NBSIR 73-274 (R)

Evaluation of Currency and Stamp Papers

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Washington, D. C. 20234

August 15, 1973

Progress Report covering the period
January 1 – June 30, 1973

Prepared for
Bureau of Engraving and Printing
U. S. Department of the Treasury
Washington, D. C. 20401

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1. SUMMARY

As part of a continuing study for the Bureau of Engraving and Printing of the U.S. Department of the Treasury, the effect of melamine resin on the retention of bending stiffness with flexing and the possibility of improving the stiffness retention of paper by treatment with acrylic resins was studied. Work was initiated on the development of a method, using a commercial laboratory beater, for refining rag pulp to produce a high degree of fibrillation with minimum cutting of the fibers.

Several years ago it was demonstrated that currency printed on dry-print paper has a longer circulation life than currency printed on wet-print paper. The latter is no longer in use. The fiber furnish of dry-print paper differs from that of the old wet-print paper and, in addition, dry-print paper contains melamine resin and glycerine. It was not known up to now which change(s) was responsible for the improved circulation life.

The effect of one of the constituents--melamine resin--on the retention of bending stiffness with flexing was evaluated. Handsheets were prepared from currency paper beater stock and were treated with various quantities of the same wet strength resin used in currency paper. The retention of stiffness was determined by flexing the handsheets on the NBS paper flexing apparatus and measuring the decrease in stiffness after flexing. The results demonstrate that the wet strength resin improves stiffness retention to a marked degree and indicates that the wet strength resin may be singularly responsible for most, if not all, of the improvements in circulation life of dry-print currency paper. The results also suggest that even greater improvements in stiffness retention might be possible by a more deliberate development of physical properties by mechanical refinement of the pulp in combination with wet strength resin.

Previous work on improving retention of cantilever stiffness with flexing by treatment of paper with acrylic latexes indicated a relationship between the retention of bending stiffness and the stiffness of the polymer used to modify the paper. Therefore, a group of acrylic resins, having a wide range of film stiffness, was used to modify wood pulp handsheets and to determine their effect on stiffness retention with flexing. The retention of stiffness was evaluated with

the aid of the NBS paper flexing apparatus. The results indicate that there is a good correlation between polymer stiffness and retention of stiffness of paper with flexing, but beyond a certain polymer film stiffness little, if any, improvement in retention of paper stiffness is produced.

In addition to the work with wood pulp handsheets, the performance of handsheets made from currency stock saturated with acrylic polymers was evaluated. The polymers investigated had a wide range of film stiffness. Modification of the handsheets and test evaluations were the same as those used on the wood pulp handsheets. The results were in good agreement with those obtained with wood pulp handsheets, indicating that it should be possible to improve the stiffness retention of currency type paper with acrylic resins.

The work performed in developing a method for beating rag pulps with a laboratory beater was inconclusive, and additional work must be done. More work also is needed on optimizing the retention of bending stiffness with flexing by treatment of paper with acrylic resins.

2. DEVELOPMENT OF A BEATER SCHEDULE FOR A LABORATORY BEATER

2.1 Background

The term "beating" is used in the paper industry to describe the mechanical treatment of fibers in a water medium. Beating involves fiber separation, fiber cutting, and "fibrillation," or fraying, of the fibers. The term beating originated from the practice, in the early days of papermaking, of impacting a wet mass of pulp in a machine similar to the familiar laboratory mortar and pestle.

The laboratory beater used in this study is similar to the so-called Hollander beater. This beater and its action has been well described by Casey [1]:

"The Hollander beater consists of an elongated tub with a dividing partition, or midfeather, which stops short of both ends of the tub. A beater roll equipped with metal bars set across the width of the roll circulates the stock in the tub, and at the same time works the fibers against bars set in a bedplate under the roll. The amount of action is controlled by raising or lowering the beater roll relative to the bedplate. There have been many modifications of this basic design of the old Hollander beater over the years, but none of the radical changes have proven to be very practical.

"The beater has a number of functions: it can beat or fibrillate the stock; it can be used to cut the fibers; or it can be used for mixing and blending the stock and the non-fibrous materials. The beater is sometimes used as a washing device and as a bleacher. However, the action of the beater is primarily of a rubbing or crushing nature whereby the fibers are subjected to a succession of hammer-like blows or impacts.

"Dull beater roll bars, high consistency of stock, and low temperature favor the rubbing or brushing action. On the other hand, if the consistency is low, the knives sharp, and the beater roll is put down hard on the bedplate, the action becomes predominantly of a cutting nature. In general, beaters with dull bars produce papers with higher bursting, tensile, and tearing strengths than beaters with sharp bars. Special beater rolls made of basalt lava can be used to produce a high degree of bruising action or "wet" beating such as is required for glassine.

". . . In general, beating improves some properties and has a bad effect on others. Thus, the papermaker must select the proper beating conditions to bring out certain properties without detracting too much from other properties. Beating must not be carried out so that any one property is emphasized too much, since this may detract from another property. By changing the beating procedure, it is possible to produce papers from the same pulp possessing radically different properties.

"In general, increased beating within the commercial range increases bursting strength, tensile strength, and folding endurance, but generally tends to decrease tearing resistance. Stretch increases on beating, with the greatest increase obtained by beating at the highest consistency. Increased beating tends to increase smoothness, hardness, and amount of fiber bonding of the fibers, but on the other hand, tends to decrease the opacity and lower the bulk and dimensional stability of the paper."

The purpose of developing a beater schedule for rag pulps with a laboratory beater is to obtain handsheets with good strength properties with minimum cutting of fibers. To achieve this, the pressure on the bedplate must be applied gradually over a period of time. If the pressure on the bedplate is applied too rapidly, serious degradation of the fiber occurs. The resulting handsheets may have good strength, but their ability to withstand flexing will be poor. The general procedure is described in reference [2].

Current work has been directed toward obtaining information on changes in fiber length distribution with beating. The relationship between beater schedule and sheet properties will be done later.

Changes in fiber length were estimated with a laboratory fiber classifier [3]. One change was made in the fiber classification procedure reported previously [4]. Five instead of 10 grams of dry fiber were used for each determination, as the reduced quantity of fibers permitted full water flow through the classifier. Otherwise, the longer-fibered masses acted as filters and retained part of the shorter fibered fractions that normally would have passed through this size screen.

