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The Effects of Multiple Recycles on Wheat Straw Fibers

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by

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Ever since the late 1960's, the concern for finding suitable replacements to wood fibers within a paper making medium has been one of the focuses for the industry. At the current time, there are only a limited amount of mills that actually utilize non-wood fibers in order to satisfy the demand for paper within developing countries. Much of the use of non-wood fibers stems from the fact that there are only limited amounts of suitable woody raw materials available to sustain their paper industry. Also, areas that dispose of their agricultural resdiues by burning the remaining stalks is starting to be discouraged. The end result is that non-wood fibers pose an interesting question to North American recycle mills which normally reject these grades of paper. In the coming years, the need to use grades of paper that contain non-wood fibers will increase in order to minimize the waste generated by their disposal. Therefore, a need to increase the knowledge of how non-wood fibers will influence paper strength properties through multiple recycles must be investigated.

Through this research project, the strength properties over four recycles were evaluated for paper which contained only softwood fibers and a mixture of softwood and wheat straw fibers. Also, handsheets that contained only wheat straw fibers were produced as a standard of comparison. Through each of the recycles, the addition of wheat straw fibers proved not to detract from the paper strength properties.

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INTRODUCTION

Production and use of non-wood fibers have been predicted to double from the current annual production rate of 400,000 tons per year as we approach the year 2010 (1) Since the late 1960's, research that has been conducted upon the topic of non-wood fiber pulps has become quite popular among countries outside of the United States. Regions in which non-wood fibers have become replacements to the use of wood fibers in paper making are mainly in Eastern European and Asian countries. Each of these areas have found that agricultural residues, such as wheat straw, can be used in paper making due to their similarities in fiber characteristics to that of hardwood fibers. It has also been found that addition of wheat straw fibers to paper can produce printing and writing grades that have a lower porosity and higher surface smoothness. These qualities are important to those who desire their paper to have a particular niche that wood fibers are unable to provide.

The use of wheat straw fibers within European nations has stemmed from the fact that agricultural wastes, as a result of overproduction and government subsidization, are able to fulfill the ever increasing demand for paper making fibers. Within the United States, the annual harvesting of wheat straw has the capability of providing about 100 million tons of usable fibres (2). Unfortunately, there are many factors that inhibit the use of these types of fibers. In order for wheat straw paper production to become a viable source of fibers, mills must find a way to overcome the high cost of transportation, storage, and losses in preparation (3).

Even though there are many impeding factors that limit the introduction of wheat straw as a fiber source, the global marketplace will continue its use for many years to come. Many recycled paper mills have answered the question of what to do with paper that has been produced with non-wood fibers by accepting anything that contains only wood based fibers. As the use of non-wood fibers increases, there will become a need to eventually accept non-wood fibers within recycling operations.

LITERATURE REVIEW

Fiber Characteristics

As a comparison against hardwood fibers, the fiber length of wheat straw fibers is approximately equal to that of both birch and eucalyptus fibers. The reported values for these types of fibers are about 0.8 mm. for eucalyptus, 0.9 mm. for birch, and 0.8 to 0.9 mm. for wheat straw (4). The coarseness values, which depict the mass per meter in length of fiber, for wheat straw fibers are approximately 0.085 mg/m. The typical birch fiber has a slightly higher coarseness (0.110 mg/m), while the eucalyptus fibers have a lower value (0.0750 mg/m) as compared to wheat straw. The break down of chemical constituents for each fiber type shows that the lignin content contained within the wheat straw stalks is lower than either birch or eucalyptus. The lignin content for wheat straw is about 20%. This is lower than that of either birch (21%) or eucalyptus (25%). Even though the lignin content is lower, the percent of cellulose in wheat straw (37%) is lower than that of both birch (41%) and eucalyptus (46%) fibers. The amount of hemicellulose ranges between 23 to 30% in wheat straw, while in birch it is generally 33%, and in eucalyptus is approximately 26%. There is a significant amount of ash that is associated with wheat straw. Both birch and eucalyptus fibers have an ash content of 0.3%, while the ash content in wheat straw is between 5 to 9%.

Paper Production Characteristics

The most significant problem encountered when using wheat straw as a fiber source in paper is the significant amount of fines that are produced during pulping and refining sequences of paper making (5). The generation of high amounts of fines prior to paper formation will lead to problems in production and washing efficiency, as well as drainage on the machine. Wheat straw fibers have tested to have about 38.9% of its fibers to be less than 0.20 mm (4).

In previous research work, it has been proven that pulps containing approximately 35 to 45% wheat straw, with the remainder being softwood, will not show any detrimental effects in drainage (3). These furnish ratios have also been shown to operate with satisfactory results upon existing machines that have been primarily running with wood based fibers. Within the pressing section of a paper machine, these pulps also have the same amount of water removal as compared to 100% wood fiber furnishes. Unfortunately, the addition of wheat straw fibers has shown to decrease wet web strength. In order to overcome this problem, the addition of a suction pick-up and pressing the sheet without an open draw are required.

As stated previously, the amount of fines that are contained within wheat straw pulps is significantly higher than typical wood fiber pulps. This will then lead to problems of removing water within the dryer sections (3). The high amount of fines will result in a decrease in the openness within the paper surface structure. As the water attempts to escape from within the paper structure, it movement is impeded by the shorter length of fibers. Therefore, the dryer section temperatures must be closely supervised in order to maximize its efficiency.

Markets That Use Wheat Straw Fibers

Typical paper products that are currently produced with wheat straw fibers as s substitute for hardwood fibers include printing and writing grades, as well as corrugated and liner boards (1). Mills that are located within China use wheat straw fibers within a majority of paper and board grades in order to satisfy their deficiencies in low wood supplies (4)

Paper and pulp markets within the European community are able to decrease the amount of agricultural residues that are created during harvesting (4). Rather than burning the stalks that remain after harvesting, they are transported to local mills that will pulp the stalks and extract as much usable fibers as possible. The types of paper that will contain these fibers include printing and writing grades.

These fibers can also be incorporated into products that possess unique properties that are directly attributed to the high fines content. Paper that is produced with straw fibers will generally have higher surface smoothness, lower porosity, improved light scattering properties, and high opacity (1, 3).

Loss in Fiber Strength Due to Recycling

There are four significant properties that are used to evaluate the development of strength for paper, and these include fiber strength, length, swelling/plasticity, and bonding potential. Testing for the strength of fibers after it has been through multiple recycles has proven to be dependent upon the fiber type within the paper. There have been conflicting reports as to whether fiber strength is decreased or increased after being recycled several times (6).

Through multiple recycles, paper strength testing has shown that interfiber bonding diminishes when paper has been tested for its tensile strength (6). The loss in tensile strength proves that the fiber to fiber bonding of the original paper is not obtained for recycled paper. This is mainly due to the closing of the external structure of the fibers when they have been repeatedly dried.

The tear strength of recycled paper proved to increase for hardwood fibers and decrease for softwood fibers after multiple recycling stages. Previous work (6) has shown that there is an inverse relationship between tearing strength and fiber to fiber bonding for paper when it has been recycled several times.

The occurrence of hornification is used to describe the effects that recycling has upon changes in the fiber structure over repeated drying and rewetting stages (6). It has been suggested that the fibers will irreversibly change in both the internal and external structure characteristics. The external surface of the fibers is composed of five different sugar polymers, most commonly referred to as hemicellulose (7). Three of these sugars are hexoses (glucose, mannose, and galactose), while the remaining two are pentoses (xylose and arabinose). It has been reported that the amount of pentosans that remain with the fibers will decrease as result of recycling (6).

Also, fibrillation of the external structure during initial refining of the fibers will not be as predominant after being recycled (6). The end result to this will be a reduction in bonding surfaces between fibers. The bulk of the fiber will also undergo a decrease in its ability to absorb water, thus reducing its ability to reswell and become flexible.

Pulp which has been initially refined will have an external structure that is delaminated. This allows for the penetration of water to the internal areas of the fiber, thus causing the fiber to swell in size (6). The drying of these fibers will cause the delaminated structure to recombine with the bulk of the fiber. The closing of the external surface inhibits the migration of water to the inner regions of the fiber.

Effect of Furnish on Recycling

The type of furnish that is present within the paper which is being recycled plays an important role in determining the changes in strength properties. Previous work has found that chemical pulps, as compared to groundwood pulps, will experience a higher degree of tensile and bursting strength losses after being recycled (6). The tearing resistance for groundwood pulps will decrease through each recycle stage, while chemical pulps have shown to actually increase in this property.

Fiber type is also an important consideration to keep in mind when determining the amount of strength losses that are expected after multiple recycling stages. One study proved that softwood and hardwood unbleached kraft pulps will demonstrate the same degree of strength losses after recycling (6).

PROBLEM STATEMENT AND OBJECTIVES

The use of non-wood fibers that are derived from agricultural residues is not a new topic of debate for the paper industry. Many countries located outside of the United States use non-wood fibers, such as wheat straw, in order to fulfill their paper production requirements. The grades of paper produced with this type of fiber will eventually become introduced to recycle operations within the U.S. Presently, recycle mills will reject any paper that is suspected of containing any non-wood fibers. This is mainly due to the insufficient knowledge that exists upon how strength properties will be affected when non-wood fibers go through multiple recycles. Therefore, a need to increase the understanding of how strength properties will be affected by recycling must be addressed. This will aid in maximizing the amount of paper that can be used and decrease the waste that is generated.

The primary objectives for this research are:

1. Determine the amount of strength losses that paper containing 70% softwood and 30% wheat straw fibers when it has undergone four stages of recycling.
2. How paper properties such as porosity and surface smoothness change over four recycles for this type of paper.
3. Prove or disprove that there is a significant difference in strength between paper that contains non-wood fibers versus 100% wood fibers.

EXPERIMENTAL DESIGN

This study was conducted in order to analyze the loss in dry strength paper properties when wheat straw fibers had been combined with softwood fibers and then recycled. In order to provide a basis for comparison, handsheets with only wheat straw fibers were produced, as well as handsheets that only contained softwood fibers. The progression of recycling and strength testing was then conducted upon both the pure softwood handsheets and the 70% softwood and 30% wheat straw handsheets. The experimental schematic is depicted below, in Figure 1.

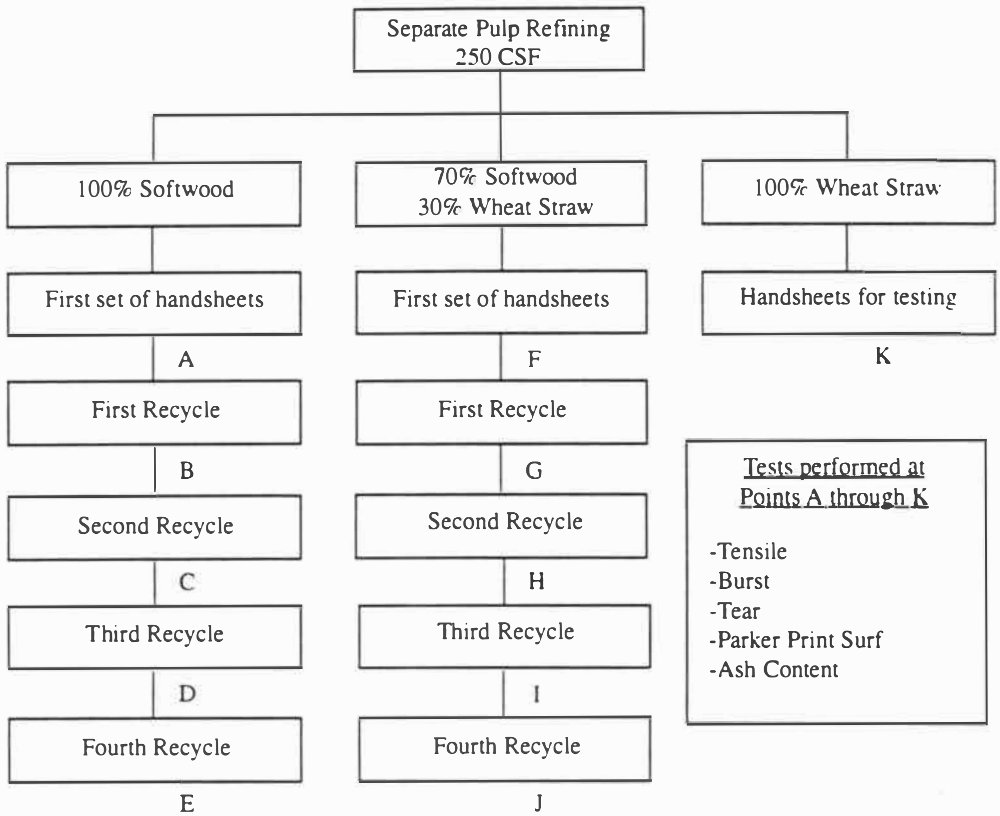

Figure 1. Experimental Schematic

Wheat Straw Pulp Preparation

Since there are no manufacturers of wheat straw pulps within the United States, the pulping of wheat straw on a lab scale was required. The straw that used for this thesis was obtained at a local feed store located in Kalamazoo, Michigan. After the bale of straw was obtained, it was cleaned to remove any unwanted materials such as leaves, dirt, seeds, internodes, and other materials that would undesirably consume pulping chemicals. After this stage of raw material preparation, the stalks were cut into lengths of approximately 5 to 7.5 cm. with the aid of a guillotine cutter. The shortened lengths of straw were then hand cleaned to remove as much undesirable materials as possible.

