INNOVATIVE GRAVITY-BASED TECHNOLOGIES AND CIRCUITS FOR FINE COAL CLEANING

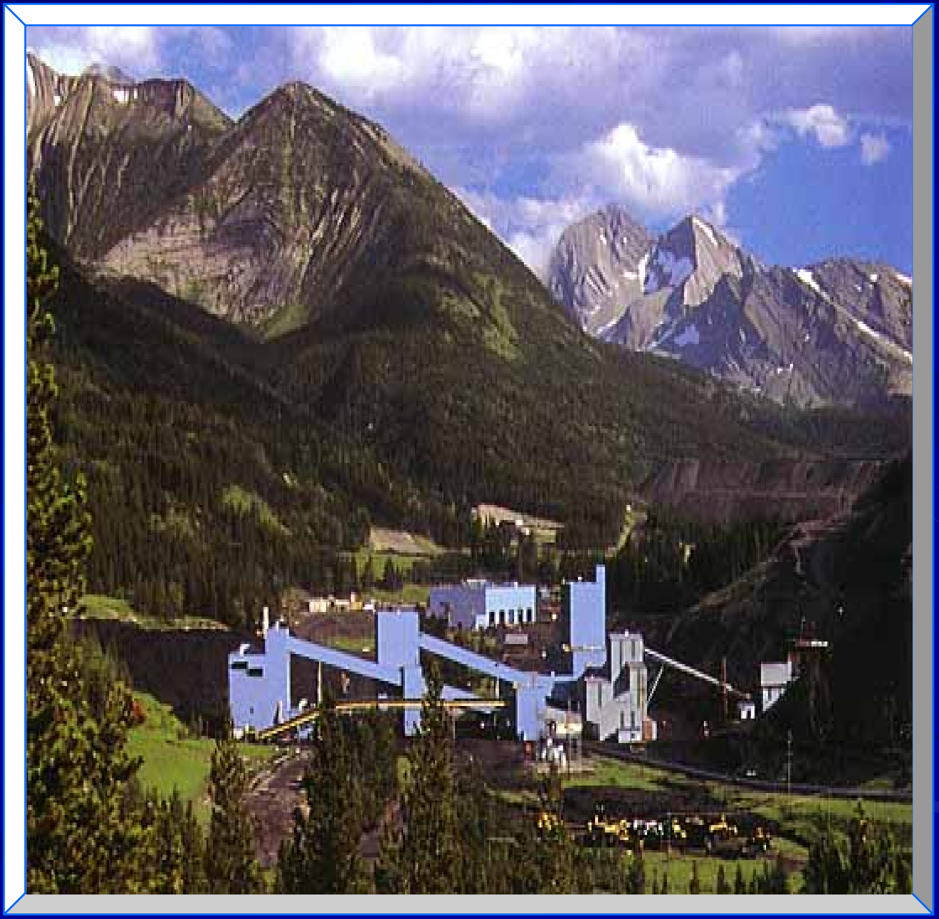
R. Q. Honaker

University of Kentucky
Department of Mining Engineering

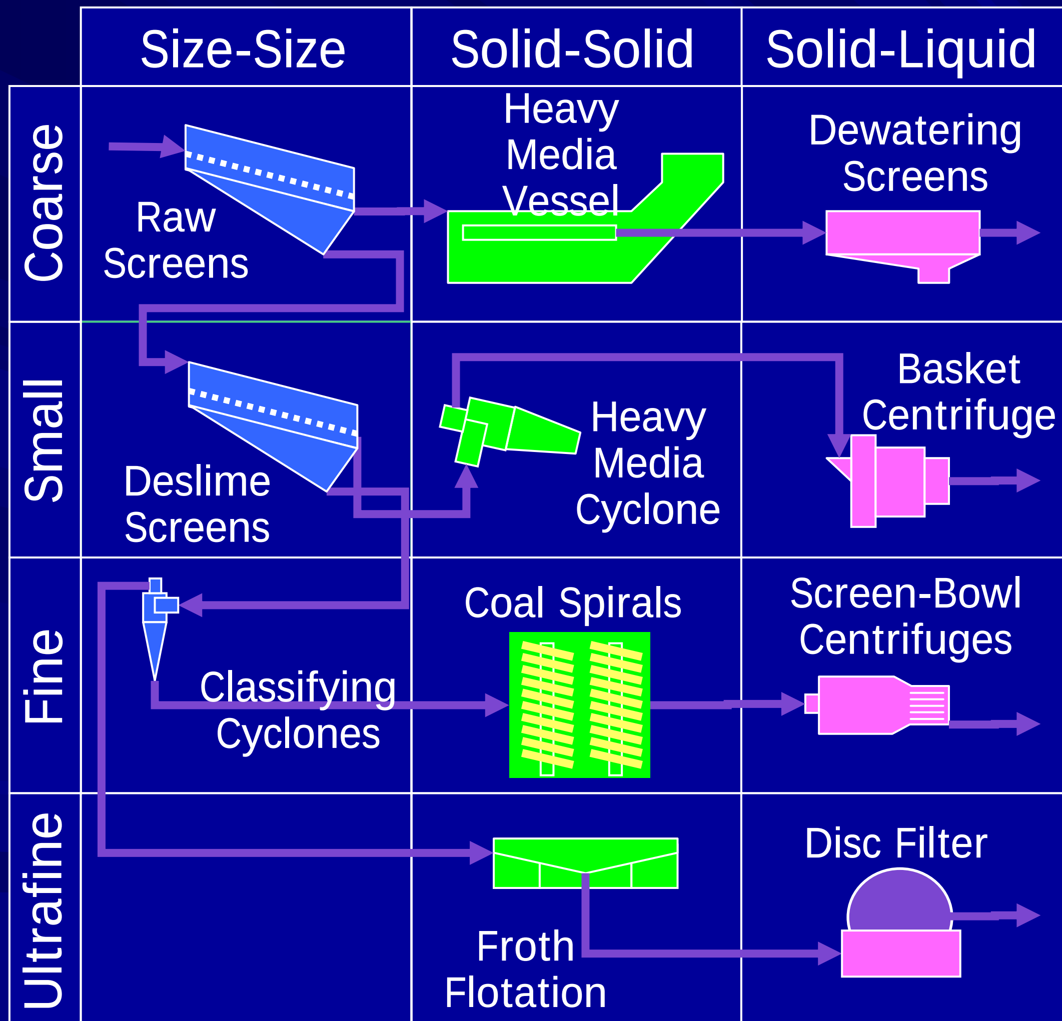
Workshop on Coal Beneficiation and Utilization of Rejects : Initiatives, Policies and Best Practices
Ranchi, India
August 22 – 24, 2007

U. S. COAL PREPARATION

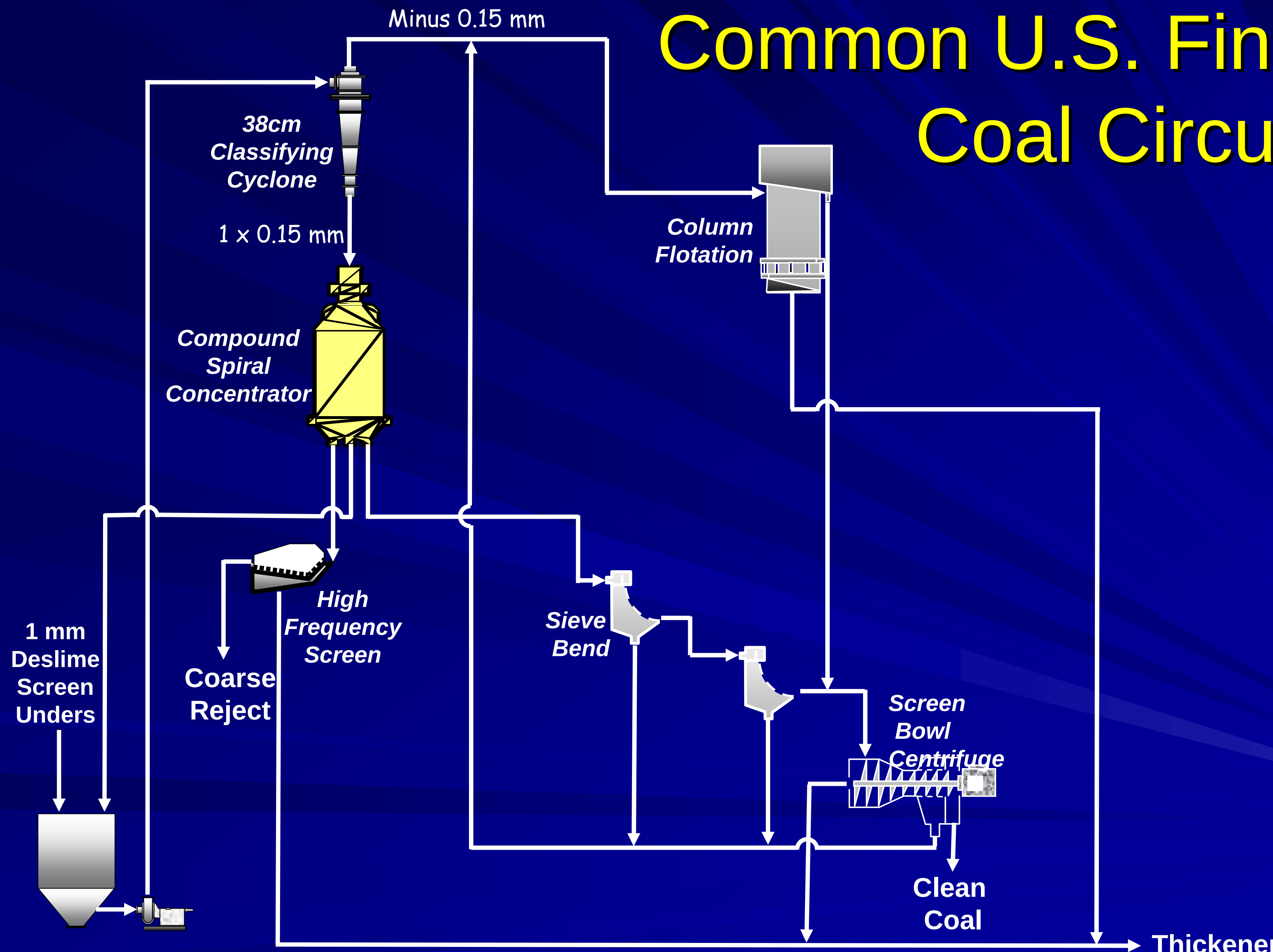
- Coal preparation involves processing to achieve the required quality for end users.
- 636 Mt of coal processed annually.
- Coal is sized and cleaned in various circuits.
- Fine (-1 mm) coal typically accounts for 12%-15% of feed (75 – 95 Mt annually)



