PULMAC INTERNATIONAL

A Division of Cowan Technologies Inc.

FIBER PROCESS CONTROL

Pulmac International

Introduction

The Pulmac Z-Span System permits the real time characterization of the quality of the fibers in pulp anywhere from the brown stock washer to the reel of the papermachine. This System expresses pulp quality in terms of three numbers; viz. a fiber strength characterization (FS number), a fiber length characterization (L number), and a characterization of fiber bonding potential (B number).

Each process through which fibers pass from the time they enter the pulp mill in the form of logs or chips until they arrive at the reel of the papermachine effects these three fiber quality numbers in a characteristic manner. When one examines the development and changes in these numbers as the pulp progresses through the pulp and papermill a pattern is quickly observed which identifies particular values of specific fiber numbers at different process locations with periods of optimum papermaking. Significant departures from this pattern are frequently found to define periods of "reduced profitability" papermaking; e.g. marginal or below spec paper at the reel, excessive papermachine breaks, excessive use of kraft softwood in mixed furnishes, forced reduction in machine speed.

Fiber process control is the means by which the management of such significant processes as cooking, bleaching, stock preparation, and sheet forming are reconfigured in order to control fiber quality numbers at values which presage profitable papermaking. This paper describes how fiber process control "works" and how it can be introduced into a mill.

STRENGTH SOLUTIONS

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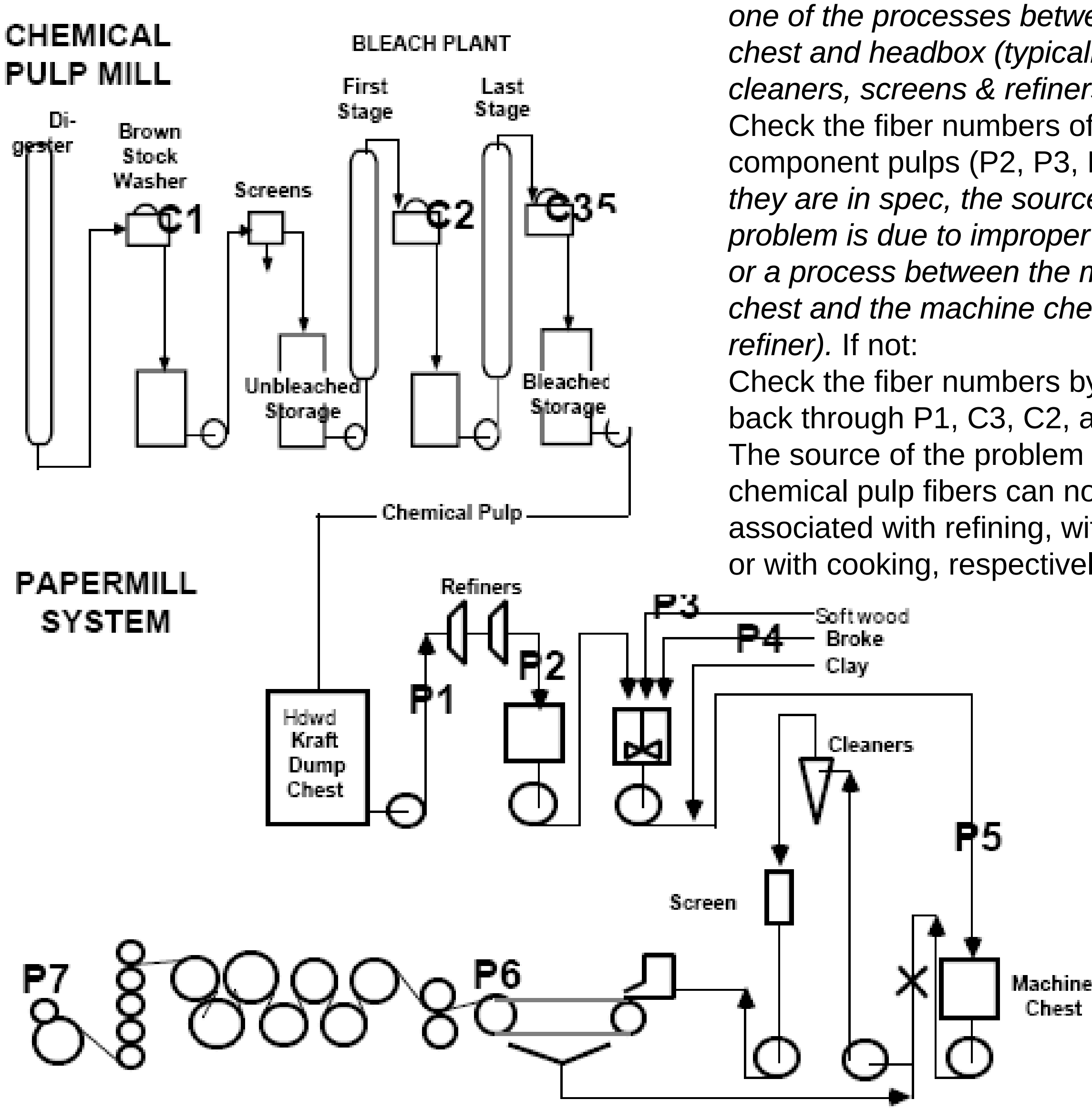
Fiber Process Control

Fiber process control means, controlling the fiber numbers everywhere from C1 in the pulp mill through P7 at the end of the papermachine. Particular fiber quality numbers at the reel of the papermachine correspond to optimum papermaking. Fiber quality testing throughout the pulp and papermill sets in place the information network which identifies the source of a quality/productivity problem at the reel of the papermachine. For instance consider the following:

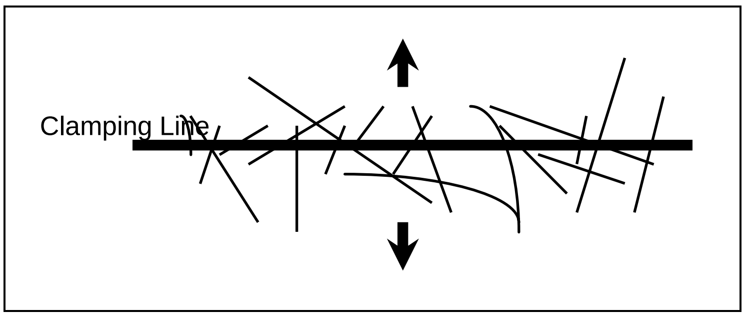
1. Quality numbers at the reel (P7) are out of spec.
2. Check the fiber numbers of the couch trim pulp (P6). *If they are in spec, the source of the problem is somewhere on the papermachine.* If not:

Check the fiber numbers of the machine chest pulp (P5). *If they are in spec, the source of the problem is one of the processes between machine chest and headbox (typically cleaners, screens & refiners)* If not:
Check the fiber numbers of the component pulps (P2, P3, P4). *If they are in spec, the source of the problem is due to improper blending, or a process between the mixing chest and the machine chest (e.g. a refiner).* If not:
Check the fiber numbers by tracing back through P1, C3, C2, and C1.
The source of the problem with the chemical pulp fibers can now be associated with refining, with bleaching, or with cooking, respectively.

