The CAVEX Cyclone: An Innovation in Dense Medium Separation Technologies

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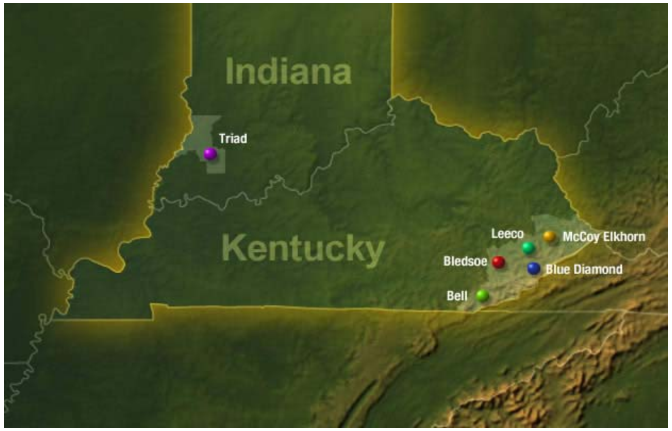
WEIR MINERALS

JamesRiver COAL COMPANY

Project Team

- Weir Minerals
  - Specialists in delivering and supporting slurry equipment solutions
  - Pumps, hydrocyclones, valves and wear resistant linings
  - Global mining and mineral processing, the power sector and general industry

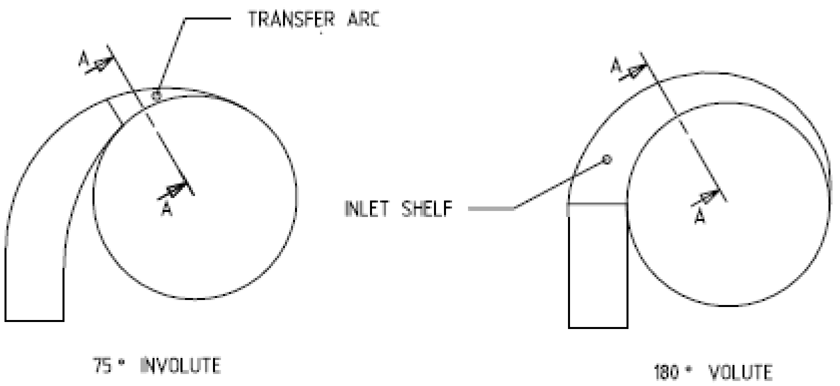
- James River Coal
  - Large steam and metallurgical coal producer
  - Six business units in the central Appalachian and Illinois Basin Coal fields



- University of Kentucky
  - Land grant school with 27,000 student enrollment.
  - Located in Lexington, Kentucky; site of the 2010 Equestrian games.
  - Large energy-based research center.
  - Mining Engineering program with enrollment of about 160.

Background

- The CAVEX cyclone was initially developed in response to industry concerns related to cyclone wear and reduced efficiencies in grinding circuits.
- Typical cyclone feed designs are the 75º and 180º involutes.
- Each of the designs were found to wear near the inlet due to turbulence and coarse particle scouring.
- Weir Minerals experts addressed the problem using years of slurry pump modeling design experience.
- The result was the CAVEX cyclone which has a three dimensional curvature along the inlet path.



CAVEX Cyclone Feed Chamber

Feed Inlet Energy Loss Reduction

- The 3-dimensional curvature of the inlet smooths the path of the fluid and reduces turbulence upon entry into the cyclone.
- The benefit is an improvement in the net inlet energy loss which increases the fluid tangential velocity and centrifugal force.
- Consider the centrifugal force (N_g) exerted on a particle in a cyclone (Bradley, 1965):

$$N_g = 2\alpha^2 \frac{V_i}{D_c g}\left(\frac{D_c}{d_c}\right)^{2n+1}$$

α= adjustment factor for inlet losses $\approx 3.7\left(\frac{D_i}{D_c}\right)$
V_i = inlet velocity
D_c & D_i = cyclone and inlet diameter
d_c = radial position of particle

