Premium coal fuels with advanced coal beneficiation

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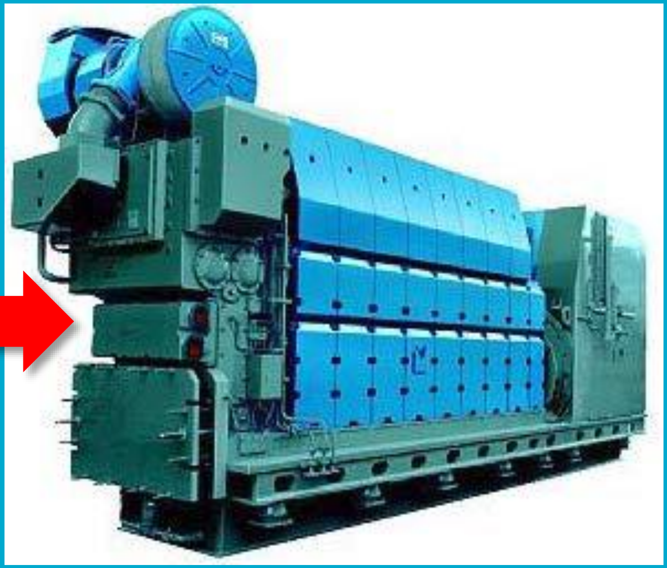


Premium coal fuels with advanced coal beneficiation

Contents

Introduction

- Greater resource recoveries are being sought by mine operators to maximize investment returns.
- Current industry trend - "by zero" recovery of fine coal to maximize resource yield and minimize environmental footprint.
- Fine coal size fraction faces the greatest barriers towards qualification as a product component.
- However, advances in liberation, flotation and dewatering create new opportunities for thermal coal operations. So…………

What are the historical barriers and how are they being overcome?

Why have advanced processing options now become viable?

Ultra-fine Coal Beneficiation

Two distinct approaches:

1. Chemical cleaning – coal structure is changed via chemical decomposition – potential is <0.2% ash residue.
2. Physical cleaning – coal structure not changed, but comminution may be applied for liberation – potential is <1% ash residue.

“Old school” thinking typically regards ash contents below 2-3%, as both technically and economically unviable because:

- “Inherent ash "of coal is usually regarded as the lowest achievable ash content
- Lower ash requires milling to finer particle size to increase liberation
- Flotation of ultra-fine coal can be problematic often requiring higher reagent dosages
- Fine coal concentrates are inevitably high in moisture (> 35%) which means costly dewatering and/or drying to produce saleable products.

Chemically Cleaned Coal

- Caustic leach process has been successfully demonstrated in Australia.
- Similar to the well-proven Bayer alumina process and also the AMAX 2-stage leach process developed with US-DOE funds in the mid-1980s.
- Ultra-low ash residue <0.2%
- Uses include slurry fuel or briquettes
- Costly option difficult to justify in current climate.

Ultra-clean Coal pilot-plant, Cessnock, NSW (Courtesy UCC Energy Pty Ltd.)

Liberation - Inherent ash constraint

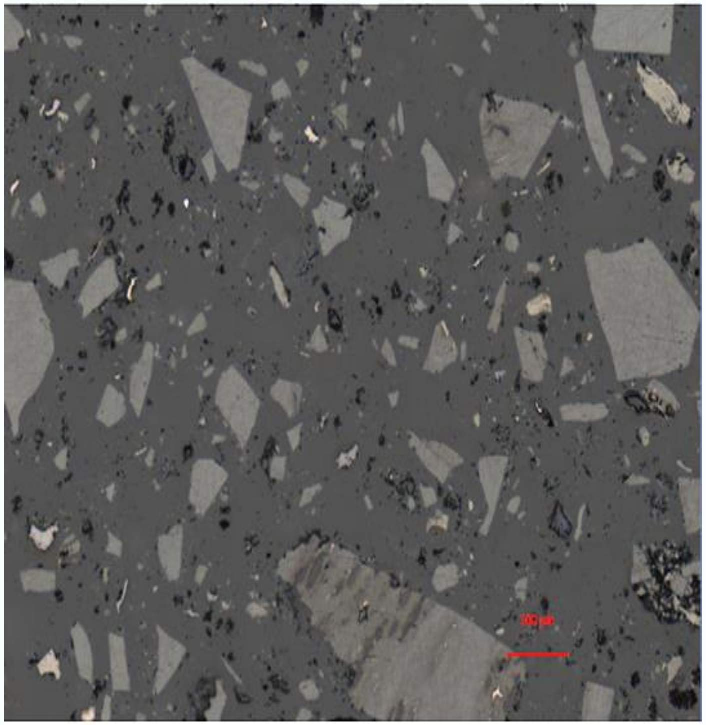
CSIRO has developed an optical reflected light microscopy system for assessing coal petrography samples.

