# Trial Mill Strength Profile Study

**May 2003**

**Introduction**
The Zero Span 3000 tensile strength testing system is a tool designed to support optimization of pulp and stock quality. Fiber strength, length and bonding properties can be measured rapidly and repeatably from pulp samples, from stock being blended and from stock being refined for the paper machine, as well as points on the paper machine itself.

**Objectives**
Measurement of fiber strength (FS), length (L) and bonding (B) was performed on pulp and paper samples representing a 8 profiles of fiber line and #2 paper machine in order to determine trends and establish baselines.

**Method**
Each sample was dewatered to 25% consistency, approximately 2 grams, oven dried equivalent, was weighed out then diluted to 0.25% consistency and processed in the Pulmac Beater for five minutes. Six test sheets were prepared from the slurry for each sample with the Pulmac Automated Sheet Former. Tensile strengths at zero and short spans were measured with the Pulmac tester on wet and dry test sheets to generate FS, L and B numbers according to the equations listed in Table 1:

**Table 1: Tensile strength measurements made with the Z-Span 3000 System**

| | | | |
|---|---|---|---|
| **FS** | **(N/cm)** | **Zo** | **wet[1] zero span tensile strength** |
| **L** | (%) | **Z+/ Zo** | **wet short span tensile strength / wet zero span tensile strength** |
| **B** | (%) | **Zd/ Z+** | **dry[2] short span tensile strength / wet short span tensile strength** |
| **TI** | **(N/cm)** | **Zd[2]** | **FS*L*B[2]** |

[1] wet tensile strength is the fiber strength without the influence of fiber bonding
[2] dry short span tensile strength measures bonding potential between fibers

Each **FS**. **L** and **B** number is the average of 16 tests per **Zo, Z+** and **Zd** result. The variation in test precision was calculated as COV (coefficient of variation). As this method is automated, results were determined within 25 minutes for each sample.

**FS** (strength) provides a measurement of the change in average fiber strength through degradation associated with pulping processes, as influenced by cooking time, temperature and the addition of chemicals. The **FS** number also provides a measure of the change in average fiber strength across refining, cleaning, and screening operations and as a result of various stock blends.

The **L** (length) number provides an indicator of the change in average fiber length as a result of fractionation, pulping and refining conditions.

The **B** (bonding) number is a measurement of the bonding potential that is generally enhanced during chemical and mechanical refining. This enhancement can be influenced by increased internal and external fibrillation caused by the refining process. (I.e. increased refining increases the **B** value).

The **TI** (Tensile Index) is an index combining all tests to predict conventional tensile strength.

**Table 2** - Averaged test results that represent the mill profiles.

| **Description** | **FS** | **L** | **B** | **TI** |
|---|---|---|---|---|
| Brown Stock PM2 | 100.4 | 0.35 | 2.05 | 147 |
| Bleached PM2 | 96.2 | 0.34 | 2.09 | 142 |
| Hardwood before refiner | 94.5 | 0.34 | 1.82 | 106 |
| Hardwood after refiner | 95.3 | 0.34 | 2.75 | 247 |
| Softwood before refiner | 80.1 | 0.60 | 1.47 | 103 |
| Softwood after refiner | 83.3 | 0.64 | 1.78 | 168 |
| 'Q' | 85.5 | 0.38 | 2.35 | 178 |
| 'M' | 86.1 | 0.38 | 2.47 | 197 |
| Couch-Trim | 82.3 | 0.36 | 2.55 | .193 |

**Table 3** - Average test results for the pulp mill's screened brown stock and fully bleached.

| **Sample** | **FS** | **L** | **B** | **TI** |
|---|---|---|---|---|
| Brown Stock | 100.4 | 0.35 | 2.05 | 147 |
| Bleached | 96.2 | 0.34 | 2.09 | 142 |
| **% Diff** | **-4.1%** | **-2.6%** | **1.7%** | **-3.3%** |

