PROOF OF CONCEPT TEST AND EVALUATION
LASENTEC REFINING SENSOR

ANNUAL PROGRESS REPORT

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LASENTEC REFINING SENSOR
1990 EVALUATION & DEVELOPMENT REPORT

1. ABSTRACT

The Scanning Laser Microscopes (SLM) LAB-TEC 150 and PAR-TEC 200, were evaluated as instruments for monitoring fiber development during refining.

The LAB-TEC 150 did not produce repeatable results which could be related to fiber development, as measured by Canadian Standard Freeness or hand sheet physical strength properties.

The PAR-TEC 200 was found to correlate to strength development (Burst and Tensile Indices) during the first stages of laboratory Valley beating of bleached hardwood and softwood pulps. Preliminary testing of the PAR-TEC 200 in a pilot scale refining circuit was inconclusive. The influence of several process variables on instrument readings was investigated including flow rate, probe position and consistency. It is likely that a dual sensor system would be required in a commercial mill environment, to eliminate the effect of process variables.

The next phase of the evaluation and development program will include two investigations: (1) A more scientific evaluation of which changes in fiber morphology the sensor is detecting during refining, and (2) a continuation of the in-line development; with a goal of eliminating process flow variables, and more accurately monitoring fiber development, by the use of two sensors, one before and after refining.

2. INTRODUCTION

On-line measurement of refining development is of vital concern to the papermaker since its control directly affects uniformity of the product, drainage, drying and energy consumption. The current methods of monitoring fiber development during refining rely on secondary measures such as: drainage rate, either measured off-line as Canadian Standard Freeness, or on-line with a number of commercial devices; energy consumption at the refiner; or changes in vacuum on the paper machine.

The purpose of refining is to enhance the properties of individual fibers in the pulp slurry by means of mechanical treatment. A direct measure of the changes taking place in the individual fibers could provide direct control of fiber development.

The Lasentec Scanning Laser Microscope is an instrument which measures the size of particles in a slurry. In this end use, those particles would be pulp fibers. Changes in mean fiber diameter and the quantity of fines produced can be measured on a statistically significant basis in real time. This provides valuable information which could be used to control the refining process. The use of this instrument in this manner was described by Mustonen, Hanseler and Preikschat.

The Scanning Laser Microscope was shown to measure changes in fiber structure (Figure 1) by detecting changes in the weighted average fiber size (dWA). These fiber changes were accompanied by changes in physical properties of pulp. The suitability of this system for monitoring fiber development in-line is the subject of this investigation.

The Scanning Laser Microscope is a proprietary technology described in more detail in Appendix I. A laser beam is focused on a very small spot at high intensity, and scanned across individual fibers. As the beam scans across individual fibers it produces back scattered light pulses which are picked up by photo detectors. The fiber size distribution is statistically determined from the classification and counting of the length of the pulse generated as the laser beam scans across individual fibers. Figure 2 shows a set of results obtained with the LAB-TEC 150.

3. OBJECTIVE

The objective of this project is to confirm that the Lasentec Scanning Laser Microscope (SLM) values correlate to fiber development during refining as indicated by handsheet physical strength properties. Once the correlation has been established, the next phase would be to establish that the sensor is ready for use in a commercial mill environment. This would include testing the effect of a number of controlled variables such as flow rate, consistency, temperature, pH and alum.

The original proposal was to look at the suitability of the sensor for both conventional refining and TMP applications. Work to date has centered entirely on the conventional application. Once that application is established, then the TMP application would be investigated.

The conventional refining program would be outlined as follows:

1. Verification of previous data.

Duplicate the results of the work done by Lasentec at the University of Washington in a Valley beater and described by Mustonen, et. al.

2. Pilot Scale Study

Install the sensor in a continuous refining system based around a 16" Beloit-Jones Double-D refiner. In this phase, various process variables and pulp types would be evaluated.

3. Commercial Application

Install the sensor in a commercial mill and monitor results in a plant setting.

The original study at the University of Washington was done with a LAB-TEC 150 designed for measuring particle size and other particle size-related properties on a laboratory bench top. An in-line version of this instrument is the PAR-TEC 200. It was needed to first establish if the LAB-TEC and especially the PAR-TEC would be able to monitor fiber development during refining. It was most important that the in-line PAR-TEC probe be demonstrated as suitable for monitoring refining, as this unit was being looked at as the in-line probe for mill use.

4. **EQUIPMENT**

- 4.1. **LAB-TEC 150**

The LAB-TEC 150 is in commercial use as a fiber analyzer for pulp and paper applications. This laboratory system is shown in Figure 3. Undiluted pulp samples are placed in a supplied beaker and the agitator turned on. A user friendly menu steps the user through the set-up, measuring and print-out process. A typical set of results for pulp is shown in Figure 2. The change in mean size or weighted average mean size is reported as indicative of changes in the pulp slurry which relate to strength development due to refining.

- 4.2 **PAR-TEC 200**

The PAR-TEC 200 shown in Figure 4, is an in-line version process analyzer for particle size measurements.

The measuring principle for the PAR-TEC 200 is the same as for the LAB-TEC 150 (see Appendix I). The results from the PAR-TEC 200 can be reported as shown in Figure 5.

In this investigation the unit was utilized in 3 different configurations: (1) It was used to measure particle size in a beaker by inserting the probe head into the agitated slurry, as shown in Figure 6. (2) The probe was also mounted directly in a Valley beater, as shown in Figure 7. (3) The last configuration was to install it in a Pilot Refiner Circuit, as shown in Figures 8 and 9.

4.3 Pilot Refiner Circuit

The Herty pilot refiner circuit is shown in Figure 9. This consists of a 4"-10 foot section of clear PVC pipe ahead of a 16" Beloit-Jones Model 4216 refiner, with a probe port just before the refiner. On the exit side of the refiner, are three additive ports and an in-line mixer. From here, it is a straight horizontal 9 foot run through another section of 4" clear PVC pipe to the second probe position. A Fisher & Porter flow controller is used to maintain flow at 4.5 ft/sec (180 gpm). Samples are taken from the drain line following the flow controller. The PAR-TEC 200 probe is mounted as shown in Figure 8, in a side position of the 4" pipe, to avoid the effects of material stratification such as air on top and contaminants on bottom of the pipe. Refiner plates D58707040 and D58707041 were used for refining the hardwood pulp. Refiner plates D58707002 and D58707003 were used for refining softwood pulp.

4.4 Pilot Flow Loop

A separate flow loop is set-up using one of the sections of the PVC pipe and no refiner. Pulp is pumped from a 1500 gallon chest through the PVC pipe and past the probe. Flow is controlled with a Fisher & Porter flow controller installed after the probe and before returning the stock to the 1500 gallon chest. The purpose of the flow loop set-up is to investigate the influence of variables such as flow, probe position and consistency on the readings in a recirculation loop without doing any refining on the pulp.

5. EXPERIMENTAL

5.1 Materials

Two types of bleached kraft pulp were used in this study. The bleached southern softwood kraft was Albacel from Federal Paper Board Co., Inc. The bleached southern hardwood pulp was Astracel, also from Federal Paper Board Co., Inc. Sufficient pulp was purchased at the beginning of

the contract, so that all the testing to date has come from the same shipment of pulp.