System collects and creates mosaic images so that quantitative information can be obtained on individual coal grains, i.e. **Coal Grain Analysis** (CGA).

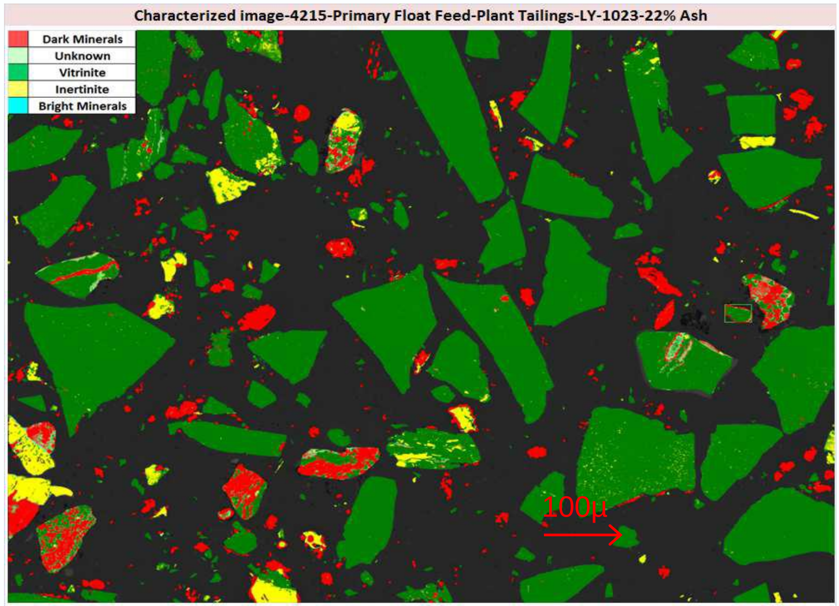
CGA generally requires only small representative sub-samples of <1mm material.

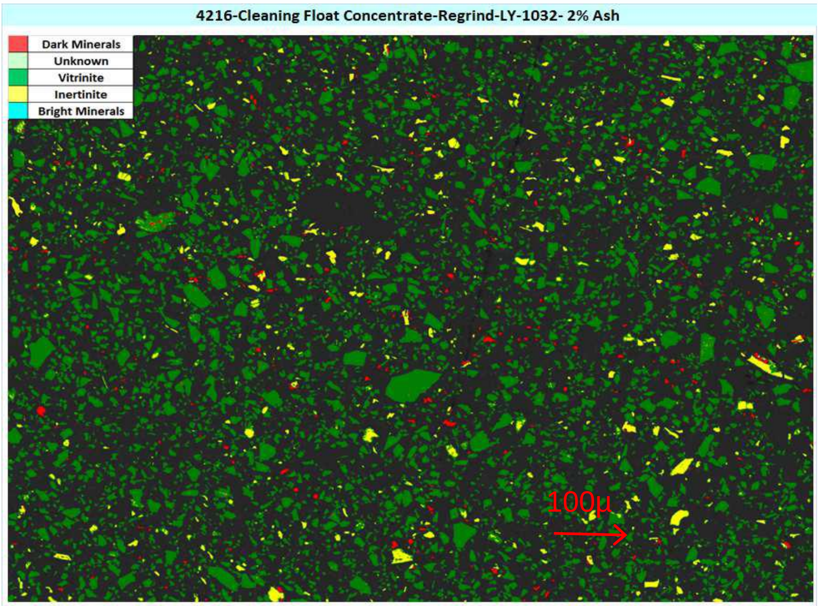
Size and compositional information, i.e., **macerals** vitrinite, inertinite, liptinite and **minerals** can be determined for each particle.

Information can then also be used to estimate % mass, density & “ash” value of each particle.



Liberation – CGA Images Confirm Status





Characterised images for Raw Coal Tailings Feed compared with Final Concentrate. (Courtesy QCAT-CSIRO)

