EVALUATION OF A FULL-SCALE C40 FALCON CONCENTRATOR FOR FINE COAL CLEANING

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EXECUTIVE SUMMARY

Column flotation provides excellent recovery of ultrafine coal while producing low ash content concentrates. However, like other flotation processes, column flotation is not efficient for treating fine coal containing significant amount of mixed-phase particles. Recent studies have shown that mixed-phased particles can be more efficiently treated using enhanced gravity separators. A test program conducted on a C10 Falcon Concentrator was found to be capable of producing compliance coal from high pyritic, low organic sulfur content coals while achieving energy recovery values great than 90%. The excellent separation performance achieved by the Falcon Concentrator was also indicated by a probable error (E_p) value of 0.12 at gravity-cut points between 1.5 and 1.7. This separation performance was obtained at throughput capacity values between 2 to 4 tons/hour in a 10-inch diameter unit. However, the mass throughput and the ability of the Falcon Concentrator to maintain the exceptional performance upon scale-up to industrial-size units were unknown. In this project, an industrial-scale 40-inch diameter Falcon concentrator (C40) having an estimated throughput capacity of 100 tons/hour was designed and constructed by the manufacturer and tested by the authors in a closed-circuit system to evaluate its potential for cleaning fine coal in operating preparation plants.

The 40-inch diameter (C40) Falcon Concentrator studied in this investigation utilized a vertically-mounted bowl that was sloped outward from bottom to top at an angle of 10° from vertical. The purpose of the sloped bowl is to utilize a portion of the applied centrifugal force to create an upward force parallel to the bowl wall which forces the solids bed toward the top of the bowl. The heavy particles forming the beached particle bed near the bowl wall is removed through a series of chutes spaced at equal distances along the circumference of the bowl. The underflow material travels through 36 nozzles that are equipped with pinch valves for controlling the underflow rate. The light particles travel over the chutes and a lip to report to the overflow stream as the clean coal product. The C40 unit tested has the ability to provide a centrifugal force of about 210 times the natural gravitation pull (or 210 *g*'s). The unit required a floor space of 10 x 10 ft^2 and stood approximately 15 ft tall.

The C40 Falcon unit was evaluated in a closed-circuit system which was capable of supplying 2000 gallons/minute of feed. In this circuit, the overflow product was directly fed to a product sump and the underflow stream was directed to a tailings sump and then pumped to the product sump. The material in the product sump was then pumped back to the feed sump. Additional water to the circuit is only added through the small amounts provided as gland water for the feed and product pumps. The feed coal samples used in this study were a flotation feed that was nominally -28 mesh and a refuse sample collected from an inactive tailings pond. Both coal samples were originally extracted from the Illinois No. 6 coal seam. Upon charging the sample into the feed sump, the slurry was passed through a trash screen of 16 mesh to remove material that had potential to plug the underflow orifices in the Falcon unit.

Initial tests were performed to evaluate the effect of operating parameters on the separation performance provided by the C40 Falcon Concentrator. The applied centrifugal force and the tailings underflow rate were found to have a large effect on the combustible recovery of the 16 x 100 mesh size fraction and on the ash rejection of both the 16 x 100 mesh and the 100 x 400 mesh size fractions. Increasing the centrifugal force from about 50 to 140 *g*'s resulted in a 40% decrease in the recovery of combustibles in the 16 x 100 size fraction of the refuse pond material. However, increasing the feed flow rate at a given centrifugal force was found to increase the combustible recovery by about 20%. This is due to a decrease in the particle residence time which is insufficient to allow the coarser particles sufficient time to report to the underflow ports. Increasing the centrifugal force from 50 to 200 *g*'s resulted in a gradual reduction in the combustible recovery for the 100 x 400 size fraction. However, the ash rejection improved significantly from about 40 to 75%. Increasing the volumetric feed rate from 1400 to 1800 gallons/min was found to decrease the ash rejection by nearly 10% due to the shorter particle retention time. Little or no effect was obtained on the -400 mesh size fraction.