The straw was then placed within the M&K digester, followed by the cooking liquor. The ratio of cooking liquor to straw was approximately 5:1. The cooking liquor used was to obtain 17% active alkali with a sulfidity of 15%. The two cooks performed were conducted at a cooking temperature of 165 °C for approximately 45 minutes. The final yield for the combined cooks was evaluated to be 42.5%. At the end of cooking, the pulps were combined together and hand washed over a 200 mesh screen. Breaking up the softened straw was primarily done by hand, followed by dispersing of the pulp within a laboratory blender. The final screening process involved the use of a six cut vibratory screen and a 250 mesh count pillow case. A sample was taken in order to perform a fiber analysis with a Kajaani FS - 100 Analyzer.

A single pulp sample that weighed 300 grams, at a consistency of 10%, was used to determine the refining curve by measuring the Canadian Standard Freeness after refining in a PFI mill over a series of revolutions. Once a curve had been established, the remaining pulp was adjusted to the same consistency as before and separated into portions of 300 grams in mass. Each sample was then refined at the same number of revolutions so that the freeness value was about 250 mL CSF.

Softwood Pulp Preparation

The softwood pulp was obtained from Consolidated Papers. The pulp was tested for moisture content and initial freeness. A sample was set aside so that a fiber analysis on the Kajaani FS - 100 Analyzer could be performed. After the original freeness was determined, a 300 gram sample at 10% consistency was set aside so that another refining curve could be established. The remainder of the pulp was adjusted to a 10% consistency and separated into 300 gram samples. The samples were then refined for the determined number of revolutions that would produce a 250 mL CSF.

Handsheet Production

After the two pulps had been refined to the desired freeness value, handsheets were produced on the Noble and Wood Handsheet machine. Fifty handsheets of the 100% softwood and 70% softwood / 30% wheat straw were produced to have a dry mass of 2.50 +/- 0.03 grams. For the 100% wheat straw, only ten handsheets were made since these were not required to undergo recycling. Each set of handsheets were placed within a conditioning room prior to testing.

Handsheet Recycling

The remaining handsheets were then placed within water for a time period of at least four hours. The pulp and water was transferred to the disintegrator up to a total volume of 2000 +/- 25 mL at a consistency of 1.5%. Each sample was then disintegrated for 10,000 revolutions. The pulps were then separately dewatered to a consistency of 10% over a 200 mesh screen. At this point, samples with a mass of 300 grams were divided up and refined to a freeness of 250 CSF. After refining, the pulp was placed within a 5 gallon bucket and redispersed with a laboratory scale mixer. Once again, a set of handsheets with an individual mass of 2.50 +/- 0.03 grams were made and set aside for testing. For each recycle stage, the above procedures were repeated until four stages of recycling had been accomplished.

Strength Testing

The ten handsheets from the original set of handsheets, as well as each recycle, were placed within the conditioning lab for a time period of at least 24 hours. Each handsheet was tested for porosity and surface smoothness on the Parker Print Surf machine. Next, destructive testing for burst, tensile, and tear were performed according to TAPPI standards. The recorded values for each of their tests were calculated for their corresponding index value.

Ash Content

The testing for ash content was performed on a sample from each set of handsheets. The samples were first placed within an oven, that had been previously set to 105 °C, for a time period of at least one hour. Each sample's mass was recorded, followed by insertion into an ash oven that was set at 525 °F. Once the paper had been completely burned off, the crucibles were removed from the oven and weighed for the final mass, after cooling in a desiccator.

RESULTS AND DISCUSSION

Results

The results of each test performed can be found at the end of this report within Appendix A. These tables contain both the raw data and the index values for the corresponding tests. Average values and standard deviation for each set of handsheets are displayed in the right hand side of the tables. For each group of handsheets, the average test results and standard deviations are located below the columns for their corresponding test.

Discussion

Original Handsheets

Figure 2 displays the average burst index for the three original sets of handsheets. Out of all the test specimens, the highest value for bursting strength came from the paper made with 100% wheat straw. The average for this set was 5.57 kPa*m^2/g, with a standard deviation of 0.27 kPa*m^2/g. The handsheets made with only softwood fibers burst at an average pressure of 4.71 kPa*m^2/g. The standard deviation for this group was 0.29 kPa*m^2/g. The bursting strength for the samples made with 70% softwood and 30% wheat straw averaged to be 4.61 kPa*m^2/g (+/- 0.40).

This graph shows that at the same amount of refining, paper made exclusively from wheat straw fibers will have a higher bursting. Also, one can see that the addition of wheat straw fibers to softwood fibers will not appreciably affect bursting strength.

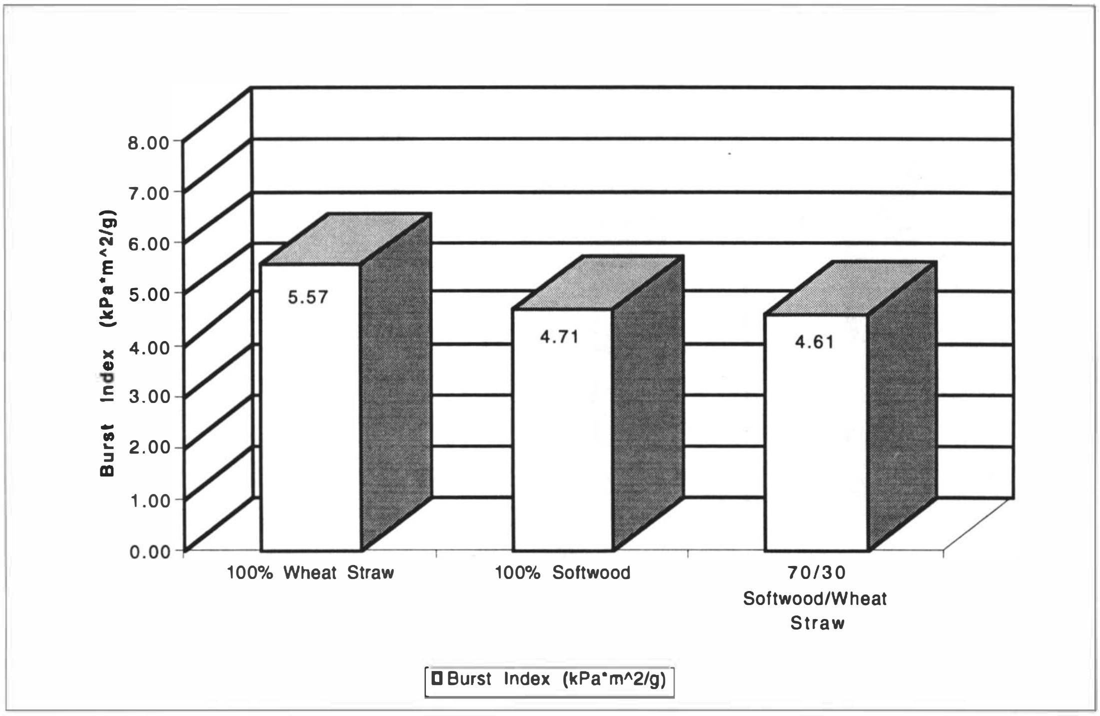

Figure 2. Burst Index for Each Original Set of Handsheets

The next figure (Figure 3) shows the average results for the tensile index for the three sets of samples. Wheat straw handsheets showed to have the highest tensile index out of the three sets. The average value for this paper was 81.0 N*m/g (+/- 5.61 N*m/g). Test results for 100% softwood versus the addition of wheat straw fibers did not show to have a significant difference between the two. The softwood handsheets had an average tensile index of 65.4 N*m/g (+/- 4.32 N*m/g), while the combination of the two had a tensile index of 66.8 N*m/g (+/- 4.71 N*m/g). The negligible difference in tensile index values shows that wheat straw does not cause a decrease in strength.

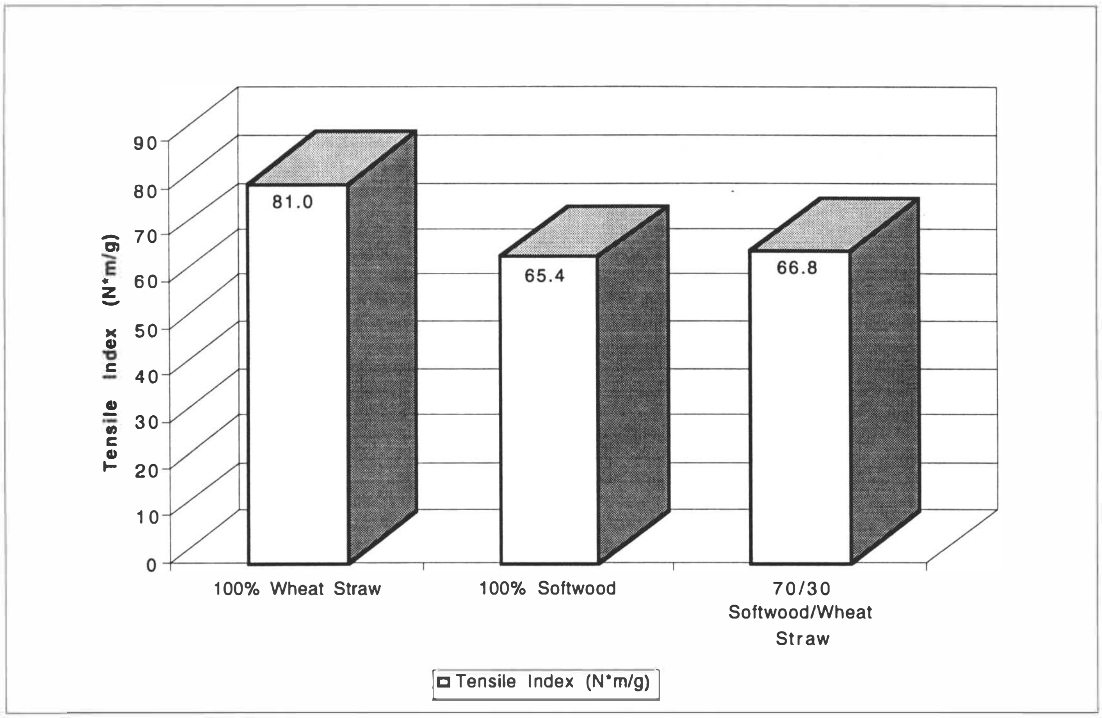

Figure 3. Tensile Index for Each Original Set of Handsheets

Measurements for the tearing resistance of paper show that paper which is made with only wheat straw fibers are not as strong as 100% softwood fibers sheets (Refer to Figure 4). The softwood sheets had a tear index value of 7.38 mNm^2/g, with a standard deviation of 0.45 mNm^2/g. For the paper containing wheat straw fibers, the average tear index came out to be 4.06 mNm^2/g (+/- 0.24 mNm^2/g). The figure also shows that the combination of the two fiber types will be have a tear index of 5.84 mNm^2/g (+/- 0.46 mNm^2/g), which is between the results for each of the individual fiber sets.

