ADVANCED COAL CLEANING AND COAL RECOVERY

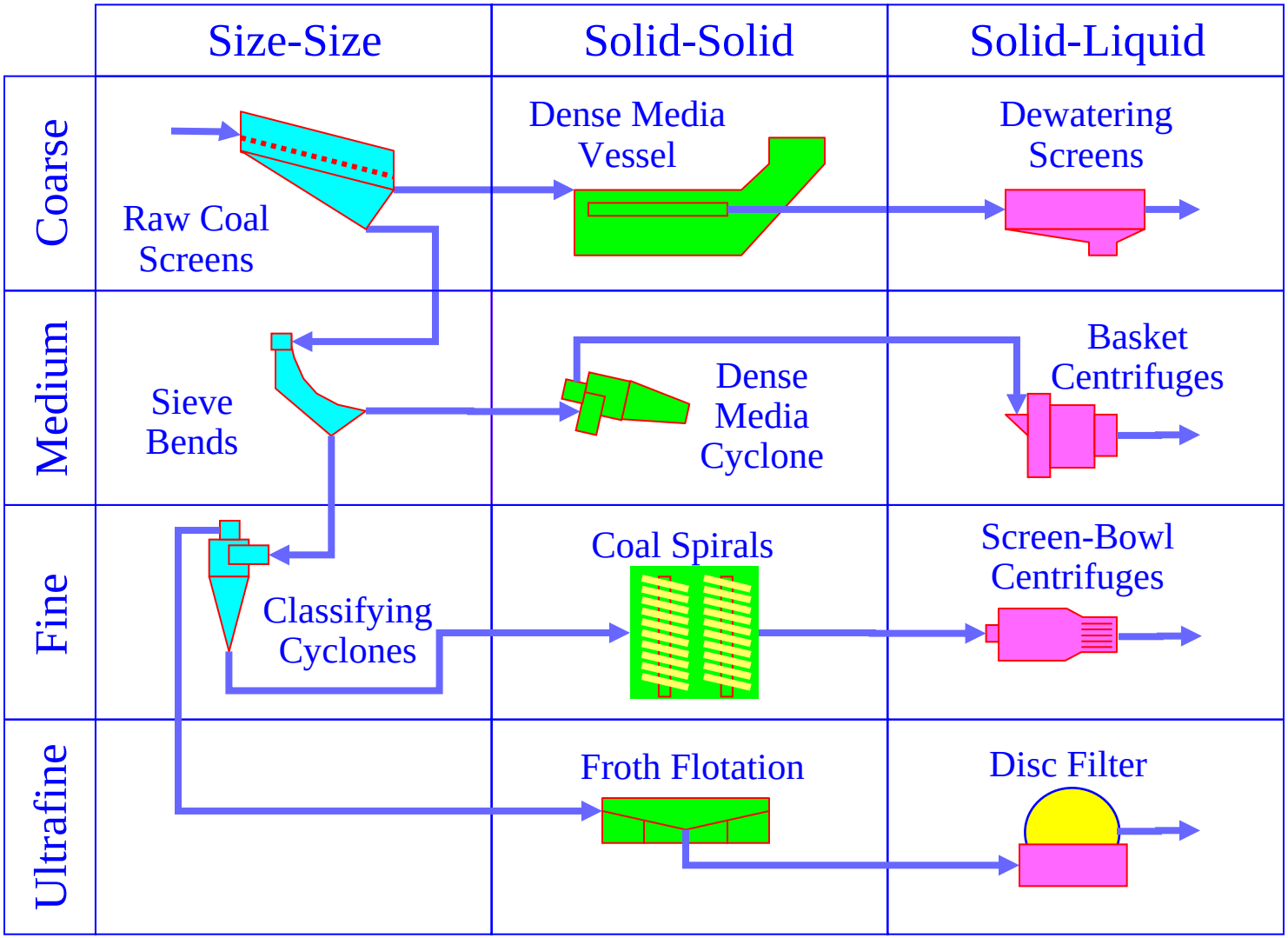
US-India Coal Working Group Meeting
April 4-5, 2006

by

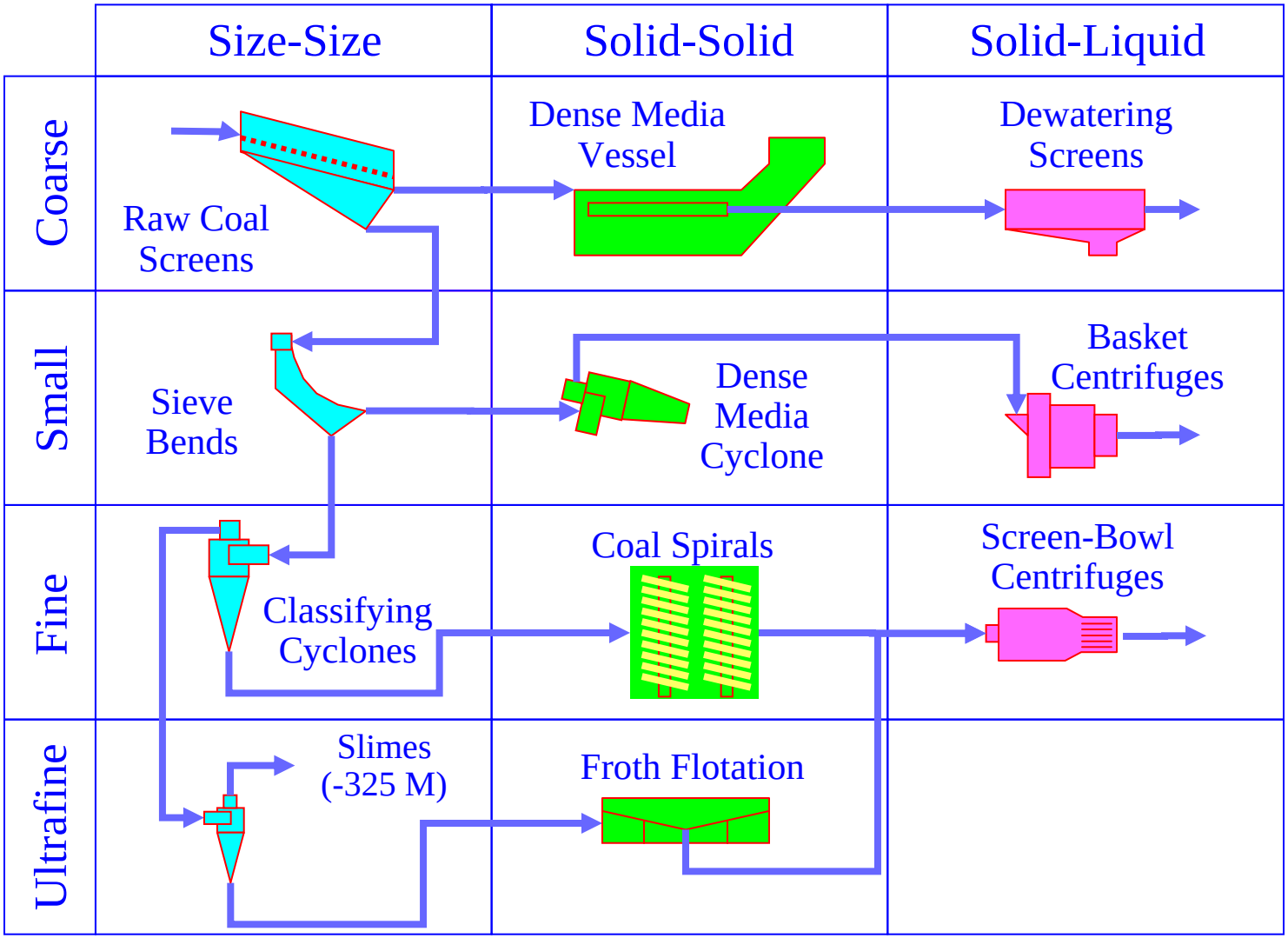
Roe-Hoan Yoon
Virginia Tech

http://www.castconsort.org

Separation Processes Used for Coal



In the absence of advanced Solid-Liquid Separation Technologies coal fines are still being discarded.



