition:
  - Positive or negative pressure change
  - Can be as minute as varying the hydrostatic head from reciprocating pumps
    OR
  - As large as massive pressure changes from foaming and the use of propellants (i.e. 60 MPa)
Pressure Perturbation Limits

- Dissipates rapidly as it propagates from the wellbore
- Viscosity prolongs pressure rise and fall time
- Friction losses occur along permeability channels

Drainage Geometry Conformance

Why Do Continuous Sand Extraction (CSE) (CPTS) Pumps Produce More Sand???
CSE surge pump
CSES

Canadian Patent 2,232,948

De-stabilizing sand bridges

Negative well bore pressure perturbation

Overburden pressure

↑

Perforation
or pore throat
De-stabilizing sand bridges

Positive well bore pressure perturbation

Overburden pressure

Perforation or pore throat

CSES

Comparison of 8 Wells Showing Production 3 Mths Before and 3 Mths after Tool Installation

Includes 3 wells that were Shut In Prior to Insertion Avg 4m3/d
Drainage Geometry Conformance

Steady draw down worst case scenario

- Steady pressure gradient
- Lower pressure gradient laterally more stability
- Greatest pressure gradient at tip
- Intact formation

Drainage Geometry Conformance

Perturbed draw down

- Fluctuating pressure gradient
- Intact formation

Intact formation
**Drainage Geometry Control**

- Perturbations conforms drainage
- Steady draw down propagates worm hole growth of the weakest sands

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- Perturbations conforms drainage
  - Perturbations dissipate rapidly
  - Employ immediately after completion
Continuous Sand Extraction with surge Tool (CSES) Applied on Completion – Drainage Geometry Conformance

- Advantages
  - Pumping equipment is capitalized
  - The pumps can economically rebuilt in extreme sand cut environments
  - The surge action enhances sand failure – conforming wormhole initiation and destabilises bridging

- Needs to be applied upon completion
  - Surge action only effects near well

- Study in progress 3 new completions are being equipped with CSESs

Example of Downhole Pressure Perturbation With CSES
Offset PCP example – 3.46m³/d average

CSES Applied on Completion – 7.33m³/d average
20% sand cut
CSES Applied on Completion - 6.74m³/d avg
66 % sand cut

Questions and Discussion
**Pump Problems?**

- **Bridging in tubing**
  - Plug off at intake
  - Smaller ID tubing
  - Perforated joints
  - Perforated tag bars
  - Hollow rods
  - Hollow rotors
  - Multi intake PCPs
  - CSE – ETU through THIGK valves
  - Others?

- **Bridging in the Annulus**
  - Plugged off inflow
  - Smaller ID tubing
  - Perforated joints
  - Perforated tag bars
  - Hollow rods
  - Hollow rotors
  - Multi intake PCPs
  - CSE – ETU through THIGK valves
  - Others?

**Possible Solutions:**

- **Bridging in annulus**
  - Loading and continuous loading
  - Reciprocating tubing pumps
  - Coil tubing the annulus
  - Others?

- **Plug off at intake**
  - Loading and continuous
  - Flush by
  - Scope foam head
  - Service rig – circulate down, line bail, tubing bail, clean out
  - Charge/bail out, pump
  - Extended rotors
  - Paddle rotors
  - BHP landing Dev
  - Gizmo’s
  - Tail joints
  - Perforated joints
  - Perforated tag bars
  - Hollow rods
  - Hollow rotors
  - Multi intake PCPs
  - CSE – ETU through THIGK valves
  - Others?

- **Bridging in tubing**
  - Smaller ID tubing
  - Stable foam stimulation
  - Scope foam head
  - Re-perforating
  - Filling
  - Perforation wash
  - Bailing / swabbing
  - Sebree tool
  - Propellant stimulation
  - Abrasi-Jet, Penetrators
  - Reciprocating tubing pumps
  - CSES
  - Others?
Decline Rates for Diagnostics

- **Catastrophic**
  - Mechanical
  - Shale collapse
  - Near well bridging

- **Gradual**
  - Loss of foamy oil drive
  - Flow impairment from load fluid
  - Formation bridging

Hours to a week

A week to months

Approaches to Cold Heavy Oil Production:
Workover Practices and Strategies

March 15th, 2000
Tropical Inn – Lloydminster AB

M. Dusseault, K. Hayes, M. Kremer, C. Wallin
The Tools Reviewed in the Workshop

- Loading
- Continuous loading
- Circulating
-Flushes and superflushes
- Swabbing
- Sand line bailers
- Tubing bailers
- Select perf washes and perf cleaning
- Coil tubing and CTU flushes
- Pump to surface
- Portable PTS
- Continuous PTS
- Re-perf
- Chemical treatments
- Propellant stimulation
- Stable foam clean outs (tubing) and stimulations
- Coil tubing foam clean outs
- Abrazi jet
- Proppant/Hydraulic fracturing
- Pressure pulsing