5.2 Valley Beater Studies

5.2.1.

Bleached hardwood and softwood pulps were soaked over night, before being subjected to beating in a one pound laboratory Valley beater. Samples were taken before beating began, and then at pre-determined freeness levels. Five points were sampled for testing the hardwood pulp, and seven points for the softwood pulp. Each sample was tested for Canadian standard freeness, Kajaani fiber length, bursting strength, tensile strength, and tearing resistance. LAB-TEC 150 and PAR-TEC 200 measurements were both taken in a beaker on 1.2% consistency pulps. Sufficient pulp was taken at the middle point of each curve for Bauer McNett classifications, and additional testing of each classification point.

5.2.2

In its first evaluation, the output of the LAB TEC instrument indicated that service repairs were required. The output was skewed towards smaller size counts as seen in Figure 10. When the LAB-TEC 150 was returned after servicing, the Valley beater study was repeated. Two five point Valley beater runs were made with the hardwood pulp. Two seven-point Valley beater runs were made with softwood pulp. An extra large sample was taken at the midpoint of each curve for Bauer-McNett classification. Each classification was tested for Lasentec values (LAB-TEC and PAR-TEC) and Kajaani fiber size. The LAB-TEC 150 values were taken as conventional beaker measurements. The PAR-TEC 200 probe was installed directly into the Valley beater as shown in Figure 7. During each PART-TEC measurement, the weight was removed from the bed plate to reduce beating for the duration of the measurement.

5.3 Pilot Refining Study

5.3.1 Softwood Pulp

The single PAR-TEC 200 probe available was mounted after the refiner. In an actual mill use, two probes would be required, one before and one after the refiner, so that the changes in pulp characteristics occurring during refining could be accurately monitored.

Pulp was disintegrated in a Black-Clawson hydropulper and transferred to a 7000 gallon chest where consistency was adjusted to 2.5%. The softwood pulp was refined in a single pass through the refiner, with no recirculation. Following

the single pass, the pulp was sewered. At a flow of 4.5 ft/sec samples were taken at 5 different power settings, ranging from 0 (no load) to 121 kw. Each PAR-TEC measurement consisted of duplicate readings, taken one right after the other. A pulp sample, for other tests, was taken when the second PAR-TEC reading began. Each power setting was duplicated, for a total of 10 samples and readings.

The samples taken from the drain line were tested for Canadian Standard Freeness, Kajaani fiber length, bursting strength, tensile strength, and tearing resistance. The PAR-TEC 200 was used to make dynamic measurements, with the probe in-line, as well as off-line as a beaker sample with the probe installed as shown in Figure 6. The two sets of measurements were taken in order to compare the 2 measuring configurations. The probe was checked and focus adjusted using a reference PVC solution.

For wood pulp applications, the sensor only counts pulses in 2 opposing 90° quadrants of the circular scan path, in an attempt to remove the influence of flow on the measurements. For softwood pulp, the active scanning areas of the sensor were oriented parallel to the pulp flow.

5.3.2 Hardwood Pulp

The refiner plates were changed to a finer bar pattern, D58707040 and D58707041. The probe was mounted with the active scanning areas across the flow for the hardwood pulp. Pulp preparation and testing was the same as for the softwood pulp, except the 5 net power readings ranged from 0 (no load) to 50 kilowatts.

5.4 Pilot Flow Loop

The refining circuit results indicated that flow conditions could be an important source of variation. Using a single clear PVC section of pipe, described in section 4.4, a flow loop was set up to investigate if flow rate, consistency and probe position could explain some of the results obtained with the refining circuit.

The trial program consisted of evaluating the probe at two flow rates, 4.2 and 1.8 ft/sec, and a number of probe positions, achieved by moving the probe in and out of the probe holder, at 1/2 inch intervals. These initial tests were done at consistencies ranging from 2.6 to 1.6%.

As the testing progressed, it was found that focus could have an influence on the mean size results. By the end of the program, focus was checked and adjusted as necessary after each change in condition, i.e. either a change in flow rate or probe position.

6. RESULTS

6.1 Valley Beater Results

6.1.1 LAB-TEC 150

In the first trial series, the LAB-TEC 150 readings did not show a good correlation to Canadian Standard Freeness or physical strength results. Refer to Tables 1 to 4. It was also noticed that the particle size distribution was very skewed, towards the smaller channel counts, see Figure 10. The instrument was returned to Lasentec for servicing.

Upon receiving the instrument back from Lasentec, a second series of tests was conducted. Measurement of the particle size distribution was more typical of a hardwood or softwood pulp. Results of the second series of tests are shown in Figures 11, 12, 13 and 14. It can be seen that the results do not show an acceptable correlation between LAB-TEC 150 readings and pulp strength or freeness. Figure 13 does show a general relationship.

In order to gain a better scientific understanding of which changes in fiber morphology the SLM is detecting, one refined pulp sample was classified into four Bauer-McNett fractions. LAB-TEC 150 and Kajaani measurements were taken and are shown in Figures 15 and 16. For the softwood pulp there is a significant parallel relationship, although the offset varies with screen mesh. For hardwood pulp the results were not as good. The sensor readings paralleled Kajaani readings for the middle fractions, but not the whole pulp or 100 mesh fraction.

Since the objective of the program was to establish the use of the SLM as an in-line tool for monitoring fiber development, it was decided not to pursue further test work with the LAB-TEC 150.

6.1.2 PAR-TEC 200

The first Valley beater trial with measurements made in a beaker, was inconclusive. The PAR-TEC results are shown in Figures 17, 18, 21 and 22. It can be seen that in the early stages of beating, the PAR-TEC mean size generally follows Canadian Standard Freeness with the softwood pulp, (Figure 17) and strength development, (Figure 21). For the hardwood pulp, there is no clear relationship, as seen in Figures 18 and 22.

In the second Valley beater trial, mounting the PAR-TEC 200 probe directly in the beater improved the results as seen in Figures 19, 20, 23 and 24. The PAR-TEC mean size results generally follow the development of the physical strength properties of burst index and tensile index, for

the softwood pulp (Figure 23). The results for the hardwood pulp were again found to be less promising (Figure 24). For hardwoods, the sensor is not indicating as significant a change in particle size. This may be the instrument, or it may reflect actual fiber morphological behavior.

The investigation of individual Bauer-McNett pulp fractions for one refined sample was repeated for the PAR-TEC 200, in order to gain additional understanding of which fiber elements this sensor is detecting and monitoring. The results are shown in Figures 25-28. The relationship between PAR-TEC sensor readings and C.S.F. reading (Figures 25 and 26) is not consistent. The whole pulps and 14/20 mesh sample readings show a good correlation. The other mesh fractions are less clear to interpret. The relationship between PAR-TEC readings and Kajaani fiber length, Figures 27 and 28, is reasonably good for the softwood 8, 14, 28 and 100 mesh fractions, and the hardwood 20, 35 and 28 mesh fractions. The softwood and hardwood whole pulps and hardwood 100 mesh correlation is less clear.