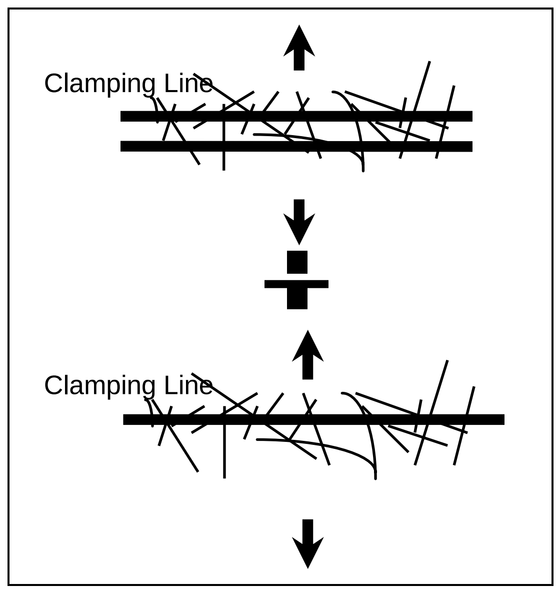


Pulmac Fiber Quality Numbers

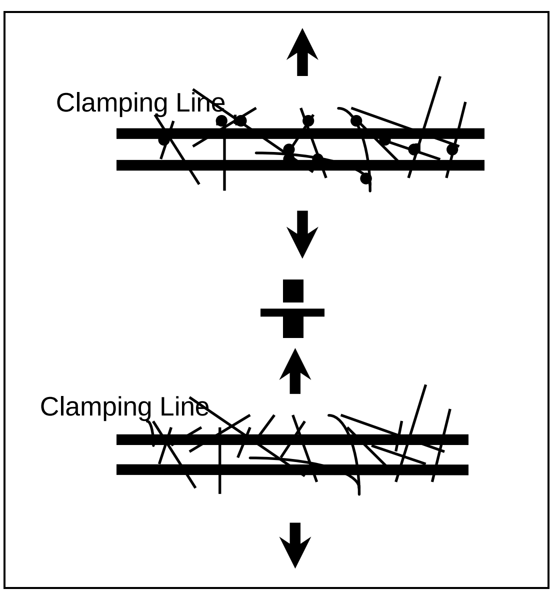
The Z-Span System allows the fibers in any pulp sample to be assessed in terms of three fiber numbers; Fiber Strength, Fiber Length, and Fiber Bonding.
The FS number relates to the average strength of the individual fibers in a standard basis weight (60 gsm) network. The L number relates to the average length of the fibers in the network. The B number relates to the bonding potential of the fibers in the network. These numbers are automatically calculated from a series of zero and short span tensile tests conducted on standard test sheets (uniform, random, 60 gsm fiber networks) according to:



$$\textbf{FS} = \textbf{Avg. of Wet Zero Spans} * \frac{\textbf{60 g/m}^2}{\textbf{Actual Bwt}}$$



$$L = \frac{\text{Avg. of Wet Short Spans}}{\text{Avg. of Wet Zero Spans}}$$



$$B = \frac{\text{Avg. of Dry Short Spans}}{\text{Avg. of Wet Short Spans}}$$

These three fiber numbers can be generated every 10 minutes with +/- 5% repeatability.

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The Chemical Pulp Mill

Fiber process control in the chemical pulp mill focuses on measurements which reliably track changes in fiber strength and length. The fiber length is determined solely by the uniformity of wood species and quality of the chips that flow to the digester. The fiber strength is significantly effected by any of the chemical treatments associated with cooking and bleaching.

In the chemical pulp mills that we have investigated, variations in the L number have not been large. However, variations in the FS number have always proved significant. This is illustrated by the data presented in Fig 1. Typically, the FS number decreases across the bleach plant. The amount of the decline depends upon the extent to which the chemical action damages fiber strength.

We have always observed significant variation in fiber strength from the digester, with the 10% range given in Fig 1 frequently being exceeded. This variation then increases with further processing, adding another 50% by the end of the bleaching operation.