TYPICAL PROCESS FLOWSHEET

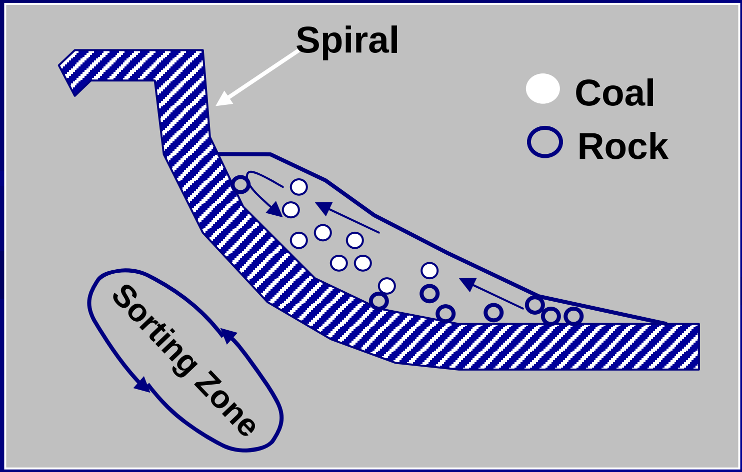


Common U.S. Fine Coal Circuit



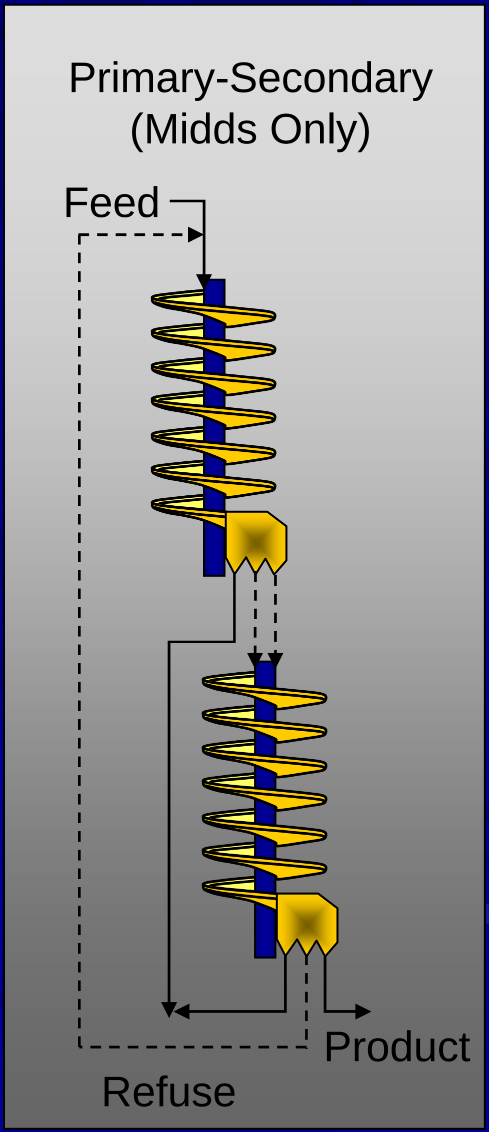
Spiral Concentrators

- 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.



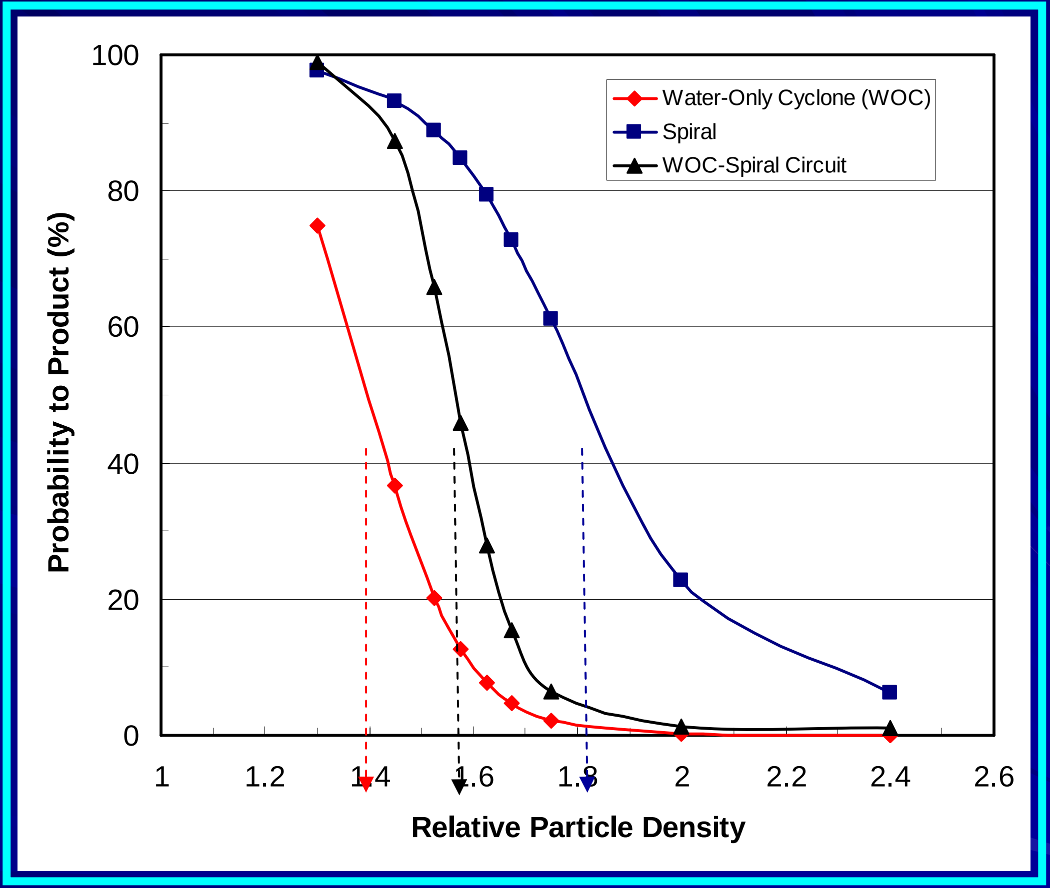
Spiral Performance Improvements

- 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.
- Commercial manufacturers have since produced spirals that achieve the Rougher-Cleaner cleaning action in a single unit.



