Coal Preparation Plant Advancements

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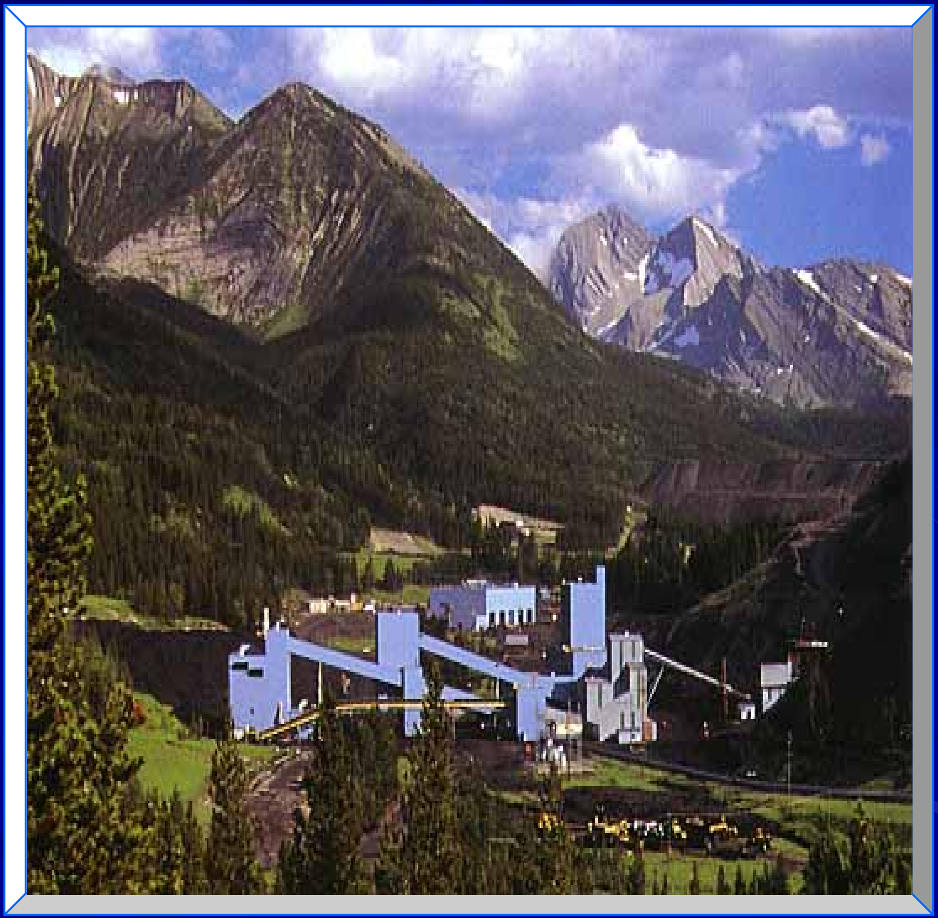
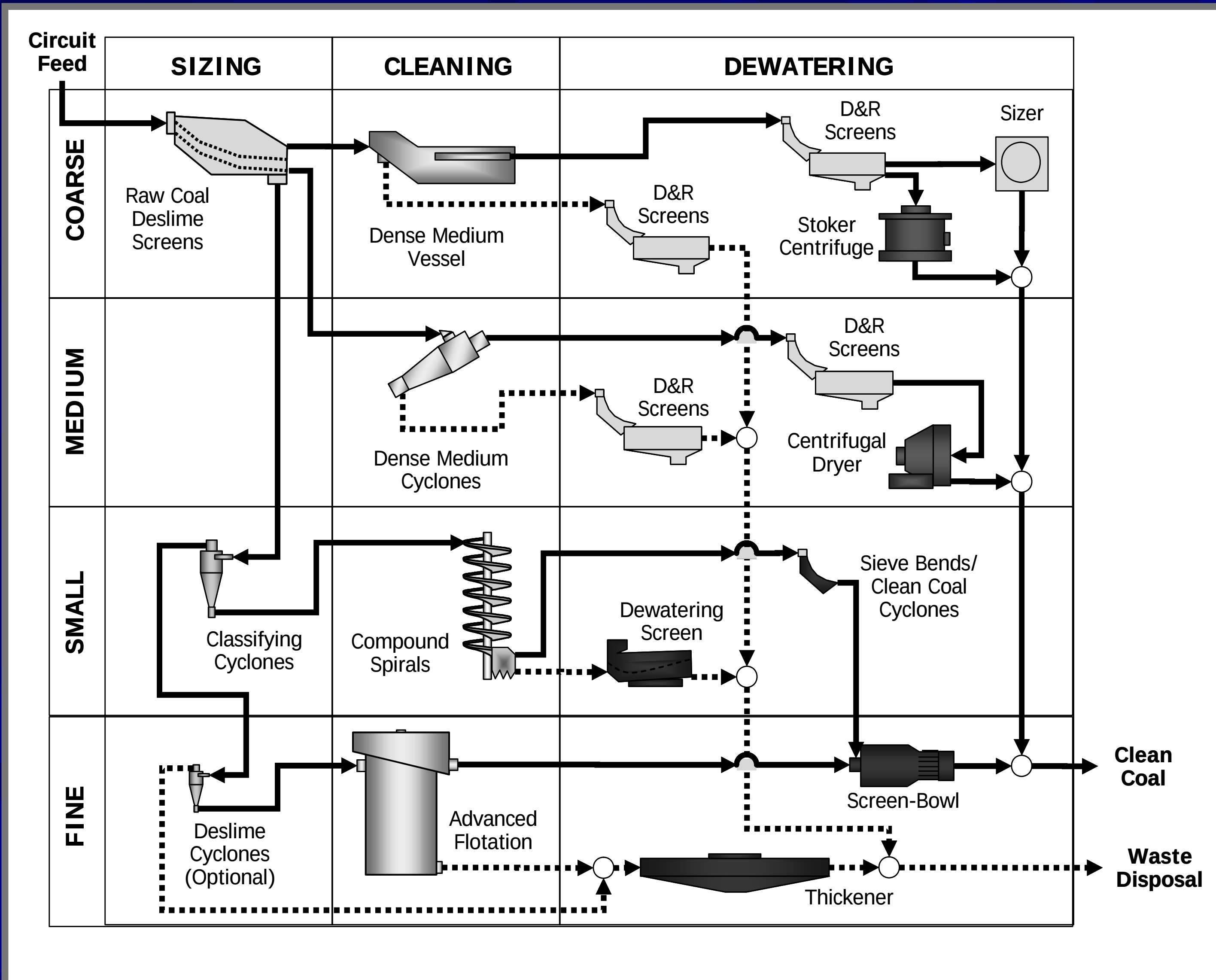
U. S. COAL PREPARATION

- Coal preparation involves processing to achieve the required quality for end users.
- 636 Mt of coal processed annually.
- Coal is sized and cleaned in various circuits.
- Fine (-1 mm) coal typically accounts for 12%-15% of feed (75 – 95 Mt annually)