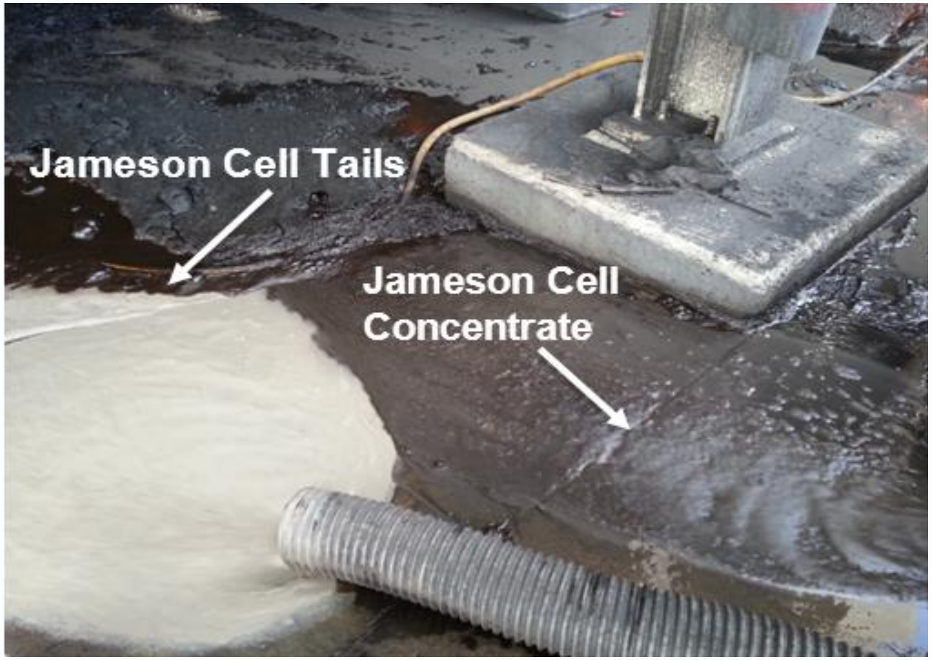
Flotation/Milling process approach

A 1tonne/h pilot-plant, owned and operated by Glencore Technology (formerly Xstrata) comprising

- two Jameson flotation cells,
- a small IsaMill, and a
- membrane filter press, etc.,
- Located at a large thermal coal operation in the Hunter Valley.

Currently testing freshly generated raw coal tailings to produce coal water slurry fuels

Milling and Sub-50µ Coal Flotation



NSW Coal Water Slurry Fuel (CWSF) Pilot Plant

- Successfully produces stable Coal Water Slurry Fuel (CWSF) from coal tailings
- CWSF can then be further refined to produce very low ash (<1% ash) Micronized Refined Coal (MRC)
- MRC produced from 2011 - 2015 for diesel engine tests
- Process information obtained also used for design of CWSF modules including a package plant and fuel handling rig.

