EVALUATION OF DRY COBBING - LTV

COLERAINE MINERALS RESEARCH LABORATORY

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Introduction

To remain competitive, the taconite companies in Minnesota must explore every opportunity to reduce costs and improve overall plant operations. Magnetic cobbing of rod mill feed is generally recognized as having the potential to reduce operating costs because of the rejection of low grade material ahead of the primary mill. Implementation of this technology requires testing that will accurately predict metallurgical performance, weight rejection and magnetic iron recovery. The savings in grinding energy that derive from rejecting a coarse, low grading product before primary milling have to carry the additional operation costs for dry cobbing and the cost of installation.

Magnetic cobbing tests on minus 3/4-inch material have always been shown to have a beneficial effect on downstream processing. In-plant dry cobbing tests have indicated a 5% increase in plant throughput with comparable iron recovery. Use of dry cobbing at even coarser sizes may be beneficial to some operations. The Coleraine Minerals Research Laboratory (CMRL) has conducted extensive research on the dry cobbing of taconite materials. This study was to determine the feasibility of dry cobbing on LTV crushed ore at minus 3-inch, minus 1-inch, and 5/8-inch and their liberation characteristics.

Test Apparatus and Procedures

The head pulley magnetic separator used for testing at CMRL is 48 inches in diameter and 24 inches wide. The fixed magnet assembly inside the drum consists of six permanent magnets with alternating N-S polarity. The effective magnet arc is about 114 degrees. The permanent magnet bars are oriented with their axes parallel to the pulley axes. The magnet configuration is an ERIEZ high-gradient assembly as shown schematically in Figures 1 and 2. Average field strength two inches above the drum ranges from 1,000 to 1,200 gauss, and at the drum surface, it ranges from 1,400 to 2,200 gauss.

The test set-up consists of a bin and variable speed belt feeder that discharges directly to the head pulley belt. To allow for reasonable sample volumes at the high feed rates required, sideboards are used to reduce the effective pulley width to about 12 inches. The discharge from the head pulley is collected in a multiple splitter box system as indicated on the schematic presented as Figure 3. Inclination of the belt is at about 12 degrees. The first magnet is positioned just beyond the point where centrifugal force allows the material to leave the belt. This separates the individual particles so that there is a better opportunity for the non-magnetic particles to escape and follow their free fall trajectory and report to the tailings bin. The material collected in each compartment of the splitter box is weighed and then crushed, and a sample is prepared for magnetic iron determination. In this series of tests, the magnetic iron determination is based on Davis tube concentration and analyses at minus 200 mesh. The magnetic iron data are used to calculate grade and recovery curves that can be used to predict performance.

The bulk samples were shipped from LTV mine pit in 55 gallon drums with top size up to 12 inches. The sample included area #6, 2WX, and two batches from area 2E as 2E-1 and 2E-2. The "as is" sample was screened at 3", and plus 3-inch material was crushed down to minus 3-inch and blended with 3-inch undersize. A composite sample was blended with 36.0% of area #6, 25.0% of 2WX, 16.5% of area 2E-1, and 22.5% of area 2E-2. The composition was made according to the blends of annual feed stock to the plant. Each area sample and the composite sample were split into three portions. One remained as minus 3-inch, and the others were crushed down to minus 1-inch and minus 5/8-inch. A composite sample was blended at each size at the same composition as minus 3-inch material. The composite sample blend is used to evaluate and optimize operation conditions for each of the three sizes of feed. Following these tests, the remaining four samples of three different feed sizes were run at the conditions that appeared to give the best results.

The magnetic concentration test will yield five products as follows: a magnetic concentrate, three middling products, and a tailings. Each product will be weighed and analyzed independently for magnetic iron, and the data will be used to construct concentrate grade/weight recovery curves and concentrate grade/magnetic iron recovery curves. A composite concentrate and tailings was prepared from one test at each feed size to be used for batch ball mill grind and Davis tube tests to evaluate the liberation characteristics of the ore.

Results and Discussion

Tests were conducted on composite samples of each size sample to determine the operation conditions. The individual samples were run with the optimum conditions. Belt speed was run at 550 ft/min, determined in earlier studies. Dry cobbing data are presented in Tables 1 through 6. These tables present the weight distributions for the magnetics, three middlings and tailings for each test. The magnetic iron percent, cumulative weight recovery and cumulative magnetic iron percent were calculated and presented in these tables as well. The results are also presented in graphs in Figures 4 through 11, which presented in both complete range and detailed range where magnetic iron recovery is close to 98%. These graphs show the relationship between the weight recovery and the magnetic iron recovery.

Liberation grind and Davis tube test data are presented in Tables 7 through 9. The samples were the composite samples of the test with optimal conditions. Data were obtained by batch ball mill grinds and the Davis tube tests. Included are the grind time, percent minus 270 mesh, Davis tube weight recovery and concentrate Fe and SiO_2 percent. The head analyses, grind, weight recovery and Davis tube silica have also been calculated. Graphical presentation of these data are shown in Figures 16 through 18. The Davis tube concentrate silica obtained at each grind from the cobber concentrate and cobber tailings were presented in the graphs. In addition, the calculated percent silica in the Davis tube concentrate based on the crude ore has been included for comparison.

Minus 3-inch material was run over a 48-inch diameter separator drum to make a five product split. The composite sample test data are presented in Table 2 and Figures 4 through 7. Four different feed rates of 300, 250, 200, and 100 LTPHPFMW* were tested. With the same weight recovery, the magnetic iron recovery increases with a decrease in the feed rate. At 98% of magnetic iron recovery, there is no improvement with further decrease of the feed rate from 150 LTPHPFMW to 100 LTPHPFMW. The individual samples were run at 150 LTPHPFMW.

Minus 1-inch composite material was run with a slower feed rate at 210, 150, and 75 LTPHPFMW. There is significant improvement over the cobbing on minus 3-inch material. At the feed rate of 75 LTPHPFMW, with 98% magnetic iron recovery, the tail reject can be as high as 14.0%. The individual samples were run at 75 LTPHPFMW. Minus 5/8-inch composite material was run at feed rates of 150 and 75 LTPHPFMW. There is no significant improvement over 1-inch material. The individual samples were run at 75 LTPHPFMW.

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* LTPHPFMW = Long Tons Per Hour Per Foot of Magnet Width

All three size tests of the individual samples yield the same pattern on magnetic iron recovery vs. concentrate weight recovery. The samples of area 2E and area 2WX yield higher iron recovery than samples of area #6 at the same concentrate recovery.

Standard batch ball mill grinds and Davis tube tests were run on composite samples of the concentrate and tailings from each size material. Minus 3-inch were run at 150 LTPHPFMW; minus 1-inch and minus 5/8-inch were run at 75 LTPHPFMW. The concentrate for liberation grind was a composite of the concentrate and middlings from the dry cobbing test so that the magnetic iron recovery was at 98%. The rest of the material was combined as tails.

The liberation grind data are shown in Tables 7 through 9 and presented in Figures 16 through 18. The percent silica in the Davis tube concentrate from each of the three batch ball mill grinds are plotted against the percent minus 270 mesh for both the concentrate and tailings. In addition, these results were used to calculate the theoretical results that would have been obtained by treating the crude ore feed. The liberation characteristics of the tails clearly indicated that the advantage of dry cobbing of minus 1-inch is great improvement on the down stream processing. The liberation characteristics of minus 1-inch and minus 5/8-inch showed no differences.

Conclusions

Coarse magnetic cobbing of the crushed ore has shown the advantages of rejecting a portion of low grade ore so that the energy consumption on the down stream grinding could be reduced.

With the magnetic iron recovery to the concentrate at 98%, there is an optimum size, at minus 1-inch, which achieved the rejection of 14% by weight on composite sample. Coarser material showed less weight rejection at 9%. There is no improvement on weight rejection when the material was further crushed down to minus 5/8-inch.

The dry cobbing on the crushed ore not only reduced energy consumption of the down stream grinding, but it also improved the liberation characteristics, which enables making a better concentrate.

Table 1. Cobbing Test on LTV Taconite Ore
Cobbing With CMRL Alternating Pole Head Pulley
on Composite Sample at Minus 3-Inch

Dry Magnetic Cobber Data Test No. -3 Inch, Composite, 300 LTPHPFMW

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag		Magnetic Iron		Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	43.0	30.1	43.0	30.1	63.0	13.4
Mid-I	24.0	16.7	67.0	25.3	82.5	10.9
Mid-II	13.2	12.8	80.2	23.2	90.7	9.7
Mid-III	14.2	9.7	94.4	21.2	97.4	9.6
Tails	5.6	9.6	100.0	20.6	100.0	
Head	100.0	20.6				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 298.5
Splitter Position: Multiple

Dry Magnetic Cobber Data Test No. -3 Inch, composite, 200 LTPHPFMW

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag		Magnetic Iron		Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	47.4	30.6	47.4	30.6	69.5	12.1
Mid-I	23.1	15.8	70.5	25.7	87.0	9.2
Mid-II	12.5	10.2	83.0	23.4	93.2	8.4
Mid-III	13.1	8.2	96.1	21.3	98.3	9.1
Tails	3.9	9.1	100.0	20.9	100.0	
Head	100.0	20.9				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 201.5
Splitter Position: Multiple

Table 1. Continued

Dry Magnetic Cobber Data Test No. -3 Inch, Composite, 150 LTPH

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
	Mag			Magnetic Iron		Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	46.3	31.1	46.3	31.1	69.8	11.6
Mid-I	21.3	15.7	67.6	26.2	86.0	8.9
Mid-II	10.3	11.5	77.9	24.3	91.8	7.7
Mid-III	14.3	8.1	92.2	21.8	97.4	7.0
Tails	7.7	7.0	99.9	20.6	100.0	
Head	100.0	20.6				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 152.9
Splitter Position: Multiple

Dry Magnetic Cobber Data Test No. -3 Inch, Composite, 100 LTPHPFMW

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
	Mag			Magnetic Iron		Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	52.1	31.3	52.1	31.3	76.8	10.3
Mid-I	20.7	14.9	72.8	26.6	91.4	6.7
Mid-II	9.3	6.9	82.1	24.4	94.4	6.7
Mid-III	13.1	6.0	95.2	21.9	98.1	8.5
Tails	4.8	8.5	100.0	21.2	100.0	
Head	100.0	21.2				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 100.5
Splitter Position: Multiple

Table 2. Cobbing Test on LTV Taconite Ore
Cobbing With CMRL Alternating Pole Head Pulley
On Individual Sample at Minus 3-Inch

Dry Magnetic Cobber Data Test No. -3 Inch Area 2WX

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag		Magnetic Iron		Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	46.3	30.9	46.3	30.9	71.2	10.8
Mid-I	21.3	14.9	67.6	25.9	87.0	8.1
Mid-II	10.3	12.1	77.9	24.0	93.2	6.2
Mid-III	14.3	6.8	92.2	21.4	98.1	5.0
Tails	7.7	5.0	99.9	20.1	100.0	
Head	100.0	20.1				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 159.3
Splitter Position: Multiple

Dry Magnetic Cobber Data Test No. -3 Inch Area #6

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag		Magnetic Iron		Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	49.4	29.7	49.4	29.7	69.4	12.8
Mid-I	24.7	16.1	74.1	25.2	88.2	9.6
Mid-II	10.5	11.3	84.6	23.4	93.9	8.4
Mid-III	11.5	8.6	96.1	21.7	98.5	7.9
Tails	3.9	7.9	100.0	21.1	100.0	
Head	100.0	21.1				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 156.5
Splitter Position: Multiple