2.2 Experimental

The beating procedure was as follows: The cotton pulp (360 grams) was torn into pieces approximately 2 inches square, and soaked overnight in 20 liters of water in an 88 liter stainless steel container. The following day, the mixture was agitated for 1 hour with a propeller stirrer. The mixture was then transferred to the beater, and the stainless steel container was rinsed with 1 to 1 1/2 liters of water. The water level in the beater was then brought to 23 liters, which had been previously determined and marked.

The roll was started while the bedplate lever arm was supported so that no possible contact with the roll could occur. After circulation had proceeded for 1 to 2 minutes, the bedplate lever arm was released, but no weight was placed on it. The lever arm was counterbalanced so no force was exerted on the roll when the beater contained 23 liters of water. The time of beating was considered to have started at the moment the bedplate lever arm was released.

Aliquots were removed from the beater at definite time intervals of beating under varying load conditions. Just prior to taking aliquots, the bedplate lever arm was raised to stop the beating action while the roll continued to rotate to ensure good mixing. Three samples were taken at each interval, two for fiber classification and one for the weight control.

2.3 Results and Discussion

The results of two beater runs are given in Table 1A. The only difference between the two runs was the time of beating at each load level, but the results are greatly different. Of significance is the gradual decline in fraction V in run 2 during the first 3 hours of beating, accompanied by a slight increase in fractions I through IV. As beating continued, fraction I declined and fractions II through V increased.

The gradual decline in fraction V during the first hours of run 2 could be due to fibrillation. As the fibers are fibrillated, the formation of a mat on the screen occurs sooner and is more complete at an earlier time than with unfibrillated fibers. More small fibers and debris are trapped on the larger screens, resulting in a decline in fraction V. This will be verified in subsequent work on developing a beater schedule.

3. EFFECT OF MELAMINE RESIN ON THE RETENTION OF STIFFNESS OF CURRENCY PAPER WITH FLEXING

3.1 Background

Previous work [5] with wet strength resins indicated that the increase in circulation life between the mill wet- and dry-print currency paper may be due to the melamine resin used in the dry print paper and, to a lesser degree, to the fiber content. More work has been done to determine whether the wet strength resin was indeed the major factor in increased circulation life.

3.2 Experimental

Some beater stock for currency paper was obtained from the manufacturer of currency paper, and handsheets (70 g/m^2) containing different quantities of wet strength resin were prepared from the stock.

The beater stock came in two containers labeled cotton and flax. It was assumed that the containers consisted of 100 percent of each pulp. The stock was mixed accordingly to produce handsheets containing 75 percent cotton and 25 percent linen. However, it was later determined that the container marked flax consisted of a 1-1 mixture of cotton and linen. Consequently, the resulting handsheets contained 87 percent cotton and 13 percent linen. Since the purpose of this investigation was to determine the effect of melamine resin on the retention of stiffness of currency paper, the difference in the fiber composition from regular currency paper was not considered to be an important factor.

Sufficient water was added to the stock in a stainless steel container to make a 1 percent consistency. Aliquots were taken (approx. 650 cm^3), diluted with 1000 cm^3 tap water, and disintegrated for 7500 revolutions with a British disintegrator [2]. The contents were then transferred to 2-liter beakers and enough 12 percent solution of melamine resin was added to each beaker so that it contained either 3 or 9 percent resin based on the weight of fiber. The pH of the mixture was 4.15 with 3 percent resin and 3.45 with 9 percent resin. The mixture was stirred frequently during a 30 minute interval. Since no change in pH was observed during the time of treatment, no adjustment of the pH with aluminum sulfate was necessary in order to obtain good resin adsorption.

The mixture was then transferred to the deckle box of the handsheet machine and a sheet was formed. A quick check on the wet strength of the handsheets indicated that the resin was insufficiently cured. Therefore, the handsheets were placed in an oven at 105°C and cured for 1 hour. Following curing, the wet strength was approximately 50 percent of the dry strength. One half of each 12 x 12 inch handsheet was flexed 1000 times over 1/8 inch rollers, and the other half was used as an unflexed control.

3.3 Results and Discussion

The results of the physical tests of flexed and unflexed paper are given in Tables 2 and 3, and the standard deviations of the data are given in Tables 4 and 5.

The wet strength resin produced a significant improvement in the retention of cantilever stiffness. These results strongly indicate that the increase in circulation life of currency printed on dry-print currency paper is due to the melamine resin added to the paper and not to the change in fiber composition.

There is a marked decrease in air permeability of the sheets containing melamine resin. It is unlikely that the resin forms a film during sheet formation which could account for the decline in air permeability. In any case, the addition of the melamine resin must, in some way, increase sheet density or affect the structure of the sheet. Perhaps the resin causes the debris and fibrils to form a network in the interstices of the sheet and produce a film-like material in currency paper, as has been shown in earlier reports [4, 6, 7].

With the exception of wet strength, melamine resin has the greatest effect on folding endurance of all the physical properties evaluated. The increase in folding endurance is almost 10 fold at the highest level of treatment. Previous work performed at NBS [8, 9, 10] showed that currency type paper, which has a folding endurance equal to or exceeding that of the present currency paper, can be produced <u>without</u> melamine resin. Limited work with melamine resin on some experimental currency-type papers [10] indicated that the folding endurance of the high fold paper could be increased further with the addition of melamine resin. It would be of great interest to evaluate the durability of a currency-type paper whose folding endurance is developed to a maximum through mechanical refinement followed by treatment with melamine resin.

4. MODIFICATION OF WOOD PULP HANDSHEETS BY TREATMENT WITH ACRYLIC LATEXES

4.1 Background

In the last NBS Report [11] to BEP, it was shown that modification of paper with acrylic latexes, either by beater addition or paper saturation, improves the retention of stiffness with flexing. Paper saturation was superior to beater addition, and there appeared to be a correlation between the retention of stiffness of the paper with flexing and the film stiffness of the polymer. In order to confirm this, wood pulp handsheets were treated with four acrylic latexes having a wide range of film stiffnesses.

4.2 Experimental

Four acrylic latexes were used in this investigation and are designated as K-3, HA-8, HA-16, and AC-201. A relative parameter of film stiffness is the temperature (T_{300}) at which the torsional modulus of an air dried film is 300 kg/cm^2. The respective temperatures for T_{300}, which were estimated by the manufacturer for the four latexes used in this investigation, are as follows:

Latex	K-3	HA-8	HA-15	AC-201
T_{300}, °C	-32	-14	33	45

This represents a much wider range of film stiffness than was investigated previously [11].

