Vapour-Liquid Equilibria and Solvent Recovery from Oil Sands Froth Treatment Tailings Streams

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Creating Value from Waste™

- **Development of a new source of heavy minerals to meet growing world demand**
- **2%** Increase in recoveries of processable bitumen for integration with existing upgrading infrastructure
- **75%** Reduction of tailings solvent losses with related GHG and VOC emissions reduction
- **25%** Reduction of fresh water draw from the Athabasca River and thickened tailings per Directive 74

**CVW™ Technology**
Titanium’s CVW™ technology is designed to intercept FTT before discharge to ponds and recover valuable minerals, lost bitumen, solvents and water.

• Naphtha contributes directly to fugitive methane, VOC emissions from tailings ponds
• Process naphtha removed from raffinates (AER mandate ~4 bbl/kbbl dry bitumen)
• Results in current losses of up to 1.4 Mbbls, and fugitive releases of 1 Mt GHGe and 40 kt VOC
Technologies Overview

Process flow diagram

- Bitumen Recovery
  - Flotation
  - Thickener
  - Distillation
  - Solvent extraction
  - Raffinates naphtha recovery to offer environmental benefits and enable minerals recovery

- Tailings Treatment
  - Flotation
  - Thickener
  - Distillation
  - Solvent extraction

- HMC Production (cleaning)
  - Flotation
  - Thickener
  - Distillation
  - Solvent extraction

- Minerals Separation
  - WHIMS HT circuit
  - N/M
  - N/C
  - Fit-for-reuse water
  - Electrical power

- Utilities
  - Steam boiler
  - Electrical power

- Project on-site
  - Project off-site

- Fits for reuse water
- Electrical power

- Tailings
- Zircon
- Water
Tailings Solvent Recovery
R&D program overview

Phase 1: laboratory-scale thermodynamic experiments
- Determine the vapour-liquid equilibrium of tailings over a range of
  - Operating temperatures
  - Contained solvent content
  - TIC process raffinates from naphtha-based tailings

Phase 2: bench-scale kinetic experiments
- Impact of residence time and conditioning intensity on separation performance
- Settling rate/consolidation rate considerations

Phase 3: live demonstration pilot
- Optimize design criteria
- Validate performance at large scale
- Determine operating envelope
- Identify scaling issues
Tailings Solvent Recovery
Phase 1 – VLE experiments

Objective
• To determine the equilibrium thermodynamics governing phase separation in process raffinates

Overview
• Partnered with D-Y Peng at University of Saskatchewan
• Experiments to include a range of temperatures under different feed and operating conditions
• 96 experimental runs tested
Tailings Solvent Recovery
Phase 1 – experimental equipment
Tailings Solvent Recovery
Phase 1 – vapour liquid equilibria
Tailings Solvent Recovery
Phase 1 – vapour liquid equilibria

![Graph showing vapour phase H/W (w/w) vs. Pressure (kPa) for different temperatures.]

- T = 60°C, condition 1
- T = 70°C, condition 2
- T = 80°C, condition 2
Tailings Solvent Recovery
Phase 2 – kinetics experiments

Objectives

• To identify unit operations suitable for tailings solvent recovery
• To determine the conditioning intensity criteria required to achieve/approach thermodynamic equilibrium
• Experiments to include a range of operating conditions including
  • Heat addition rate
  • Liquid hold-up
  • Conditioning intensity
Tailings Solvent Recovery

Phase 2 – results
Demonstration Plants

Phase 3 – tailings solvent recovery validation

Objectives

• $19 million operator-specific, demonstration pilot at CanmetENERGY Froth Treatment Pilot
• Integrated operation of technologies to performance targets, including tailings management
• Optimization of CAPEX/OPEX, design scaling (Tier 1 EPCM)
• 10 kg/min nominal rate for NFT tailings; 1 kg/min for PFT tailings
• 1000 material balances; 50,000 analytical samples (Maxxam Analytics)

Consortium Partners

• Suncor, Syncrude, CNRL (tailings provision; expertise/review)
• Sustainable Development Technology Canada (SDTC; $6.4M)
• Alberta Energy ($3.5M)
• Sojitz Corporation (minerals markets)

Independent Reviews

• COSIA – Tailings Technology Roadmap; priority ranking #16
• Canadian Council of Academies 2015
• Operators: Syncrude, CNRL, Suncor, Iluka Resources, ...
• Consultants: CanmetENERGY, Jacobs Consultancy, Pembina Institute...
Titanium’s Pilot at CanmetENERGY
Titanium’s Pilot at CanmetENERGY
Demonstration Plants
Phase 3 – demonstration tailings steam stripping units
Demonstration Plants
Phase 3 – tailings distillation results

Assumptions:
- 98% bitumen recovery
- FT tailings slurry 17% solids
- process dilution N/B = 0.7
Demonstration Plants

Phase 3 – tailings distillation results

Liquid Holdup (t/t_r) vs. Naphtha Recovery (% wt)

- S/F = 0.05; R/F = 1
- S/F = 0.05; R/F = 6
- S/F = 0.1; R/F = 6
- S/F = 0.1; R/F = 1

Raffinate Naphtha (% wt) vs. Tailings Naphtha (% wt)

- Week 15
- Week 16
- Week 17
- Week 18
- Week 19
Demonstration Plants

Phase 3 – recovered solvent quality
Summary

- Detailed VLE experimentation enabled optimized thermodynamics in design of tailings distillation unit

- Kinetic experiments enabled understandings of mass transfer conditions required to reach VLE

- Titanium’s CVW™ tailings distillation unit validated at demonstration pilot
  - Reduces naphtha loss to tailings by up to 80%
  - Achieves residual losses of ~0.7 bbl/kbbl (compared to current ~4 bbl/kbbl)
  - Can prevent the release of 3-5 Mt/a of GHG and 50 kt of VOC from tailings ponds annually by 2030