Table 2. Continued

Dry Magnetic Cobber Data Test No. -3 Inch Area 2E-1

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
	Mag			Magnetic Iron		Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	47.4	31.8	47.4	31.8	73.4	10.4
Mid-I	19.1	15.4	66.5	27.1	87.7	7.5
Mid-II	10.9	9.2	77.4	24.6	92.6	6.8
Mid-III	15.0	8.2	92.4	21.9	98.6	3.9
Tails	7.6	3.9	100.0	20.5	100.0	
Head	100.0	20.5				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 150.8
Splitter Position: Multiple

Dry Magnetic Cobber Data Test No. -3 Inch Area 2E-2

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
	Mag			Magnetic Iron		Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	52.1	31.3	52.1	31.3	76.8	10.3
Mid-I	20.7	14.9	72.8	26.6	91.4	6.7
Mid-II	9.3	6.9	82.1	24.4	94.4	6.7
Mid-III	13.1	6.0	95.2	21.9	98.1	8.5
Tails	4.8	8.5	100.0	21.2	100.0	
Head	100.0	21.2				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 155.6
Splitter Position: Multiple

Table 3. Cobbing Test on LTV Taconite Ore
Cobbing With CMRL Alternating Pole Head Pulley
on Composite Sample at 1-Inch

Dry Magnetic Cobber Data Test No. -1 Inch 209.7 LTPH

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag		Magnetic Iron		Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	56.3	27.6	56.3	27.6	77.5	10.3
Mid-I	18.7	12.7	75.0	23.9	89.3	8.6
Mid-II	11.1	10	86.1	22.1	94.9	7.4
Mid-III	11.3	7.7	97.4	20.4	99.2	6.2
Tails	2.6	6.2	100.0	20.1	100.0	
Head	100.0	20.1				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 209.7
Splitter Position: Multiple

Dry Magnetic Cobber Data Test No. -1 Inch 159.0 LTPH

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag		Magnetic Iron		Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	56.1	29.4	56.1	29.4	81.5	8.5
Mid-I	16.8	11.4	72.9	25.3	91.0	6.7
Mid-II	10.4	8.7	83.3	23.2	95.5	5.5
Mid-III	12.6	5.8	95.9	20.9	99.1	4.5
Tails	4.1	4.5	100.0	20.2	100.0	
Head	100.0	20.2				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 159.0
Splitter Position: Multiple

Dry Magnetic Cobber Data Test No. -1 Inch 74.6 LTPH

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag		Magnetic Iron		Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	52.9	31.5	52.9	31.5	82.9	7.3
Mid-I	14.5	11.3	67.4	27.2	91.1	5.5
Mid-II	9.2	7.9	76.6	24.8	94.7	4.5
Mid-III	14.7	5.3	91.3	21.7	98.6	3.2
Tails	8.8	3.2	100.1	20.1	100.0	
Head	100.0	20.1				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 74.6
Splitter Position: Multiple

Table 4. Cobbing Test on LTV Taconite Ore
Cobbing With CMRL Alternating Pole Head Pulley
on Minus 1-Inch sample, Individual Areas

Dry Magnetic Cobber Data Test No. -1 Inch Area 2WX

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag	Magnetic Iron			Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	53.6	31.7	53.6	31.7	85.2	6.4
Mid-I	15.6	9.4	69.2	26.7	92.6	4.8
Mid-II	12.0	6.7	81.2	23.7	96.6	3.6
Mid-III	14.4	3.7	95.6	20.7	99.3	3.3
Tails	4.3	3.3	99.9	20.0	100.0	
Head	100.0	20.0				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 75.4
Splitter Position: Multiple

Dry Magnetic Cobber Data Test No. -1 Inch Area #6

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag	Magnetic Iron			Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	62.4	28.8	62.4	28.8	86.6	7.4
Mid-I	16.7	10.4	79.1	24.9	95.0	5.0
Mid-II	9.9	6.8	89.0	22.9	98.2	3.4
Mid-III	8.5	3.2	97.5	21.2	99.5	4.1
Tails	2.4	4.1	99.9	20.8	100.0	
Head	100.0	20.8				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 77.3
Splitter Position: Multiple

Table 4. Continued

Dry Magnetic Cobber Data   Test No.   -1 Inch   Area 2E-1

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag	Magnetic Iron			Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	58.1	31.6	58.1	31.6	88.2	5.9
Mid-I	15.8	8.6	73.9	26.7	94.8	4.2
Mid-II	9.8	5.6	83.7	24.2	97.4	3.3
Mid-III	12.6	3.3	96.3	21.5	99.4	3.4
Tails	3.6	3.4	99.9	20.8	100.0	
Head	100.0	20.8				

Belt Speed (FPM) = 550   CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 74.2
Splitter Position: Multiple

Dry Magnetic Cobber Data   Test No.   -1 Inch   Area 2E-2

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag	Magnetic Iron			Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	55.2	31.1	55.2	31.1	85.2	6.6
Mid-I	16.5	9.6	71.7	26.2	93.1	4.9
Mid-II	12.4	6.4	84.1	23.2	97.0	3.8
Mid-III	12.2	3.8	96.3	20.8	99.3	3.7
Tails	3.8	3.7	100.1	20.1	100.0	
Head	100.1	20.1				

Belt Speed (FPM) = 550   CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 75.9
Splitter Position: Multiple

Table 5. Cobbing Test on LTV Taconite Ore
Cobbing With CMRL Alternating Pole Head Pulley
On Minus 5/8-Inch Composite Sample

Dry Magnetic Cobber Data   Test No.   -5/8 Inch   155.5 LTPH

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag		Magnetic Iron		Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	64.2	26.9	64.2	26.9	86.8	7.4
Mid-I	16.8	9.4	81.0	23.3	94.7	5.6
Mid-II	9.1	6.8	90.1	21.6	97.8	4.5
Mid-III	8.0	4.7	98.1	20.2	99.7	3.5
Tails	1.8	3.5	99.9	19.9	100.0	
Head	100.0	19.9				

Belt Speed (FPM) = 550   CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 155.5
Splitter Position: Multiple

Dry Magnetic Cobber Data   Test No.   -5/8 Inch   74.4 LTPH

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag		Magnetic Iron		Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	59.6	30.1	59.6	30.1	88.6	5.7
Mid-I	16.1	7.4	75.7	25.3	94.5	4.6
Mid-II	10.9	5.7	86.6	22.8	97.6	3.6
Mid-III	11.0	3.8	97.6	20.7	99.7	2.9
Tails	2.4	2.9	100.0	20.2	100.0	
Head	100.0	20.2				

Belt Speed (FPM) = 550   CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 74.4
Splitter Position: Multiple

Table 6. Cobbing Test on LTV Taconite Ore
Cobbing With CMRL Alternating Pole Head Pulley
On Minus 5/8-Inch Individual Area Samples

Dry Magnetic Cobber Data Test No. -5/8 Inch Area 2WX

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag	Magnetic Iron			Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	58.3	30.5	58.3	30.5	88.8	5.4
Mid-I	16.3	7.4	74.6	25.5	94.8	4.1
Mid-II	11.1	5.2	85.7	22.8	97.7	3.2
Mid-III	11.9	3.2	97.6	20.4	99.6	3.2
Tails	2.4	3.2	100.0	20.0	100.0	
Head	100.0	20.0				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 74.4
Splitter Position: Multiple

Dry Magnetic Cobber Data Test No. -5/8 Inch Area #6

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag	Magnetic Iron			Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	65.0	29.9	65.0	29.9	89.9	6.3
Mid-I	15.5	8.3	80.5	25.7	95.8	4.6
Mid-II	9.2	5.9	89.7	23.7	98.3	3.5
Mid-III	8.2	3.7	97.9	22.0	99.7	2.8
Tails	2.1	2.8	100.0	21.6	100.0	
Head	100.0	21.6				

Belt Speed (FPM) = 550 CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 77.3
Splitter Position: Multiple

Table 6. Continued

Dry Magnetic Cobber Data   Test No.   -5/8 Inch   Area 2E-1

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag	Magnetic Iron			Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	59.7	30.4	59.7	30.4	89.2	5.5
Mid-I	15.7	7.6	75.4	25.7	95.0	4.1
Mid-II	10.8	5.4	86.2	23.1	97.9	3.1
Mid-III	11.0	3.2	97.2	20.9	99.6	2.6
Tails	2.8	2.6	100.0	20.4	100.0	
Head	100.0	20.4				

Belt Speed (FPM) = 550   CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 75.2
Splitter Position: Multiple

Dry Magnetic Cobber Data   Test No.   -5/8 Inch   Area 2E-2

	Product Analyses		Cumulative Conc. Analyses			Cum Tail
		Mag	Magnetic Iron			Mag
Product	Wt%	Fe %	Wt. %	(%)	(Rec. %)	Fe %
Mag-I	61.0	29.0	61.0	29.0	89.8	5.1
Mid-I	16.7	6.9	77.7	24.3	95.7	3.8
Mid-II	10.6	4.8	88.3	21.9	98.2	3.0
Mid-III	9.5	3.0	97.8	20.1	99.7	2.8
Tails	2.2	2.8	100.0	19.7	100.0	
Head	100.0	19.7				

Belt Speed (FPM) = 550   CMRL Alternating Pole Head Pulley
Feed Rate (LTPHPFMW) = 75.5
Splitter Position: Multiple

Table 7 -3" Dry Cobbing, Liberation Grind Test, Feed Rate at 150 LTPH

Cob Con Wt Rec. %	94.0
Cob Conc. Mag Fe Recovery %	98.0

% -270 mesh	Time(min.)	Wt Rec.(%)	Mag Fe (%)	SiO2 (%)	Fe (%)
		Conc.			
80.1	11.0	28.9	18.8	6.91	65.1
84.2	11.9	29.8	19.5	6.63	65.4
87.5	13.2	28.4	18.8	6.20	66.2
		Tail			
80.2	12.0	13.5	8.6	9.18	63.8
85.8	13.2	13.2	8.5	8.64	64.5
88.1	14.0	13.4	8.7	8.46	64.7
		Calculated Feed			
80.1	-	28.0		7.05	
84.3	-	28.8		6.75	
87.5	-	27.5		6.34	

Table 8 -1" Dry Cobbing, Liberation Grind Test, Feed Rate at 75 LTPH

Cob Conc. Wt Rec. %	86.0
Cob Conc. Mag Fe Recovery %	98.0

% -270 mesh	Time (min.)	Wt Rec. (%)	Mag Fe (%)	SiO2 (%)	Fe (%)
		Conc.			
79.5	10.5	34.8	22.5	7.72	64.6
83.0	11.0	34.2	22.6	6.91	66.1
89.6	13.0	33.0	21.8	6.18	66.2
		Tail			
79.0	12.2	6.4	3.9	13.78	61.2
85.1	13.3	6.2	3.9	12.13	62.3
88.0	14.5	6.1	3.9	10.97	63.4
		Calculated Feed			
79.5	-	34.2		7.84	
83.0	-	33.6		7.01	
89.6	-	32.5		6.28	