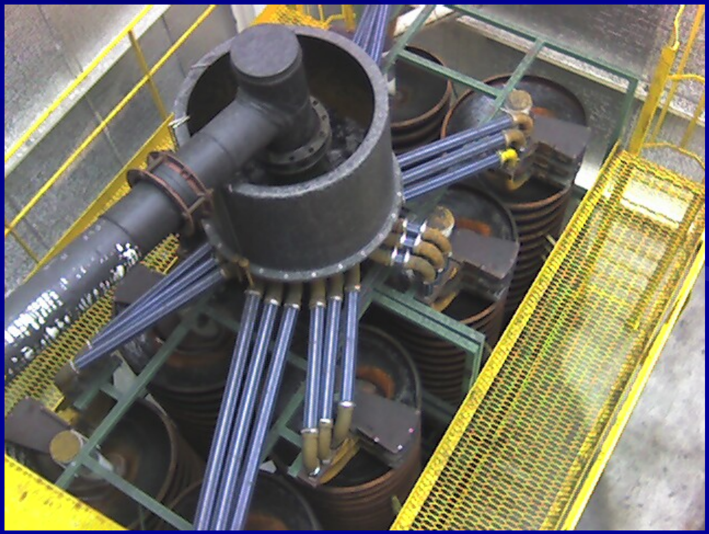


Typical Process Flow Sheet For Steam Coal Production

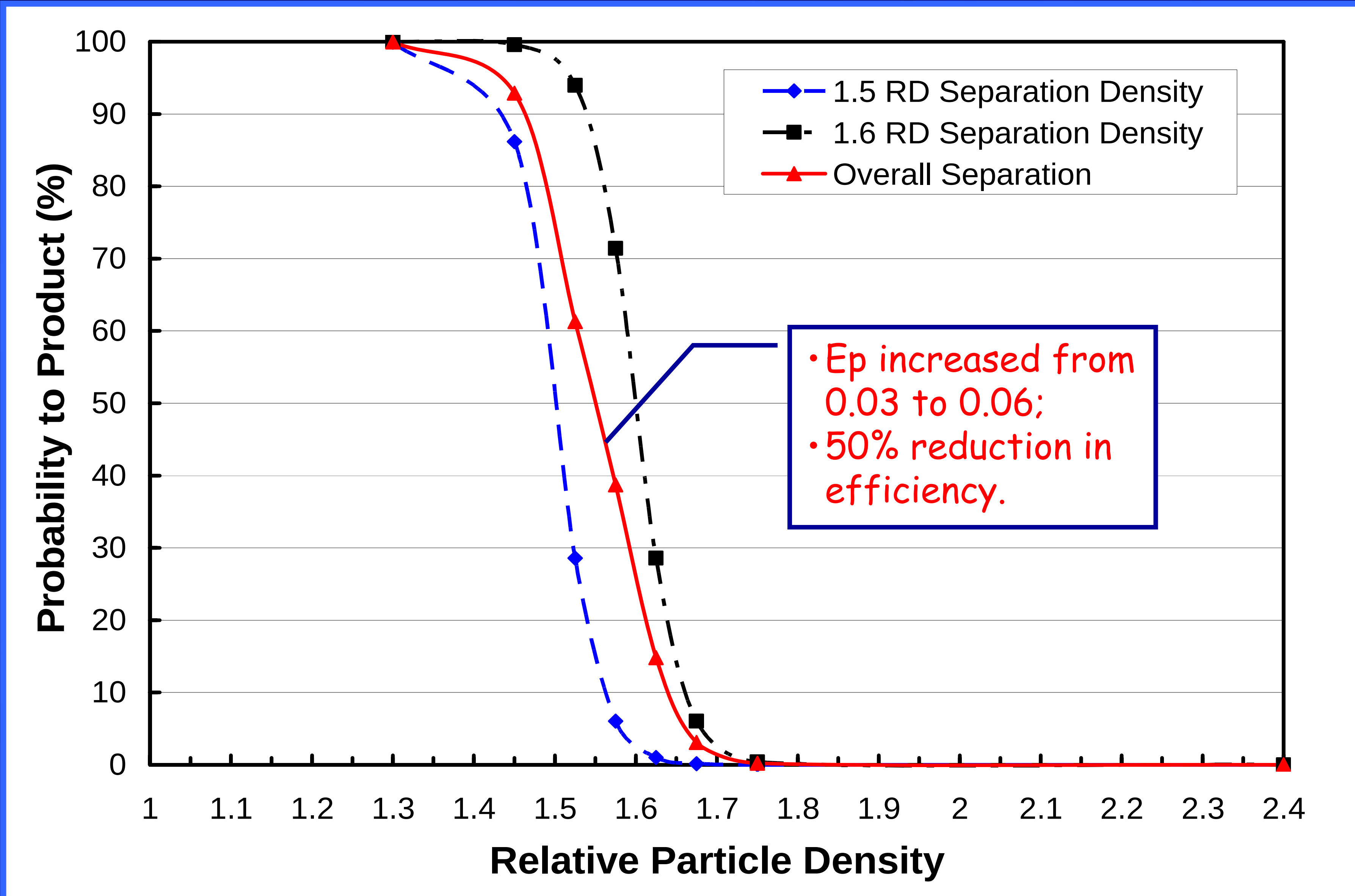


Distribution Inefficiencies: Design Implications

- A number of major plant design changes have been based on poor distribution to various process units.
- Poor distribution results in unequal feed volumetric and mass flow rates.
- Unequal flow rates typically lead to varying separation performances.



Poor Distribution = Reduced Efficiencies



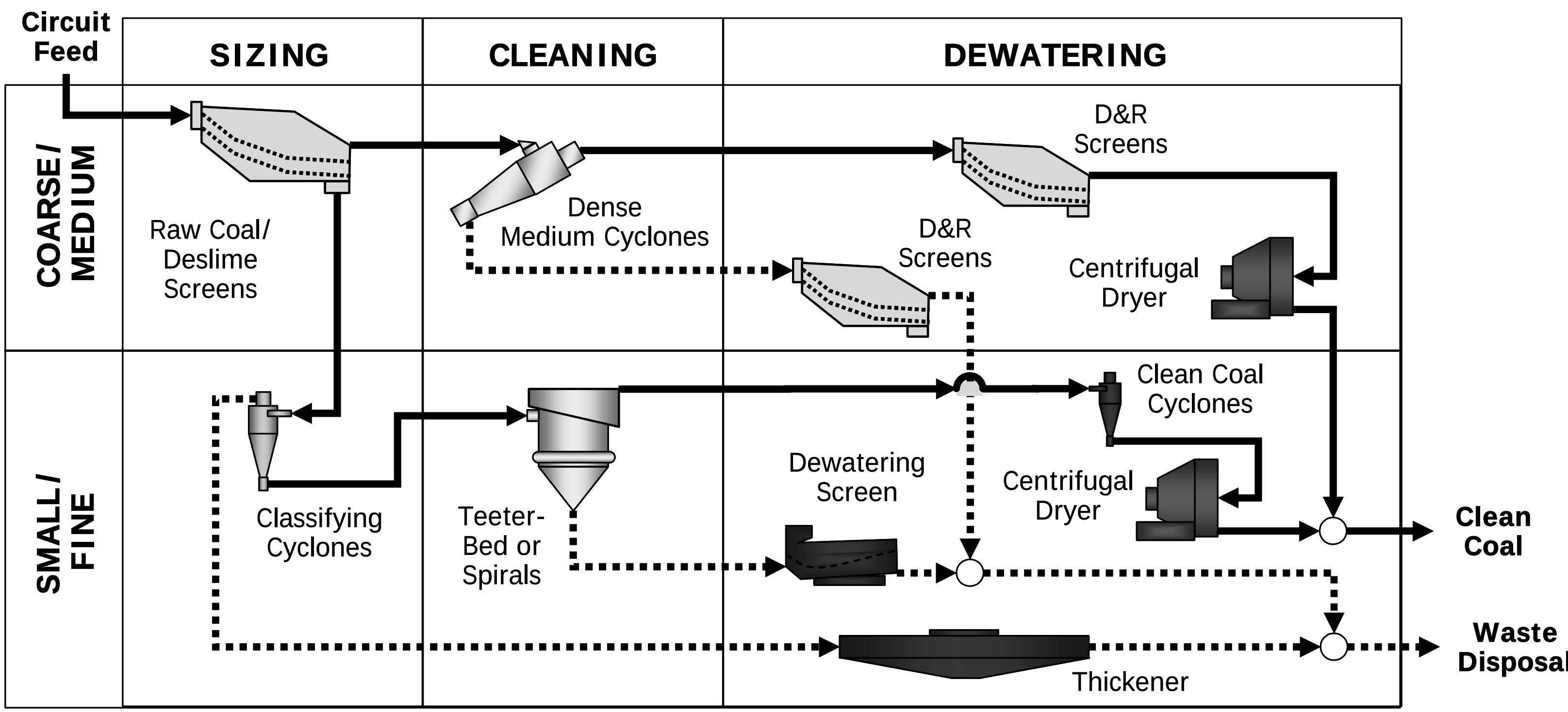
Rules-of-Thumb

- For two or more separators having the same efficiency but different separation densities, the overall efficiency is lower than the efficiency of the single unit.
- For two or more separators having different separation efficiencies, the overall efficiency is the weighted average of the efficiencies from the individual units.