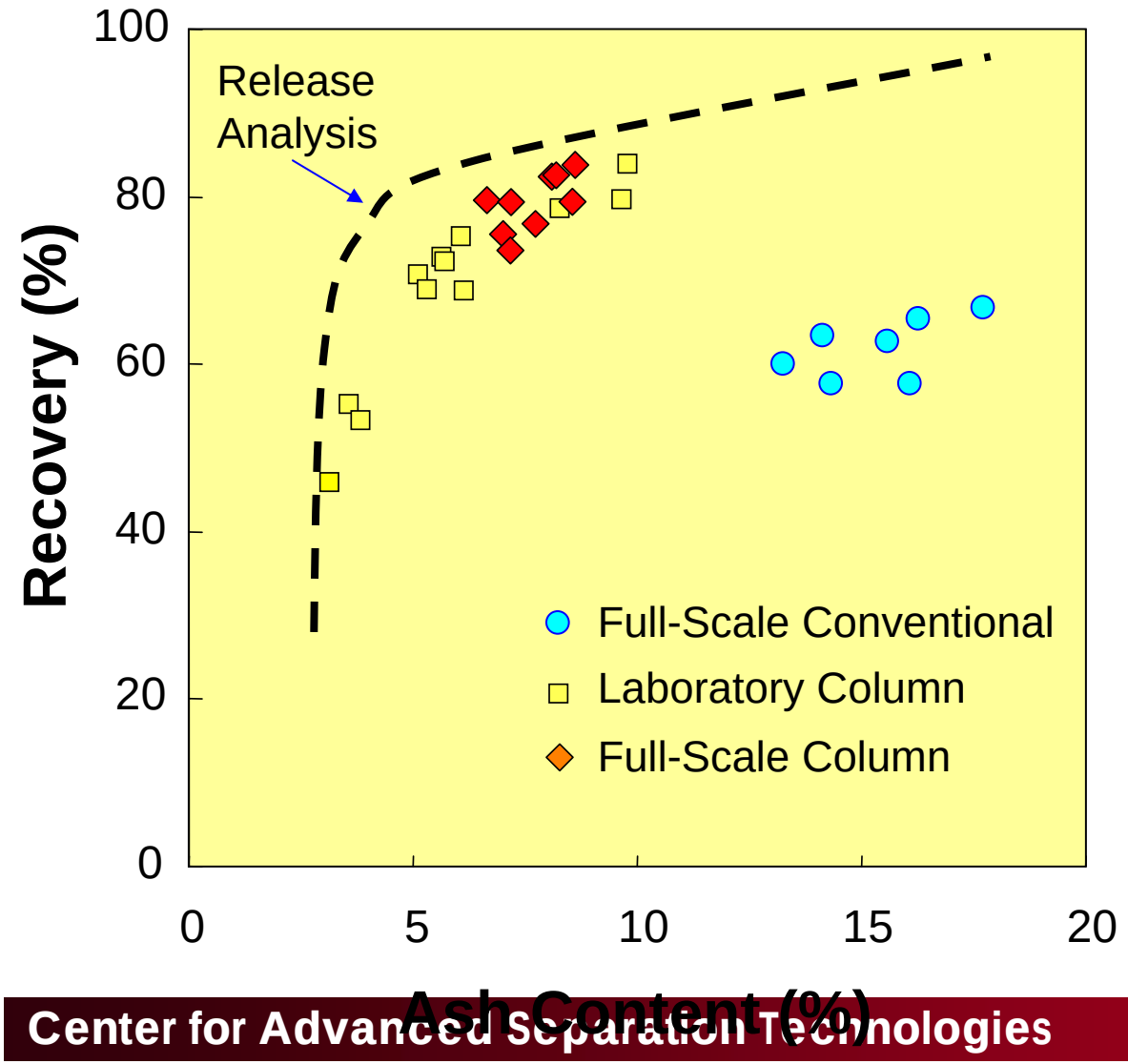
Impoundments

- 3 billion tons of fine coal
  - *In 713 impoundments*
  - *Mostly in Central Appalachia.*
- Main cause
  - *Lack of appropriate Separation Technologies*
    - *Solid-Solid (Fine particles)*
    - *Solid-Liquid (Dewatering)*

Application of Advanced Separation Technologies

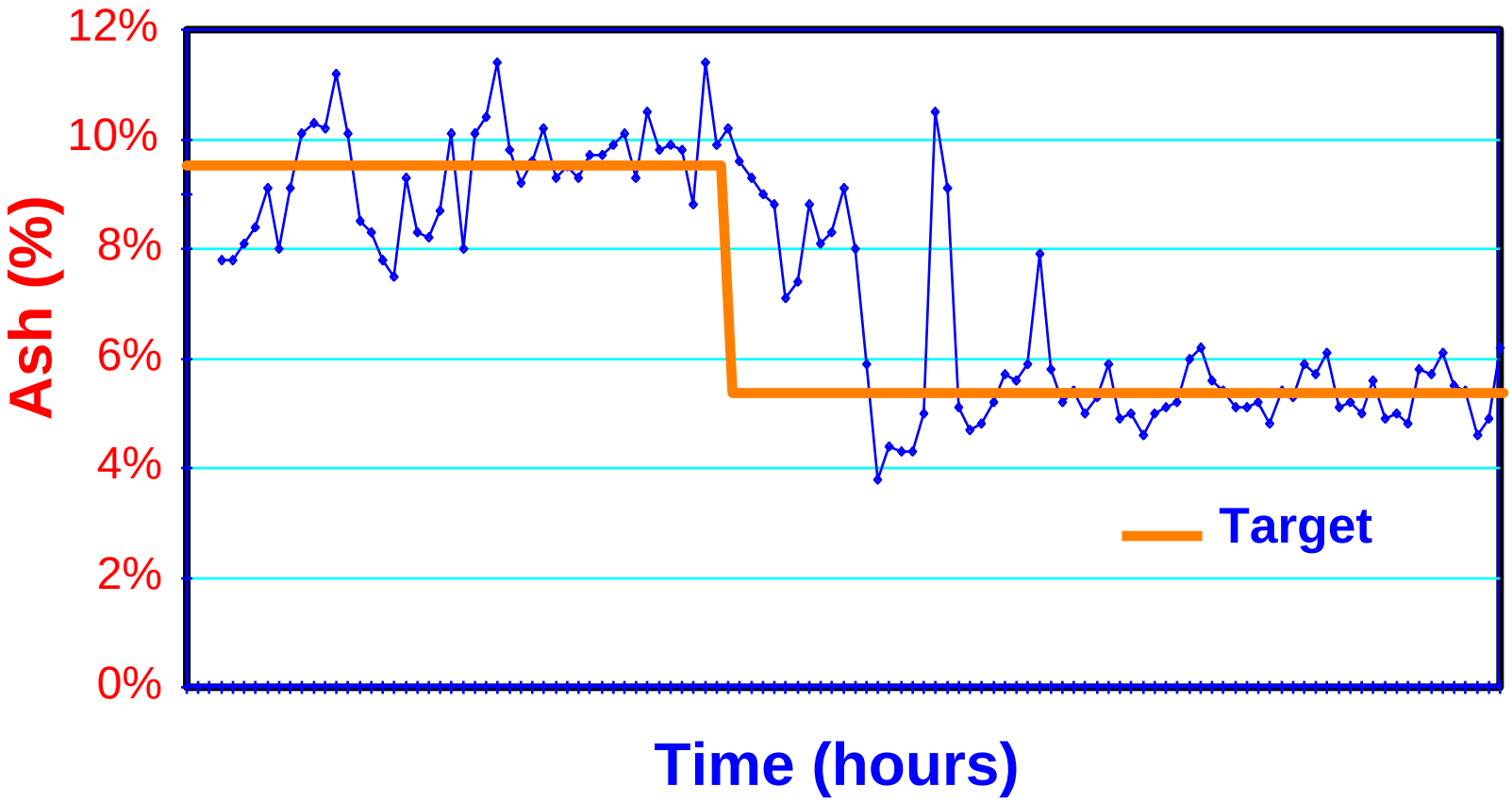
- **Use of advanced separation technologies at Middle Fork**
  - ***Recovered coal***
  - ***Reuse of impoundment***
    - ***No new impoundment***
    - ***No new permits***