The C40 Falcon Concentrator was found to be effective at reducing the ash content of the 16 x 400 mesh size fraction in flotation feed (i.e., nominally -28 mesh) and refuse pond samples while maintaining a high recovery of combustibles. For the flotation feed sample, the ash content in the 100 x 400 mesh size fraction was reduced from 11.3% to 5.4% while recovering 93% of the combustibles. For the high ash refuse sample, the ash contents in the 16 x 100 and 100 x 400 mesh size fractions were reduced from 22.1% to 8.0% and 31.6% to 14.8%, respectively, while maintaining recovery values slightly greater than 80%. Little or no ash reduction was achieved for the -400 mesh size fraction.

High rejections of total and pyritic sulfur were achieved from the treatment of the low sulfur content flotation feed sample and the high sulfur refuse pond sample using the C40 Falcon Concentrator. For the flotation feed sample, the total sulfur contents of the 16 x 100 and 100 x 400 mesh size fractions were reduced from 1.19% to 1.08% and 1.23% to 0.87%, which equates to a sulfur rejection of 27% and 42%, respectively. This sulfur reduction was achievable due to the rejection of heavy coal pyrite to the tailings stream. For the refuse pond sample, the total and pyritic sulfur contents in the 16 x 400 mesh size fraction were reduced from about 7.9% to 2.7% and 5.5% to 1.1%, respectively, while recovering slightly greater than 80% of the combustible material. This corresponds to a pyritic sulfur rejection of nearly 90%. In general, 80% to 90% rejection of pyritic sulfur was consistently achieved throughout the test program on the 16 x 100

mesh size fraction of the refuse pond sample while recovering between 70% to 80% of the combustible material. For the 100 x 400 mesh size fraction, 70% to 80% pyritic sulfur rejection was commonly obtained while recovering 80% to 95% of the combustibles.

The metallurgical performance results obtained from the treatment of the refuse pond sample using the C40 Falcon unit were found to be nearly equal to those achieved by the C10 Falcon unit. This finding indicates that small scale C10 Falcon tests can be used to evaluate the potential of the C40 Concentrator.

Mass feed flow rates and feed solid contents as high as 94 tons/hr and 20% by weight, respectively, have been efficiently treated using the C40 Falcon Concentrator. This mass flow rate is approximately four to ten times the capacity of other enhanced gravity concentrators. The main reason for the high throughput capacity of the Falcon unit is its ability to apply a centrifugal force greater than 200 *g*'s, which is significantly higher than the 60 *g*'s provided by the Knelson and Kelsey Jig enhanced gravity concentrators. In fact, based on the test data, higher feed flow rates and centrifugal forces may enhance the energy recovery for the 16 x 100 mesh size fraction while maintaining or possibly improving the ash rejection in the 100 x 400 mesh size fraction. This may allow more efficient treatment of a feed having a wide range of particle sizes such as the 27:1 particle size ratio effectively treated in this study.

A total of 170 hours of operation has been logged on the C40 Falcon Concentrator during this investigation. During this period, no major mechanical problems have neither occurred nor been identified. The cumulated power consumption was 2100 kilowatt-hours. Using an estimated average of 50 ton/hr for the mass feed flow rate treated during this study, the power cost for the C40 Falcon unit is less than $0.10/ton.

