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The Separate Refining of a Fractionated Recycled Pulp

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THE SEPARATE REFINING
OF A
FRACTIONATED RECYCLED PULP

by

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Abstract

This is a study of the effects of fractionation on total refining energy and final sheet strength. A selectifier screen was used to fractionate an input recycled pulp into long and short fiber lengths. Each of the three pulps were refined in a PFI mill then the long and short fiber groups were recombined in the same proportion as they split and formed into handsheets. The handsheets made via fractionation were found to be no stronger, per unit energy into the refiners, than the handsheets of the unfractionated input fibers. Two interesting points, one, that each pulp consumed different energy amounts per unit time in the refiner, and two, that pulp particles which pass through linen pillowcases have no paper-making value.

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I. Introduction

The Paper Recycling Pilot Plant at Western Michigan University has a Black Clawson Selectifier Screen. This unit has .018 inch slotted and 1/16 inch perforated screens, and can meet practically any operating conditions including fiber fractionation. By fractionating recycled pulp (100% old corrugated) into long and short fiber lengths, refining each part separately, and recombining the two streams in the same proportion as they were fractionated, I can compare handsheets of this stock to those made from unfractionated refined pulp for strength properties and for net energy input to the refiner.

II. Literature Survey

A. Fractionation for Sheet Strength

Peckman and May (1) refined samples of softwood kraft (long fibers) and hardwood kraft (short fibers) separately, and as mixtures in a Valley beater. The mixutre level of softwood to hardwood was maintained at 60% to 40% respectively, but the blends were made by (a) mixing the pulps before refining, (b) refining each pulp separately and mixing the two pulps at the same refining time interval, (c) refining each pulp separately and mixing the two pulps at different refining time intervals. Standard TAPPI handsheets were made and tested for bursting, tearing, tensile strength, and folding endurance. The results obtained indicated that some small strength advantage might be obtained by refining the two pulps separately and then mixed together. Fractionation of a recycled pulp yields long and short fiber streams which I refined separately and recombined in the same proportion as the streams were fractionated into. I then compared handsheets made from an unfractionated refined stock to that obtained by fractionation and separate refining, to observe any strength differences.

B. Fractionation for Net Energy:

Because of the nature of the recycled fibers, being once refined already, only a minimal amount of refining is required to brush up the matted down fibrils in either the fractionated or unfractionated pulps. By fractionating the pulp into short (fines) and long fibers, I can tailor the refining on each stream to the fiber in that stream. The short fiber resembles fines, which need little or no refining to enhance their bonding character. This allows me energy saving in two ways.

a) The refining energy can be focused on the fibers requiring the refining and get better refining efficiency.

b) The flow of stock passed through a refiner is about two thirds of the total flow to the papermaking, ie., reduced tonnage through the refiners.

One obvious and valid claim is the added handling equipment required to process two pulp streams as opposed to one of an unfractionated pulp stream may offset the savings in refiner energy consumption. In conversations with unnamed individuals from the industry, I've been told that the energy requirements for refining of stock constitutes as much as 40% of the mill's energy, and that a small efficiency increase in refining can yield great savings in energy consumption, and may offset the capital investment and operating cost of a second pulp handling system in the long-run.

III. Special Equipment

A. Black Clawson Selectifier Screen:

The W.M.U. Paper Recycling Pilot Plant has a Black Clawson Selectifier Screen for pressure screening and fiber fractionating purposes. The unit has both a .018" slotted and 1/16 inch perforated baskets. Flow rates of about 1000 to 2000 gpm at 1% consistency are common, but for fractionation higher consistencies of around 2% are advisable, at a reduced flow rate.

B. PFI Mill:

The PFI Mill is a recently designed device for pulp evaluation. The mill is designed to refine 20 to 40 grams of oven-dry pulp with a consistency of 10 to 15%. The beating elements consist of a roll with chiselled bars and a circular, smooth beater house. The roll and house are independently driven in the same direction, but at different peripheral speeds. The beater house is charged with pulp and rotated to press the pulp into an endless band around the inside of the beater housing. As the roll always runs at a higher speed than the housing, the roll bars will cut out sections of the pulp band and transport the pulp into the beating zone. Beating conditions such as pulp concentration, beating pressure, relative peripheral speeds and bar and housing distance may be varied within wide limits.

IV. Experimental Procedure

A. Pulp Preparation: 100% old corrugated boxboard furnish was chosen for the wide variation of fiber lengths it contains. The inner fluting is made of short fibers, the outer liners are made of long fibers. The stock was dispersed in the pilot plant's hydropulper at 5% consistency, then diluted to 2.5% in a retaining chest. It was then run across a Johnson screen to remove plastics and staples and passed once through a deflaker to defiber any bundles or clumps of fibers. (Figure 1)

B. Fractionation: The circulating system shown in Figure 1 allows for the operation and tuning of the fractionating process. The loop contains a flow meter on the input leg and one on the accepts or short fiber leg. The flow of the third leg is found by subtraction.

From the flow meter data and consistency measurements on the samples obtained, a mass balance with respect to water and fiber is done, determining the proportion or split of fiber flows. My fractionation run split at 72.3% long fiber leg and 27.7% short fiber leg, as calculated in Appendix A. The Clark classifier and fiber length determination by projection was used to determine the distributions of fiber lengths in each pulp. The results are reported in Table 1 and Figure 2.