**Table 4 -** The effect of refining on the strength properties of the hardwood pulp. A similar picture to the first report exits. There is a large increase generated in the bonding number (**B**) without a corresponding loss in Fiber Strength (**FS**) or Fiber Length (**L**). Some of the Bonding number increase may be the result of pre-refining white water dilution that may have raised the weight contribution of fines and starches with no corresponding contribution to resistance to failure under z-span loading.

| **Sample** | **FS** | **L** | **B** | **TI** |
|---|---|---|---|---|
| Bleached | 96.2 | 0.34 | 2.09 | 141 |
| Unrefined | 94.9 | 0.34 | 2.15 | 106 |
| Refined | 95.2 | 0.34 | 2.74 | 247 |
| **% Diff** | **-0.4%** | **2.3%** | **29.7%** | **87.8%** |

**Table 5** - The effect of refining on the strength properties of the softwood pulp. There is a large increase in the bonding number (**B**) across the refiner along with an increase in both Fiber Strength (**FS**) and effective Fiber Length (**L**) numbers.

| **Sample** | **FS** | **L** | **B** | **TI** |
|---|---|---|---|---|
| Unrefined | 80.1 | 0.60 | 1.47 | 103 |
| Refined | 83.3 | 0.64 | 1.78 | 168 |
| **% Diff** | **4.0%** | **6.8%** | **21.3%** | **63.6%** |

**Table 6** - Stock Blend. The composite fiber quality numbers of the blended stock should be predicable as the weighted average of the fiber quality numbers associated with the component pulps.

| **Sample** | **FS** | **L** | **B** | **TI** |
|---|---|---|---|---|
| Refined Hardwood | 95.2 | 0.34 | 2.74 | 247 |
| Refined Softwood | 83.3 | 0.64 | 1.78 | 168 |
| ‘Q’ | 85.5 | 0.38 | 2.35 | 178 |
| Blended | 86.1 | 0.38 | 2.47 | 197 |

**Table 7** - The effect of screening and cleaning in the feed system. (Note:It appears that some fractionation is occurring in that the longer stiffer and stronger fibers are being rejected. This offers an explanation for the lower FS, lower L and higher B number)

| Sample | FS | L | B | TI |
|---|---|---|---|---|
| 'M' | 86.1 | 0.38 | 2.47 | 197 |
| Couch-Trim | 82.3 | 0.36 | 2.55 | 193 |
| **% Diff** | **-4.5%** | **-3.5%** | **3.2%** | **-1.9%** |

**Table 8 -** shows the profile coefficient of variation relationships for 8 samples. As expected the L. B, and TI cv. increases as the pulp is affected by more unit processes. The FS remains stable with the exception of the softwood pulp.

| Sample | FS | L | B | TI |
|---|---|---|---|---|
| Brown Stock | 1.7% | 3.4% | 1.8% | 3.9% |
| Bleached | 2.4% | 1.6% | 1.6% | 4.6% |
| E unrefined | 1.1% | 1.3% | 3.3% | 6.3% |
| F refined | 2.4% | 3.2% | 2.6% | 4.7% |
| FL unrefined | 7.3% | 3.3% | 5.6% | 6.9% |
| FL refined | 5.7% | 3.0% | 4.9% | 7.3% |
| Q | 1.6% | 2.0% | 4.8% | 8.9% |
| M | 3.0% | 5.8% | 5.7% | 8.1% |
| Couch-Trim | 1.7% | 6.5% | 7.1% | 8.7% |