FIG 1 FIBER STRENGTH

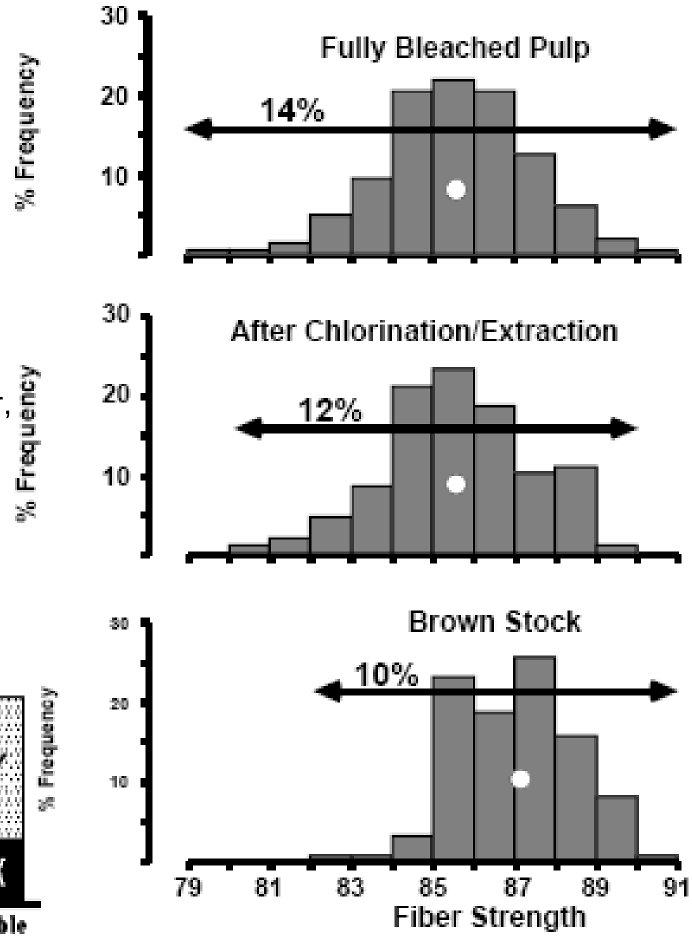
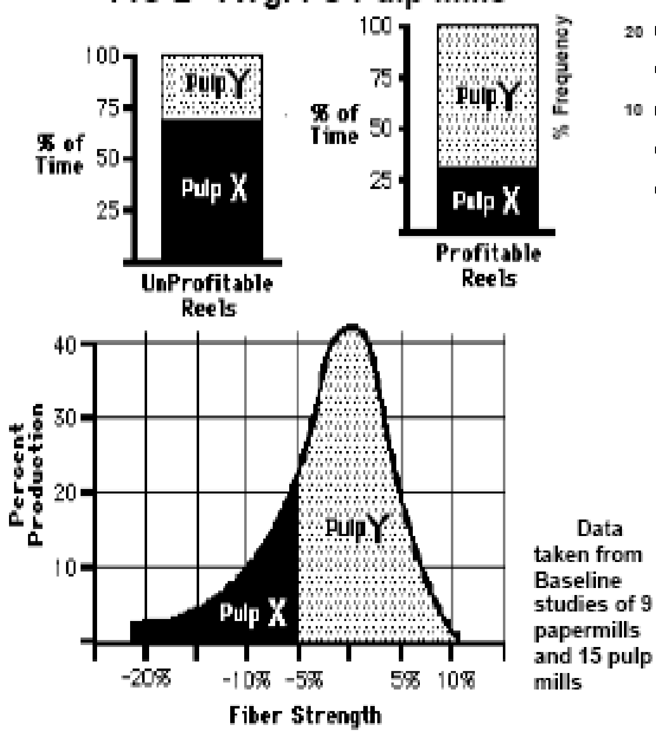


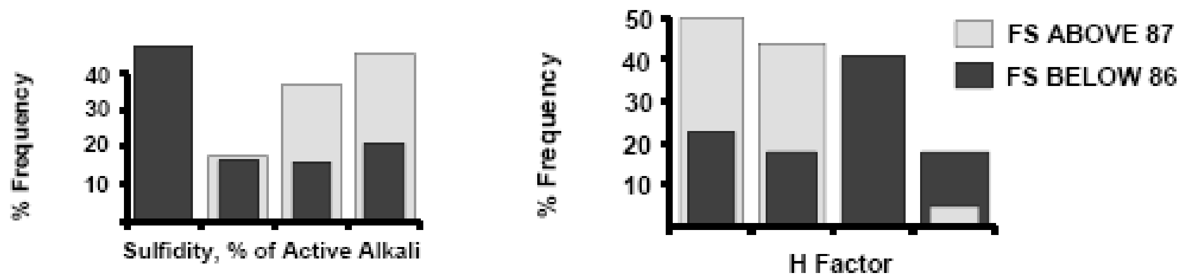
FIG 2 Avg. FS Pulp Mills



These typical variations in fiber strength create much higher likelihood of poorer Papermachine productivity. This is shown in figure 2.

Current experience suggests that perhaps 50-70% of low fiber strength product can be correlated with pulp mill production problems and the specific procedures used to deal with them. This is illustrated in Fig 3 where low fiber strength product is associated with high H factor or low sulfidity.

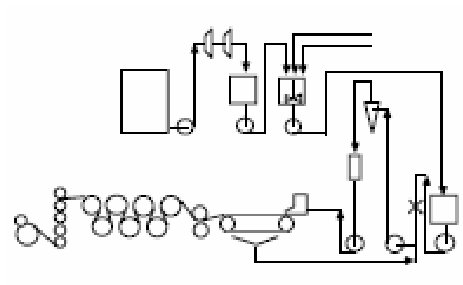
FIG 3 CONSEQUENCES OF PRODUCTION PROBLEMS



Other periods of low fiber strength production are indicative of less obvious process instabilities or chip quality variations. For instance increased dirt count in a bleached pulp (corresponding to increased shives being delivered to the bleach plant), elicits a response (increased bleaching) which can be detrimental to fiber strength. That is, measuring and seeking to control brightness and dirt count without reference to impact on fiber strength inevitably exacerbates the latter problem.

The goal of fiber process control in the chemical pulp mill is to maintain a target FS number at constant L number.

The Papermachine Delivery System
(Refining)



The papermachine delivery system develops fiber quality by refining, then brings together all the components of a furnish (refined fiber, broke, clay, etc.), subjects this furnish to final process adjustments (cleaning, screening, tickler refining, etc.) and delivers it as a controlled flow to the stuff gate and on to the papermachine.

<u>Refining of Chemical Pulp:</u>

Fibers produced in the pulp mill are usually subjected to the mechanical action of refiners in the stock prep area of the mill. The objective is to enhance the felting and bonding properties of the fibers so that on the papermachine they will develop the particular properties (strength, porosity, smoothness, etc.) which a given paper grade requires. Such terms as freeness, hydration, fibrillation, etc. are used to express this enhancement.
What does refining do to the Pulmac fiber quality numbers, and what does that tell us about the refining process? Contrasting studies of commercial refining at two different mills, plus data from laboratory beating are instructive.

<u>The FS Number:</u> One effect of refining is to dekink fibers, thereby increasing their FS number. This effect has also been observed for a commercial refiner (Study A). This is illustrated in Fig 1.

Another action of a refiner is to create fines or debris. In a standard basis weight test sheet production of fines means replacement of fibers with a measurable FS value, by particles that are too small to be clamped by the FQT and therefore make no contribution to the FS number. The net consequence is a tendency to reduce the FS number in proportion to the percentage of fines produced. A consistent pattern of reducing the FS number was observed in Study B of a commercial refiner. This is illustrated in Fig 2.

Tracking the FS number across the refiner informs as to the relative balance between enhancing the FS number by de-kinking fibers or reducing it by the creation of fines.