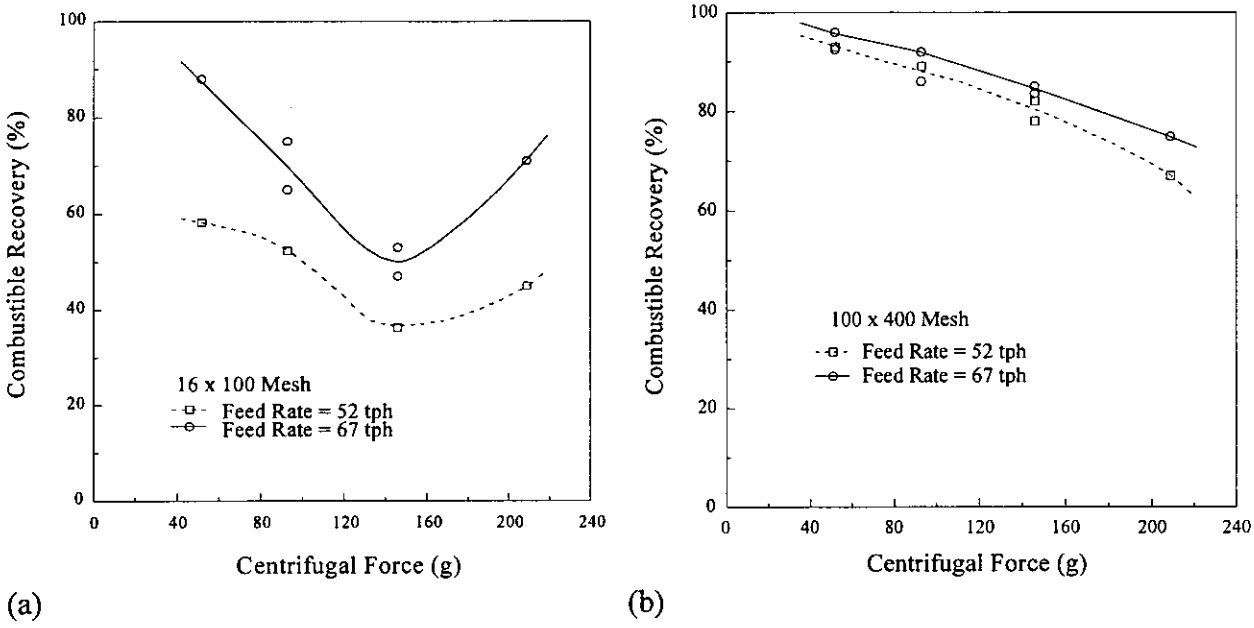


Figure 1. The centrifugal force effect on the combustible recovery obtained for the (a) 16 x 100 and (b) 100 x 400 mesh size fractions of the Illinois No. 6 tailings pond sample using a constant tailings rate.