A bleached kraft wood pulp was beaten in a PFI laboratory mill at 10 percent consistency, with no clearance between bedplate and roll, for 5,000 revolutions at 3.4 kilograms force and a relative velocity of roll to bedplate of 6 m/sec. The beating was done in distilled water. A total of 920 g pulp was beaten in 23 separate charges and then combined in a large stainless steel container. The pulp was diluted with sufficient distilled water to make a 1 percent suspension and was stirred vigorously for 1 hour prior to handsheet preparation. Aliquots of the 1 percent suspension were treated in

the British disintegrator for 7,500 revolutions, transferred to the deckle box of the handsheet mold, and sheets were made in the usual way. Each sheet was weighed after drying and only those sheets whose weight per unit area was 70 $g/m^2 \pm 5$ percent were retained. The sheets were then separated into 10 groups of 6 sheets each by a random selection.

The paper saturation was performed as follows: The felts which are used in wet pressing of handsheets were saturated with either a 5 or 10 percent emulsion of the acrylic. A handsheet was placed between felts and passed through the calender rolls on the sheet machine. The excess latex was squeezed out, saturating the paper with latex. As the felt and paper proceeded through the rolls, the excess latex in the paper was squeezed out. The wet sheet saturated with acrylic was lifted from the felt and dried on the drying drum at 95°C for approximately 3 minutes. The weight of the sheet was determined after drying and by difference the percent of polymer in the sheet was determined.

The effect of acrylic resins on the retention of physical properties was evaluated by determining the decline in physical properties after 1000 double flexes over 1/8 inch rollers on the NBS paper flexer.

4.3 Results and Discussion

The results are given in Tables 6-9, and the standard deviation of the results are given in Tables 10-13.

The effect of the acrylic latexes on the extensional and plastic stiffness of wood pulp handsheets was dependent on the film stiffness of the acrlyic polymers. Handsheets treated with polymers having a T_{300} less than 0°C had an extensional stiffness lower than the control, while handsheets treated with the two latexes having a T_{300} above 0°C resulted in an increase in extensional stiffness. The other tensile properties behaved similarly except that handsheets treated with AC-201 (T_{300} = 45°) showed no increase or a slight decrease in properties over those treated with HA-16 (T_{300} = 33). In other words, as T_{300} increased above 33°C, the relationship between film stiffness and tensile properties did not hold.

In general, Elmendorf tear decreased with increasing film stiffness. There appeared to be little if any relationship between film stiffness and folding endurance. Sonic modulus increased with torsional stiffness, but the increase appeared to level off as T_{300} increased above 33°C. Cantilever stiffness decreased when the handsheets were modified with soft acrylic latexes and approached the stiffness of handsheets prepared in the regular manner as the polymer stiffness increased. As expected, air permeability declined after saturation with acrylic latexes.

The polymers having a T_{300} below 0°C did not produce satisfactory improvements in stiffness retention with flexing. It is quite apparent that the very soft polymers are unsatisfactory for improving stiffness retention. Both of the polymers having T_{300} above 0°C did improve stiffness retention significantly (two sided t test). However, stiffness retention was appreciably better with HA-16 (T_{300} = 33°) than with AC-201 (T_{300} = 45°), which is the stiffest polymer that has been evaluated. Apparently, AC-201 forms a brittle film that cracks during flexing as indicated by the substantial increase in air permeability after flexing. The cracking of the polymer film would be analagous to the cracking of the matrix in currency paper [4].

The above results indicate that there is a relationship between the stiffness of the acrylic polymer used in paper saturation and the retention of stiffness with flexing. However, there apparently is an optimum polymer stiffness beyond which little if any improvement in stiffness retention occurs.

5. MODIFICATION OF HANDSHEETS MADE FROM CURRENCY STOCK BY TREATMENT WITH ACRYLIC LATEXES

5.1 Background

All of the evaluations of acrylic latexes so far have been performed on wood pulp handsheets. As cotton and linen are used in the manufacture of currency paper and as different pulps respond differently to latex treatments, it was necessary to determine the effect of acrylic latexes on the retention of stiffness of handsheets made from currency stock. The latexes chosen for this study had been used previously on wood pulp handsheets.

5.2 Experimental

Five acrylic resins having a wide range of film stiffness were used in this investigation. The designations of the five latexes and their T_{300} temperatures are as follows:

Latex	K-3	P-339	AC-61	HA-16	AC-201
T_{300}, °C	-32	3	16	33	45

Each of the latexes has been evaluated previously on wood pulp handsheets and the results were reported either in section 4 of this report or in the last NBS Report [11].

The method of treatment is described in section 4.2 of this report, except that the handsheets were made from currency stock. The fiber composition was 87 percent cotton and 13 percent linen. The results before and after flexing 1000 times over 1/8 inch rollers are given in Tables 14 and 15, and the standard deviation of the data are given in Tables 16 and 17.

5.3 Results and Discussion

The best improvement in stiffness retention occurred with the polymers having a T_{300} of 16°C or higher. Of the three latexes falling into this category, AC-61 (T_{300} = 16°) appeared to produce the greatest improvement in stiffness retention. Handsheets treated with AC-61 also contained a larger amount of polymer, and this factor may be partially responsible for the better performance. Nevertheless, it is apparent that modification of handsheets with acrylic latexes can lead to an improvement in stiffness retention with flexing. Still another factor to be considered is that none of the handsheets were treated with melamine resin. Conceivably, a combination of wet strength resin and acrylic latex may result in still further improvement of stiffness retention.

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Table 1A. Fiber classification of cotton pulp beaten in a Niagara laboratory beater.

Run No.	Weight on Bedplate kg	Beating Time hrs	Σ hrs.	fraction / screen mesh	Weight Retained in Fractions, %[1] I (+14)	II (-14 +35)	III (-35 +65)	IV (-65 +150)	V (-150)
1	0	0	1		56	19	10	4	11
	0.5	1	2		51	21	11	4	13
	1.0	1	3		44	27	13	5	11
	1.5	1	4		40	31	14	5	10
2	0	1	1		53	22	12	5	8
	0	1	2		54	25	13	5	2
	0.5	1	3		56	25	13	5	1
	0.5	1	4		53	23	13	5	6
	1.0	1	5		41	31	15	5	9
	1.0	1	6		32	33	15	6	14
	1.5	1	7		20	36	16	7	21
	1.5	1	8		9	41	20	9	21

[1] Fiber fractionation data, by convention, are given in the literature as -, passed through a specific mesh screen, and +, retained by a smaller mesh screen. Thus, the % retained in Fraction II had passed through a 14 mesh screen (-14) but was retained on a 35 mesh screen (+35).