Pilot Plant Fuel Production

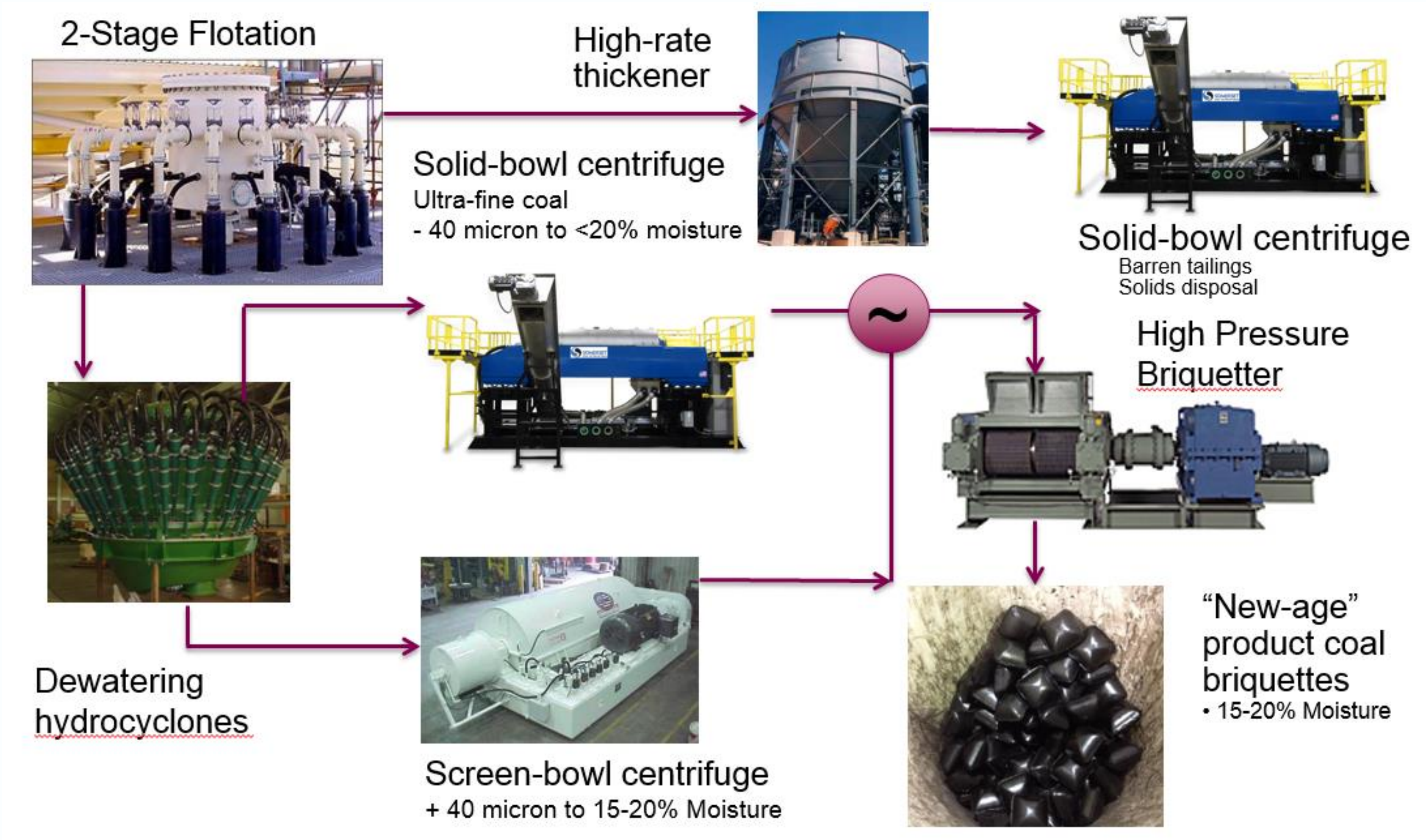
Dewatering Technology

Equipment	Throughput (dry solids)	Product Moisture (% w/w)
Horizontal belt filter	50-130 t/h	20-30
Screen bowl centrifuge	20-60 t/h	16-27
Centribaric centrifuge	15-20 t/h	15-20
Vacuum disc filter	50-150 t/h	20-32
Hyperbaric disc filter	30-150 t/h	17-25
Solid bowl centrifuge	10-18 t/h	18-25
Membrane Filter press	15-30 t/h	14-32