Microcel Flotation



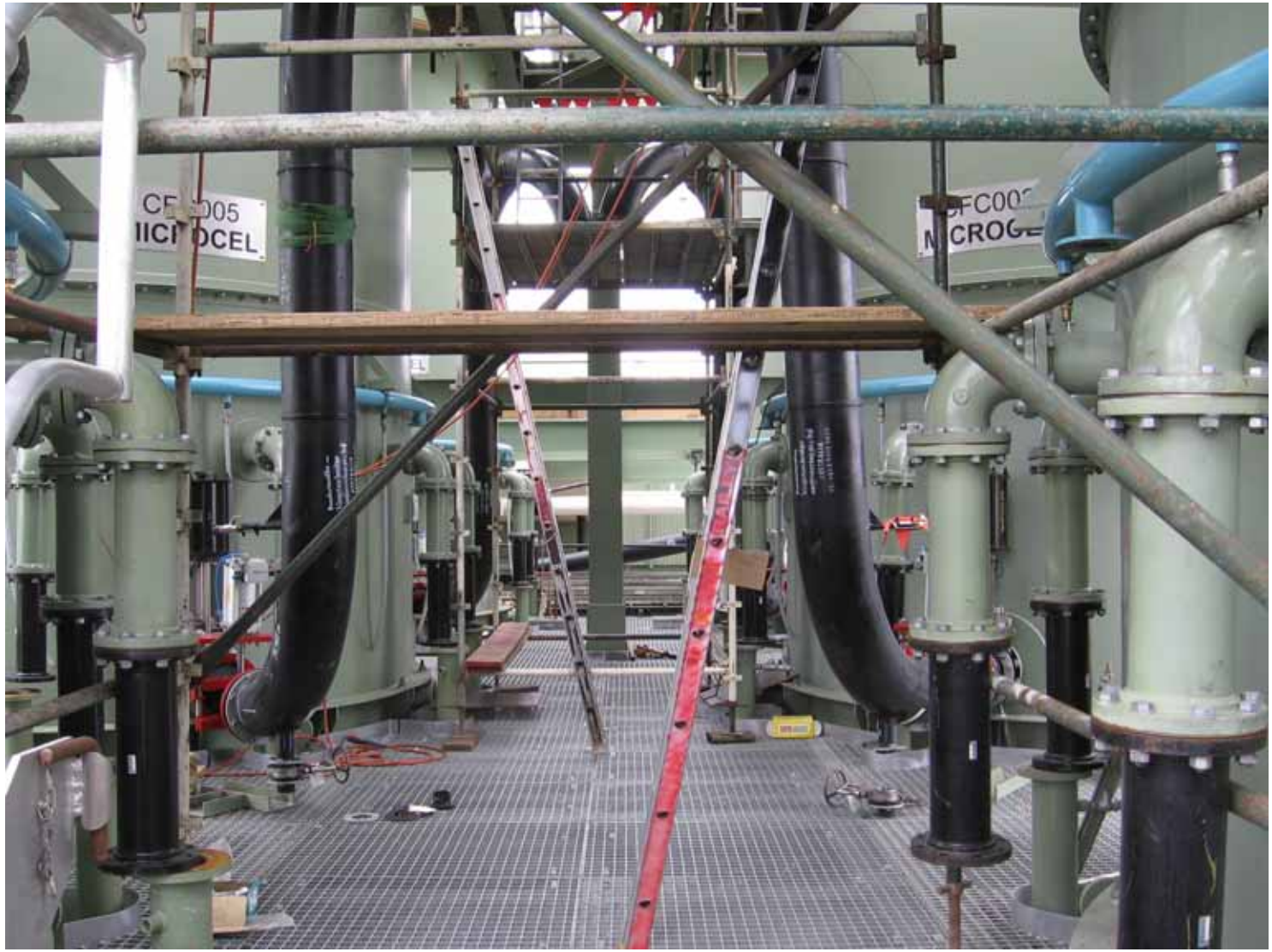
Microcel at BMA

Cleaner Coal at BMA

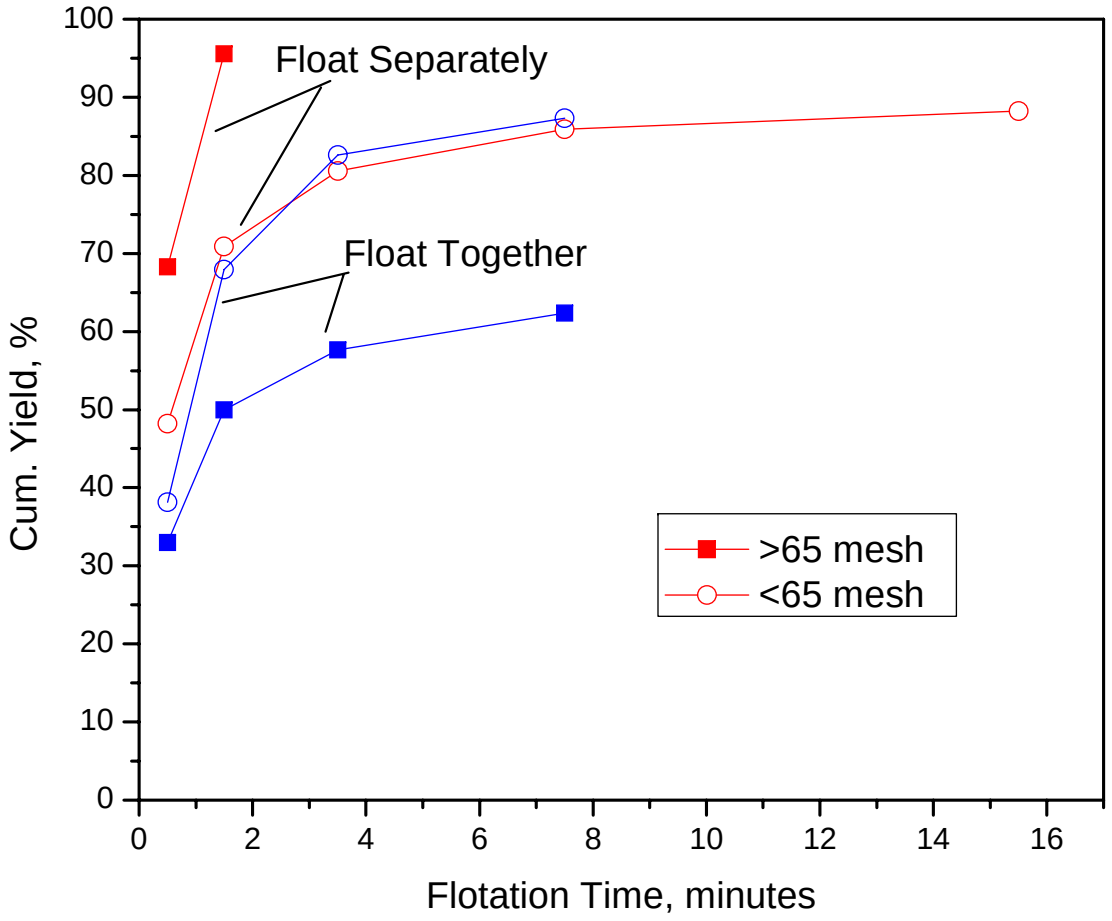


New Installations in Australia

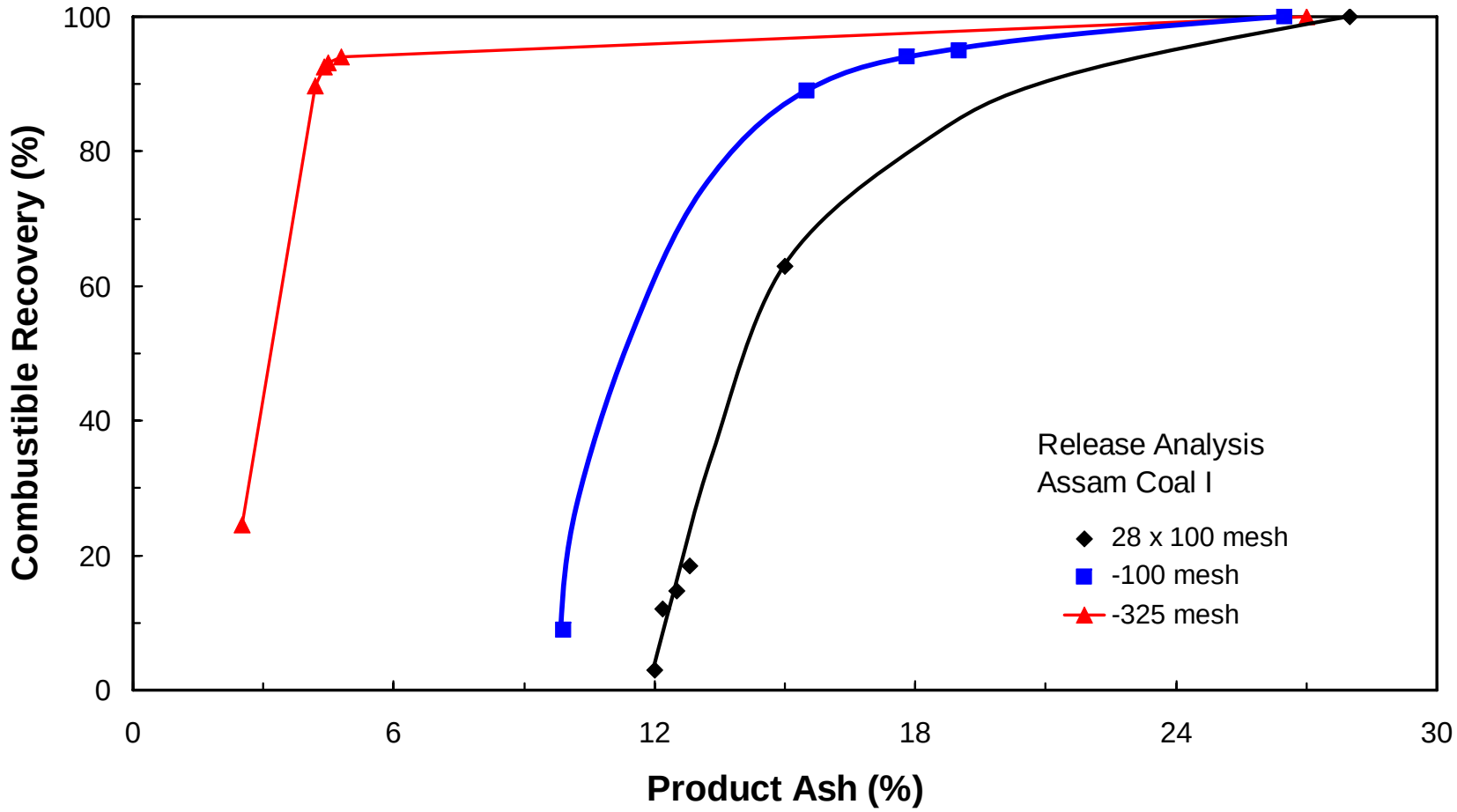
Microcel In Australia



An Indian Coal

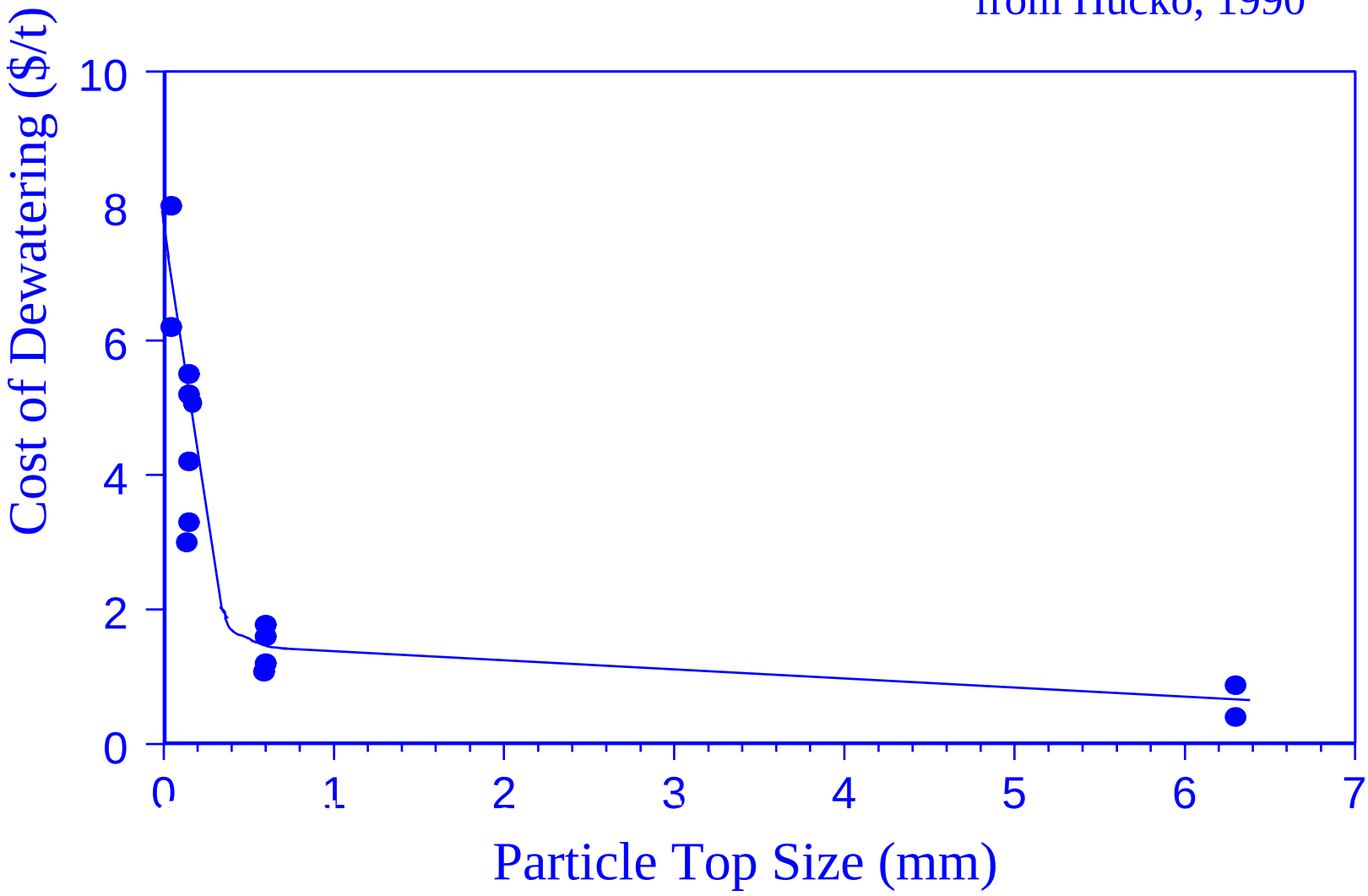


Fine coal produces lower-ash coal.