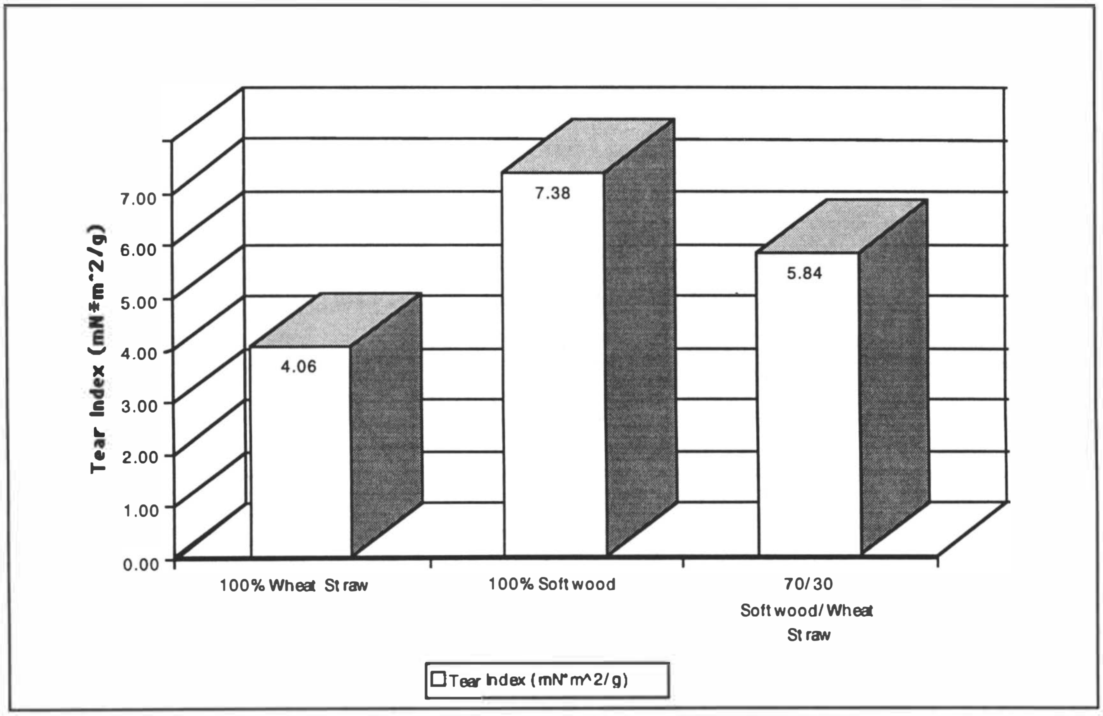

Figure 4. Tear Index for Each Original Set of Handsheets

Effects of Recycling on Strength

Results for the burst index for both the 100% softwood and 70/30 softwood/wheat straw are shown in Figure 5 and Tables 1 and 2. As stated earlier, the burst index for the original handsheets of each of two fiber types were approximately equal to one another. Testing for burst index after each recycle showed that the use of wheat straw and softwood pulps would yield higher average values.

After the paper samples had been recycled for the first time, strength of the 100% softwood handsheets achieved lower values than the combination of the two fibers. The 70/30 softwood/wheat straw average burst index was 4.01 kPa*m^2/g (+/- 0.39 kPa*m^2/g), while the softwood average was 3.82 kPa*m^2/g (+/- 0.26 kPa*m^2/g). The loss in burst index after the first recycle showed that the 100%

softwood decreased by 23.3%. The burst index for the 70/30 showed a decrease in strength (15.0%) that was less than the pure softwood handsheets.

Table 1
Results for the Average Burst Index After Four Recycles for the 100% Softwood Handsheets

	Burst Index (kPa*m^2/g)	Standard Deviation (kPa*m^2/g)	Loss in strength (%)
Original Handsheets	4.71	0.29	----------
First Recycle	3.82	0.26	23.3
Second Recycle	3.13	0.78	22.0
Third Recycle	3.02	0.19	3.64
Fourth Recycle	2.45	0.18	23.3

Table 2
Results for the Average Burst Index After Four Recycles for the 70% Softwood / 30% Wheat Straw Handsheets

	Burst Index (kPa*m^2/g)	Standard Deviation (kPa*m^2/g)	Loss in strength (%)
Original Handsheets	4.61	0.40	----------
First Recycle	4.01	0.39	15.1
Second Recycle	3.61	0.24	11.1
Third Recycle	3.42	0.23	5.56
Fourth Recycle	3.00	0.18	14.0

The decrease in average burst index after the second recycle was 22.0% for the 100% softwood handsheets. Compared to the loss in strength for the 70/30 softwood/wheat straw handsheets (11.1%), this was greater. Also, the average burst index values for the softwood handsheets were lower than those for the 70/30 handsheets.

The next stage of recycling proved to have burst index losses that were less than in any of the pervious recycles. At this point in the study, it seemed as though there would be an observed leveling effect for strength losses in bursting index. However, the fourth recycling stage for both sets of paper showed to have strength losses that were about equal to the first and second recycles. The decrease in average burst index for the 70/30 handsheet was approximately 5.56% after the third recycle, while the fourth recycle experienced a loss of 14.0%. The 100% softwood handsheets also showed to have the same trend. The loss in average burst index changed from 3.64% after the third stage to 23.3% after the fourth stage.

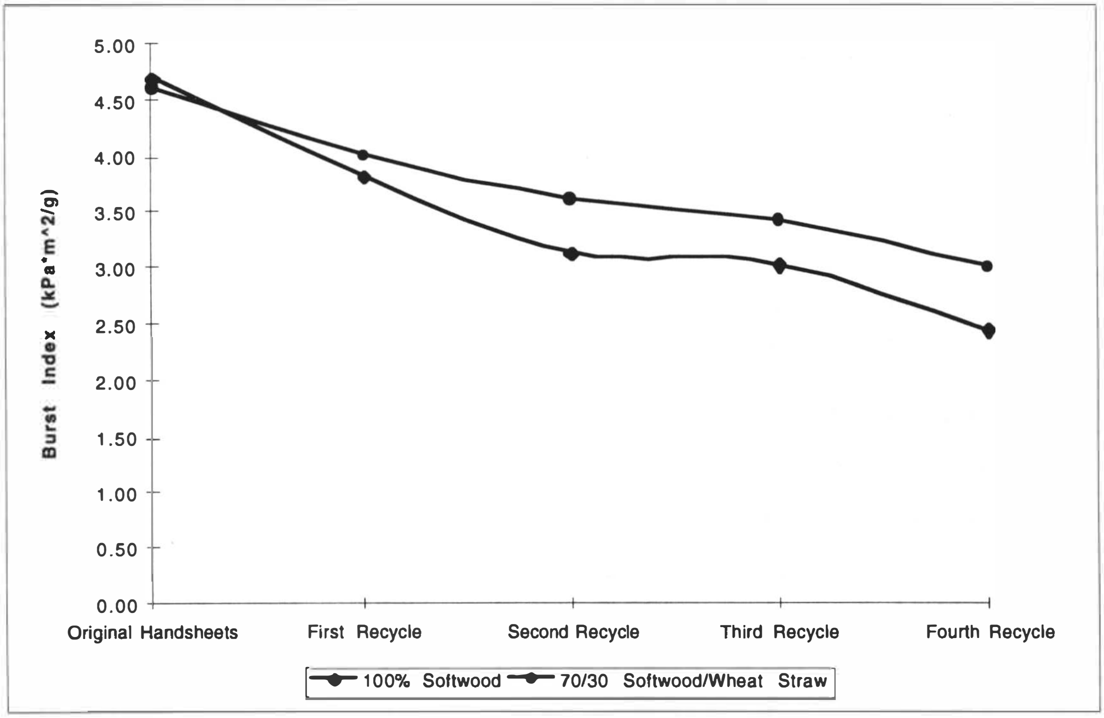

Figure 5. Burst Index After Four Stages of Recycle

Each of the sets of handsheets were also subjected to testing for average tensile index (Tables 3 and 4). The first set of handsheets tested to have approximately the same value for both the 100% softwood and the 70/30 softwood/wheat straw samples. This demonstrated that the wheat straw fibers did not significantly change the strength of paper when added with softwood fibers.

Table 3
Results for the Average Tensile Index After Four Recycles for the 100% Softwood Handsheets

	Tensile Index (N*m/g)	Standard Deviation (N*m/g)	Loss in strength (%)
Original Handsheets	65.45	4.324	----------
First Recycle	57.17	3.509	14.48
Second Recycle	50.75	5.382	12.65
Third Recycle	48.47	4.544	4.704
Fourth Recycle	40.86	1.312	18.62

Table 4
Results for the Average Tensile Index After Four Recycles for the 70% Softwood / 30% Wheat Straw Handsheets

	Tensile Index (N*m/g)	Standard Deviation (N*m/g)	Loss in strength (%)
Original Handsheets	66.80	4.710	----------
First Recycle	62.93	4.711	6.150
Second Recycle	53.69	4.690	17.13
Third Recycle	51.83	3.643	3.589
Fourth Recycle	46.45	2.281	11.58

Over the four stages of recycling, the 70% softwood / 30% wheat straw handsheets proved to result in average tensile index values that were approximately equal to that of the 100% softwood handsheets (Figure 6). The first recycle stage had a decrease of average tensile index value of about 14.5% for the softwood handsheets. On the other hand, the mixed fiber handsheets had a loss in average tensile index appreciably lower (6.2%). After the handsheets had been recycled for a second time, the 70/30 softwood/wheat straw handsheets experienced a higher loss in average tensile index value, even though the average value was still above the 100% softwood handsheets. Testing after the third stage demonstrated the same decrease, followed by an increase, as was observed for the average burst index values. The 100% softwood handsheets' average tensile index strength loss after the fourth recycle resulted in being higher than any of the previous stages, while the softwood/wheat straw handsheets did not surpass the earlier stages.

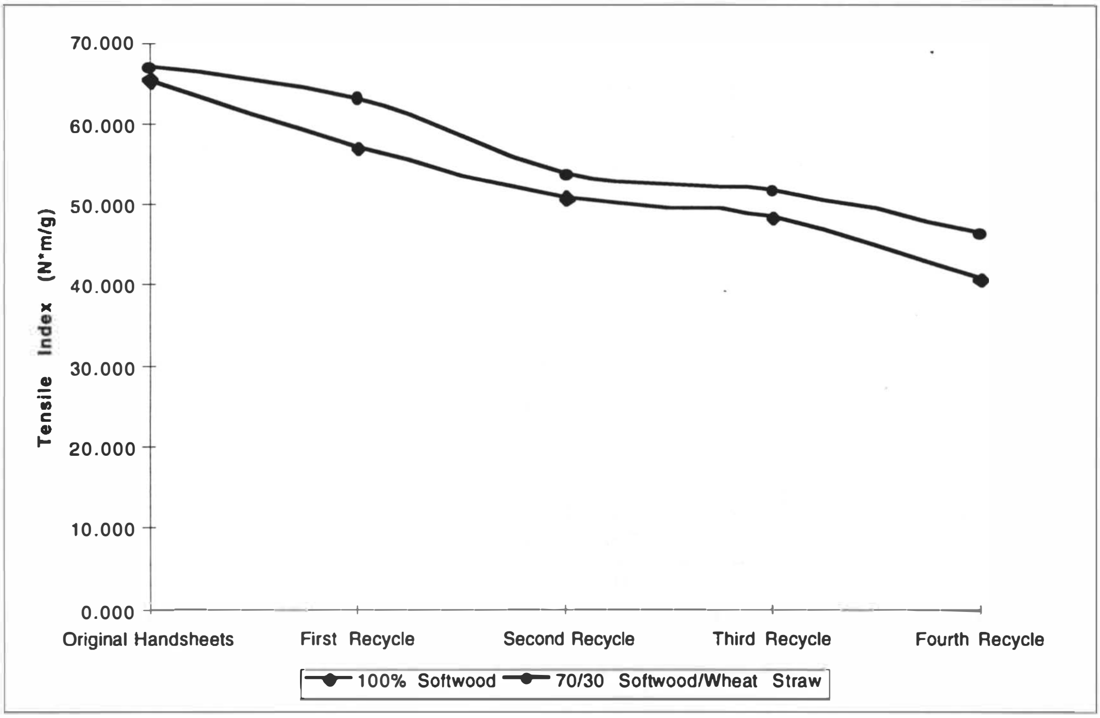

Figure 6. Tensile Index After Four Stages of Recycle

The tear index values did not significantly change throughout each of the recycle stages. The average values for the 100% softwood handsheets in Table 5 shows that the tear index of 7.4 mN*m^2/g for the original handsheets was the highest. The first, second, and fourth recycle stages did not significantly change from this initial value. The average tear index after the third recycle of the 100% softwood handsheets resulted in being lower than the rest. The percent change in average tear index values shows that there was a loss of approximately 2.8% and 7.4% after the first and third recycles, respectively. Conversely, the second and fourth recycles increased in average tear index.

As can be seen in Table 6, the 70% softwood / 30% wheat straw handsheets also did not vary significantly from recycle to recycle. The initial handsheets and second recycle handsheets averaged a tear index value of 5.8 mN*m^2/g. The highest average result was observed for the handsheets produced after the first recycle (6.4 mN*m^2/g). The third and fourth recycle average results were approximately equal to one another, as well as the rest of the group.