FIG 1 REFINING STUDY "A" INCREASING THE FS NUMBER

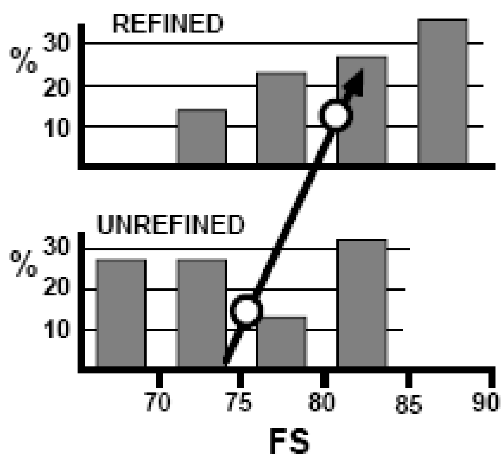
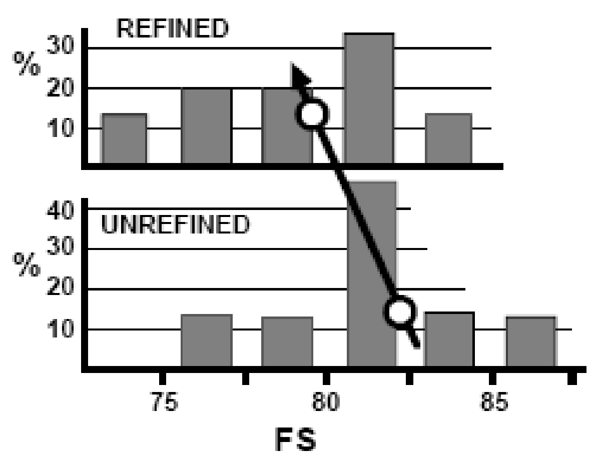


FIG 2 REFINING STUDY 'B' DECREASING THE FS NUMBER



The L Number: The L number reflects the average *effective* length of fibers. The presence of fines has the same proportional effect on the numerator and the denominator of the L equation, and therefore is cancelled out. Refining can cut fibers and thereby cause a reduction in the L number. On the other hand the mechanism which eliminates fiber kinking also tends to reduce curl. That is, as the fiber swells due to hydration, it not only dekinks the fibers but also tends to straighten them out. The straightening out of fibers causes an increase in the L number. That is, the effective length increases.

In Figs 3 and 4 can be observed the different effect on the L number of the A and B commercial refining studies. In the former, fiber straightening predominates, in the latter fiber cutting.

Tracking the L number across the refiner informs as to the relative balance between enhancing the L number by straightening fibers or reducing it by cutting fibers.

FIG 3
REFINING STUDY 'A'
INCREASING THE L NUMBER

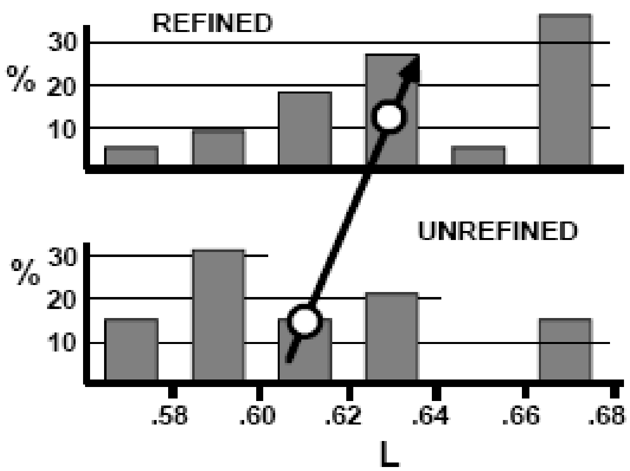
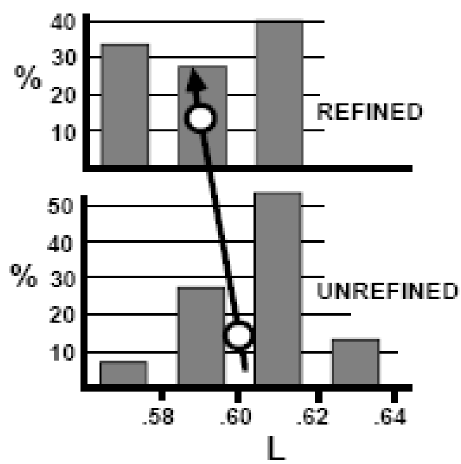


FIG 4
REFINING STUDY 'B'
DECREASING THE L NUMBER



The B Number: The B number reflects the extent to which drying links fibers through the process of hydrogen bonding. Although many different aspects of a fiber will influence this result (e.g. fiber flexibility, internal and external fibrillation, fiber swelling, character of fines, fiber shrinkage, intensity of wet pressing, etc.) the B number simply summarizes the total consequence. The Z-Span System produces test sheets using an arbitrary but controlled wet pressing and drying environment such that differences in the B number reflect changes in a fibers *potential* for bonding. It is a primary objective that refining will increase the bonding potential of fibers to the level necessary to allow a particular papermachine to produce a specific paper grade.

The effect on the B number of the two commercial refiner studies are presented in Figs 5 and 6. As expected, in both cases a significant increase in the B number occurs. However, the percentage increase is greater for Study A (20%) compared to Study B (15%).

FIG 5
REFINING STUDY 'A'
B NUMBER INCREASE

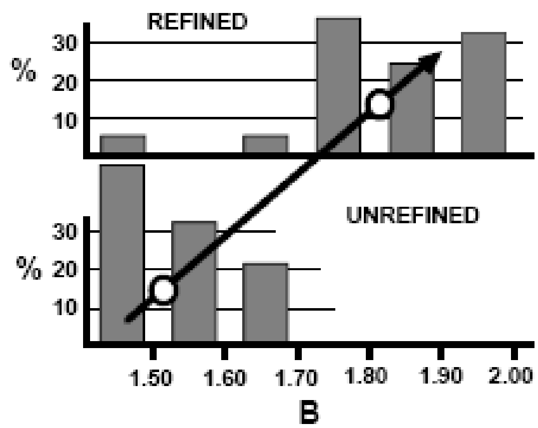
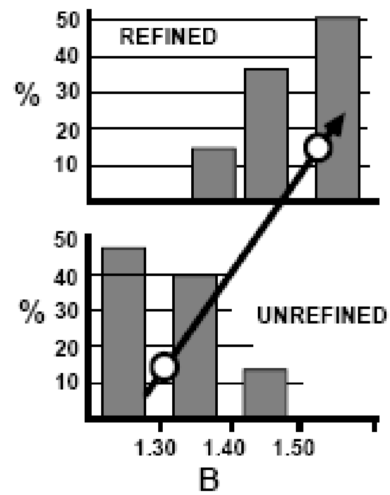


FIG 6
REFINING STUDY 'B'
B NUMBER INCREASE



Leveraging:

It is characteristic of pulps produced within a given mill that changes in the FS number induced by the action of the cooking and/or bleaching chemicals also changes the manner in which the fiber responds to refiner treatment. This is illustrated in Fig 7 by a laboratory study of the PFI mill characteristics of pulps produced by a commercial operation. The number of revolutions of the PFI mill required to reduce the pulp freeness to a constant level diminishes significantly as the FS number declines. In essence, reducing the FS number in the pulp mill makes the pulp easier to beat. This effect can also be observed in the commercial area when refining conditions remain essentially unchanged over a period when the FS number does change. This is shown in Fig 8 for the Study A refining data, where the B number developed at constant refining correlates inversely with the FS number. That is, as fiber strength from the pulp mill falls, the same refining produces a higher B number.