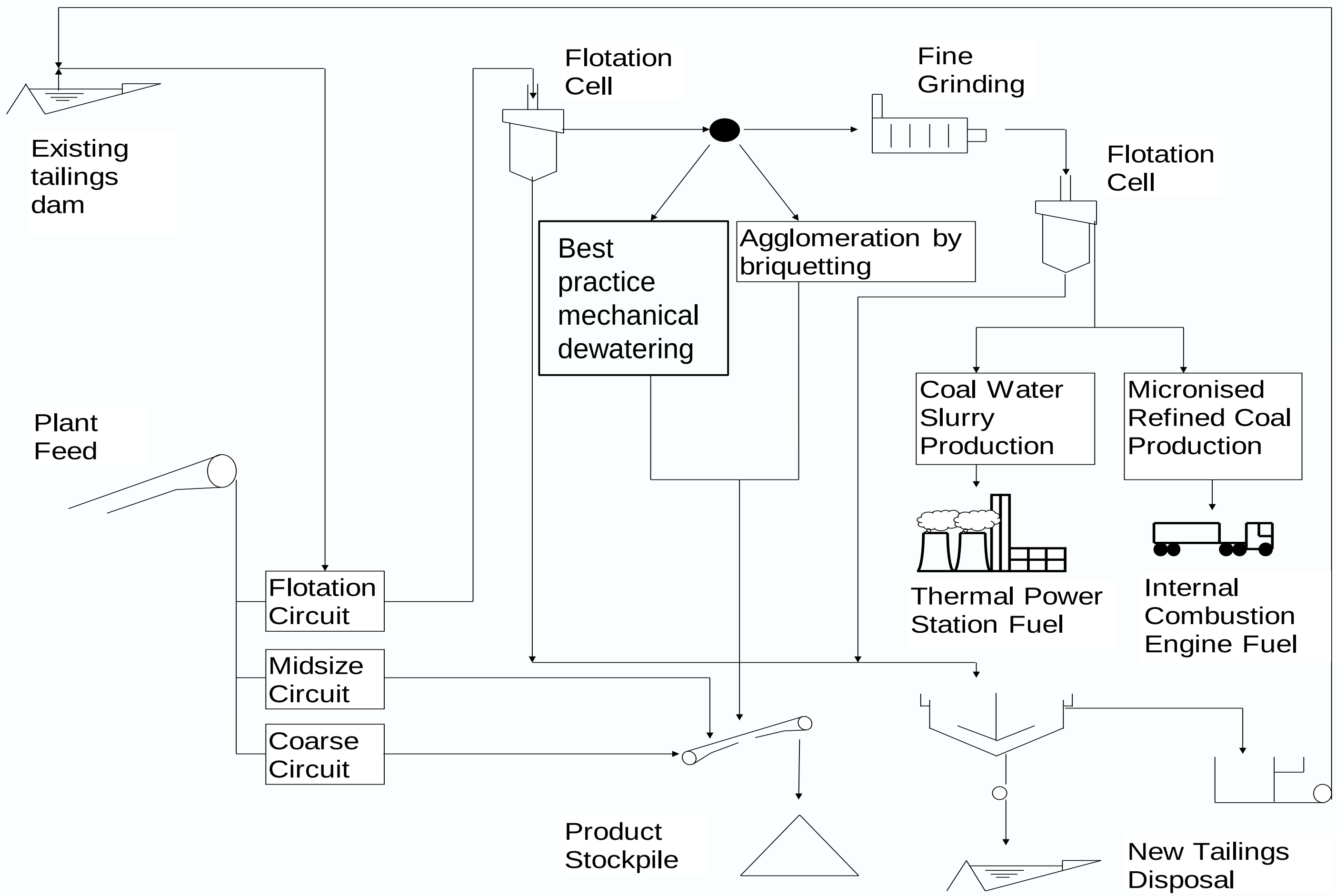
Ultrafines

Key objective is to achieve a cake moisture of 20% or lower for ultrafines

Emerging Coal Fines Treatment Circuit

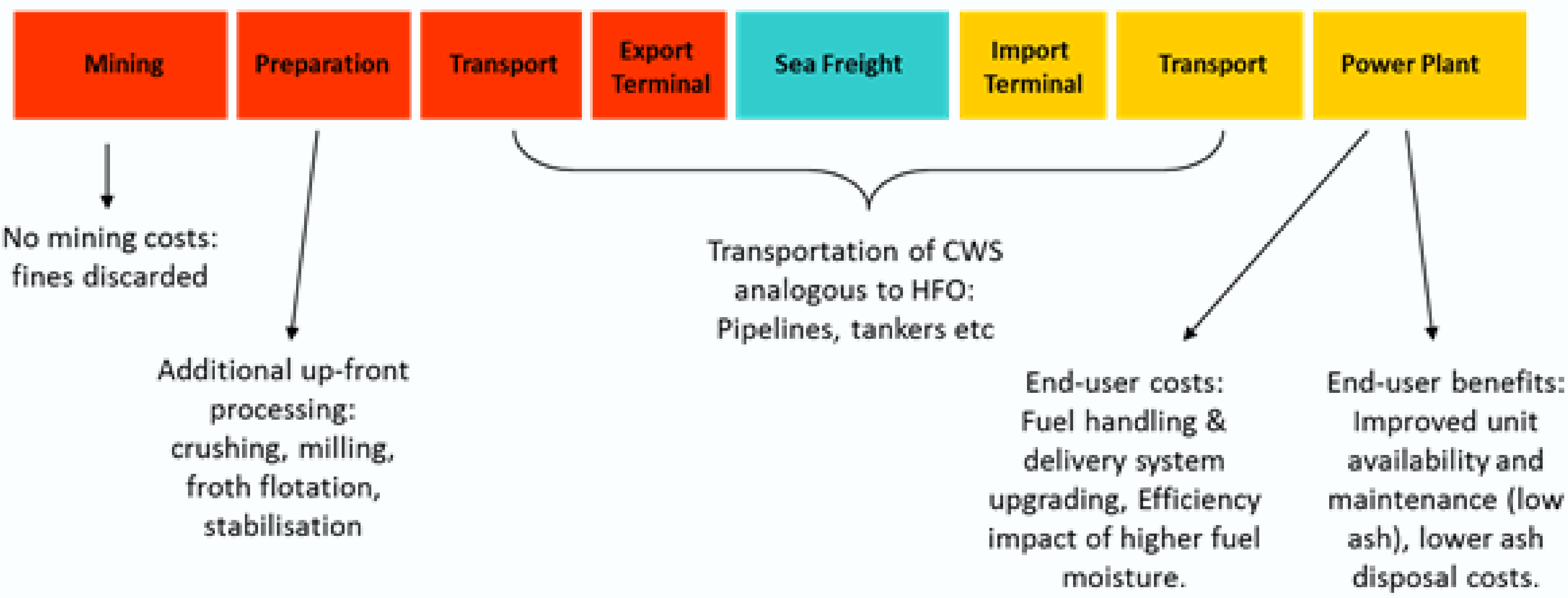


Wider Fines Treatment Options



Coal Supply Chain

- Current Coal Supply Chain (CSC) has been hampered by an inability to dewater and efficiently transport fine coal.
- Innovative approach - recover and use all the ultrafines via <u>coal-water slurry</u> thereby recovering potential “lost coal” creating higher yield and lower cost/tonne.