Table 9 -5/8" Dry Cobbing, Liberation Grind Test, Feed Rate at 75 LTPH

Cob Con Wt Rec. %	88.5
Cob Conc. Mag Fe Recovery %	98.0

% -270 mesh	Time (Min.)	Wt Rec.	Mag Fe	SiO2 (%)	Fe(%)
			Conc.		
79.5	10.5	34.7	22.7	6.92	65.4
83.0	11.0	34.2	22.5	6.61	65.9
89.6	13.0	34.1	22.6	6.09	66.4
			Tail		
79.2	12.3	5.6	3.4	13.49	61.2
83.6	13.0	5.6	3.5	12.24	62.4
87.8	14.5	5.3	3.4	10.72	63.5
			Calculated Feed		
79.5	-	31.4		7.68	
83.1	-	30.9		7.26	
89.4	-	30.8		6.62	

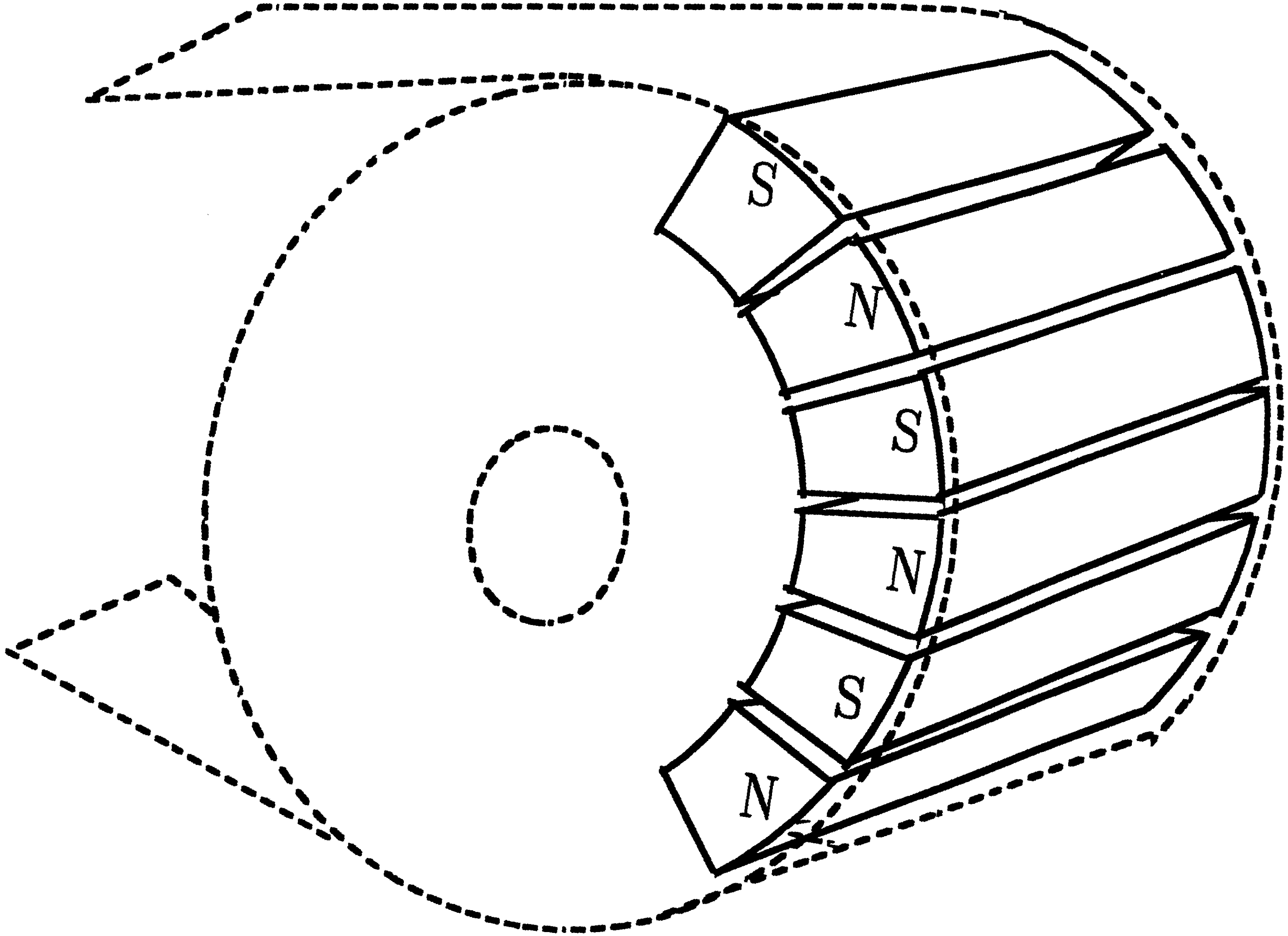


Figure.1 Schematic of 6-pole Magnetic Polley

Gauss Readings for 48-Inch Diameter

High-Gradient Magnet

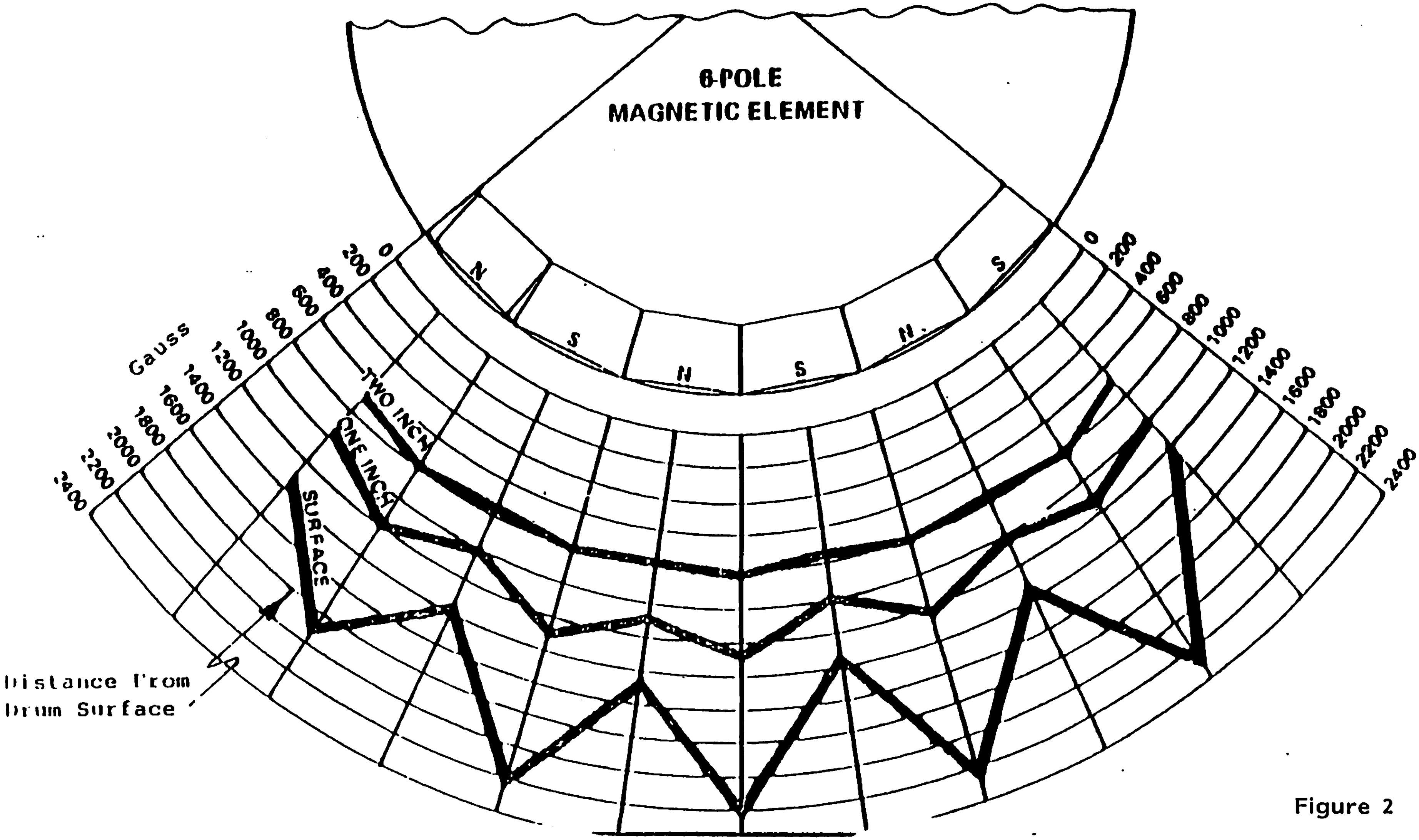


Figure 2

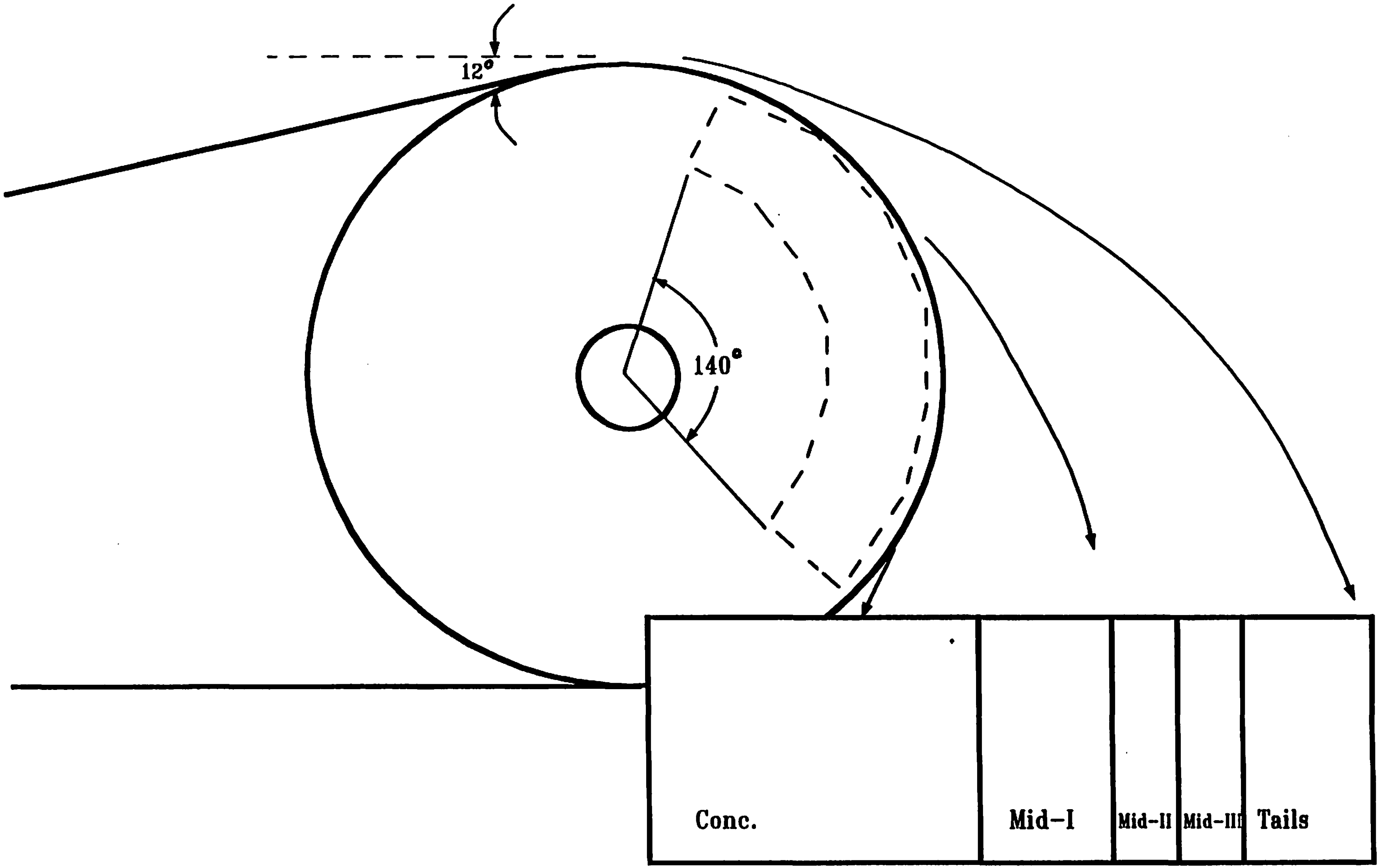


Figure 3. Schematic of Splite Box of Head Pulley Products

Figure 4. CMRL Alternating Pole Head Pulley Test Data
Plot of Concentrate Weight Recovery Against Magnetic Iron Recovery
LTV Minus 3-Inch Taoconite Ore

