# **Table of Contents**

# Cold Heavy Oil Production with Sand in the Canadian Heavy Oil Industry

# Some Recommendations Relating to Alberta Heavy Oil

- 1. Royalty/Taxation Regime
- 2. Survey of CHOPS Economic and Recovery Impact
- 3. The Issue of Upgrading Capacity
- 4. Technologies and Resource Recovery Efficiency
- 5. Suspended Wells
- 6. Use of Natural Gas as a Fuel for Thermal Recovery
- 7. Reporting Sand Volumes and Waste Volumes Monthly

# 1 Introduction

- 1.1 Issues and Definitions
  - 1.1.1 The Scope of the Report
  - 1.1.2 Definitions
- 1.2 General Geological Setting
- 1.3 CHOPS and Other New Technologies
  - 1.3.1 CHOPS
  - 1.3.2 Other New Production Technologies
- 1.4 Canadian Heavy Oil Production
  - 1.4.1 Production and Upgrading
  - 1.4.2 Increase in Heavy Oil vs. Conventional Oil Production
  - 1.4.3 Heavy Oil Price Cyclicity

# 2 World Conventional and Heavy Oil

- 2.1 Sources of Hydrocarbons
- 2.2 How Much Heavy Oil is There?
  - 2.2.1 World and Canadian Heavy Oil Resources
  - 2.2.2 Canadian Heavy Oil Belt Resources
- 2.3 World Issues
- 3 CHOPS

- 3.1 CHOPS and Related Technologies
- 3.2 History of CHOPS Development
  - 3.2.1 History of Sand Production in Canadian Heavy Oil
  - 3.2.2 Current CHOPS status worldwide
- 3.3 Typical Alberta Reservoirs
- 3.4 Typical CHOPS Well Behavior Summary
- 3.5 CHOPS Production Behavior
  - 3.5.1 Production Profiles
  - 3.5.2 Well Productivity and Evolution
- 3.6 Typical Sanding Rates in Canadian Wells and Fields
- 3.7 What Constitutes a CHOPS Project?

4 Physical Processes in CHOPS Production

- 4.1 Reservoir Mechanisms Maintaining Sand Influx
  - 4.1.1 Energy Sources and Stresses
- 4.2 Flow Enhancement Mechanisms
  - 4.2.1 Darcy Velocity Increase with Sand Influx
  - 4.2.2 Permeability Enhanced Zone Development
  - 4.2.3 Foamy Oil Behavior in Viscous Oil
  - 4.2.4 Elimination of Skin Effects
  - 4.2.5 Change of Mechanisms with Time
- 4.3 Channels or Compact Growth Zone?
  - 4.3.1 Uniform Remolded Zone Growth Concepts
  - 4.3.2 Piping Channel (Wormhole) Growth Concepts
  - 4.3.3 Combined Compact and Wormhole Processes
- 4.4 Discussion of Stresses
  - 4.4.1 Stresses in the Wellbore Region
  - 4.4.2 Reservoir-Scale Stress Changes
  - 4.4.3 Stresses Around a Channel

# 5 Case Histories: Luseland Field & Horizontal Wells

- 5.1 Luseland Field History and Reservoir Parameters
- 5.2 Production History for Luseland Field

- 5.3 Individual Well Behavior
- 5.4 Field Behavior
- 5.5 Horizontal Versus Vertical Wells?
  - 5.5.1 Lindbergh Field Horizontal/CHOPS Comparison
  - 5.5.2 Plover Lake Field
  - 5.5.3 Cactus Lake Field
  - 5.5.4 Evaluation of Non-Thermal Horizontal Wells vs Vertical CHOPS Wells
- 5.6 The Mathematical Simulation of CHOPS
  - 5.6.1 Non-Conventional Processes in CHOPS
    - 5.6.1.1 Liquefaction of Sand
    - 5.6.1.2 The Enhanced Permeability Zone=
    - 5.6.1.3 Foamy Oil Behavior
    - 5.6.1.4 Slurry flow
  - 5.6.2 Conventional Approaches to Simulation
  - 5.6.3 Stress-Flow Coupling and Physics-Based Modeling
- 5.7 CHOPS or Not?

### 6 Canadian CHOPS Production Practices

- 6.1 Initiating and Sustaining Sand Influx
- 6.2 Lifting Approaches
  - 6.2.1 Reciprocating Pumps and Related Devices
  - 6.2.2 Continuous Sand Extraction CSE Pump
  - 6.2.3 Jet Pump Development and Use
- 6.3 Progressing Cavity Pumps
  - 6.3.1 Evolution of PC Pump Use in Canadian Heavy Oil
  - 6.3.2 Current PC Pump Practice in the HOB
  - 6.3.3 "Sloppy-fit" PC Pumps
  - 6.3.4 Charge Pumps
  - 6.3.5 Constant Elastomer Thickness PC Pumps
  - 6.3.6 Rotor Wear
  - 6.3.7 Downhole Drives for PC Pumps
- 6.4 PC Bottom Hole Configuration and Operational Management