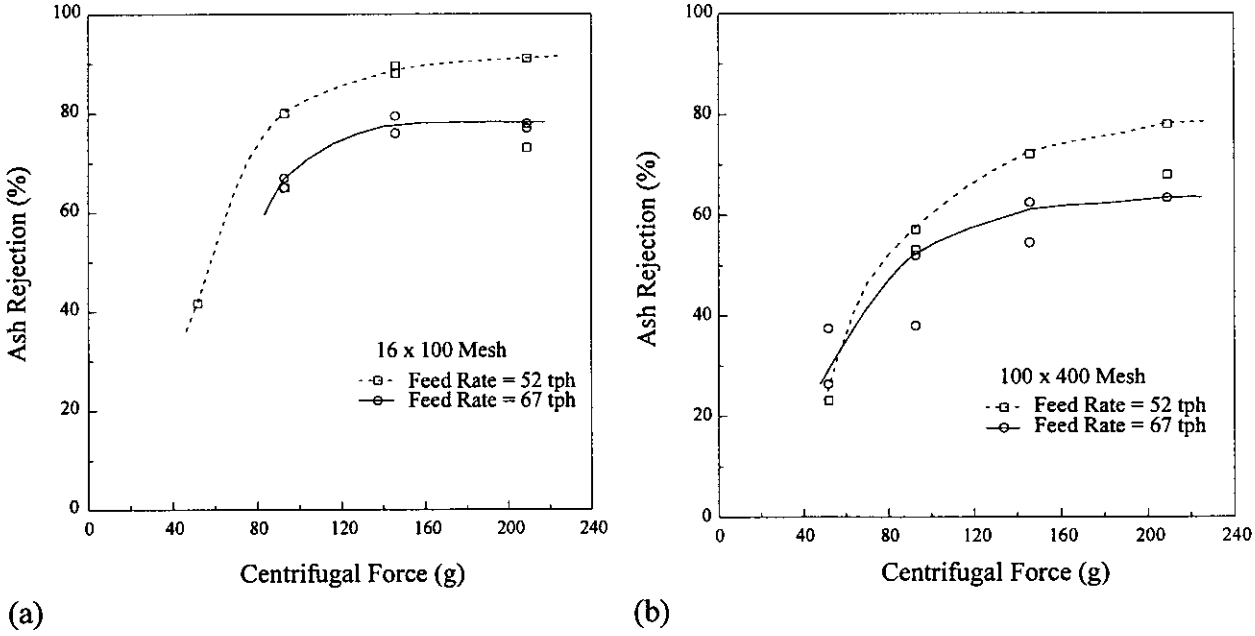


Figure 2. The centrifugal force effect on the ash rejection achieved on the (a) 16 x 100 and (b) 100 x 400 mesh size fractions of the Illinois No. 6 tailings pond sample while maintaining the tailings rate at a constant value.

Table 1. Results showing the reduction in ash content achieved at nearly constant combustible recovery values on the 16 x 100 mesh and 100 x 400 mesh size fractions of the tailings pond sample as the centrifugal force is increased. Mass feed flow rate = 67 tph.

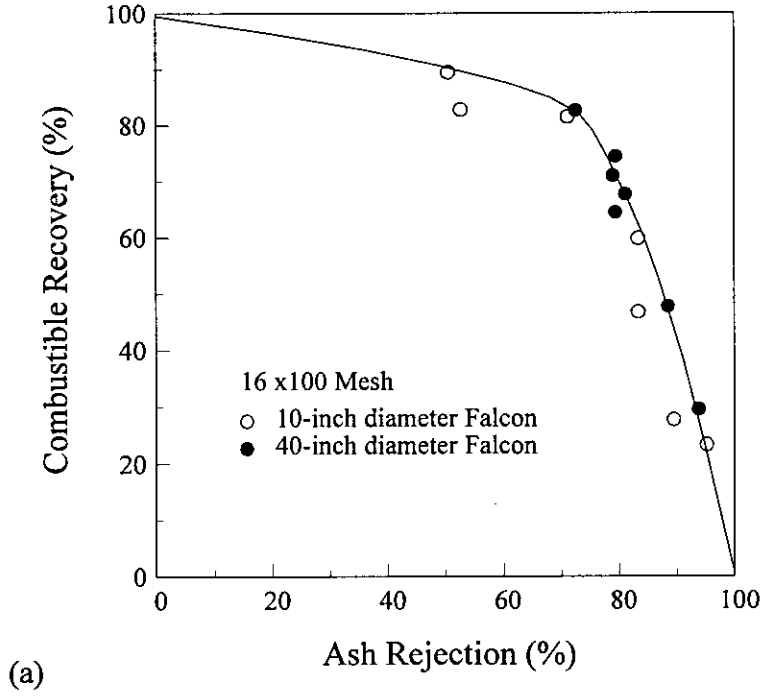
Centrifugal Force (g's)	Size Fraction (mesh)	Ash Content (%)		Combustible Recovery (%)
		Feed	Product	
50	16 x 100	14.3	6.46	65.3
50	100 x 400	23.0	17.7	92.4
90	16 x 100	14.3	5.96	66.0
90	100 x 400	23.0	15.1	91.0
145	16 x 100	14.3	5.34	67.0
145	100 x 400	23.0	11.9	88.2

Table 2. Metallurgical performance results obtained over a range in mass feed flow rates from the treatment of a flotation feed coal sample using the C40 Falcon Concentrator; full nozzle flow and a centrifugal force of 200 *g*.