Table 5
Results for the Average Tear Index After Four Recycles for the 100% Softwood Handsheets

	Tear Index (mN*m^2/g)	Standard Deviation (mN*m^2/g)	Change in strength (%)
Original Handsheets	7.4	0.5	----------
First Recycle	7.2	0.6	-2.8
Second Recycle	7.3	0.5	1.4
Third Recycle	6.8	0.5	-7.4
Fourth Recycle	7.1	0.4	4.2

Table 6
Results for the Average Tear Index After Four Recycles for the 70% Softwood / 30% Wheat Straw Handsheets

	Tear Index (mN*m^2/g)	Standard Deviation (mN*m^2/g)	Change in strength (%)
Original Handsheets	5.8	0.5	----------
First Recycle	6.4	0.5	9.4
Second Recycle	5.8	0.5	-10
Third Recycle	6.1	0.5	4.9
Fourth Recycle	6.0	0.3	-1.7

The difference between the two sets shows that the handsheets composed of only softwood fibers will, for the most part, have a higher average tear index through the four stages of recycling (Figure 7). The 100% softwood handsheets that were made after the third stage of recycling was the only result that was approximately equal to the handsheets which contained wheat straw fibers.

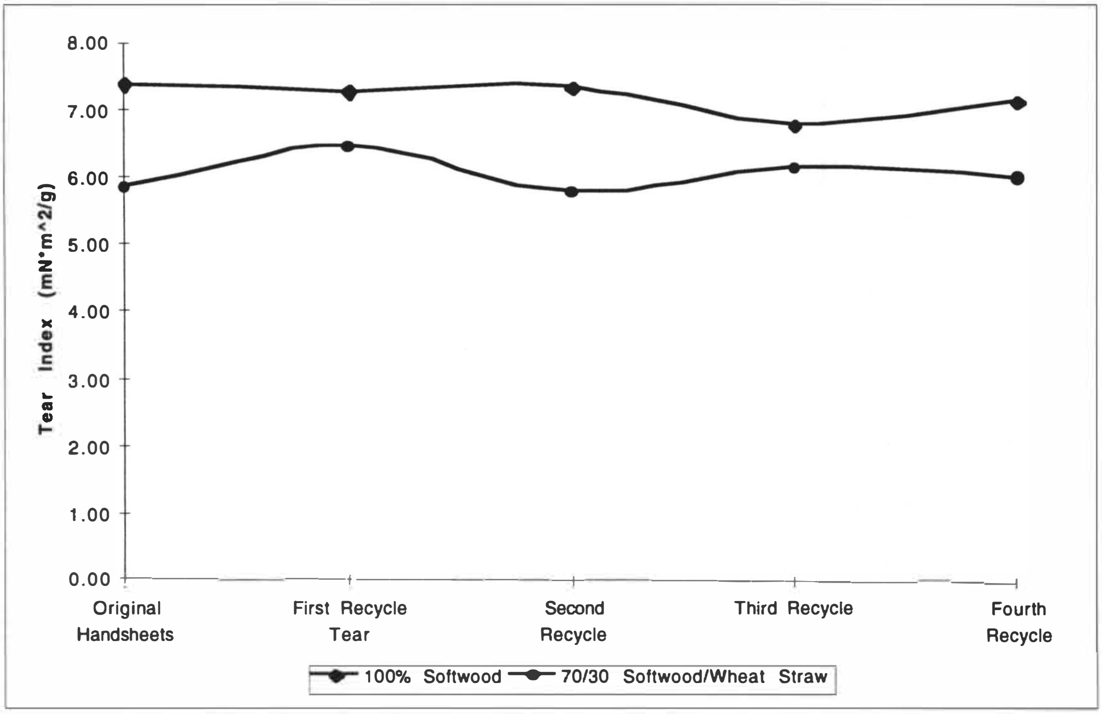

Figure 7. Tear Index After Four Stages of Recycle

As stated in a prior section, the ash content of wheat straw is significantly higher than the typical hardwood sources of paper making fibers. By this fact, the percent ash, for each of the recycle stages, was performed as a means of tracking the presence of the wheat straw fibers in order to show that the fibers were not lost as fines. Table 7 shows that the handsheets produced with 100% wheat straw fibers had a higher ash content than the 100% softwood handsheets.

Table 7
Results for Ash Content After Four Stages of Recycle

	100% Softwood (Percent Ash)	70% Softwood / 30% Wheat Straw (Percent Ash)	100% Wheat Straw (Percent Ash)
Original Handsheets	0.44	0.66	0.72
First Recycle	0.45	0.59	----------
Second Recycle	0.48	0.63	----------
Third Recycle	0.71	0.93	----------
Fourth Recycle	0.47	0.59	----------

The combination of the two types of fibers resulted in being lower than 100% wheat straw samples, and higher than the 100% softwood handsheets. The amount of ash that was tested to be within the initial 100% softwood handsheets resulted in being lower than the 70% softwood / 30% wheat straw sample. The difference in ash content can also be noted for the first, second, and fourth recycles (Figure 8). The third recycle, for the two sets of samples, showed to have a higher ash content than the rest of the results.

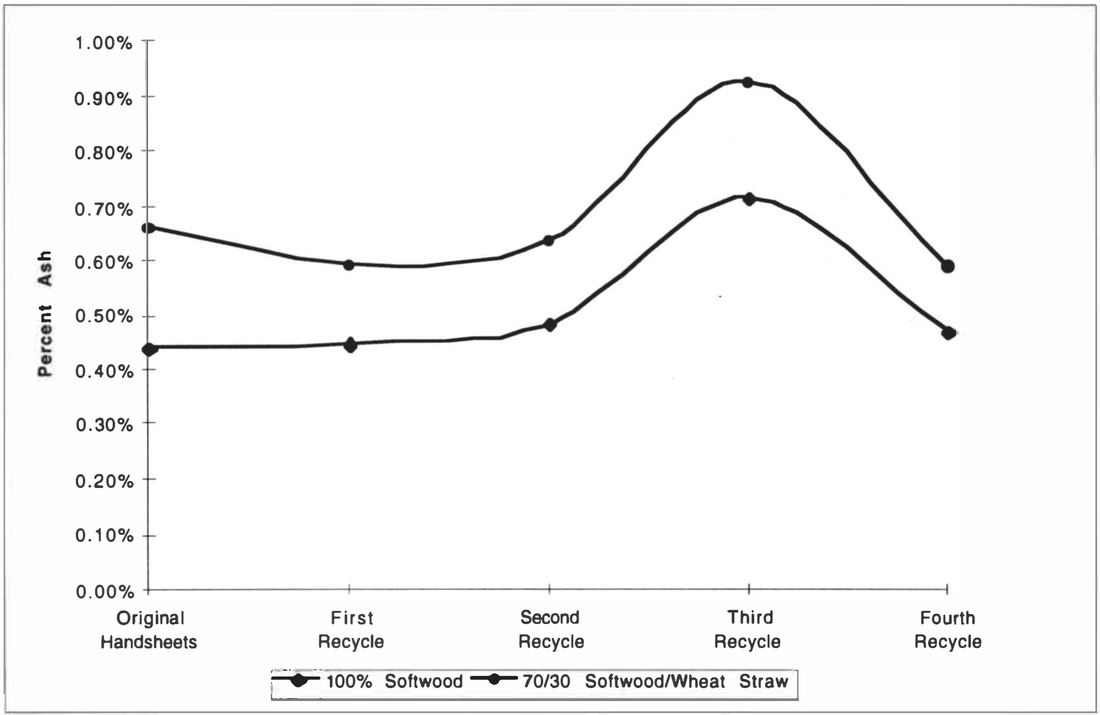

Figure 8. Percent Ash After Four Stages of Recycle

The above results display that the ash content of paper which has been made with wheat straw fibers will be greater than that of softwood fibers. It can also be concluded that wheat straw fibers are not preferentially lost in the form of fines during the process of recycling.

CONCLUSIONS

1. For the most part, paper that was produced with wheat straw fibers that had been refined to the same degree as softwood fibers will be equal in dry strength. Also, the combination of the types of pulps will not significantly alter the strength properties as well.

2. Paper which contains 30% wheat straw fibers and 70% softwood fibers did not show significantly altered dry strength properties after being recycled for four stages. In some cases, handsheets that were made with the two fibers were tested to have strength properties above that of the 100% softwood handsheets.

3. The ash content of paper that is produced with wheat straw fibers is significantly greater than wood fibers. This was used as a means of showing that the wheat straw fibers remained in the paper through the four stages of recycling.

SUGGESTIONS FOR FURTHER STUDY

The purpose of this study was to determine how the loss in strength properties for paper that contains wheat straw fibers compares against paper that only contained softwood fibers. Further studies can attempt to incorporate other non-wood fibers with similar characteristics as hardwood fibers.

Between each of the recycle stages, the pulps were refined to approximately the same freeness as the original pulps. If one wanted, they could perform recycles on the same mixture of softwood and wheat straw pulps on multiple samples, but have three or four different levels of refining. This will be able to show how this type of pulp will respond to different levels of refining. Also, one can determine if there is an optimum level of refining over multiple recycles.

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APPENDIX A

Testing Results

100% Wheat Straw

													Average	
Handsheet (#/mass)	Caliper (1/1000 in)	Burst (psi)	Tensile (Kgf)	Tear (eu)	Roughness (microns)		Porosity (ml/min.)		Basis weight (g/m^2)	Burst index (kPa*m^2/g)	Tensile index (N*m/G)	Tear Index (mN*m^2/g)	Burst index (kPa*m^2/g)	Tensile index (N*m/G)
1)	3.700				9.840	11.060	75.410	82.910						
2.450	3.850	46.500	7.637	6.500	9.770	11.060	74.590	76.290	59.336	5.399	84.149	4.299	5.240	84.149
	3.700				9.590	10.670	79.320	84.140						
	4.000	43.750			9.470	10.590	81.200	81.190		5.080				
	3.650				9.830	10.760	83.680	81.850						
	3.850													
2)	3.650				9.590	10.590	91.800	84.260						
2.450	3.700	48.750	7.616	6.000	9.770	10.500	82.480	82.070	59.336	5.661	83.918	3.968	5.632	80.821
	4.000				9.770	10.590	74.560	78.270						
	4.100	48.250	7.267		9.770	11.060	79.860	81.670		5.603	80.072			
	3.900				9.830	11.160	75.590	73.200						
	4.050		7.122								78.474			
3)	3.800				9.900	10.760	72.130	73.210						
2.510	4.100	48.250	7.807	6.500	9.770	10.960	93.100	99.920	60.789	5.469	83.966	4.196	5.455	76.964
	4.100				9.840	10.590	102.000	98.350						
	4.050	48.000	6.505		9.770	10.960	76.380	70.100		5.440	69.963			
	3.950				9.710	10.670	102.200	94.510						
	3.850													
4)	4.100				9.710	10.420	56.010	61.010						
2.450	3.900	47.000	7.039	6.000	9.960	10.420	66.660	65.000	59.336	5.458	77.560	3.968	5.487	76.552
	4.000				9.830	10.670	60.680	73.330						
	3.850	47.500	6.856		9.710	11.060	70.830	72.030		5.516	75.543			
	4.050				9.770	10.420	75.500	63.720						
	3.900													
5)	3.900				9.710	10.770	103.900	107.300						
2.450	3.950	46.500	6.864	6.000	9.710	10.860	88.410	103.100	59.336	5.399	75.632	3.968	5.472	76.127
	4.150				9.650	10.680	91.610	90.580						
	3.850	47.750	6.652		9.830	10.860	97.550	86.170		5.545	73.296			
	3.750				9.780	10.590	83.390	79.970						
	3.700		7.211								79.455			
6)	4.000				10.110	10.340	114.800	82.330						
2.520	3.900	47.500	7.321	7.000	9.650	10.670	78.480	88.020	61.031	5.362	78.426	4.501	5.419	77.323
	4.150				10.040	10.260	76.200	76.980						
	3.900	48.500	7.342		9.970	10.590	81.760	83.190		5.475	78.651			
	4.150				9.970	10.680	100.700	82.140						
	4.150		6.991								74.891			
7)	3.950				10.040	10.330	69.560	73.730						
2.500	4.050	47.500	8.134	6.500	10.040	10.580	61.220	69.960	60.547	5.405	87.833	4.213	5.462	80.990
	3.750				10.110	10.670	66.420	83.550						
	3.850	48.500	6.915		9.970	10.260	73.300	70.530		5.519	74.670			
	4.000				9.900	10.420	101.200	86.640						
	4.100		7.452								80.468			
8)	4.100				10.040	11.060	96.940	90.040						
2.500	3.950	52.500	7.632	6.000	10.040	11.170	80.730	77.380	60.547	5.974	82.412	3.889	6.031	82.657
	4.250				9.970	10.670	73.110	76.490						
	4.000	53.500	7.697		10.040	10.960	71.630	86.610		6.088	83.114			
	4.200				10.110	10.860	84.930	98.630						
	4.250		7.635								82.444			
9)	3.950				9.830	10.410	65.590	60.480						
2.570	3.700	47.500	8.507	6.000	10.110	10.670	56.140	65.220	62.242	5.258	89.358	3.783	5.452	91.092
	4.100				10.110	10.500	77.480	61.660						
	4.000	51.000	9.015		9.970	10.500	59.170	67.910		5.646	94.695			
	4.150				10.040	10.500	58.150	57.240						
	4.300		8.494								89.222			
10)	3.800				9.830	11.160	54.380	55.920						
2.570	3.900	55.500	7.538	6.000	10.030	10.760	50.670	63.010	62.242	6.144	79.180	3.783	6.019	82.450
	4.200				9.900	10.760	65.480	49.140						
	4.200	53.250	8.166		9.700	11.160	49.900	56.240		5.895	85.777			
	4.150				9.900	10.860	62.070	51.430						
	3.850		7.844								82.394			
								77.275	60.474	5.567	80.983	4.057	Average	
								14.502	1.148	0.272	5.609	0.236	Standard Dev	