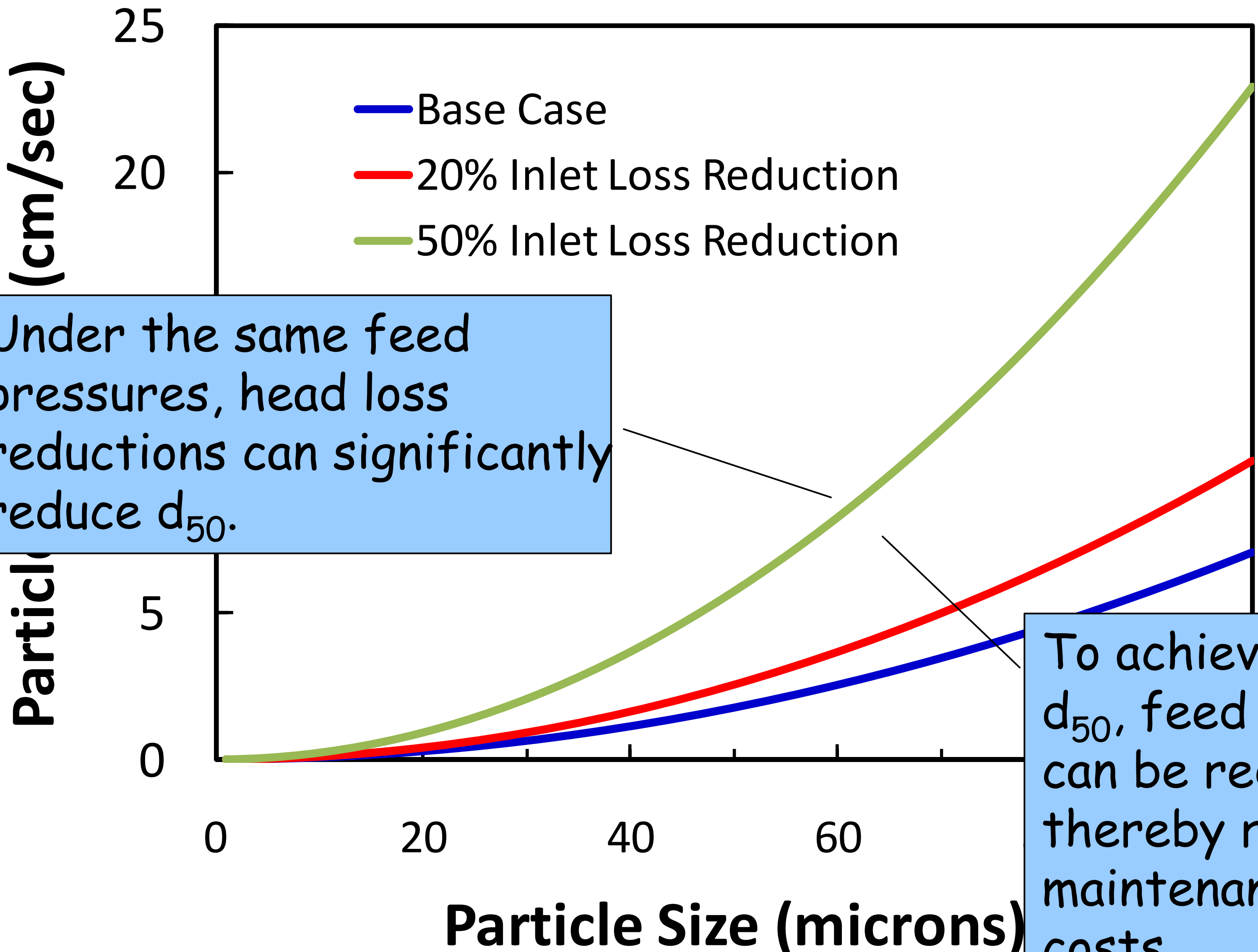
Particle Velocity in a Centrifugal Field

- In mineral or coal processing, the objective of a hydrocyclone is to separate coarse (or high density) particles from fine (or low density) particles.
- This process is achieved in a centrifugal field within a very few seconds.
- The particle velocity, v_t , within a cyclone can be estimated by:

$$v_t = \frac{N_g\, g d^2 \left(\rho_s - \rho_m\right)}{18\,\mu} \left(1 - \phi\right)^{3.65}$$

d = particle size
g = gravitational acceleration
ρ_s & ρ_m = solid and medium densities
ϕ= fractional volumetric solid concentration
μ = medium viscosity

Benefits of Inlet Head Loss Reduction



Under the same feed pressures, head loss reductions can significantly reduce d_{50}.

To achieve the same d_{50}, feed pressure can be reduced thereby reducing maintenance & energy costs.

Industrial Findings – Classification

- JK Tech evaluation of a 100mm CAVEX classifying cyclone found a 30% improvement in classification efficiency over a standard cyclone.
- Wear life on 250mm units reportedly increased by around 300% in three different SAG/ball mill circuits in Australia.
- The wear was evenly distributed.
- Classification efficiency improved by 8% at an Australian operation and 30% at a Canadian operation.
- Particle size cut point was reduced by 15% under the same operating pressure.