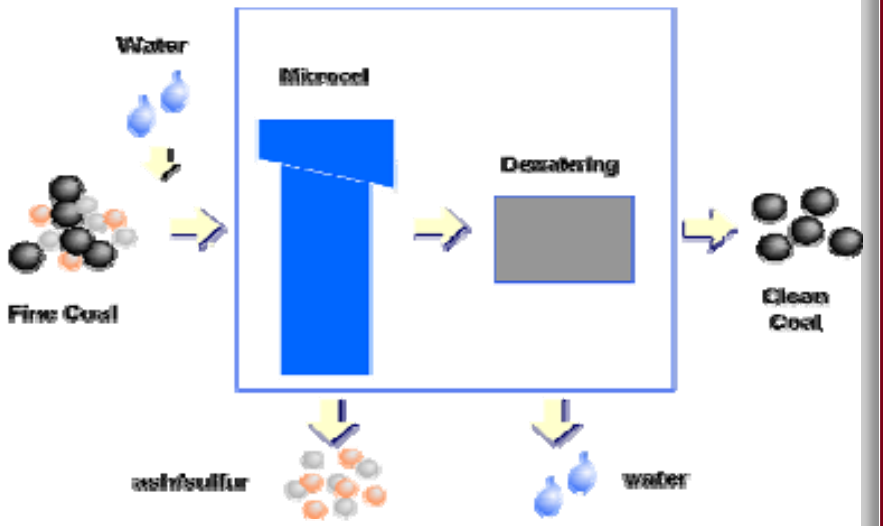
Fine coal dewatering is costly.

from Hucko, 1990



Advanced Coal Cleaning Technologies at Virginia Tech

- Microcel flotation
- Dewatering
  1. *Dewatering aids*
     - *Licensed to Nalco*
     - *Pinnacle pond recovery plant*
       - *Due to completion in July 2006*
  2. *Hyperbaric centrifuge*
     - *Licensed to Decantor*
     - *Pilot-scale tests is ongoing*
  3. *Hyperbaric horizontal belt filter*
     - *Pilot-scale tests is ongoing*
  4. *Dewatering by displacement*
     - *An engineering company is exploring commercialization potential*
  5. *Polymer injection system for Screen-bowl centrifuges*
     - *18 installations*



Dewatering fine coal helps you increase revenue.

Existing Dewatering	Clean (tph, ar)	Moisture (%, ar)	Ash (%, ar)	Heat (Btu/lb, ar)
Coarse (1.50 SG)	552.6	5.0	12.0	12450
Fines Circuits	85.0	14.0	10.5	11325
Total Plant	**637.6**	**6.2**	**11.8**	**12300**

Improved Dewatering	Clean (tph, ar)	Moisture (%, ar)	Ash (%, ar)	Heat (Btu/lb, ar)
Coarse (1.50 SG)	552.6	5.0	12.0	12450
Coarse (1.5x1.6 SG)	**25.8**	**5.0**	**25.0**	**10500**
Fines Circuits	81.2	10.0	11.0	11852
Total Plant	**659.7**	**5.6**	**12.4**	**12300**

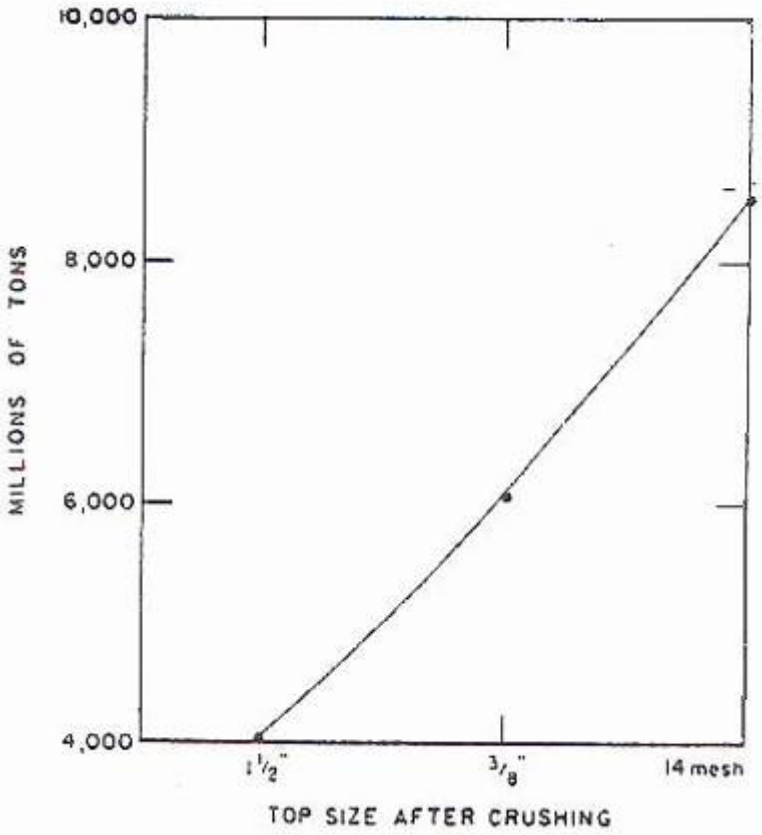
Tonnage Gain = 659.7-637.6 = **22 tph**
Value = 22 ton/hr x $50/ton x 5,000 hr/yr = **$5.5 MM/yr**

Great Payback! Dump moisture on steam contracts, it's 100% inert!

Fine coal cleaning is good for the country.

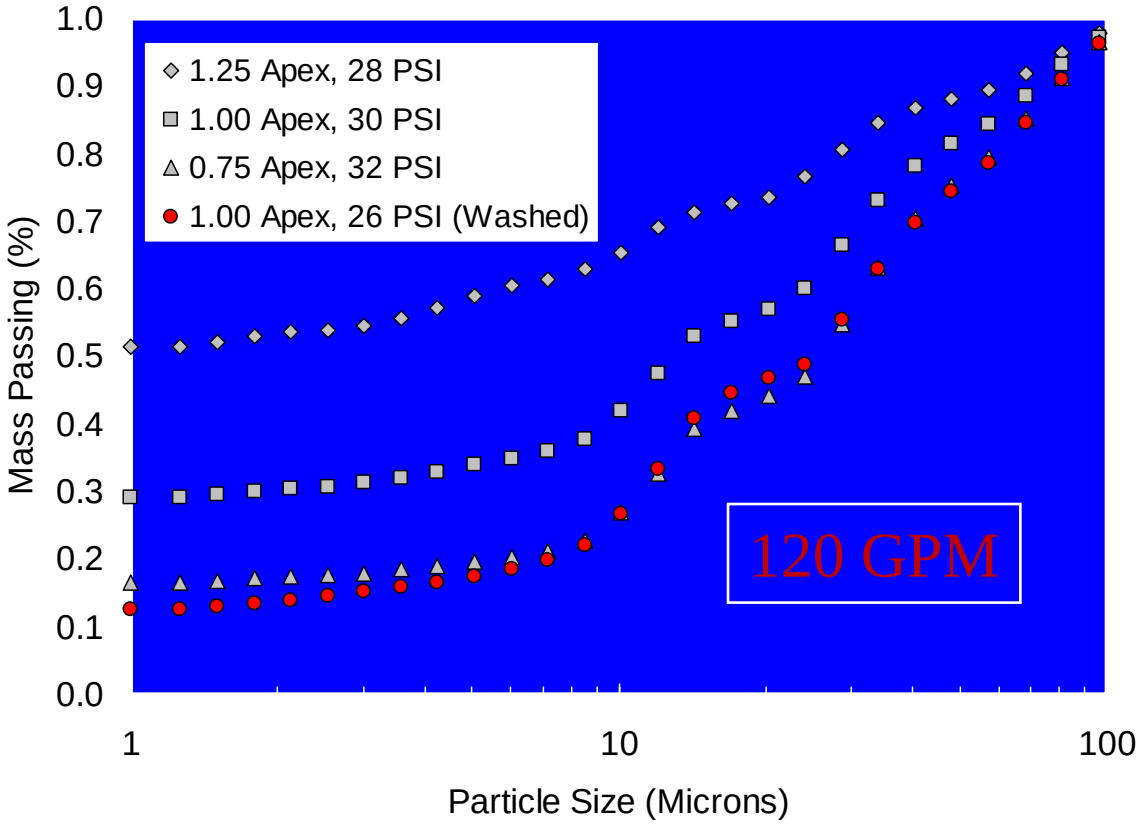
Results show that dry coal can be obtained without thermal drying.

M_b/M_c Ratio	Percent Moisture at Specified Feed Solids Content		
	5% Solids	15% Solids	30% Solids
0.5	---	15.1	9.6
0.75	---	10.7	6.5
1.0	12.5	8.8	>1.0
1.5	5.5	3.5	---
2.0	1.4	1.1	---



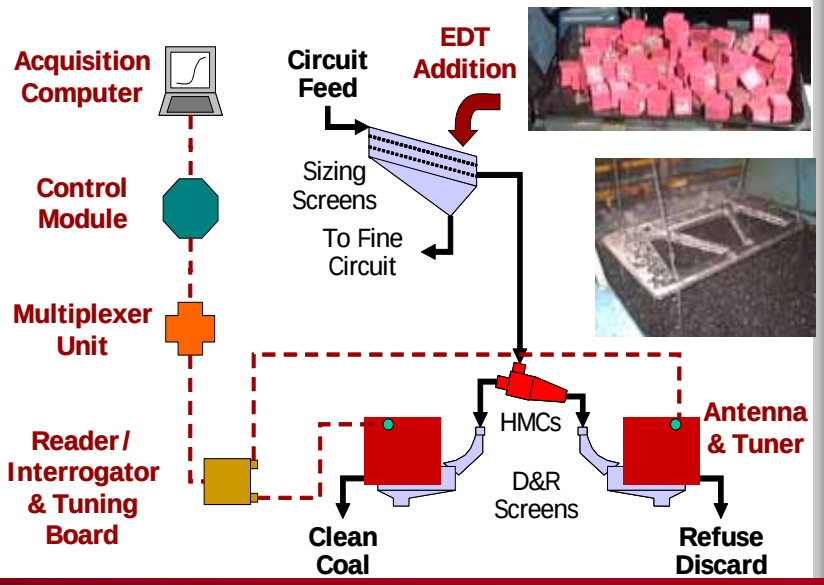
By decreasing the top size of the coals cleaned from 1.5 inches to 14 mesh, US can double its reserve for compliance coal (DOE report by Cavallero, et al. 1991)