The laboratory results indicate there is an overall response of the PAR-TEC instrument to changes in fiber dimensions during refining. It is unclear at this point as to the relationship between instrument readings and fiber morphology.

6.2 Refining Circuit Studies

The refining circuit was used to monitor strength development following a single pass through a Beloit-Jones 16" Double-D refiner. While in-line PAR-TEC measurements were being made at various refining energy inputs, samples were collected for further testing. Besides measuring C.S. Freeness, Kajaani fiber length and pulp strength properties, a pulp sample was placed in a beaker and the PAR-TEC probe used to measure mean size as shown in Figure 6.

6.2.1 Correlation with C.S. Freeness

Figures 29 and 30 show the relation between in-line and beaker sample PAR-TEC sensor readings and C.S.F. The PAR-TEC readings do not show the same refining response sensitivity as does freeness although the trends are uniform. Note also, that the in-line readings for softwood pulp refining are lower than beaker sample readings (Figure 30), while for the hardwood pulp samples the in-line readings are higher (Figure 31). This lack of consistency between in-line and baker samples indicates there may be in-line flow effects that need to be investigated.

6.2.2 Correlation with Strength Property Development

Figures 31 and 32 compare the PAR-TEC readings with pulp strength development. For the softwood pulp refining in Figure 32, it can be seen that there is a correlation between in-line PAR-TEC results and strength development.

The hardwood results show that with the refiner plates chosen, there was very little strength development (Figure 31) for the energy applied. The results are not as consistent as with the softwood pulp but there does appear to be some correlation between strength development and PAR-TEC results.

6.3 Flow Loop Studies

The primary goal of this study was to determine if flow rate, consistency, and probe position had a significant influence on PAR-TEC mean size measurement. Ideally, there should be no effect, and the PAR TEC readings should remain constant.

6.3.1 Effect Flow Rate

Figure 33 indicates flow rate does have an effect. This needs to be eliminated if the unit is to be commercialized.

6.3.2 Effect of Probe Position

Figure 34 indicates probe position can have an effect. For future work, one particular position will be selected. The position of 0.5 to 1 inches from wall gave the highest response readings. In a commercial application, position may only have an influence when the probe is first installed. It would have to be installed so the value which gave the best response to refining was achieved.

6.3.3 Effect of Consistency

From 1.65% to 2.32% consistency, there was no effect on PAR-TEC readings. There was an effect at 2.62% consistency, as seen in Figure 35.

6.3.4 Effect of Focus Adjustment

As testing progressed, it was found that the probe was very sensitive to focus adjustment. Part of the set-up procedure includes a display screen with peak count value. Focus adjustment is made until the maximum value is achieved. When the focus was checked after making a process adjustment, such as changing flow rate, it was often found that the focus had to be re-adjusted. For each of the last 14 samples, the PAR-TEC mean size was checked after the

change in process variable, and again after the focus adjustment. The results are shown in Table 17 and Figure 36. It can be seen that there can be large changes in apparent particle size by changing the focus. All the values in Table 15 are focus adjusted values.

7. CONCLUSIONS

7.1 The results obtained with the Lab-TEC 150 sensor in the original study performed at the University of Washington could not be reproduced. The LAB-TEC 150 is not an in-line refining sensor, but is currently being utilized as a lab instrument.

7.2 The PAR-TEC 200 particle size analyzer results appear to relate to refining development of softwood pulp, both in the Valley beater and in-line. Hardwood pulp results were less clear.

7.3 PAR-TEC 200 readings do vary significantly with different pulp fractions, indicating the sensor is responding to different fiber morphologies and dimensions. The exact relationship is not clear at this time.

7.4 It appears that in a commercial environment where any number of process variables can influence the mean size readings, two sensors will be required. The upstream and downstream readings must cancel out effect of flow rate, consistency, etc. and give a direct response to changes in the pulp due to refining.

8. FUTURE WORK

It has been shown that the PAR-TEC 200 mean size reading relates to burst and tensile strength, when bleached softwood pulp is beaten in a laboratory Valley beater or refined in a 16" disc refiner.

The next phase of the evaluation and development will attempt to accomplish two objectives:

- A. Provide a better scientific understanding of what changes in fiber structure the scanning laser microscope is sensitive to in its readings. An expansion of the work performed on individual pulp fractions is proposed.
- B. Identify and attempt to minimize the effects of process flow variables through the use of a dual probe arrangement before and after the refiner.

A. FUNDAMENTAL WORK

The fundamental, scientific work is designed to provide a better understanding of the particle size measurements made with the PAR-TEC probe and how sensitive these measurements are to fiber development during refining under controlled conditions. The proposed work would entail a more detailed study of bleached softwood pulp at each of three freeness levels. The three freeness levels would be unbeaten pulp(+700 ml CSF), and two lower levels. Refining would be done in the laboratory beater where fibers receive a uniform treatment. A similar study will be done at a single freeness point from the 16" Beloit-Jones Double-D refiner, once a suitable measuring configuration is established. Approximately the same C.S. freeness will be chosen for the disc refiner study to determine if the PAR-TEC is sensitive to the differing fiber development occurring with the two different refining methods.

Pulp from each sample point would be subjected to the following analyses: Lasentec measurements, Canadian Standard freeness, tensile strength, tearing resistance, apparent density, Kajaani fiber length and coarseness, and photomicrographs. Each sample would also be classified with a 4 screen Bauer-McNett classifier. A portion of the overflow would be captured and filtered, so that the "fines" fraction could be analyzed. Sufficient pulp would be collected in each fraction to do C. S. freeness(except for the fines fraction), Kajaani measurements, Lasentec measurements, and photomicrographs. At each freeness level, a final Bauer-McNett sample, consisting of the whole pulp minus the fines would also be tested in the same manner as the individual Bauer-McNett fractions.

The data will be examined and analyzed to infer correlations between the fiber characteristics as quantified by the above test results and the Scanning Laser Microscope.

B. Two-Probe Study

The original investigation has indicated that various process variables can have an influence on the PAR-TEC mean size readings. To overcome the influence of process variables, it is recommended that a two-probe system be investigated, which could neutralize these interferences.

One of the two sensors to be utilized could be the PAR-TEC 200 unit already at Herty. The other sensor would be the PAR-TEC 100 used as the in-line sensor for measuring consistency in a flow loop. The only significant difference between the two sensors is that the PAR-TEC 100 also measures bulk back-scattered light. Both sensors contain a Scanning Laser Microscope(SLM) for use as a method for

measuring fiber development. The in-line, two-probe system would be developed with assistance from an outside consultant who has worked on the design of the units for Lasentec(2).

Further testing is already provided for under Task I-B, Item 1, of the original proposal, (Set-up and Calibration). The effects of flow velocity, probe position, and consistency will be re-evaluated using the two-probe system, to determine if it can successfully monitor fiber development at a consistency of 4% or greater. The maximum consistency which can be handled at Herty (4-4.5%), will be included in the investigation.

If the two-probe system cannot successfully eliminate the effect of flow rate and/or consistency, then alternative methods of sample presentation would need to be investigated, such as off-line testing or side-stream testing, with or without sample dilution.