Stuff Not Reviewed in the Workshop

- Mechanical remedies list
- Sebree tool
- Scope tool
- CTU/flush units
- Gas management
- Sand management
- CSE with surge tools
- Balls checks for PTS
- Others?
- Completion strategies
  - Shale strategies
  - PAPWF
  - Delayed water encroachment
- Combined and staged approach
- Others?
Staged Approach

- Minimize risk
  - Diagnose, confirm, determine the extent of the problem
  - Treat and evaluate treatment
  - Re-treat or attempt a different treatment
  - Evaluate
  - Produce with a different production strategy
  - Abort when necessary
  - Example: Severe Inflow Blockage Program (SIBP)
    - A work in progress

Post Workover Production Strategies

- Change production rates
- Change pumping fluid level and/or annular gas pressure
- Change pumping equipment
- Start or modify load program
- And so on, and so on …
- Congruent with workover strategy
The Pitfalls:

- Cookie cutters and magic pills
  - Without proper diagnosis, too frequently
  - Flush Production
- Flavor of the week and trends
- The lure of the latest and greatest
- Successes – misplaced credit
- Too rapid or slow application – tracking
- Complacency
- Changing too many variables
- Lowered one servicing cost but increasing another
- Wrong diagnosis – wrong conclusion (that doesn’t work)

The 80/20 Rule

- Spending 80% of the time working on 20% of the production
- Can we make good wells better?
Dilation/failure by pressure

Positive well bore pressure perturbation
Dilation/failure by pressure

Negative well bore pressure perturbation

Overburden pressure

Intact formation

Negative Perturbations Naturally More Conformed

Energy is virgin reservoir pressure

More and stronger perturbations are better
Loss of Solution Gas

- Reservoir heterogeneity
- Asymmetric drainage geometry from wormhole growth
- Blockages caused by formation debris
- Water and/or gas breakthrough
- Casing venting during production interruption or production suspension

While producing the more mobile portions of the reservoir, the less mobile become more so
Near Well Bore Blockage

Viscosity increases

Weakest sand

Oil and sand production

Ex-solviing gas

Near Well Bore Blockage

Depleted Zone

Path of Least Resistance and That Is NOT Where the Problem Is

Treatment Fluid

Dead Oil
SIBP Example – 11-23

- Mid Oct '05 executed SIBP
- Cutter stock was pulsed to treat SCHMAG
- Fluid level rose
- Foam circulation and surging produced debris and oil operation continued for 3 days
- Installed CSES to de-stabilize debris and sand bridges
- Producing 9 m³/d with 16 joints of fluid

Diagnostic Logs for 11-23

OH GR

Diagnostic GR
Production Data for 11-23

[Graph showing oil production rate over time with post CSES data highlighted]
Another Staged Intervention
C1-18

- Chemicals were placed by a perf wash tool to treat SCHMAG and left 7 days to soak
- Sebree tool and bailing were used to remove debris from the well bore and near well area over a 2 day period

Incremental Production for C1-18
During Intervention

[Graph showing cumulative oil production over time and production rate for 32.8 m³/d equivalent calendar day.]
Production Data for C1-18

Questions and Discussions
Chemical and/or fluid stimulation

- Should be done with pressure perturbations
  - Enhances formation access
  - Adds energy to the reaction
  - Dislodges blockage mechanisms
  - Initiates particulate movement
- Volumes should be relative to produced sand

Odyssey Tool
Conventional Perf Wash Tool

Perf wash
Perf wash

Just load chemical
Chemical placed with positive perturbations

A Successful Odyssey Tool Job

Production Rate of Oil/Water (m³) Versus Weeks from Before & After Usage of Pulsating Pulse Powerwave Tool

- Pre-Powerwave Oil & Water Production Trends
- Post-Powerwave Oil & Water Production Trends
- Sparky Formation Zone
- Linear (Avg. Measured Oil (m³))
- Linear (Avg. Measured Water (m³))

Stimulation Intervention (Approx. @ Week 6)
A successful perf wash Tool Job

Odyssey Pulse Tool vs Perf Wash Tool Study

- Definitions:
  - Technical success: Sustained production for 3 months or the limit of the data of at least half of prior peek production
  - Pay out success: Can not be an economic success if not a technical success and has sustained production for 3 months or the limit of the data of 1.5m3/d
  - Profitable success: Same as above but with sustained production of 5m3/d
Odyssey Pulse Tool vs Perf Wash Tool Study

- All wells were relatively new (i.e. weeks to 2 months)