- 6.4.1 PC Pump Bottom-Hole Installation
- 6.4.2 Surface Drives
- 6.4.3 PC Pump Operation in a New CHOPS Well
- 6.4.4 PC Pump Rates, Sand Tolerance
- 6.4.5 PC Pumps as Surface Transfer Pumps
- 6.5 Sand Transport and Erosion
  - 6.5.1 Erosion Problems in Tubulars and Wellheads
  - 6.5.2 Sand Transport in Flowlines

#### 7 Well Instrumentation

- 7.1 Downhole Measurements
  - 7.1.1 BHP Gauges
  - 7.1.2 Other Downhole Measurements
- 7.2 Surface Monitoring Equipment
  - 7.2.1 Fluid Production Metering
  - 7.2.2 Stocktank Measurements
- 7.3 Gas Sampling
- 7.4 BS&W Measurements
- 7.5 Risk, Chaotic Behavior, Sampling
  - 7.5.1 Risk from Sanding
  - 7.5.2 Chaotic Behavior and Sampling
  - 7.5.3 Recommended Sampling Program for a CHOPS Field
- 7.6 Requirements for Reporting to Regulatory Agencies

#### 8 Workovers for CHOPS Wells

- 8.1 Surface, Wellbore, Reservoir
- 8.2 Time Series Information
- 8.3 Types of Workover
- 8.4 Workover Methods
- 8.5 Staged Workover Strategy
  - 8.5.1 Stages to Manage Risk
  - 8.5.2 Workover Payback
- 8.6 Summary

#### 9 Sand and Fluids Management at the Surface

- 9.1 Stocktanks (Vertical Gravity Separators)
- 9.2 Produced Materials Management
  - 9.2.1 Water Management
  - 9.2.2 Gas Management
  - 9.2.3 Sand Extraction from Stocktanks
  - 9.2.4 Stable Emulsion Management
- 9.3 Treatment of Fluids
  - 9.3.1 Solids Separation at Local Batteries
  - 9.3.2 Stable Emulsion Treatment
  - 9.3.3 Other Approaches Used in the Past
- 9.4 Materials Management for an Integrated CHOPS Project

#### **10** Environmental Aspects and Regulations

- 10.1 Introduction and Information Sources
  - 10.1.1 Definition of Wastes
  - 10.1.2 Classification of Sand Wastes
  - 10.1.3 Volumes of Produced Sand, Limits to Sand Production
- 10.2 Other Hydrocarbon Fluid Wastes From CHOPS
  - 10.2.1 Stable Emulsion
  - 10.2.2 Slops, Site Clean-Up Wastes, Treater Residues
- 10.3 Large Storage Tank Sludges and Solids
  - 10.3.1 Storage Tanks as Separators
  - 10.3.2 Cleaning or Decommissioning of Facilities Containing Sludges
- 10.4 Environmental Interactions
  - 10.4.1 Landfills and Subsurface Groundwater Protection
  - 10.4.2 Surface Stockpile Issues
  - 10.4.3 Surface Spills of Oilfield Wastes
  - 10.4.4 Environmental Liability, Companies and Contractors
- 10.5 History of Regulatory Authority Development
  - 10.5.1 History of Environmental Guideline Development
  - 10.5.2 EUB (Alberta Energy Utilities Board)

10.5.3 SEM (Saskatchewan Energy and Mines Ministry)

#### 11 Waste Transport, Treatment, Disposal

- 11.1 Introduction
- 11.2 Stocktank Cleaning and Stockpiling
  - 11.2.1 Stocktank Cleaning Practices
  - 11.2.2 Stockpiles, "Eco-Pits", and Concrete Sumps
  - 11.2.3 Clean-up of Slops
  - 11.2.4 Treatment of Stable Emulsions
- 11.3 Sand Disposal by Road Use and Land Spreading
  - 11.3.1 Road Spreading: Methods, Advantages and Disadvantages
  - 11.3.2 Sand Incorporation into Road Bases
  - 11.3.3 Land Spreading: Methods, Advantages, Disadvantages
- 11.4 Permanent Landfill Placement
- 11.5 Sand Washing Approaches
  - 11.5.1 Sand Washing by Thermal and Non-Thermal Methods
    - 11.5.1.1 Non-thermal washing
    - 11.5.1.2 Thermal Washing:
  - 11.5.2 Sand Wettability Issues
  - 11.5.3 Generation of Additional Streams
  - 11.5.4 Summary of Washing Technologies for Produced Sand
- 11.6 Produced Sand as Industrial Feedstock
  - 11.6.1 Cement Plant Feedstock
  - 11.6.2 Road Asphalt Component
  - 11.6.3 Glass and Fiberglass Sand
  - 11.6.4 Sand Blasting or Other Uses
  - 11.6.5 Industrial Uses Summary
- 11.7 Salt Cavern Placement of Produced Sand
  - 11.7.1 Why Salt Caverns?
  - 11.7.2 Salt Cavern Potential for Toxic Waste Disposal
  - 11.7.3 Cavern Design and Management
    - 11.7.3.1 Cavern Development and Design