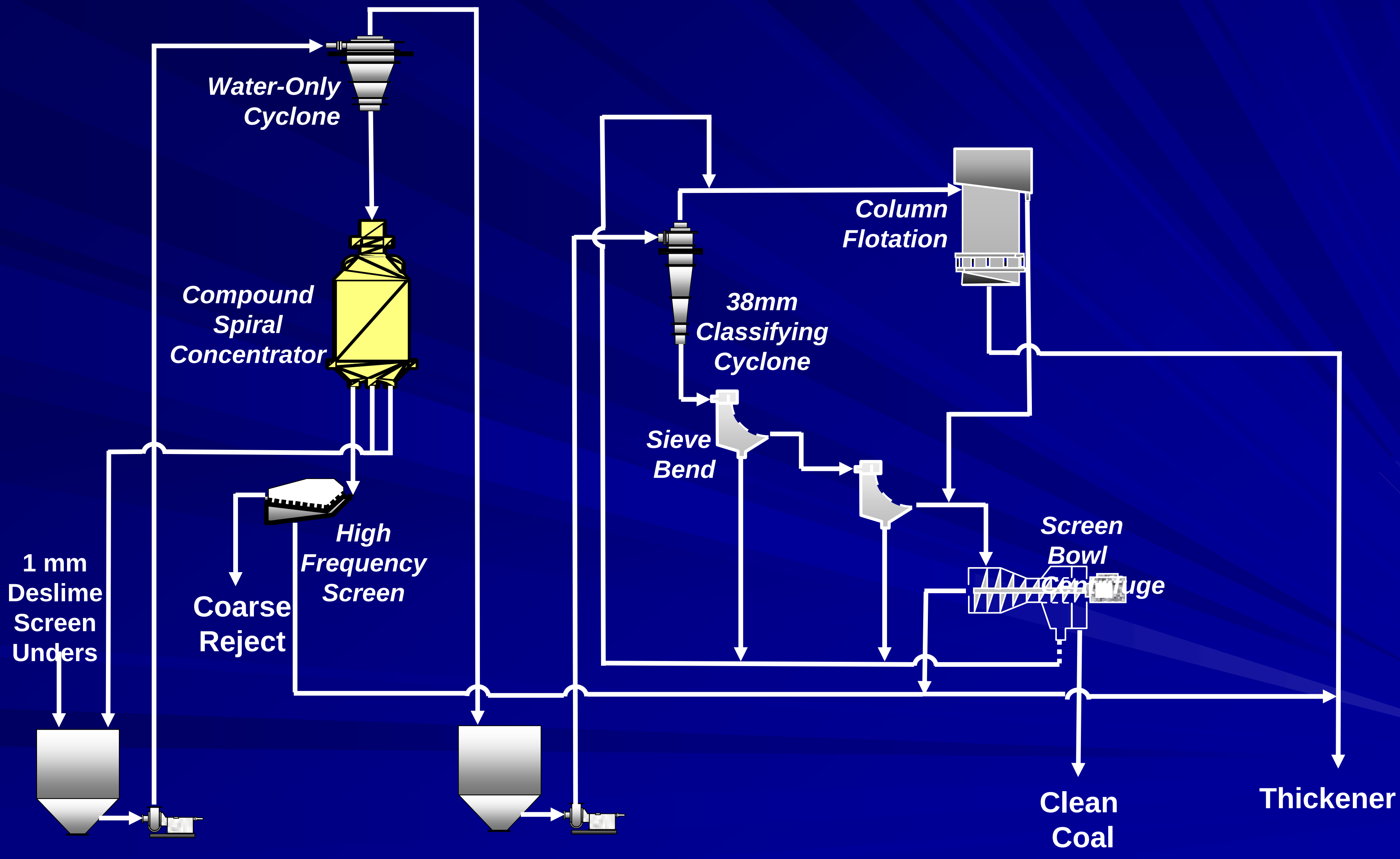
Water-Only Cyclone – Spiral Circuit

- 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.



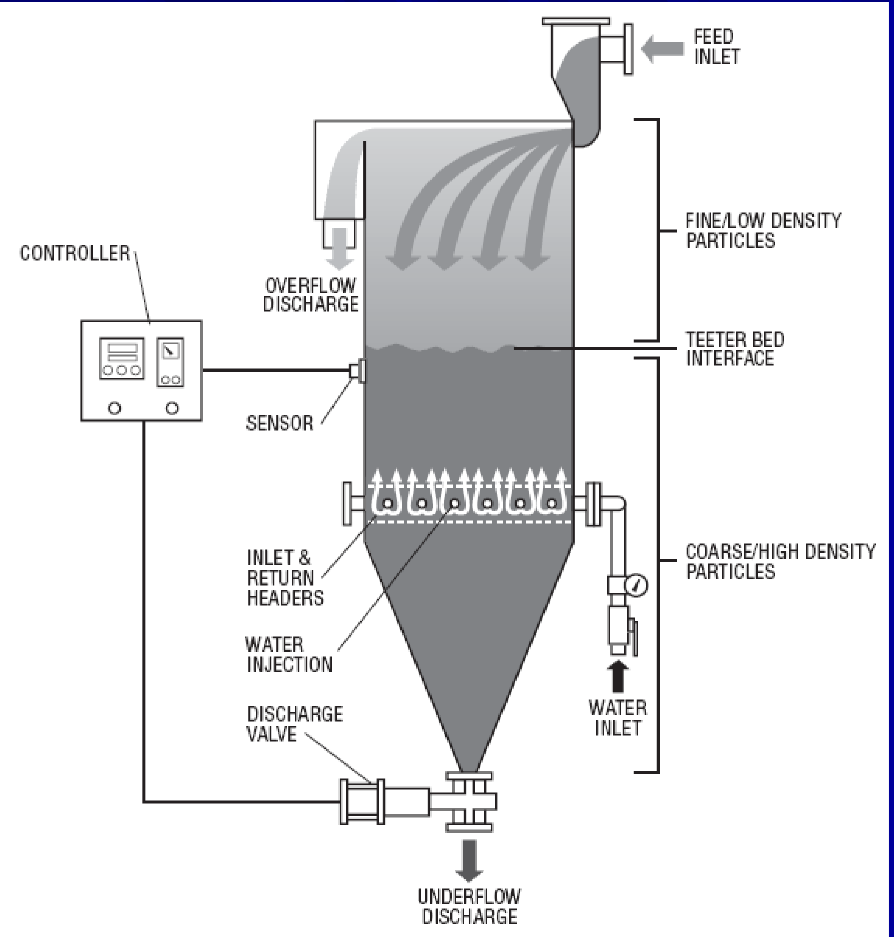
WOC: Ep = 0.10
Spiral: Ep = 0.15
WOC-Spiral: Ep = 0.06

Water-Only/Spiral Fine Coal Circuit



Teeter-Bed Separations

- 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.
- 2 tph/ft^2 capacity.
- Effective over a particle size range 5:1.



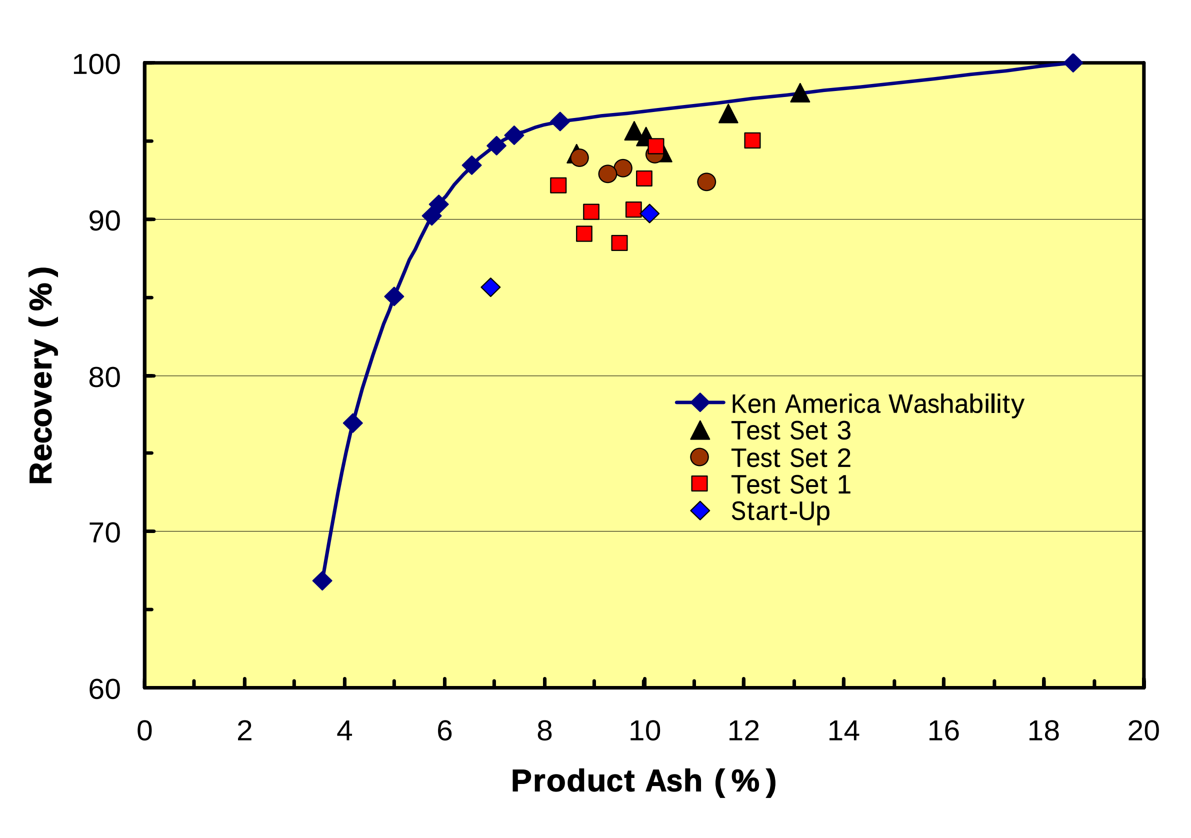
CrossFlow Separator

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%.