**Figure 1** shows the average of eight profile relationships among the PM 2 processes.

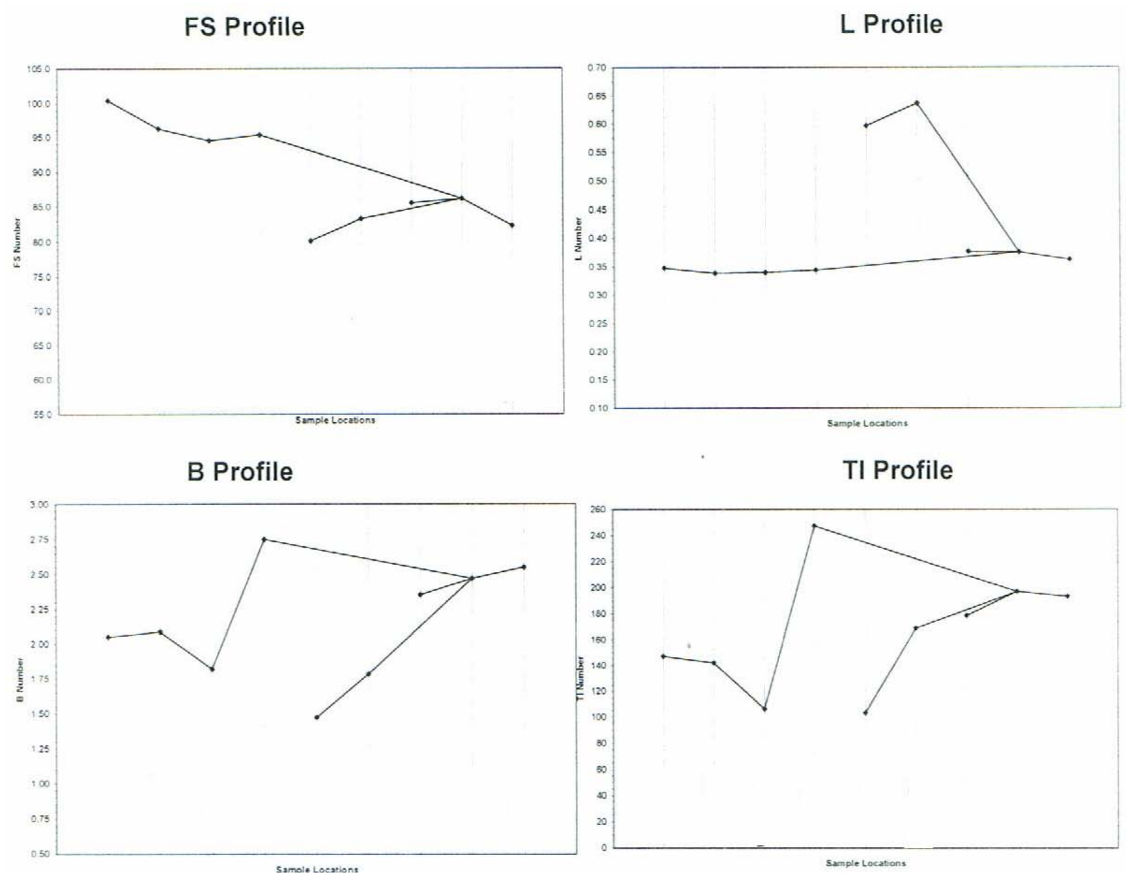


**Figure 2** shows the relationship between the FS coefficient of variation and the  PM 2 profile. The coefficients of variations are quite stable with the exception of the softwood. There appears to be more variation in the incoming softwood than should be expected.