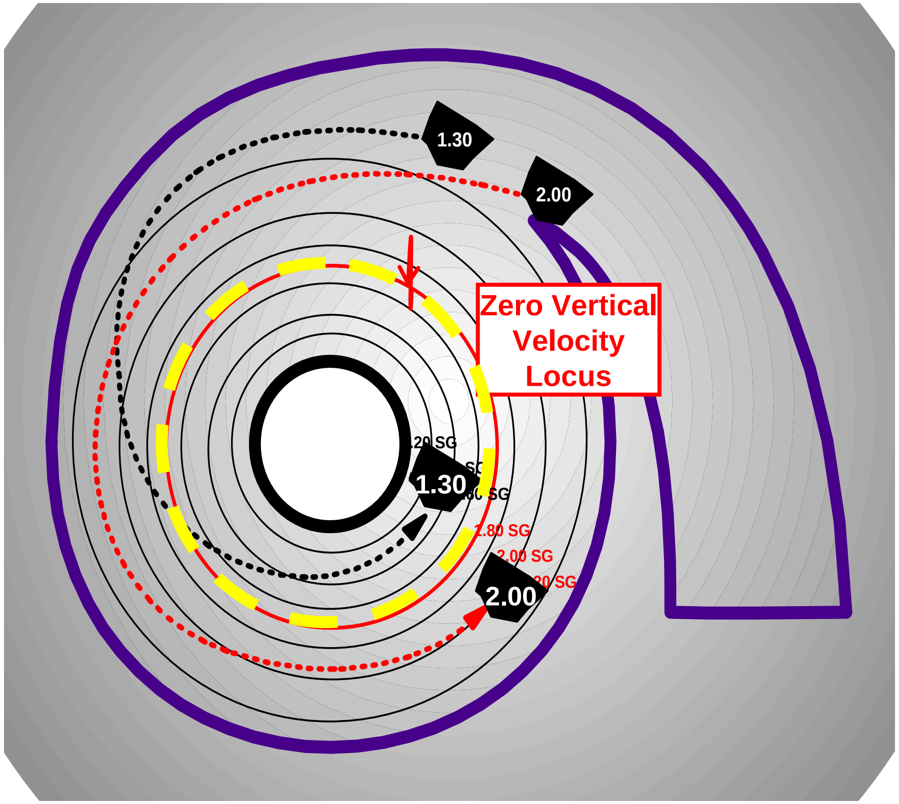
CAVEX Cyclone

Dense Medium Objectives

- Evaluate the separation performance of a CAVEX cyclone when used as a Dense Medium Cyclone.
- Conduct pilot-scale tests to evaluate the separation performance of the CAVEX dense medium application.
- Compare the separation performance with that achieved by an industrial standard DMC unit in an operating preparation plant.

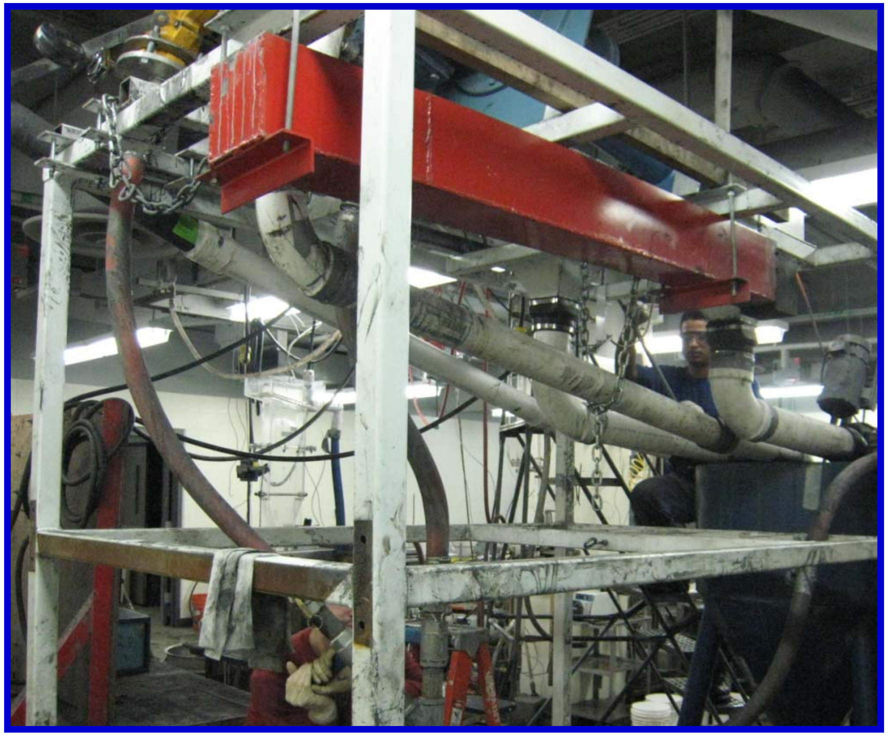
Dense Medium Cyclone Separation

- Dense medium cyclones are commonly used for separating coal from rock.
- Fine (-45 micron) magnetite is added to water to form a medium.
- Medium density is adjusted to a value between the density of coal and rock.
- High density rock moves through the medium to the cyclone wall and out the apex.
- Light coal particles report to the overflow stream.