Table 1B. Fiber classification of currency beater stocks.

	Weight Retained in Fractions, %				
Fraction----	I	II	III	IV	V
Screen mesh ----	+14	-14 +35	-35 +65	-65 +150	-150
100% cotton beater stock	34	29	15	8	15
50-50 cotton-linen beater stock	36	27	13	7	17

Table 2. Tensile properties of flexed and unflexed handsheets made from currency beater stock treated with the wet strength resin presently used in currency paper.

Resin	Extensional[1] Stiffness		Breaking Strength		Elongation to Break		Energy to Break		Load at Yield		Elongation at Yield		Plastic[3] Stiffness		Wet Strength	
%	kg		kg		%		kg-cm		kg		%		kg		kg	
	W	L[2]	W	L	W	L	W	L	W	L	W	L	W	L	W	L
							Unflexed									
0	455	465	4.4	4.4	3.2	3.0	1.0	0.9	3.3	3.3	0.8	0.8	49	52	0.1	0.1
3	539	503	7.0	6.9	4.2	4.6	2.0	2.1	4.9	4.7	1.0	1.1	68	61	2.7	2.8
9	546	561	7.1	7.5	4.2	4.3	2.0	2.2	5.1	5.3	1.0	1.1	64	64	3.7	3.6
control[4]	483	457	4.7	4.5	3.3	3.3	1.1	1.1	3.5	3.3	0.8	0.8	50	53	0.1	0.1
							Flexed 1,000 double flexes over 1/8" rollers									
0	319	207	4.3	4.3	3.2	3.9	0.9	1.0	3.0	3.3	1.0	1.6	49	48	0.1	0.1
3	459	305	6.9	6.5	4.3	4.6	2.0	1.9	4.9	4.6	1.1	1.6	64	65	2.9	2.8
9	480	328	7.3	7.2	4.5	4.7	2.2	2.2	5.3	5.2	1.2	1.7	63	67	3.5	3.5
control	315	215	4.3	4.6	3.8	4.0	1.1	1.1	3.1	3.4	1.0	1.7	49	52	0.1	0.1

[1] Initial slope of load-strain curve.
[2] W = width and L = length of flex samples.
[3] Slope of latter portion of load-strain curve.
[4] Sheets made in conventional manner.

Table 3. Physical properties of flexed and unflexed handsheets made from currency beater stock treated with wet strength resin presently used in currency paper.

Resin	Elmendorf Tear		MIT Fold Endurance		Cantilever Stiffness		Air Permeability	Sonic Modulus[1]		Weight per Unit Area
%	g		1000 g double folds		g-cm		$cm^3/min/10cm^2$	$kg/cm^2 x 10^{-3}$		g/m^2
	W	L[2]	W	L	W	L		W	L	
Unflexed										
0	132	140	400	490	2.3	2.3	208	9.9	9.9	73
3	135	138	2650	3060	2.7	2.7	141	10.7	10.2	74
9	126	121	3300	3390	2.9	2.7	143	10.2	10.3	76
control[3]	137	129	650	380	2.5	2.5	175	9.8	9.6	75
Flexed 1,000 double flexes over 1/8" rollers										
0	127	122	340	350	1.1	0.7	231	7.1	5.2	--
3	127	121	2670	2560	2.0	1.1	146	9.5	6.9	--
9	112	116	3380	3030	2.2	1.4	149	9.2	7.2	--
control	138	122	280	450	1.4	0.7	180	6.7	4.9	--

[1] Sonic modulus based on cellulose density of 1.54.
[2] W = width and L = length of 6"x12" flex samples.
[3] Sheets made in conventional manner.

Table 4. Standard deviation[1], from data in Table 2, for tensile properties of flexed and unflexed handsheets made from currency beater stock treated with wet strength resin presently used in currency paper.

Resin	No. of Specimens		Extensional Stiffness		Breaking Strength		Elongation to Break		Energy to Break		Load at Yield		Elongation at Yield		Plastic Stiffness		Wet Strength	
%			kg		kg		%		kg-cm		kg		%		kg		kg	
	W	L[2]	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L
Unflexed																		
0	6	6	48.5	57.1	0.3	0.4	0.3	0.6	0.2	0.2	0.3	0.3	0.08	0.09	5.6	11.8	0.004	0.01
3	6	6	39.9	21.0	0.4	0.2	0.4	0.2	0.3	0.1	0.3	0.2	0.13	0.10	4.7	5.7	0.2	0.2
9	5	6	44.2	35.9	0.5	0.5	0.5	0.3	0.4	0.3	0.3	0.3	0.04	0.06	7.3	6.2	0.1	0.4
control	6	6	33.3	55.5	0.2	0.4	0.3	0.6	0.1	0.3	0.2	0.3	0.06	0.08	5.8	10.1	0.01	0.01
Flexed 1,000 double flexes over 1/8" rollers																		
0	6	6	20.1	21.2	0.3	0.1	0.3	0.4	0.1	0.1	0.3	0.2	0.1	0.3	7.6	13.7	0.01	0.01
3	6	6	25.8	42.5	0.3	0.4	0.2	0.4	0.2	0.2	0.3	0.3	0.07	0.3	4.6	7.5	0.2	0.2
9	6	6	11.8	37.7	0.2	0.4	0.3	0.4	0.2	0.3	0.3	0.5	0.07	0.3	6.0	5.2	0.2	0.09
control	6	6	48.4	21.5	0.3	0.5	0.5	0.4	0.2	0.2	0.3	0.4	0.2	0.3	5.6	7.5	0.005	0.02

[1] $s = \sqrt{\frac{n\Sigma X^2 - (\Sigma X)^2}{n(n-1)}}$

[2] W = width and L = length of 6"x12" flex samples.

Table 5. Standard deviation[1], from data in Table 3, for physical properties of flexed and unflexed handsheets made from currency beater stock treated with wet strength resin presently used in currency paper.