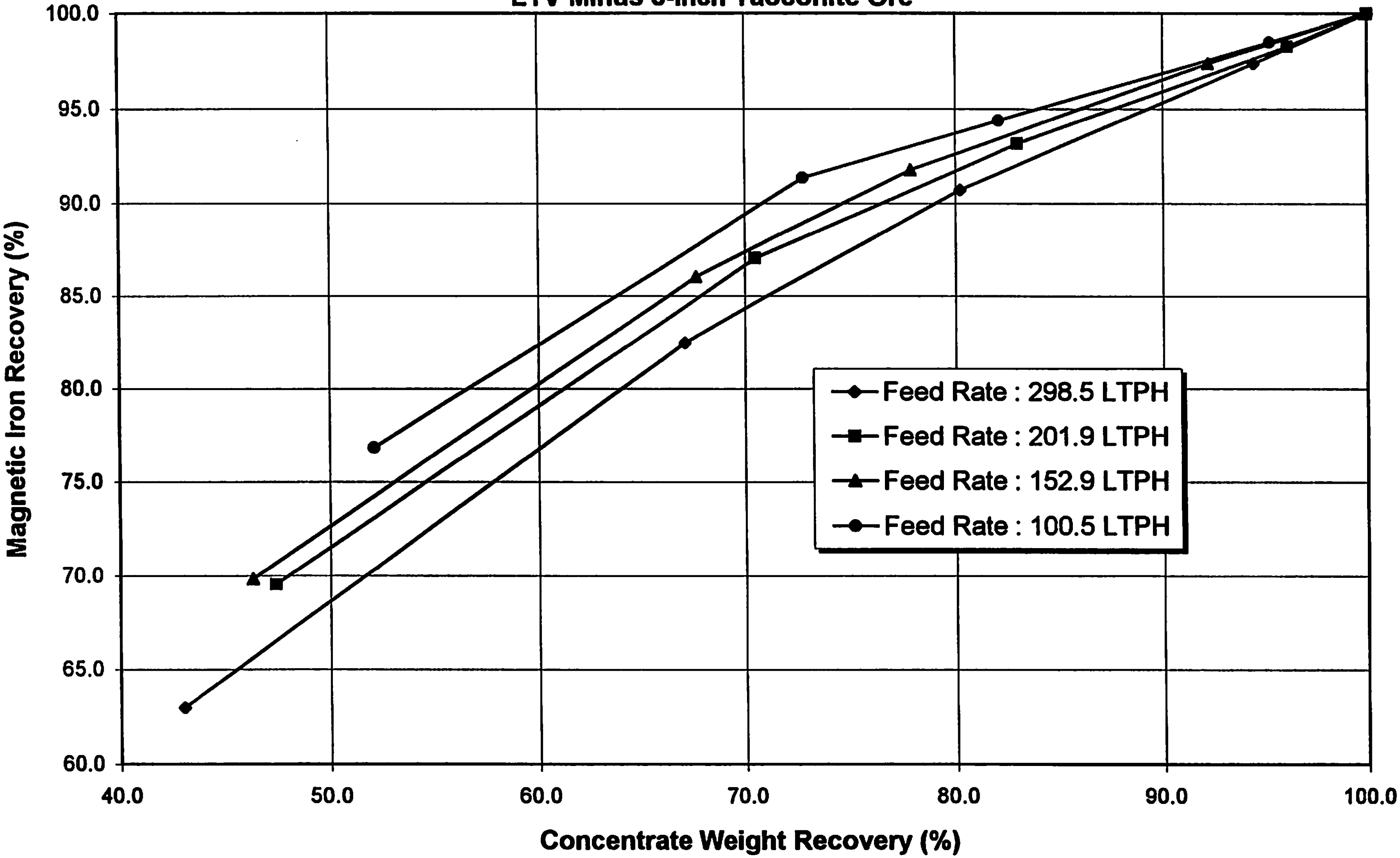
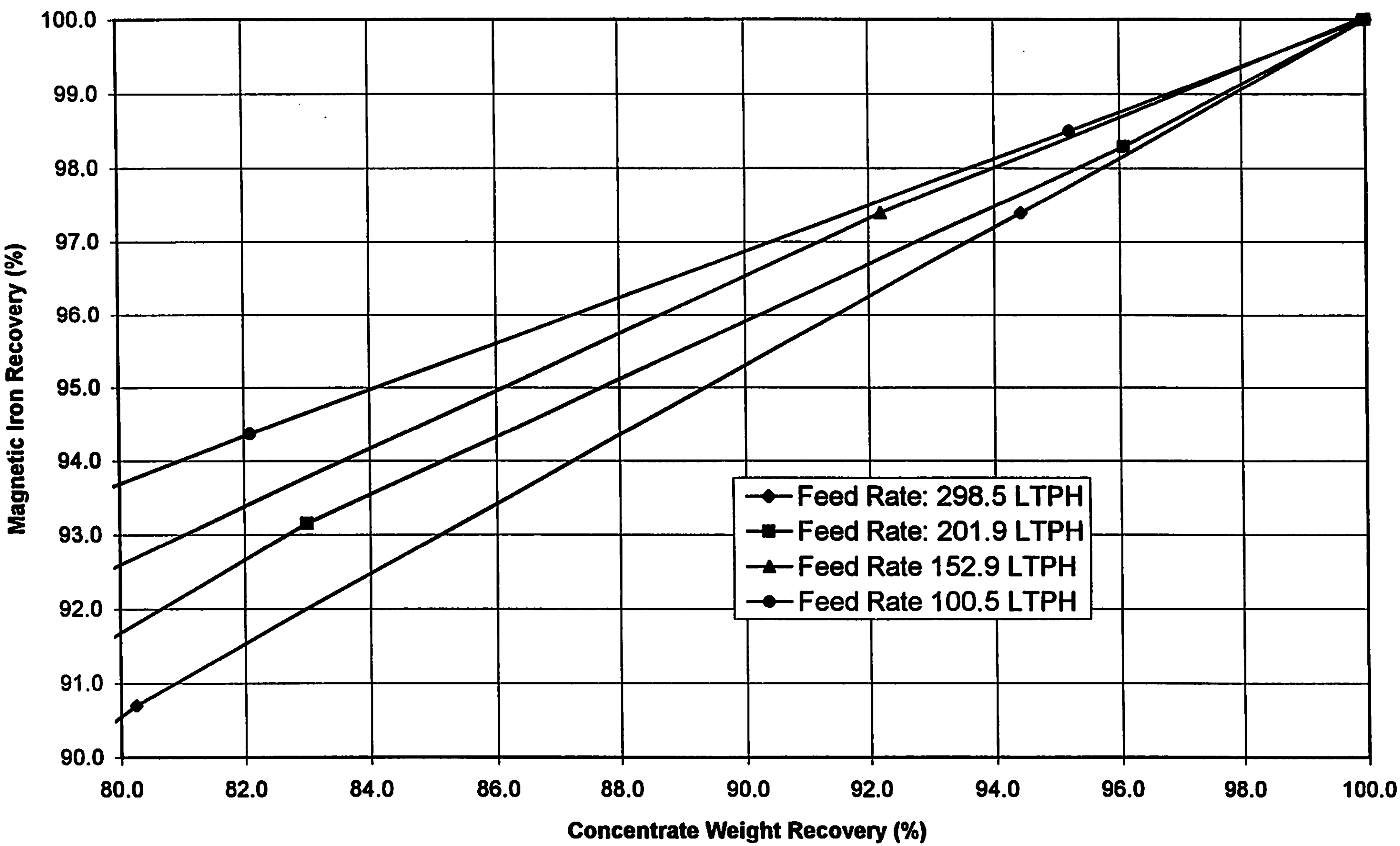


Figure 5. CMRL Alternating Pole Head Pulley Test Data Plot of Concentrate Weight Recovery Against Magnetic Iron Recovery LTV Minus 3 Inch Taconite Ore



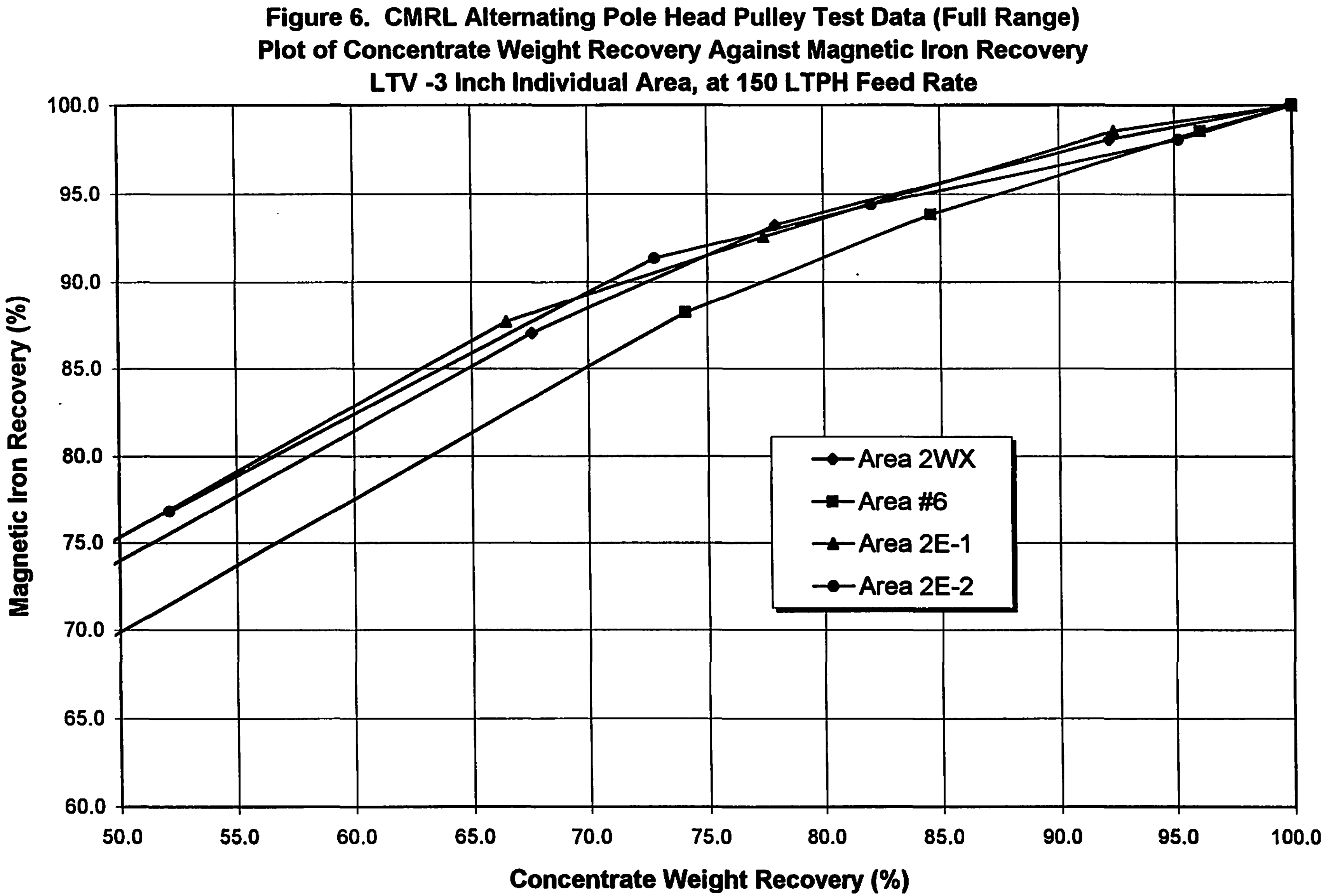


Figure 6. CMRL Alternating Pole Head Pulley Test Data (Full Range)
Plot of Concentrate Weight Recovery Against Magnetic Iron Recovery
LTV -3 Inch Individual Area, at 150 LTPH Feed Rate
Magnetic Iron Recovery (%)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0
95.0
100.0
Concentrate Weight Recovery (%)
Area 2WX
Area #6
Area 2E-1
Area 2E-2