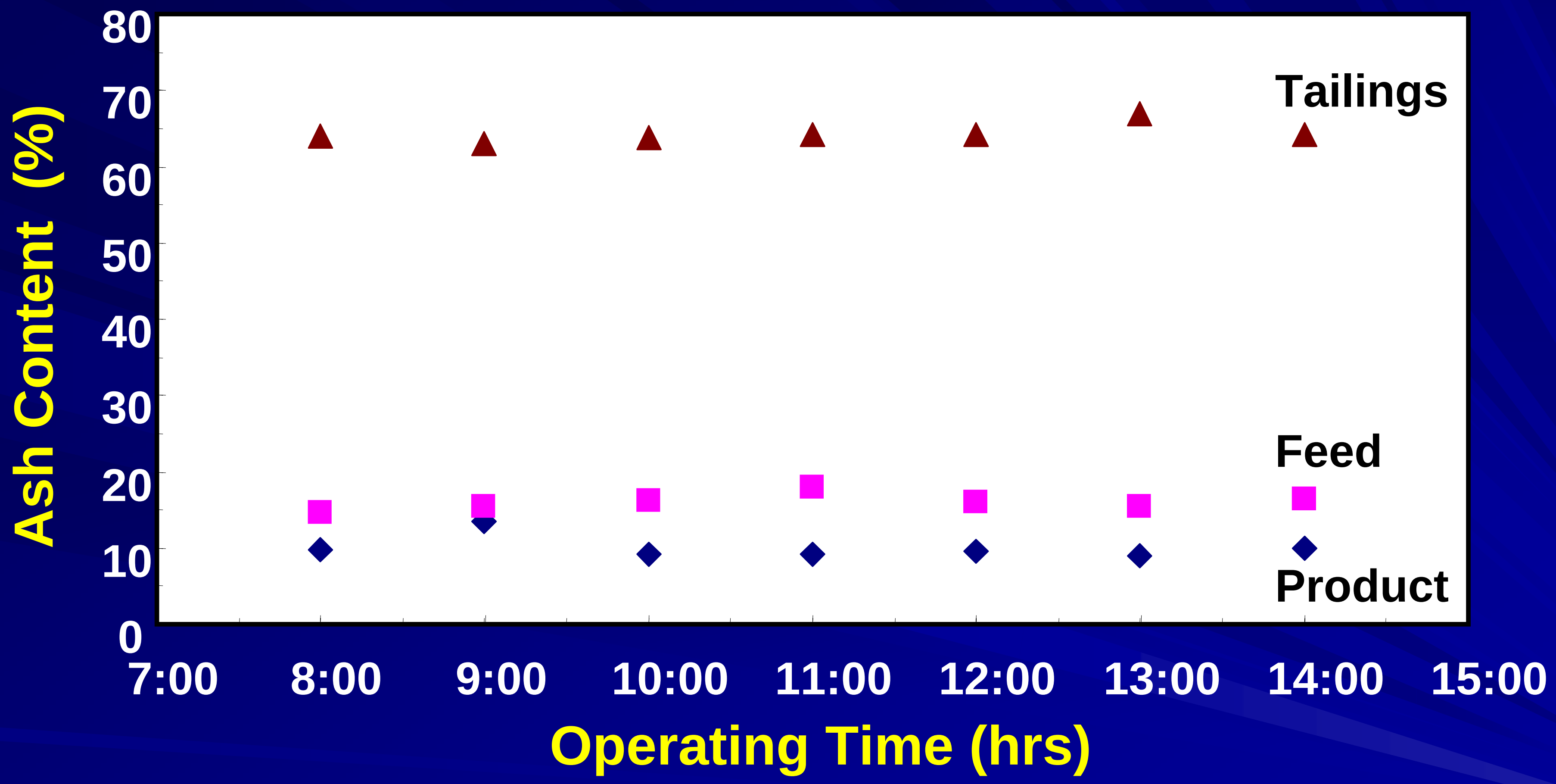


Particle Size-by-Size Performance

Particle Size (mesh)	FEED		PRODUCT		TAILINGS		YIELD (%)	RECOVERY (%)
	Weight (%)	Ash (%)	Weight (%)	Ash (%)	Weight (%)	Ash (%)		
+ 8	13.64	15.76	12.42	7.55	19.77	72.11	87.3	95.8
8 x 16	29.05	16.02	25.17	8.08	32.13	69.08	87.0	95.2
16 x 65	57.31	16.54	62.41	10.96	48.09	64.34	89.5	95.5
Total	100.00	16.28	100.00	9.81	100.00	67.40	88.8	95.6

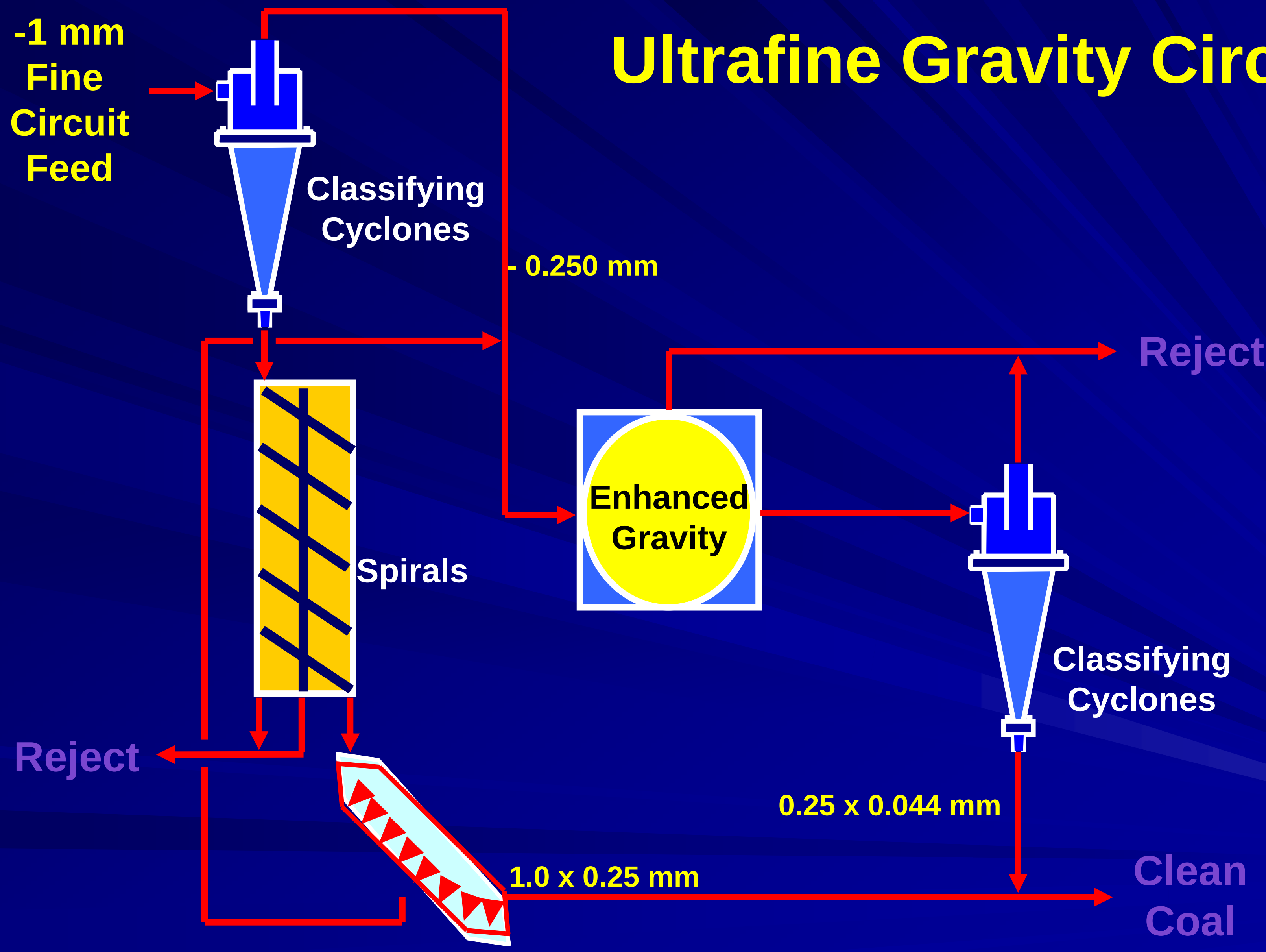
- A particle size-by-size analysis of the process streams shows that 56.5% of the ash-bearing material is removed from the +8 and 8 x 16 mesh fractions while recovering 95% of the combustible material.
- A significant finding is the high ash contents in the +8 mesh tailings material (>70%). The ash content of this fraction in the initial tests was around 48%.