Advanced Hydrocyclone



Electronic Density Tracers

- Project:
  - *Develop electronic "tags" to monitor performance of density separators.*
- Status:
  - *Tag/antenna system constructed using transponder technology.*
  - *Automated system accurately detected 98.5% of tracers added, while lower manual count gave a misleading result.*
  - *Field study indicated potential savings of $1 MM per plant by improving recovery and reducing waste.*
- Applicability:
  - *Coal, Base Metals, Diamond*



Flotation Model

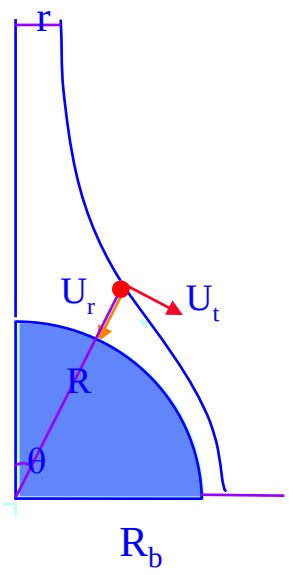
Under Laminar Flow Conditions

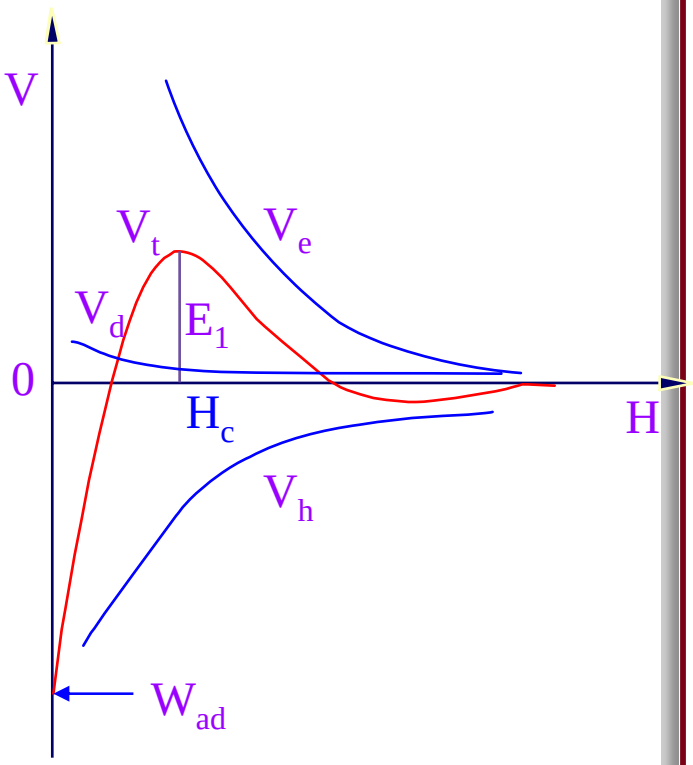
(Yoon and Mao, JCIS, 1996; Mao and Yoon, IJMP, 1997)

$$\frac{dN}{dt} = -kN$$

$$k = \frac{1}{4} S_b P$$

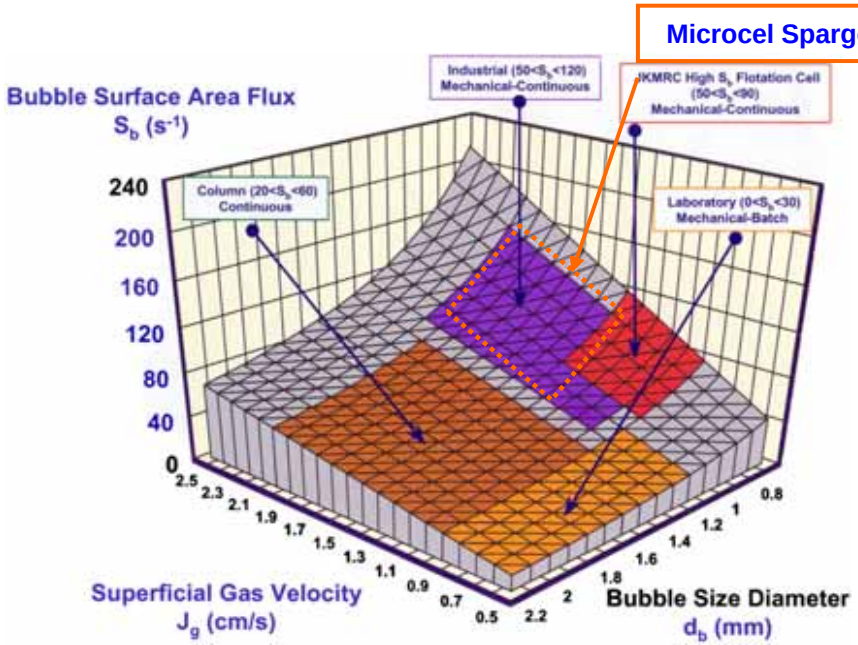
$$P = P_c P_a (1 - P_d)$$





$$k = \frac{1}{4} S_b \left[\frac{3}{2} + \frac{4 Re^{0.72}}{15} \right] \left(\frac{D_p}{D_b} \right)^2 \exp\left(-\frac{E_1}{E_k} \right) \left[1 - \exp\left(-\frac{W_{ad} + E_1}{E_k'} \right) \right]$$

Microcel


Microcel Sparger
Bubble Surface Area Flux
S_b (s^{-1})
Industrial (50<S_b<120)
Mechanical-Continuous
JKMRC High S_b Flotation Cell
(50<S_b<90)
Mechanical-Continuous
Column (20<S_b<60)
Continuous
Laboratory (0<S_b<30)
Mechanical-Batch
240
200
160
120
80
40
0
2.5
2.3
2.1
1.9
1.7
1.5
1.3
1.1
0.9
0.7
0.5
Superficial Gas Velocity
J_g (cm/s)
2.2
2
1.8
1.6
1.4
1.2
1
0.8
Bubble Size Diameter
d_b (mm)

Pond recovery at Pinnacle Mine

Wyoming County, WV

- Pilot-scale tests
  - *Moisture reduction*
    - *From 29% to 16%*
  - *Throughput*
    - *2-3 times higher*
  - *200 tons/hr plant is being built by Bea Technologies*

A Solution for Indian Coal

Energy Policy Act 2005

(1) innovations for existing plants (including mercury removal);

(2) gasification systems;

(3) advanced combustion systems;

(4) turbines for synthesis gas derived from coal;

(5) carbon capture and sequestration research and development;

(6) coal-derived chemicals and transportation fuels;

(7) liquid fuels derived from low rank coal water slurry;

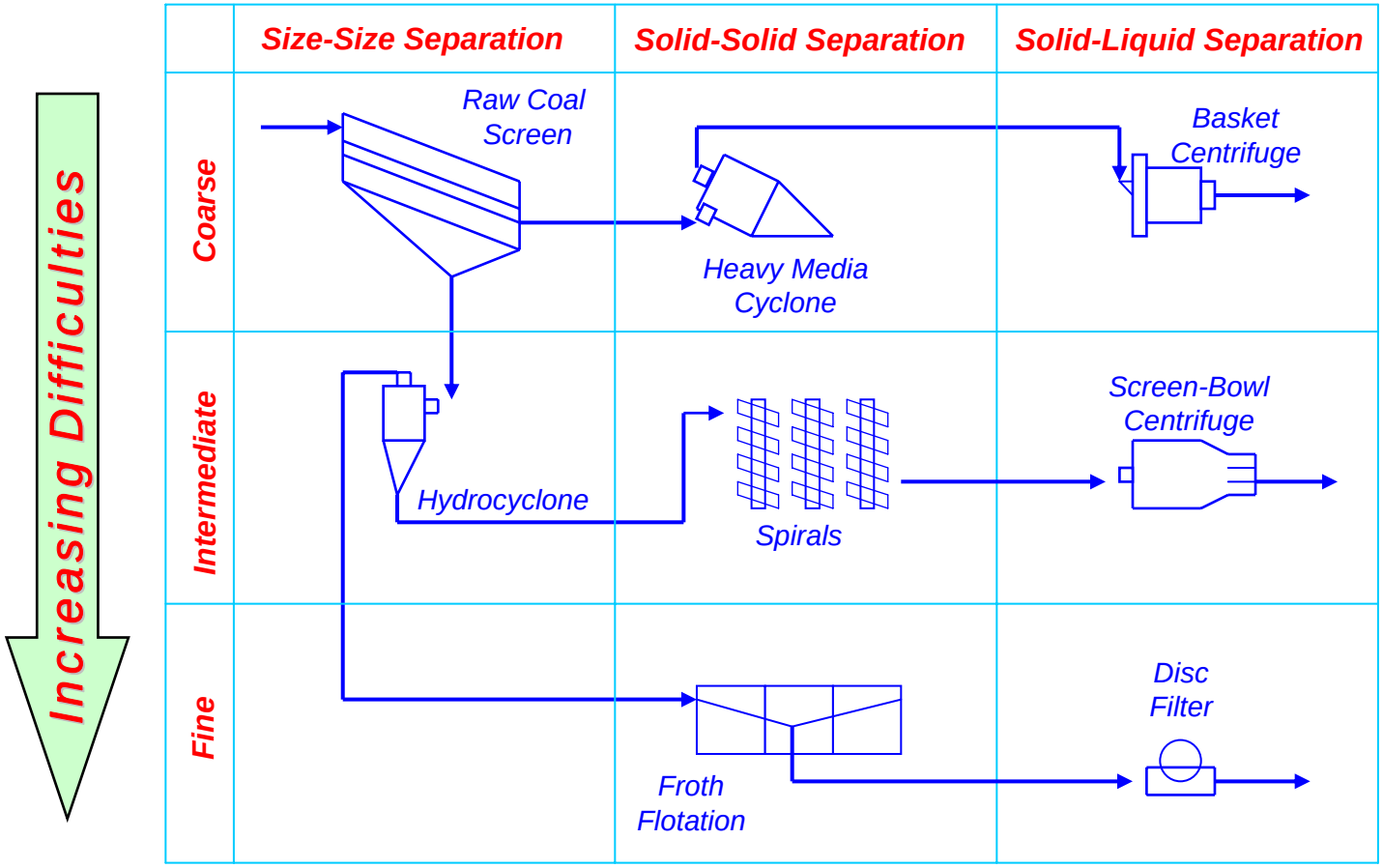
(8) solid fuels and feedstocks;