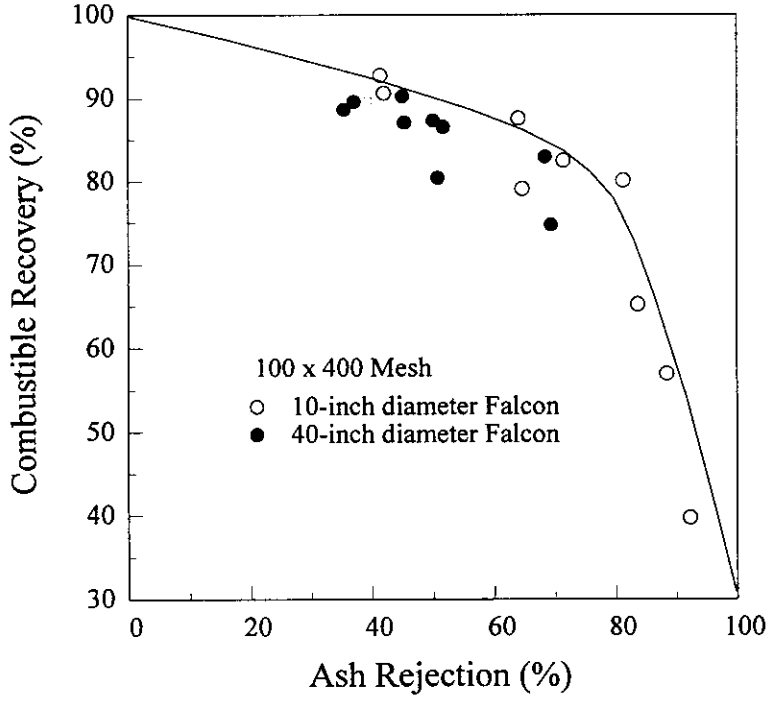
Feed Mass Flow (tph)	Size Fraction	Ash Content (%)			Combustible Recovery (%)
		Feed	Product	Tailings	
94	16 x 100	14.7	4.21	47.6	85.1
	100 x 400	9.74	5.39	45.2	93.4
	-400	46.5	44.6	54.1	82.8
68	16 x 100	14.2	3.62	35.6	75.2
	100 x 400	9.02	4.20	44.7	92.8
	-400	44.9	44.5	55.4	97.0
46	16 x 100	15.0	3.40	28.9	61.8
	100 x 400	9.20	2.95	40.5	89.0
	-400	44.5	43.6	54.1	93.2

Table 3. Metallurgical performance results showing the ability of the C40 Falcon Concentrator to reduce the total and pyritic sulfur contents of the refuse pond sample. Operating conditions vary among the six tests.

Test Number	Size Fraction (mesh)	Total Sulfur		Pyritic Sulfur		Pyr Sulfur Rejection (%)	Combustible Recovery (%)
		Feed (%)	Product (%)	Feed (%)	Product (%)		
1	16 x 100	7.93	2.91	5.60	1.05	89.4	67.7
	100 x 400	7.26	4.69	4.85	1.74	72.4	87.1
2	16 x 100	7.37	2.85	5.78	0.92	91.2	64.5
	100 x 400	7.95	4.57	4.37	1.95	68.5	80.4
3	16 x 100	5.00	2.55	2.65	0.73	80.7	75.2
	100 x 400	4.98	3.28	2.60	1.40	53.2	93.3
4	16 x 100	4.50	2.55	2.27	0.80	76.8	73.8
	100 x 400	5.14	3.40	3.09	1.65	52.9	94.0
5	16 x 100	3.83	2.30	1.54	0.55	87.4	39.3
	100 x 400	4.52	2.45	2.24	0.84	72.4	83.7
6	16 x 100	6.10	2.50	4.11	0.74	87.5	74.8
	100 x 400	5.63	2.77	3.89	1.04	79.7	87.6



(a)



(b)

Figure 3. A comparison between the metallurgical performances achieved from the treatment of the (a) 16 x 100 and (b) 100 x 400 mesh size fractions of the Illinois No. 6 tailings pond sample using the 10-inch and 40-inch diameter Falcon concentrators.