- 11.7.3.2 Waste Placement in a Salt Cavern
- 11.7.3.3 Management of Cavern Growth
- 11.7.3.4 Placement of Produced Sand in Caverns
- 11.7.3.5 Liquids Management in Salt Caverns
- 11.7.4 Rock Mechanics and Geological Engineering Issues
- 11.7.5 Monitoring Salt Cavern Disposal
- 11.8 Slurry Injection of Solid Sand and Other CHOPS Wastes
  - 11.8.1 Principles of Site and Well Selection for Slurry Injection
    - 11.8.1.1 Target Formation Selection
    - 11.8.1.2 Geological Conditions for Maximum Environmental Security
    - 11.8.1.3 Well Perforations
    - 11.8.1.4 Wellbore Cementation
    - 11.8.1.5 Tubing and Casing Design and Conditions
  - 11.8.2 Operational Practices
    - 11.8.2.1 General Approach
    - 11.8.2.2 Daily Injection Cycle Procedure (Figure 11.8)
    - 11.8.2.3 Flow-Through Waste Mixing System
    - 11.8.2.4 Fixed or Mobile Injection Operations
    - 11.8.2.5 Slops, Sludge, Drilling Mud, and Emulsion Disposal in Wells
  - 11.8.3 Environmental Compliance and Monitoring for Process Control
  - 11.8.4 PanCanadian-Terralog Automated Sludge Injection Well
  - 11.8.5 Disadvantages
- 11.9 Other Treatment Options
  - 11.9.1 Thermal Decomposition
  - 11.9.2 Biodegradation Cells
  - 11.9.3 Chemical Treatments

## 12 Economic Analysis of Disposal Options

- 12.1 General Statement and Background of Cost Estimates
  - 12.1.1 Uncertainty and Variance in Costs
  - 12.1.2 Corporate Cost Figures
  - 12.1.3 Comparative NOW Disposal Costs in West Texas

- 12.2 Stocktank Cleaning Approaches and Costs
  - 12.2.1 High Pressure Jetting and Vacuum Trucks
  - 12.2.2 Auger Trucks and LHD Units
  - 12.2.3 Better Ways to Clean Stocktanks
- 12.3 Transportation and Handling Costs
  - 12.3.1 Lease Stocktanks
  - 12.3.2 Sand Transportation
  - 12.3.3 Stockpiling and Handling Costs
- 12.4 Land Spreading and Road Spreading Costs
- 12.5 Landfill Costs
- 12.6 Sand Washing Costs
- 12.7 Salt Cavern Placement Costs
  - 12.7.1 Third-Party Operated Salt Caverns
  - 12.7.2 Use of Existing Salt Caverns
- 12.8 Slurry Waste Injection
  - 12.8.1 Mobile Injection Unit Operating Costs
  - 12.8.2 Static Dedicated Slurry Injection Site Operating Costs
  - 12.8.3 Central Integrated Disposal Facility for "Custom" Disposal
- 12.9 Costs of Other Approaches
- 12.10 Climatic and Geographic Issues

#### 13 Technology and the Canadian Heavy Oil Industry

- 13.1 The Old Technologies
  - 13.1.1 Problems with Older Technologies
  - 13.1.2 Cyclic Steam Stimulation (CSS)
  - 13.1.3 Steam-Drive Methods
  - 13.1.4 In Situ Combustion Methods
- 13.2 Producers of Alberta Primary Heavy Oil
  - 13.2.1 History of Major Oil Companies in CHOPS
  - 13.2.2 Other Companies
  - 13.2.3 Public Research Agencies
- 13.3 Science and Technology Development in Heavy Oil

- 13.3.1 AOSTRA: Alberta Oil Sands Technology and Research Authority
- 13.3.2 Technology Emergence
- 13.4 Emerging Technologies
  - 13.4.1 VAPEX
  - 13.4.2 THAI<sup>TM</sup>: Toe-to-Heel Air Injection
  - 13.4.3 Pressure Pulsing Technologies
    - 13.4.3.1 Darcy Theory and Biot Theory
    - 13.4.3.2 The Porosity Dilation (PD) Wave
    - 13.4.3.3 Benefits to Flow Processes
    - 13.4.3.4 Field Successes for Pressure Pulsing
- 13.5 After CHOPS?
  - 13.5.1 PPT With CHOPS
  - 13.5.2 SAGD With CHOPS?

## 14 Appended Documents

- 14.1 Appendix 1: CANADA'S OIL SANDS AND HEAVY OIL DEPOSITS
- 14.2 Appendix 2: HEAVY OIL POTENTIAL: THE NEXT 50 YEARS
- 14.3 Appendix 3: CANADIAN-VENEZUELAN COMPARISON
- 14.4 Appendix 4: END NOTES
- 14.5 Appendix 5: DISPOSAL OF DIRTY LIQUID USING SLURRY FRACTION INJECTION