Figure 7. CMRL Alternating Pole Head Pulley Test Data (Detai)
Plot of Concentrate Weight Recovery Against Magnetic Iron Recovery
LTV Minus 3-Inch Individual Taconite Ore, 150 LTPH

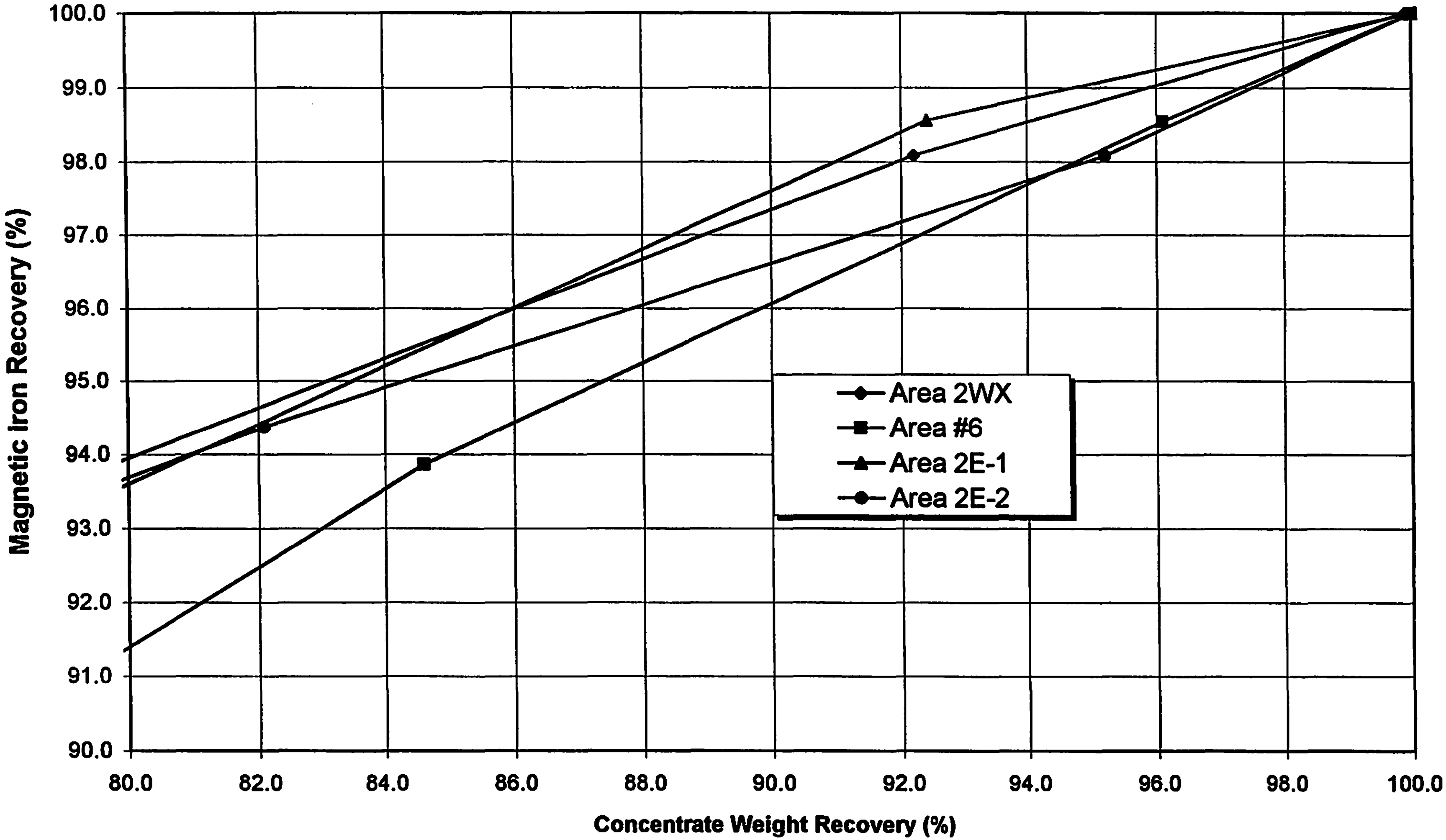


Figure 8. CMRL Alternating Pole Head Pulley Test Data
Plot of Concentrate Weight Recovery Against Magnetic Iron Recovery
LTV - 1 Inch Composite, at Different Feed Rate

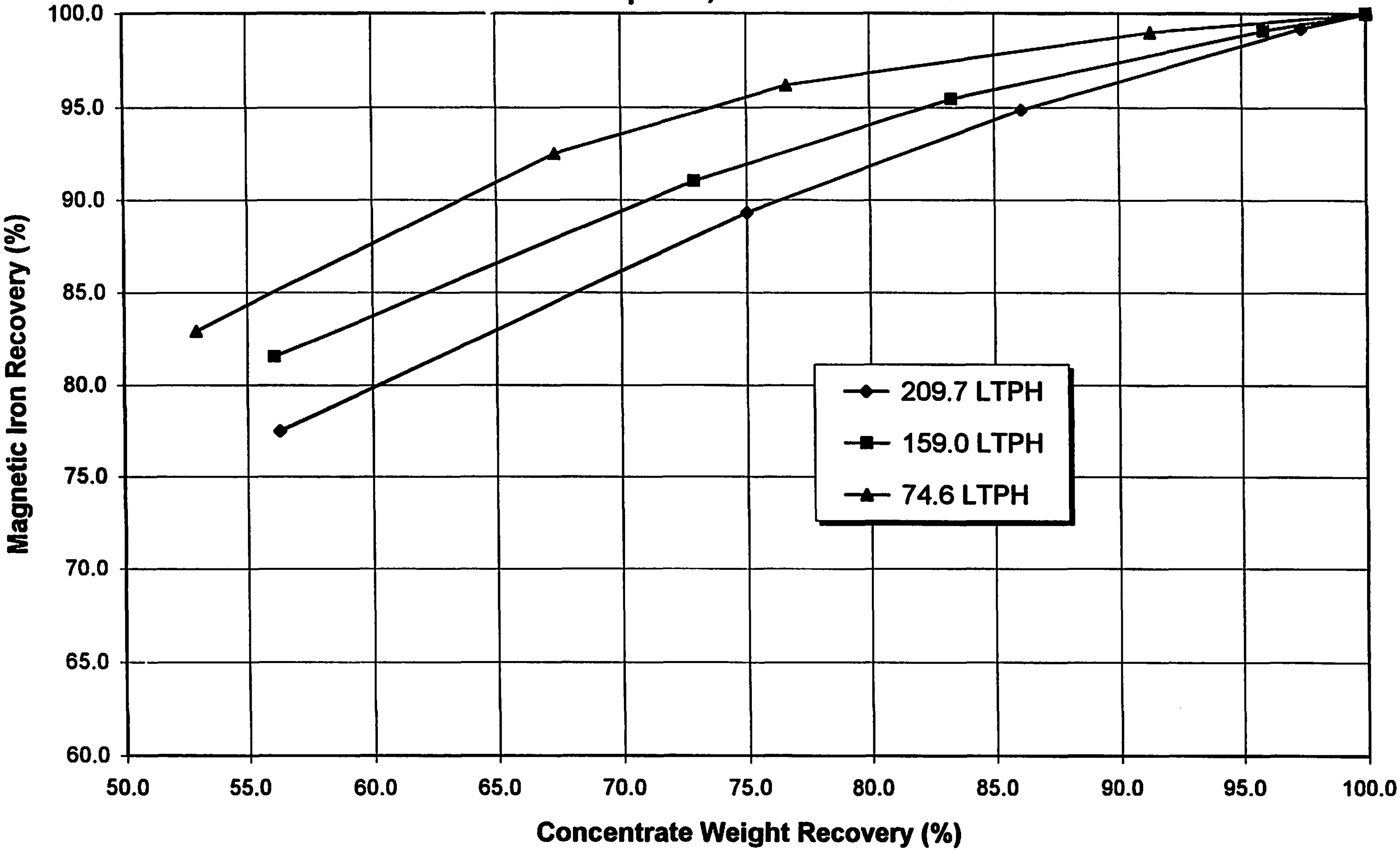


Figure 9. CMRL Alternating Pole Head Pulley Test Data
Plot of Concentrate Weight Recovery Against Magnetic Iron Recovery
LTV Minus 1-Inch Taconite Ore