100% Softwood

Handsheet (#/mass)	Caliper (1/1000 in)	Burst (psi)	Tensile (Kgf)	Tear (eu)	Roughness (microns)		Porosity (ml/min.)		Basis weight (g/m^2)	Burst index (kPa*m^2/g)	Tensile index (N*m/G)	Tear Index (mN*m^2/g)	Average Burst index (kPa*m^2/g)	Average Tensile index (N*m/G)
1)	4.850				10.670	11.760	945.900	704.300						
2.500	4.800	44.000	5.611	10.000	10.580	11.760	829.900	881.400	60.547	5.007	60.589	6.481	4.580	62.558
	4.850				10.760	11.760	863.700	892.500						
	4.800	36.500	5.973		10.760	11.630	806.300	897.100		4.154	64.498			
	5.150				10.950	12.180	829.400	869.000						
	5.100		5.796								62.587			
2)	4.950				10.670	11.630	545.700	571.300						
2.520	5.050	41.000	6.446	11.000	10.770	11.510	459.400	543.500	61.031	4.629	69.053	7.072	4.854	66.937
	5.000				10.670	11.390	632.200	610.500						
	4.900	45.000	6.051		10.500	11.630	612.300	621.400		5.080	64.821			
	5.050				10.770	12.340	545.800	668.800						
	5.250													
3)	5.000				10.860	12.030	667.100	607.800						
2.470	5.300	39.500	6.574	11.000	10.860	12.180	678.800	926.300	59.820	4.550	71.850	7.216	4.708	72.101
	5.200				10.500	11.630	526.700	520.500						
	5.300	42.250	6.620		10.950	11.760	602.200	535.600		4.866	72.352			
	4.950				10.670	11.760	585.400	588.100						
	5.000													
4)	5.000				10.860	11.630	858.700	618.600						
2.470	5.300	39.000	6.177	11.000	11.170	12.330	573.200	583.200	59.820	4.492	67.511	7.216	4.391	66.494
	5.150				10.950	11.760	629.100	556.800						
	5.200	37.250	6.325		10.860	12.040	632.500	553.000		4.290	69.128			
	5.100				11.270	12.180	1071.000	887.500						
	5.350		5.750								62.844			
5)	5.100				10.770	11.890	665.500	752.700						
2.480	5.250	41.750	5.619	12.000	10.960	12.030	672.600	654.000	60.063	4.789	61.165	7.840	4.732	60.918
	5.250				11.060	12.330	634.900	696.400						
	5.250	40.750	5.643		11.060	11.890	819.500	635.300		4.675	61.426			
	5.050				10.950	11.510	650.200	699.700						
	5.150		5.527								60.163			
6)	5.350				11.270	11.500	1003.000	792.700						
2.470	5.200	41.000	6.177	12.000	10.590	11.760	823.800	945.600	59.820	4.722	67.511	7.872	4.866	62.991
	5.150				10.590	11.760	729.500	543.300						
	5.250	43.500	5.350		10.950	11.630	568.700	497.000		5.010	58.472			
	5.150				10.330	11.760	588.700	938.600						
	5.100													
7)	5.200				11.160	11.890	901.700	604.400						
2.530	5.250	45.000	6.467	12.500	11.160	11.890	508.600	931.300	61.274	5.060	69.004	8.005	4.905	67.524
	5.150				11.060	11.630	612.500	890.400						
	5.500	42.250	6.322		11.060	12.170	590.500	609.600		4.751	67.457			
	5.350				10.510	12.030	1010.000	607.400						
	5.250		6.196								66.112			
8)	5.150				11.060	12.180	939.100	428.000						
2.500	5.050	43.500	6.016	11.500	11.270	12.030	693.900	667.100	60.547	4.950	64.962	7.453	5.064	70.577
	5.450				10.760	11.890	392.600	810.500						
	5.150	45.500	6.631		11.060	12.030	482.400	879.600		5.178	71.603			
	5.300				10.950	11.750	779.700	990.400						
	5.250		6.961								75.166			
9)	5.100				11.050	12.330	718.600	522.700						
2.520	5.000	39.750	6.145	11.500	11.070	11.620	620.700	542.200	61.031	4.487	65.828	7.394	4.586	63.229
	5.100				11.160	12.030	578.400	620.700						
	5.000	41.500	5.672		11.270	12.490	612.300	765.100		4.685	60.761			
	5.100				11.060	11.390	676.300	744.500						
	5.000		5.890								63.097			
10)	5.200				10.950	11.760	715.300	1103.000						
2.470	4.950	37.500	5.603	11.000	10.960	12.030	872.600	765.100	59.820	4.319	61.237	7.216	4.406	63.052
	5.100				11.060	12.030	703.600	843.000						
	5.000	39.000	6.075		10.770	11.760	863.900	855.800		4.492	66.396			
	5.000				10.860	11.900	1138.000	951.600						
	4.950		5.629								61.521			

Porosity	Basis weight	Burst index	Tensile index	Tear Index	
713.873	60.377	4.709	65.449	7.376	Average:
161.347	0.583	0.287	4.324	0.451	Standard Dev.:

First Recycle

Handsheet (#/mass)	Caliper (1/1000 in)	Burst (psi)	Tensile (Kgf)	Tear (eu)	Roughness (microns)		Porosity (ml/min.)		Basis weight (g/m^2)	Burst index (kPa*m^2/g)	Tensile Index (N*m/G)	Tear Index (mN*m^2/g)	Average Burst index (kPa*m^2/g)	Average Tensile index (N*m/G)
1)	4.700				10.130	11.380	551.900	530.400						
2.500	4.700	36.250	5.560	12.500	9.980	11.330	494.800	498.000	60.547	4.125	60.038	8.101	4.082	59.437
	4.750				10.130	11.100	479.700	552.100						
	4.850	35.500	5.423		10.130	11.220	552.400	479.400		4.040	58.559			
	4.800				10.280	11.110	549.300	504.900						
	4.700		5.530								59.714			
2)	4.450				10.130	11.220	452.300	395.200						
2.510	4.650	37.250	5.898	11.000	10.130	11.110	453.000	358.100	60.789	4.222	63.434	7.101	3.953	61.810
	4.400				10.360	11.570	372.500	419.500						
	4.500	32.500	5.748		10.200	11.450	431.200	471.000		3.684	61.821			
	4.800				9.920	11.220	447.200	449.300						
	4.700		5.595								60.175			
3)	4.900				10.060	11.220	503.100	381.100						
2.530	5.000	34.000	5.466	12.000	10.200	11.450	510.500	374.600	61.274	3.823	58.323	7.685	3.711	54.848
	4.900				10.130	11.330	373.800	410.500						
	4.900	32.000	4.991		10.280	11.700	450.900	541.400		3.598	53.255			
	4.750				10.210	11.330	325.700	411.800						
	4.850		4.964								52.967			
4)	4.850				10.130	11.570	521.200	607.800						
2.530	5.000	37.250	5.597	11.500	10.280	11.320	596.100	638.500	61.274	4.189	59.721	7.365	4.076	57.174
	5.100				10.280	11.440	590.900	568.100						
	4.900	35.250	5.689		10.200	11.110	552.100	523.600		3.964	60.703			
	5.000				10.360	11.110	697.500	767.700						
	5.050		4.789								51.099			
5)	4.900				10.280	11.220	482.200	475.300						
2.510	4.750	32.500	4.666	11.500	10.280	11.570	527.600	433.100	60.789	3.684	50.184	7.423	3.712	53.263
	4.650				10.130	11.690	433.200	481.000						
	4.750	33.000	4.693		10.200	11.700	460.500	549.700		3.740	50.474			
	4.500				10.360	11.330	515.100	467.500						
	4.650		5.498								59.132			
6)	5.050				10.530	11.450	619.800	505.900						
2.530	4.850	29.500	5.466	11.000	10.280	11.220	612.400	521.300	61.274	3.317	58.323	7.044	3.486	59.131
	5.100				10.130	11.570	496.700	601.800						
	4.900	32.500	5.817		10.530	11.450	576.300	660.500		3.655	62.068			
	5.000				10.360	11.570	590.700	580.500						
	4.850		5.342								57.000			
7)	4.500				10.140	11.330	583.200	498.600						
2.490	4.650	36.750	5.103	12.000	9.990	11.450	719.500	538.300	60.305	4.199	55.325	7.808	4.042	57.529
	4.550				10.140	11.220	571.200	554.800						
	4.750	34.000	5.519		10.140	11.450	596.100	547.600		3.885	59.835			
	4.750				10.210	11.330	673.800	772.200						
	4.600		5.297								57.428			
8)	4.700				9.920	11.570	575.600	561.100						
2.470	4.750	32.750	5.544	10.500	10.130	11.220	541.000	551.600	59.820	3.772	60.592	6.888	3.886	58.290
	4.750				10.440	11.560	538.500	553.700						
	4.700	31.250	5.275		10.290	11.450	638.500	670.000		3.599	57.652			
	4.600				10.130	11.450	571.400	501.500						
	4.750		5.181								56.625			
9)	4.750				10.710	11.110	578.500	552.600						
2.470	4.700	30.000	5.149	9.500	10.280	11.450	484.700	525.700	59.820	3.455	56.275	6.232	3.571	55.962
	5.000				10.140	11.830	540.700	444.800						
	4.950	32.000	5.007		10.290	11.220	667.600	768.600		3.686	54.723			
	4.800				10.280	11.110	437.400	488.200						
	4.800		5.205								56.887			
10)	4.650				10.530	11.330	593.500	598.600						
2.520	4.850	35.750	4.948	10.500	10.360	11.450	719.700	534.000	61.031	4.036	53.006	6.751	3.852	54.259
	4.700				10.360	11.220	698.100	523.300						
	4.700	32.500	5.109		10.450	11.450	684.100	621.100		3.669	54.730			
	4.800				10.210	11.450	641.300	704.700						
	4.750		5.138								55.041			

539.456	60.692	3.817	57.170	7.240	Average:
95.451	0.562	0.257	3.509	0.553	Standard Dev.:

Second Recycle

Handsheet (#/mass)	Caliper (1/1000 in)	Burst (psi)	Tensile (Kgf)	Tear (eu)	Roughness (microns)		Porosity (ml/min.)		Basis weight (g/m^2)	Burst index (kPa*m^2/g)	Tensile index (N*m/G)	Tear Index (mN*m^2/g)	Average Burst index (kPa*m^2/g)	Average Tensile index (N*m/G)
1)	4.700				10.130	11.330	1617.000	1284.000						
2.470	5.000	27.500	3.358	11.500	10.210	11.220	1400.000	1372.000	59.820	3.167	36.701	7.544	3.196	46.464
	5.000				10.200	11.450	1299.000	1499.000						
	4.950	28.000	4.765		9.990	11.330	1360.000	1485.000		3.225	52.078			
	4.800				10.200	11.560	1286.000	1265.000						
	4.900		4.631								50.614			
2)	4.850				10.130	11.570	1993.000	1692.000						
2.510	4.900	28.000	4.768	11.000	10.210	11.230	1531.000	1398.000	60.789	3.174	51.281	7.101	3.131	52.173
	4.850				10.210	11.330	1359.000	1549.000						
	4.900	27.250	5.012		10.290	11.220	1615.000	1486.000		3.089	53.905			
	4.950				10.280	11.450	1469.000	1359.000						
	4.950		4.773								51.335			
3)	4.750				10.360	11.570	1202.000	1531.000						
2.480	4.900	28.500	4.644	11.000	10.130	11.570	1499.000	1263.000	60.063	3.269	50.551	7.186	3.413	51.683
	5.000				10.060	11.570	1398.000	1500.000						
	4.850	31.000	4.585		10.060	11.330	1484.000	1358.000		3.556	49.909			
	4.900				10.130	11.330	1427.000	1373.000						
	4.850		5.015								54.590			
4)	4.900				10.140	11.450	798.000	1004.000						
2.490	4.750	26.000	5.385	13.000	10.360	11.570	812.500	694.300	60.305	2.971	58.382	8.459	3.228	50.796
	5.000				10.280	11.450	759.200	874.000						
	4.950	30.500	4.231		10.370	11.110	879.500	790.500		3.485	45.871			
	4.850				10.060	11.110	667.000	657.100						
	5.000		4.440								48.137			
5)	4.700				10.280	11.220	708.300	712.600						
2.500	5.000	32.250	4.977	11.500	9.850	11.570	716.100	692.500	60.547	3.670	53.743	7.453	3.755	43.211
	4.900				9.920	11.110	638.700	680.300						
	4.750	33.750	3.514		10.210	11.010	813.700	780.900		3.841	37.945			
	4.750				9.920	11.220	726.900	718.800						
	4.800		3.514								37.945			
6)	4.900				9.920	11.330	1372.000	1191.000						
2.470	4.800	31.000	5.208	10.500	9.920	11.330	1133.000	1222.000	59.820	3.571	56.920	6.888	3.484	54.541
	4.800				9.980	11.330	1414.000	1169.000						
	5.100	29.500	4.483		9.920	11.570	1192.000	1274.000		3.398	48.998			
	4.700				9.990	11.330	1081.000	1189.000						
	4.800		5.280								57.707			
7)	4.950				10.130	11.330	2500.000	2272.000						
2.500	4.700	29.500	4.795	11.000	9.980	11.440	1940.000	1868.000	60.547	3.357	51.777	7.129	3.158	50.741
	4.650				10.130	11.330	2461.000	2306.000						
	4.850	26.000	4.905		10.290	11.450	1967.000	2420.000		2.959	52.965			
	4.950				10.060	11.330	1866.000	2020.000						
	4.500		4.397								47.480			
8)	5.100				10.130	11.220	1582.000	1487.000						
2.530	5.050	27.500	4.867	10.500	10.130	11.450	1347.000	1220.000	61.274	3.092	51.932	6.724	1.546	53.603
	5.000				10.060	11.110	1386.000	1582.000						
	5.300		5.149		10.130	11.000	1440.000	1427.000		0.000	54.941			
	4.850	32.000			10.210	11.010	1456.000	1617.000						
	5.000		5.055								53.938			
9)	4.850				9.790	11.220	1776.000	1968.000						
2.470	4.800	26.500	4.706	11.500	10.200	11.570	1618.000	1776.000	59.820	3.052	51.434	7.544	2.966	50.807
	4.850				10.130	11.450	1892.000	1692.000						
	5.000	25.000	4.389		10.280	11.570	1798.000	1820.000		2.879	47.969			
	4.800				10.440	11.220	2138.000	1869.000						
	5.000		4.851								53.018			
10)	5.000				10.290	11.450	1756.000	1635.000						
2.480	5.100	28.000	4.778	11.000	10.200	11.330	1693.000	2049.000	60.063	3.212	52.010	7.186	3.384	53.494
	4.850				10.060	11.330	2109.000	2202.000						
	5.000	31.000	5.229		10.130	11.330	1846.000	2022.000		3.556	56.919			
	5.000				10.210	11.220	2049.000	1694.000						
	5.000		4.736								51.553			

Porosity	Basis weight	Burst index	Tensile index	Tear Index	
1442.809	60.305	3.126	50.752	7.321	Average:
466.907	0.484	0.780	5.382	0.480	Standard Dev.

Third Recycle

Handsheet (#/mass)	Caliper (1/1000 in)	Burst (psi)	Tensile (Kgf)	Tear (eu)	Roughness (microns)		Porosity (ml/min.)		Basis weight (g/m^2)	Burst index (kPa*m^2/g)	Tensile index (N*m/G)	Tear index (mN*m^2/g)	Average Burst index (kPa*m^2/g)	Average Tensile index (N*m/G)
1)	4.900				10.290	10.290	689.600	709.800						
2.530	5.150	25.500	4.631	10.500	9.920	10.810	791.900	703.300	61.274	2.867	49.414	6.724	2.924	48.496
	4.900				10.060	11.570	728.200	853.400						
	4.950	26.500	4.405		9.990	11.210	654.900	705.500		2.980	47.002			
	5.150				10.280	11.450	713.000	707.900						
	4.800		4.599								49.072			
2)	5.050				10.060	11.010	645.700	607.300						
2.520	4.800	31.000	4.561	10.000	9.990	11.570	597.000	575.800	61.031	3.500	48.860	6.429	3.133	50.624
	4.850				10.130	11.570	651.900	654.900						
	4.800	24.500	4.974		10.060	11.330	664.900	601.800		2.766	53.284			
	4.900				10.130	11.010	572.800	637.000						
	4.950		4.642								49.728			
3)	4.750				10.130	10.060	688.400	649.200						
2.500	5.000	28.500	5.028	10.000	10.200	10.280	648.400	663.500	60.547	3.243	54.293	6.481	3.172	44.863
	5.000				9.920	11.220	725.400	681.500						
	4.700	27.250	3.117		10.130	11.220	768.800	664.700		3.101	33.658			
	4.700				9.860	11.330	657.900	670.800						
	4.900		4.319								46.638			
4)	4.950				10.200	11.220	661.300	708.900						
2.530	4.850	27.500	4.797	11.500	10.130	11.220	837.000	705.900	61.274	3.092	51.185	7.365	2.952	50.822
	4.700				10.130	11.450	716.800	764.800						
	4.850	25.000	4.542		10.060	11.570	655.100	701.500		2.811	48.464			
	4.800				10.130	11.220	702.900	721.400						
	4.950		4.950								52.817			
5)	4.800				10.200	11.110	681.900	716.800						
2.470	5.000	24.500	4.811	9.000	10.060	11.450	622.000	677.900	59.820	2.822	52.581	5.904	2.966	53.681
	5.000				9.920	11.330	651.400	651.700						
	4.850	27.000	4.891		9.910	11.330	723.700	597.200		3.110	53.456			
	4.650				9.910	11.220	645.500	649.200						
	5.000		5.033								55.008			
6)	4.700				10.620	11.220	652.100	643.600						
2.480	4.850	26.250	4.942	11.500	10.370	11.830	604.600	794.800	60.063	3.011	53.795	7.513	2.882	50.834
	4.850				10.280	11.450	854.600	903.800						
	4.950	24.000	5.146		10.610	11.330	630.000	548.700		2.753	56.016			
	4.750				10.450	11.000	640.600	1029.000						
	4.800		3.922								42.692			
7)	4.650				10.140	11.450	575.600	552.100						
2.510	4.850	26.500	4.468	11.000	10.370	11.110	541.000	551.600	60.789	3.004	48.054	7.101	3.032	46.079
	4.900				10.280	11.450	523.600	568.100						
	4.750	27.000	4.012		10.360	11.110	561.100	590.900		3.060	43.150			
	4.700				10.060	11.570	576.300	660.500						
	4.850		4.373								47.033			
8)	4.650				10.130	11.330	667.100	626.300						
2.490	4.500	26.000	4.103	10.500	10.200	11.330	678.800	654.000	60.305	2.971	44.483	6.832	3.056	45.242
	4.550				10.290	11.220	688.100	672.600						
	4.750	27.500	4.119		10.060	11.330	602.200	635.300		3.142	44.657			
	4.600				10.210	11.450	585.400							
	4.500		4.297								46.586			
9)	4.700				10.280	11.220	607.800	634.900						
2.500	4.750	28.500	4.344	10.000	10.370	11.830	620.500	650.200	60.547	3.243	46.907	6.481	3.101	46.072
	4.850				10.620	11.000	635.600	596.700						
	4.650	26.000	4.275		10.610	11.330	699.700	696.400		2.959	46.162			
	4.750				10.450	11.450	752.700	719.500						
	4.850		4.181								45.147			
10)	4.550				10.510	11.310	655.800	777.000						
2.520	4.500	25.000	4.531	10.500	10.380	11.550	680.500	681.900	61.031	2.822	48.538	6.751	2.935	48.017
	4.500				10.140	11.630	657.800	665.500						
	4.600	27.000	4.474		10.290	11.320	671.300	717.000		3.048	47.928			
	4.850				10.230	11.110	689.000	702.500						
	4.700		4.442								47.585			

Porosity	Basis weight	Burst index	Tensile index	Tear index	
670.735	60.668	3.015	48.473	6.758	Average:
77.902	0.501	0.186	4.544	0.478	Standard Dev.:

Fourth Recycle

Handsheet (#/mass)	Caliper (1/1000 in)	Burst (psi)	Tensile (Kgf)	Tear (eu)	Roughness (microns)		Porosity (ml/min.)		Basis weight (g/m^2)	Burst index (kPa*m^2/g)	Tensile index (N*m/G)	Tear index (mN*m^2/g)	Average Burst index (kPa*m^2/g)	Average Tensile index (N*m/G)
1)	4.800				9.650	10.340	627.800	549.300						
2.490	4.850	23.500	3.694	10.500	10.040	10.670	638.500	552.400	60.305	2.685	40.049	6.832	2.571	40.569
	4.800				9.970	10.260	61.100	551.900						
	4.900	21.500	3.782		9.970	10.670	667.700	494.800		2.456	41.003			
	4.850				9.830	10.680	552.100	479.700						
	4.850		3.750								40.656			
2)	4.950				10.040	10.330	452.300	495.200						
2.510	4.750	22.000	3.819	11.500	10.040	10.580	453.000	508.100	60.789	2.494	41.074	7.423	2.550	40.325
	4.850				9.970	10.260	472.500	419.500						
	4.800	23.000	3.843		9.900	10.420	531.200	471.000		2.607	41.332			
	4.900				10.110	10.410	447.200	449.300						
	5.150		3.586								38.568			
3)	4.900				10.110	11.160	510.500	481.100						
2.500	4.950	21.000	3.611		9.970	10.590	483.800	474.600	60.547	2.390	38.992		2.304	40.961
	5.150				10.040	10.670	425.700	510.500						
	4.850	19.500	3.973		10.110	10.500	503.100	541.400		2.219	42.901			
	4.700				10.360	11.220	450.900	521.800						
	4.850		3.796								40.990			
4)	4.600				10.110	10.760	541.200	530.400						
2.480	4.650	20.000	3.756	11.500	9.830	11.160	596.100	523.600	60.063	2.294	40.885	7.513	2.352	41.175
	4.500				9.700	10.500	570.800	488.000						
	4.550	21.000	3.821		9.900	10.500	552.100	479.400		2.409	41.593			
	4.750				10.030	10.860	577.500	504.900						
	4.600		3.771								41.048			
5)	4.500				10.130	11.210	582.200	575.300						
2.470	4.550	23.500	3.624	11.000	10.210	10.760	527.600	533.100	59.820	2.707	39.608	7.216	2.534	39.247
	4.750				9.900	11.440	493.200	521.000						
	4.450	20.500	3.553		10.060	11.220	560.500	549.700		2.361	38.832			
	4.600				10.200	11.100	515.100	517.500						
	4.650		3.596								39.302			
6)	4.950				10.060	11.220	619.600	525.900						
2.530	4.700	22.500	3.962	10.500	10.200	11.450	612.400	521.300	61.274	2.530	42.275	6.724	2.614	41.891
	4.850				10.360	11.350	598.700	601.800						
	4.950	24.000	4.001		9.990	11.110	576.300	630.500		2.699	42.691			
	4.800				10.250	11.110	590.700	580.500						
	4.850		3.815								40.707			
7)	4.700				10.130	11.230	583.200	498.600						
2.510	4.750	21.500	3.706	10.000	10.210	11.210	619.500	558.300	60.789	2.437	39.859	6.455	2.579	41.311
	5.000				10.110	11.110	571.200	554.800						
	4.750	24.000	3.966		10.280	11.210	546.100	527.600		2.720	42.655			
	4.900				10.530	11.330	523.800	572.200						
	4.800		3.851								41.418			
8)	4.500				10.360	11.330	593.500	561.100						
2.480	4.500	19.000	3.712	11.000	10.200	11.330	719.700	571.600	60.063	2.180	40.408	7.186	2.323	39.626
	4.750				10.060	11.210	698.100	553.700						
	4.650	21.500	3.511		10.290	11.000	684.100	670.000		2.466	38.218			
	4.600				10.210	11.330	641.300	551.500						
	4.550		3.698								40.254			
9)	4.500				10.440	11.330	578.500	552.600						
2.480	4.450	23.000	3.747	11.000	10.450	11.570	514.700	541.000	60.063	2.638	40.787	7.186	2.438	40.990
	4.600				10.060	11.330	540.700	571.400						
	4.450	19.500	3.815		10.210	11.440	667.600	534.800		2.237	41.527			
	4.550				10.450	11.110	437.400	588.200						
	4.500		3.735								40.657			
10)	4.650				10.130	11.330	598.600	575.600						
2.510	4.700	20.500	4.023	11.500	10.210	11.220	534.000	538.500	60.789	2.324	43.268	7.423	2.239	42.530
	4.650				10.450	11.440	523.300	638.500						
	4.600	19.000	3.892		10.280	11.330	621.100	525.700		2.154	41.859			
	4.550				10.350	11.450	629.600	668.600						
	4.750		3.948								42.462			