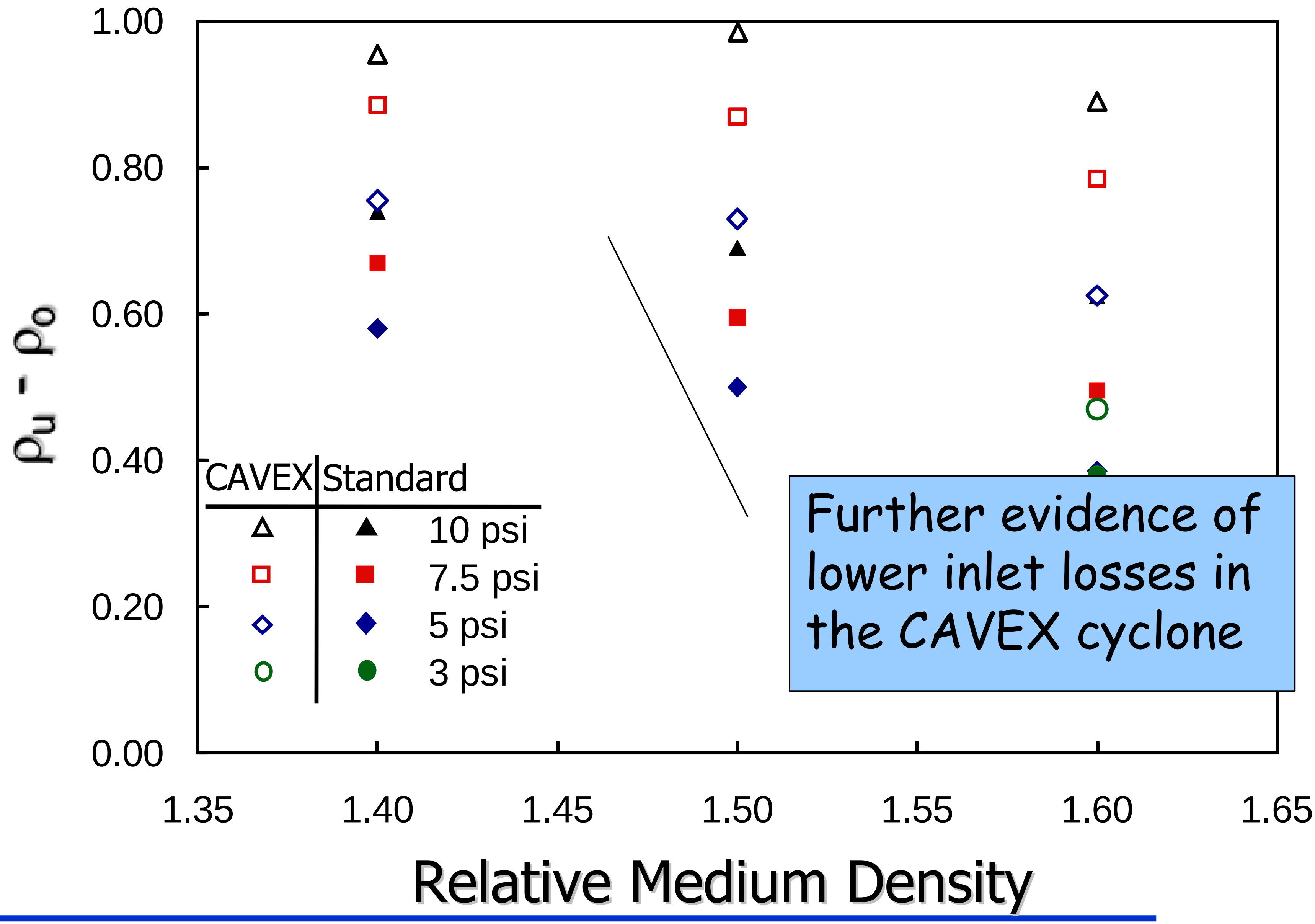


Pilot-Scale Tests

- Side-by-side testing with a CAVEX and industrial standard
- Feed was nominally 6 x 1 mm
- Cyclone dimensions:
  - Diameter: 150 mm
  - Vortex Finder: 63.5 mm
- Medium-to-Coal Ratio: 5:1
- Test Program:
  - Medium Density: 1.4, 1.5, 1.6
  - Apex Diameter: 38, 45, 52 cm
  - Pressure: 2.5, 5.0, 7.5 psi



Medium Stability Comparison



Feed Coal Particle Size

Particle Size Fraction (mm)	Individual		Cumulative	
	Wt (%)	Ash (%)	Wt (%)	Ash (%)
+ 12.7	0.45	36.05	0.45	36.05
12.7 x 6.3	33.27	46.40	33.73	46.26
6.3 x 3.2	30.98	45.78	64.71	46.03
3.2 x 2	12.49	45.10	77.20	45.88
2 x 1	15.56	45.28	92.75	45.78
- 1	7.25	47.06	100.00	45.87
Total	100.00	45.87		

Feed Washability Characteristics

Density Fractions	Individual		Cumulative	Mass	Combustible
	Wt (%)	Ash (%)	Ash (%)	Yield (%)	Recovery (%)
Float-1.3	37.22	2.41	2.41	37.22	67.91
1.3x1.4	9.39	9.89	3.92	46.61	83.73
1.4x1.5	2.69	22.06	4.91	49.30	87.64
1.5x1.6	1.87	30.84	5.86	51.17	90.07
1.6x1.75	0.72	40.38	6.34	51.89	90.87
1.75x1.9	1.19	50.92	7.33	53.08	91.96
1.9x2.1	1.00	64.94	8.40	54.08	92.62
2.1-Sink	45.92	91.40	46.51	100.00	100.00
Total	100.00	46.51			

Separation Performance Comparison

Test Number	CAVEX			Standard		
	Product Ash (%)	Tailings Ash (%)	Recovery (%)	Product Ash (%)	Tailings Ash (%)	Recovery (%)
1	5.92	86.10	86.8	6.39	86.87	87.7
2	5.75	86.25	87.0	6.18	86.86	87.7
3	5.63	86.41	87.1	6.30	85.89	86.7
4	5.76	86.00	86.7	6.17	87.67	88.6
5	6.11	86.18	87.0	6.22	86.22	87.0
Average	5.83	86.18	86.9	6.23	86.70	87.6
Theoretical Recovery (%)			89.5			91.1
Organic Efficiency (%)			97.1			96.2

Relative Medium Density = 1.50

In-Plant Evaluation Program

- In-plant evaluation conducted at James River Coal Company's LEECO 64 coal preparation plant.
- Performance evaluation conducted on a 500mm diameter CAVEX cyclone installed in parallel with a industrial standard DMC having the same dimensions.
- Evaluation team:
  - James River Coal
  - Morris-Coker
  - Weir Minerals International
  - University of Kentucky
  - Precision Testing

In-Plant Test Program

- Feed was nominally 6 x 1 mm.
- Cyclone dimensions:
  - Diameter: 500 mm
  - Vortex Finder: 210 mm
  - Apex Diameter: 140 mm
- Four separate medium specific gravities were evaluated over an 80 minute period each.
  - SG values: 1.50, 1.55, 1.60 and 1.65
- Medium-to-Coal Ratio: 3.0 – 3.5:1
- The product and tailings streams of both DMC units were processed on separate Drain&Rinse screens.
- Incremental samples collected every 10 minutes over an 80 minute period.
- Precision Testing Laboratories performed sample collection and analyses.