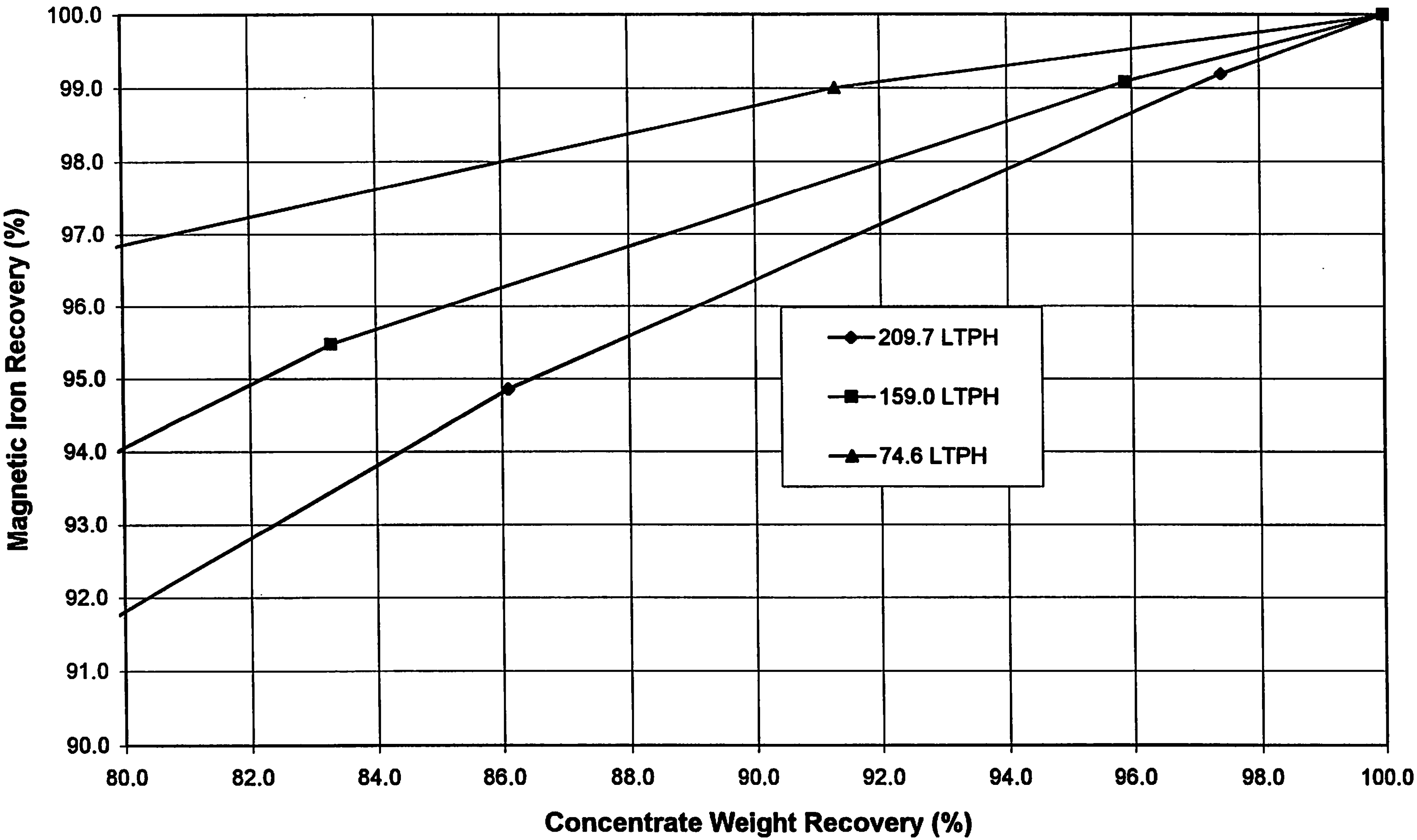


Figure 10. CMRL Alternating Pole Head Pulley Test Data (Full Range)
Plot of Concentrate Weight Recovery Against Magnetic Iron Recovery
LTV Minus 1-Inch Individual Area, at 75 LTPH Feed Rate

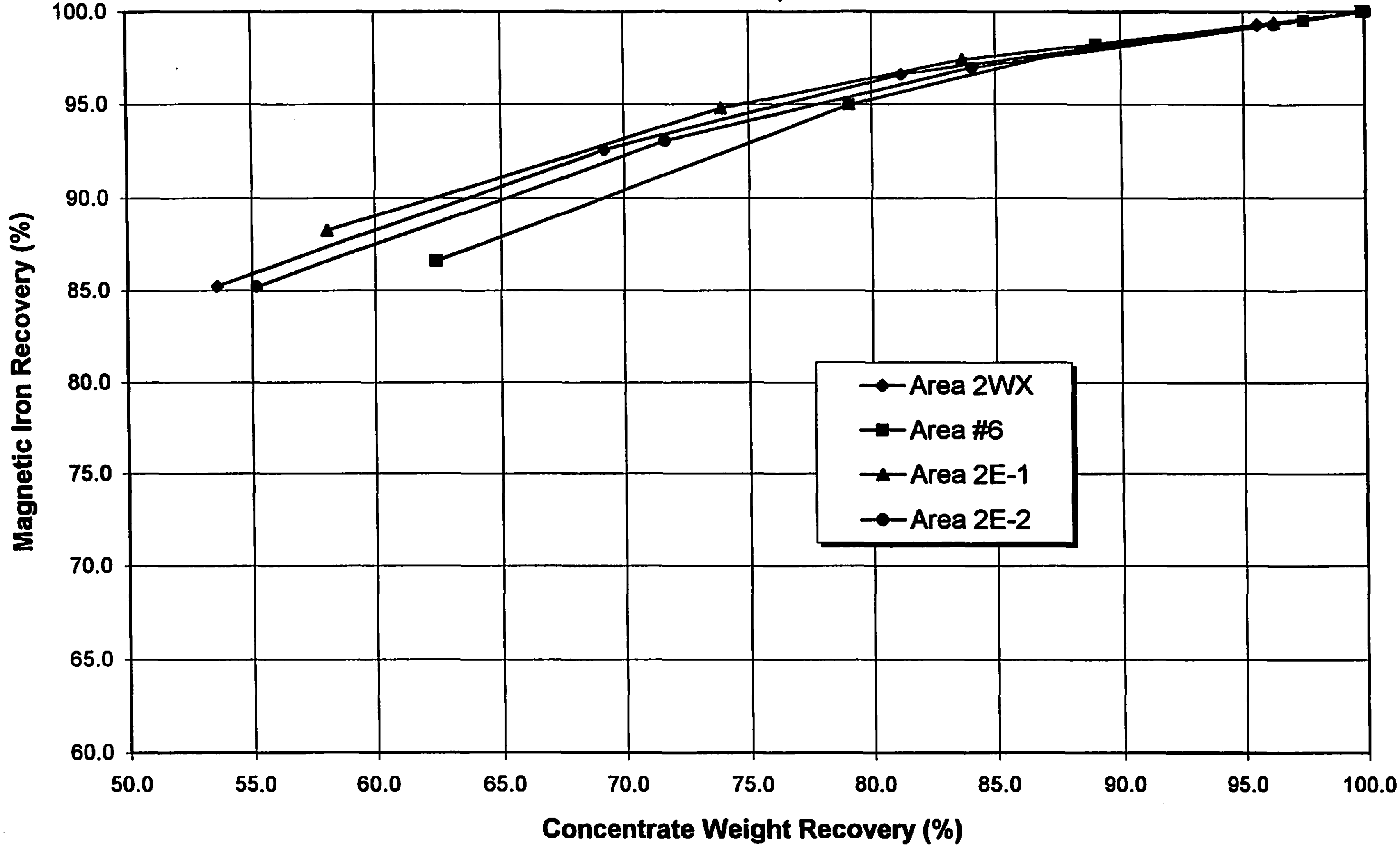


Figure 11 **CMRL Alternating Pole Head Pulley Test Data (Detail)**
Plot of Concentrate Weight Recovery Against Magnetic Iron Recovery
LTV Minus 1-Inch Individual Ore, 75 LTPH

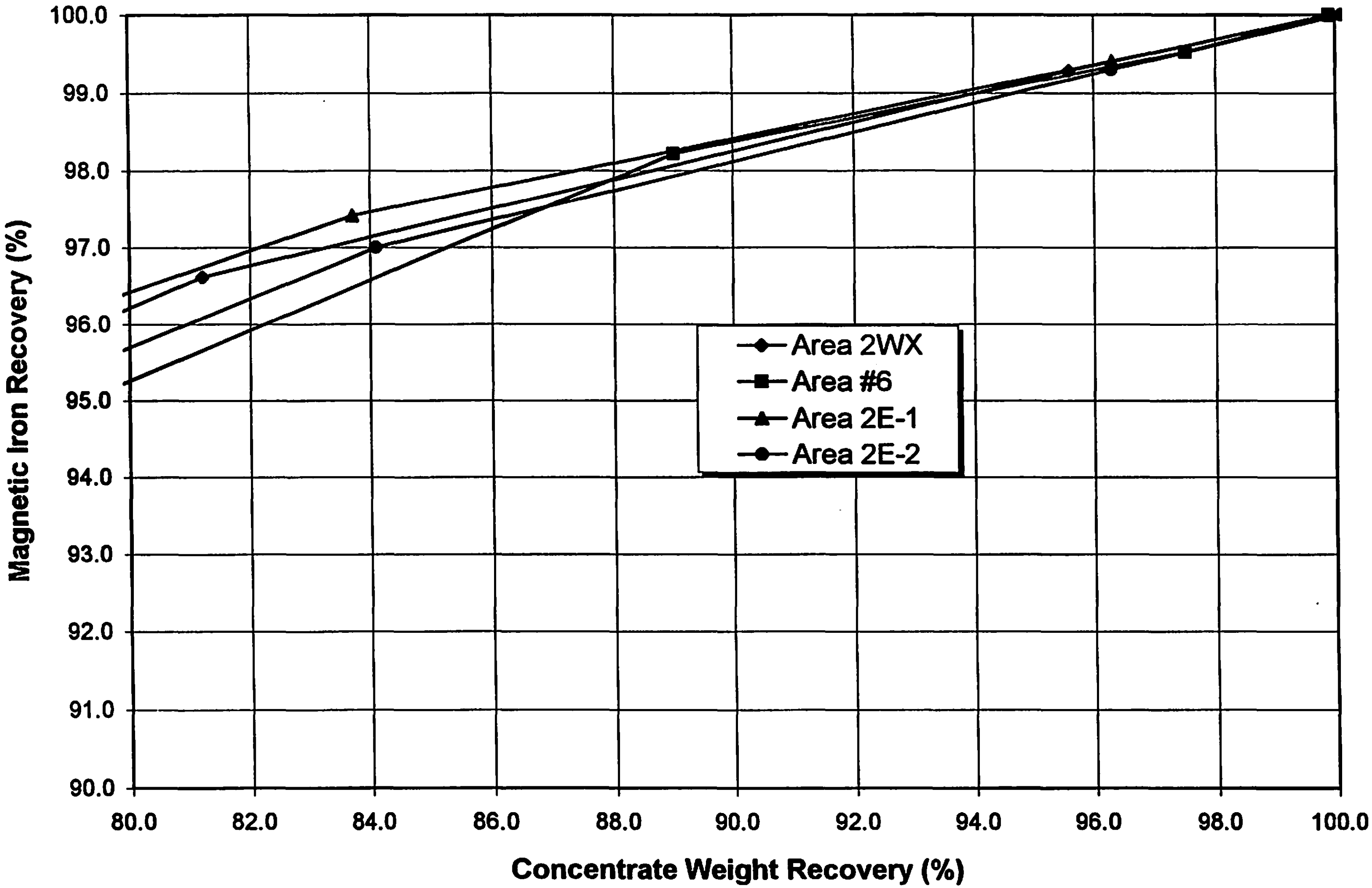


Figure 12. CMRL Alternating Pole Head Pulley Test Data (Full Range)
Plot of Concentrate Weight Recovery Against Magnetic Iron Recovery
LTV -5/8 Inch Composite, at Different Feed Rate