C. Fiber Conditioning: The three pulps were refrigerated and chemically preserved with formaldehyde for storage.

For the refining in the PFI mill, the pulp had to be at 10% consistency. The problem arises when concentrating the pulp, all of the fines **must be** retained. The devised procedure (Figure 3) for handling this problem includes several steps:

a) rolling the pulp down a sidehill screen to get the bulk of water out, which is collected.

b) filtering the collected water through a linen pillow case to capture fines to be mixed back into the pulp immediately, and collecting the filtered water.

c) retaining and using the filtered water in a control group to determine the papermaking property of any fiber not filtered out.

D. Refining and Energy Consumption: For the purpose of evaluating energy consumption the pulp batches were refined at identical beating conditions:

a) Batches of 40 grams oven dry pulp at 10% consistency for all runs.

b) Starting temperature of the beating chamber and pulp at room temperature.

c) Beating pressures were the same 1.8 KgF/cm bar height.

d) The same beating element differential speeds.

The only variable involved was the beating time and the energy imparted to a given pulp.

Energy consumption of the PFI mill was measured with a kilowatt meter installed in the power supply lines. An interesting consideration was that the energy imparted to the three pulps was different and particular for each pulp. Calibration curves for energy consumption vs. time for each pulp is shown in Figure 4.

The refining times involved and their corresponding energy comsumptions is tabled in Table 2. Energy consumption in HPD/T was calculated from the calibration curve for the pulp integrated over the refining time.

E. Handsheet Preparation and Testing: The handsheets were prepared on a Noble and Wood handsheet machine. There were three groups of handsheets prepared:

a) Handsheets made from the input stock which was refined at varying degrees.

b) Handsheets made from the same input stocks as group (a) but made with the control water from the pulp preparation steps.

c) Handsheets made from combining the long and short fibers at a set proportion of 72.3% long to 27.7% short fiber.

All handsheets were tested for Basis Weight, Tear, and Tensile. The data was entered in the W.M.U. computer for manipulation. The tear and tensile values have all been corrected by basis weight variation.

V. Results Presentation

A. Pulp Preparation: Figure 1 shows flow diagrams for the equipment used in the pulp preparation.

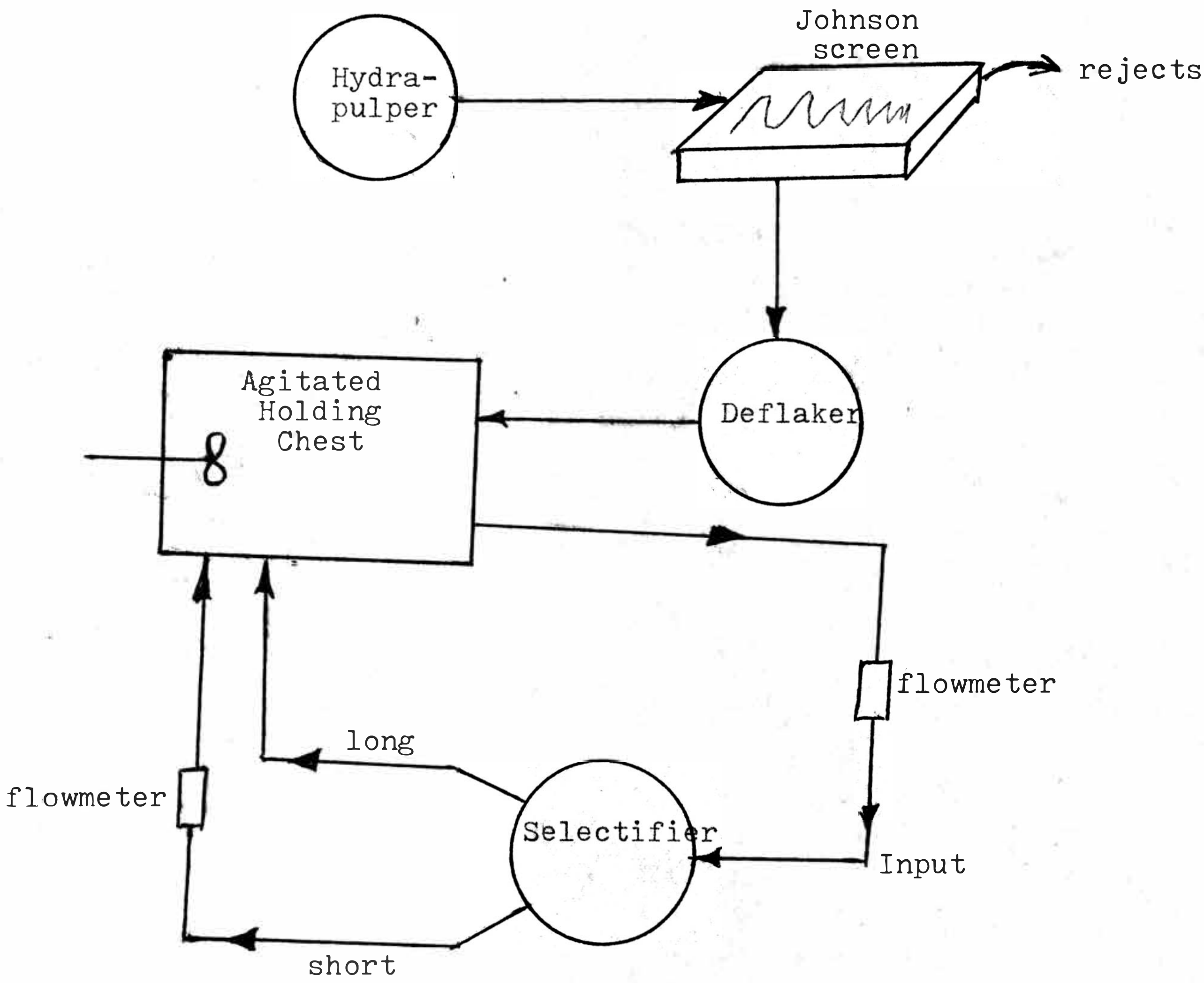
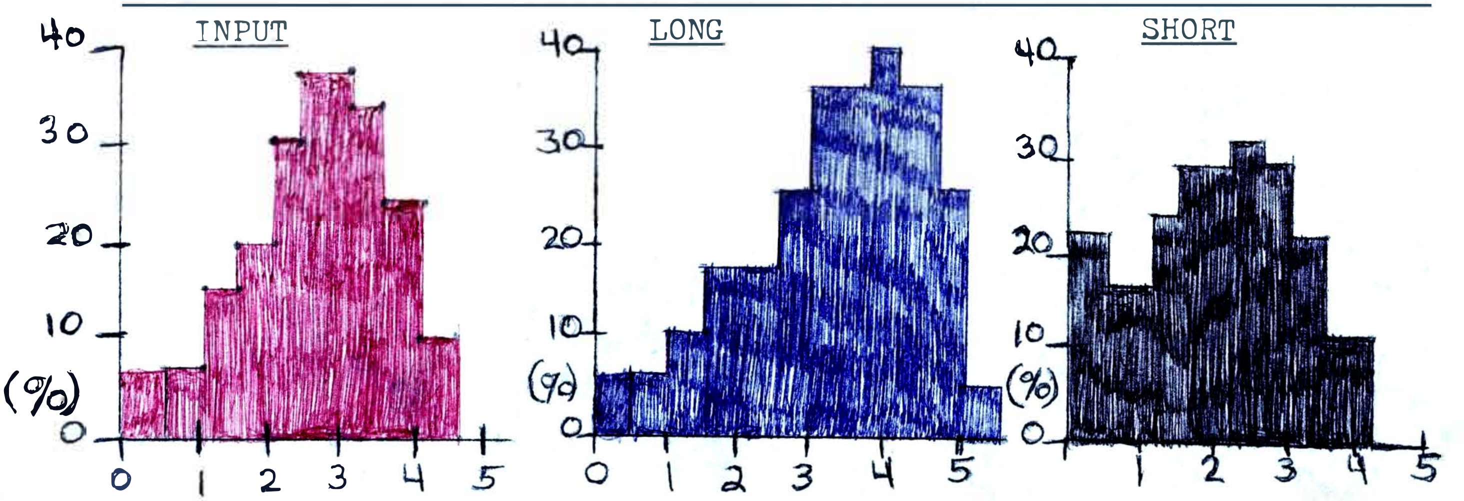