Ramifications on Plant Design

- Large Diameter DMC vs. Standard DMC.
- Water-Only Cyclone/Spiral Circuit versus Spiral Circuit.
- Teeter-Bed Separators versus Spiral Circuits.
- Large (3') Diameter Classifying Cyclone versus 15" Cyclones.
- Banana Screen versus Incline Screen.

New Steam Coal Plant Design: Reduced Distribution

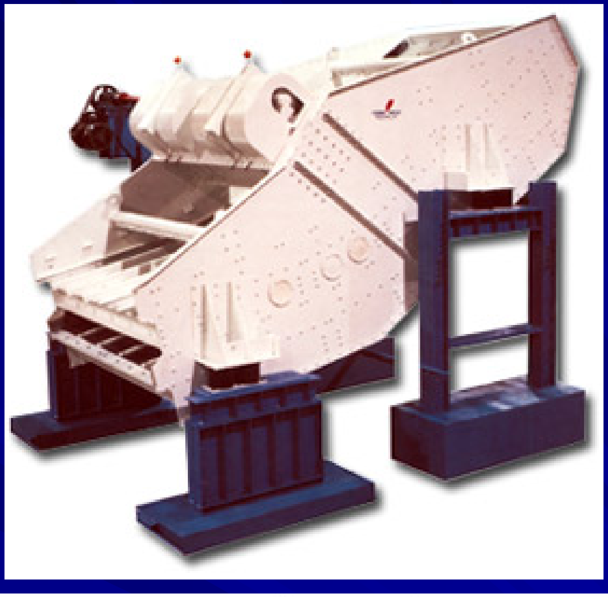


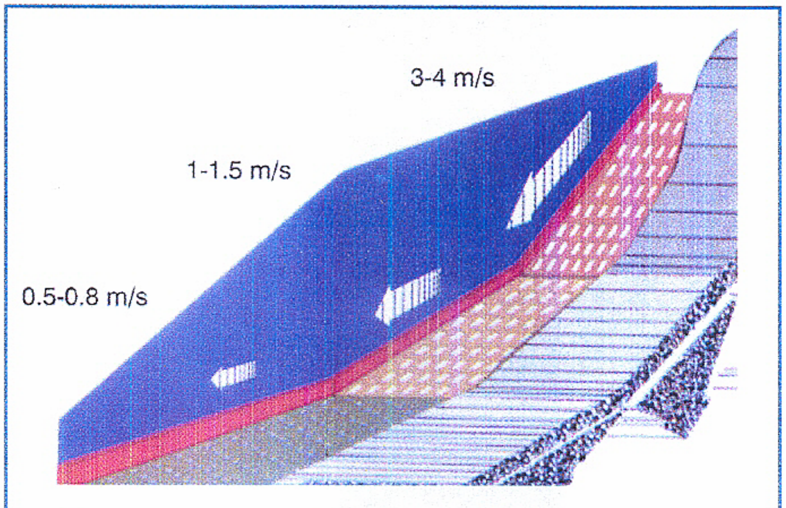
Trend Problems

- The efficiency of large units over a given particle size range may be lower than that achieved by smaller units.
- Efficiency of high capacity technologies may be less than the lower capacity separators that require feed distributors.

Banana Screens

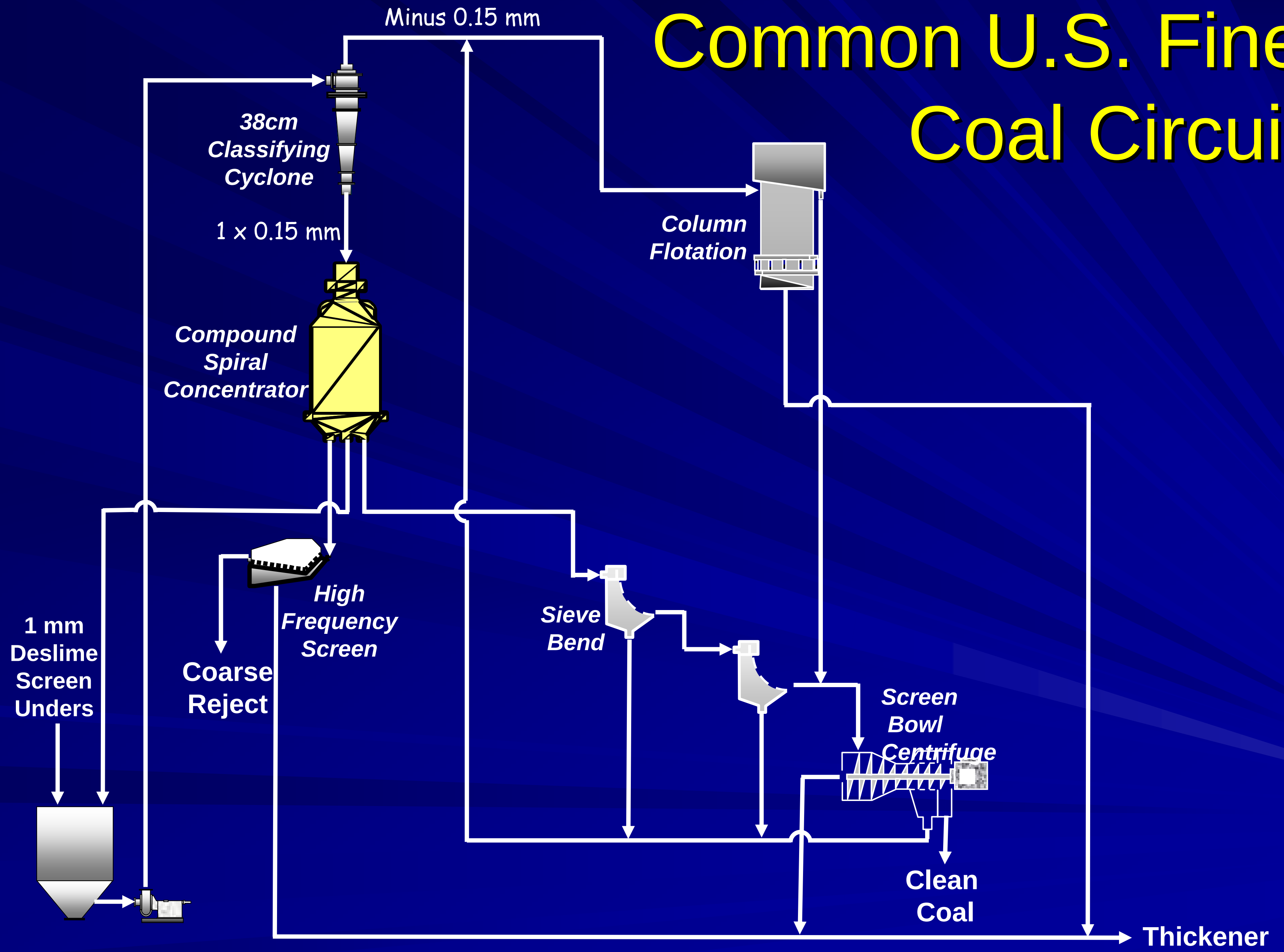
- Australian technology
- Used for deslime screening and drain&rinse screen applications.
- Screen-deck with multiple slopes (2 to 6) which reduces in inclination from the feed end.
- As a result, the velocity of the material is fast at the feed end and slows toward the discharge.
- The high inclinations provide a very thin particle bed which allows the undersize material to pass through the screen more efficiently.
- 50% increase in feed capacity.