FIG 7
LABORATORY STUDY
LEVERAGING EFFECT

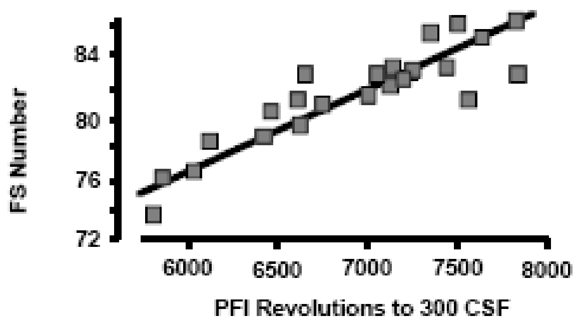
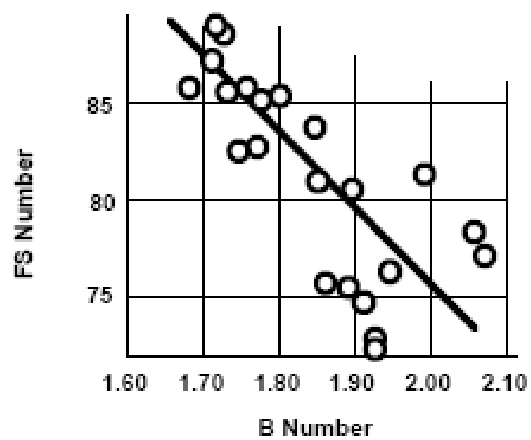


FIG 8
STUDY 'A'
LEVERAGING EFFECT

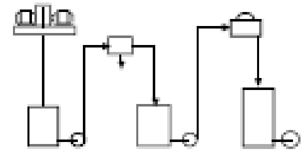


Summary:

Comparing the A and B Studies leads to the conclusion that the Study A commercial refiner possesses a greater hydration to cutting ratio than the Study B refiner. This results in the former demonstrating a greater increase in the B number and a net gain in FS and L numbers due to fiber dekinking and straightening being more dominant than fiber cutting and fines production. The opposite performance is exhibited by the Study B refiner.

The goal of fiber process control in refining is to decide on the proper balance between hydration and cutting, and then to maintain the FS, L, and B numbers at the target levels which reflect this decision. Due to the leveraging effect such control is made difficult if not impossible without proper control of the FS number in the pulp mill.

The Mechanical Pulp Mill



Fiber process control in the mechanical pup mill focuses on Measurements which reliably track changes in fiber strength, length, bonding. Mechanical pulping creates particles generally of smaller than fiber dimensions rather than fibers per se. It does so by mechanical rather than chemical means. These two important distinctions determine the significance of Fiber Quality numbers for mechanical pulps.

In the absence of chemical attack, the actual fiber strength exhibited by mechanical pulps is uneffected by any normal changes in processing conditions. On the other hand the process typically produces copious fines. It is changes in the fines content rather than any changes in true fiber strength which are responsible for changes in the FS number. That is, changes in the FS number indicate changes in the fines content of the mechanical pulp.

The L and B numbers, on the other hand retain the same significance as when testing chemical pulps.

Mechanical pulps are available today in a number of forms ranging from conventional groundwood through refinedwood, pressurized groundwood, to TMP and CTMP. In Table I are illustrated the Fiber Quality numbers for a variety of these different kinds of mechanical pulps.

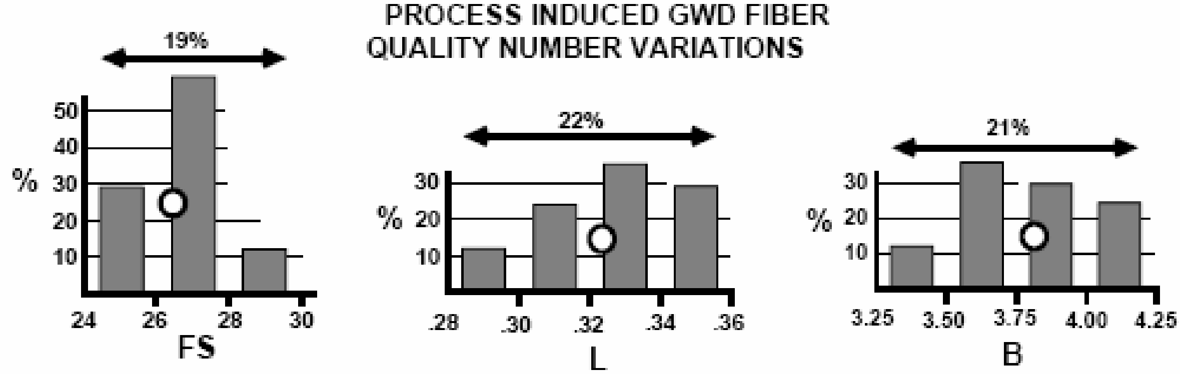
TABLE I
Fiber Quality Numbers of Mechanical Pulps

	FS	L	B
Groundwood	26.5	0.32	3.80
Refinedwood	38.1	0.43	3.18
Pressurized Gwd	35.1	0.49	2.59
TMP	40.5	0.64	2.13

These numbers reflect the large differences in particle sized distribution known to Characterize these different approaches to mechanical pulp production. The large fines content (low FS number) and reduced average particle (fiber) length (L number) of conventional groundwood are the factors which determine its poor strength and good printing performance in a paper network. The large quantity of fines add significantly to bonding potential, and so the B number is seen to decline steadily with mechanical pulps which contain longer fiber elements and less fines material.