(9) advanced coal-related research;

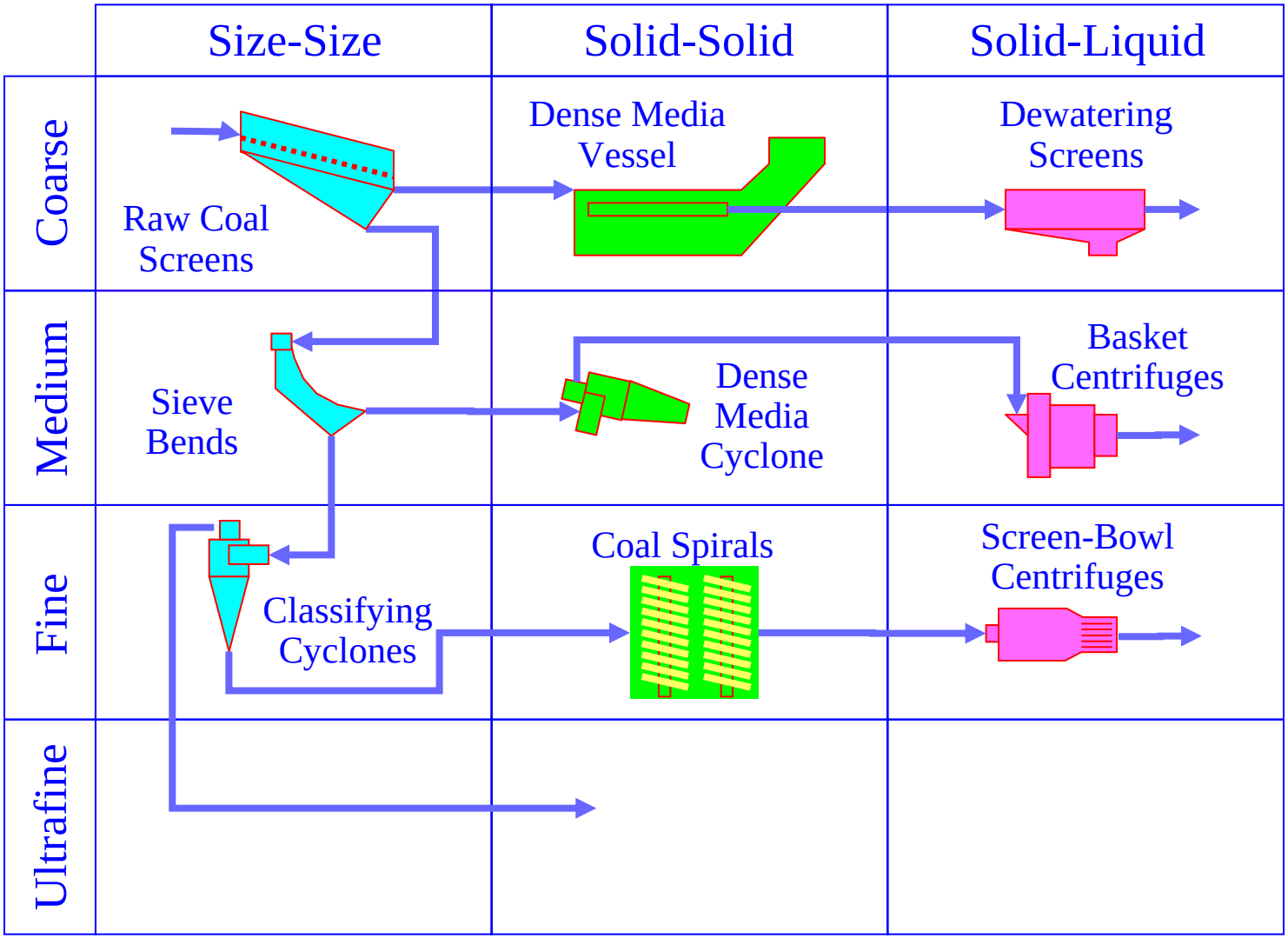
(10) advanced separation technologies; and

(11) fuel cells for the operation of synthesis gas derived from coal.