Resin	No. of Specimens		Elmendorf Tear		MIT Fold Endurance		Cantilever Stiffness		Air Permeability	Sonic Modulus	
%			g		1000 g double folds				$cm^3/min/10cm^2$	$kg/cm^2 x10^{-3}$	
	W	L[2]	W	L	W	L	W	L		W	L
					Unflexed						
0	6	6	6.3	8.4	125	174	0.2	0.3	8.7	0.3	0.3
3	6	6	27.4	29.0	501	904	0.2	0.1	5.4	0.6	0.5
9	5	6	13.4	13.7	447	650	0.3	0.1	8.4	0.5	0.4
control	6	6	7.6	14.5	269	116	0.2	0.2	8.2	0.6	0.4
			Flexed 1,000 double flexes over 1/8" rollers								
0	6	6	5.7	8.0	57	90	0.1	0.07	15.2	0.2	0.6
3	6	6	11.8	12.4	559	395	0.2	0.07	11.9	0.3	0.5
9	6	6	9.9	18.7	676	560	0.2	0.1	12.0	0.3	0.2
control	6	6	12.5	14.4	89	137	0.3	0.05	9.6	0.6	0.2

[1] $s = \sqrt{\frac{n\Sigma X^2 - (\Sigma X)^2}{n(n-1)}}$

[2] W = width and L = length of 6"x12" flex samples.

Table 6. Tensile properties of unflexed wood pulp handsheets treated with various acrylic resins by paper saturation technique.

Acrylic Resin		Extensional[1] Stiffness		Breaking Strength		Elongation to Break		Energy to Break		Load at Yield		Elongation at Yield		Plastic Stiffness	
Type	%	kg		kg		%		kg-cm		kg		%		kg	
		W	L[2]	W	L	W	L	W	L	W	L	W	L	W	L
K-3	4.3	603	611	6.5	6.7	3.0	2.9	1.3	1.3	4.0	4.2	0.7	0.8	108	115
	7.0	572	578	5.7	6.3	2.8	2.7	1.1	1.1	3.7	4.3	0.7	0.8	105	108
HA-8	4.5	577	653	7.2	7.7	3.6	3.2	1.7	1.6	4.5	4.9	0.8	0.8	100	116
	6.9	601	673	8.0	8.2	3.9	3.6	2.0	1.9	4.7	4.9	0.8	0.8	113	120
HA-16	5.2	770	766	10.0	10.0	3.8	3.6	2.4	2.3	5.2	5.1	0.8	0.8	157	172
	7.7	765	844	10.7	11.4	3.9	3.7	2.6	2.7	5.3	5.8	0.8	0.8	172	189
AC-201	3.9	794	802	9.7	9.6	3.6	3.3	2.3	2.0	5.3	5.2	0.8	0.7	155	170
	8.1	849	889	10.7	10.1	3.6	2.8	2.4	1.8	6.1	6.0	0.8	0.8	166	198
control	water[3]	674	732	7.9	8.2	3.4	3.2	1.8	1.7	4.2	4.7	0.7	0.7	136	144
	regular[4]	779	787	8.9	8.7	3.6	3.5	2.1	2.0	5.1	4.8	0.7	0.7	136	136

[1]Initial slope of load-strain curve.
[2]W = width and L = length of 6"x12" flex sample.
[3]Post-treatment was done with water only.
[4]Handsheets were made in conventional manner with no post-treatment.

Table 7. Tensile properties of wood pulp handsheets treated with various acrylic resins by paper saturation technique after flexing 1000 times over 1/8 inch rollers.

Acrylic Resin		Extensional[1] Stiffness		Breaking Strength		Elongation to Break		Energy to Break		Load at Yield		Elongation at Yield		Plastic Stiffness	
Type	%	kg		kg		%		kg-cm		kg		%		kg	
		W	L[2]	W	L	W	L	W	L	W	L	W	L	W	L
K-3	4.3	436	280	6.0	6.6	3.3	3.3	1.2	1.2	3.9	5.0	1.0	1.8	95	115
	7.0	411	313	5.7	6.0	3.1	3.1	1.1	1.1	4.0	4.1	1.1	1.4	84	111
HA-8	4.5	452	319	6.9	7.2	3.5	3.4	1.5	1.4	4.3	5.2	1.0	1.7	105	120
	6.9	489	350	7.8	7.7	3.9	3.7	1.9	1.6	4.7	5.3	1.0	1.6	113	118
HA-16	5.2	646	401	9.3	9.0	3.8	3.6	2.2	1.8	4.7	5.5	0.8	1.5	155	172
	7.7	703	529	10.9	10.6	4.3	3.8	2.8	2.2	5.0	5.7	0.9	1.2	170	192
AC-201	3.9	630	385	9.0	9.1	3.6	3.5	2.0	1.8	4.7	5.8	0.9	1.7	156	182
	8.1	751	439	10.4	10.3	3.6	3.8	2.3	2.2	5.9	6.6	0.9	1.7	166	175
control	water[3]	635	354	8.1	7.7	3.5	4.0	1.8	1.8	4.8	4.7	0.8	1.4	127	117
	regular[4]	536	316	7.3	7.8	3.6	3.5	1.6	1.5	4.0	5.6	0.8	1.8	120	136

[1]Initial slope of load-strain curve.
[2]W = width and L = length of 6"x12" flex sample.
[3]Post-treatment was done with water only.
[4]Handsheets were made in conventional manner with no post-treatment.

Table 8. Physical properties of unflexed wood pulp handsheets treated with various acrylic resins by paper saturation technique.

Acrylic Resin		Sonic[1] Modulus		Elmendorf Tear		MIT Fold Endurance		Cantilever Stiffness		Air Permeability	Weight per Unit Area
Type	%	$kg/cm^2 x10^{-3}$		g		1000 g double folds		g-cm		$cm^3/min/10cm^2$	g/m^2
		W	L	W	L	W	L	W	L		
K-3	4.3	13.1	12.7	89	95	1130	1610	2.1	2.1	499	78
	7.0	12.4	13.2	87	109	1320	1240	1.9	2.2	407	79
HA-8	4.5	13.0	13.8	98	97	1880	2170	2.0	2.2	502	78
	6.9	13.4	13.5	80	77	2320	2360	2.2	2.1	318	80
HA-16	5.2	15.3	14.6	86	87	2060	2160	2.7	2.7	545	80
	7.7	14.9	15.5	83	77	2370	2370	2.8	2.8	382	82
AC-201	3.9	14.9	14.6	89	88	1720	1640	2.8	2.6	476	78
	8.1	15.4	15.3	79	82	1890	1870	2.9	2.9	332	80
control	water[2]	14.1	14.8	90	99	1960	2010	2.6	2.4	559	77
	regular[3]	14.7	14.7	87	96	2110	2050	2.9	2.8	555	77

[1]Sonic modulus based on cellulose density of 1.54.
[2]Post-treatment was done with water only.
[3]Handsheets were made in conventional manner with no post-treatment.