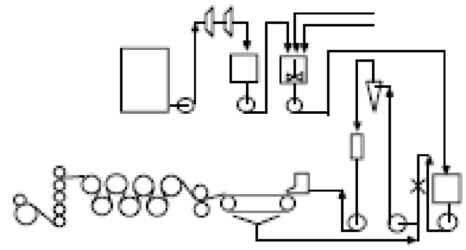
In Fig 1 are shown typical variations in the Fiber Quality numbers encountered during a study in a conventional groundwood mill. In the normal use of mechanical pulps, these variations feed directly into a mixed furnish and then impact on papermaking performance.

FIG 1
PROCESS INDUCED GWD FIBER QUALITY NUMBER VARIATIONS



The goal of fiber process control in the groundwood mill is to decide on the proper particle size distribution and desired bonding contribution of the groundwood pulp and then to maintain the FS, L, and B numbers at the target levels which reflect these conditions.

The Papermachine Delivery System
(Blending)



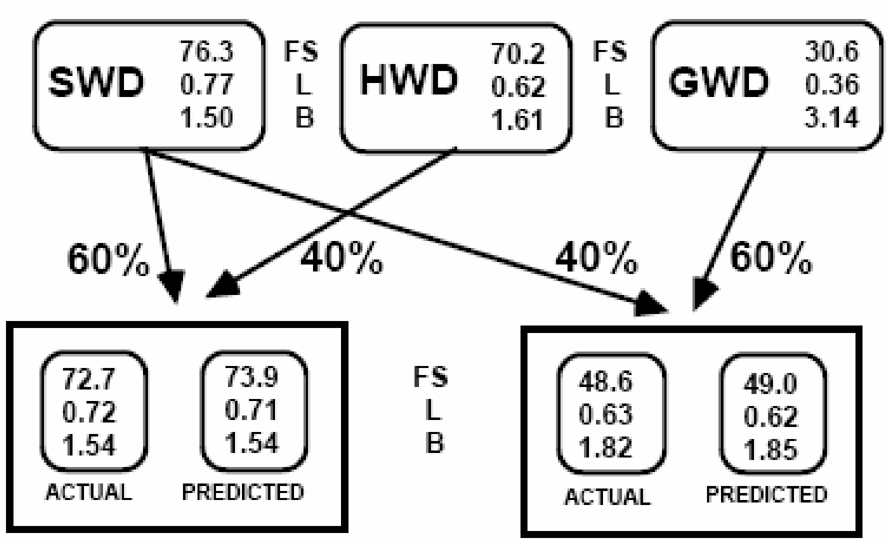
The papermachine delivery system develops fiber quality by refining, then brings together all the components of a furnish (refined fiber, broke, clay, etc.), subjects this furnish to final process adjustments (cleaning, screening, tickler refining, etc.) and delivers it as a controlled flow to the stuff gate and on to the papermachine.

Blending:

When two or more components are mixed, any property of the mixture will be the predictable sum of the component properties so long as the components *do not interact.* For instance the volume of a mixture of sand and water is the sum of the component volumes. This is untrue, however, for a mixture of sugar and water. Here the volume of the mixture is much less than the sum of the component volumes. This is because sugar and water interact. The sugar dissolves into spaces which are not accessible to the sand, which does not interact with water.

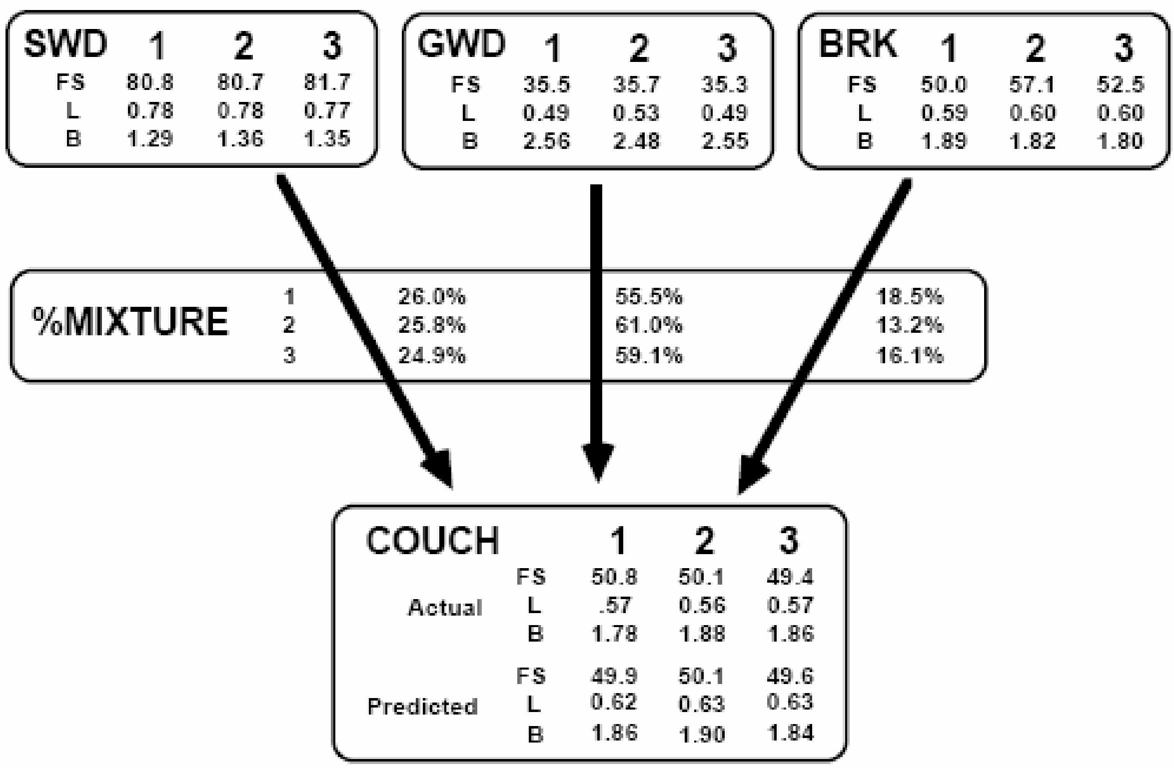
When fiber components are mixed together, the FS, L, and B numbers are additive. In terms of fiber quality testing, the fibers act the same whether they are in mixtures or alone. This is illustrated in Fig 1 for laboratory mixtures of typical commercial pulps used in mixed furnishes. The short span for these tests was set at 0.2 mm to accommodate the groundwood component.