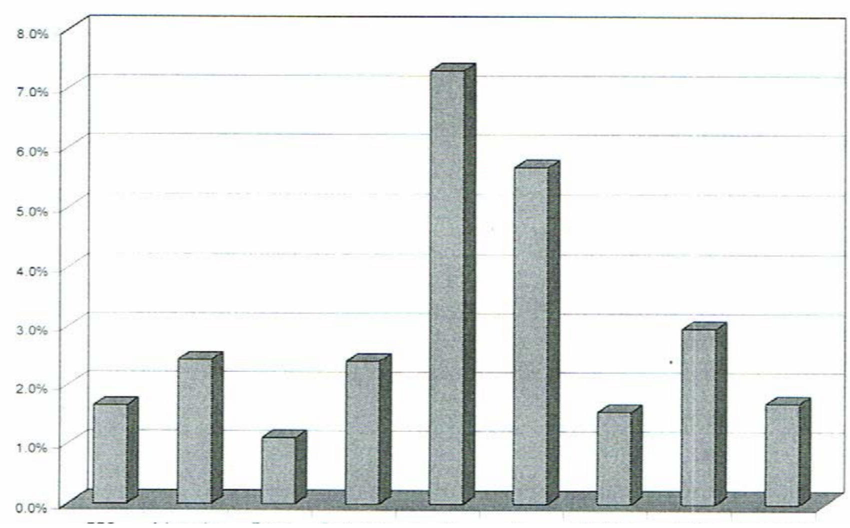



**Figure 3** shows the relationship between the L coefficient of variation and the PM2 Profile. These data are quite stable with the exception of 'M' and Couch Trim. This increase is a result of the shutting off softwood addition to the blend for two of the profile dates.

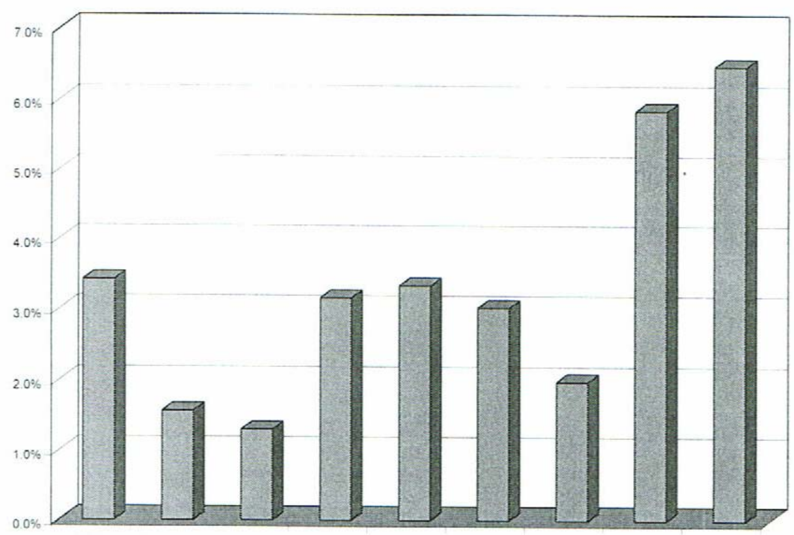


**Figure 4** shows the relationship between the B coefficient of variation and the PM2 Profile. The softwood FS variability noted earlier is also present in the B number. The highest variability resides in the couch trim sample suggesting the addition of filler or some other chemistry is responsible.

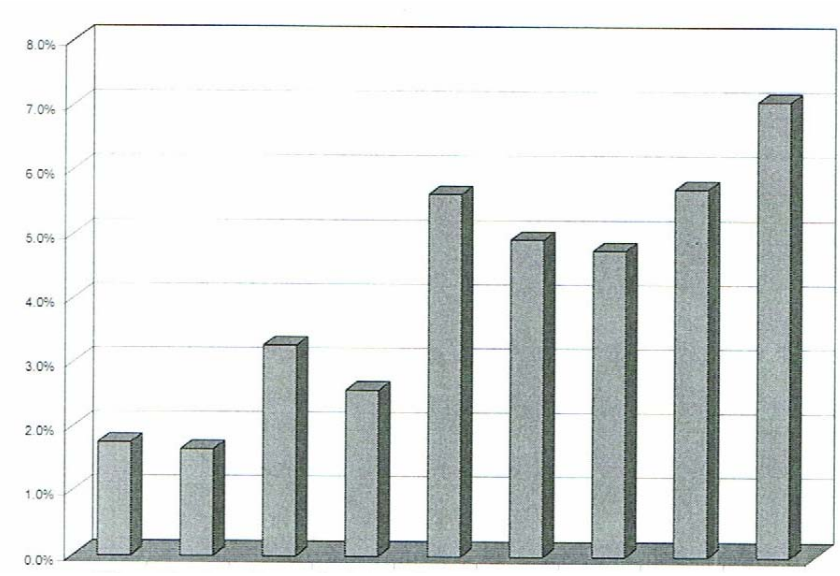



**Figure 5** - shows the relationship between the TI coefficient of variation and the PM2 Profile. This index shows the increased variation throughout the profile as each unit process adds its contribution to the end-state condition of the pulp fibers.
each unit process.