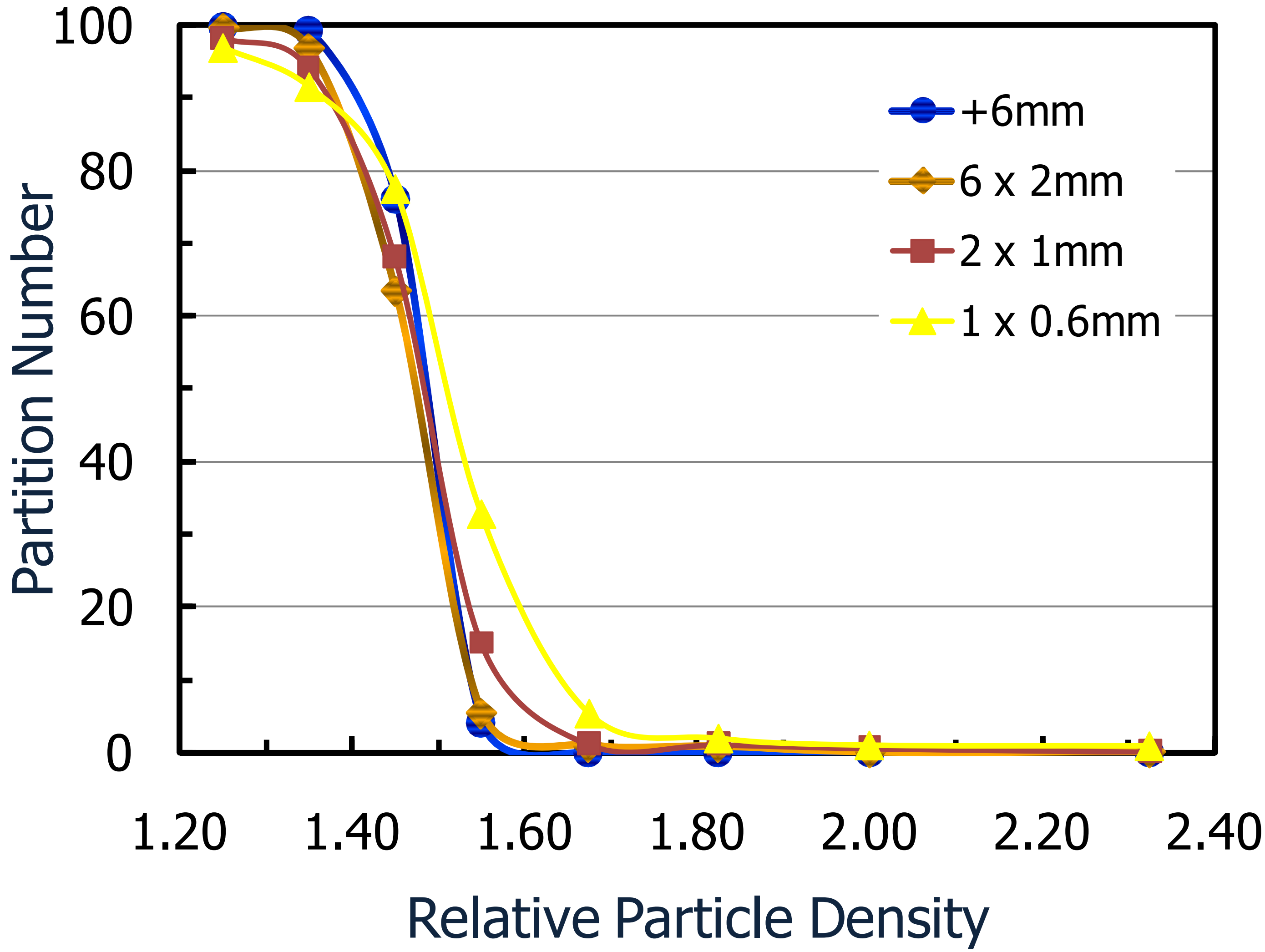
Amburgy Coal Washability

Sp. Gr.	Weight (%)	Ash (%)
1.30 Float	31.25	2.52
1.40 Float	8.26	8.75
1.50 Float	2.89	19.35
1.60 Float	1.86	30.78
1.75 Float	1.11	40.19
1.90 Float	0.61	49.77
2.10 Float	0.96	63.91
2.10 Sink	53.06	91.84
Total	100.00	52.74