Table 9. Physical properties of wood pulp handsheets treated with various acrylic resins by paper saturation technique after flexing 1000 times over 1/8 inch rollers.

Acrylic Resin		Sonic[1] Modulus		Elmendorf Tear		MIT Fold Endurance		Cantilever Stiffness		Air Permeability
Type	%	$kg/cm^2 x10^{-3}$		g		1000 g double folds		g-cm		$cm^3/min/10cm^2$
		W	L	W	L	W	L	W	L	
K-3	4.3	10.4	7.6	97	89	1330	1320	1.2	0.7	593
	7.0	10.5	7.9	89	90	1220	1360	1.3	0.8	509
HA-8	4.5	11.2	8.3	83	87	1800	1650	1.3	0.8	537
	6.9	11.9	9.6	82	92	2760	1980	1.5	0.9	423
HA-16	5.2	13.0	9.8	77	83	2280	1430	2.0	1.3	561
	7.7	13.6	11.8	80	71	2440	2070	2.2	1.8	322
AC-201	3.9	12.4	9.1	81	76	2080	1710	2.0	1.3	503
	8.1	13.7	10.4	76	79	1850	1490	2.5	1.6	420
controls	water[2]	10.4	7.8	94	92	2150	1530	1.4	0.8	656
	regular[3]	12.2	7.7	97	86	1900	1720	2.0	0.9	632

[1]Sonic modulus based on cellulose density 1.54.
[2]Post-treatment was done with water only.
[3]Handsheets were made in conventional manner with no post-treatment.

Table 10. Standard deviation, from data in Table 6, for tensile properties of unflexed wood pulp handsheets treated with various acrylic resins by paper saturation.

Acrylic Resin		No. of Specimens		Extensional Stiffness		Breaking Strength		Elongation to Break		Energy to Break		Load at Yield		Elongation at Yield		Plastic Stiffness	
Type	%			kg		kg		%		kg-cm		kg		%		kg	
		W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L
K-3	4.3	6	5	44.7	47.4	0.2	0.4	0.2	0.3	0.1	0.2	0.2	0.4	0.07	0.07	5.7	20.2
	7.0	6	6	52.6	25.5	0.5	0.4	0.6	0.2	0.3	0.1	0.2	0.4	0.12	0.08	16.4	8.4
HA-8	4.5	6	6	53.9	79.8	0.4	0.4	0.2	0.3	0.1	0.2	0.2	0.4	0.06	0.11	8.3	15.4
	6.9	6	6	56.7	26.8	0.5	0.2	0.2	0.2	0.3	0.1	0.5	0.4	0.04	0.07	12.1	14.5
HA-16	5.2	6	6	30.7	44.0	0.6	0.8	0.3	0.3	0.3	0.3	0.3	0.3	0.05	0.06	16.4	14.8
	7.7	6	6	23.7	32.9	0.6	0.6	0.4	0.3	0.4	0.3	0.3	0.7	0.05	0.08	9.7	12.2
AC-201	3.9	6	6	32.5	52.9	0.3	0.4	0.3	0.1	0.2	0.1	0.2	0.1	0.07	0.03	14.8	13.9
	8.1	6	6	38.9	38.4	0.6	0.9	0.2	0.3	0.2	0.3	0.5	0.3	0.08	0.04	13.8	14.0
control	water	6	6	50.5	26.1	0.6	0.6	0.2	0.3	0.2	0.3	0.3	0.4	0.02	0.05	18.3	15.2
	regular	6	6	66.7	37.2	0.6	0.9	0.1	0.2	0.2	0.3	0.3	0.4	0.06	0.04	12.4	11.7

Table 11. Standard deviation, from data in Table 7, for tensile properties of wood pulp handsheets treated with various acrylic resins by paper saturation technique after flexing 1000 times over 1/8 inch rollers.

Acrylic Resin		No. of Specimens		Extensional Stiffness		Breaking Strength		Elongation to Break		Energy to Break		Load at Yield		Elongation at Yield		Plastic Stiffness	
Type	%			kg		kg		%		kg-cm		kg		%		kg	
		W	L	W	L	W	L	W	L	W	L	W	L	W	L	W	L
K-3	4.3	6	6	57.6	20.6	0.4	0.4	0.3	0.2	0.1	0.1	0.3	0.5	0.08	0.19	15.8	12.7
	7.0	6	6	34.8	28.5	0.3	0.3	0.2	0.2	0.1	0.1	0.3	0.4	0.06	0.21	12.5	18.1
HA-8	4.5	6	6	22.3	36.8	0.3	0.5	0.3	0.2	0.2	0.2	0.4	0.4	0.10	0.21	15.4	23.6
	6.9	6	6	51.7	31.3	0.6	0.6	0.2	0.2	0.2	0.2	0.6	0.6	0.11	0.18	15.0	15.7
HA-16	5.2	6	6	40.5	34.2	0.4	0.7	0.1	0.4	0.2	0.3	0.3	0.9	0.06	0.32	16.0	18.9
	7.7	6	6	20.6	83.3	0.3	0.2	0.2	0.1	0.2	0.1	0.4	0.5	0.09	0.17	19.5	13.8
AC-201	3.9	6	6	46.4	58.0	0.7	0.5	0.2	0.3	0.3	0.2	0.3	1.0	0.10	0.50	12.0	12.3
	8.1	6	6	33.9	25.9	0.7	0.7	0.4	0.2	0.4	0.2	0.6	0.5	0.10	0.15	17.6	18.2
control	water	6	6	37.3	10.5	0.3	0.4	0.3	0.3	0.2	0.2	0.3	0.3	0.04	0.14	6.8	17.6
	regular	6	6	44.2	57.4	0.6	0.5	0.3	0.3	0.3	0.3	0.5	0.6	0.09	0.37	17.2	10.1

Table 12. Standard deviation, from data in Table 8, for physical properties of unflexed wood pulp handsheets treated with various acrylic resins by paper saturation.