Figure 1

B. Fractionation: Table 1 and Figure 2 report the results of the fiber fractionating process. Table 1 reports the breakdown of fiber lengths by percentage and mean fiber length of each leg of the Clark Classifier.

TABLE 1

	1st Leg	2nd Leg	3rd Leg	4th Leg	Fines
Input Stock %	28.2%	36.4%	20.5%	10.7%	4.2%
-Mean Fiber-length	3.35mm	2.97mm	1.88mm	1.03mm	<1.03mm
		(total mean = 2.45mm)			
Long Stock %	28.6%	36.6%	20.5%	13.1%	1.2%
-Mean fiber-length	4.45mm	3.16mm	1.57mm	0.93mm	<0.93mm
		(total mean = 3.14)			
Short Stock %	2.3%	32.5%	25.9%	16.1%	23.1%
-Mean Fiber-length	3.88mm	2.55mm	1.34mm	0.68mm	<0.68mm
		(total mean = 1.41mm)			



Mean Length = 2.15mm Mean Length = 3.14mm Mean Length=1.41mm

Figure 2

C. Fiber-Conditioning: Figure 3 is a diagram of the procedure that was used to thicken the pulps to the 10% consistency required for refining.

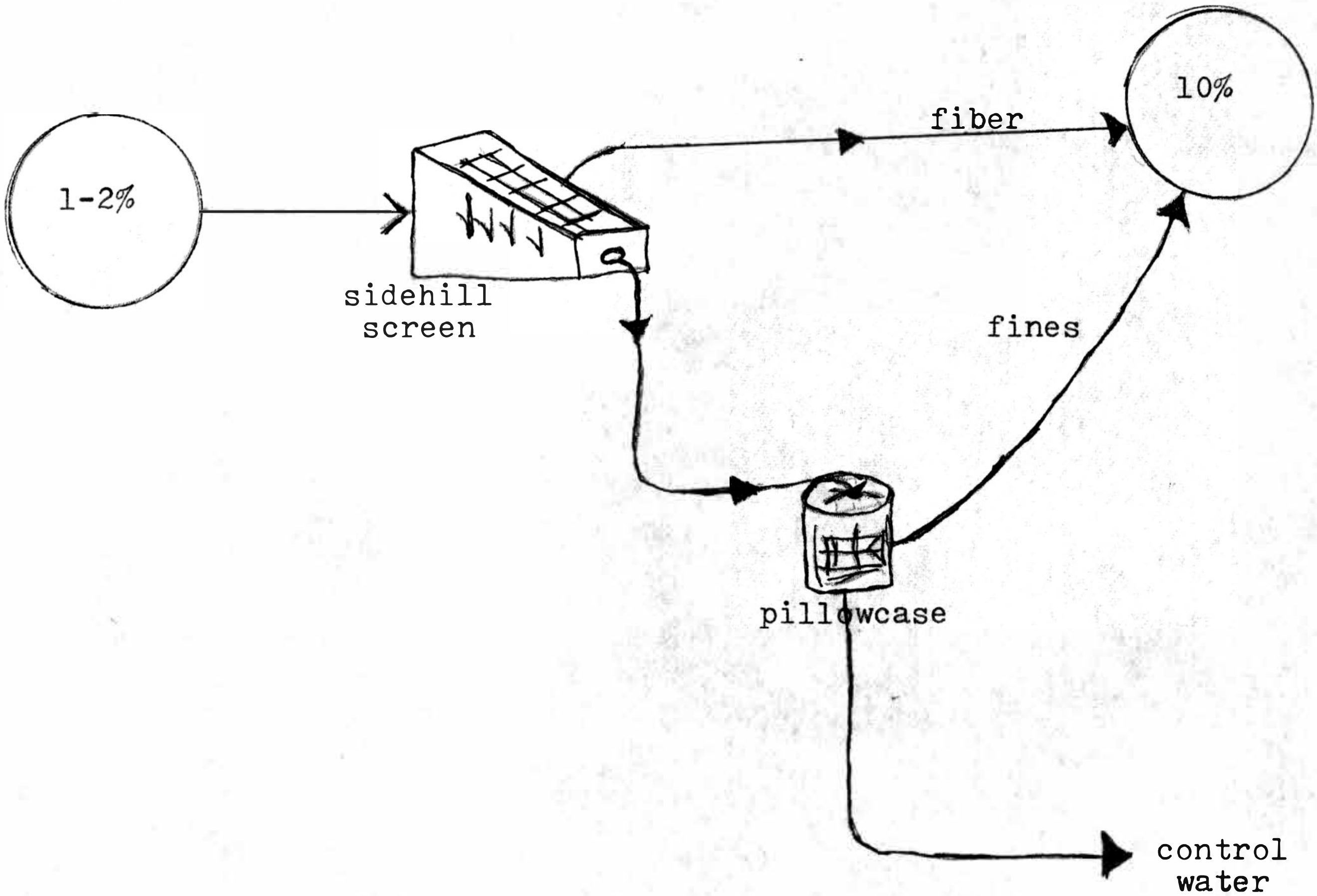


Figure 3

D. Refining and Energy Consumption: Figure 4 is a diagram showing the calibration curves for each pulp, which was used to determine HPD/T. Table 2 shows the refining times and corresponding energy consumption for each pulp.