Innovative Coal Supply Chain

<u>New Low-cost Fuel</u>

- Coal-water slurry fuel (CWSF) at ~70% solids prepared from coarser (bi-modal) particle size distribution (p80 of 0.075 mm)
- Use for direct firing to boilers as a potential replacement for heavy fuel oil (HFO), or partial replacement for Pulverized Fuel (PF)
- Transport as slurry fuel - avoids sticky, wet or dusting coal problems
- Lower tailings disposal cost - paste-thickening, further dewatering for co-disposal with coarse plant discards and mining waste.

<u>User Benefits</u>

- <u>No further grinding needed</u>, significantly lowering cost
- Major O&M savings and lower ash disposal cost
- Reduced thermal efficiency offset by cost reductions from recovering lost coal from tailings.
- Potential to replace > 30% of the pulverised coal capacity.
- **Value Proposition:** a 1.0 to 1.5 c/kWh saving once the boiler has been converted for CWSF.

Micronized Coal Water Slurry

Optimization of the fuel cycle (DICE)

Ultra efficient diesel engine generation

Mining → Process → Transport → Utilisation

- Coal tailings sources
- Including tailings impoundments

- Increased grade recovery
- Recovery of ultra fines
- Minimal dewatering

- Road/rail/ship – cake or slurry
- Pipeline coal water fuels
- Higher solids paste for longer distance

- Mine-mouth or centralized
- Distributed generation
- Support of renewables

Conclusions

- "Deep cleaning" via liberation and subsequent beneficiation has offered significant potential downstream improvements, i.e.,
  - maximised resource recovery,
  - minimised transport and handling costs,
  - numerous end-user process improvements,
  - reduced maintenance and wear,
  - lower environmental impacts and
  - other sustainable improvements.
- Ultrafine coal beneficiation has matured via progressive froth flotation improvements
- Dewatering the concentrate was a barrier, but emergence of membrane filter presses, hyperbaric disc filters or high-g decanter centrifuges now offers commercial solutions.
- Briquetting and agglomeration has progressed to machine capacities of up to ~40 ton/h for fine coal applications to improve product handling.
- Manufacture of stable coal-water slurries with > 65% solids and stable micronized slurries with > 60% solids have reached commercial adoption.
- **Scene is now set** for new generation clean coal technologies with minimal wasted energy, lowest ash disposal costs and reduced SO_x, NO_x and CO_2 emission costs.

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Thank you for your time

Questions?