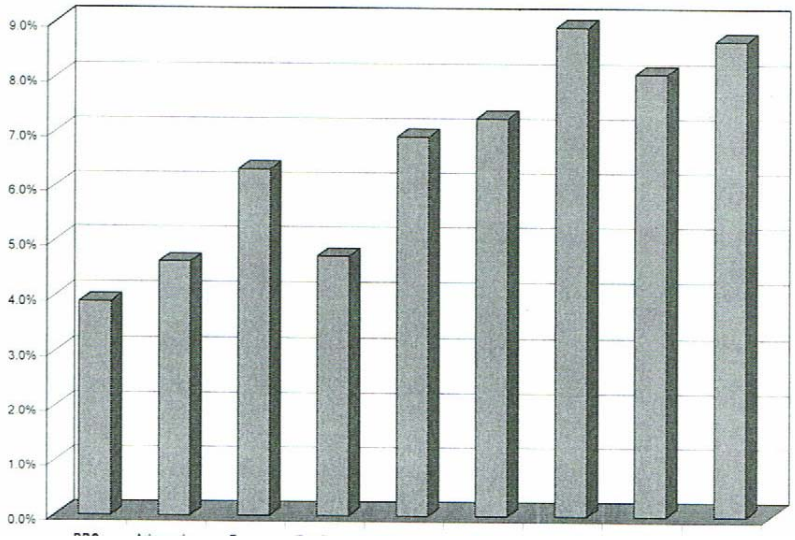


**Figure 6** shows profile information to compare the average results with the profiles where baled. Instead of slush, hardwood was used. The FS number is reduced in refining for the bales as compared to hardwood slush pulp. As expected, here is no difference between the L number in baled or slush form. B Numbers for baled pulp are lower, even at the couch.