Amburgy Particle Size Analysis

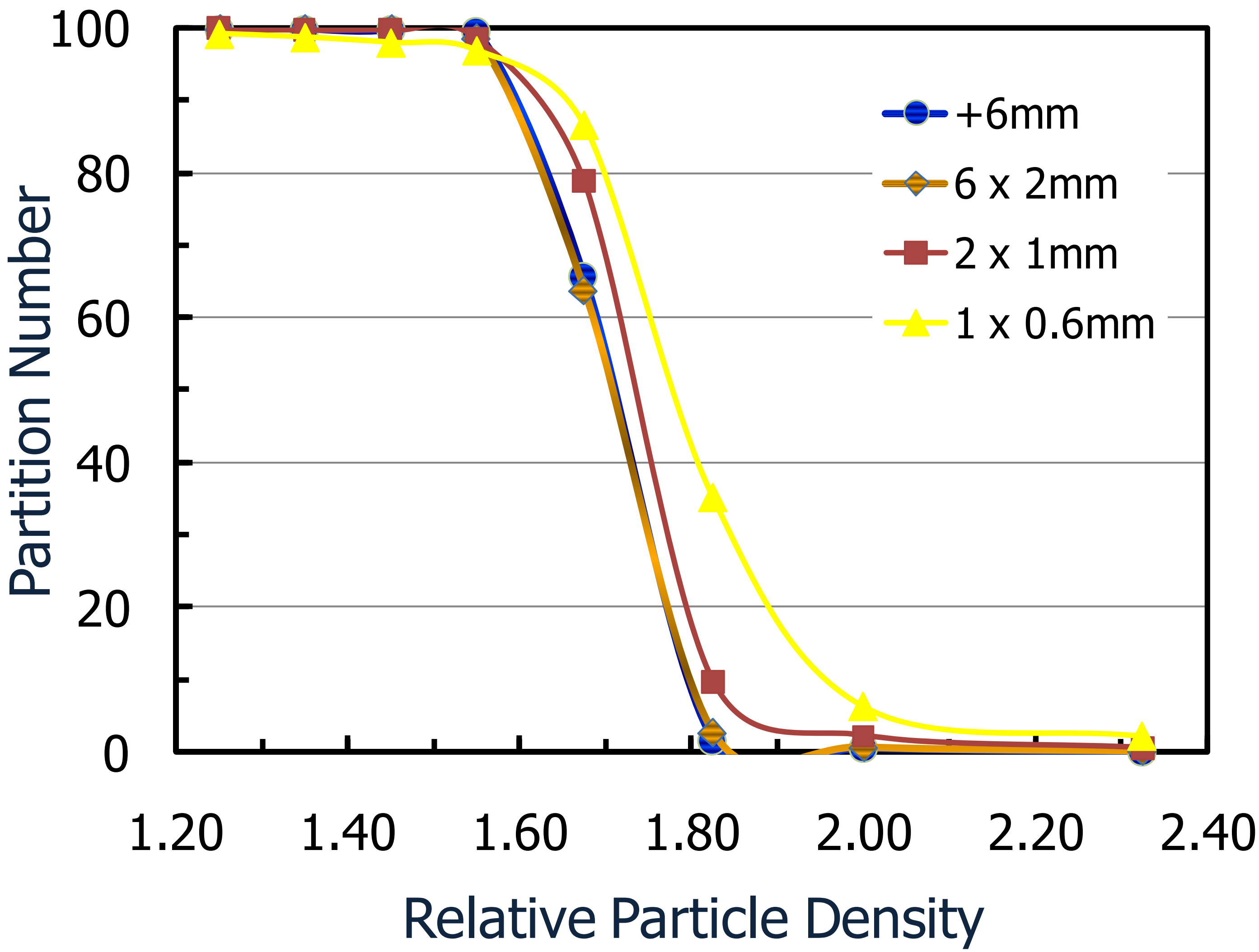
Particle Size (mm)	Weight (%)	Ash (%)
+6	38.65	52.92
6 x 2	40.56	52.28
2 x 1	17.28	53.40
1 x 0.6	3.51	55.19
Total	100.00	52.74

Size-by-Size Partition Curves – 1.5 SG



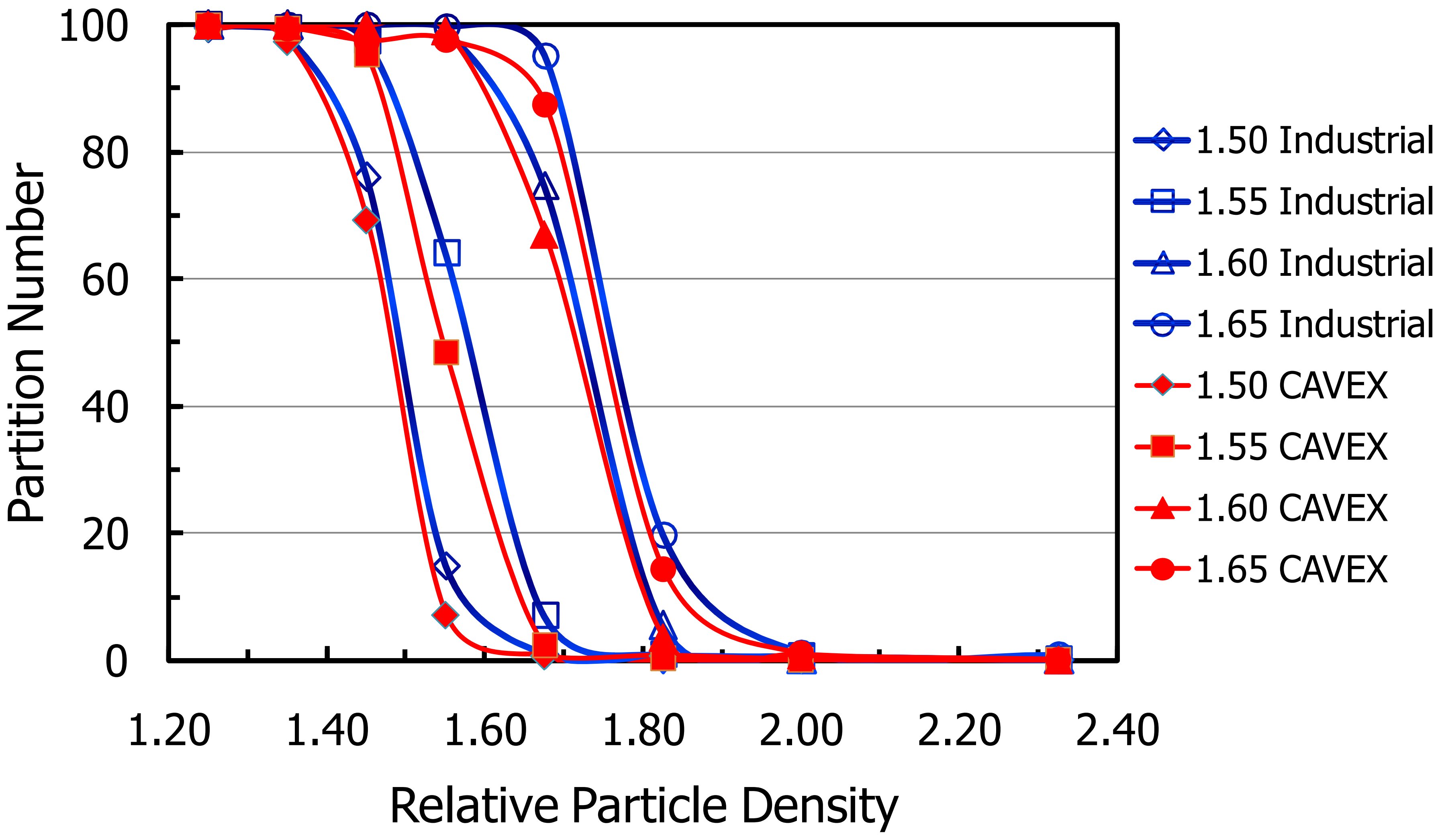
Size	Ep
+6	0.026
6 x 2	0.035
2 x 1	0.049
1 x .6	0.070