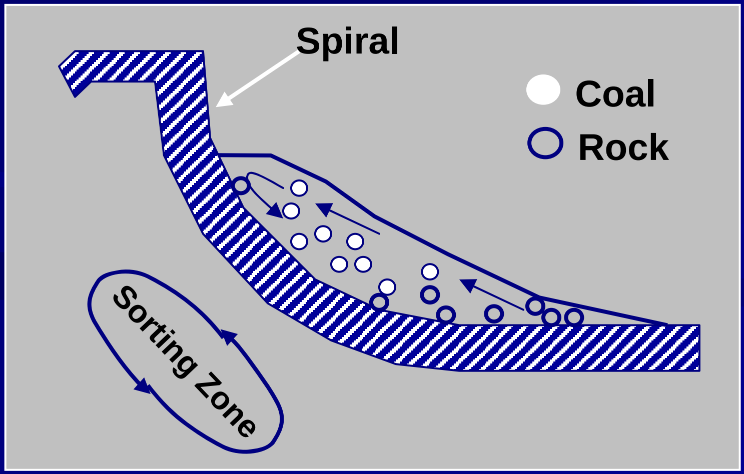
Characteristic material flow over Multi Slop Banana Screen

Common U.S. Fine Coal Circuit



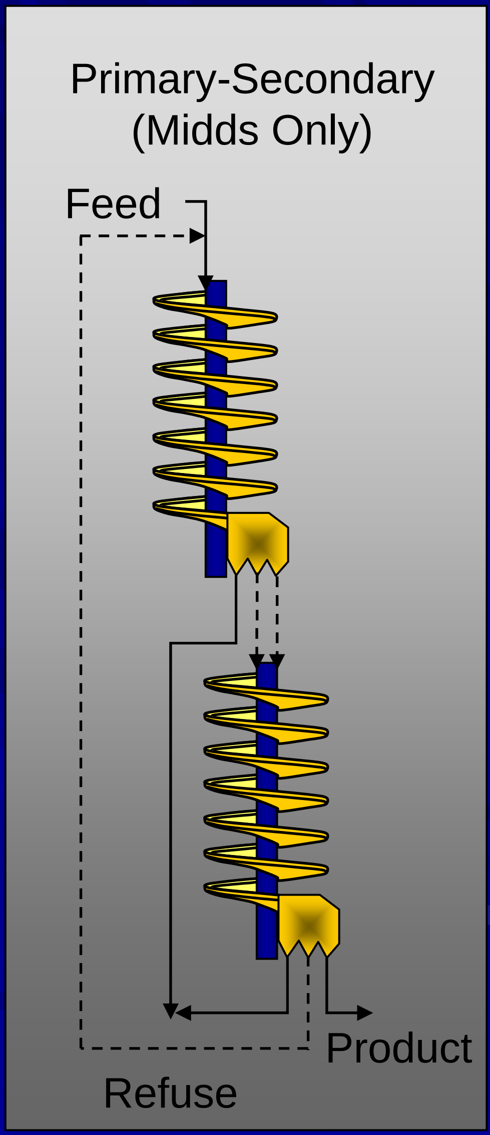
Spiral Concentrators

- Flowing film separator.
- Produces three product streams.
- 3-3.5 tph/start; 30 gpm/start.
- Three starts on one axis.
- Separation density = 1.8 RD; Ep = 0.15 – 0.18.
- Typical 5-10% high density particle by-pass.



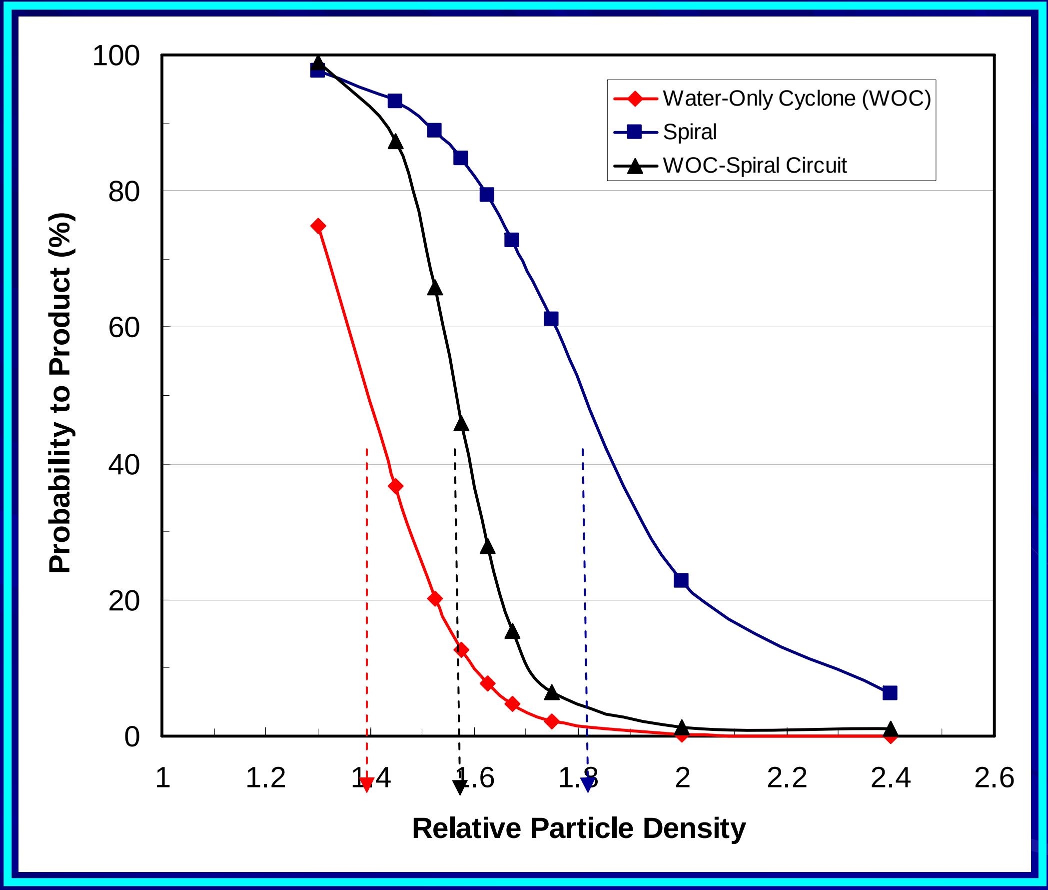
Spiral Performance Improvements

- Luttrell et al. performed circuit analysis to reduce separation density and improve efficiency.
- Rougher-Cleaner arrangement with middling recycle the most practical.
- Separation densities of around 1.7 at Ep = 0.18.
- Significant economic gains have been reported from plant installations.
- Single units using Rougher-Cleaner cleaning action have been developed.