Once the optimum measuring configuration is established, an extensive series of laboratory tests would be conducted to more thoroughly understand the capabilities and limitations of the Lasentec two-probe system. The tests to be performed are Lasentec measurements, Canadian Standard freeness, tensile strength, tearing resistance, apparent density, Kajaani fiber length and coarseness, and photomicrographs. The first series of tests would be done on bleached softwood kraft, single stage refined through a 16" Beloit-Jones Double-D refiner. One pulp sample would be fractionated with the Bauer-McNett classifier and studied in the same manner as the Valley beater samples, in Section 8A.

After it is established that the 2-probe system can successfully monitor fiber development on softwood bleached pulp, a more thorough study of the effect of additional process variables on the system would be investigated. (Task I B, Item 2 of the original proposal). The final phase of the pilot scale investigation would be the evaluation of additional pulp types. (Task I B, Item 3).

FOOTNOTES

¹ Mustonen, M, Hanseler, J. and Preikschat, E, "In-Line" Measurement of the Refining Effect - An Important New Tool in the Pulp and Paper Industry, presented at the 19th Annual Meeting of the Fine Particle Society, 1988, Particulate Powder Technology, July 18-22, 1988.

² Markku Mustonen, a former employee of Lasentec, has offered to assist with the in-line development of the sensor. He has an intimate knowledge of both the hardware and software used with the Lasentec sensors, for both refining and consistency applications. He did the original study with the LAB-TEC 150 at the University of Washington. Dr. Preikschat of Lasentec has agreed to give him the necessary assistance. A copy of his resume is included as Appendix II.

Fig. 1 . Changes in burst, fold and tear strength of a sulfite pulp as a function of beating action (minutes of beating in a 'valley' beater.

FIGURE 2

***** LAB-TEC 150 FIBER ANALYZER *****
 REFINING EFFECTS TESTING AT THE UNIVERSITY OF WASHINGTON
 SAMPLE ID: SOFTWOOD
 TEST DATE: 06/27/88
 TEST TIME: 09:59:45

Fig. Data display of the fiber size distribution of unrefined Kraft softwood pulp at 1.65% consistency.

Data Sheet

LASENTEC **LSI**

LAB-TEC™ 150 **FIGURE 3**
Fiber Analyzer
 for Pulp and Paper Applications

Fig The LAB-TEC 150 system with analyzer unit and dedicated output computer.

FIGURE 4

Data Sheet

LASENTEC.

PAR-TEC™ 200/250

**In-Line Process Analyzer
for Particle Size Measurements
with Intrinsically Safe Probe Configuration***

Fig 1. The PAR-TEC™ 200/250 with probe head, field unit and analyzer unit.

FIGURE 5

PAR-TEC PARTICLE ANALYSIS SUMMARY

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PAR-TEC Particle Analysis by Scanned Count : Percent Per Channel

Sample ID : SOFTWOOD-1
Date : 10/07/80
Time : 08:42:32
Cycles : 5
Scaling : 1.00

Cycle Time : 2.2 sec.
Avg Counts/Cycle : 3612
Averaged last 10 cycles

Scanned Counts Mean : 42.1 microns
SDev : 38.1

Fig. 6
The PAR-TEC™ 100 with
bench top unit, dedicated
P/C (IBM compatible)
computer probe head and
adjustable stand.

FIGURE 7

PAR-TEC 200
SENSOR IN VALLEY BEATER

FIGURE 8

FIGURE 9

Herty Foundation

Conventional Refining Circuit

FIGURE 10

LAB-TEC 150 RESULTS
FEBRUARY, 1990 TRIAL

***** LAB-TEC 150 Fiber Analyzer *****

SAMPLE ID:
TEST DATE: 02/13/89
TEST TIME: 08:41:27

		Percent					RAW	WEIGHT	
		0	20	40	60	80	100	COUNT	COUNT
40	0						12%	5719	5719
30							0%	33	33
20							4%	1728	1728
15							4%	2065	2065
10							9%	4117	4117
5							12%	5649	5649
2							16%	7525	7525
< 2							44%	21393	21393

COUNTS PER CYCLE (AVG): 48229   ACCUMULATED COUNT: 482291
 MEAN SIZE: 8.32
 W.AVERAGE FIBER SIZE: 31.94
 OPTICAL DENSITY: 341.2
 SAMPLE CYCLES: 10
 SAMPLE TIME: 3.2 sec.

LAB-TEC Comparison to C. S. Freeness

Figure 11
Softwood Beating

Figure 12
Hardwood Beating

LAB-TEC Comparison to Pulp Strength

Figure 13
Softwood Beating

Left Axis
Burst Index, Units = $\text{kPa} \cdot \text{m}^2 / \text{g}$
Tensile Index, Units = $\text{N} \cdot \text{m} / \text{g} \times 0.1$

Figure 14
Hardwood Beating

Left Axis
Burst Index; Units = $\text{kPa} \cdot \text{m}^2 / \text{g}$
Tensile Index; Units = $\text{N} \cdot \text{m} / \text{g} \times 0.1$

Bauer-McNett Classifications LAB-TEC Results

Figure 15
Softwood Pulp
June 1990

Figure 16
Hardwood Pulp

PAR--TEC Comparison to C. S. Freeness

Figure 17
Softwood Beating
February 1990

Figure 18
Hardwood Beating
February 1990

Figure 19
Softwood Beating
June 1990

Figure 20
Hardwood Beating
June 1990

PAR-TEC Comparison to Pulp Strength

Figure 21
Softwood Beating
February 1990

Left Axis -
Burst Index, Units = $\text{kPa} \cdot \text{m}^2/\text{g}$
Tensile Index, Units = $\text{N} \cdot \text{m}/\text{g} \times 10$

Figure 22
Hardwood Beating
February, 1990

Left Axis -
Burst Index, Units = $\text{kPa} \cdot \text{m}^2/\text{g}$
Tensile Index, Units = $\text{N} \cdot \text{m}/\text{g} \times 0.1$

Figure 23
Softwood Beating
June 1990

Left Axis -
Burst Index, Units = $\text{kPa} \cdot \text{m}^2/\text{g}$
Tensile Index, Units = $\text{N} \cdot \text{m}/\text{g} \times 10$

Figure 24
Hardwood Beating
June 1990

Left Axis
Burst Index, Units = $\text{kPa} \cdot \text{m}^2/\text{g}$
Tensile Index, Units = $\text{N} \cdot \text{m}/\text{g} \times 0.1$

Bauer-McNett Classifications PAR-TEC Results

Figure 25
Softwood Pulp
February 1990

Figure 26
Hardwood Pulp
February 1990

Figure 27
Softwood Pulp
June 1990

Figure 28
Hardwood Pulp
June 1990

PAR-TEC Comparison to C. S. Freeness

Figure 29
Hardwood Refining

Figure 30
Softwood Refining

PAR-TEC Comparison to Pulp Strength

Figure 31
Hardwood Refining

Left Axis—
Burst Index, $\text{kPa} \cdot \text{m}^2/\text{g}$
Tensile Index, $\text{n} \cdot \text{m}/\text{g}^2 \times 0.10$

Figure 32
Softwood Refining

Left Axis
Burst Index, Units = $\text{kPa} \cdot \text{m}^2/\text{g} \times 10$
Tensile Index, Units = $\text{N} \cdot \text{m}/\text{g}^2$