Crossflow Coal Performance



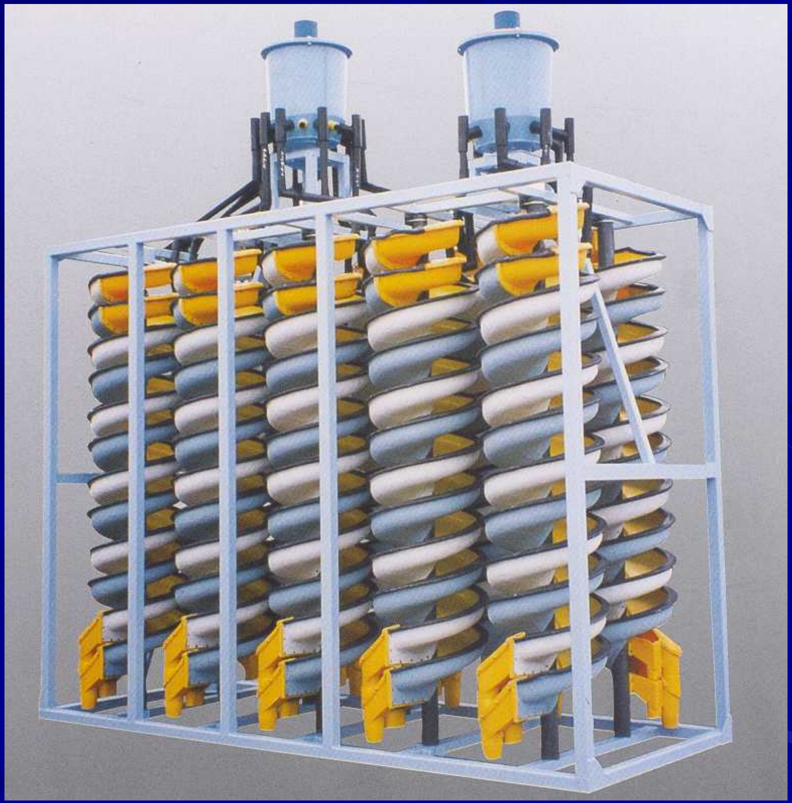
- The average feed, product and tailing ash contents were 15.97%, 9.99% and 64.34%, respectively.

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

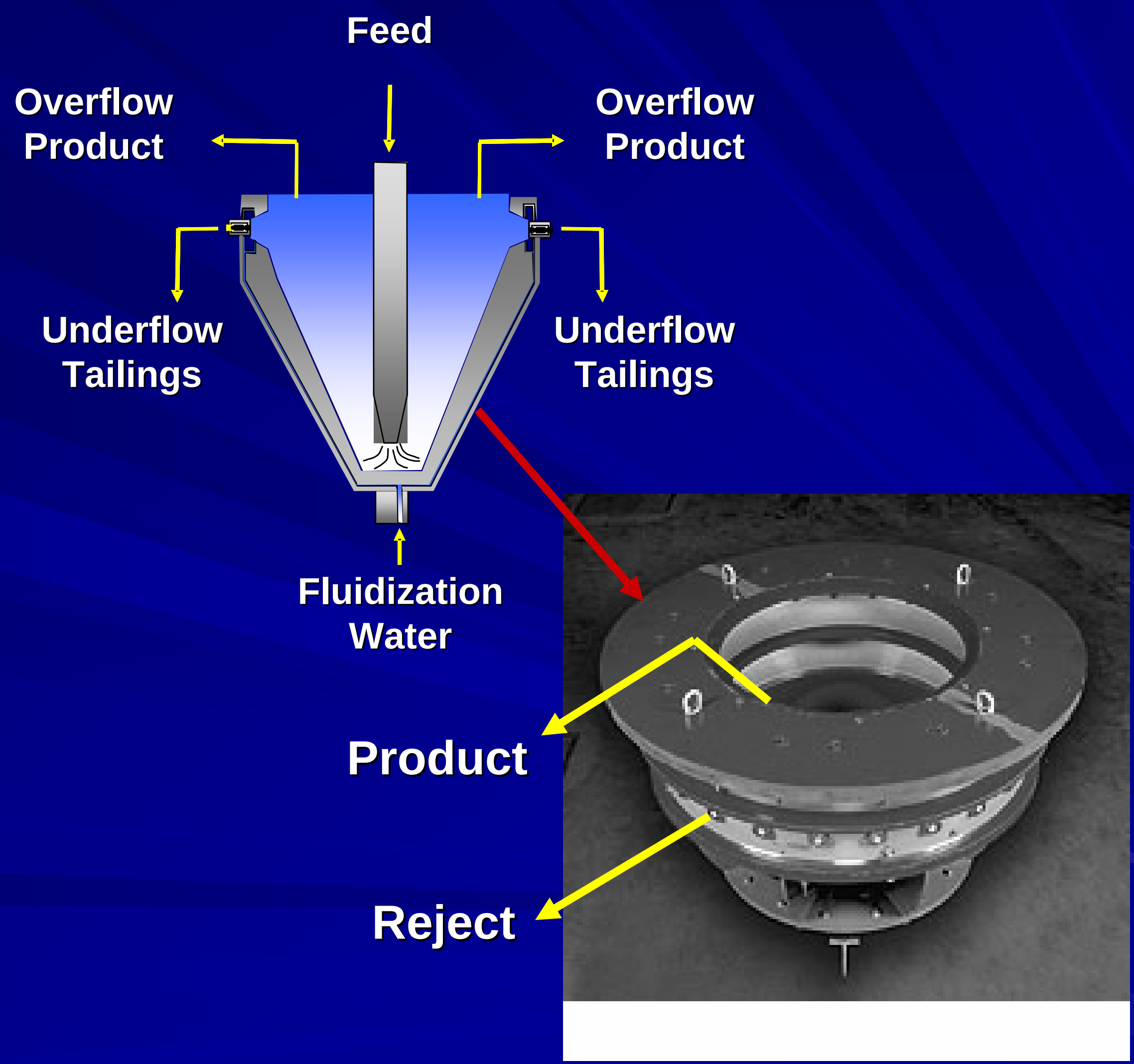
Particle Size (mesh)	Spiral Feed		Spiral Product		Spiral Mids 1		Spiral Mids 2		Spiral Tailings	
	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)
16 x 100	19.60	2.64	16.34	2.43	25.52	2.67	16.75	3.34	15.49	4.34
100 x 325	45.13	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

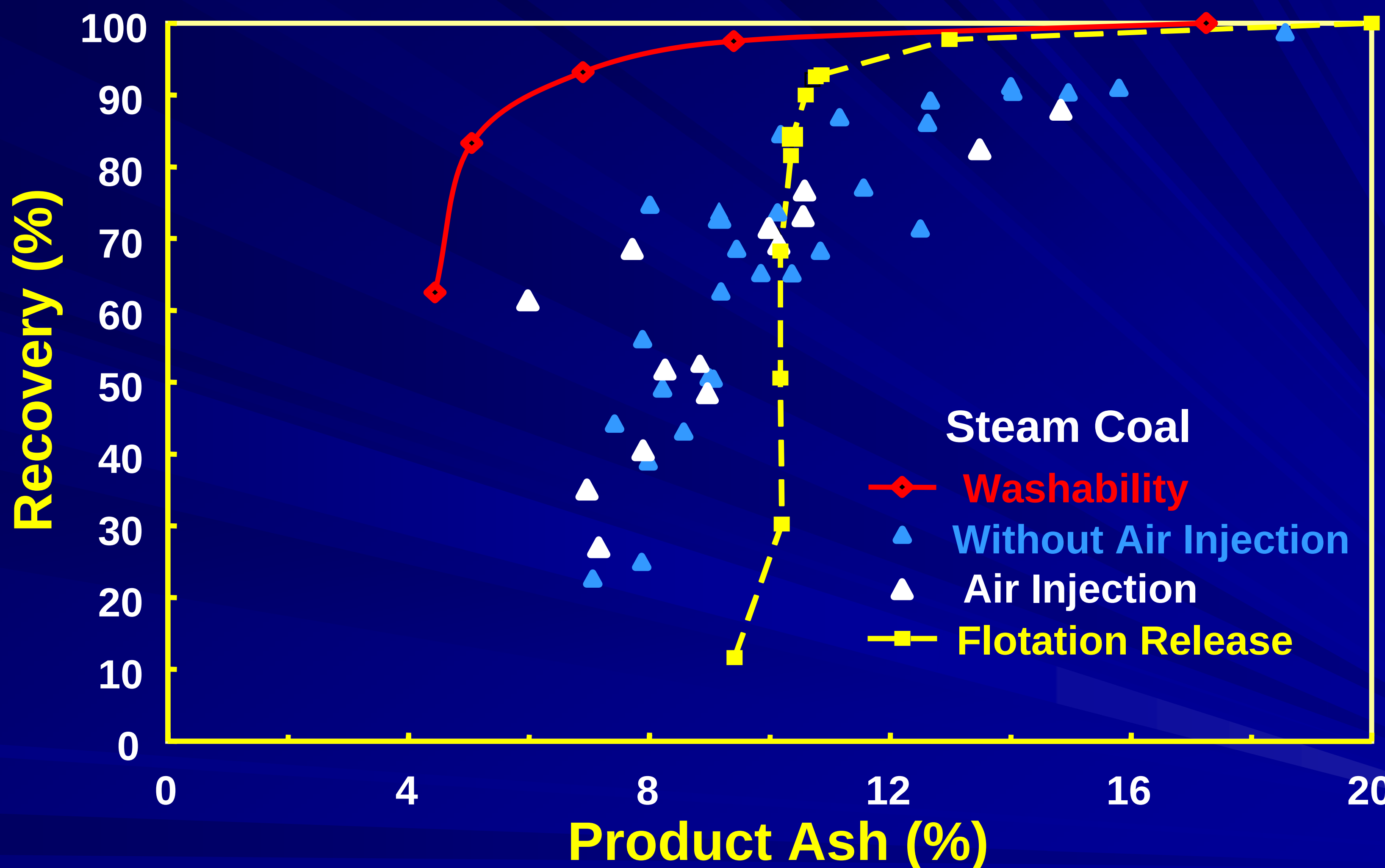
Particle Size (mesh)	Spiral Feed		Spiral Product		Spiral Mids 1		Spiral Mids 2		Spiral Tailings	
	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)	Weight (%)	T. Sulfur (%)
16 x 100	19.60	2.64	17.50	2.45	25.26	2.54	21.92	2.97	20.16	4.38
100 x 325	45.13	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