FIG 1
THE FIBER QUALITY NUMBERS OF PULP MIXTURES



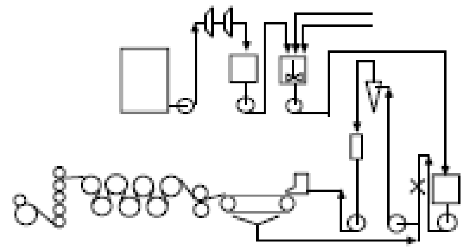
Since fiber numbers are additive, fiber quality numbers of the mixed furnish (couch trim pulp) is predictable from a knowledge of the fiber quality numbers of the component pulps and the mixing proportions. This connection has been examined and some results are Presented in Fig 2.

FIG 2
THE FIBER QUALITY NUMBERS OF PULP MIXTURES



These data were also obtained using a short span setting of 0.2 mm. Although the FS and B numbers of the couch trim pulp are closely predicted from component values, the L number is consistently below the predicted value. Stock cleaners and a papermachine screen are used in this particular papermachine system. The tendency of these processes to preferentially remove longer fibers is a probable explanation of this discrepancy. This observation highlights the fact that any differences in the fiber quality numbers at the couch trim stock from the values predicted from a knowledge of component fiber numbers can be used as a means to characterize just what it is that intervening processes are doing to the fibers.

The Papermachine Delivery System
(Papermachine)



The papermachine delivery system develops fiber quality by refining, then brings together all the components of a furnish (refined fiber, broke, clay, etc.), subjects this furnish to final process adjustments (cleaning, screening, tickler refining, etc.) and delivers it as a controlled flow to the stuff gate and on to the papermachine.

Couch Trim Pulp to Paper at the Reel:

For those papermachines producing paper grades (Z-Span testing is limited to paper grades below a critical basis weight of about 100 gsm) the fiber quality numbers derived from the Z-Span System measurements on the couch trim pulp can be compared with the fiber quality numbers determined for the actual paper at the reel. Such comparative data are presented for five reels of paper sampled on different days over a period of several weeks.

TABLE I
Comparison of Fiber Quality Numbers
Couch Pulp - Paper at the Reel

Paper at theReel			Couch Trim Pulp			Paper/Couch Ratio		
ES	L	B	ES	L	B	ES	L	B
46.1	0.61	1.87	49.4	0.58	1.75	0.93	1.05	1.12
41.9	0.55	2.00	47.0	0.57	1.78	0.89	0.96	1.12
50.3	0.60	1.89	48.0	0.57	1.78	1.05	1.05	1.02
50.2	0.55	1.86	50.8	0.57	1.78	0.99	0.96	1.04
48.8	0.58	1.76	50.1	0.56	1.88	0.97	1.04	1.01
47.5	**0.58**	**1.88**	**49.1**	**0.57**	**1.79**	**0.97**	**1.01**	**1.06**

The fibers in the couch trim pulp are the same fibers that are in the paper at the reel of the papermachine. The only reason that they should not exhibit the same fiber quality numbers is that the fiber *arrangement* that is tested can be quite different. The couch trim pulp is processed in the Z-Span System to produce a test sheet characterized by a random fiber orientation and highly uniform formation. By contrast the sheet at the reel has been formed by a commercial papermachine which introduces a variable preferred alignment of fibers in the machine direction, and a variable non-uniformity of formation quality (normally inferior to that produced by the Z-Span System). The differences shown in Table I illustrate the characteristic impact of orientation and uniformity on fiber quality numbers.

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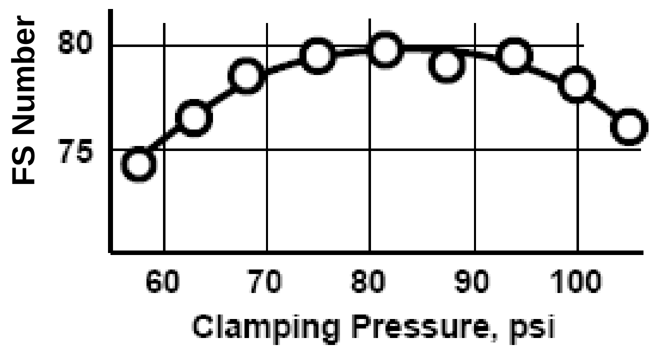
FS Number: A wet zero span test is conducted by clamping the fibers in the test sheet. The clamping pressure can be varied. When this is done a characteristic clamping curve is produced as illustrated in Fig 1. Increasing the clamping pressure reduces micro-slippage at the clamping jaws and thereby increases the number of fibers effectively clamped when failure occurs. The result is an increasing wet zero span value. However, above some critical level, which depends upon the material being tested, the pressure of clamping begins to damage the fibers and thereafter the wet zero span values decline.

Non-uniformity in a fiber network means that the actual clamping pressure exerted on the fibers across the width of the clamping jaw will vary. The clamping load will tend to be carried preferentially by heavy spots so that the clamping pressure will be above average in such regions and below average at light spots. High pressure at the heavy spots can damage fibers while low pressure at the light spots can allow excessive micro-slippage. In both cases the contribution to the wet zero span value will decline. For the same fibers, increasing the non-uniformity of formation will reduce the FS numbers. Since Z-Span test sheets are more uniform than commercial paper, the FS number at the reel will tend to fall below the FS number for the couch pulp.

FIG 1
CLAMPING PRESSURE CURVE



The L Number: The impact of non-uniformity is the same on both zero and short span tests. Since the L number is determined by a ratio, the non-uniformity effect cancels out. However, the L number of the paper is based on tests conducted in the machine direction. Fibers aligned in the direction of testing appear to be longer. Thus fiber alignment in the sheet will increase the L number relative to a randomly oriented test sheet. This effect is not great, but will tend to increase the L number in the paper over that for the couch pulp.

The B Number: The above comment about the impact of non-uniformity applies also to the B number. But the B number also depends on just how the test sheet has been pressed and dried. For instance increasing the pressing load or increasing the tension applied during drying will both tend to increase the effectiveness of bonding in the resulting sheet. In the Z-Span System the test sheet is pressed at a load generally lower than that applied in a Commercial press. Also whereas the test sheet is totally restrained during drying it does not exert the positive tension that exists in the machine direction of commercial paper. For these Reasons a tendency for the B number to be higher at the reel than for the couch pulp is to be expected.