Acrylic Resin		No. of Specimens		Sonic Modulus		Elmendorf Tear		MIT Fold Endurance		Cantilever Stiffness		Air Permeability
Type	%			$kg/cm^2 x10^{-3}$		g		1000 g double folds		g-cm		$cm^3/min/10cm^2$
		W	L	W	L	W	L	W	L	W	L	
K-3	4.3	6	6	0.7	1.1	8.1	10.2	253	707	0.1	0.2	44.1
	7.0	6	6	1.1	0.6	7.9	18.2	365	471	0.1	0.2	70.7
HA-8	4.5	6	6	0.1	0.7	8.9	11.5	302	355	0.2	0.2	30.8
	6.9	6	6	0.5	0.4	5.1	4.2	509	641	0.1	0.1	32.1
HA-16	5.2	6	6	0.5	0.5	10.8	13.7	456	153	0.2	0.1	58.8
	7.7	6	6	0.9	0.6	7.6	9.3	468	411	0.1	0.2	28.2
AC-201	3.9	6	6	0.7	0.5	19.0	8.1	342	378	0.2	0.1	23.6
	8.1	6	6	1.1	1.0	10.1	10.7	209[1]	346[1]	0.1	0.2	22.7
control	water	6	6	0.7	1.2	7.2	11.9	413	469	0.2	0.1	23.9
	regular	6	6	1.3	0.6	7.3	7.3	414	518	0.1	0.3	51.5

[1]5 specimens.

Table 13. Standard deviation, from data in Table 9, for physical properties of wood pulp handsheets treated with various acrylic resins by paper saturation technique after flexing 1000 times over 1/8 inch rollers.

Acrylic Resin		No. of Specimens		Sonic Modulus		Elmendorf Tear		MIT Fold Endurance		Cantilever Stiffness		Air Permeability
Type	%			$kg/cm^2 x10^{-3}$		g		1000 g double folds		g-cm		$cm^3/min/10cm^2$
		W	L	W	L	W	L	W	L	W	L	
K-3	4.3	6	6	0.9	0.2	11.4	11.7	417	382	0.10	0.03	73.0
	7.0	6	6	0.7	0.4	15.4	11.5	585	535	0.11	0.03	55.8
HA-8	4.5	6	6	0.4	0.4	12.3	14.0	466	660	0.08	0.02	30.6
	6.9	6	6	0.9	0.4	16.7	17.7	482	397	0.18	0.06	37.6
HA-16	5.2	6	6	0.3	0.4	8.4	11.0	239	232	0.18	0.05	63.8
	7.7	6	6	0.7	0.5	11.3	4.7	182	366	0.15	0.15	24.0
AC-201	3.9	6	6	0.5	0.3	14.3	8.1	437	141	0.15	0.07	38.0
	8.1	6	6	0.6	0.3	6.2	7.8	237	261	0.32	0.10	24.0
control	water	6	6	0.4	0.3	7.4	11.4	292	237	0.12	0.02	44.2
	regular	6	6	0.7	0.6	15.3	11.7	390	469	0.11	0.05	59.7

Table 14. Tensile properties of flexed and unflexed handsheets made from currency stock and treated with various acrylic resins by paper saturation technique.

Acrylic Resin		Extensional[1] Stiffness		Breaking Strength		Elongation to Break		Energy to Break		Load at Yield		Elongation at Yield		Plastic Stiffness	
Type	%	kg		kg		%		kg-cm		kg		%		kg	
		W	L[2]	W	L	W	L	W	L	W	L	W	L	W	L
						Unflexed									
K-3	8.7	341	365	4.0	4.2	3.6	3.1	1.0	0.9	3.0	3.1	1.0	0.9	41	53
P-339	8.3	405	459	6.2	7.1	4.8	5.2	2.0	2.3	4.3	5.1	1.1	1.2	53	56
AC-61	12.3	575	594	7.8	8.4	4.8	4.5	2.6	2.6	5.1	5.6	0.9	1.0	72	79
HA-16	8.7	585	625	7.1	7.8	4.4	4.4	2.2	2.4	4.8	5.2	0.9	0.9	68	75
AC-201	10.1	638	728	7.1	8.2	3.9	4.0	1.9	2.3	5.0	5.7	0.9	0.9	71	83
control	water[3]	473	488	4.2	4.7	3.1	3.3	1.0	1.1	3.1	3.5	0.7	0.8	49	52
	regular[4]	418	449	4.2	4.5	3.1	3.5	0.9	1.1	3.1	3.3	0.9	0.8	53	48
						Flexed 1,000 times over 1/8" rollers									
K-3	--	259	197	3.9	4.1	3.8	3.6	1.0	0.9	2.8	3.2	1.2	1.7	46	53
P-339	--	319	225	6.3	6.4	5.0	4.6	2.0	1.8	4.4	4.9	1.5	2.3	54	66
AC-61	--	466	320	7.8	7.8	5.2	4.8	2.7	2.3	5.1	5.6	1.2	1.9	71	77
HA-16	--	472	341	7.1	7.4	4.8	4.5	2.3	2.1	4.6	5.1	1.1	1.7	70	79
AC-201	--	550	304	7.2	7.6	4.2	4.1	2.1	1.9	5.1	5.9	1.0	2.1	67	85
control	water[3]	299	217	4.2	4.4	3.6	3.6	1.0	1.0	3.0	3.4	1.1	1.7	50	54
	regular[4]	326	195	4.4	4.4	3.6	4.0	1.1	1.1	3.3	3.2	1.1	1.7	48	56

[1] Initial slope of load-strain curve.
[2] W = width and L = length of 6"x12" flex sample.
[3] Post-treatment was done with water only.
[4] Handsheets were made in conventional manner with no post-treatment.

Table 15. Physical properties of unflexed handsheets made from currency stock and treated with various acrylic resins by paper saturation technique.

Acrylic Resin		Sonic[1] Modulus		Elmendorf Tear		MIT Fold Endurance		Cantilever Stiffness		Air Permeability	Wet Strength		Weight per Unit Area
Type	%	$kg/cm^2 x10^{-3}$		g		1000 g double folds		g-cm		$cm^3/min/10cm^2$	kg		g/m^2
		W	L[2]	W	L	W	L	W	L		W	L	
						Unflexed							
K-3	8.7	8.9	9.4	156	142	480	490	1.7	1.7	109	0.3	0.3	78
P-339	8.3	10.9	11.4	130	147	3770	3270	1.9	2.0	114	0.4	0.5	78
AC-61	12.3	12.0	12.9	131	145	2320	2660	2.8	2.7	103	1.0	1.0	81
HA-16	8.7	11.6	12.1	141	127	2090	2050	2.9	2.8	113	0.5	0.5	79
AC-201	10.1	12.0	13.0	126	123	1580	1790	3.0	3.0	114	1.0	1.1	79
control	water[3]	10.0	10.3	122	131	340	420	2.2	1.9	186	0.1	0.1	72
	regular[4]	9.2	9.3	134	133	490	390	2.3	2.3	182	0.1	0.1	74
				Flexed 1000 times over 1/8" rollers									
K-3	8.7	7.3	6.3	146	135	470	550	1.0	0.7	121	--	--	--
P-339	8.3	9.6	7.7	131	134	3630	3450	1.4	0.9	128	--	--	--
AC-61	12.3	10.6	8.6	130	127	2680	2160	2.3	1.5	108	--	--	--
HA-16	8.7	10.2	7.8	134	140	1960	2040	2.2	1.3	116	--	--	--
AC-201	10.1	10.3	7.5	120	126	1810	1820	2.5	1.4	130	--	--	--
control	water[3]	6.8	5.2	136	119	320	390	0.9	0.6	209	--	--	--
	regular[4]	7.2	4.8	133	122	330	360	1.4	0.7	199	--	--	--