Enhanced Gravity Concentration

- Commercial units available that provide up to 300 g's
- Units utilize basic principles of jigging, tabling, fluidized bed or flowing film.
- The Knelson Concentrator is a fluidized bed unit.
- Feed slurry is injected into the center and accelerated by mechanical action.
- High density particles migrate to the bowl wall and discharged through controlled pinch valves.
- Low density particles flow naturally over the top lip of the bowl.

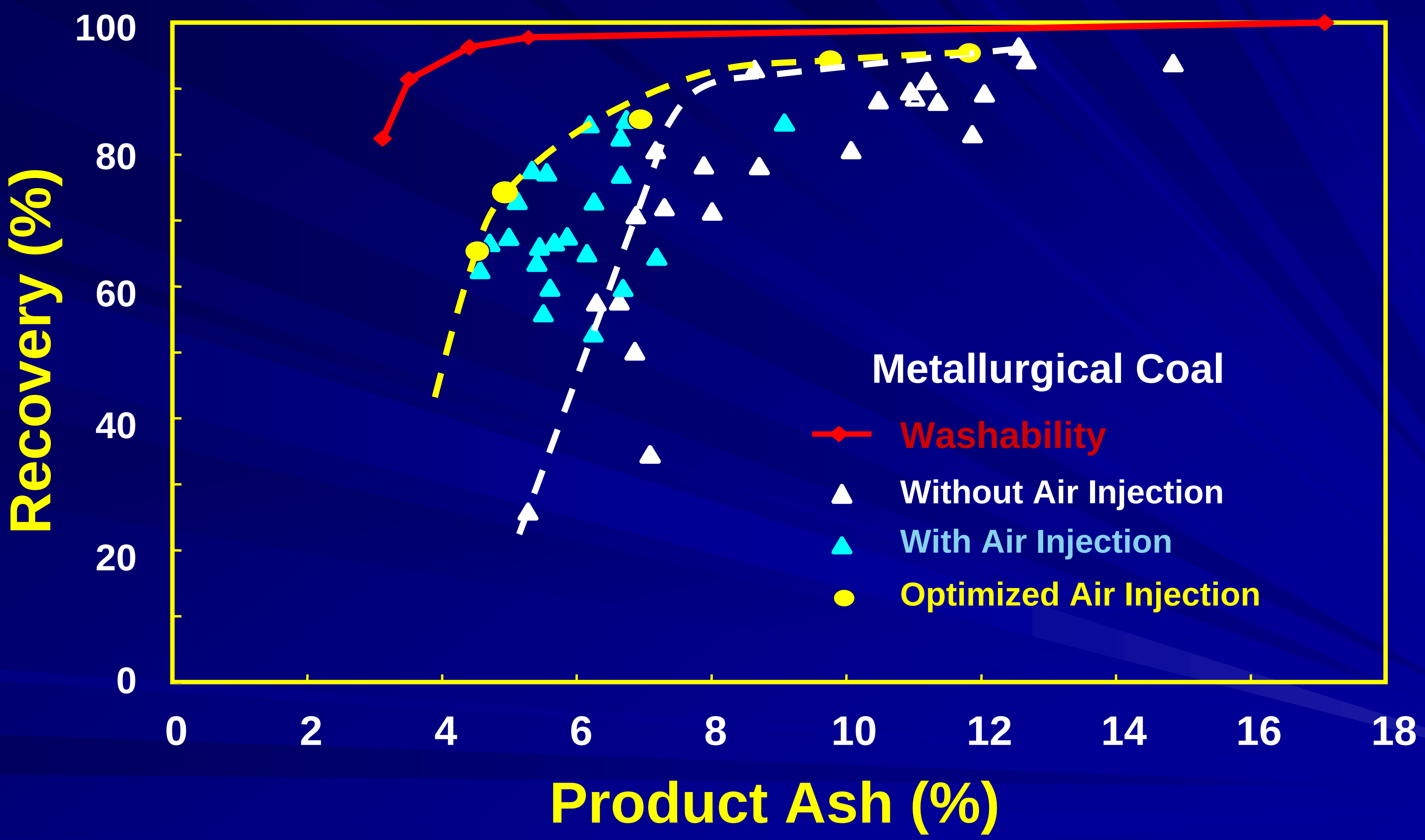


Knelson Steam Coal Performance



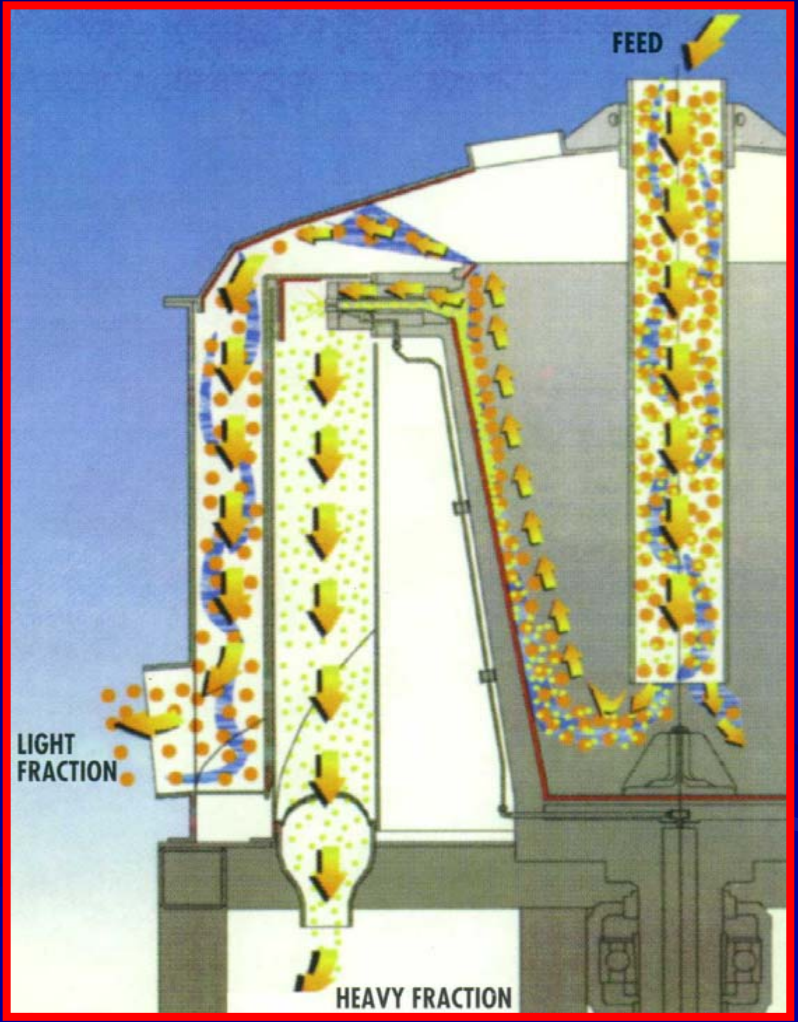
•Knelson concentrator provided superior performance compared to flotation.