Simplified Flowsheet

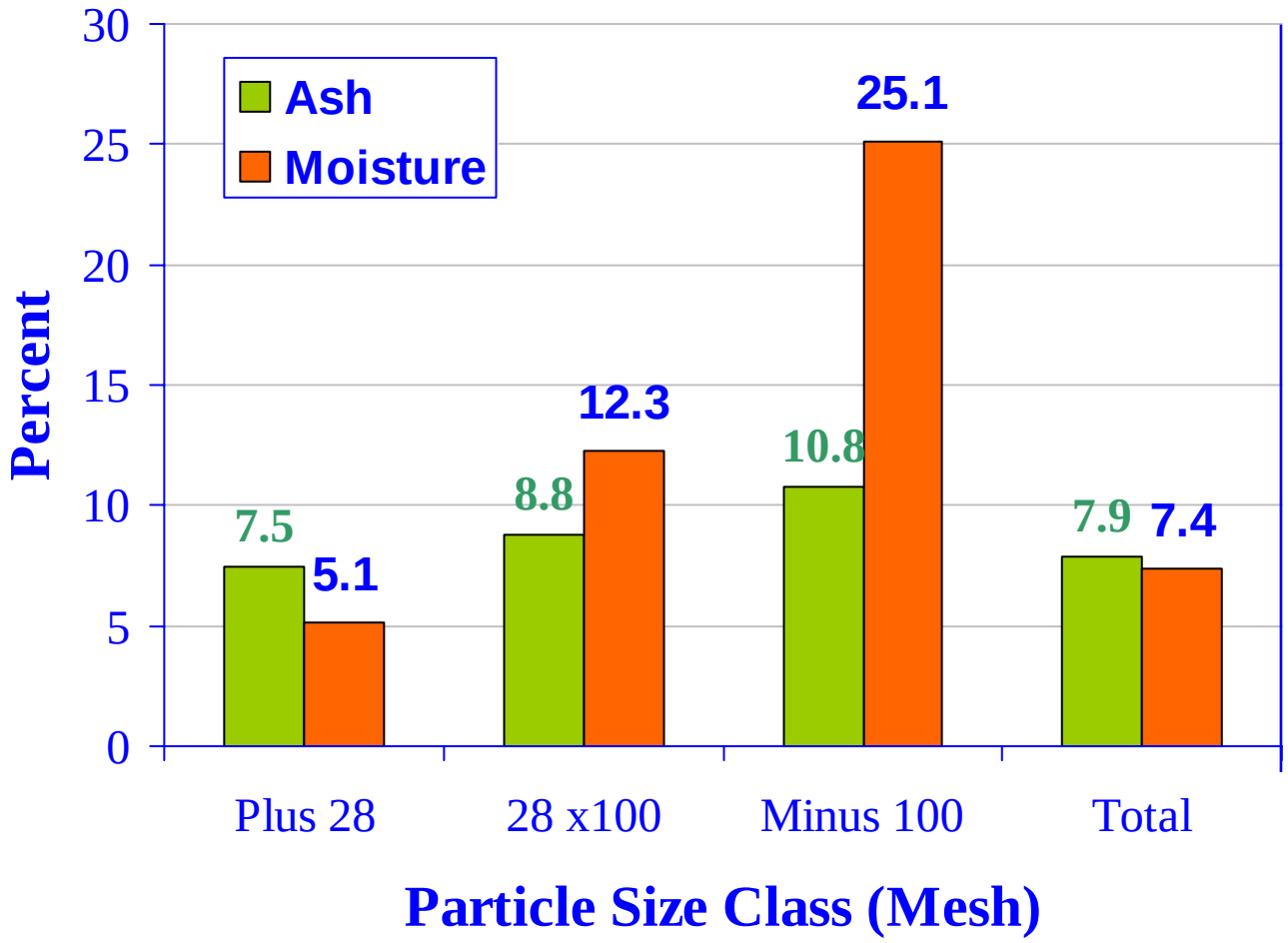


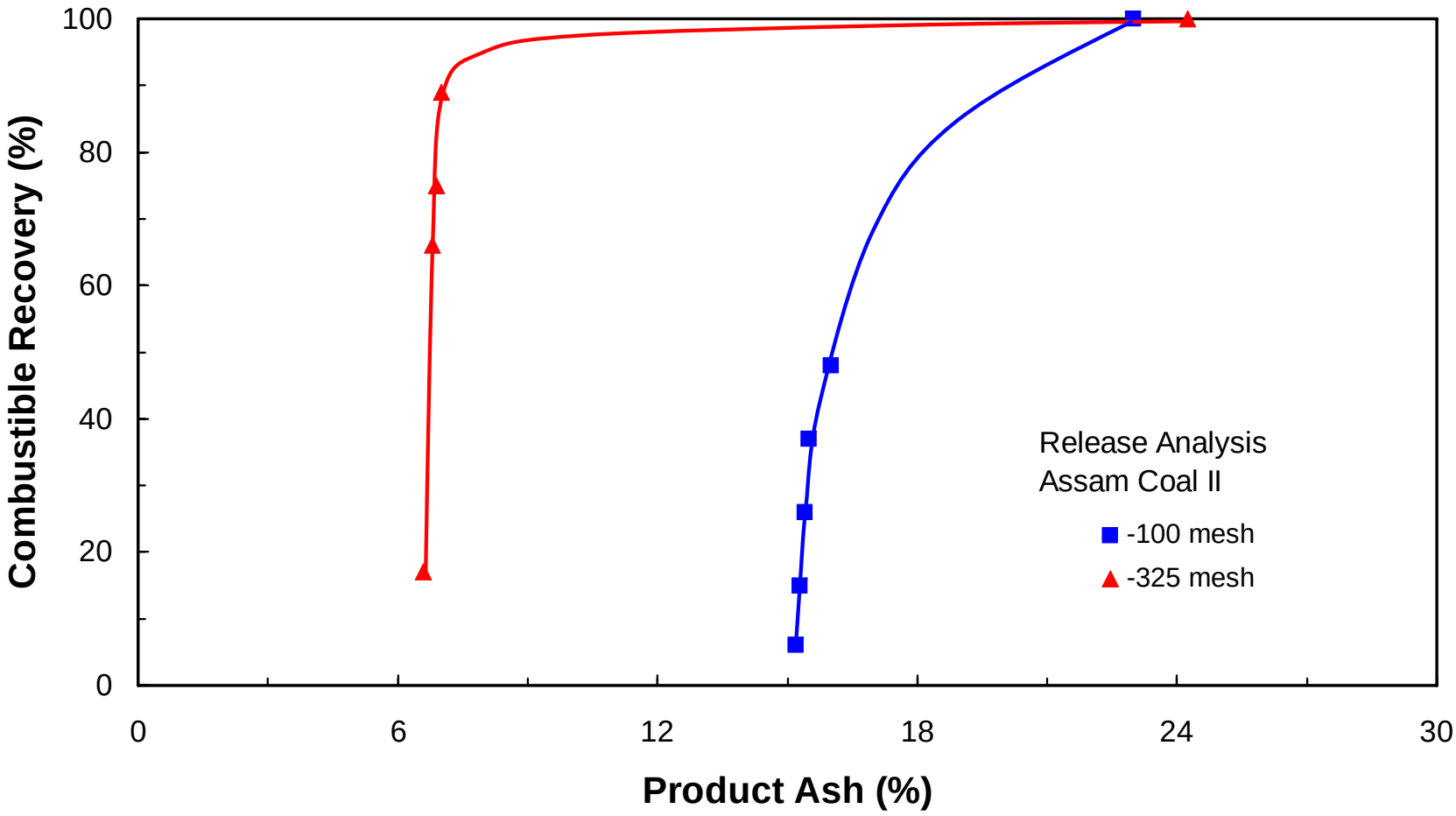
Separation Processes Used for Coal



Microcel at BHP

Typical Ash/Moisture in Product Stream




Combustible Recovery (%)
100
80
60
40
20
0
0
6
12
18
24
30
Product Ash (%)
Release Analysis
Assam Coal II
-100 mesh
-325 mesh

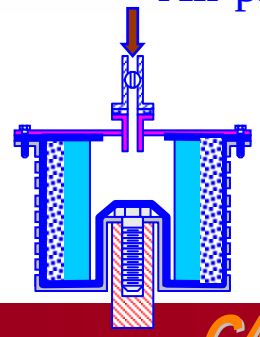
Hyperbaric Centrifuge

Table 60 Effect of Using Compressed Air for the Centrifugal Filtration of a Pittsburgh Coal[3]

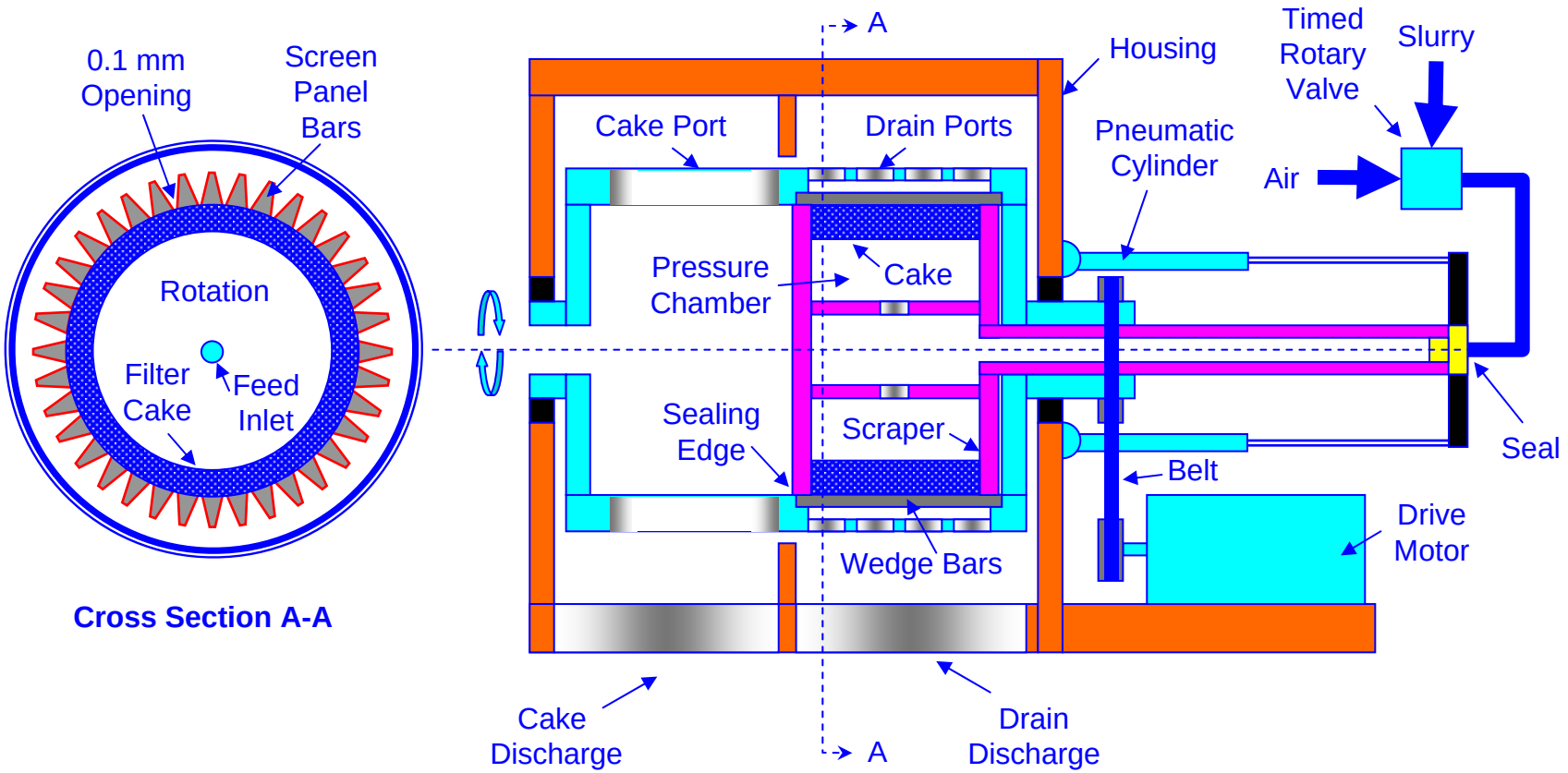
Drying Cycle or Centrifugation Time (sec)	Cake Moisture (wt %)		
	Air Pressure[1] Alone	Centrifugal Force[2] Alone	Centrifugal Force[2] & Air Pressur[1]
30	27.5	24.4	14.2
60	25.8	22.6	12.9
120	23.8	21.0	10.6

[1] 100 kPa of air pressure; [2] 2000 G; [3] 0.45 inch cake thickness.

Air pressure

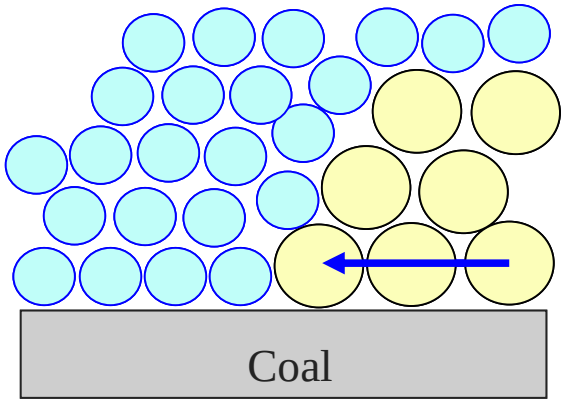


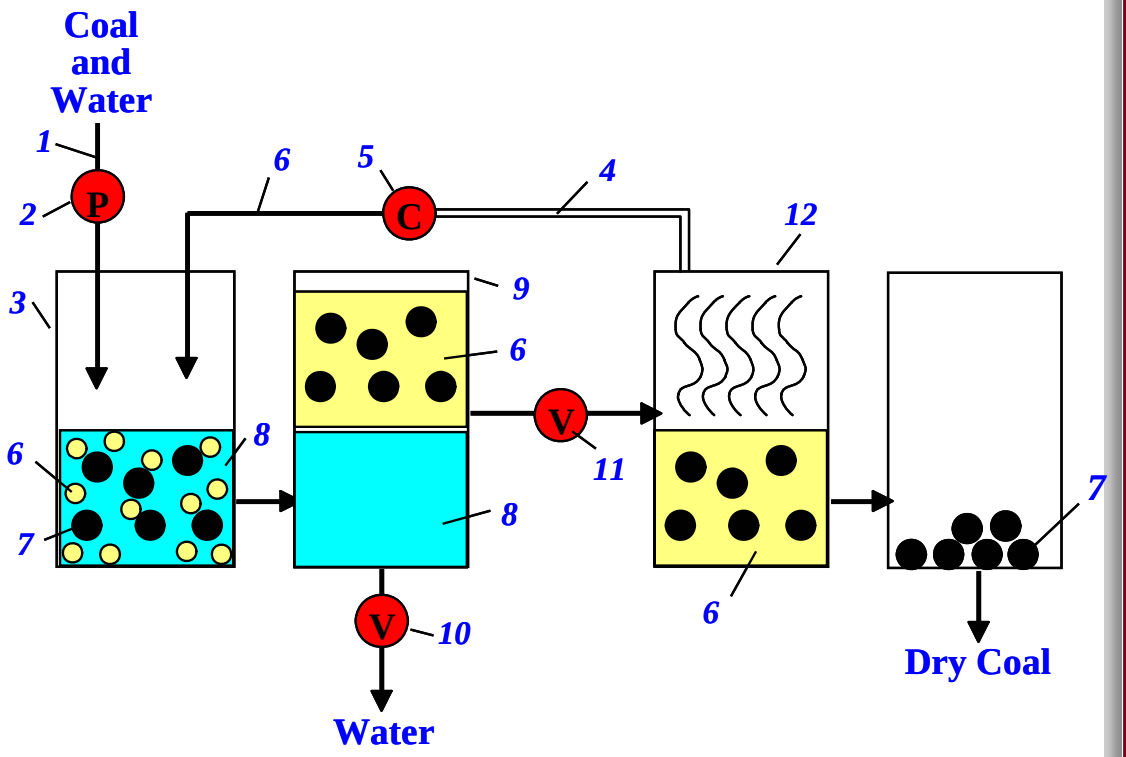
Semi-continuous unit



Dewatering by Displacement (1)

(Liquid butane displaces water from coal surface.)