Size-by-Size Partition Curves – 1.6 SG

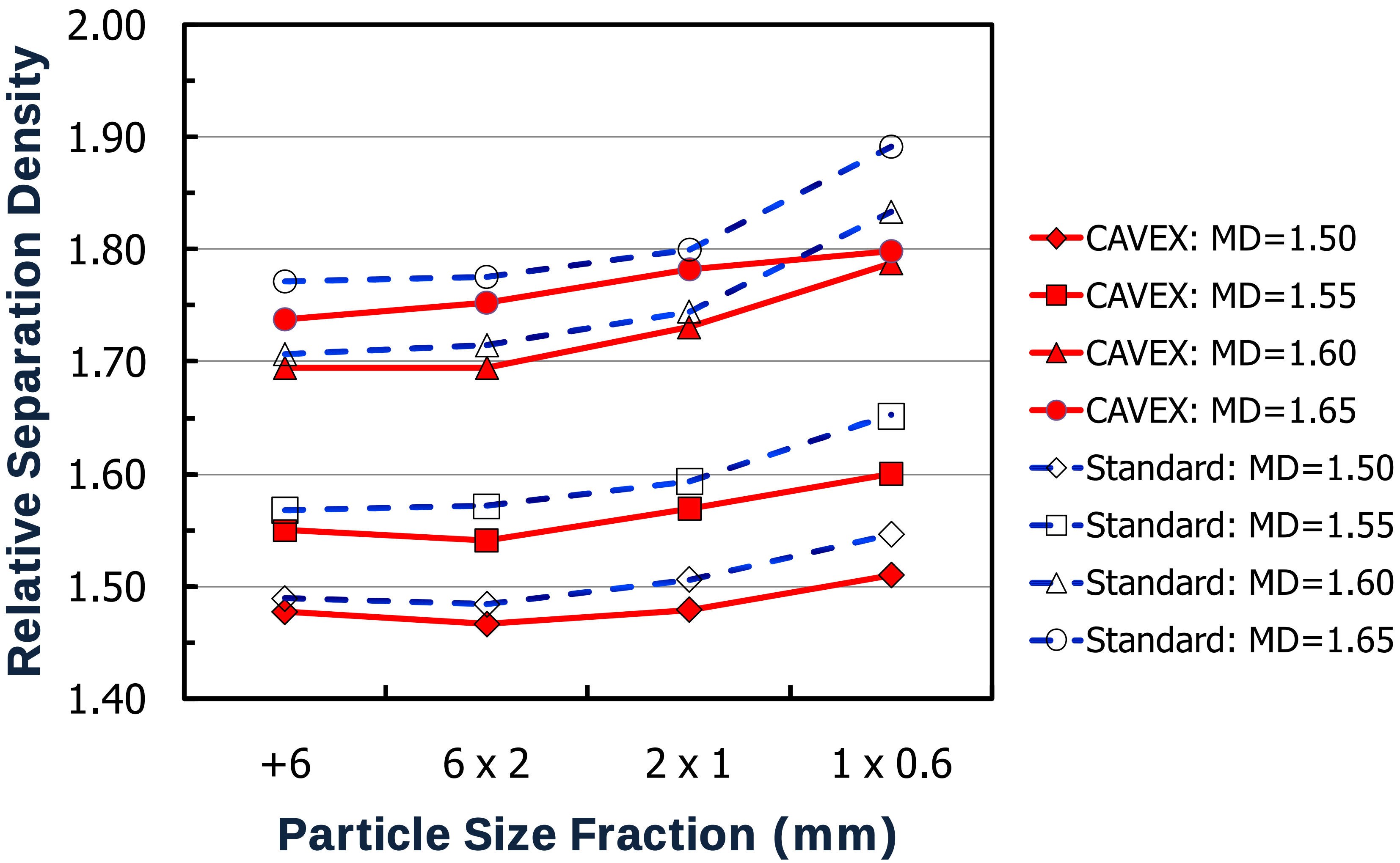


Size	Ep
+6	0.033
6 x 2	0.039
2 x 1	0.047
1 x .6	0.071

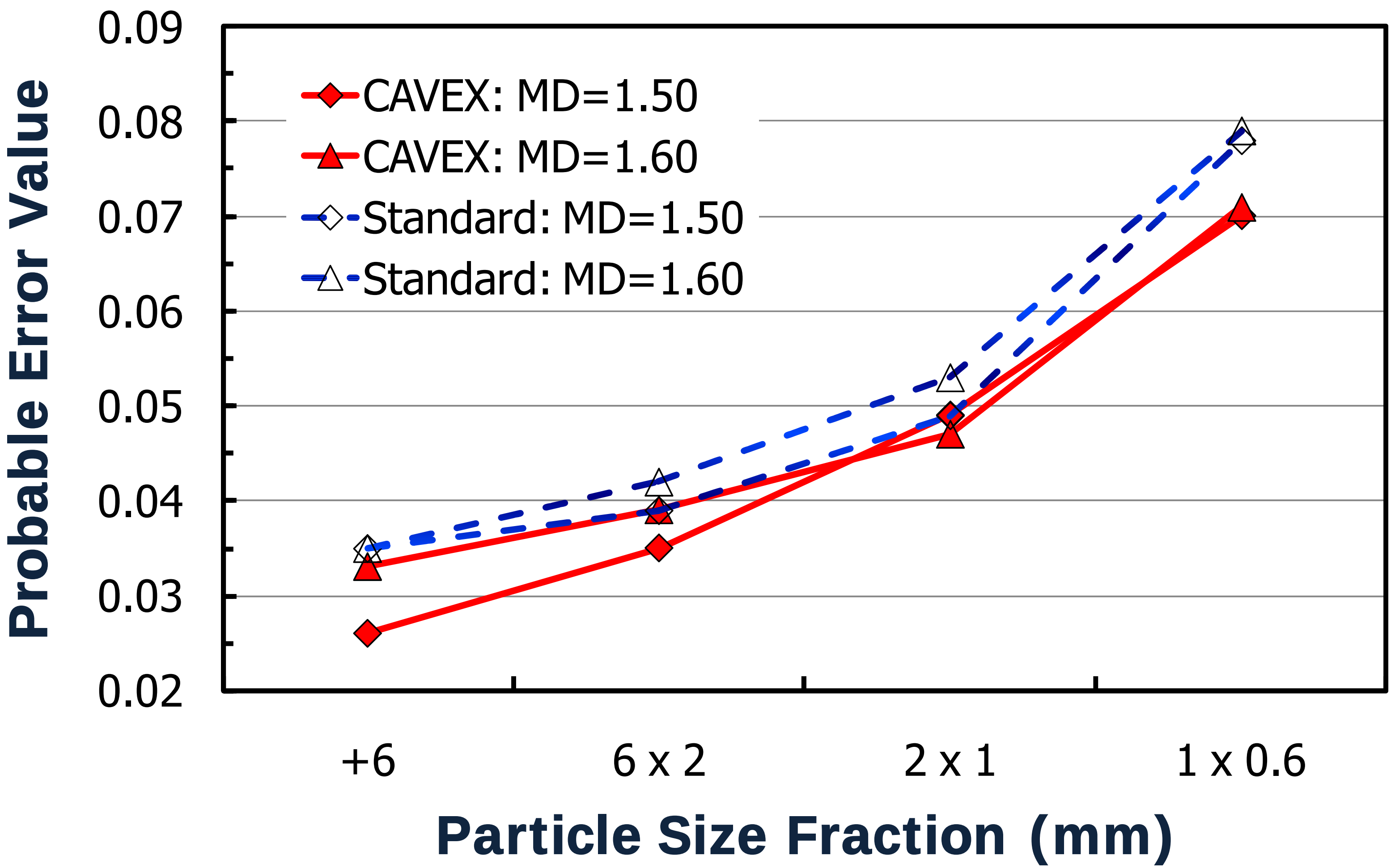
Partition Curve Comparison



Particle Size-by-Size Separation Density



Size-by-Size Separation Efficiency



11.7% greater efficiency by the CAVEX for the finest size fraction.

Separation Performance Comparison

Medium Sp. Gr.	CAVEX			Industrial Standard		
	Product Ash (%)	Mass Yield (%)	Recovery (%)	Product Ash (%)	Mass Yield (%)	Recovery (%)
1.50	4.56	41.91	84.6	4.74	41.8	84.3
1.55	5.60	41.29	84.8	5.63	41.5	85.2
1.60	6.40	51.38	90.6	6.33	51.3	90.5
1.65	6.79	46.85	89.7	6.84	46.8	89.5

Summary & Conclusions

- The key performance feature of the CAVEX cyclone is the novel inlet design which reduces turbulence and wear.
- Previous results and data from the current study indicates that the novel inlet chamber reduces head loss and thus elevates the amount of energy available for the separation process.
- A comparison of separation performance data indicates that the CAVEX unit provides at least equivalent performances.
- The typical upward separation density shift with decreasing particle size appears less for the CAVEX unit.
- Probable error values tend to suggest that efficiency is slightly better than the industrial standard dense medium cyclone.

Questions