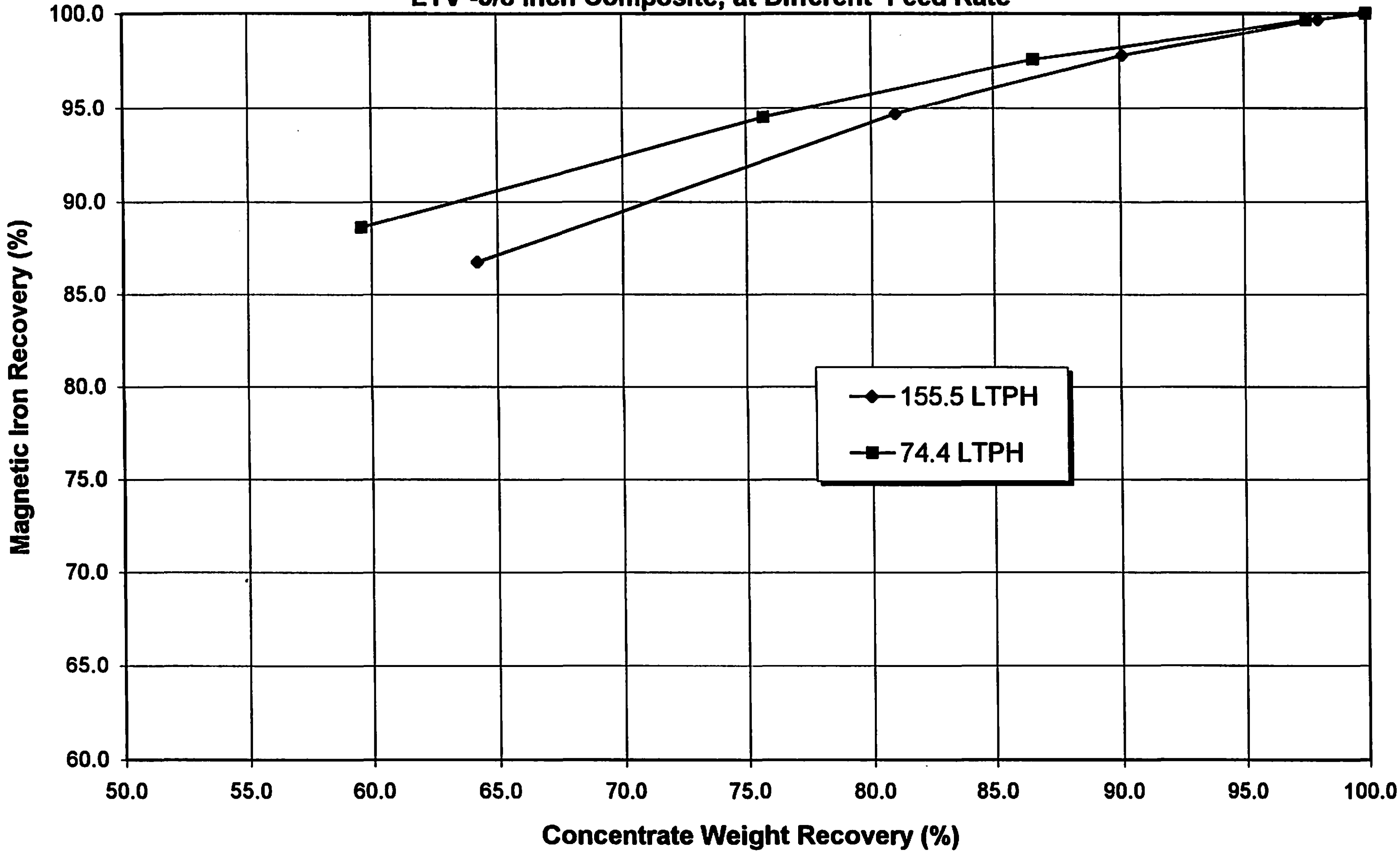


Figure 13. CMRL Alternating Pole Head Pulley Test Data (Detail)
Plot of Concentrate Weight Recovery Against Magnetic Iron Recovery
LTV Minus 5/8-Inch Composite Ore

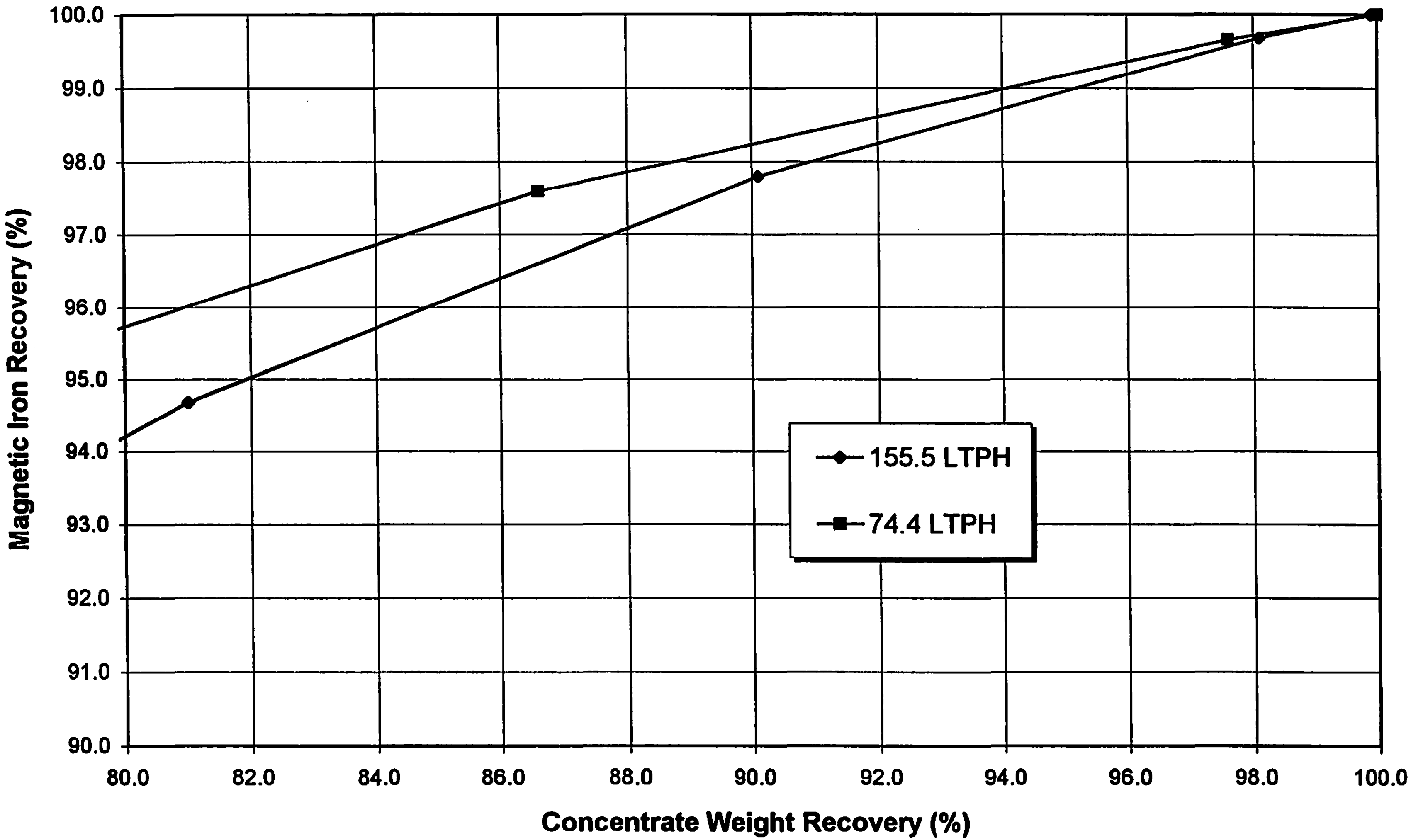


Figure 14. CMRL Alternating Pole Head Pulley Test Data
Plot of Concentrate Weight Recovery Against Magnetic Iron Recovery
LTV -5/8 Inch Individual Area, at 75 LTPH Feed Rate

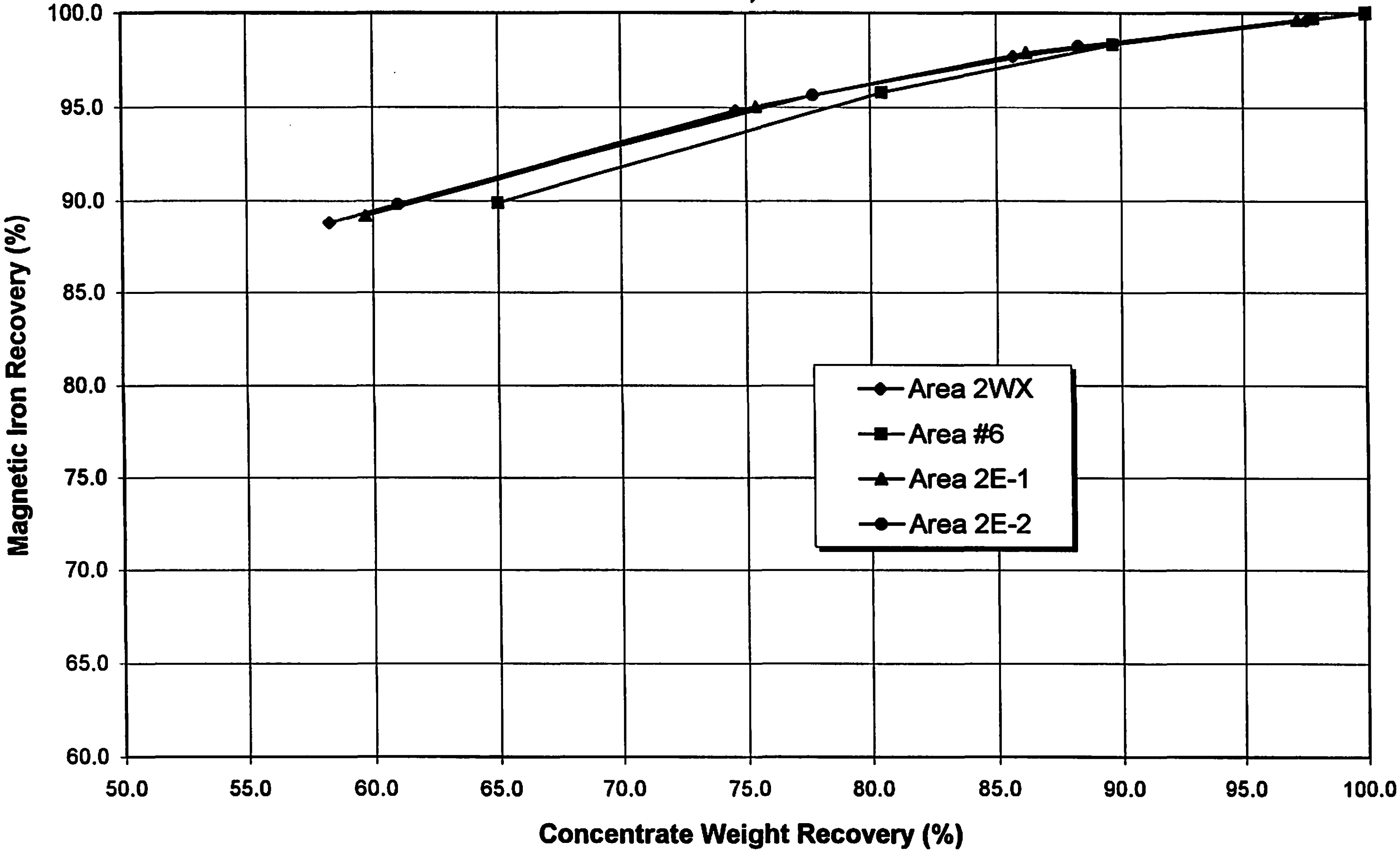


Figure 15. CMRL Alternating Pole Head Pulley Test Data (Detail)
Plot of Concentrate Weight Recovery Against Magnetic Iron Recovery
LTV Minus Minus 5/8-Inch Individual Ore, 75 LTPH