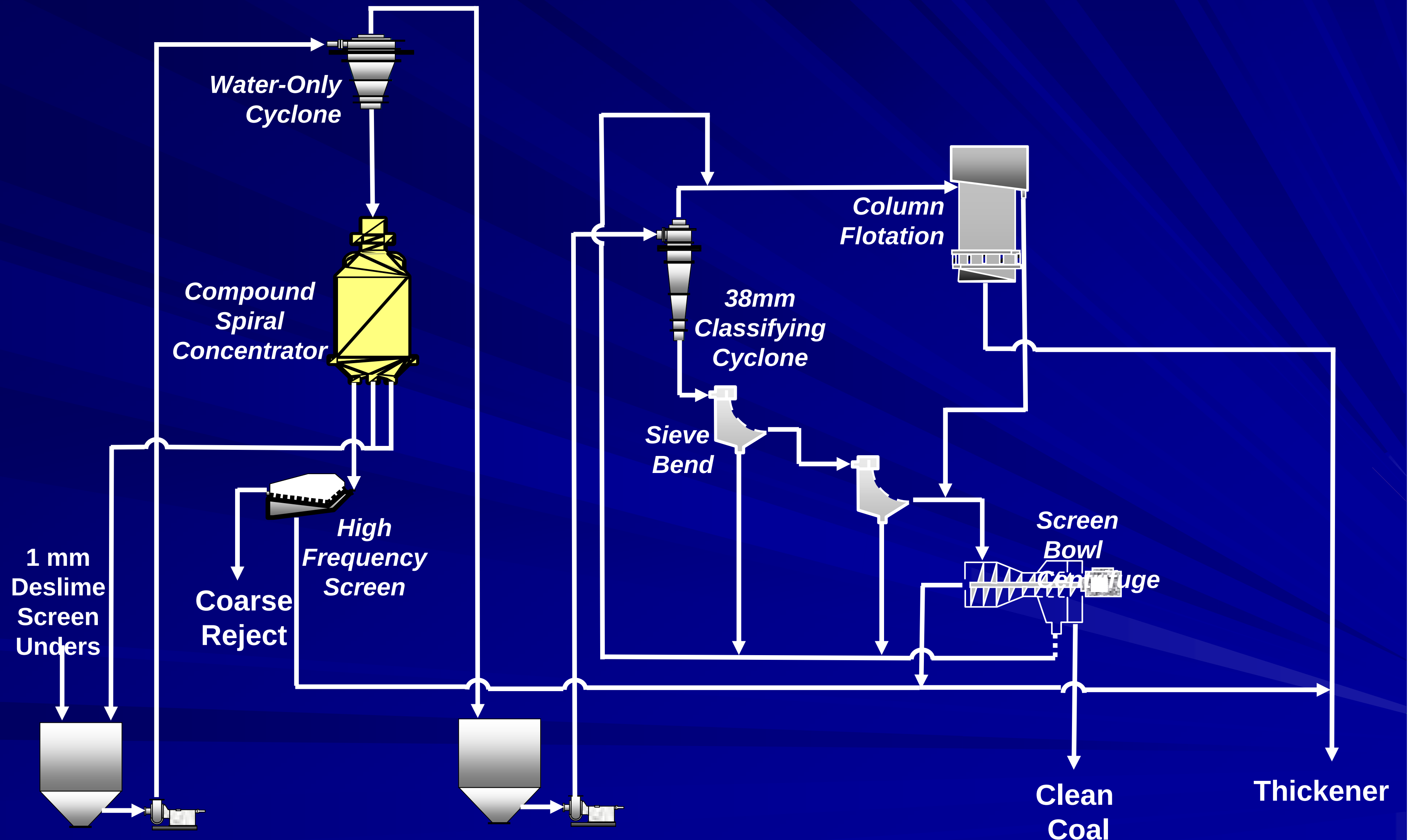
Water-Only Cyclone – Spiral Circuit

- Unloads feed distribution to spirals.
- Recent emphasis in metallurgical coal production is lowering the separation density of the fine circuit.
- Water-only cyclones provide a low density cut but tend to lose coal.
- Spirals tend to ensure 100% coal recovery but have a high density cut.
- Combining the two units provides an efficient low density separation.



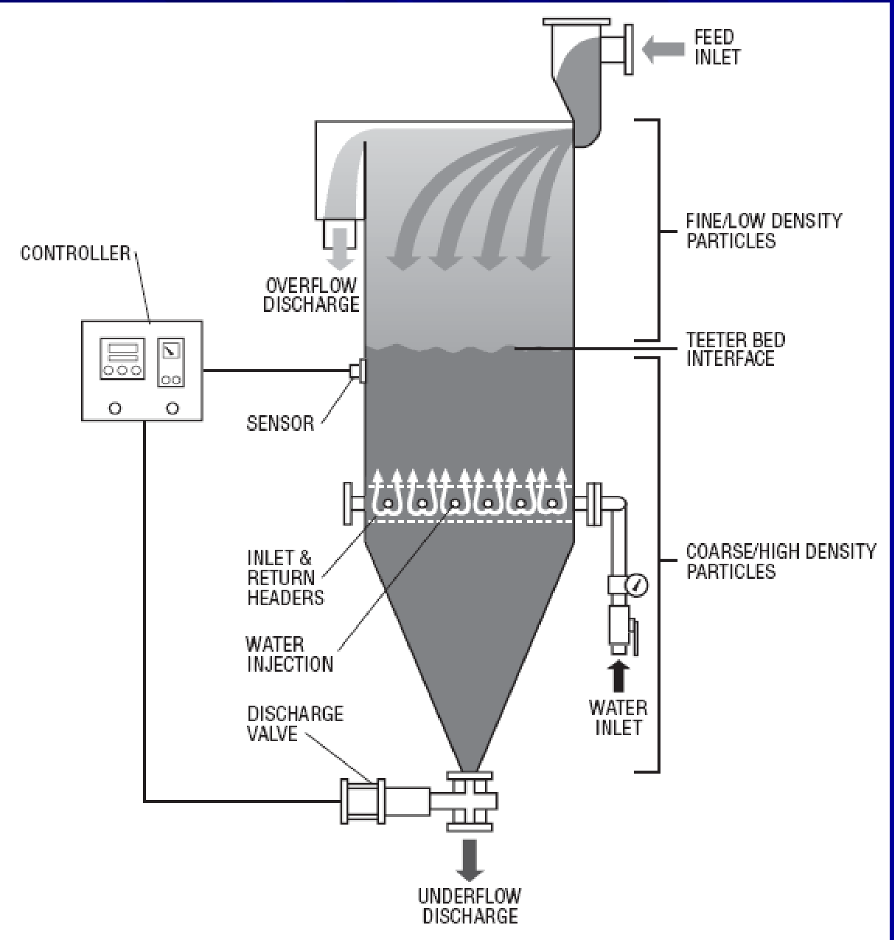
WOC: Ep = 0.10
Spiral: Ep = 0.15
WOC-Spiral: Ep = 0.06

Water-Only/Spiral Fine Coal Circuit



Teeter-Bed Separations

- High capacities (2 tph/ft^2) eliminates distribution problems associated with spirals.
- Low pressure water injection at the bottom of the separation chamber fluidizes the high-density particles.
- Fluidized particle bed = autogenous medium.
- Can be used as an alternative or in conjunction with spirals.
- Effective over a particle size range 5:1.



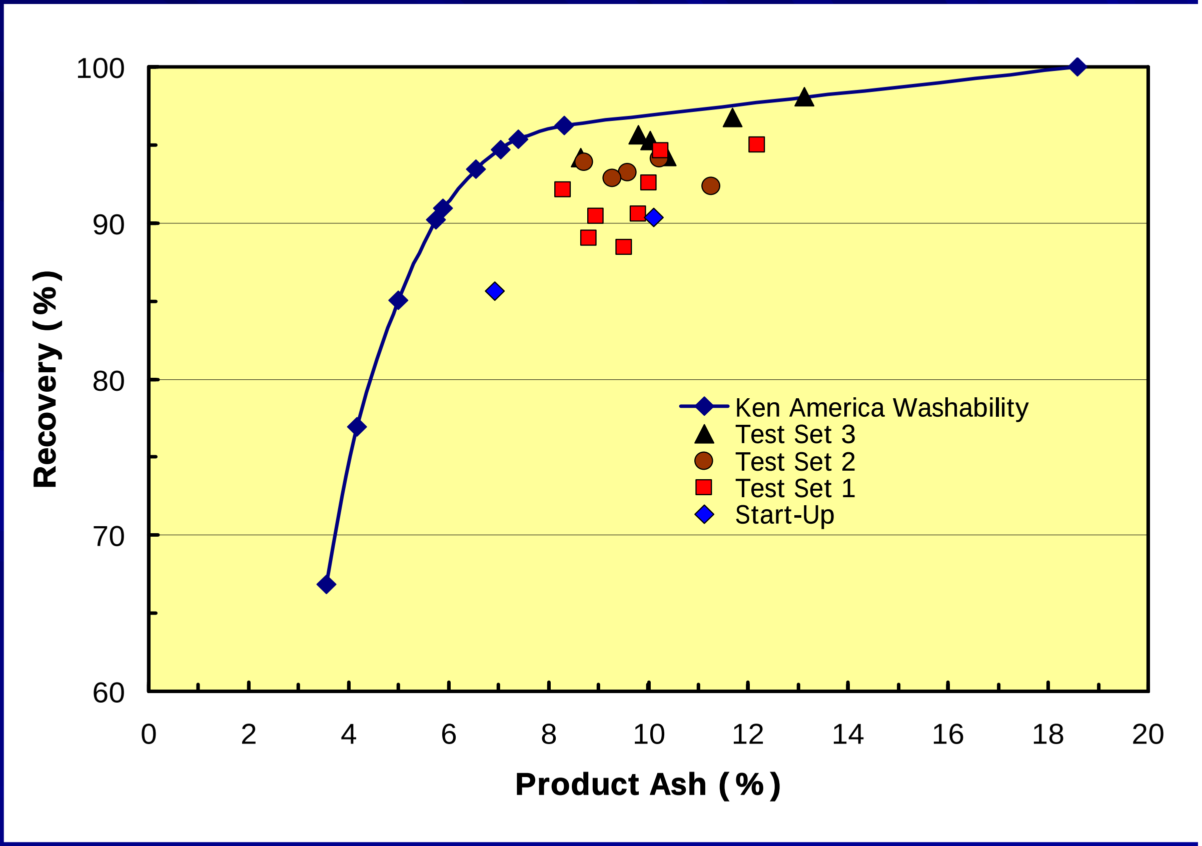
CrossFlow Separator

Teeter-Bed Installation

- 650 ton/hr plant
- HMC/Teeter-bed/Flotation plant
- 140 tph, 2 x 0.25 mm treated by Teeter-Bed.
- 3 x 3 m^2 Crossflow Teeter-Bed unit used.

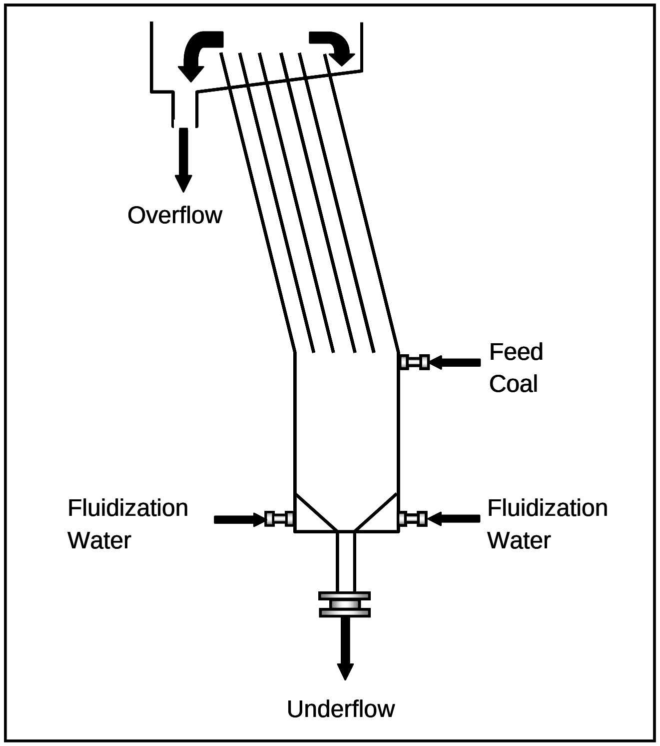
Teeter-Bed Performance

- Parametric evaluation was performed to improve start-up performance.
- 9% ash product achieved with organic efficiency greater than 95%.



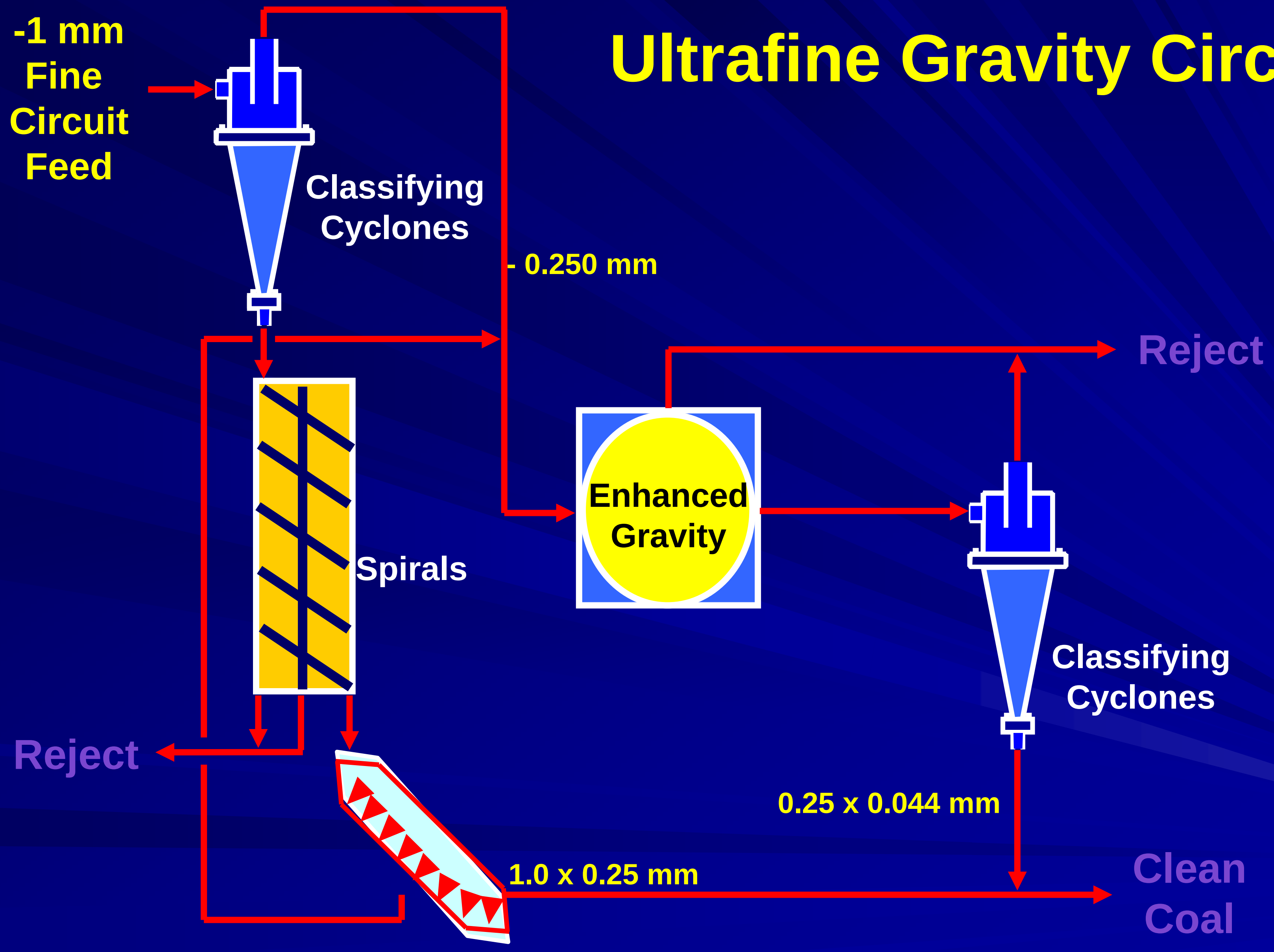
Reflux Teeter Bed Separator

- Utilizes inclined parallel plates to accelerate particle movement.
- Typical of TBS units, performance varies with particle size.



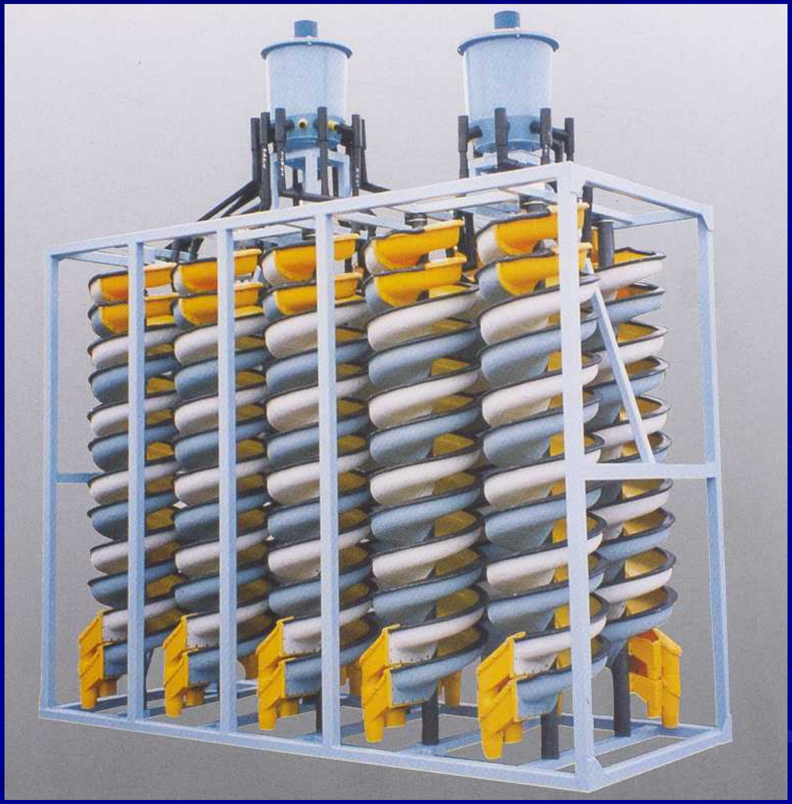
Parameter	Overall	Particle Size Fraction (mm)				
		2 x 1.4	1.4 x 1.0	1.0 x 0.7	0.7 x 0.5	0.5 x 0.25
ρ_{50}	1.70	1.47	1.53	1.60	1.74	1.91
Ep	0.15	0.04	0.03	0.06	0.08	0.15

Ultrafine Gravity Circuit



Spiral Concentrator Application for Ultrafine Coal Cleaning

- Recent studies have found that spirals such as the SX7 can provide an effective gravity-based separation performance for -100 mesh coal.
- Required volumetric flow rate is around 15 gpm/start and feed solids content should be nearly 15% by weight.
- Currently, two U.S. coal preparation plants use spirals in this application.