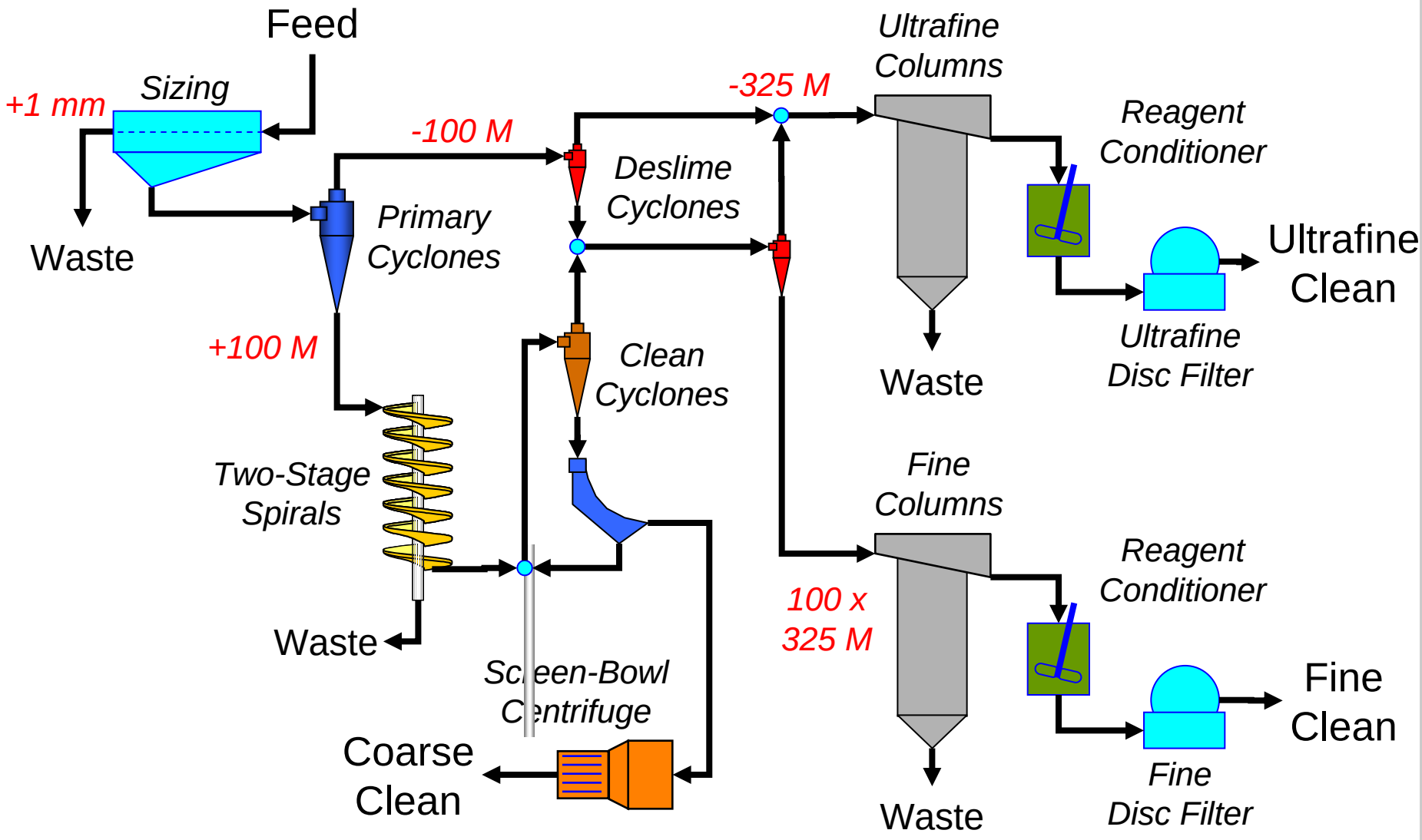


An engineering company is exploring commercialization potential.

Dewatering Aids (2)

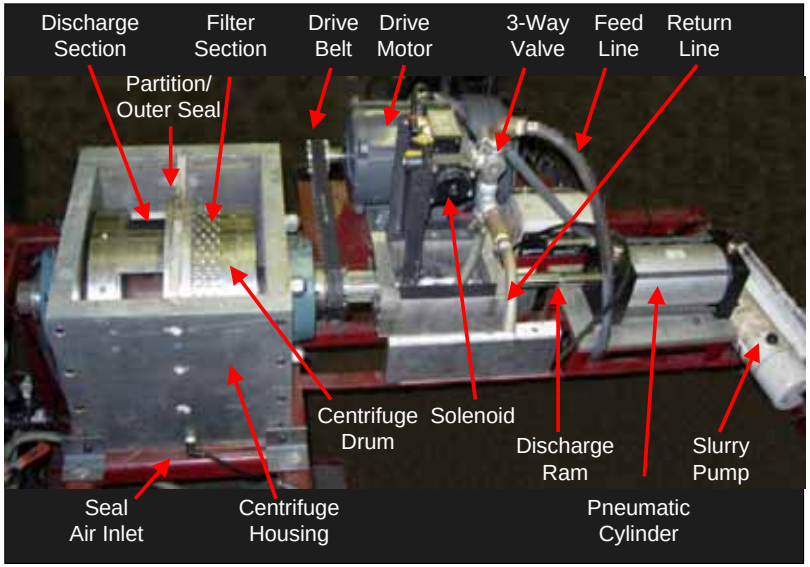
Pinnacle plant flowsheet

(due to completion in January 2006)



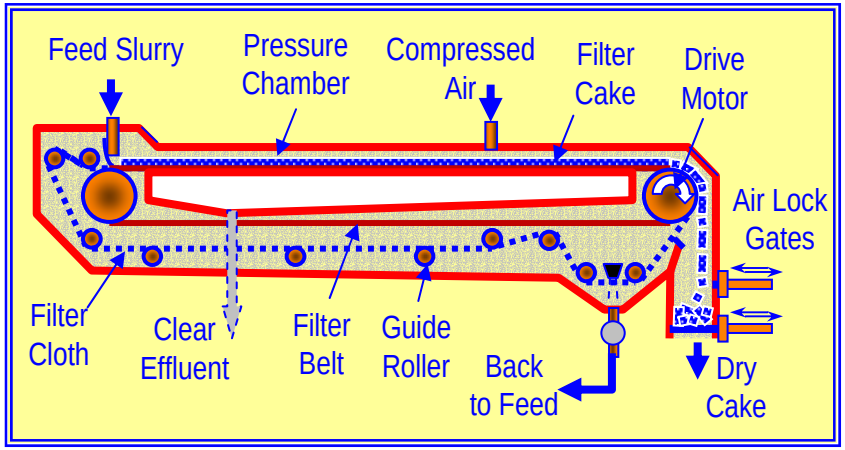
Hyperbaric Filter Centrifuge

- Project:
  - *Develop a pressurized (hyperbaric) filter centrifuge for solid-liquid separation.*
- Status
  - *Pilot-scale unit constructed and tested*
  - *One test reduced moisture from 11.0% to 1.86%.*
  - *Flotation product from Moss 3, VA*
    - *No air 15.9% moisture*
    - *15 sec air 10.3%*
    - *120 sec air 6.7%*
- US patent issued
  - *6 international patents applied for*
- Applicability:
  - *fine coal*
  - *Mineral fines*
  - *municipal sludge*
  - *Food*
  - *others.*



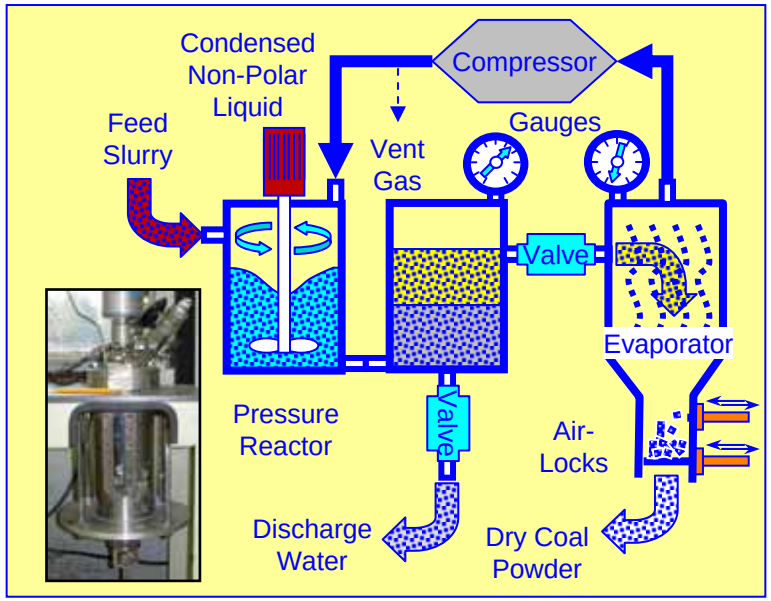
Hyperbaric Belt Filter

- Project:
  - *Development of high efficiency, high pressure belt filter for solid-liquid separation.*
- Status:
  - *Project just beginning, but design and construction of prototype is well underway.*
  - *Contact with a major equipment producer to further develop, manufacture, and sell the unit.*
- Applicability:
  - *Coal and Minerals, Municipal Waste Sludge, Environmental Applications*



Hydrophobic Dewatering

- Project:
  - *Develop of novel solid-liquid separation process can compete with thermal drying methods.*
- Status:
  - *Process uses recyclable non-polar liquid to displace moisture*
  - *Bench-scale tests successfully completed with moistures <1%.*
  - *Concept patent issued and new disclosures expected.*
  - *Marketing discussions underway with a major engineering firm.*
- Applicability:
  - *Coal and Minerals, Municipal Waste Sludge, Environmental Applications*



Test Condition	Moisture (%)	Yield (%)
5 ml P	2.90	89.6
5 ml P + 1 ml E	2.17	75.5
5 ml P + 12 ul RU	1.89	74.2
5 ml P + 12 ul FA	0.67	49.9
5 ml P + 120 ul O	1.15	14.0