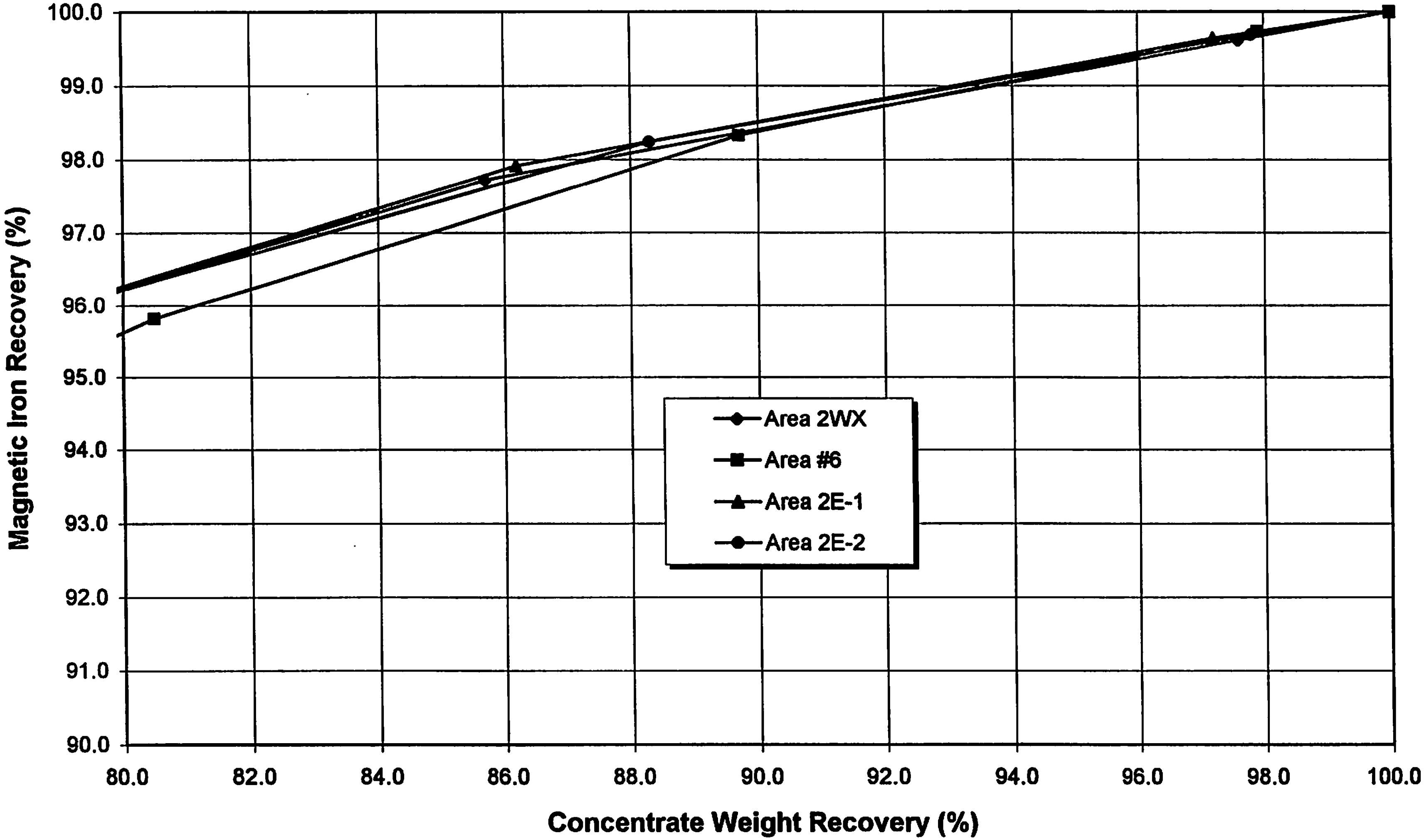


Figure 16. -3" Dry Cobbing Lib Grind Test

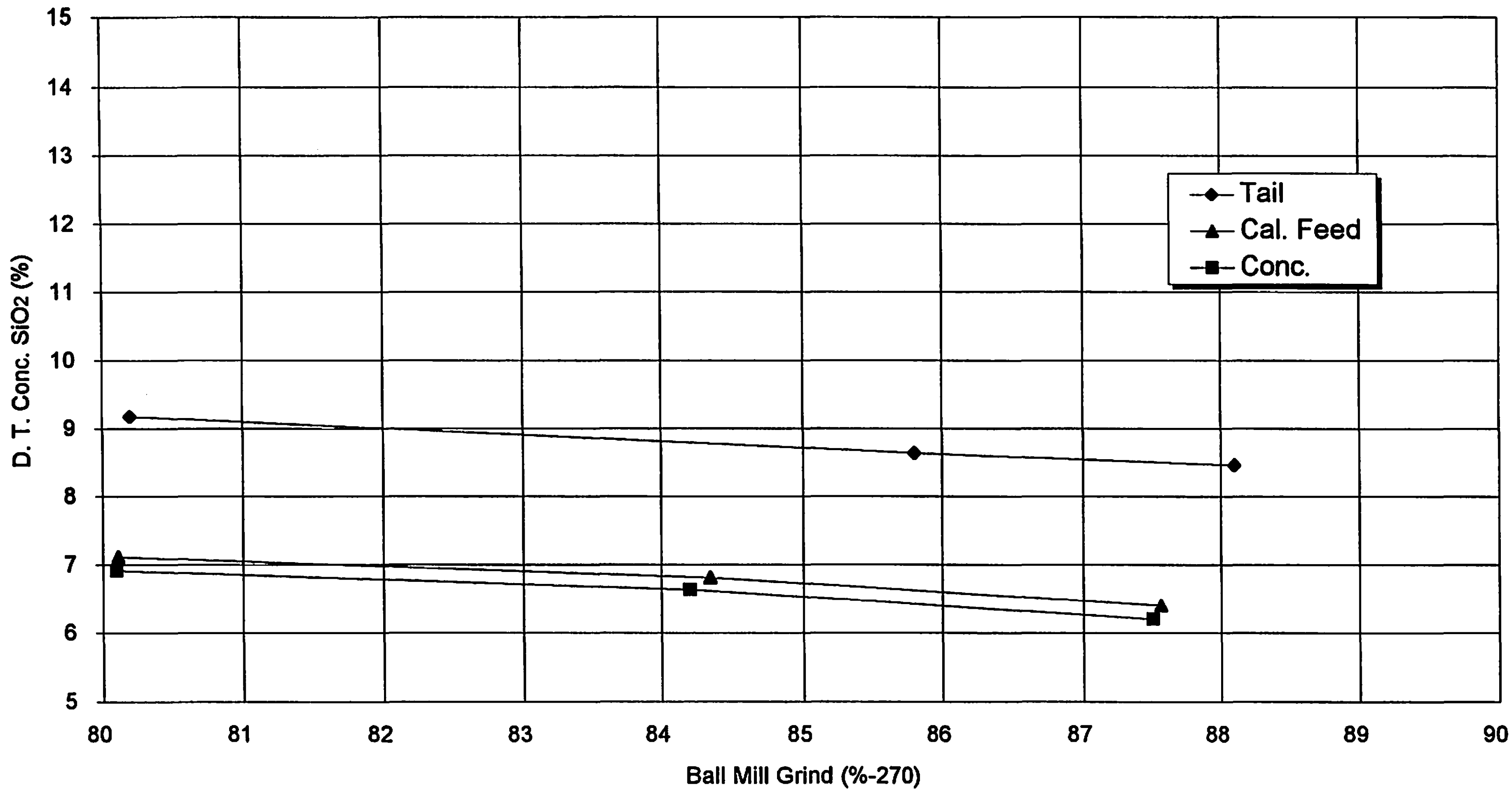


Figure 17. -1" Dry Cobbing Lib Grind Test

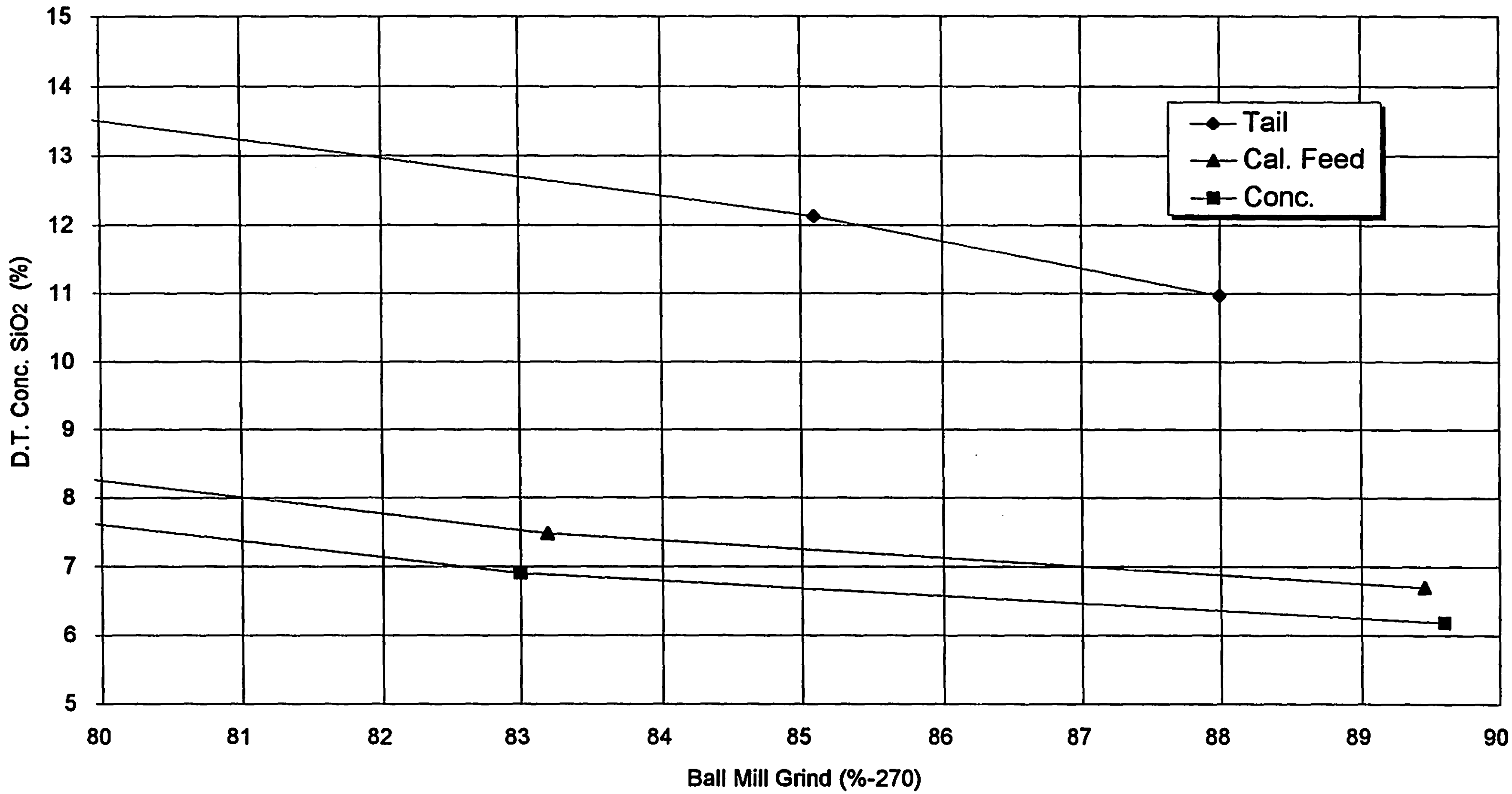


Figure 18. -5/8" Dry Cobbing Lib Grind Test