Knelson Separation Performance

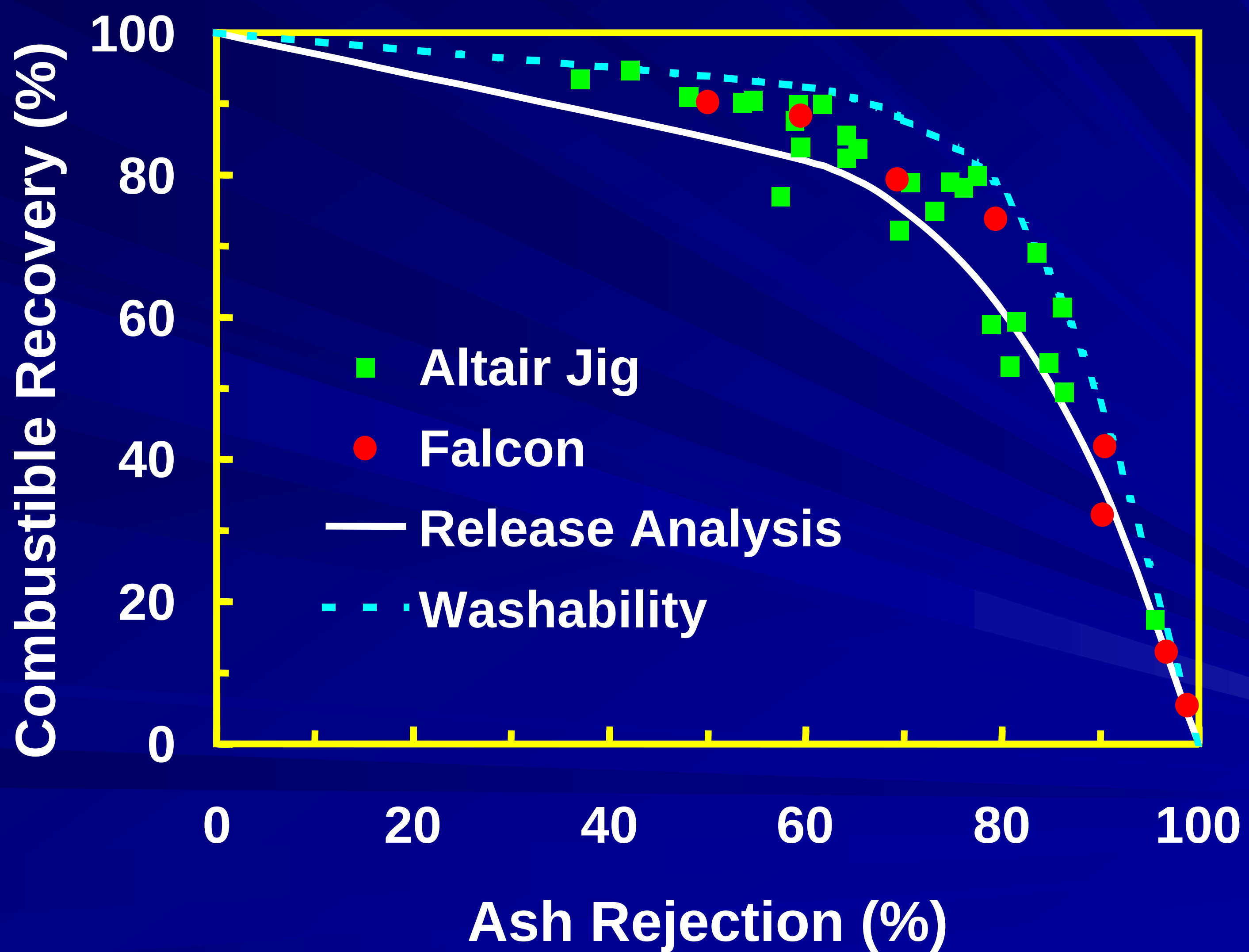


Falcon Concentrator

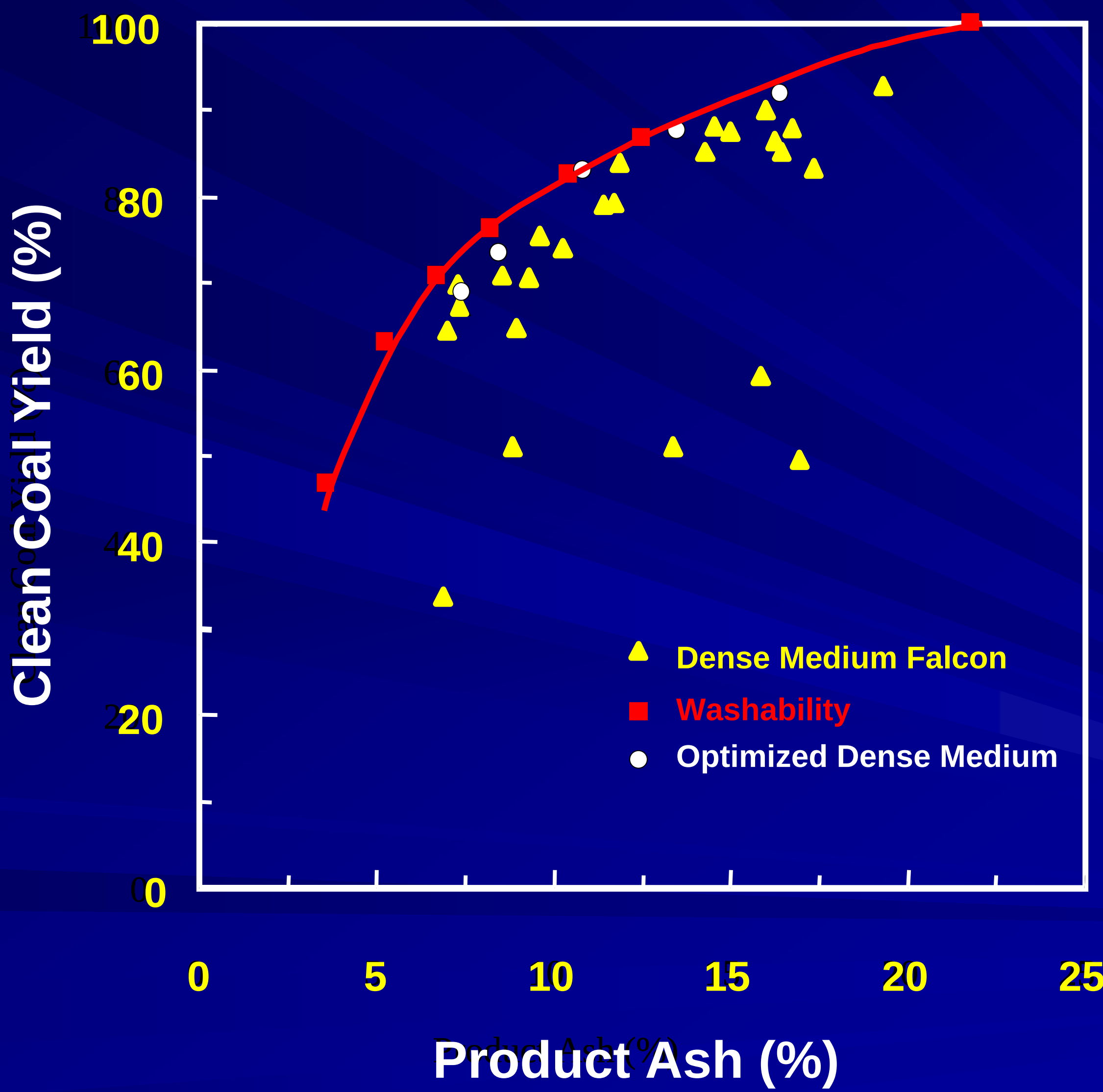
- Centrifugal flowing film separator.
- Feed slurry containing 20% solids is injected onto a spinning rotor and accelerated.
- Particle bed is formed with heaviest particles near the bowl wall.
- Valves along top circumference of bowl are controlled to discharge the reject.



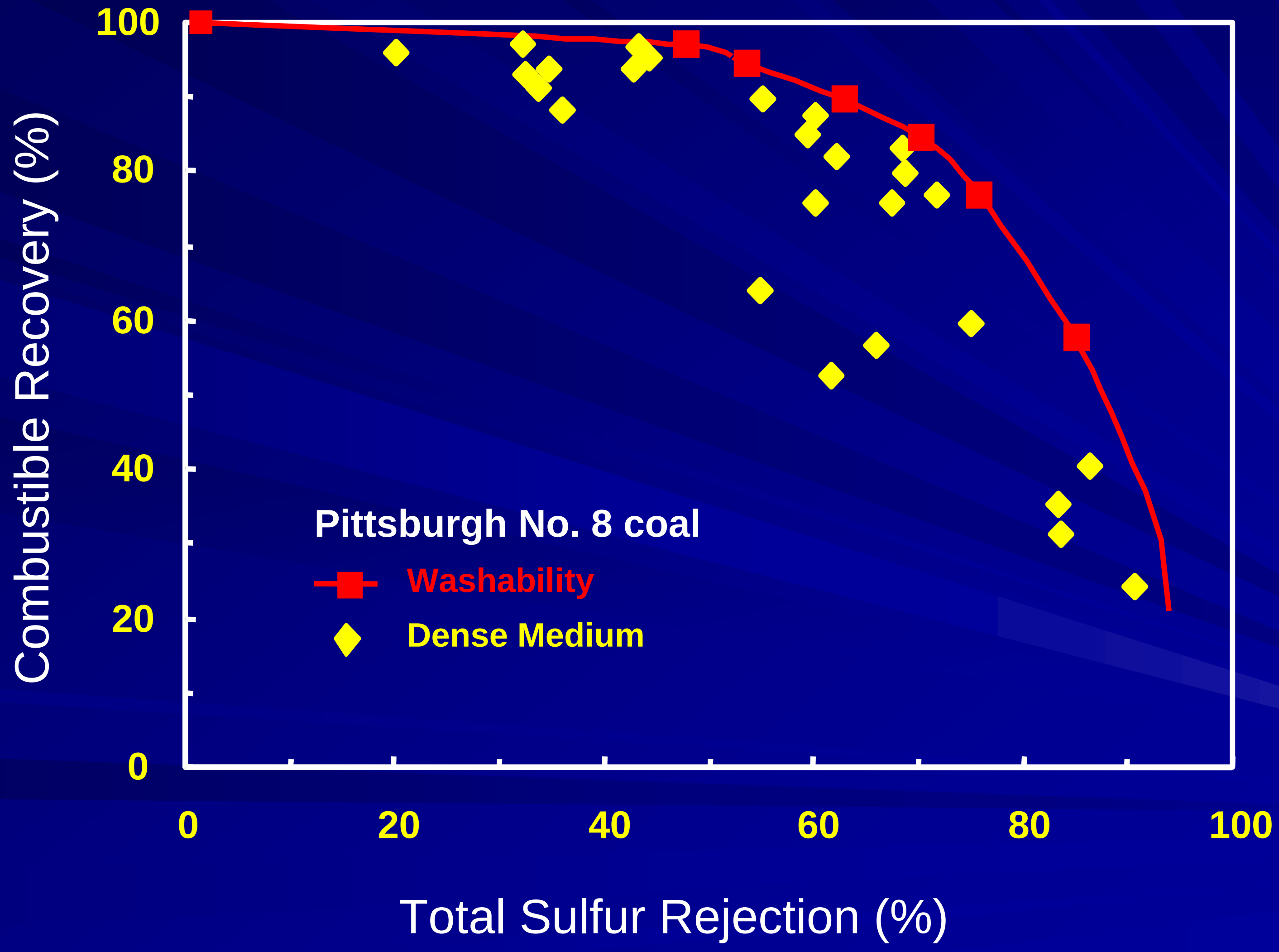
Water-Only Enhanced Gravity Separations on 300 x 45 Micron Coal