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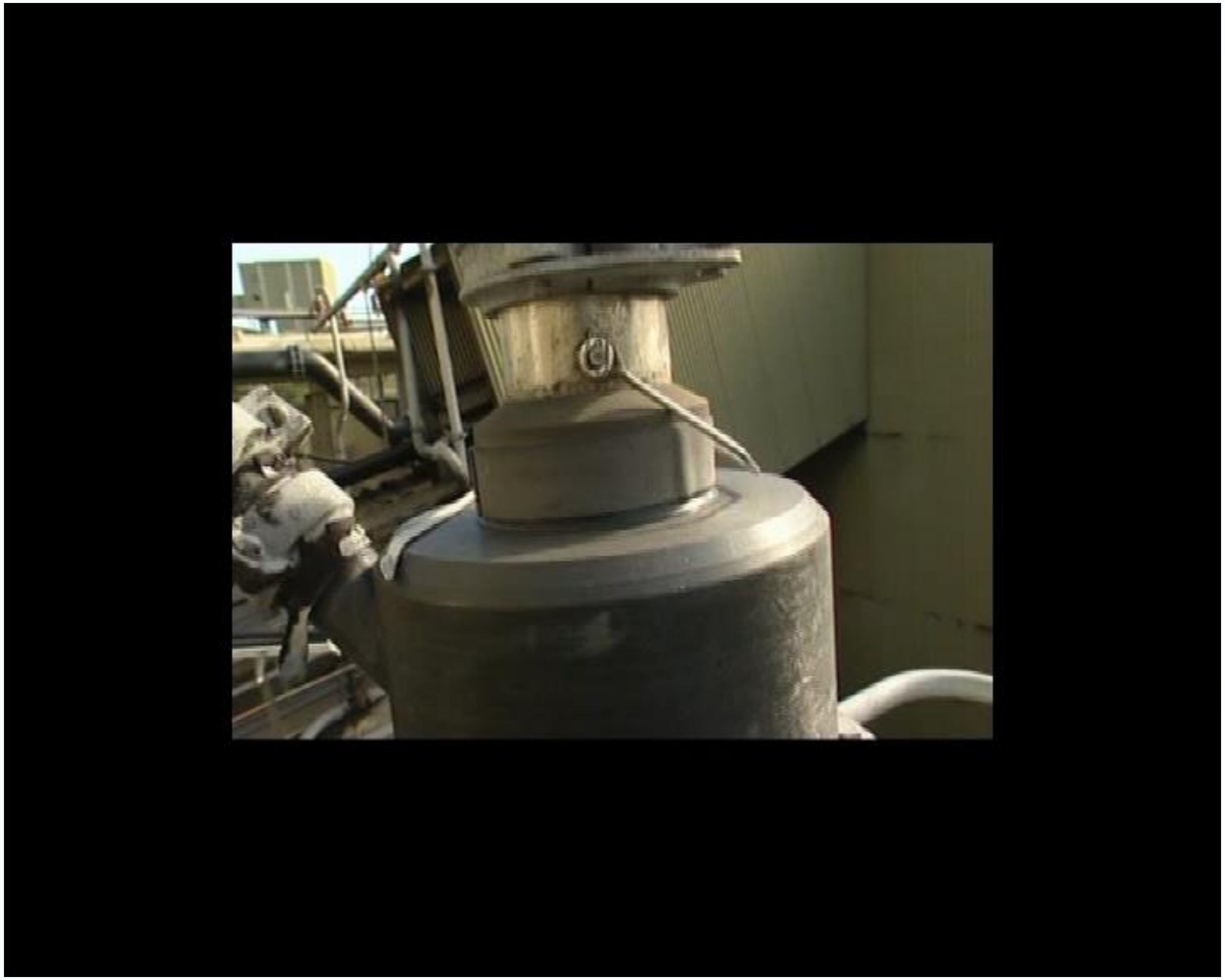
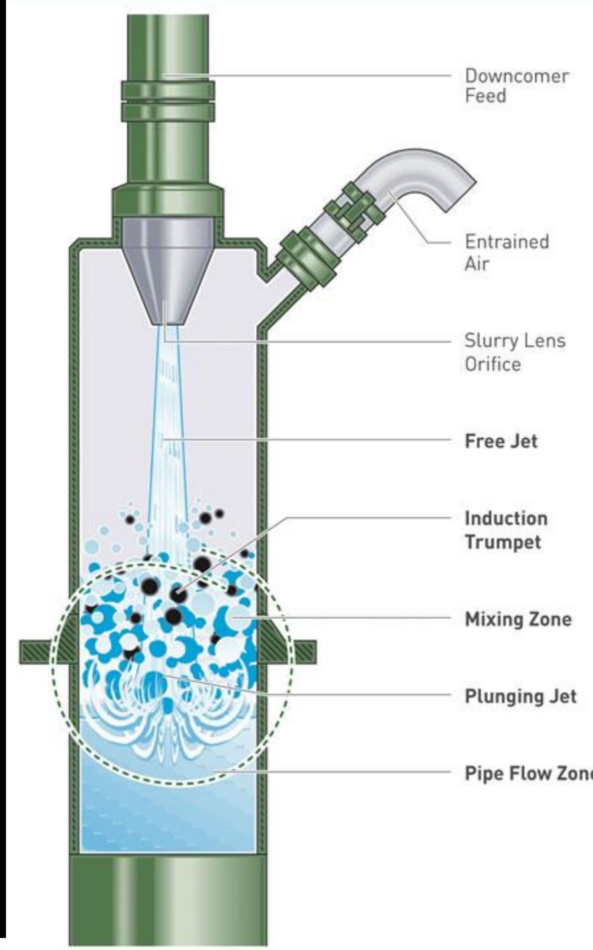
CSIRO