[1]Sonic modulus based on cellulose density of 1.54.
[2]W = width and L = length of 6"x12" samples.
[3]Post-treatment was done with water only.
[4]Handsheets were made in conventional manner with no post-treatment.

Table 16. Standard deviation, from data in Table 14, for tensile properties of handsheets made from currency stock and treated with various acrylic resins by paper saturation technique.

Acrylic Resin Type	%	No. of Specimens W	No. of Specimens L	Extensional Stiffness kg W	Extensional Stiffness kg L	Breaking Strength kg W	Breaking Strength kg L	Elongation to Break % W	Elongation to Break % L	Energy to Break kg-cm W	Energy to Break kg-cm L	Load at Yield kg W	Load at Yield kg L	Elongation at Yield % W	Elongation at Yield % L	Plastic Stiffness kg W	Plastic Stiffness kg L
Unflexed																	
K-3	8.7	6	6	30.3	42.7	0.2	0.2	0.2	0.2	0.06	0.1	0.2	0.3	0.05	0.07	6.5	9.1
P-339	8.3	5	6	23.3	56.0	0.3	0.6	0.4	0.3	0.3	0.3	0.4	0.6	0.11	0.11	6.0	9.6
AC-61	12.3	6	6	50.6	58.6	0.5	0.2	0.7	0.2	0.5	0.1	0.4	0.4	0.13	0.10	8.3	6.0
HA-16	8.7	6	6	49.9	67.8	0.3	0.8	0.5	0.4	0.3	0.5	0.2	0.5	0.09	0.06	5.5	8.9
AC-201	10.1	6	6	47.8	28.2	0.3	0.5	0.1	0.4	0.1	0.3	0.3	0.4	0.06	0.11	5.2	9.8
control	water	6	6	56.9	29.5	0.2	0.2	0.4	0.1	0.2	0.1	0.3	0.2	0.11	0.09	10.0	4.0
	regular	6	6	44.3	45.0	0.2	0.2	0.4	0.4	0.2	0.1	0.1	0.2	0.2	0.09	10.6	8.5
Flexed 1000 times over 1/8" rollers																	
K-3	--	6	6	36.3	19.2	0.3	0.2	0.4	0.2	0.2	0.1	0.2	0.2	0.2	0.2	4.3	9.2
P-339	--	5	6	23.4	23.2	0.5	0.4	0.3	0.3	0.3	0.3	0.5	0.5	0.1	0.3	2.7	16.3
AC-61	--	6	6	17.3	22.2	0.5	0.4	0.3	0.3	0.3	0.2	0.4	0.5	0.2	0.3	6.1	4.9
HA-16	--	6	6	28.8	47.2	0.5	0.5	0.5	0.3	0.4	0.2	0.3	0.7	0.1	0.5	9.2	6.5
AC-201	--	6	6	60.2	6.8	0.2	0.8	0.4	0.6	0.2	0.5	0.2	0.5	0.1	0.2	7.7	12.7
control	water	6	6	23.2	25.7	0.2	0.2	0.4	0.3	0.1	0.1	0.3	0.2	0.1	0.3	8.2	6.7
	regular	6	6	8.1	21.7	0.5	0.3	0.7	0.4	0.3	0.2	0.4	0.2	0.2	0.1	10.9	11.0

Table 17. Standard deviation, from data in Table 15, for tensile properties of handsheets made from currency stock and treated with various acrylic resins by paper saturation technique.

Acrylic Resin		No. of Specimens		Sonic Modulus		Elmendorf Tear		MIT Fold Endurance		Cantilever Stiffness		Air Permeability	Wet Strength		Weight per Unit Area
Type	%			$kg/cm^2 x10^{-3}$		g		1000 g double folds		g-cm		$cm^3/min/10cm^2$	kg		g/m^2
		W	L	W	L	W	L	W	L	W	L		W	L	
								Unflexed							
K-3	8.7	6	6	0.4	0.5	18.8	15.2	166	122	0.3	0.2	5.8	0.02	0.02	3.1
P-339	8.3	6	6	0.4	0.6	10.8	25.0	683	508	0.2	0.2	6.2	0.01	0.03	1.6
AC-61	12.3	6	6	0.3	0.5	8.8	12.9	297	516	0.2	0.2	2.9	0.07	0.13	1.8
HA-16	8.7	6	6	0.6	0.4	17.9	9.4	493	480	0.3	0.5	0.6	0.02	0.03	2.7
AC-201	10.1	6	6	0.6	0.8	13.5	14.0	441	475	0.5	0.3	7.9	0.06	0.07	2.0
control	water	6	6	0.3	0.4	5.7	6.7	91	225	0.2	0.2	14.4	0.01	0.01	1.6
	regular	6	6	0.5	0.8	10.7	7.8	258	164	0.4	0.3	13.2	0.01	0.01	1.9
						Flexed 1000 times over 1/8" rollers									
K-3	--	6	6	0.2	0.2	18.3	8.0	99	283	0.2	0.03	6.6	--	--	--
P-339	--	6	6	0.3	0.1	11.7	15.9	759	692	0.2	0.09	9.7	--	--	--
AC-61	--	6	6	0.3	0.4	19.6	17.1	437	479	0.4	0.10	6.4	--	--	--
HA-16	--	6	6	0.3	0.3	14.5	21.0	272	450	0.2	0.13	8.5	--	--	--
AC-201	--	6	6	0.4	0.4	10.8	14.9	366	327	0.3	0.10	7.4	--	--	--
control	water	6	6	0.3	0.1	13.5	5.6	102	133	0.06	0.06	7.5	--	--	--
	regular	6	6	0.3	0.2	14.9	4.6	95	139	0.2	0.07	11.4	--	--	--