Dense-Medium Application in the Falcon Separator
Pittsburgh No. 8 Coal

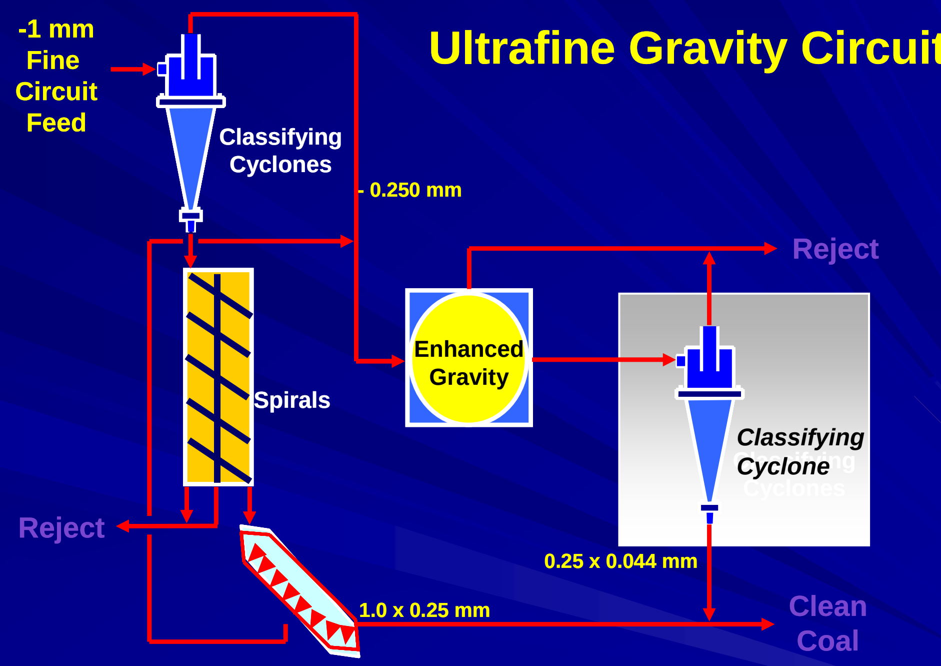


Sulfur Rejection Performance

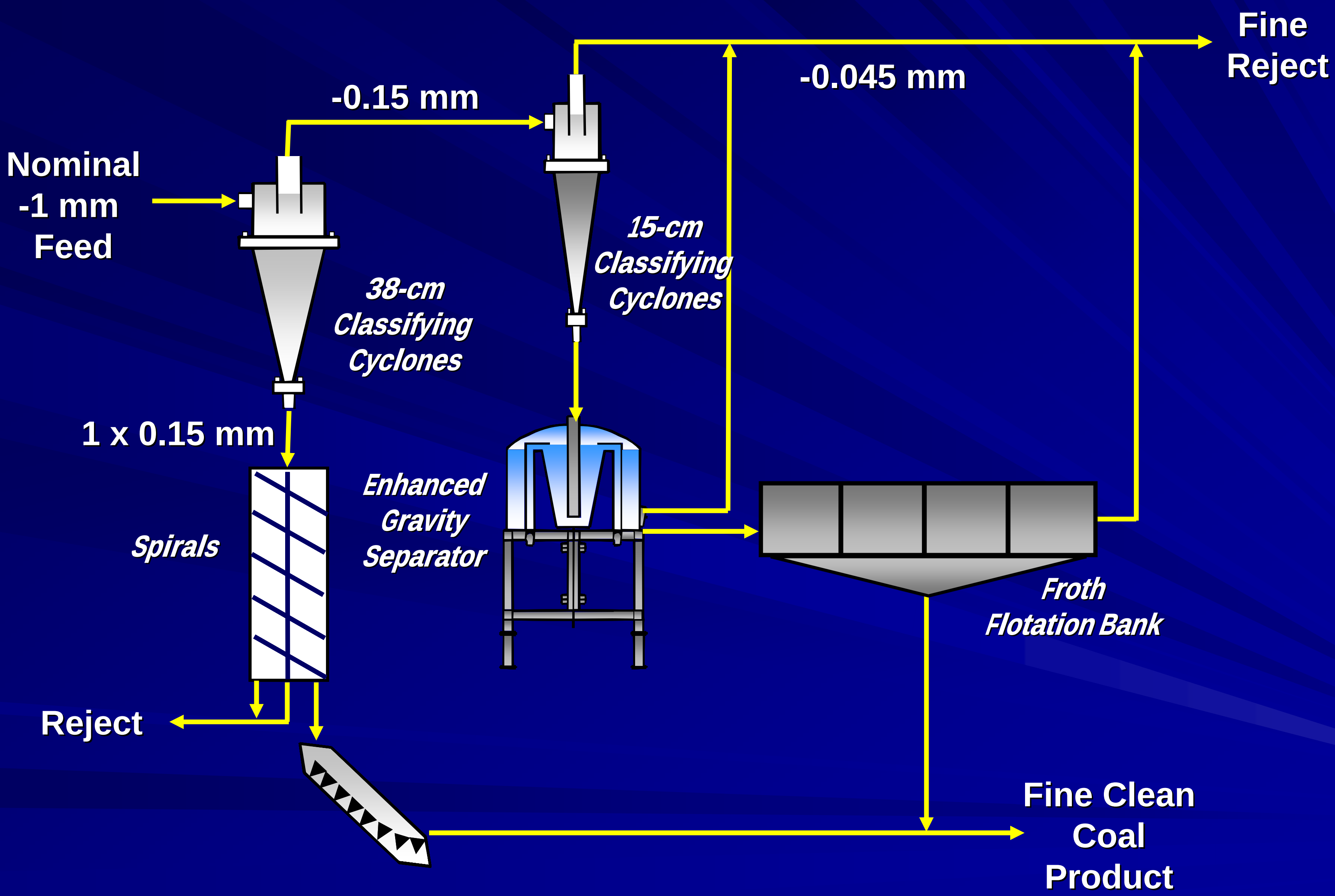


Ultrafine Gravity-Based Circuit Requirement

- To produce an acceptable ultrafine clean coal product from a gravity-based system, the high clay slimes must be removed.
- Unfortunately, the slimes tend to report with the water in classification systems.
- When water recovery is restricted, density effects results in the loss of coal to the slime stream.
- Screening is typically limited by a low open area and blinding.
- The most efficient desliming process commercially available is column flotation.



Enhanced Gravity-Flotation Circuit



Summary – Fine Gravity Circuits

- Innovative fine coal circuits involving two-stage, rougher-cleaner spiral units have been successful commercially using conventional low cost dryers for product dewatering.
- Teeter-bed separators have been found to provide very efficient fine coal cleaning for nominal 2 x 0.25 mm coal.

Summary-Ultrafine Gravity Circuits

- Spiral concentrators operated under specified feed conditions provide significant ash and total sulfur rejections for the +44 microns coal.
- Similar results have been achieved from enhanced gravity separators on full-scale units.
- However, the inability to commercially achieve efficient ultrafine classification limits gravity-based technologies.
- Column flotation is the most efficient desliming technology.
- For coals containing a relatively high level of pyritic sulfur and/or middling particles, a spiral/enhanced gravity and froth flotation circuit provides better technical performance; economics must be proven.