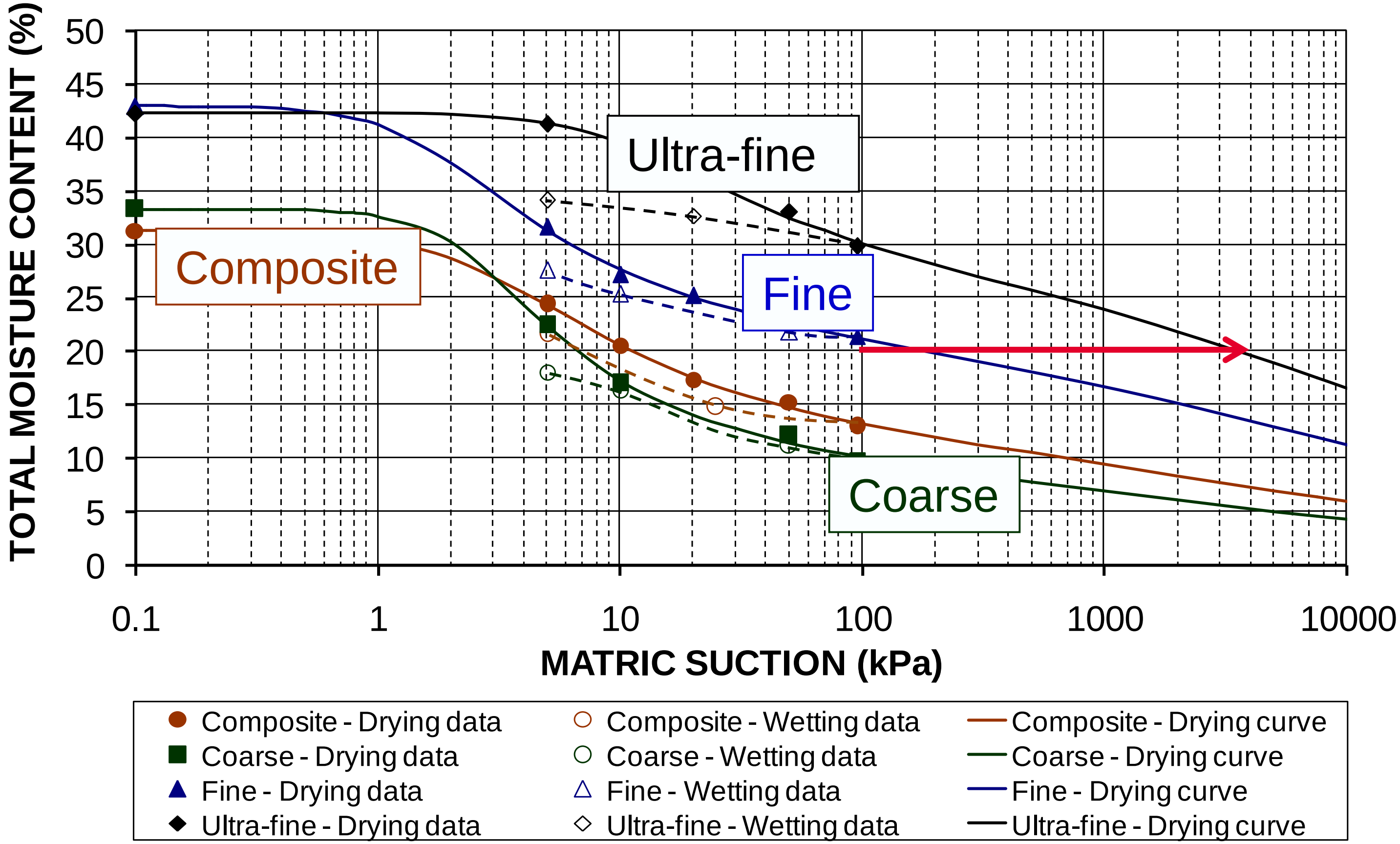
The Jameson Cell - Downcomer





Product Coal Moisture Relationships

- Soil Water Characteristic Curve (SWCC), related to pore size distribution, in turn related to Particle Size Distribution[1].
- Matric Suction is related to Applied Pressure



[1] Source: Prof David Williams; Univ Queensland - *D.Williams@uq.edu.au*

Coal Water Slurry Fuel

Comparison of Coal Supply Chain Costs for Electricity Generation

Conventional Coal

FOB 80 $/t | CIF 90 $/t | Total Costs = 144 $/t | Total Costs = 5.5 c/kWh

Mining	Preparation	Transport	Export Terminal	Sea Freight	Import Terminal	Transport	Power Plant
60 $/t	5 $/t	10 $/t	5 $/t	10 $/t	5 $/t	5 $/t	44 $/t
2.0 c/kWh	0.2 c/kWh	0.5 c/kWh	0.2 c/kWh	0.5 c/kWh	0.2 c/kWh	0.2 c/kWh	1.6 c/kWh

Coal Water Slurry

FOB 36 $/t | CIF 47 $/t | Total Costs = 105 $/t | Total Costs = 4.0 c/kWh

Mining	Preparation	Transport	Export Terminal	Sea Freight	Import Terminal	Transport	Power Plant
	20 $/t	11 $/t	5 $/t	11 $/t	5 $/t	6 $/t	47 $/t
	0.8 c/kWh	0.5 c/kWh	0.2 c/kWh	0.5 c/kWh	0.2 c/kWh	0.2 c/kWh	1.7 c/kWh