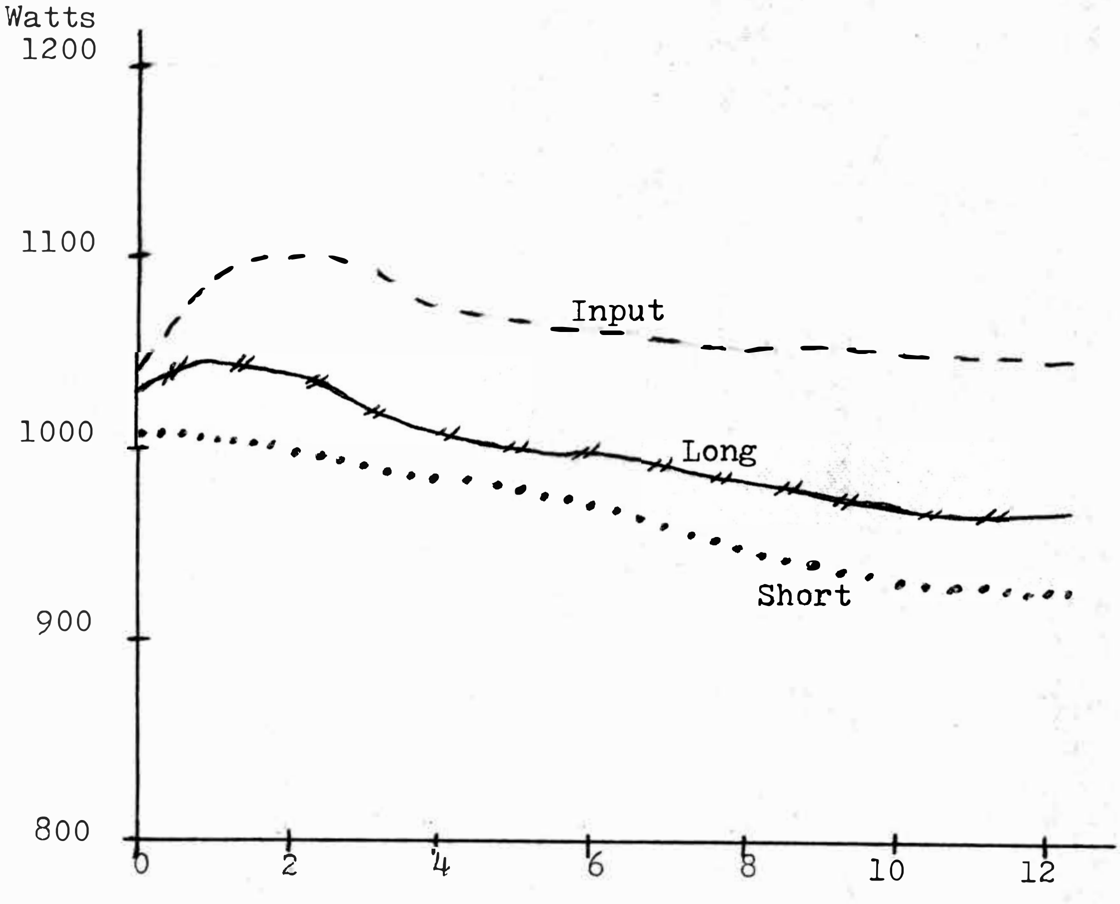


Figure 4

Table 2

Input Fibers

Time	HPT/D
0	0
2	45.7
4	92.0
6	136.8
8	181.0
10	224.8
12	268.1

Short Stock Refining Time (Min.) 27.3%

Long Stock Refining Time (Min.) 72.7%

HPT/D

Long Stock Refining Time (Min.)	0	2	4
0	0	11.7	35.1
2	32.1	43.8	67.2
4	63.6	75.3	98.7
6	94.5	106.2	129.6
8	125.0	136.8	160.2
10	155.2	166.9	
12	184.9		

E. Handsheet Test Result: All of the test data is contained on the computer printout sheets on the following pages.

i) Observations 1-8 are the results for the input fiber.

ii) Observations 9-11 are the results for the input fibers formed with the control water from the the thickening process.

iii) Observations 12-29 are the results for the long and short fiber mixtures as indicated under the variable headings.

Variable	Variable Description
Long	(Applies for Observations 12-29 only) denotes the time, in minutes of refining, of the long fiber portion of the handsheet makeup.
Short	(Applies for Observations 12-29 only) denotes the time, in minutes of refining of the short fiber portion of the handsheet makeup.
BW	Mean basis weight of handsheets tested.
SDBW	Standard deviation of the basis weights of the handsheets tested.
TR	Tear strength of handsheet tested.
SDTR	Standard deviation of tear strength
TN	Tensile strength of handsheets
SDTN	Standard deviation of tensile strength.
Energy	Calculated input energy in HPD/T for handsheet.

OBS	LONG (VAR)	ENERG	SHORT	BW	SDBW	TR	SDTR	TN	SDTN
1	1.000000	0.0000000	0.0000000	3.283300	0.7700000E-01	88.92273	2.280000	4.550300	0.3700000
2	1.000000	45.73500	2.000000	3.336100	0.7420000E-01	112.4067	13.21600	6.132910	0.7937000
3	1.000000	92.01000	4.000000	3.301400	0.7110000E-01	121.0396	2.308000	7.239656	0.3265000
4	1.000000	136.8060	6.000000	3.342500	0.7440000E-01	111.2939	10.58000	7.782857	0.9655000
5	1.000000	181.0520	8.000000	3.147300	0.6590000E-01	110.5710	10.58400	8.578782	0.6233000
6	1.000000	224.7910	10.00000	3.166400	0.5510000E-01	97.01870	7.797200	10.26797	0.7854000
7	1.000000	268.1080	12.00000	3.221000	0.7370000E-01	86.61906	3.829600	10.85728	0.8423000
8	3.000000	0.0000000	0.0000000	3.092700	0.6640000E-01	96.03259	14.37560	4.158987	0.2356000