Ultrafine Spiral Concentrator Ash Rejection Performance

Test 1 Performance (Higher Yield)

Particle Size (mesh)	Spiral Feed		Spiral Product		Spiral Mids 1		Spiral Mids 2		Spiral Tailings	
	Weight (%)	Ash (%)	Weight (%)	Ash (%)	Weight (%)	Ash (%)	Weight (%)	Ash (%)	Weight (%)	Ash (%)
16 x 100	19.60	8.44	16.34	5.22	25.52	6.80	16.75	14.77	15.49	34.90
100 x 325	45.13	19.33	44.82	11.18	43.21	16.19	49.11	45.58	52.99	57.84
-325	35.28	53.74	38.84	46.39	31.27	57.53	34.14	67.71	31.53	74.49
Total	100	29.34	100	23.88	100	26.72	100	47.98	100	59.54

Test 2 Performance (Lower Product Ash)

Particle Size (mesh)	Spiral Feed		Spiral Product		Spiral Mids 1		Spiral Mids 2		Spiral Tailings	
	Weight (%)	Ash (%)	Weight (%)	Ash (%)	Weight (%)	Ash (%)	Weight (%)	Ash (%)	Weight (%)	Ash (%)
16 x 100	19.60	8.44	17.50	4.94	25.26	5.99	21.92	6.80	20.16	36.87
100 x 325	45.13	19.33	58.26	10.71	42.27	12.00	47.18	16.19	52.56	56.33
-325	35.28	53.74	24.24	47.13	32.47	51.64	30.91	57.53	27.29	68.68
Total	100	29.34	100	18.53	100	23.35	100	26.91	100	55.78

Ultrafine Spiral Concentrator Total Sulfur Rejection Performance

Test 1 Performance

Particle Size (mesh)	Spiral Feed		Spiral Product		Spiral Mids 1		Spiral Mids 2		Spiral Tailings	
	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)
16 x 100	19.60	2.64	16.34	2.43	25.52	2.67	16.75	3.34	15.49	4.34
100 x 325	45.13	3.37	44.82	2.7	43.21	3.07	49.11	4.77	52.99	5.62
-325	35.28	5.77	38.84	2.31	31.27	5.19	34.14	7.31	31.53	8.48
Total	100	4.07	100	2.50	100	3.63	100	5.40	100	6.32

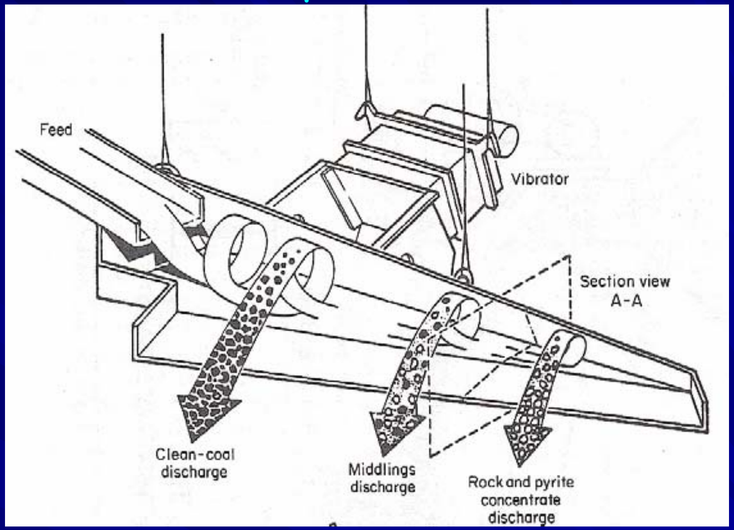
Test 2 Performance

Particle Size (mesh)	Spiral Feed		Spiral Product		Spiral Mids 1		Spiral Mids 2		Spiral Tailings	
	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)
16 x 100	19.60	2.64	17.50	2.45	25.26	2.54	21.92	2.97	20.16	4.38
100 x 325	45.13	3.37	58.26	2.64	42.27	3.00	47.18	4.05	52.56	5.86
-325	35.28	5.77	24.24	4.44	32.47	4.9	30.91	7.78	27.29	9.91
Total	100	4.07	100	3.04	100	3.50	100	4.97	100	6.67

Dry Coal Cleaning

- Dry coal cleaning was popular from 1930 – 1990.
- Peak production was 25.4 million tons annually in 1965.
- Largest all-air cleaning plant was 1400 tph in Pennsylvania (1968).
- Several commercial technologies developed in the period of 1900 – 1950.
- Decline was due to the need for efficient low density cuts and environmental health concerns (underground & surface).
- Recent U.S. resurgence is in large part due to the need to reduce transportation costs and clean western U.S coals.
- Alminerals modified the Stomp jig to provide a completely automated commercial unit.
- Allair jig has been commercially successful (Mining Engineering, 2007).

FMC Separator (1940)



Alminerals Allair Jig

Potential Dry Cleaning Applications

- Dry coal cleaning technologies effectively achieve density separations > 1.85 RD.
- Separations at relatively high densities to remove 'nearly' pure rock is referred to as ***deshaling***.
- Dry deshaling technologies are less expensive than wet cleaning processes:
  - Capital Cost: $6,200/tph versus $13,000/tph
  - Operating Cost: $0.50/ton versus $1.95/ton.
- Deshaling can be applied at the mine site prior to loading and transportation to the end user.

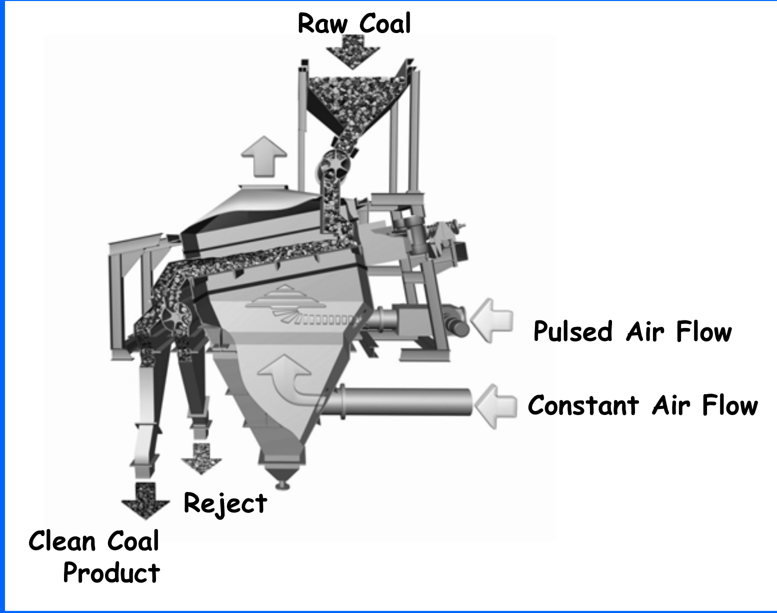
ROM Coal

Dry Coal Cleaning Technology

High-Density Rock

All-Air Jig: Density-Based Separation

- The All-Air Jig is a unit modified from the Stomp Jig.
- Coal is fluidized by a constant flow of air across a perforated table.
- Pulsating air provides the jigging action.
- Nuclear density gauge used to assist the control of reject rate.
- Units up to 100 tph are available.