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- Technical: 36%
- Fail: 64%
- Payout: 21%
- Fail Profitable: 79%
- Fail Profitable: 7%
- Fail: 93%
### Odyssey Pulse Tool vs Perf Wash Tool Study

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| TTI | 14      | 2              | 9           | 7               | 4               | 12             |
|     | 88%     | 13%            | 56%         | 44%             | 25%             | 75%            |

### Odyssey Pulse Tool Different Well Set – older wells – public data

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| TTI | 4        | 9              | 4           | 9               | 3               | 10             |
|     | 31%      | 69%            | 31%         | 69%             | 23%             | 77%            |
**Latest Study - ?**

- Started with Severe Inflow Blockage Program and Inflow and Production Impairments from Loss of Solution Gas in Cold Production - Sawatzky and Hayes
- Chemical pill and chase fluid volume is relative to the produced sand (i.e. 20%)
  - Combined intervention using Odyssey tool for chemical placement and Sebree swab tool to re-establish solution gas drive.
  - 2 wells done to date. The first has 2 weeks of 9.3m/d production with 38.5% BS&W with 13 joint fluid level to chase.
  - The second well operations were suspended due to extremely high sand cuts – a foam clean out is planned.
  - 6+ jobs are in the works

**Loss of Solution Gas**

- Reservoir heterogeneity
- Asymmetric drainage geometry from wormhole growth
- Blockages caused by formation debris
- Water and/or gas breakthrough
- Casing venting during production interruption or production suspension
- Under balance events during drilling and/or completions

**While producing the more mobile portions of the reservoir, the less mobile become more so**
Sebree Swab Stimulation on a Disposal Well

- In 9hrs recovered 158m3 of water and 25m3 of sand
- Prior injection was less than 300m3/d and inadequate
- Currently the well is taking 400m/d on vacuum

Sebree Swab Tool Current Initiative

- Rigless Completions:
  - Manage completion and construction costs on new drills
  - To ensure inflow is established from problems such as low pressure, drilling damage and reluctant gas break out.
  - To enhance gas break out and conform sand failure; optimizing drainage geometry
**Case History - Alberta Pressure Pulsed Water**

**Pulsed Polymer Flooding**

- Conventional water flooding is expanding to more viscous reservoirs
- Pressure pulsed water flooding currently deployed in 500 – 1000cps reservoirs
- CNRL’s polymer flooding experience is economically successful up to 10,000cps or greater
- Pulsed polymer flooding will be able to increase flooding applications to - ?
- It’s possible to implement pulsed polymer flooding very soon
- Pulsed polymer flooding is the least riskiest EOR option
- Imagine pressure supported production in the CHOPS region
Enormous Drainage Geometries

Attachment 7
TRACER TESTS - SECTIONS 28, 29 & 32-55-6 W4M

after Andrew Squires and Earl Jensen
Recon CHOPS Workshop Calgary Sept 21, 2011

Dual induction and SFL curve example
Potential Water Sources in Oil and Gas Wells

Diagram showing layers of geological features including gas cap, oil, seal, wormhole, formation water, and "extraneous" water.
Progressive incursion of water from non-producing zone (formation "B") results in intermediate compositions.

Mass-Balance equations may determine how much of each water source is being produced.

Formation "B"

Water incursion (behind pipe)

Water cut may or may not increase.

Initial production water composition (Sw)

Formation "A"

Water coning trend

Production Water Origin and Isotopic Changes with Time/Source
HDD Examples 133 Samples Per Meter (SPM)

- Demonstrates value for picking intervals to avoid shale damage
- Demonstrates the potential for exploiting oil over water where vertical permeability impairments exist – current works in progress Ex 4

Ex. 1
Mini Plot

Perfs 535 -538

Of interest 547 -550 vertical permeability impairment may stop bottom water?
Ex. 1

Perforated interval

Ex. 1

Permeability impairment
Ex. 3

Mini Plot

Perfs 525 – 527.5

Of interest 534 -535 vertical permeability impairment may stop bottom water?

Ex. 3

Perforated interval
**HDD Example 5**

- Demonstrates value for picking gas interval permeability 442.3 – 442.5 over possible water ???
- Demonstrates thin zone between carbonate lenses at 447.2 – 447.7
**High Resolution Example**

- Schlumberger high definition log
- Demonstrates laminate cap rock
- Example well had severe inflow blockage (see pictures from intervention)
- Perforations 446.0 to 452.0
Normal Resolution

High Resolution
A Completion Example

Proposed 8 meters of perforations
A Completion Example High Definition Data (HDD) Log

Suggested 3.4 meters of perforations

Only shot 1.8 meters too much sand inflow rigless operation

Well produced about 15m³/d

Top Water Example of Extreme Density Oil
Questions and Discussions