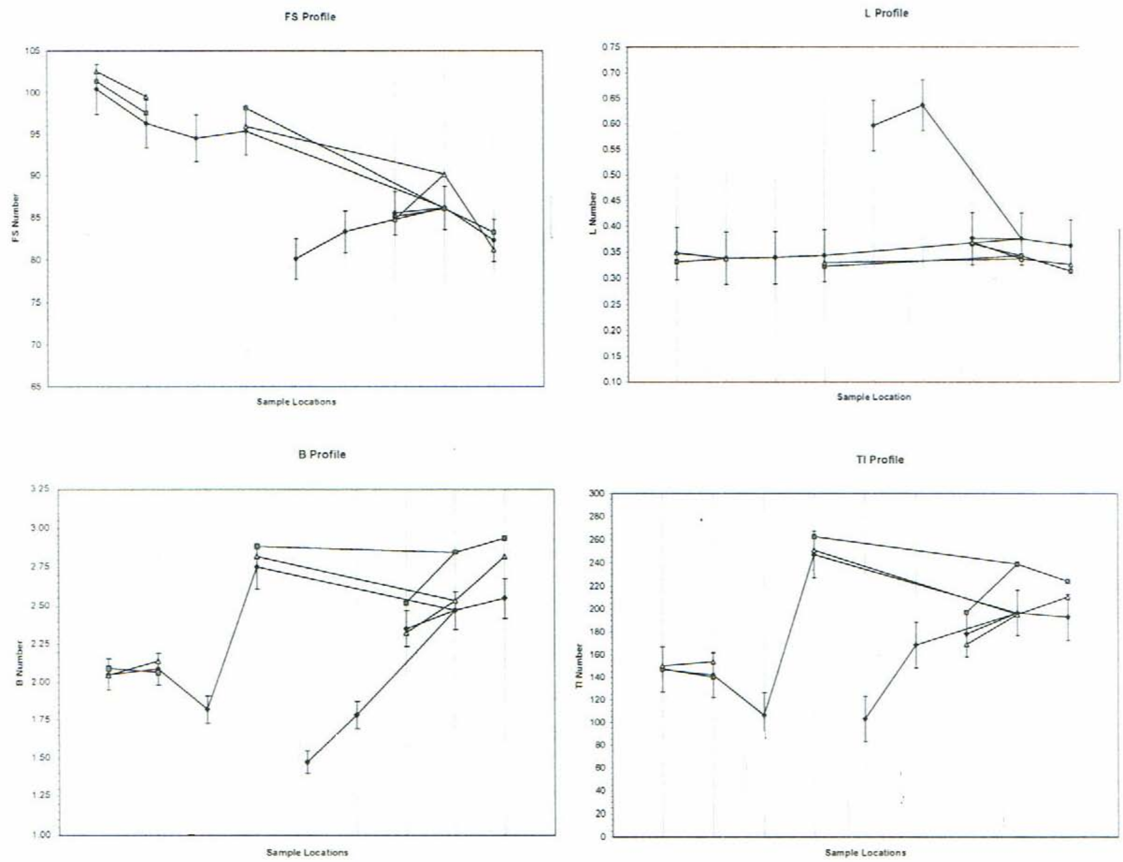
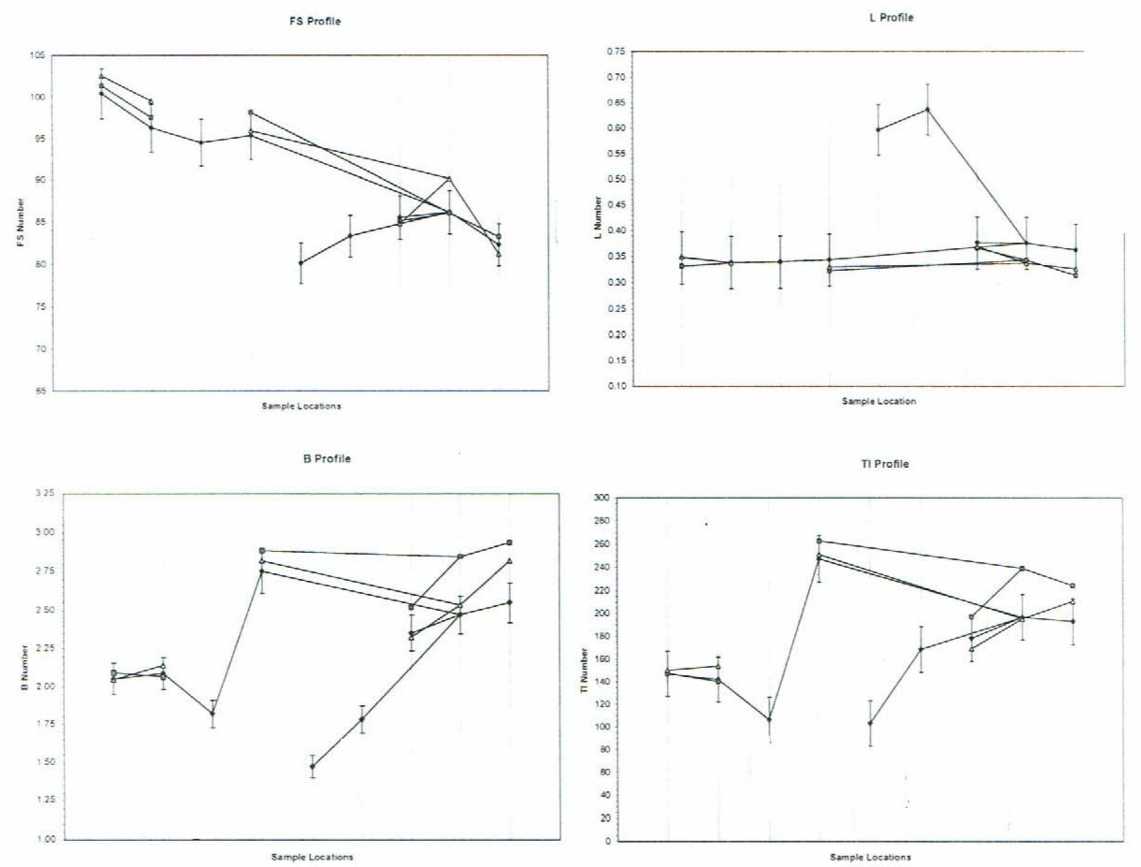