Porosity	Basis weight	Burst index	Tensile index	Tear index	
545.554	60.450	2.450	40.863	7.107	Average:
79.069	0.460	0.183	1.312	0.360	Standard Dev.:

70/30 SW/WS

Handsheet (#/mass)	Caliper (1/1000 in)	Burst (psi)	Tensile (Kgf)	Tear (eu)	Roughness	(microns)	Porosity	(ml/min.)	Basis weight (g/m^2)	Burst index (kPa*m^2/g)	Tensile index (N*m/G)	Tear Index (mN*m^2/g)	Average Burst index (kPa*m^2/g)	Average Tensile index (N*m/G)
1)	4.350				10.860	11.630	146.700	145.400						
2.510	4.450	32.000	6.421	8.000	10.860	11.890	149.200	154.400	60.789	3.627	69.059	5.164	4.052	69.984
	4.400				10.760	11.890	156.500	132.800						
	4.350	39.500	6.711		10.850	11.630	160.000	155.300		4.477	72.178			
	4.650				10.670	12.180	144.100	153.200						
	4.450		6.389								68.715			
2)	5.000				10.860	11.890	161.700	222.000						
2.490	5.000	42.250	6.293	10.000	10.680	12.330	176.400	148.400	60.305	4.827	68.226	6.507	4.470	61.085
	4.750				10.950	11.890	234.100	199.000						
	5.150	36.000	5.203		10.500	12.030	193.400	237.500		4.113	56.409			
	4.800				10.670	11.890	147.600	192.800						
	4.850		5.407								58.620			
3)	4.700				10.410	12.180	198.100	199.800						
2.530	4.750	38.250	6.293	8.500	10.500	12.030	168.000	182.300	61.274	4.301	67.147	5.443	4.512	69.694
	4.550				10.860	12.180	186.100	210.700						
	4.550	42.000	6.843		10.340	12.330	183.300	232.000		4.723	73.016			
	4.750				10.410	11.890	214.600	174.400						
	4.600		6.459								68.919			
4)	5.050				10.580	11.890	143.200	195.400						
2.500	5.250	42.250	6.513	9.000	10.860	11.760	184.700	163.400	60.547	4.808	70.329	5.833	4.879	63.447
	5.000				10.670	11.750	152.900	160.900						
	5.000	43.500	6.199		10.260	11.750	120.100	109.500		4.950	66.938			
	4.650				11.050	11.760	144.000	161.600						
	4.750		4.915								53.073			
5)	4.650				10.760	11.890	116.700	114.000						
2.470	4.600	45.250	6.658	10.000	10.340	12.170	137.900	107.500	59.820	5.212	72.768	6.560	5.111	69.449
	4.750				10.580	11.750	113.900	121.500						
	4.700	43.500	6.287		10.410	12.030	169.000	124.300		5.010	68.713			
	4.650				10.260	12.030	107.400	117.900						
	4.800		6.118								66.868			
6)	4.650				10.260	11.890	120.300	242.700						
2.470	4.750	38.000	6.097	9.500	10.110	12.030	169.500	124.200	59.820	4.377	66.636	6.232	4.550	66.367
	4.800				10.580	11.890	193.200	147.900						
	5.000	41.000	6.193		10.180	12.490	191.000	162.100		4.722	67.686			
	5.150				10.260	12.030	124.300	192.200						
	5.250		5.927								64.778			
7)	4.650				10.110	12.180	139.300	145.300						
2.510	4.900	44.000	6.494	9.000	10.420	11.380	103.100	113.700	60.789	4.987	69.844	5.810	5.058	70.968
	4.650				10.040	12.180	103.500	116.300						
	4.850	45.250	6.703		10.040	11.880	135.200	138.200		5.129	72.092			
	5.000				10.110	11.750	185.000	103.500						
	4.700													
8)	4.900				10.340	12.330	116.300	121.900						
2.510	5.000	38.500	6.027	8.500	10.860	11.890	162.300	180.600	60.789	4.364	64.822	5.487	4.321	64.607
	4.900				10.500	12.030	118.900	122.300						
	4.750	37.750	5.954		10.590	11.630	106.500	107.600		4.279	64.036			
	4.850				10.500	11.630	140.000	132.200						
	4.750		6.040								64.961			
9)	4.800				10.670	11.760	123.600	123.200						
2.480	4.700	39.500	6.338	8.500	10.670	12.030	150.600	167.400	60.063	4.531	68.991	5.553	4.445	67.246
	4.850				10.950	11.890	163.900	129.400						
	4.800	38.000	5.970		10.850	12.030	126.400	119.900		4.359	64.985			
	4.900				10.580	11.760	114.600	130.000						
	4.700		6.225								67.761			
10)	4.900				10.420	11.630	278.700	234.700						
2.490	4.900	44.500	5.691	9.000	10.760	11.760	226.000	219.500	60.305	5.084	61.699	5.856	4.741	66.502
	4.950				10.950	11.890	286.500	308.700						
	5.100	38.500	6.663		10.340	12.030	234.700	242.900		4.399	72.238			
	5.150				10.850	11.890	219.500	268.500						
	4.900		6.048								65.570			
								162.534	60.450	4.614	66.796	5.844	Average:	
								46.303	0.473	0.401	4.710	0.464	Standard Dev.:	

First Recycle

Handsheet (#/mass)	Caliper (1/1000 in)	Burst (psi)	Tensile (Kgf)	Tear (eu)	Roughness (microns)		Porosity (ml/min.)		Basis weight (g/m^2)	Burst index (kPa*m^2/g)	Tensile index (N*m/G)	Tear Index (mN*m^2/g)	Average Burst index (kPa*m^2/g)	Tensile index (N*m/G)
1)	4.300				10.450	11.110	300.000	301.400						
2.500	4.600	36.250	4.803	9.500	10.370	11.110	302.300	328.600	60.547	4.125	51.864	6.157	4.082	55.708
	4.700				10 360	11.000	312.500	322.800						
	4.700	35.500	5.423		10.440	11.330	312.300	309.200		4.040	58.559			
	4.500				10.280	11.110	374.600	325.600						
	4.550		5.251								56.701			
2)	4.750				10.210	11.220	303.600	293.300						
2.500	4.650	29.000	5.672	10.000	10.210	11.450	310.900	300.800	60.547	3.300	61.248	6.481	3.499	61.550
	4.700				10.450	11.220	266.800	279.300						
	4.550	32.500	5.283		10.060	10.910	291.600	299.800		3.698	57.047			
	4.700				10.370	11.330	288.800	320.300						
	4.700		6.145								66.355			
3)	4.750				10.200	11.330	335.500	341.500						
2.470	5.000	34.250	5.874	10.000	10.280	11.330	349.100	322.800	59.820	3.945	64.199	6.560	3.700	62.633
	4.800				10.620	11.110	322.600	330.800						
	4.550	30.000	5.592		10.210	11.220	307.900	327.900		3.455	61.117			
	4.650				10.290	11.110	323.000	322.400						
	4.550		5.726								62.582			
4)	4.800				10.370	11.330	319.600	329.900						
2.490	4.550	39.500	6.540	9.500	10.360	11.110	306.800	348.400	60.305	4.513	70.904	6.182	4.356	69.744
	4.600				9.990	10.900	326.400	298.700						
	4.500	36.750	6.601		10.200	11.330	391.400	311.700		4.199	71.565			
	4.600				10.360	11.220	301.100	327.100						
	4.750		6.158								66.763			
5)	4.500				10.280	11.220	412.100	406.400						
2.530	4.600	33.000	5.667	11.500	10.210	11.220	339.900	402.600	61.274	3.711	60.468	7.365	3.854	60.745
	4.550				10.370	11.000	350.300	353.400						
	4.600	35.550	5.533		10.060	11.330	421.300	405.200		3.997	59.038			
	4.550				10.200	11.440	417.000	330.700						
	4.450		5.879								62.730			
6)	4.550				10.450	11.570	363.100	356.500						
2.480	4.800	35.250	6.003	9.500	10.290	11.220	325.500	456.900	60.063	4.044	65.344	6.207	4.115	66.121
	4.750				10.280	10.900	350.300	379.500						
	4.600	36.500	6.282		10.450	11.100	419.400	283.800		4.187	68.381			
	4.550				10.060	11.110	316.200	336.300						
	4.550		5.938								64.637			
7)	4.850				10.210	11.330	337.200	324.300						
2.530	4.800	41.000	5.356	11.000	10.060	11.330	402.500	346.100	61.274	4.610	57.149	7.044	4.554	65.711
	5.050				10.130	11.000	317.600	351.500						
	5.100	40.000	6.604		10.360	11.220	275.400	277.200		4.498	70.466			
	4.700				10.280	11.690	291.600	278.600						
	4.900		6.515								69.516			
8)	4.600				10.530	11.210	310.400	327.500						
2.530	4.750	36.500	6.091	9.000	10.450	11.110	349.300	304.200	61.274	4.104	64.992	5.764	3.651	64.515
	4.700				10.360	11.220	313.300	274.400						
	4.600	32.000	5.989		10.440	11.330	267.500	267.100		3.598	63.904			
	4.900				10.360	11.220	269.900	274.000						
	4.550		6.059								64.651			
9)	4.800				10.360	11.320	349.000	370.300						
2.480	4.750	35.750	5.522	9.500	10.200	11.330	375.900	354.600	60.063	4.101	60.109	6.207	4.345	63.080
	4.900				10.360	11.110	432.000	353.900						
	4.650	40.000	5.828		10.200	11.110	327.000	441.000		4.589	63.440			
	4.650				9.990	11.110	365.900	328.900						
	4.750		6.035								65.693			
10)	4.900				10.280	11.210	501.600	419.400						
2.510	4.850	30.000	5.388	10.000	10.200	11.330	413.700	443.900	60.789	3.400	57.949	6.455	3.712	59.537
	4.600				10.050	11.210	399.100	519.800						
	4.950	35.500	5.557		10.360	11.330	452.900	409.800		4.024	59.767			
	4.750				10.060	11.110	415.000	472.800						
	4.850		5.662								60.896			
								344.616	60.595	4.007	62.934	6.442	Average:	
								53.994	0.545	0.386	4.711	0.465	Standard Dev.:	