100 tph All-Air Jig Performance

Coal Type	Feed Ash (%)	Product Ash (%)	Tailings Ash (%)	Mass Yield (%)
1	23.93	13.73	68.12	81.10
2	10.14	7.37	49.89	93.49

Coal Type	Feed Sulfur (%)	Product Sulfur (%)	Tailings Sulfur (%)	Mass Yield (%)
1	6.05	3.77	8.06	81.10
2	4.33	3.17	22.79	93.49

FGX Separator

- Separation based on riffling table principles with air as medium.
- Processes 75 x 6 mm coal; however, -6 mm may cleaned separately.
- 10%-20% minus 6mm material needed as an autogenous medium.
- Less than 7% surface moisture.
- High separation densities; ~2.0 Relative Density (RD).
- Probable error (Ep) values between 0.2–0.3.
- Chinese Technology based on previous designs. (10 – 480 tph units).
- Eriez Manufacturing represents the technology in the U.S..

240 tph Commercial Unit

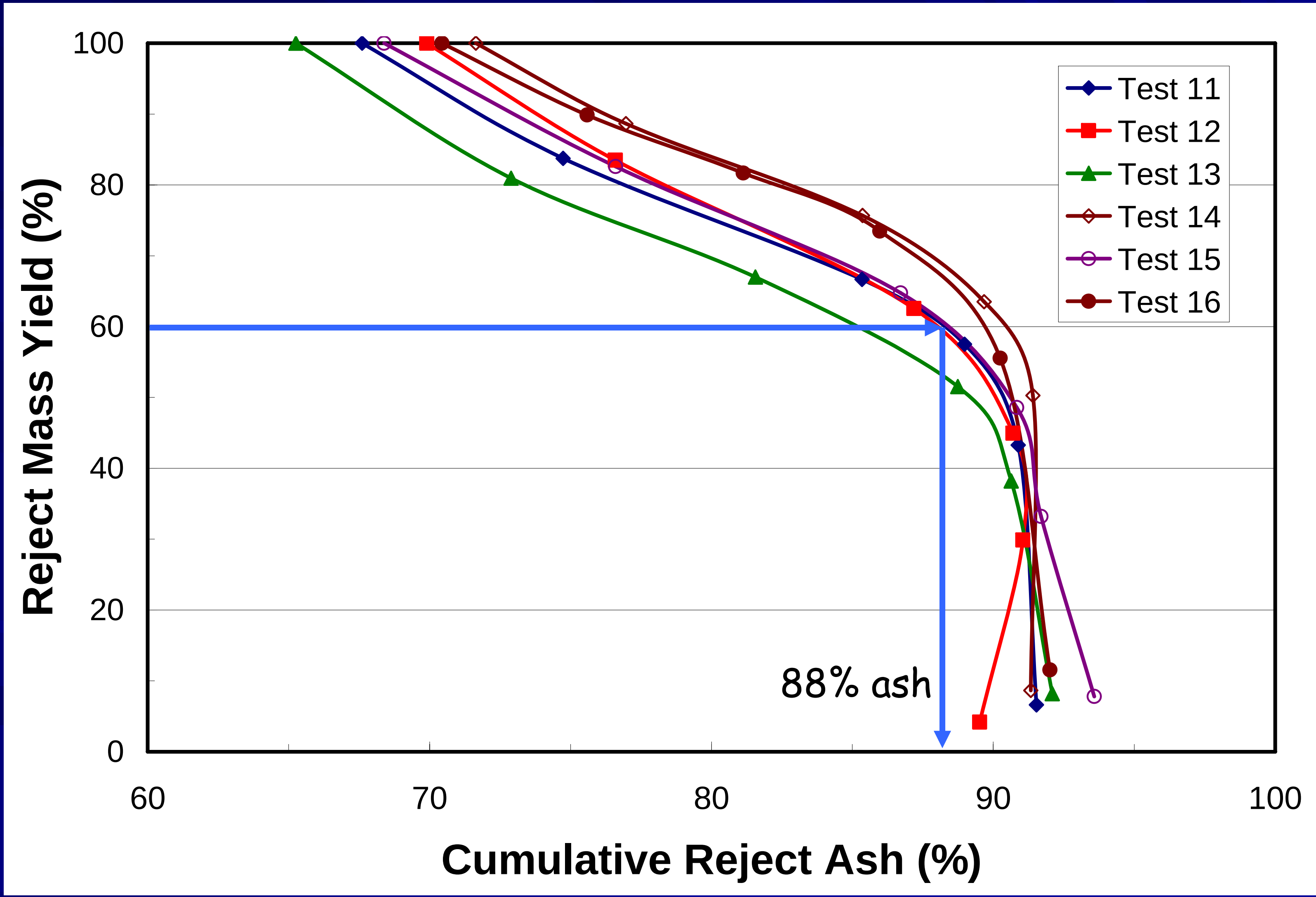
FGX Deshaling Performance

Deshaling Performance: 33.5% Reject Rate

Test No.	Feed Ash (%)	Product Ash (%)	Middlings Ash (%)	Reject Ash (%)	Yield (%)
1	50.00	19.46	83.38	89.03	53.5
2	51.69	34.05	87.08	89.51	66.5
3	54.88	29.09	78.19	87.75	48.4
4	48.27	25.75	80.42	89.92	55.9
5	51.58	25.97	78.41	91.37	58.8
6	46.70	17.87	68.21	88.34	44.5
7	50.84	16.84	55.11	87.30	34.6
8	54.33	15.53	62.70	87.02	34.0
9	38.05	29.02	82.04	89.80	58.5
10	50.18	19.69	78.26	90.09	51.1
11	45.88	34.50	86.30	91.09	66.7
12	49.93	12.88	72.51	90.13	46.1
13	47.14	13.96	57.02	88.90	37.3
14	51.69	14.78	71.90	87.95	43.4
15	47.87	12.63	73.30	89.38	42.9
Aver.	49.27	21.47	74.32	89.17	49.5

Note the ability to reduce ash from 49.3% to 12.6%

East Kentucky Underground Coal (20 mile haul distance)



Central Appalachia Bituminous Coal (Site No. 2)

- West Virginia underground coal containing around 60% ash.
- Yield to the reject & 1.6 RD float-sink performed.

Test Number	Middlings & Reject Combined		Reject Only	
	% of Feed	% Float 1.6 RD	% of Feed	% Float 1.6 RD
1	50.7	3.71	35.9	1.51
2	49.5	2.82	33.0	0.90
3	55.1	3.72	36.6	1.32
4	52.4	2.73	36.4	0.78

Economic Benefit

- Unit Capacity = 500 tph
- Yield to Reject = 36.4%
- Reject Amount = 500 x 0.364
  = 182 tph
- Annual Operating Hours
  = 6000 hrs/yr
- Total Reject left at mine
  = 182 tons/hr x 6000 hrs/yr
  = 1,092,000 tons

Transportation Savings

- Transportation Cost
  = 0.30 $/ton*mile
- Mine-to-Plant Distance
  = 20 miles
- Transportation Cost/ton
  = 20 x 0.30 = $6.00/ton
- Reduction in Tons Hauled
  = 1,092,000 tons/yr
- Annual Transportation Savings
  = 1,092,000 x $6 =
  = $6,552,000

Lost Coal Cost

- Total Deshaler Reject
  = 182 tons/hr
- % 1.60 Float in Reject
  = 0.78%
- Total Coal Loss
  = 182 x 0.0078 = 1.42 tph
- Annual Coal Loss
  = 1.42 x 6000 hrs/yr
  = 8518 tons
- Sales Price = $50/ton
- Lost Coal Cost
  = 8518 x 50 = $425,880/yr

Summary Economic Benefit

- FGX Operating Cost
  = $0.50/ton
- Annual Operating Cost
  = $0.50 x 500 x 6000
  = $1,500,000/yr

- Summary:

Transportation Savings = $6.55M
Coal Loss Cost = $0.43M
Operating Cost = $1.50M

Net Profit Gain = $4.62M

Capitol Cost = $3200/tph
500 tph unit = $1.6 M

Summary

- The most recent changes in coal processing plants are linked to two issues affecting plant efficiency:
  - Maintaining constant incremental qualities across each circuit.
  - Reducing effects of distribution errors.

Summary

- Higher capacity units are being employed which has reduced circuit complexity.
- Performance problems have occurred with the large single units.
- Various fine coal technologies and circuits have been commercialized to reduce separation density.

Summary

- A resurgence in dry coal cleaning has occurred due to the need to process low rank coals and deshale high-ash eastern U.S. coals.
- Separators have demonstrated the ability to remove material having an ash content > 88% which represents up to 60% of the feed.
- Current commercial installations are successful.

Comments/Questions?