**Table 9** - The difference in refining between the baled and slush hardwood pulps. The B and TI numbers are considerably higher for slush than baled pulp before refining. However, this step change is does not evident after refining. However, to get to the same bonding figures, the refined baled pulp shows lower FS numbers implying that more energy is put into baled than slush pulp.

| **Sample** | **FS** | **L** | **B** | **TI** |
|---|---|---|---|---|
| Hardwood Slush | 96.2 | 0.34 | 2.09 | 141 |
| EucaliptoBaled | 94.9 | 0.34 | 1.82 | 106 |
| **% Diff** | **-14%** | **-0.6%** | **-12,9%** | **-24.4%** |
| Hardwood Refined from slush | 96.3 | 0.34 | 2.75 | 250 |
| Hardwood refined from baled | 91.5 | 0.34 | 2.73 | 236 |
| **% Diff** | **-5%** | **0.2%** | **-.6%** | **-5.7%** |

**Figure 7 -** shows the profile information to compare average results with profiles where, on two occasions, no softwood was used. The FS number is elevated in the 'M' but somehow compensated for at the couch. (possibly more filler?) As expected, the L number is lower when the softwood is not added in the blend. The B number is elevated after refining and becomes even more so with the addition of the higher than normal B number 'Q'. The FS number compensation that is noted between the 'M'" and the couch is also evident with the couch B number. The TI profile is similar to that of the B number.



# Conclusion

The Pulmac Z-Span 3000 Rapid Strength Tester is a repeatable system for troubleshooting, optimization, and monitoring of the contribution of fiber quality to paper strength and, ultimately runnability.

Fiber Strength, Length, Bonding. and Tensile Index numbers were generated on profiles (8 process locations) from 10 different dates over a month and a half period. By plotting Strength Profiles individual profiles can be compared with average profiles. Normal variability can be established for each unit process to set a process norm. This same data set can be used to quickly troubleshoot at any point in time or location where a process upset is occurring.

The following unit process comparisons were found:

- Overall pulp mill variability and strength loss was minimal.
- Fiber Strength for the hardwood pulp is consistently stronger than that of the softwood pulp
- There is a characteristic increase in bonding of 20% for the softwood" and 30% for the hardwood pulp.

The following conclusions were drawn from comparing the  variability in unit processes:

- Overall pulp mill variability was very low.
- The Fiber Strength Number indicates high variability in the softwood pulp.
- There was a general increase in variability of the Tensile Index as each unit process contributed to the overall pulp quality.

The following process conditions were sensitively characterized:

- Baled pulp, replacing slush pulp, was used to support a pulp mill shutdown for two days. It appears that higher energy is used to refine baled pulp as evidenced for a reduction in FS number after refining for baled pulp.

- 100% substitution of the softwood with the hardwood was done for two days associated with higher basis weight grades. On both days the Length number reflected the softwood reduction at the "'M' and Couch locations in comparison to the times when the softwood was used. The increased Bonding compensated for smaller Length number in the Tensile Index for the final couch location.

Using tools like profile comparisons and bench mark targets data generated with the Pulmac Z-Span 3000 Rapid Strength Testing System can enable troubleshooting and optimization at each process location.