The Paper to Couch Ratio: The above explanations indicate that the fiber numbers at the reel will tend to differ from the numbers for the couch pulp depending upon papermachine processes. The ratios of the FS, L, and B numbers, paper to couch, thus become indicators of papermachine performance. As long as performance is "normal", these ratios will remain constant at their characteristic value. If something happens to alter the uniformity of formation, or changes are made that effect pressing or drying, one or more of these ratios will change.

Poor papermaking performance can be blamed either on the quality of the furnish or the operation of the papermachine. The comparison of paper and couch data provides means to assess this question. For instance a period of poor performance papermaking which corresponds to one or more couch fiber numbers being outside a target range while the paper To couch ratios remain unchanged is evidence of a furnish problem. On the other hand couch numbers being unchanged while one or more paper to couch ratios change significantly is evidence for a papermachine problem.

This kind of evaluation is illustrated by the data in Table II. Periods of different quality performance are being compared. In one (bottom set of data) the paper tensile values are low compared to other periods (top set of data). The fiber numbers for the couch pulp are essentially the same, independent of the period of operation. However, a substantial change can be noted in regard to the paper to couch FS number ratio. This has fallen significantly in those periods when the paper tensile strength has fallen. In this instance it is clear that the decline in paper tensile is due to a papermachine problem; i.e. uniformity of formation has declined significantly.

TABLE II
Evaluating the Causes of a Paper Tensile Problem

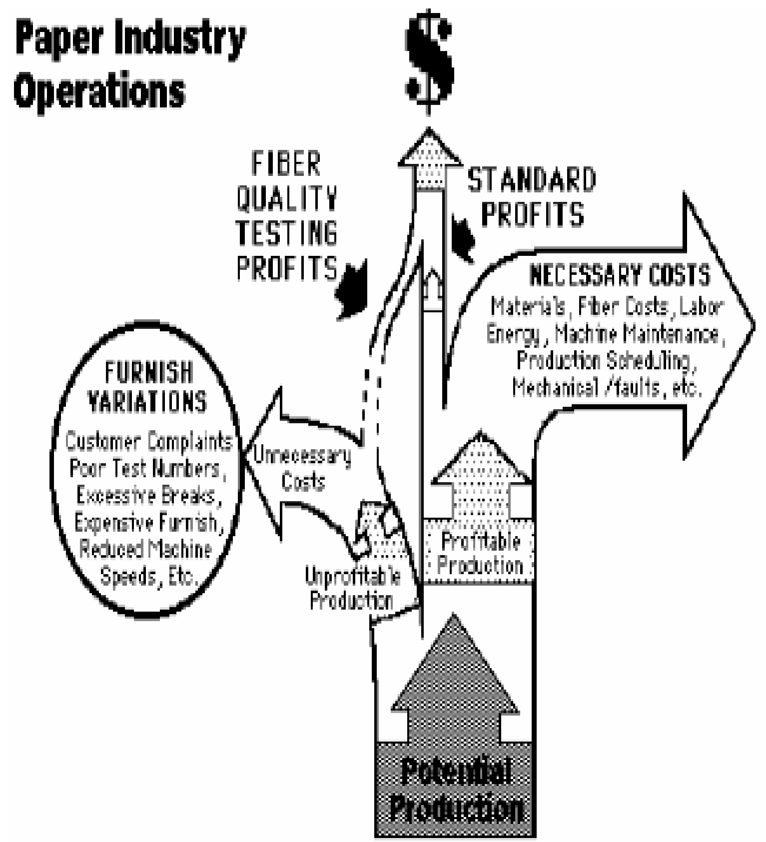
Paper Properties			Paper at Reel			Couch Trim			Paper/Couch Ratio		
Tensile	%Ash	A*	FS	L	B	FS	L	B	FS	L	B
3.8	21.8	2.00	46.1	0.61	1.87	49.4	0.58	1.75	0.93	1.05	1.12
4.1	24.3	1.85	50.3	0.60	1.89	48.0	0.57	1.78	1.05	1.05	1.02
4.4	24.5	1.76	50.2	0.55	1.86	50.8	0.57	1.78	0.99	0.96	1.04
3.8	22.3	1.93	48.8	0.58	1.76	50.1	0.56	1.88	0.97	1.04	1.01
4.0	**23.2**	**1.89**	**48.9**	**0.59**	**1.85**	**49.6**	**0.57**	**1.80**	**0.98**	**1.03**	**1.05**
3.3	22.1	1.89	42.2	0.57	2.09	46.9	0.58	1.87	0.90	0.98	1.07
3.3	20.5	1.92	43.4	0.58	1.92	50.6	0.58	1.83	0.86	1.00	0.97
3.5	20.4	1.92	44.0	0.58	2.02	48.1	0.58	1.71	0.91	1.00	1.06
3.4	20.6	1.89	43.6	0.62	1.83	51.4	0.61	1.71	0.85	1.02	1.11
3.3	20.4	1.89	43.0	0.58	2.01	48.7	0.57	1.78	0.88	1.02	1.10
3.4	**20.4**	**1.90**	**43.2**	**0.59**	**1.97**	**49.1**	**0.58**	**1.78**	**0.88**	**1.00**	**1.08**

Introducing Fiber Process Control

The Reward:

The technology of zero and short span measurement has now matured to a level where it can be exploited by the Pulp and Paper Industry. The information base currently available to support the production of pulp and paper is silent in respect to fiber properties. *Yet it is fiber properties which are a determining factor in respect to paper quality and papermaking performance.* The standards currently accepted as "normal" both in respect to broke production and machine operating efficiencies reflect the current quality of information. Without better information such standards are indeed normal.

A significant portion of such typical profit-eating problems as low quality paper at the reel, excessive papermachine breaks, forced reduction in machine speed, and extra use of kraft in mixed furnishes, can be traced to the fact that fiber properties have departed significantly from the norm. Today that fact is totally transparent. Mills not only have no idea what fiber property might be responsible for which operating problem, they have no idea what fiber properties are desirable in the first place. As a consequence every papermill problem initiates a trial and error solution in which the errors, compounded over the course of a normal year, amount to millions of dollars of forgone profits.



Fiber testing in the mill is now technologically and economically feasable. Once papermakers know what fiber properties they *need* to ensure profitable papermaking, and all processes from the pulp mill through bleaching, refining, and papermaking receive feedback information on precisely what they are *doing* to this fiber quality, today's expensive trial and error system will be transformed into a properly managed system relying on fiber process control to lead the way to the adoption of new standards of efficiency.

This new approach cannot fail to save millions of dollars of what is currently the unrealized profit sacrificed each year to a lack of a creditable fiber process control strategy.