9	3.000000	92.01000	4.000000	3.179300	0.5050000E-01	126.0655	19.10000	6.915201	0.8750000
10	3.000000	181.0520	8.000000	3.205100	0.3930000E-01	112.3210	5.656800	8.678107	0.9655000
11	3.000000	268.1080	12.00000	3.124400	0.3010000E-01	101.7795	2.309200	9.205768	1.159300
12	0.0000000	0.0000000	0.0000000	3.118000	0.2720000E-01	87.87672	4.676000	4.604586	0.2609000
13	0.0000000	11.73900	2.000000	3.223600	0.1386000	94.55267	6.066000	5.362793	0.6162000
14	0.0000000	35.13000	6.000000	3.139000	0.3680000E-01	98.75744	6.889600	5.782096	0.2878000
15	2.000000	32.10500	0.0000000	3.139100	0.8180000E-01	113.5357	9.756800	6.821223	0.4373000
16	2.000000	43.84400	2.000000	3.050400	0.1740000E-01	118.0173	9.797600	6.474528	0.2562000
17	2.000000	67.23500	4.000000	3.203000	0.4820000E-01	114.6425	4.560400	6.449297	0.7033000

OBS	VAR LONG	ENERG	SHORT	BW	SDBW	TR	SDTR	TN	SDTN
18	4.000000	63.59700	0.0000000	3.160800	0.1790000E-01	120.2224	16.65320	7.348900	0.8202000
19	4.000000	75.33600	2.000000	3.200400	0.1740000E-01	102.1748	3.829600	7.545900	0.5128000
20	4.000000	98.72700	4.000000	2.867600	0.3060000E-01	110.4757	13.44600	7.793974	0.3563000
21	6.000000	94.47000	0.0000000	3.016500	0.6340000E-01	112.1828	13.38640	7.046900	0.8153000
22	6.000000	106.2090	2.000000	3.029100	0.3780000E-01	103.7920	3.346400	7.366000	0.7130000
23	6.000000	129.6000	4.000000	2.981000	0.6320000E-01	109.6947	15.79000	8.470245	0.4996000
24	8.000000	125.0420	0.0000000	3.108900	0.9450000E-01	94.95320	4.560400	7.375084	1.646000
25	8.000000	136.7810	2.000000	3.047500	0.2490000E-01	95.81611	4.618800	7.432322	0.9501000
26	8.000000	160.1720	4.000000	2.994200	0.1960000E-01	104.2015	6.531600	8.316078	0.7171000
27	10.00000	155.1510	0.0000000	2.785200	0.1176000	93.92503	3.346400	8.186127	0.9841000
28	10.00000	166.8900	2.000000	3.118800	0.4000000E-01	98.11466	5.163600	8.492208	0.5589000
29	12.00000	184.9780	0.0000000	3.032200	0.5060000E-01	107.8425	2.000000	7.618231	0.6033000

Figures 5 and 6 show the relationship of Input fibers without control water make-up and Input fibers with control water, with respect to tear strength and tensile strength respectively.

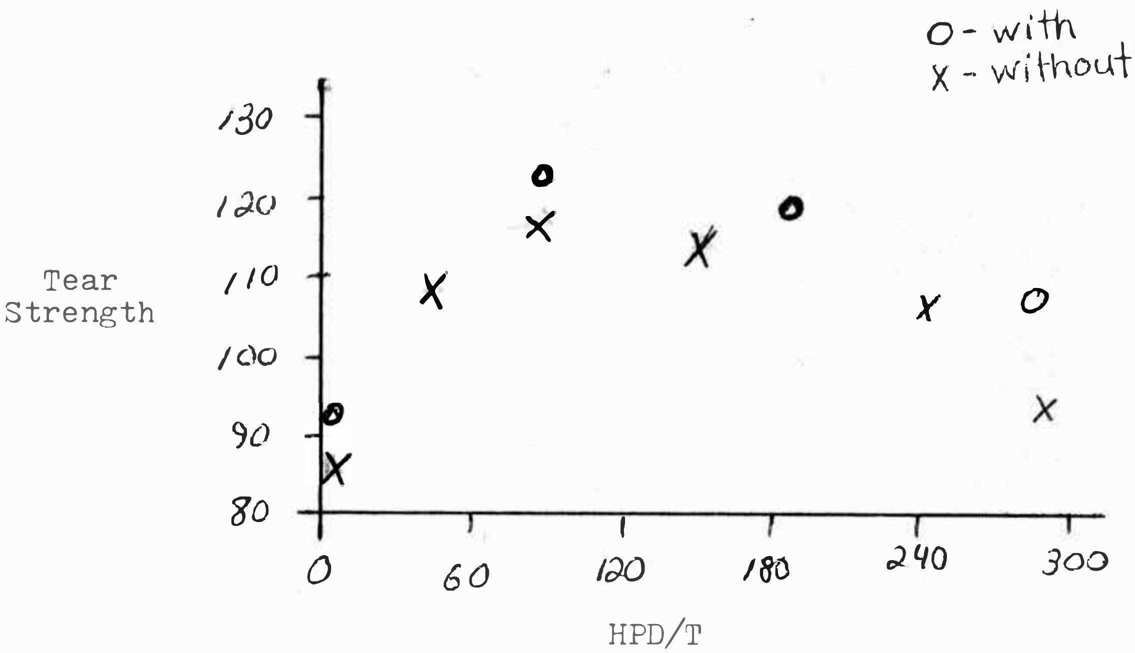


Figure 5

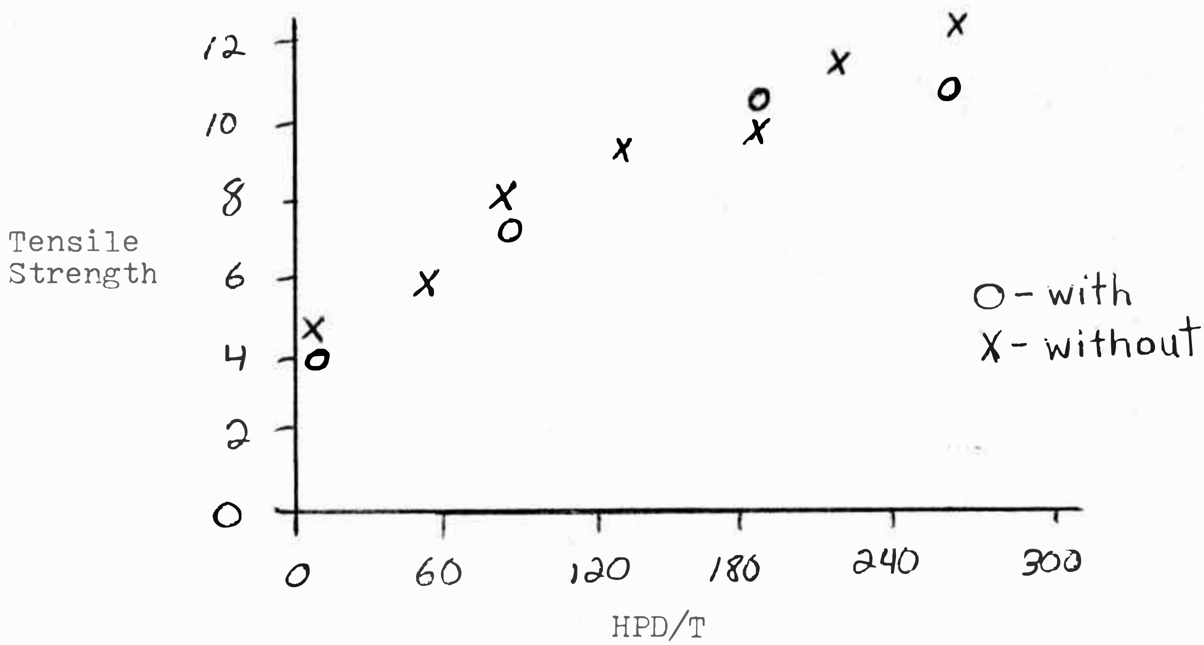


Figure 6

Figures 7 and 8 are plots of tear strength and tensile strength vs. energy input, respectively. The squares represent the input pulps and the triangles represent long and short fiber mixtures.

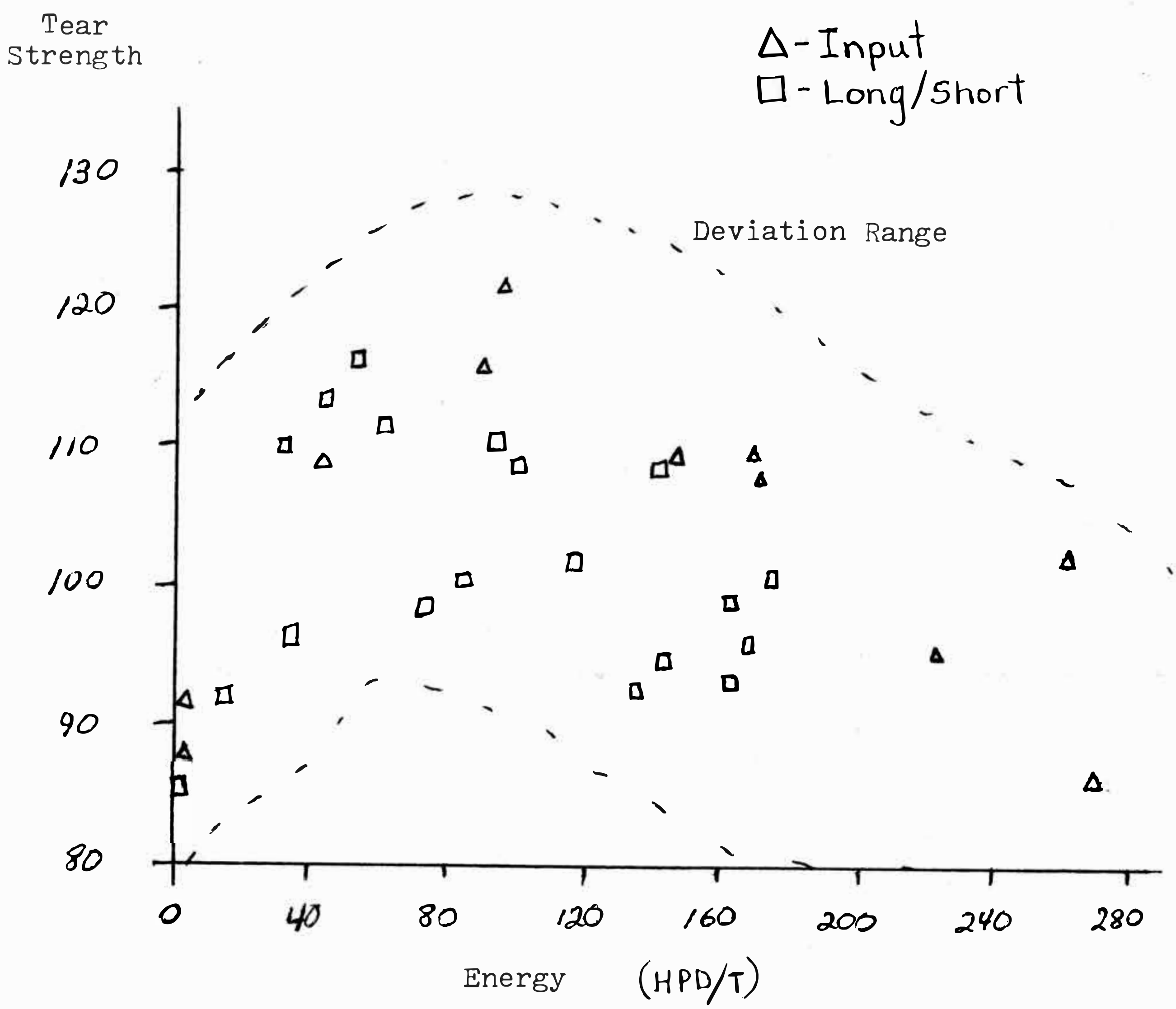
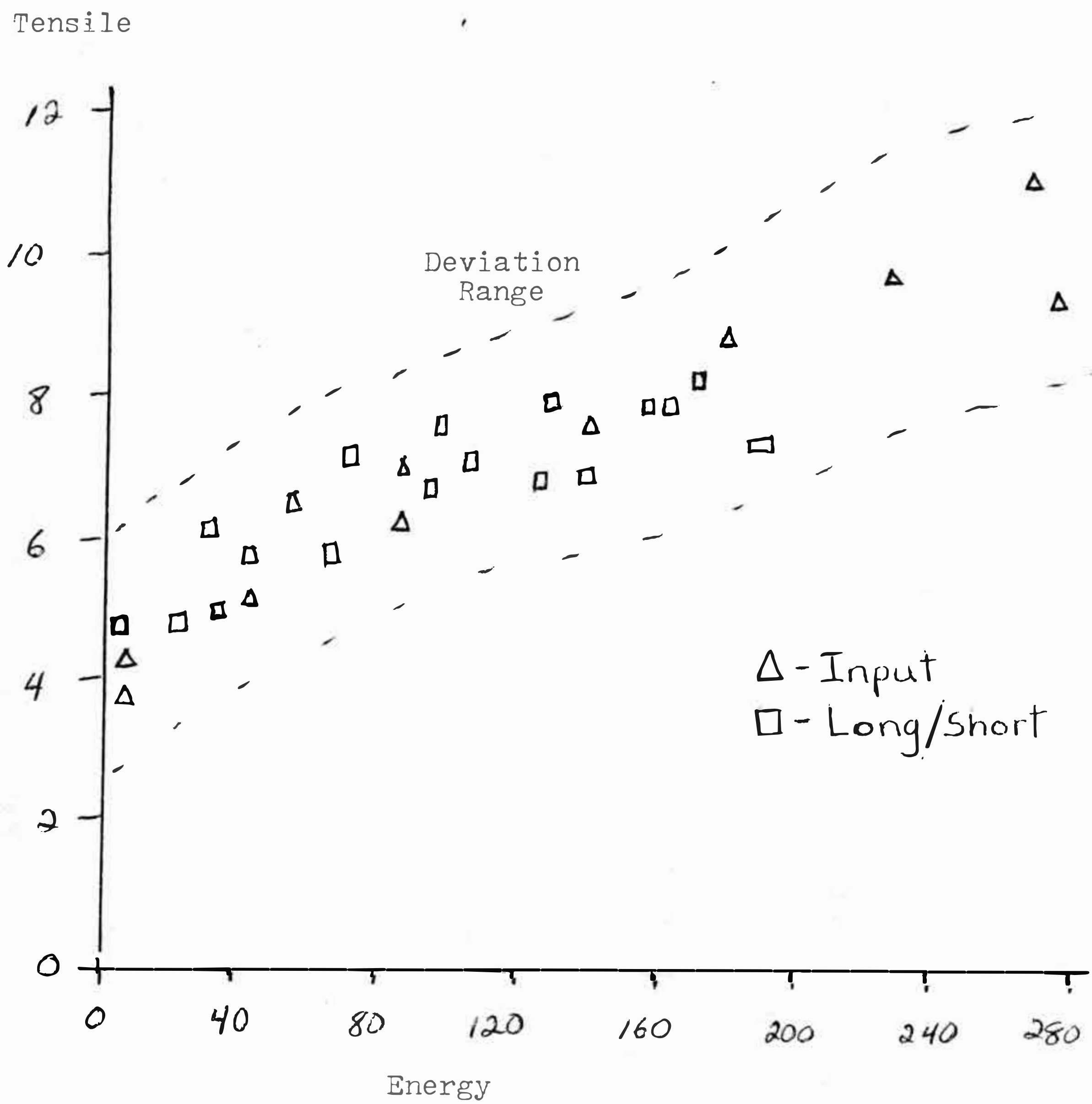


Figure 7



Tensile
12
10
8
6
4
2
0
Deviation
Range
Δ - Input
□ - Long/Short
0
40
80
120
160
200
240
280
Energy

Figure 8

VI. Discussion of Results and Conclusions

A. Fractionation: Table 1 and Figure 2 represent the degree of separation of long from the short fibers I attained with the Black Clawson Selectifier Screen. Clearly the mean fiber lengths bare out that a good separation took place. Keep in mind that the bar graphs for the long and short fibers are not directly additive, there is about three units of long fiber for every one unit of short in the input fiber.

B. Refining and Energy Consumption: Table 2 and Figure 3 were used together to determine the energy consumption for each pulp refined. An explanation for the differences in energy consumption is difficult. Perhaps a pulp exhibits cohesive characteristics, or flexibility somewhat in line with the bonding strength values for paper. A mixture of fiber lengths yields an overall stronger sheet than does either a sheet made of all long fiber or a sheet of short fiber. The long fiber distributes forces over many bonding sites while the short fibers fill between the long and provide bonding between, much like the trade-off of between tear and tensile strengths.

C. Handsheet Test results: Figures 5 and 6 show the relationship between the two sets of handsheets made with and without the control water. Though a slight trend may be seen in Figure 5, tear strength vs. energy consumption. When the standard deviation is applied to the points, the areas created overlap nearly completely. Figure 6, tensile vs. energy consumption, should be more sensitive to bonding differences accountable by fines, because tensile strength is greatly attributed to bonding. Figure 6 shows overlap of not only the deviations but also the points. I conclude no difference between the sheet strengths of the handsheets made with and without the control water from the fiber thickening steps.

Figures 7 and 8 are the plots of tear strength and tensile strength vs. energy consumption respectively. The squares represent the input fibers and the triangles represent the long short fiber mixtures. From the overall randomness of the triangles and squares above one-another, and the overlapping of standard deviations, I conclude that there is no difference in the strengths of the handsheet, for equal amounts of energy consumed by their refining.

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Appendix A

Input Consistency = 2.0%

Short Fiber Consistency = 0.88%

Long Fiber Consistency = 4.0%

Flowrates

Input stream	128.7 gpm
Short stream	81.6 gpm
Long stream	47.1 gpm

Fiber Split Calculations

	Input		Short		Long
flowrates	128.7	=	81.6	+	47.1
lbs./min. (8.34 lb./gal)	1073.4	=	680.5	+	392.9
at	2.0%		0.88%		4.0%
$\frac{\text{lb. O.D. Fiber}}{\text{min.}}$	21.5	=	6.0	+	15.5

Short $= \frac{6}{21.5} = 27.7\%$

Long $= \frac{15.5}{21.5} = 72.3\%$