Figure 33
Flow Effects

Figure 34
Position Effects

Figure 35
Consistency Effect

Figure 36
Effect of Focus Adjustment

Table 1

Lasentec Study   Project 4103
Feb. 13, 1990

Hardwood 1

Sample Time					0	1	2	3	4
					0	4	9	15	19
Freeness, ml CSF					614	584	525	425	300
Lab-Tek	Mean	Size	Dia	A	3.32	4.42	4.71	5.19	5.03
	Mean	Size	Dia	B	3.94	4.41	4.57	4.90	4.96
	Mean	Size	Dia	AVG	3.63	4.42	4.64	5.05	5.00
	Delta Mean Size, (dM)					0.79	1.01	1.42	1.37
	Weighted Average		Dia	A	25.09	27.65	27.26	27.55	27.51
	Weighted Average		Dia	B	26.22	27.91	27.08	27.28	27.27
	Weighted Average		Dia	AVG	25.66	27.78	27.17	27.42	27.39
	Delta Weighted Average, (dWA)					2.13	1.52	1.76	1.73
	Mean	Size	Dia		35.8	34.7	34.0	35.4	34.7
	Delta Mean Size, (dM)					-1.1	-1.8	-0.4	-1.1
Kajaani	Weighted Average		Length		0.92	0.92	0.92	0.87	0.88
	Arith. Average		Length		0.59	0.58	0.58	0.55	0.54
Physical Properties									
	Apparent Density	g/cc			0.483	0.518	0.556	0.611	0.637
	Burst Index	kPa*m ² /g			0.22	0.62	1.03	1.60	1.94
	Tensile Index	N*m/g			10.14	16.58	24.02	32.88	38.97
	Tear Index	mN*m ² /g			1.80	4.15	4.93	5.68	5.85

Table 2

Lasentec Study   Project 4103
Feb. 13, 1990

Hardwood 2

Sample	0	1	2	3	4
Time	0	4	9	15	19
Freeness, ml CSF	632	572	528	419	308
Lab-Tek Mean Size Dia A	4.08	4.48	3.34	5.05	4.76
Mean Size Dia B	4.12	4.55	3.37	4.93	4.73
Mean Size Dia AVG	4.10	4.52	3.36	4.99	4.75
Delta Mean Size, (dM)		0.42	-0.75	0.89	0.64
Weighted Average Dia A	26.28	27.23	28.00	27.94	27.34
Weighted Average Dia B	26.43	27.35	28.15	27.78	27.25
Weighted Average Dia AVG	26.36	27.29	28.08	27.86	27.30
Delta Weighted Average, (dWA)		0.94	1.72	1.51	0.94
Par-Tek Mean Size Dia	33.50	33.70	33.30	32.80	33.20
Delta Mean Size, (dM)		0.20	-0.20	-0.70	-0.20
Kajaani Weighted Average Length	0.91	0.92	0.91	0.88	0.88
Arith. Average Length	0.59	0.59	0.58	0.55	0.54
Physical Properties					
Apparent Density g/cc	0.49	0.54	0.56	0.61	0.64
Burst Index kPa*m ² /g	0.24	0.72	1.05	1.66	2.11
Tensile Index N*m/g	9.75	19.66	24.37	34.01	38.59
Tear Index mN*m ² /g	1.97	4.71	5.51	6.08	6.00

Table 3

Lasentec Study   Project 4103
Feb. 14, 1990

Softwood 1

					0	1	2	3	4	5	6
Sample					0	8	11	19	25	30	39
Time											
Greenness, ml CSF					727	695	655	590	530	456	303
Lab-Tek	Mean	Size	Dia	A	8.32	9.95	9.33	10.89	11.72	12.54	12.82
	Mean	Size	Dia	B	8.13	10.02	9.66	10.72	11.72	12.46	12.60
	Mean	Size	Dia	AV	8.23	9.99	9.50	10.81	11.72	12.50	12.71
	Delta Mean Size, (dM)					1.76	1.27	2.58	3.49	4.27	4.49
	Weighted Average	Dia	A		31.94	33.42	32.73	33.87	34.38	34.81	35.11
	Weighted Average	Dia	B		31.78	33.39	33.01	33.83	34.34	34.83	35.05
	Weighted Average	Dia	AV		31.86	33.41	32.87	33.85	34.36	34.82	35.08
	Delta Weighted Average, (dWA)					1.54	1.01	1.99	2.50	2.96	3.22
Par-Tek	Mean	Size	Dia		38.4	42.1	42.7	41.5	43.6	43.8	42.9
	Delta Mean Size, (dM)					3.7	4.3	3.1	5.2	5.4	4.5
Kajaani	Weighted Average	Length			2.59	2.60	2.52	2.45	2.50	2.47	2.31
	Arith. Average	Length			1.39	1.41	1.32	1.30	1.27	1.27	1.13
Physical Properties											
Apparent Density					g/cc	0.528	0.576	0.598	0.622	0.641	0.677
Burst Index					kPa*m ² /g	1.38	2.71	3.07	3.92	4.67	5.34
Tensile Index					n*m/g	23.79	38.97	44.82	54.46	60.08	66.93
Tear Index					mN*m ² /g	20.62	22.44	19.42	14.83	14.37	13.03

Table 4

Lasentec Study Project 4103

Feb. 14, 1990

Softwood 2

					0	1	2	3	4	5	6
Sample Time					0	7	13	19	26	31	39
Freeness, ml CSF					727	707	655	600	523	457	310
Lab-Tek	Mean	Size	Dia	A	8.76	10.02	10.34	12.39	11.99	9.05	12.23
	Mean	Size	Dia	B	8.74	10.13	10.63	12.35	11.80	8.78	12.86
	Mean	Size	Dia	AVG	8.75	10.08	10.49	12.37	11.90	8.92	12.55
	Delta Mean Size, (dM)					1.33	1.74	3.62	3.15	0.17	3.80
	Weighted Average		Dia	A	32.82	33.44	33.90	35.04	34.66	34.10	35.38
	Weighted Average		Dia	B	32.85	33.51	34.04	35.05	34.58	34.00	35.82
	Weighted Average		Dia	AVG	32.84	33.48	33.97	35.05	34.62	34.05	35.60
	Delta Weighted Average, (dWA)					0.64	1.13	2.21	1.78	1.22	2.77
Par-Tek	Mean	Size	Dia		39.0	41.3	42.2	41.6	43.6	43.0	42.8
	Delta Mean Size, (dM)					2.3	3.2	2.6	4.6	4.0	3.8
Kajaani	Weighted Average		Length		2.63	2.5	2.44	2.44	2.54	2.44	2.56
	Arith. Average		Length		1.47	1.35	1.27	1.24	1.32	1.25	1.30
Physical Properties											
	Apparent Density	g/cc			0.537	0.576	0.607	0.609	0.645	0.655	0.683
	Burst Index	kPa*m ² /g			1.30	2.60	3.34	.00	4.63	4.79	5.49
	Tensile Index	n*m/g			23.29	36.58	49.2	55.53	61.88	64.45	72.36
	Tear Index	mN*m ² /g			16.64	20.94	18.14	15.35	13.42	13.33	11.95

Table 5

Bauer-McNett Results
February 13, 1990
Hardwood

		Sample	Whole	Screen				"Fines"
			Pulp	20 mesh	35 mesh	48 mesh	100 mesh	
Percent Retained		1	---	24.20	26.03	11.73	13.20	24.84
		2	---	20.94	28.32	10.79	13.28	26.67
		Ave	---	22.57	27.18	11.26	13.24	25.76
Par-Tek Mean-Size,micron		1	34.0	38.6	34.8	35.6	36.8	
		2	33.3	36.0	36.0	36.2	35.9	
		Ave	33.7	37.3	35.4	35.9	36.4	
Lab-tek Mean Size,micron		1	4.64	5.73	5.53	4.52	6.17	
		2	3.36	6.68	5.64	4.81	5.15	
		Ave	4.00	6.20	5.59	4.66	5.66	
Weighted Average		1	27.17	29.13	28.62	27.86	29.52	
		2	28.08	29.85	28.70	27.99	28.31	
		Ave	27.63	29.49	28.66	27.92	28.91	
Freeness,ml CSF		1	525	750	728	710	669	
		2	528	738	731	691	656	
		Ave	527	744	730	701	663	

Table 6

Bauer-McNett Results
February 13, 1990
Softwood

		Sample	Whole	Screen				"Fines"
			Pulp	14 mesh	28 mesh	48 mesh	100 mesh	
Percent Retained		1	---	69.6	8.1	13.7	6.2	2.4
		2	---	65.9	8.6	13.7	5.7	6.1
		Ave	---	67.8	8.4	13.7	6.0	4.3
Jar-Tek	Mean-Size,micron	1	41.5	46.3	43.1	41.4	42.4	
		2	42.2	44.8	49.3	44.7		
		Ave	41.9	45.6	46.2	43.1	42.4	
Lab-tek	Mean Size,micron	1	10.81	11.45	10.92	10.24	7.80	
		2	12.37	9.85	9.99	9.62	4.99	
		Ave	11.59	10.65	10.45	9.93	6.39	
	Weighted Average	1	33.85	33.90	33.59	33.45	31.05	
		2	35.04	34.23	33.27	32.97	27.86	
		Ave	34.45	34.06	33.43	33.21	29.46	
Freeness,ml CSF		1	590	758	721	725	631	
		2	600	760	*	718	*	
		Ave	595	759	721	722	631	

Combined with Sample 1 to yield enough pulp to do C.S. Freeness test.

Table 7

Lasentec Study Project 4103

June 12, 1990

Hardwood 1

					0	1	2	3	4
Sample					0	5	10	15	20
Time					599	556	473	372	273
Freeness, ml CSF									
Lab-Tek	Mean	Size	Dia	A	11.22	10.92	12.35	10.43	10.87
	Mean	Size	Dia	B	11.11	10.77	12.28	12.24	10.65
	Mean	Size	Dia	AVG	11.165	10.845	12.315	11.335	10.76
	dM					-0.32	1.15	-0.17	-0.405
	Weighted Average	Dia	A		21.36	20.94	22.47	19.71	20.36
	Weighted Average	Dia	B		21.29	20.72	22.39	22.04	20.09
	Weighted Average	Dia	AVG		21.325	20.83	22.43	20.875	20.225
	dWA					-0.495	1.105	-0.45	-1.1
Par-Tek	Mean	Size	Dia		39.0	39.9	40.1	40.3	40.4
	dM					0.9	1.1	1.3	1.4
	Specific Volume				248.2	229.8	343.9	263.5	333.9
Kajaani	dSV					-18.4	114.1	-80.4	70.4
	Weighted Average	Length			0.94	0.94	0.91	0.87	0.86
	Arith. Average	Length			0.62	0.59	0.56	0.54	0.53
Physical Properties									
	Apparent Density	g/cc			0.471	0.515	0.544	0.590	0.620
	Burst Index	kPa*m ² /g			0.27	0.68	1.09	1.61	2.09
	Tensile Index	N*m/g			11.27	19.45	26.59	33.23	39.06
	Tear Index	mN*m ² /g			2.95	4.64	6.43	6.98	6.00

Table 8

sentec Study   Project 4103
June 12, 1990

Hardwood 2

Sample					0	1	2	3	4
Weight					0	5	10	15	20
Greenness, ml CSF					604	550	476	358	269
Lab-Tek	Mean	Size	Dia	A	10.54	11.56	12.56	12.74	11.74
	Mean	Size	Dia	B	10.72	11.52	12.53	12.76	11.81
	Mean	Size	Dia	AVG	10.63	11.54	12.55	12.75	11.78
	dM					0.91	1.91	2.12	1.14
	Weighted Average	Dia	A		21.16	21.54	22.57	22.91	21.59
	Weighted Average	Dia	B		21.40	21.45	22.54	22.97	21.72
	Weighted Average	Dia	AVG		21.28	21.50	22.56	22.94	21.66
	dWA					0.215	1.275	1.660	0.375
Bar-Tek	Mean	Size	Dia		39.6	39.8	39.8	40.0	40.0
	dM					0.2	0.2	0.4	0.4
	Specific Volume				207	320	182	224	205.5
	dSV					113	-25	17	-1.5
Jaani	Weighted Average	Length			0.90	0.91	0.90	0.91	0.88
	Arith. Average	Length			0.58	0.57	0.56	0.56	0.54
Physical Properties									
	Apparent Density	g/cc			0.481	0.519	0.543	0.574	0.600
	Burst Index	kPa*m ² /g			0.28	0.73	1.12	1.61	2.12
	Tensile Index	N*m/g			12.45	19.93	25.24	31.49	38.68
	Tear Index	mN*m ² /g			2.85	4.42	6.02	6.52	6.34

Table 9

Lasentec Study   Project 4103
June 13, 1990

Softwood 1

Sample					0	1	2	3	4	5	6
Time					0	5	10	15	20	30	40
Freeness, ml CSF					710	679	637	564	510	339	196
Lab-Tek	Mean	Size	Dia	A	14.76	16.78	16.66	18.13	18.42	18.97	19.42
	Mean	Size	Dia	B	14.42	16.50	16.68	17.07	17.94	18.91	19.28
	Mean	Size	Dia	AV	14.59	16.64	16.67	17.60	18.18	18.94	19.35
	Delta Mean Size, (dM)					2.05	2.08	3.01	3.59	4.35	4.76
	Weighted Average	Size	Dia	A	26.39	28.67	28.14	29.84	31.07	30.60	31.22
	Weighted Average	Size	Dia	B	25.92	28.31	28.13	28.98	30.46	30.63	31.09
	Weighted Average	Size	Dia	AV	26.16	28.49	28.14	29.41	30.77	30.62	31.16
	Delta Weighted Average, (dWA)					2.34	1.98	3.26	4.61	4.46	5.00
Par-Tek	Mean	Size	Dia		47.1	49.8	50.8	51.3	51.1	51.4	51.6
	Delta Mean Size, (dM)					2.7	3.7	4.2	4.0	4.3	4.5
	Specific Volume, %				245.1	225.2	285.8	238.9	398.2	286.8	281.5
	Delta Specific Volume, (dSV)					-19.9	40.7	-6.2	153.1	41.7	36.4
Kajaani	Weighted Average	Length			2.45	2.41	2.40	2.45	2.30	2.24	2.29
	Arith. Average	Length			1.34	1.29	1.24	1.28	1.17	1.10	1.13
Physical Properties											
Apparent Density		g/cc			0.489	0.529	0.559	0.587	0.604	0.638	0.658
Burst Index		kPa*m ² /g			1.35	2.39	3.20	3.76	4.41	5.25	5.47
Tensile Index		N*m/g			20.90	34.08	41.80	51.45	57.74	66.85	72.81
Tear Index		mN*m ² /g			18.69	19.57	18.37	15.67	14.29	12.33	11.70

Table 10

Lasentec Study   Project 4103
June 13, 1990

Softwood 2

Sample Time					0	1	2	3	4	5	6
					0	5	10	15	20	30	40
Freeness, ml CSF					706	682	630	584	514	338	196
Lab-Tek	Mean	Size	Dia	A	15.57	15.04	18.23	16.34	18.48	17.39	19.08
	Mean	Size	Dia	B	15.49	15.52	18.25	16.20	18.48	17.47	19.00
	Mean	Size	Dia	AVG	15.53	15.28	18.24	16.27	18.48	17.43	19.04
	Delta Mean Size,(dM)					-0.25	2.71	0.74	2.95	1.90	3.51
	Weighted Average Dia				A	27.70	27.46	29.87	29.20	30.46	29.96
	Weighted Average Dia				B	27.56	28.00	29.93	29.10	30.53	30.00
	Weighted Average Dia				AVG	27.63	27.73	29.90	29.15	30.50	29.98
	Delta Weighted Average,(dWA)					0.10	2.27	1.52	2.87	2.35	3.48
Par-Tek	Mean	Size	Dia		51.3	52.2	53.3	53.2	53.8	54.0	53.8
	Delta Mean Size,(dM)					0.9	2.0	1.9	2.5	2.7	2.5
	Specific Volume,%				206.6	213.3	260.9	273.5	233.5	346.3	331.7
	Delta Specific Volume,(dSV)					6.7	54.3	66.9	26.9	139.7	125.1
Kajaani	Weighted Average		Length		2.59	2.64	2.51	2.26	2.4	2.33	2.36
	Arith. Average		Length		1.44	1.44	1.32	1.14	1.17	1.19	1.17
Physical Properties											
Apparent Density		g/cc			0.504	0.535	0.558	0.599	0.624	0.633	0.666
Burst Index		kPa*m ² /g			1.33	2.18	3.17	3.74	4.45	5.08	5.67
Tensile Index		N*m/g			22.28	32.69	43.02	51.98	56.59	67.52	71.54
Tear Index		mN*m ² /g			18.47	22.02	19.34	16.10	13.90	12.52	11.76

Table 11

Bauer-McNett Results
 June 12-13, 1990
 Hardwood

		Sample	Whole Pulp	Screen		48 mesh	100 mesh	"Fines"
Percent Retained		1	---	20.53	30.79	7.72	15.64	25.32
		2	---	17.65	32.19	8.72	16.10	25.34
		Ave	---	19.09	31.49	8.22	15.87	25.33
Mar-Tek	Mean-Size	1	40.1	38.3	37.4	36.0	39.6	
		2	39.8	38.2	38.4	38.4	38.9	
		Ave	40.0	38.3	37.9	37.2	39.3	
Lab-tek	Mean Size	1	12.32	11.16	10.39	8.91	10.81	
		2	13.54	11.04	10.03	10.47	10.44	
		Ave	12.93	11.10	10.21	9.69	10.62	
	Weighted Average	1	22.43	20.98	20.16	19.44	20.63	
		2	22.56	20.68	19.01	20.33	20.08	
		Ave	22.50	20.83	19.59	19.89	20.35	
Kajaani	Weighted Average	1	0.91	1.50	1.10	0.88	0.67	
		2	0.90	1.52	1.12	0.94	0.68	
		Ave	0.91	1.51	1.11	0.91	0.68	
	Arith. Average	1	0.56	1.28	0.94	0.75	0.55	
		2	0.56	1.31	0.97	0.78	0.56	
		Ave	0.56	1.30	0.96	0.77	0.56	

Table 12

Bauer-McNett Results
June 12-13, 1990
Softwood

		Sample	Whole	Screen			
			Pulp	8 mesh	14 mesh	28 mesh	100 mesh "Fines"
Percent Retained		1	---	35.59	17.70	15.01	23.08
		2	---	30.57	19.38	14.96	23.80
		Ave	---	33.08	18.54	14.99	23.44
							8.62
Lab-Tek Mean-Size		1	51.3	49.0	49.7	49.8	47.9
		2	53.2	50.2	49.6	48.8	47.4
		Ave	52.3	49.6	49.7	49.3	47.7
Lab-tek Mean Size		1	17.60	19.02	16.61	17.64	14.71
		2	16.27	19.78	17.57	16.82	15.79
		Ave	16.94	19.40	17.09	17.23	15.25
Weighted Average		1	29.41	30.57	28.77	29.01	27.79
		2	29.15	31.00	29.26	28.41	27.41
		Ave	29.28	30.78	29.01	28.71	27.60
Ajaani Weighted Average		1	2.45	3.57	3.20	2.51	1.45
		2	2.26	3.58	3.20	2.54	1.46
		Ave	2.36	3.58	3.20	2.53	1.45
Arith. Average		1	1.28	2.80	2.66	2.08	1.07
		2	1.14	2.92	2.73	2.15	1.10
		Ave	1.21	2.86	2.70	2.12	1.09

September 4, 1990

Table 13
Lasentec Study

Hardwood

Sample I.D.	Net Specific Refining Energy kWhr/T	Par-Tek		Par-Tek Laboratory Mean Size microns	Kajaani Weighted Average Length	Arith. Average Length	Free- ness	Physical Tests			
		In-Line Mean Size microns	Mean Size microns					Apparent Density g/cc	Burst Index kPa* $\hat{m}^2$ /g	Tensile Index N* $\hat{m}$ /g	Tear Index mN* $\hat{m}^2$ /g
HW-0-1	0	44.75	42.55	0.82	0.47	562	0.507	0.70	18.96	5.10	
HW-0-2	0	45.40	41.30	0.90	0.59	554	0.501	0.77	18.39	4.82	
HW-7.5-1	7.3	44.90	41.65	0.90	0.57	535	0.503	0.92	21.47	5.71	
HW-7.5-2	7.3	45.00	40.50	0.86	0.55	514	0.509	0.92	19.87	5.30	
HW-15-1	14.7	45.55	42.15	0.88	0.56	524	0.458	0.84	19.93	5.17	
HW-15-2	14.7	44.40	40.85	0.86	0.54	467	0.521	1.19	23.53	5.68	
HW-30-1	29.4	43.70	41.60	0.86	0.55	487	0.452	0.82	20.03	4.75	
HW-30-2	29.4	43.85	39.55	0.89	0.57	456	0.512	0.93	21.07	5.66	
HW-50-1	48.9	43.55	41.35	0.82	0.51	474	0.463	0.90	19.96	4.90	
HW-50-2	48.9	43.75	39.70	0.85	0.54	453	0.529	1.05	22.14	5.43	

Table 14

Lasentec Study

September 4, 1990

Softwood

Sample I.D.	Net Specific Refining Energy kWhr/T	Par-Tek		Par-Tek Laboratory		Kajaani		Arith.		C. S. Freeness ml	Apparent Density		Burst		Tensile		Tear	
		In-Line Mean Size microns	Mean Size microns	Weighted Average Length	Weighted Average Length	Length	Length	Average Length	Average Length		g/cc	g/cc	Index kPa* m^2/g	Index kPa* m^2/g	Index $\text{N}^*\text{m}/\text{g}^2$	Index $\text{N}^*\text{m}/\text{g}^2$	Index $\text{mN}^*\text{m}^2/\text{g}$	Index $\text{mN}^*\text{m}^2/\text{g}$
SW-0-1	0	46.60	51.70	2.58	1.34	695	0.505	2.59	34.77	24.50								
SW-0-2	0	46.45	50.95	2.53	1.33	675	0.508	2.40	34.60	27.69								
SW-15-1	14.7	46.05	55.00	2.61	1.40	639	0.537	3.00	39.27	25.62								
SW-15-2	14.5	46.85	51.80	2.72	1.46	656	0.520	2.89	38.88	25.13								
SW-30-1	29.4	46.10	51.70	2.47	1.25	611	0.545	3.46	44.98	21.64								
SW-30-2	29.4	46.70	52.45	2.66	1.40	582	0.555	3.46	44.86	23.64								
SW-70-1	68.5	46.25	52.55	2.26	1.12	448	0.593	3.97	47.67	16.91								
SW-70-2	68.5	45.65	51.15	2.44	1.26	384	0.600	4.03	52.86	17.29								
SW-MAX-1	118.0	45.70	50.65	1.79	0.82	269	0.633	4.32	55.90	13.77								
SW-MAX-2	118.0	44.60	50.80	2.18	1.02	229	0.636	4.19	55.02	13.59								

Table 15

Flow Loop Testing
September 18-19, 1990

Test No.	Consistency %	Pulp Velocity ft/sec	Flow gpm	Position in.	Adjust (1)	PAR-TEC Mean Size u	Focus
1	2.61	4.2	175	1.5	0	41.0	6000
3	2.61	1.8	75	1.5	0	41.8	
4	2.61	1.8	75	0.5	1	45.6	6000
6	2.61	4.2	175	0.5	0	43.6	
7	2.61	4.2	175	1	0	46.5	5700
9	2.61	1.8	75	1	0	50.2	
10	2.61	1.8	75	2	0	46.0	770
12	2.61	4.2	175	2	0	40.3	
13	2.61	1.8	75	1.5	0	40.4	5200
15	2.61	1.8	75	1.5	0	42.0	
17	2.61	4.2	175	1.5	0	41.0	
17	2.32	4.2	175	1.5	1	40.9	5900
18	2.32	1.8	75	1.5	0	42.9	5800
19	2.32	1.8	75	2	0	42.5	6000
20	2.32	4.2	175	2	0	42.0	
21	2.32	4.2	175	1	1	44.1	5600
22	2.32	1.8	75	1	0	46.3	4900
24	2.32	1.8	75	0.5	0	48.2	4900
25	2.32	4.2	175	0.5	0	46.6	
26	2.32	1.8	75	0.5	0	48.9	
27	2.32	4.2	175	0.5	0	46.7	
28	2.13	4.2	175	0.5	0	44.6	
29	2.13	1.8	75	0.5	0	45.8	5400
30	2.13	1.8	75	1.5	0	42.3	
31	2.13	4.2	175	1.5	0	42.2	
32	2.13	1.8	75	1.5	0	47.2	
33	2.13	4.2	175	1.5	1	42.3	5500
35	2.13	4.2	175	1	0	43.2	5500
36	2.13	1.8	75	1	0	44.9	
37	2.13	1.8	75	2	1	46.7	5000
38	2.13	4.2	175	2	0	46.2	
39	2.13	1.8	75	2	1	45.9	5100
40	2.13	4.2	175	2	1	44.0	5600
41	2.13	1.8	75	2	1	48.6	5400
42	2.13	1.8	75	1.5	0	46.5	
43	2.13	4.2	175	1.5	0	44.3	
44	2.13	4.2	175	0.5	0	44.5	5800
45	2.13	1.8	75	0.5	1	44.6	5300
46	1.65	4.2	175	0.5	0	44.1	5100
47	1.65	1.8	75	0.5	1	46.5	3900
48	1.65	1.8	75	1	0	45.5	4600
49	1.65	4.2	175	1	0	44.1	5300
50	1.65	4.2	175	1.5	1	43.8	4300
51	1.65	1.8	75	1.5	1	47.3	4400
52	1.65	1.8	75	2	1	44.2	4200
53	1.65	4.2	175	2	0	43.2	5300
54	1.65	4.2	175	1.5	1	44.0	5400
55	1.65	1.8	75	1.5	1	45.3	4600
56	1.65	1.8	75	0	1	45.4	4700
57	1.65	4.2	175	0	1	44.8	5100
58	1.65	4.2	175	1.5	1	42.6	5800
59	1.65	1.8	75	1.5	1	43.3	4600
60	1.65	1.8	75	0	1	48.1	5000
61	1.65	4.2	175	0	1	44.5	5500

Table 16

Model fitting results for PAR TEC

Independent variable	coefficient	std. error	t-value	sig.level
CONSTANT	51.807388	2.419372	21.4136	0.0000
low Rate	-0.019293	0.0061	-3.1626	0.0029
position	-1.421378	0.545382	-2.6062	0.0126
consistency	-1.400861	0.974036	-1.4382	0.1578
-SQ. (ADJ.) = 0.2508 SE= 2.064783 MAE= 1.631784 DurbWat= 0.775				
previously: 0.0000	0.000000	0.000000	0.000000	0.000
6 observations fitted, forecast(s) computed for 0 missing val. of dep. var.				

Table of means for FAR TEC mean size

Level	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95 Percent Confidence for mean	
low Rate						
75	24	45.429167	.5069527	.2707776	44.868887	45.989447
175	22	43.579545	.4027860	.2828180	42.994352	44.164735
position						
0.5	12	45.795833	.4728003	.3829374	45.003478	46.588189
1	8	45.581250	.7719952	.4690006	44.610816	46.551684
1.5	15	43.033333	.5900901	.3425096	42.324629	43.742038
2	11	44.486364	.7286379	.3999651	43.658775	45.313952
consistency						
1.65	8	44.812500	.5093545	.4690006	43.842066	45.782934
2.13	17	44.905882	.4440349	.3217318	44.240170	45.571594
2.32	10	44.880000	.8812302	.4194869	44.012018	45.747982
2.61	11	43.486364	.9620076	.3999651	42.658775	44.313952
Total	46	44.544565	.1955868	.1955868	44.139866	44.949264

END

**DATE
FILMED**

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