Second Recycle

Handsheet (#/mass)	Caliper (1/1000 in)	Burst (psi)	Tensile (Kgf)	Tear (eu)	Roughness	(microns)	Porosity	(ml/min.)	Basis weight (g/m^2)	Burst Index (kPa*m^2/g)	Tensile index (N*m/G)	Tear Index (mN*m^2/g)	Average Burst Index (kPa*m^2/g)	Tensile index (N*m/G)
1)	4.500				10.450	11.110	611.100	695.200						
2.530	4.350	31.000	4.926	8.500	10.530	11.000	756.200	580.800	61.274	3.486	52.561	5.443	3.570	51.014
	4.450				10.360	11.210	683.900	635.900						
	4.450	32.500	4.757		10.280	11.010	667.200	638.400		3.655	50.758			
	4.400				10.360	11.110	646.100	594.400						
	4.450		4.660								49.723			
2)	4.350				10.060	11.220	1266.000	1214.000						
2.490	4.600	28.250	4.446	8.000	10.200	11.450	1192.000	1182.000	60.305	3.228	48.202	5.206	3.385	46.977
	4.450				10.360	11.210	1362.000	1210.000						
	4.200	31.000	4.118		9.990	11.110	1362.000	1361.000		3.542	44.646			
	4.350				10.210	11.110	1375.000	1191.000						
	4.400		4.435								48.082			
3)	4.500				10.280	11.100	1429.000	1265.000						
2.510	4.650	29.000	4.913	8.500	10.130	11.110	1154.000	1163.000	60.789	3.287	52.840	5.487	3.372	51.059
	4.500				10.060	11.440	1255.000	1163.000						
	4.700	30.500	4.816		10.360	11.220	1153.000	1374.000		3.457	51.797			
	4.650				10.200	11.220	1290.000	1232.000						
	4.550		4.513								48.538			
4)	4.600				10.530	11.330	655.300	777.000						
2.530	4.500	35.000	5.476	9.500	10.280	11.010	680.500	681.900	61.274	3.936	58.430	6.084	3.893	56.751
	4.750				10.130	11.210	687.800	687.800						
	4.550	34.250	5.412		10.360	11.330	702.500	717.000		3.851	57.747			
	4.750				10.450	11.110	689.000	671.600						
	4.600		5.068								54.076			
5)	4.750				10.130	11.000	986.100	1013.000						
2.500	4.550	31.000	4.609	8.000	10.060	11.210	958.100	887.900	60.547	3.528	49.769	5.185	3.385	50.421
	4.750				10.210	11.110	909.100	1051.000						
	4.650	28.500	4.639		10.450	11.110	1100.000	1090.000		3.243	50.093			
	4.450				10.280	11.330	902.400	958.700						
	4.400		4.760								51.400			
6)	4.700				10.360	11.330	1014.000	1007.000						
2.470	4.600	34.500	5.439	9.000	10.200	11.330	945.800	999.200	59.820	3.974	59.445	5.904	3.887	60.844
	4.850				10.210	10.710	999.700	984.600						
	4.550	33.000	5.294		10.210	11.000	932.200	1106.000		3.801	57.860			
	4.650				10.060	11.330	926.300	944.700						
	4.550		5.968								65.227			
	4.650				10.440	11.330	541.400	586.200						
2.470	4.750	29.500	5.302	9.500	10.450	11.110	633.700	607.300	59.820	3.398	57.948	6.232	3.484	57.135
	4.650				10.210	11.570	591.900	637.000						
	4.550	31.000	5.396		10.290	11.330	616.000	607.800		3.571	58.975			
	4.700				10.450	11.440	599.300	602.300						
	4.650		4.985								54.483			
8)	4.650				10.130	11.330	625.300	660.500						
2.510	4.700	29.500	5.605	8.500	10.530	11.450	651.200	621.500	60.789	3.344	60.283	5.487	3.655	57.501
	4.550				10.210	11.220	667.700	681.500						
	4.600	35.000	5.060		10.450	11.330	613.200	567.200		3.967	54.421			
	4.650				10.280	11.440	557.100	648.600						
	4.550		5.374								57.798			
9)	4.750				9.990	11.320	1245.000	1223.000						
2.470	4.500	33.500	4.711	9.500	10.130	10.810	1171.000	1242.000	59.820	3.858	51.488	6.232	3.786	54.672
	4.700				9.990	11.330	1324.000	1214.000						
	4.700	32.250	5.187		10.360	11.210	1243.000	1144.000		3.714	56.691			
	4.750				10.060	11.570	1162.000	1287.000						
	4.650		5.109								55.838			
10)	4.750				9.980	11.000	946.900	1170.000						
2.520	4.800	33.500	5.060	10.000	10.210	11.110	1035.000	960.700	61.031	3.782	54.205	6.429	3.697	50.545
	4.650				10.060	11.100	1022.000	927.100						
	4.700	32.000	4.384		10.210	11.330	1058.000	1042.000		3.613	46.964			
	4.650				10.280	11.010	978.100	985.800						
	4.500		4.711								50.467			

930.657	60.547	3.612	53.692	5.769	Average:
260.608	0.582	0.243	4.690	0.460	Standard Dev.:

Third Recycle

Handsheet (#/mass)	Caliper (1/1000 in)	Burst (psi)	Tensile (Kgf)	Tear (eu)	Roughness (microns)		Porosity (ml/min.)		Basis weight (g/m^2)	Burst index (kPa*m^2/g)	Tensile index (N*m/G)	Tear Index (mN*m^2/g)	Average Burst index (kPa*m^2/g)	Average Tensile index (N*m/G)
1)	4.750				10.530	11.330	838.700	934.900						
2.530	4.500	31.000	4.942	8.500	10.290	10.450	971.600	927.400	61.274	3.486	52.732	5.443	3.402	51.434
	4.650				10.620	10.900	952.500	885.800						
	4.550	29.500	4.671		10.290	11.320	985.500	979.200		3.317	49.840			
	4.450				10.290	11.220	1066.000	909.400						
	4.500		4.848								51.729			
2)	4.650				10.620	11.220	943.600	978.700						
2.490	4.500	30.000	4.542	9.000	10.530	11.330	902.400	876.300	60.305	3.428	49.243	5.856	3.399	53.095
	4.700				10.530	10.910	965.800	908.600						
	4.500	29.500	5.098		10.530	11.330	945.000	985.200		3.370	55.270			
	4.650				10.530	11.220	881.000	858.900						
	4.650		5.052								54.772			
3)	4.850				10.290	11.010	1001.000	921.000						
2.530	4.650	33.000	4.870	9.000	10.450	11.330	861.900	959.300	61.274	3.711	51.964	5.764	3.767	57.583
	4.900				10.530	11.330	875.000	869.100						
	4.650	34.000	5.605		10.290	11.440	966.400	853.600		3.823	59.806			
	4.800				10.290	11.450	986.100	938.400						
	4.850		5.715								60.980			
4)	4.850				10.530	11.220	908.000	837.000						
2.520	4.700	27.000	4.778	9.500	10.450	11.330	847.700	881.300	61.031	3.048	51.184	6.108	3.175	50.624
	4.950				10.370	11.330	870.600	1043.000						
	4.750	29.250	4.698		10.210	11.450	822.900	858.400		3.302	50.327			
	4.550				10.710	11.570	841.800	847.200						
	4.750		4.701								50.360			
5)	4.550				10.530	11.000	983.800	1099.000						
2.480	4.500	29.500	4.574	9.000	10.450	11.210	847.500	985.800	60.063	3.384	49.789	5.880	3.298	50.787
	4.500				10.450	11.440	1000.000	903.000						
	4.700	28.000	4.424		10.530	11.330	874.800	880.000		3.212	48.157			
	4.600				10.280	10.900	1006.000	1020.000						
	4.650		4.999								54.416			
6)	4.600				10.290	11.330	1075.000	837.700						
2.510	4.750	31.500	5.170	9.000	10.450	11.210	933.300	858.100	60.789	3.570	55.604	5.810	3.315	52.450
	4.550				10.450	11.330	827.300	896.700						
	4.700	27.000	5.154		10.530	11.330	904.000	978.700		3.060	55.432			
	4.700				10.060	11.110	823.100	939.000						
	4.500		4.306								46.312			
7)	4.850				10.210	11.330	809.200	795.100						
2.530	4.750	28.500	5.270	10.500	10.360	11.330	932.400	892.000	61.274	3.205	56.232	6.724	3.149	52.287
	4.650				10.360	10.900	826.800	756.200						
	5.000	27.500	4.537		10.450	11.220	865.000	932.700		3.092	48.411			
	4.850				10.290	11.110	744.400	747.100						
	4.900		4.894								52.220			
8)	4.800				10.290	11.110	773.300	768.100						
2.510	5.000	32.000	4.805	10.000	10.440	11.000	813.200	828.700	60.789	3.627	51.679	6.455	3.514	52.073
	5.000				10.450	11.330	789.400	772.400						
	5.150	30.000	4.829		10.370	11.100	804.300	772.400		3.400	51.937			
	4.750				10.710	11.330	723.900	781.400						
	4.800		4.891								52.604			
9)	2.750				10.280	11.330	881.300	826.800						
2.500	4.800	31.500	4.789	10.000	10.130	11.330	872.400	858.100	60.547	3.585	51.713	6.481	3.670	51.115
	4.950				10.060	10.710	836.500	864.900						
	4.700	33.000	4.663		10.360	11.000	799.600	872.400		3.755	50.352			
	4.650				10.200	11.330	882.300	864.700						
	4.800		4.749								51.281			
10)	4.550				10.530	11.220	901.800	899.200						
2.480	4.500	29.000	4.432	10.500	10.450	11.450	916.400	878.700	60.063	3.327	48.244	6.860	3.470	46.814
	4.550				10.360	11.210	923.900	933.800						
	4.650	31.500	4.078		10.440	11.110	924.300	926.900		3.613	44.390			
	4.650				10.360	11.110	944.100	965.200						
	4.700		4.392								47.808			

892.603	60.741	3.416	51.826	6.138	Average:
76.621	0.482	0.229	3.643	0.467	Standard Dev.:

Fourth Recycle

Handsheet (#/mass)	Caliper (1/1000 In)	Burst (psi)	Tensile (Kgf)	Tear (eu)	Roughness (microns)		Porosity (ml/min.)		Basis weight (g/m^2)	Burst index (kPa*m^2/g)	Tensile index (N*m/G)	Tear Index (mN*m^2/g)	Average Burst index (kPa*m^2/g)	Tensile index (N*m/G)
1)	4.300				10.360	11.890	934.900	899.800						
2.490	4.600	26.500	4.232	9.500	10.200	12.180	927.400	982.300	60.305	3.028	45.882	6.182	3.113	45.181
	4.700				10.210	11.890	885.800	910.700						
	4.700	28.000	4.178		9.990	11.630	979.200	932.000		3.199	45.296			
	4.500				10.060	11.630	909.400	974.400						
	4.550		4.092								44.364			
2)	4.650				10.530	11.210	978.700	895.400						
2.510	4.700	28.500	4.327	9.000	10.450	11.110	876.300	863.400	80.789	3.230	46.538	5.810	3.123	45.039
	4.750				10.360	11.220	908.600	960.900						
	4.750	26.600	4.221		10.440	11.330	985.200	909.500		3.015	45.396			
	4.600				10.360	11.220	658.900	961.600						
	4.800		4.015								43.182			
3)	4.750				10.860	11.220	921.000	914.000						
2.530	4.700	27.000	4.227	8.500	10.850	11.210	959.300	907.500	61.274	3.036	45.103	5.443	2.867	46.013
	4.850				10.860	11.110	869.100	921.500						
	4.800	24.000	4.415		10.670	11.450	853.600	924.300		2.699	47.109			
	4.950				10.760	11.110	938.400	887.900						
	5.000		4.295								45.828			
4)	4.800				10.290	11.000	838.700	942.700						
2.470	4.650	25.500	4.009	9.000	10.450	11.210	971.600	924.200	59.820	2.937	43.816	5.904	2.879	44.235
	4.700				10.530	11.440	952.500	847.900						
	4.550	24.500	4.135		10.290	11.330	985.500	962.100		2.822	45.193			
	4.700				10.290	10.900	1066.000	892.200						
	4.700		3.998								43.696			
5)	4.800				10.530	11.220	943.600	845.300						
2.520	4.550	26.500	4.316	9.500	10.450	11.450	902.400	913.700	61.031	2.992	46.235	6.108	2.907	45.525
	4.600				10.450	11.210	965.800	916.300						
	4.500	25.000	4.145		10.530	11.110	945.000	938.200		2.822	44.403			
	4.600				10.280	11.110	881.000	863.500						
	4.750		4.288								45.935			
6)	4.800				10.160	11.330	1001.000	921.900						
2.490	4.750	28.500	4.178	9.000	10.110	11.450	861.900	880.600	60.305	3.256	45.298	5.856	3.171	44.837
	4.650				10.260	11.010	875.000	922.300						
	4.550	27.000	4.098		10.580	11.330	966.400	897.600		3.085	44.429			
	4.750				10.180	11.440	986.100	922.200						
	4.850		4.131								44.787			
7)	4.550				10.620	11.890	908.000	853.200						
2.490	4.450	26.500	4.278	10.000	10.290	12.030	847.700	867.400	60.305	3.028	46.380	6.507	2.856	45.079
	4.550				10.260	11.890	870.600	659.400						
	4.600	23.500	4.130		10.200	12.490	822.900	639.900		2.685	44.778			
	4.650				10.210	12.030	841.800	870.000						
	4.650		4.066								44.082			
8)	4.700				10.210	11.330	837.000	862.400						
2.500	4.700	26.000	4.528	9.000	10.360	11.330	881.300	835.000	60.547	2.959	46.894	5.833	3.129	49.085
	4.850				10.360	11.110	1043.000	856.200						
	4.650	29.000	4.656		10.450	11.220	858.400	852.600		3.300	50.277			
	4.750				10.290	11.110	847.200	853.600						
	4.650		4.453								46.084			
9)	4.750				10.060	11.330	1266.000	1182.000						
2.520	4.600	28.500	4.691	9.500	10.200	11.330	1153.000	1163.000	61.031	3.217	50.252	6.108	3.020	50.213
	4.800				10.360	10.900	1362.000	1191.000						
	4.650	25.000	4.772		9.990	11.220	1255.000	1192.000		2.822	51.120			
	4.900				10.210	11.110	1265.000	1232.000						
	4.750		4.599								49.267			
10)	4.750				10.360	11.100	1429.000	1214.000						
2.530	5.000	25.000	4.671	9.500	10.200	11.110	1154.000	1163.000	61.274	2.811	49.640	6.064	2.952	49.254
	4.800				10.210	11.440	1290.000	1210.000						
	4.550	27.500	4.674		10.210	11.220	1362.000	1361.000		3.092	49.672			
	4.650				10.060	11.220	1375.000	1374.000						
	4.550		4.503								46.046			

976.646	60.668	3.002	46.446	5.983	Average:
155.564	0.486	0.184	2.281	0.283	Standard Dev.: